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Analysis of Scale-Efficiency of Rice Production among Beneficiaries of Anchor Borrowers Programme in Adamawa State, Nigeria

A. Bitrus^{1*}, I. M. Sulumbe¹, A. Ibrahim¹ and H. Yakubu¹

¹*Department of Agricultural Economics, University of Maiduguri, Nigeria.*

Authors' contributions

This work was carried out in collaboration among all authors. Author AB carried out the statistical analysis, designed the study and wrote the protocol and first draft of the manuscript. Authors IMS and AI supervised the study and author HY managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

This study examined the scale efficiency of rice production among beneficiaries of anchor borrowers programme (ABP) in Adamawa State, Nigeria. Multistage random sampling was employed to select respondents for the study. Structured questionnaires were the instruments used for data collection. A sample of 139 farmers was used for the study. Percentages, means, frequency, ranking, and data envelopment analysis were the analytical tools employed. The results of the socioeconomic characteristics of the respondents revealed that the majority (76.3%) of them was headed by males; most (61.1%) were within the ages of 21-40 years. Results from the data envelopment analysis showed that mean scale efficiency observed was 59%, out of the rice farms studied; 78% were scale inefficient as they operated under increased return to scale (IRS) and decreased return to scale (DRS) assumptions and therefore, operated at stage I and stage III of the production process, respectively. The major constraints faced by rice farmers in the study area were identified among others to be prevalence of pests and diseases, bad roads, and high cost of labour. Finally, it was recommended among others that policies geared towards investment in pest and disease control, good access roads to farms and means of transport towards achieving effective productivity and scale efficiency should be formulated.

*Corresponding author: E-mail: amosbits@gmail.com;

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1. INTRODUCTION

Rice (*Oryza sativa*) is one of the major staple crops in Nigeria grown on over 3.2 million hectares of land [1]. Rice production in the country rose from 2.4 million metric tonnes in 1994 to 5.8 million metric tonnes in 2017 [2]. The average yield of rice in Nigeria decreased from 2.07 tonnes per hectare in 1990 to two tonnes per hectare in 2017. Nigeria is currently the largest rice producing country in Africa. However, a great variation also exists between the states in Nigeria in terms of yield, the average rice yield of the states with relatively high yields include Enugu (3 tons/ha), Imo (2.7 tons/ha) and Ebonyi (2.5tons/ha). Benue (3.6 tons/ha) and Adamawa (3.3 tons/ha) had the highest yield in 2017 [3].

In Adamawa State, rice is grown virtually in all parts of the state but its production is mainly in the hands of small-scale resource poor farmers who use traditional technology with resultant low productivity [4]. Although Adamawa is well endowed with the requisite agronomic conditions for the continuous production of rice, the State's potential has been underutilized mainly due to some constraints, viz. small scale of rice production, poor agronomic practices and low adoption of improved yield which resulted in scale inefficiencies within the rice production system.

In order to address the scale inefficiency in rice production among others in Nigeria, governments have at various times come up with policies and programmes. The programmes and policies have the objective of increasing scale of production by providing incentives to rice farmers for achieving rice self-sufficiency. Nevertheless, most of these programmes and policies were terminated without achieving their objectives. Among these programmes are: Federal Rice Research Station (FRRS) (1970), Abakaliki Rice Project (ARP) (1978), Presidential Initiative on Rice (PIR) (1999), National Rice Development Strategy (NRDS) (2009) and Rice Intervention Fund (RIF) (2011) [5].

However, Anchor Borrowers' Programme (ABP) were initiated and implemented by the Federal Government of Nigeria in 2015 through the Central Bank of Nigeria in response to a fall in agricultural productivity and scale efficiency in

the Agricultural sector in Nigeria, hence a concern to sustain domestic food supplies, as labour had moved out of agriculture into more remunerative activities that were benefiting from the oil boom. The government's adoption of the ABP concept put the smallholder sector at the center of the agricultural development strategy and marked a clear shift away from capital-intensive investment projects for selected areas of high agricultural potential. The ABPs sought to increase food production and farm incomes. In all, it was assumed that scale efficiency and productivity increases would come from the use of improved technology and availability of farm inputs [6,7].

In order to help rice farmers increase production and scale efficiency, the ABP was introduced in 2017 in Adamawa State targeting rice production. It provides the rice farmers with better and improved technologies. It is therefore important to assess whether the program objectives are achieved in terms of efficiency of scale of production. The objective of this study was to examine socio economic characteristics of rice farmers in Adamawa State, Nigeria, Specifically, to estimate their scale efficiency and describe constraints encountered among ABP rice farmers' beneficiaries in Adamawa State, Nigeria.

2. METHODOLOGY

2.1 Background to the Study Area

The study was conducted in Adamawa State, Nigeria. The state is located between latitudes 9°20'N and 9°33'N and longitudes 12°30'E and 12°50'E and covers an estimated area of about 38,741 square km with a population of 4.06 million persons [8]. The state comprised 21 local government councils with Yola as the capital. It is bounded with Taraba State from the South and West, Gombe State by its Northwest, Borno State to the North and it has an international boundary with the Cameroon Republic along its eastern border. The State has a tropical climate marked by dry and rainy seasons. The rainy season commences in April and ends in late October. The wettest months are August and September. The mean annual rainfall pattern shows that the amounts range from 79 mm in the north-west part to 197 mm in the southern part. The mean annual rainfall is less than 1000 mm in

the central and north-western part of the State. On the other hand, the north-eastern strip and the southern part have over 1000 mm of rainfall. Adamawa state has a typical West African Savanna climate with high temperature which is relatively distributed throughout the year. The maximum temperature in the state is 39.7°C, particularly in April, while minimum is as low as 15.2°C between December and January. Mean annual temperature in the state ranges from 26.7°C in the south to 27.8°C in the north eastern part of the state [9].

2.2 Sampling Procedure

Multistage sampling procedure was used in drawing sample size for the study. Adamawa state consists of three senatorial zones namely: Adamawa North, South and Central senatorial zones. All the three senatorial zones were included in the survey because the rice growing areas transverse all the zones. The first stage involved purposive selection of one Local Government Area (L.G.A) from each of the three senatorial zones well known for rice production and where ABP has been implemented. This information was obtained from the Adamawa Agricultural Development Programme (AADP). The L.G. As selected were Numan, Girie and Michika. The second stage involved purposive selection of twelve villages proportionately from the three L.G. As in the first stage. The list of rice farming villages benefiting ABP in the three L.G. As was obtained from AADP office. Twelve villages with the highest number of beneficiaries across the three LGA's were selected, that is, three villages from Numan, five villages from Girie and four villages from Michika LGA. The third stage involved estimation of sample size from the sample frame using equation 2.1 [10]. Finally, the number of respondents in each village were selected randomly using equation 2.2 [11] as shown in Table 1. The sampling frame is the list of rice farmers benefiting from ABP in the selected villages which was obtained from AADP.

2.3 Sampling Size

$$n = \frac{N}{1 + N(e)^2} \quad (1)$$

where:

n = Sample size;
N = Population size;
e = level of precision.

$$\text{Therefore, sample size was } = \frac{1277}{1 + 1277(0.08)^2}$$

$$n = \frac{1277}{9.1728} = 139.$$

The number of respondents in each village was obtained with the help of the formula below as shown in Table 1.

$$NI = \frac{n}{N} \times Ni \quad (2)$$

where:

NI = sample size in each village;
n = total number of sample size, that is 139;
N = total number of farmers in the targeted population;
Ni = total number of farmers in each village.

2.4 Source of Data

The data for the study were collected from both primary and secondary sources. Primary data were collected through administration of structured questionnaires. Trained enumerators were used to assist in data collection. The questionnaires sought information relating socioeconomic characteristics of rice farmers, production variables and output obtained in rice production in 2018 cropping season. The secondary data were obtained from the records of Adamawa State Agricultural Development Programme. The secondary information entailed the list of ABP beneficiaries.

2.5 Analytical Techniques

The analytical tools that were employed for this study were Descriptive Statistics and inferential statistics. The descriptive statistics were mean, percentages, ranking and frequency distribution. These descriptive statistical techniques helped to describe socio economic characteristics and producer constraints of rice farmers. Input used, outputs of production processes and efficiency distributions among sample farmers were also presented using descriptive statistics. The inferential statistics that was employed include Data Envelopment Analysis (DEA) which was used to achieve the objective of the study.

2.6 Data Envelopment Analysis

Data Envelopment Analysis method is a non-parametric mathematical programming technique employed to achieve the objective of the study,

that is, to determine scale efficiency. Given the constant return to scale (CRS) assumption, the best way to introduce DEA is via the ratio form such as $u'y/v'x$, where u is an $M \times 1$ vector of output weights, v is a $K \times 1$ vector of input weights, M is output on each farm and K inputs on each farm.

2.7 The Models

Scale efficiency is obtained by dividing technical efficiency due to constant return to scale by technical efficiency due to variable return to scale [12,13].

The envelopment form of the input-oriented constant return to scale DEA model is specified as follows:

$$\delta_c^j = \min_{\delta, z} \delta \quad (3)$$

Subject to

$$\begin{aligned} y^j &\leq Yz \\ Xz &\leq \delta x^j \\ z &\in R_+^N \end{aligned}$$

where:

δ_c^j = technical efficiency due to CRS
 y^j = output of j th farm
 x^j = input of j th farm
 z = vector weights to be defined

The envelopment form of the input-oriented variable returns to scale (VRS) DEA model is specified as follows:

$$\delta_v^j = \min_{\delta, z} \delta \quad (4)$$

Subject to

$$\begin{aligned} y^j &\leq Yz \\ Xz &\leq \delta x^j \\ lz &= 1 \\ z &\in R_+^N \end{aligned}$$

where:

δ_v^j
 = technical efficiency due to variable returns to scale
 y^j = output of j th farm
 x^j = input of j th farm
 z = vector weights to be defined

Given these estimates of technical efficiency, the scale efficiency measure as the ratio of the constant returns to scale technical efficiency to variable returns to scale technical efficiency:

$$S^j = \delta_c^j / \delta_v^j \quad (5)$$

$S^j = 1$, indicates scale efficiency and $S^j < 1$, indicates scale inefficiency. This technique was used to determine the scale efficiency of the rice farmers.

Table 1. Distribution of sample frame and sample size of farmers

Senatorial districts	Local government area	Villages	Sample Frame	Sample size in each village	Sample Size
Adamawa South	Numan	Kadomti	146	(139/1277) 146	16
		Imburu	103	(139/1277) 103	11
		Bolki	98	(139/1277) 98	11
Adamawa Central	Girei	Mudari	102	(139/1277) 102	11
		Lanbindo	84	(139/1277) 84	9
		Tambo	94	(139/1277) 94	10
		Dakri	96	(139/1277) 96	11
		Damare	111	(139/1277) 111	12
Adamawa North	Michika	Michika 1	128	(139/1277) 128	14
		Vi/Boka	84	(139/1277) 84	9
		Moda-	122	(139/1277) 122	13
		Ldaka	109	(139/1277) 109	12
		Bazza			
Total			1277		139

Source: Reconnaissance survey, 2019

3. RESULTS AND DISCUSSION

3.1 Socioeconomic Characteristics of Rice Farmers

Results in Table 2 revealed that 61.1% of the rice farmers were between 21-40 years of age, and the rice farmers had a mean age of 40.4 years. This indicates that the majority of the rice farmers in the study area were relatively young and physically active. The age of the farmers showed that the youths were dynamic and willing to take risks connected with adoption of new agricultural technology. The age of the farmers has an effect on the type of agricultural activities they may engage in for instance, in family labour, younger farmers spent much time on the farm and they embarked on more strenuous tasks than older farmers and children. Hence, increases productivity of rice. The finding of this study conformed to findings of [14] that carried out a study on the profit efficiency among rain-fed rice farmers in Taraba State and posited that 82% of the farmers were aged between 21-50 years old. This shows that they are predominantly youths and hence agile and economically productive.

The results revealed that male farmers constitute 76.3% as against female farmers with 23.7% which implies that male farmers dominated rice farming in the study area. This could be attributed to the fact that rice production requires an intense labour which male farmers could

provide easily as against their female counterparts. The dominance of the male farmers in rice production could also be attributed to the ability of the male farmers to access and use farm inputs (land and production inputs) easily. This result is in line with the findings of [15] who indicated in their study on Econometric analysis of rice production in Anambra State that 69.44% of respondents were male. This also supports the findings of [16] who indicated that 98.12% of the respondents were male in their study on analysis of adoption of improved rice production technologies in Jeer local government area of Borno state, Nigeria.

The result showed that 92.8% of the respondents were married and only 7.2% were single. This implies that the married were more involved in rice production than their single counterparts. This suggests that the majority of the respondents had stable families which would enrich decision-making processes especially in agricultural production and domestic responsibilities which may provide a large cheaper source of labour for cultivation [17]. This also conformed to the findings of [18] in their study on socioeconomic factors influencing rice production among male and female farmers in northern Guinea Savannah, Nigeria who indicated that 97.8% of the respondents were married.

Table 2. Socioeconomic characteristics of rice farmers

Socio-economic variables	Frequency	Percentage	Mean
Age (years)			
≤20	6	4.3	
21-30	18	12.9	
31-40	67	48.2	40.4
41-50	29	20.9	
51-60	13	9.4	
>60	6	4.3	
Sex			
Male	106	76.3	
Female	33	23.7	
Marital Status			
Married	129	92.8	
Single	10	7.2	
Household Size			
< 3	15	10.8	
3-6	31	22.3	
7-10	61	43.9	7.7
11-14	22	15.8	
> 14	10	7.2	

Source: Computed from field data. 2019

In addition, the majority (59.7%) of the farmers had household sizes that ranged between 7-14 persons. The mean household size was 8 persons. These findings suggest that large household size could be as a result of the practice of polygamy in most household in the study area. Large household sizes are typical of African traditional agriculture where household size determines the family's scale of production due to farm labour availability. The result of this study implies that rice farmers have adequate household size which may guarantee the availability of labour which in turn reduces expenses on hired labour. The result is in line with the findings of [19] in a study on Economic Analysis of Rice Production in Cross River State which revealed that 58.4% of the respondents had household size from 6-15 people and concluded that farmers had enough family labour force for rice production.

3.2 Input and Output Level in Rice Production Per Hectare

Result in Table 3 revealed the summary statistics of level of inputs used and outputs realized in rice production in the study area for better understanding of the level of productivity of the rice farmers. The inputs that were used in rice production include: seed, fertilizer, labour, herbicide, and farm size.

The results revealed that the average quantity of seed used by rice farmers was 29.26 kg/ha. The seed rate is reasonable and must have contributed tremendously to high yield. Average fertilizer used by rice farmers was 354 kg/ha, while the mean labour recorded was 25.30 mandays/ha. The mean herbicide recorded for rice farmers was 7.42 liters/ha, while the mean farm size was 1.60 ha. The output of rice varies from one farmer to another depending on the input utilization and the management practices. The average output of rice in the study area was 3240 kg/ha (3.2ton/ha) which is lower than the average yield of 3.3 ton/ha in Adamawa state in 2017 [3].

The result also revealed the coefficient of variation of each variable input used and output realized. The higher the coefficient of variation, the greater the dispersion of the variable are while the lower the ratio of standard deviation to mean return, the better your risk-return trade-off. The low coefficient of variation is a reflection of reliability (precision) of the result [20]. These authors reported that for a normal distribution,

the ratio of mean to standard deviation should be of order of three or more and 33% is often stated as the permissible upper fiducial limit of coefficient of variation.

Our findings revealed that the coefficient of variation of all the variable inputs used were 32.54%, 1.75%, 82.92% and 45.28% for seed, fertilizer, labour and herbicide, respectively. The low coefficient of variation of variable inputs implies low level of variation in the use of variable input among rice farmers in the study area. However, the coefficient of variation for fertilizer (1.75%) and seed (32.54%) were lower compared to other variable inputs used for rice production. The low variation in input used by the farmers could be attributed to the fact that they are similar in size of production. The coefficient of variation in rice output was 5.25% which implies low inconsistency in output level among rice farmers in the study area. However, if productivity status of rice output is adequately checked, it will lead to self-sufficiency in rice production. The instability in output of rice could be attributed to inadequacy of variable inputs among farmers in the study area.

3.3 Estimation of Scale Efficiency on Rice Productivity

The input oriented DEA models were used to obtain the scale efficiency of rice farmers in the study area. The models can be either constant return to scale (CRS) or variable return to scale (VRS). The study used both CRS and VRS models, where every rice farm was evaluated, given its farm size level to determine its scale measures. DEA results revealed the nature of scale efficiency score with which the sample rice farms operated.

The scale efficiency of rice farmers in Adamawa State presented in Table 4 showed that the scale efficiency scores of rice farmers range from 0.32 to 1.00 with a mean score of 0.59 (59%). This implies that the rice farms are operating in less than optimal scale size, in other words, scale efficiency among the rice farmers could be increased by 41% to operate in an optimum scale size, given the current state of technology. Out of the 139 rice farms or decision making units (DMUs) studied, 16 DMUs representing 22% scale efficiency score of the rice farms were scale efficient, while 123 DMUs representing 78% scale efficiency score of the rice farms were scale inefficient. This implies that a large proportion of rice farms were operating far below

optimal scale, these farms could increase their rice productivity and income by decreasing costs of inputs used whereas only 22% scale efficiency score operating at an optimum scale which is the most productive scale size, given the current state of technology. This result is in consonance with that of [17], which used data envelopment analysis application to evaluate farm resource management of Nigerian farmers. The study reported that most (80%) of the DMUs studied were scale inefficient and operating in less than optimal scale size.

The results also showed that 98 rice farms representing the majority (70.5%) of rice farmers in the study area were found to be operating within the increased returns to scale (IRS). This implies that they have huge potential to increase their rice productivity status through expanding their size of production and increase inputs, given that they were performing below or sub-optimum scale with their various farm sizes. Therefore, operating at stage I of the production process, where a proportionate increase in inputs for rice production will lead to a more than proportionate increase in output of rice productivity. Twenty-five rice farms representing 18% of rice farmers exhibited decrease return to scale (DRS), which imply that they were operating above or supra-optimal scale of production. Hence, operated at stage III of the production process, where a proportional increase in inputs for rice production will lead to a less than proportionate increase in output of rice productivity. Therefore, reducing the scale of production inputs will be the best option for the farmers to enhance their productivity. This is in conformity with [21] who noted that DMUs operating in DRS status can improve their overall productivity by reducing their production size.

On the other hand, only 16 rice farms representing 11.5% of rice farmers exhibited

CRS, which implies that they were operating at an optimal scale of production. They operated at stage II of the production process; hence a proportionate increase in inputs for rice production will lead to a proportionate increase in output of rice productivity level. Given the majority representing 88.5% of the rice farms operating under IRS and DRS, this suggests that rice farmers in the study area generally were scale inefficient in terms of resource used for obtaining optimum rice productivity level, since scale inefficiency is usually due to the presence of either IRS or DRS. Given the availability of funds for labour, access to credit, access to extension services, fertilizer and agrochemicals, this inefficiency may be due to the presence of drought, flood and pest infestation as the major problem facing rice production in the study area. This study is in agreement with [22]. Although in the short run, DMUs may operate with IRS or DRS, in the long run however, DMUs must shift towards CRS by expanding their size of operation and reducing their inputs cost, so as to be efficient in order to achieve the desired increase in productivity.

3.4 Constraints to Rice Production in the Study Area

Table 5 presents the result of constraints facing rice farmers. Prevalence of pest and disease attack, bad road and high cost of labour as well as access to ox-plough/tractor were indicated by 73.9%; 64.6%; 53.1%; and 46.9% of the rice farmers respectively, as the most severe problem tormenting rice production in the study area. Other constraints include high cost of transportation (34.6%), natural hazard, flood and drought (30.0%), and insecurity (21.5%). This result implies that rice farmers were faced with myriads of constraints which could affect their productivity level and scale efficiency.

Table 3. Summary statistics of input and output levels in rice production/hectare

Variable	Mean	Standard Deviation	Standard Error	Coefficient of Variation (%)
Seed (kg/ha)	29.26	9.52	0.81	32.54
Fertilizer (kg/ha)	354.00	6.19	0.53	1.75
Labour (Manday/ha)	25.30	20.98	1.78	82.92
Herbicide (Litre/ha)	7.42	3.36	0.28	45.28
Farm Size (ha)	1.60	1.12	0.09	70.00
Yield (kg/ha)	3240.00	170.00	14.42	5.25

Source: Computed from field data. 2019

Table 4. Frequency distribution of scale efficiency estimates

Return to scale	Frequency	Percentage	Scale efficiency score	Percentage
Increase Return to Scale	98	70.5	0.46	46
Decrease Return to Scale	25	18.0	0.32	32
Constant Return to Scale	16	11.5	0.22	22
Total	139	100.0	1	100
Mean			0.59	
Minimum			0.32	
Maximum			1.00	

Source: Computed from field data. 2019

Table 5. Constraints to rice production among anchor borrowers programme beneficiaries (n=139)

Constraint	Frequency	Percentage	Ranking
Pest and Diseases	96	73.9	1
Bad Road	84	64.6	2
High Cost of Labour	69	53.1	3
Access to Ox-plough/Tractor	61	46.9	4
High cost of transportation	45	34.6	5
Natural Hazard, Floods and Drought	39	30.0	6
Insecurity	28	21.5	7

Source: Field Survey, 2019

The implication is that pests and diseases attack all portions of the rice plant at all stages of growth. Its infestation could result in significant yield losses and also cause considerable and unacceptable rice yield in the field and in storage. This study is in line with that of [23] which revealed very high losses in Africa rice are attributed to pests and diseases.

An efficient transport system is critically important for efficient agricultural production. If transport services are of poor quality or expensive, then farmers will be at a disadvantage when they harvest/sell their crops. An expensive service will naturally lead to low farm gate prices and hence low productivity and scale of production. About 53.1% of the respondents mentioned the high cost of labour as a constraint. Tasks in rice production such as weed control, harvesting, processing, product drying, and transportation all require labour. Most farmers during this period rely on hired labour. Ugbajah and Uzuegbuna [24] opined that labour shortage was responsible for causative factors of decline in production in Ezeagu Local Government Area of Enugu State.

Our results also revealed that 46.9% of the farmers pointed out that Ox-plough/tractors have been a problem in the state among rice farmers which affected productivity of the farms. The availability of modern machinery not only

reduces drudge farm operations but also contributes to increase in farm size cultivated and thereby increase productivity or output, as noted by [25]. Other constraints indicated natural hazard, floods and drought (34.6%), high cost of labour (30.0%), and insecurity (21.5%). This is in line with [26] in his study on Resource use efficiency in rain-fed rice production in the Mubi local government area of Adamawa state.

4. CONCLUSION AND RECOMMENDATIONS

Based on the findings, the study concluded that the majority of the rice farms were operating in stage I and stage III of the production process, which suggests that rice farmers in the study area were scale inefficient in terms of inputs used. Since size inefficiency is usually due to the presence of either IRS or DRS, this means that there are still opportunities to increase rice productivity and income through more efficient utilization of productive resources, where a proportionate increase in inputs will lead to a proportionate increase in output level, given the current state of technology. Prevalence of pest and diseases was indicated as the major factor that torments productivity of rice farmers among anchor borrower's beneficiaries.

The following recommendations are made based on the findings of this study:

- Most socioeconomic attributes of the rice farmers investigated had meaningful bearing on the production ability to procure and use the production inputs. Hence, policies targeting increase in farm size should be implemented since the farmers were small scale farmers. The farm size can be increased by increasing the input (package) given to the rice farmers.
- Scale inefficient nature of production calls for increased scale of production by intensification through encouraging the farmers to strengthen the existing cooperative societies to meet up with the requirements of the federal government to intensify production, increase level of productivity and scale efficiently in rice production.
- Constraints facing rice production could be addressed by formulating policies geared towards investment in pest and disease control, good access roads to farms and means of transport towards achieving effective productivity.

5. LIMITATION OF THE STUDY

Most of the respondents' estimates were provided by memory recall because of the non-keeping of farm records. Probe styles and cross questioning were, however, used to elicit accurate and reliable information as much as possible.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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