Technical efficiency in rice ecologies of north central Nigeria: Implications for national self-sufficiency

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Abstract

The quest for national self-sufficiency in rice production in Nigeria has been on for several years, with various government regimes putting different policies and programs in place in order to achieve this. A large proportion of the rice produced in Nigeria comes from the north central part, with Niger State being the second largest rice producing state in north central Nigeria. The study was carried out to examine the technical efficiency and its determinants within the rice ecologies in north central Nigeria. Through the multi-stage sampling technique, one hundred and fifty-one farmers were sampled for the study. Two mini-ecologies were identified within the lowland rice ecology in the study area, namely, River Basin Authority Catchment area (RBAC) and Non River Basin Authority Catchment area (NRBAC). Differentials in rice output were determined with the Chow test while the stochastic frontier production approach was employed to determine the technical efficiency on the individual farms. There were variations in output between the mini-ecologies, while rice output was significantly influenced by farm size, quantities of fertilisers, labour and herbicides used in rice production. Average technical efficiency measures were 70.9 and 93.6% for the identified mini-ecologies namely River Basin Authority Catchment area (RBAC) and Non River Basin Authority Catchment area (NRBAC). Variables such as extension visits and level of commercialisation had significant effects on the observed variations in technical efficiency among the rice farmers. Results indicate that there is a considerable scope for increased efficiency to meet current national rice demand.

Key words: Output differential, Stochastic frontier production

Introduction

It has been estimated that about ninety per cent of the farmed land in Nigeria is rain-fed while the most important rice production system is in the rainfed lowlands (Ugalahi *et al.,* 2016) as it accounts for about half of the total rice production in the country (UNEP, 2005; Fashola *et al.*, 2011). With improved water control and use of external inputs, rain-fed lowland rice ecology systems may

become more attractive and rice yields could be increased rapidly in these systems that are inherently much more stable than the upland areas (WARDA *et al.*, 2008). Local production of rice in Nigeria is estimated at three million tonnes which has not been able to keep pace with national demand of about five million tonnes (NAMIS, 2004; NRDS, 2009; USDA-ERS, 2012). This deficit in national rice supply has attracted attention from several successive Nigerian governments leading to various interventions in the rice sub-sector of the economy (Orefi, 2011; Onyenekwe and Okorji, 2015). These interventions include the establishment of the River Basin Development Authority (RBDA) in 1976 to harness the country's water resources and optimise the country's agricultural resources for food self-sufficiency (Akanmu *et al.*, 2007). The river basins were expected to contribute positively to the nation's search for food security by reducing the country's dependence on rain-fed agriculture and increase the proportion of irrigated agriculture that would make possible two, and sometimes three cropping seasons in one year (Akanmu *et al.*, 2007; Shariff, 2009).

The Green Revolution launched in 1980 aimed at increasing food production and raw materials in order to ensure food security and self-sufficiency in basic staples which included rice. The National Special Programme on Food Security (NSPFS) was launched in 2002 with objectives which included assisting farmers to increase their output, productivity and their capacity for effective utilisation of resources for self-sufficiency. The Agriculture Transformation Action Plan (ATAP) which was launched in 2011 focuses on developing the value chain of specific commodities which include rice, cocoa, cotton, cassava and sorghum. In spite of all these interventions, the smallholder rain-fed rice farmer in Nigeria produces 4.6 tonnes of paddy per year from an annual crop area of 3.3 hectares (Ogundele and Okoruwa, 2006; Idiong, 2007). The average national yield of rice in 2012 was 1.8 tonnes of paddy per hectare (FAO, 2013), which is quite low when compared with the national average potential of 3.0 t ha^{-1} for upland system and 5.0 t ha^{-1} for lowland system (Imolehin and Wada, 2005). The consequence of this is that local rice production has not been able to meet up with the domestic demand and as a result, the importation of rice has become necessary to bridge the demand-supply gap (Bamidele *et al.*, 2010; Johnson *et al*, 2013).

Strategies for sustainable increased production are necessary for the country to become self-sufficient in rice production. These would be better built on an improved production environment with a focus on efficiency at the farm level. Efficiency refers to the minimum resource level that is theoretically required to run the desired operation in a given system (Tangen, 2006). It is measured as the ratio of output produced with given inputs relative to the maximum feasible output. A proper understanding of the performance of the rice sector and the factors affecting such performance is vital. Such understanding is expected to give room for specific policies, decisions and actions to address particular factors/situations at the farm level to bring about positive change towards the attainment of national self-sufficiency. It is therefore important to examine the factors that would contribute greatly to improving rice output in Nigeria so as to pave the way for sustainable increased production and

eventually self-sufficiency of the staple crop (Ogundari *et al.,* 2012). Self-sufficiency has been defined as the ability to meet consumption needs (particularly for staple foods) from own production rather than importing (Minot and Pelijor, 2010).

yams, sorghum, maize, groundnuts, sugarcane, melon and millet. Niger state is one of the three major rice producing states (Niger, Kaduna and Taraba) in north central Nigeria and one of the states with the largest rice land area of between 184,000 and 230,000 hectares.

Methodology

The study area
The study was carried out in Niger state which is situated in the North-Central geo-political zone and guinea savannah agro-ecological zone of Nigeria. It is situated between latitudes 8^0 20 and 11^0 30 north and longitude 3^0 80 and 7^0 20 east. Major crops cultivated in Niger state include rice,

Sampling procedure
The multi-stage sampling technique was employed for the study. This involved the random selection of two out of the three Agricultural Development Programme (ADP) zones in the State, the selection of Local Government Areas (LGAs) from the two selected ADP zones (zones I and III), the selection of villages from the LGAs and the selection of rice farmers
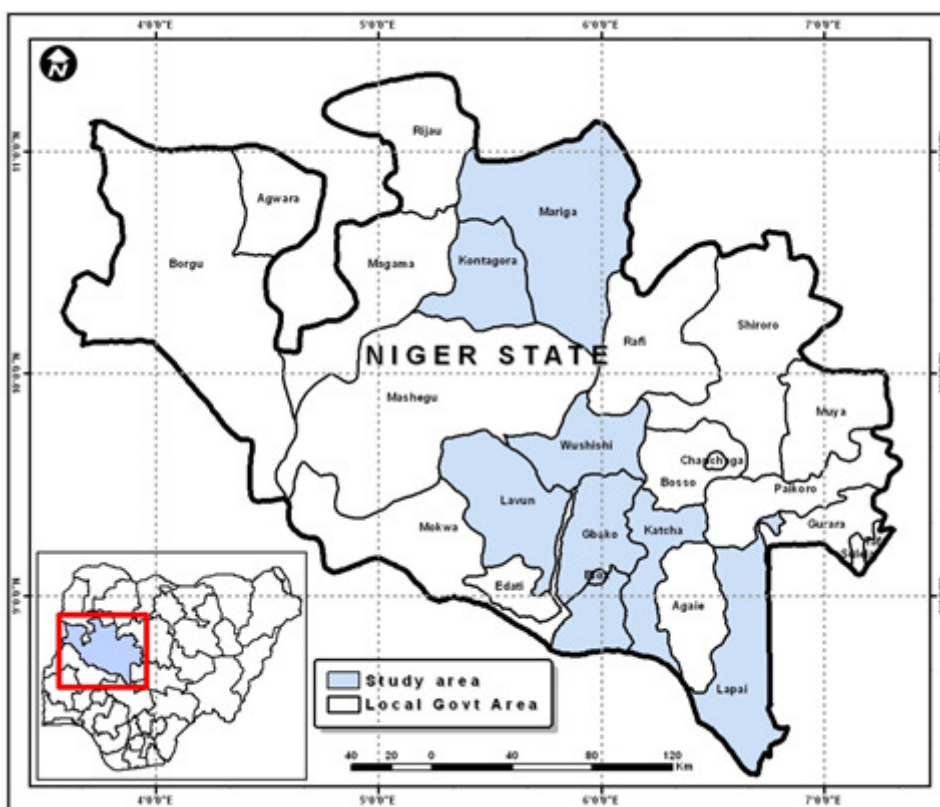

Figure 1.   Study area.

from the selected villages. A total of one hundred and fifty-one rice farmers was randomly selected from fourteen villages in seven LGAs. The lowland rice production system in the study area was divided into two major mini-ecologies based on location of the rice farms. These are rice farms located in the River Basin Authority Catchment areas (RBAC) and rice farms located outside these catchment areas, that is, Non River Basin Authority Catchment areas (NRBAC). River Basin Development Authorities were created to help reduce the country's dependence on rain-fed agriculture and increase the proportion of irrigated agriculture that would make possible two or more cropping seasons in a year (Akanmu *et al.*, 2007; Shariff, 2009). River basin catchment areas in this study refer to locations around the river basin which are expected to benefit directly in the use of agricultural water through irrigation facilities from river basin authority. Thus, out of the 151 sampled lowland rice farmers, 78 were categorised into the NRBAC group and 73 into RBAC group.

Data collection

Primary data were collected using a pre-tested structured questionnaire, copies of which were administered to the selected rice farmers *via* interview schedules. Data were collected on farm and farmers' characteristics, as well as on details of rice production.

Methods of data analyses

Chow test was used to determine the output differentials, while the method used to determine technical efficiency is the parametric approach, using the stochastic frontier model based on the estimation of the frontier production function.

The stochastic frontier production function is expressed as:

$$Y_i = f(x_i; \beta) \exp(V_i - U_i) \quad i = 1,2, ..., N \quad \text{............................ Eq. (1)}$$

Where:

Y_i = Quantity of output
x_i = vector of input quantities
β = vector of parameters

V_i is a random error assumed to be independently and identically distributed with zero mean which is associated with random factors such as measurement errors in production and weather which are out of the control of the firm/farmer. Ui represents non-negative random variables which are assumed to account for technical inefficiency in production (Coelli, 1996).

This stochastic frontier model was proposed by Meeusen and Van den Broeck (1977) and Aigner *et al.* (1977). Technical efficiency of a firm i is taken to be;

$$TE_i = \exp(-U_i) \quad \text{........................ Eq. (2)}$$

so that $0 \, d< TE < 1$

That is,

$$TE_i = Y_i/Y_i^* \quad \text{............................ Eq. (3)}$$

(output of ith farm relative to the output that could be produced by a fully efficient farm using the same input bundle. That is, observed farm output relative to the corresponding frontier output, given the available technology).

The frontier production function has been widely applied in empirical studies using farm-level data in developed and

developing countries. These include Kalirajan (1982), Bagi (1982), Oladeebo and Fajuyigbe (2007), and Masunda and Chiweshe (2015).

Parameters of the stochastic production function were estimated by the maximum likelihood method using Frontier 4.1 Software Version (Coelli, 1996).

Model specification

The empirical model employed in the stochastic production frontier is the Cobb-Douglas functional form specified as:

$$Ln\ Q = \beta_0 + \beta_1 lnX_1 + \beta_2\ lnX_2 + \beta_3 lnX_3 + \beta_4 lnX_4 + vi - ui \quad .... \text{Eq. (4)}$$

That is,

$$Ln\ Y = \beta_0 + \Sigma b_i\ lnX_i + vi - ui\ ....\ \text{Eq. (5)}$$

Where:

Ln = natural log
Q = rice output in kg; and
X_i = factor inputs in rice production

Where:

i = 1,2,———, 5;
X_1 = fertiliser (kg ha^{-1});
X_2 = Labour (mandays ha^{-1});
X_3 = Herbicide (litre ha^{-1});
X_4 = rice seeds planted (kg ha^{-1});

B_0, b_i = parameters to be estimated;

b_i = logarithm coefficient of independent variables;

v_is are assumed to be independent and identically distributed normal random errors having mean zero and variance σ_v^2

and are also distributed independently of u_i; and
u_is are non-negative technical inefficiency effects representing management factors and are assumed to be independently distributed with mean μ_i and variance σ^2 (Battasse *et al.,* 1996; Munir *et al.*, 2002) The technical inefficiency model however, is specified as:

$$\mu_1 = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 \quad .... \text{Eq. (6)}$$

Where:

μ_1 is technical inefficiency term;
Z_1 = educational level of farmer;
Z_2 = rice farming experience;
Z_3 = farm to market distance;
Z_4 = extension visits;
Z_5 = proportion of total land cultivated to rice;
Z_6 = commercialisation level; and
δ_i are parameters to be estimated.

The variables used in the Cobb Douglas functional form and in the inefficiency model are described in Table 1.

Chow test (Test for output differentials)

Chow test is a test for structural change; an econometric test to determine whether the coefficients/parameters in a regression model are the same in separate subsamples. The standard F test for the equality of two sets of coefficients in linear regression models is called a Chow test. This test was used to test for the equality of production function parameters of the two production systems. This is to determine whether there are significant differences in the production parameters of the two mini-ecologies.

Table 1.   Description of variables of Cobb Douglas functional form

Variables	Description	Unit of measurement
Fertilisers	Quantity of chemical fertilizers applied to farmers' rice plots	Kilogram hectare^{-1}
Labour	This is the product of the number of people employed and the total time worked, in hours, by each individual on the rice plot. All labour inputs (hired and family labour) involved in the production process (land preparation all through to winnowing) were incorporated and converted to man-day equivalent.	Man-days hectare^{-1}
Herbicides	Quantity of weed-control chemicals applied to farmers' rice plots	Litre hectare^{-1}
Rice seeds	These are the planting materials from which rice paddy is obtained	Kilogram hectare^{-1}
Educational level	Number of years of schooling completed by the farmers	Number of years
Rice farming experience	This is how long the farmers have been involved in rice cultivation	Number of years
Farm to market distance	This is the distance between rice farm and place of output sale	Kilometers
Extension visits	Number of interactive visits by an agricultural extension worker to a farmer in order to give advisory services and/or practical demonstrations with regards to the promotion of better rice production.	
Proportion of total land cultivated to rice	This is the proportion of farmer's total farmland that is cultivated to rice	Proportion
Commercialization level	This is the proportion of total rice produced that is sold	Proportion

For RBAC production system,

$Q = f (X_1, X_2, X_3,$————$X_n)$
sample size = N_1 .... Eq. (7)

For NRBAC production system,

$Q = f (X_1, X_2, X_3,$————$X_n)$
sample size = N_2 .... Eq. (8)

The two samples were combined to estimate a third production function given as:

$Q = f (X_1, X_2, X_3,$————$X_n)$
sample size = $N_1 + N_2$ .... Eq. (9)

Thus, Equation (9) represents the two systems combined.

Following Onyenwaku (1997) and Olomola (1998), Chow's F-statistic computed from the estimated Equations 7, 8 and 9 is given as:

$$\frac{[\Sigma e_3^2 - \Sigma e_1^2 - \Sigma e_2^2]/K_3 - K_1 - K_2}{[\Sigma e_1^2 + \Sigma e_2^2]/K_1 + K_2}$$
.... Eq. (10)

Where:

Σe_1^2, Σe_2^2, Σe_3^2 are error sum of squares for Equations 7,8 and 9 respectively

K_1, K_2 and K_3 are degrees of freedom for Equations 7,8 and 9 respectively.

If F calculated is greater than tabulated F, there is significant difference in production parameters between the two groups. However, if F calculated is less that tabulated F, there is no significant difference in production parameters of the two groups. That is, the production parameters are equal and there are no structural differences between the two systems. Therefore, if the *F* statistic exceeds the critical *F*, we reject the null hypothesis that the two regressions are equal.

Results and discussion

Socio-demographic characteristics of respondents

Majority (over 90%) of the farmers were male, indicating that rice farming in the study area is male-dominated. The average age of rice farmers under RBAC and NRBAC were 42.48 and 47.95 years respectively (Table 2). This implies that the rice farmers are within active productive age range, and can therefore still farm actively for several more years. With regard to the number of years of formal education obtained by the farmers, those under RBAC had an average of 3.51 years while those under NRBAC had an average of 4.68 years of schooling.

All the farmers had been growing rice for an average of 22.8 years. These farmers are therefore not new entrants into the business of rice farming, but can be referred to as experienced rice farmers. Average distance travelled between home and rice farm by the farmers was 2.41 km and 2.26 km in NRBAC and RBAC respectively. The average farm size cultivated to rice was 2.47 hectares in NRBAC and 3.05 in RBAC. The minimum proportion of rice produced that is sold (commercialization level) in both mini-ecologies is 58.3% while the maximum is 95.0%. However, the average level of commercialization in NRBAC and RBAC was 80% and 82% respectively. This implies that rice production by these farmers is mainly commercial. The importance of

Table 2. Socio-demographic characteristics of respondents

Characteristics	Sample mean	
	NRBAC	RBAC
Age (years)	47.95	42.48
Formal education (years)	4.68	3.51
Sex		
Male	98.72	91.79
Female	1.28	8.21
Household size	11.85	11.13
Experience in rice farming (years)	22.59	21.40
Size of rice farm (hectares)	2.47	3.05
Distance between farm and homestead (km)	2.41	2.26
Number of extension visits received per year	13.33	11.29
Commercialisation level (%)	80	82

agricultural extension services in agricultural development can not be over-emphasised. Visits by extension workers to farmers are vital to farm productivity. The numbers of such visits received by the respondents are shown in Table 2.

Estimation of Cobb Douglas production function model parameters is given in Table 3. For RBAC rice farms, inputs which significantly influence rice output positively were size of rice farm, fertilisers, agrochemicals and labour. Inputs which significantly and positively influenced rice output in NRBAC rice farms on the other hand are farm size, seeds and labour. This implies that increase in the quantities of these inputs used would bring about increase in quantity of rice produced.

Chow test result from Equations 7, 8, 9 and 10 for output differential using parameters from Table 1 gave an F calculated value of 7.2151 with corresponding tabulated F values of 2.321 and 1.8307 at 1 and 5% respectively. Since $F_{cal} Ã F_{tab}$, the null hypothesis is rejected. Thus, there are significant differences in output levels between the two mini-ecology production systems.

A t-test was carried out to confirm the output differential magnitude between the two mini-ecologies.

NRBAC	2.46 t ha^{-1}
RBAC	1.53 t ha^{-1}
Difference	0.94 t ha^{-1}
t-stat	7.41***

(*** significant at 1%)

The quantitative results shown in this study confirms the qualitative results of Johnson *et al.* (2013), who reported the existence of wide variations in the intensity of production, use of modern inputs and water control in lowland rice system in Nigeria.

Technical efficiency model results
The estimated gamma parameter (Ò) of the inefficiency model indicates that about ninety-nine per cent (99.92%) and fifty-five per cent (55.51%) of the variation in

Table 3. Parameter estimates of Cobb Douglas production function model for lowland mini-ecologies

Variable	NRBAC		RBAC		Pooled	
	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
lnFmsz	0.5222 (0.0533)	9.79***	0.9922 (0.4015)	2.47**	0.3486 (0646)	5.40***
lnSd	0.2768 (0.0005)	6.66***	-0.1461 (0.1626)	-0.90	0.1989 (0.0263)	7.56***
lnFert	0.0067 (0.0110)	0.61	-0.8936 (0.0116)	-2.12**	0.0076 (0.0116)	0.66
lnHerb	0.0113 (0.0094)	1.20	1.3279 (0.3314)	4.01***	-0.0009 (0.0087)	-0.11
lnLab	-0.0217 (0.2831)	-0.08	0.8351 (0.1813)	4.61***	0.8719 (0.0777)	11.22***
Const	6.5437	6.04	7.7197	3.39	2.9452	9.19
R^2	0.8912		0.8589		0.8404	

*Significant at 10% level; **Significant at 5% level; ***significant at 1% level; Figures in parentheses= standard errors
Ln = natural logarithm; Fmsz = farm size; Sd = rice seed; Fert = fertilizers; Herb = herbicides; Lab = labour

rice output within the RBAC and NRBAC groups respectively, was due to differences in their technical efficiencies. The Technical Efficiency (TE) score distribution was between 0.317 and 0.994, with a mean of 0.709 for RBAC group; while that for the NRBAC group was between 0.100 and 0.992 with a mean of 0.936.

About eighteen per cent (17.95%) of the rice farms in RBAC areas operated at a technical efficiency level of between 0.10 and 0.50; while only 6.85% of the farms in NRBAC areas operated at the same level. Thus, 82.05% of farms in RBAC areas and 93.15% of farms in NRBAC areas operated at technical efficiency levels above 0.50. However, 50.00% of farms in RBAC and 82.19% of farms in NRBAC areas operated at technical efficiency levels above 0.75.

Although rice farms in the RBAC category are expected naturally to have higher technical efficiency by virtue of their location in the river basin area and potential benefits of their location, this was not the case. There is, therefore, considerable scope for efficiency improvements towards greater output that would lead to increased farm incomes and

promote self-sufficiency in rice production for the nation.

The estimated maximum likelihood parameters of the production function frontier with inefficiency model indicate that the variables (farming experience, extension visits and commercialisation level) had negative and significant effects on inefficiency levels for rice farms in the RBAC group. However, for rice farms in the NRBAC group, only two variables (extension visits and commercialisation level) had negative and significant effects on inefficiency levels. This highlights the importance of the role of extension workers in farmers' productivity and efficiency. The more interactions the rice farmers have with extension workers, the higher their technical efficiency would be for increased output. In addition, the more market-oriented the rice farmers are (higher commercialisation level), the lower their technical inefficiency. According to Bravo-Ureta and Pinheiro (1997), the shortfalls in efficiency however indicates that there can be increase in output without new technology and without the use of additional conventional inputs

Conclusion

Results from the study indicate significant differentials in output quantities between the mini-ecologies of the lowland rice production system in the study area. Factors which positively and significantly influence rice output include farm size, seed, fertilisers, herbicides and labour. However, there is considerable scope for increased rice production in the study area through improvements in technical efficiency especially in the RBAC areas. Since the RBAC areas are expected to benefit directly in the use of agricultural water from river basin authority through

irrigation facilities, it is important that efforts by appropriate authorities be directed towards revitalising the non-functional irrigation facilities for better production in the RBAC areas in order to pave the way for sustainable increased rice production in the mini-ecology. For both mini-ecologies, higher frequency of contacts with extension workers by rice farmers will contribute significantly to increased efficiency. This would be the result when extension workers communicate appropriate technologies to farmers and follow-up such technologies through proper monitoring of farmers' activities to ensure desired outcome. This implies that there is need for a very vibrant national agricultural extension system for farmers to be able to contribute effectively towards national self-sufficiency in rice production. Commercialization level also had significant influence on the technical efficiency. In other words, the more market-oriented the rice farmers are, the more technically efficient they would be in producing more rice.

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