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Determinant of technical efficiency in vegetable production under Fadama in northern guinea savannah, Nigeria

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Vegetables play a significant role in raising nutritional level by adding proteins, vitamins, fat and minerals to the mainly starchy diet of the people in Africa. This study estimated technical efficiency and identified its determinants in vegetable production under Fadama in Kaduna State in Nigeria. A sample of 192 Fadama farmers was used. Data Envelopment Analysis and a Tobit model were used for data analysis. The results showed that, about 51% of the total Fadama land cultivated was devoted to sole vegetable enterprises, while the mixed cropping enterprises occupied the remaining land. Technical efficiency in vegetable production in the study area ranged from 39 to 100 percent, with a mean value of 93 percent. All the vegetable crop enterprises clustered towards a high technical efficiency score. The significant factors influencing technical efficiency in vegetable production under Fadama included, age of farmers ($P< 0.01$), education ($P< 0.01$), farm size ($P< 0.05$), integration with output markets ($P< 0.01$), period of cultivation ($P< 0.01$) and land tenure system ($P< 0.05$).

Keywords: Data Envelopment Analysis, tobit model, farm size, output markets

Introduction

Vegetables play a significant role in raising nutritional level by adding proteins, vitamins, fat and minerals to the mainly starchy diet of the people in Africa (Taylor, 1988). They also provide employment and food for the teeming population; source of foreign exchange and income for farmers (Oladoja *et al*., 2006). The production of vegetables under *Fadama* or the seasonally flooded low lying areas is an important component of the farming systems in northern Nigeria, where irrigation is practiced. This is because, it is a very lucrative economic activity due to the availability of markets in the vicinity of production areas and in the southern states where there is high demand for them (Alamu, 1996). Finding ways to increase technical efficiency in agriculture and rural

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income without jeopardising the *Fadama* resources is an important policy goal that could enhance the living conditions of the farmers in the *Fadama* communities (Ibrahim, 2009). This is because, *Fadama* resources are both economically and ecologically significant, and constitute an important safety net for the rural poor. On the other hand, the maintenance of productivity in agricultural production which is a component of efficiency (Lingard and Rayner, 1975) is equally a fundamental component of sustainability (Santacoloma, 2000). This implies that an increase in efficiency will enhance productivity and subsequently, the sustainability of agricultural production systems. Thus, it is expected that if *Fadama* farmers improve the efficiency of their use of inputs, they simultaneously achieve economic and environmental objectives which are considered a prerequisite for sustainability (De Koeijer *et al*., 2002). In this way, enhancing efficiency would support sustainability as a result of the linkage between efficiency and sustainability.

The identification of factors that influence technical efficiency is a prerequisite for the development of efficiency improvement programmes for crop production in *Fadama* areas (Ibrahim, 2009). This is because policy issues which indirectly enhance the productive potentials of crop production under *Fadama,* such as the introduction of new technologies, or those which improve the level of farm efficiency are best addressed from the insight provided from such studies. This, therefore raises the question of the likely variables that could be manipulated by policy makers in order to enhance the level of efficiency of *Fadama* farmers and, hence, improve the productivity of vegetable production in Kaduna state and Nigeria as a whole. The objective of the study was to estimate the technical efficiency on vegetable farms and identify the determinants of technical efficiency among vegetable farmers.

Materials and methods

The study was conducted in Kaduna State which is located in the Northern Guinea Savanna Zone of Nigeria. The state is located on the southern end of the High Plain of Nigeria, bounded by parallel $9^o03'$N and $11^o32'$N; and extends from the upper River Mariga on $6^o05'$E to $8^o48'$E on the foot slopes of the scarp of Jos Plateau (Bello, 2000). In the *Fadama*, the dark grey clay soils (vertisols) have become highly valued and are focused on for intensive agricultural activities, especially during the dry season. Large areas of such *Fadamas* are used for economically valuable market gardening for growing tomatoes, chillies, sweet pepper, okra, onion, Irish potato and sugar cane using tradition “shadulf” irrigation (in the flood-plain Fadama of Galma and Tubo basins) (Bello, 2000). Presently, the traditional irrigation scheme is too small and laborious to cope with the rate of expansion and agricultural development of the Fadama lands.

Sampling technique

The population for the study comprised the dry season vegetable farmers that cultivate tomato, onion and pepper under *Fadama* in Kaduna state. Purposive sampling was used to select seven local government areas (LGAs) noted for intensive production of vegetables from the ten LGAs participating in the *Fadama* II project. The second National *Fadama* development project (NFDP II) is an extension of the first National *Fadama* development project. The design of NFDP II draws heavily on key lessons learnt from the NFDP 1. A total of eighteen states in Nigeria fulfilled the eligibility criteria for participation in the project. Out of the eighteen states, the World Bank supports twelve while the African Development Bank supports six states. Each eligible state can select only ten local government areas for participation in the project. The project development objective is to sustainably increase the income of *Fadama* users through empowering communities to take charge of their own development agenda and by reducing conflict among *Fadama* users. Furthermore, four LGAs (Soba, Giwa, Kubau and Birni-Gwari) were randomly sampled from the seven LGAs. From the lists of registered *Fadama* farmers in the four LGAs, a proportionality factor was used to determine the number of *Fadama* farmers sampled from each LGA (Table 1). A total of 200 farmers were selected for the study by simple random sampling. However, only 192 farmers gave complete responses which were used for analysis. The proportionality factor is specified according to Asika (1991) as follows:- $n = m/N * 200$. 1

Where, n= Sample size per Local Government, m= Number of registered *Fadama* Users Groups members per local government and N= Total number of registered *Fadama* Users Groups members.

Primary data were collected with the aid of questionnaires administered by trained enumerators. The data collected covered farmers' socioeconomic and crop production variables. The socioeconomic variables included age, level of education, and membership of cooperatives, farm size, number of extension visits, household size and composition, level of farm specialisation and land tenure system. Data on inputs such as size of *Fadama* plot (ha), labour (Mandays), urea fertilizer (kg), N-P-K fertilizer (kg), insecticides (litres) and seeds (kg) were collected. Data on the quantity of tomato, onion, sweet and hot pepper harvested per plot within a production cycle of about three to four were also collected.

Table 1. Number of *Fadama* farmers sampled for the study

Local Government Area	Number of registered *Fadama* farmers	No. of *Fadama* farmers sampled
Soba	553	57
Kubau	601	62
Giwa	378	39
Birnin Gwari	407	42
Total	1939	200

Data analysis and theoretical considerations

The collected data were analysed using descriptive statistics, Data Envelopment Analysis (DEA) and Tobit Regression Analysis. Data Envelopment Analysis is a non-parametric, linear programming based frontier analysis method that was originally developed to analyse the performance of organisations whose goals are not limited to profit maximisation (Charnes *et al.*, 1978). The envelope form of the input-oriented variable returns to scale DEA model was used to calculate the technical efficiency (TE) scores. The model was presented for a case where there are data on K inputs and M outputs for each of the N farms cropped by the *Fadama* farmers sampled. For the i-th farm, input and output data are represented by the column vectors si and ji, respectively. The KxN input matrix, S, and the MxN output matrix, J, represent the data for all farms in the sample. The model was specified according to Coelli *et al.* (1998) and Sharma *et al.* (1999) as follows:-

$$\min_{\theta,\lambda} \theta,$$

Subject to $-j_i + J\lambda \geq 0$ 2

$\theta s_i - S\lambda \geq 0$ 3

$N1'\lambda = 1$ 4

$\lambda \geq 0$

Where θ is a scalar, N1 is a Nx1 vector of ones, λ is an Nx1 vector of constants which shows the intensity with which each farm is used in order to construct the frontier of the production possibilities set. J λ and S λ are the efficient projections on the frontier. The value of θ obtained is the technical efficiency score for the i-th farm. The score which will always vary between zero and one, one indicating that the farm lies on the frontier and is efficient. Equation 4 in the model ($N1'\lambda = 1$) is the convexity constraint which makes the model to have a variable returns to scale (VRS) specification. Without it, the model would have a constant return to scale specification (CRS) (Fraser and Cordina, 1999).

The inputs considered include; size of *Fadama* plot (ha), labour (Mandays), urea fertilizer (kg), N-P-K fertilizer (kg), insecticides (Litres) and seeds (kg). The outputs were the quantity of tomato, onion, sweet and hot pepper harvested per plot within a production cycle of about three to four months. Efficiency scores were estimated using the Computer program DEAP Version 2.1 described in Coelli (1996).

In order to identify the determinants of technical efficiency, a Tobit regression model was estimated by expressing the measures of technical efficiency obtained from DEA as a function of factors hypothesised to influence it. However, as indicated in Dhungana *et al.* (2004), the efficiency scores from DEA are limited to values between zero and one. Thus, according to Ray (2004), the dependent variable in the Tobit regression equation cannot be expected to have a normal distribution because they are censored between zero and one. In addition, the ordinary least squares regression will not provide consistent estimates for a censored dependent variable hence, a Two-limit Tobit model originally presented by Rosett and Nelson (1975) was used in this study. This model is appropriate because the dependent variable is the level of technical efficiency from DEA, thus, the dependent variable must be between zero and one. The Two-Limit Tobit Model can be represented as:

$$y_i^* = B'x_i + \varepsilon_i, \qquad 5$$

where y_i^* is a latent variable (unobserved for values less than zero and greater than one) representing the level of technical efficiency of *Fadama* farmers, x is a vector of independent variables, which includes the factors impacting on technical efficiency, B' is a vector of unknown parameters, and ε_i, is a disturbance term assumed to be independently and normally distributed with zero mean and constant variance σ; and i = 1, 2,...n (n is the number of observations). Denoting y_i (technical efficiency) as the observed dependent (censored) variable, we have:

$$y_i = \begin{cases} 0 & \text{if } y_i^* \le 0 \\ y_i^* & \text{if } 0 \le y_i^* \le 1 \\ 1 & \text{if } y_i^* \ge 1 \end{cases}$$

The parameters of the Tobit model were estimated through the Maximum Likelihood Method (Zegeye, 1990). The independent variables hypothesised to determine technical efficiency in vegetable production under *Fadama* are as follows:

Age in year (d_1), this serves as a proxy for farming experience (Munroe, 2001). Level of education (d_2) EDU, was also measured as number of years in school. Membership of cooperatives (d_3) MOC, was measured based on the number of years of membership in the cooperative. Farm size (d_4) FSIZE, farm size was measured in hectares. Access to extension agents (d_5) EXTCONT was measured as a dummy variable. D=1 if Yes otherwise, D=0. Ratio of hired to total labour (d_6) LBRATIO both hired and family labour were measured in man-days; 8 hours of work by an average man. Norman (1972) conversion factor was utilised to convert 'woman' and 'child' labour.

Ownership of an irrigation device (d_7) IRDEVICE- This was measured as a dummy variable. D=1 if an irrigation device such as pumping machines is owned, otherwise D=0. Number of females in the household (d_8), NWFMALES. Level of farm specialisation (d_9), FSPEC was measured as a dummy variable, where 70% or more of total revenue is from one crop enterprise=1, otherwise D =0, Santarossa (2003). Land tenure system (d_{10}) LTEN was measured as a dummy variable. D=1 if the land is privately owned, D=0 if otherwise. Degree of integration with output markets (d_{11}) INT was measured as the ratio of total value of output sold and the total value of output produced in grain equivalents. This gives an idea about how much of its output the farm sells in the market (Latruffe *et al.*, 2005). Source of irrigation water (d_{12}) IRRWAT was measured as a dummy variable. D=1 if surface water, and, D=0 if underground water was used. The period of cultivation (d_{13}) PERCULT was measured as a dummy variable. D=1 if farmers cultivate their land only during the dry season, otherwise D=0.

Results and discussions

Cropping enterprises among the Fadama farmers

The vegetable production systems obtainable in the study area were identified and the result is presented in Table 2. The result shows that both sole and mix vegetable cropping systems were practiced by the *Fadama* farmers in the study area. In terms of land area cultivated, about 51% of the total *Fadama* land cultivated was devoted to sole vegetable enterprises. The mixed cropping enterprises occupied the remaining land. The most common mixtures included; tomato/onion, sweet pepper/tomato, hot pepper/tomato, sweet pepper/onion and the hot pepper/onion enterprises. The onion/tomato/pepper enterprises was the least in terms of both the percentage of total *Fadama* land area cultivated (2%) and the numbers of *Fadama* plots cultivated. In addition, majority of the *Fadama* plots (30%) were planted with tomato as a sole crop. Among the largest percentage of the total *Fadama* land cultivated (25.5%) was devoted to the cultivation of tomato/onion enterprise. In terms of both land area cultivated and the number of *Fadama* plots cultivated, the sole tomato, tomato/onion and the sole onion enterprises were the important enterprises for vegetable production in the study area. This implied that tomato and onion were very important vegetables in the study area. The pattern of land allocation observed may be connected to the returns /earnings from the respective vegetable enterprises. A study by Sani and Haruna (2010) in Northern Nigeria shows that about ₦230,144.50 and ₦428,890.0 was obtainable per hectare from onion and tomato production respectively. The study also shows that about 17-41% of the available land was devoted to the cultivation of these two vegetables.

Table 2. Enterprise combinations for vegetable production

Crop combination	Number of plots	Total area cultivated (ha)	Percentage of total area cultivated
Tomato/onion	30	46.4	25.5
sole tomato	53	43.2	23.8
Sole onion	44	27.95	15.40
Sole sweet pepper	24	13.15	07.2
Sweet pepper/onion	10	11.7	06.4
Sweet pepper/tomato	25	09.31	05.0
Sole hot pepper	19	09.07	05.0
Hot pepper/onion	17	08.9	05.0
Hot pepper/tomato	13	08.58	04.7
Onion/tomato/pepper*	07	03.2	02.0
Total	242**	181.46	100.0

* Both sweet and hot pepper.
** Some *Fadama* farmers had more than one plot.

Technical efficiency estimates on vegetable farms

The estimates of technical efficiency obtained using the computer program DEAP are presented in Table 3. The maximum score found within the samples was 100%, therefore, only minimums are reported here. The technical efficiency in vegetable production in the study area differed substantially, ranging from 39 to 100%, with a mean value of 93%. This result indicates that if the sample farms operated at full technical efficiency levels they could reduce, on an average, input use by 7 percent with the application of same technology and without reducing the level of output. This implies that the same level of output could be produced at less cost.

Table 3. Technical efficiency estimates on vegetable farms

Crop enterprises	Technical Efficiency (%)	
	Minimum	**Mean**
Sole onion	46	92
Sole tomato	54	90
Hot pepper sole	66	95
Sweet pepper sole	54	89
Mean for the sole crops		91.5
Tomato/onion	61	95
Sweet pepper/tomato	68	95
Hot pepper/tomato	39	91
Sweet pepper/onion	62	93
Hot pepper/onion	90	94
Mean for the mixed crops		93.6
Overall mean		93

The sweet pepper enterprise had the least mean technical efficiency score (89%). The tomato/onion, sweet pepper/tomato and the sole hot pepper enterprises on the other hand, had the highest mean technical efficiency scores (95%); as such, to be fully technically efficient, input usage should be reduced by five percent. The sole sweet pepper enterprise can only be fully technically efficient if input usage is reduced by 11%. The explanation for this is that in the input oriented DEA model, efficiency scores are likely to be biased towards higher scores (i.e., towards one), especially when the most efficient farms are not contained in the sample and inefficient farms define the estimated frontier (Latruffe *et al.*, 2005). This normally happens when the output obtained is less than the potential. Thus, the efficiency of farms was measured relative to this sample frontier, rather than the population frontier, which is preferred (Fraser and Cordina, 1999).

The implication of the finding is that the prevailing system for vegetable production in the study area requires a review, because the *Fadama* farmers are not very efficient in realising the expected output levels giving the available technology and resources. This finding disagrees with that of Ajibefun *et al.* (2002) that Nigerian farmers are efficient in realising the expected output giving the level of technology and resources. A likely explanation for this disagreement is the fact that vegetable production takes place under very delicate and fragile production systems. In addition, *Fadama* lands are under pressure due to the competing land uses to which they are put, conflict among different users, mounting demographic pressures as well the complicated tenural arrangements obtainable in *Fadama* communities (Ibrahim, 2009). These factors are not likely to allow for an efficient utilisation of resources in crop production under *Fadama.* The average technical efficiency score for the mixtures was higher (93.6%) compared closely with (91.5%) for the sole enterprises (Table 3). Based on the foregoing, the mixtures seem to be more technically efficient than the sole crop enterprises. This finding implies that there are significant scope economies in the production of vegetables under *Fadama*. The high level of technical efficiency observed for the mixtures can be attributed to the fact that specialisation may decrease technical efficiency in the presence of scope economies (Featherstone *et al.*, 1997). Thus, the cultivation of vegetables in mixtures would enable Fadama farmers to benefit from scope economies or cost reduction due to the cultivation of more than one crop on a piece of land. Ultimately over time, this can lead to efficiency in production of vegetables under *Fadama*.

Determinants of technical efficiency on Fadama farms

The estimates of the marginal effects of the explanatory variables on technical efficiency were obtained from the marginal effects option of the Tobit Model in the Limdep Version 7 package (Table 4). This was because the regression coefficients in the Tobit model cannot be interpreted directly as estimates of the magnitude of the marginal effects of changes in the explanatory variables on the expected value of the dependent variable (Fernandez-Cornejo *et al.*, 2001). The final results show that the significant factors influencing technical efficiency in vegetable production under *Fadama* include, age of farmers ($P< 0.01$), education ($P< 0.01$), farm size ($P< 0.05$), integration with output markets ($P< 0.01$), period of cultivation ($P< 0.01$) and land tenure system ($P< 0.05$). The age of the *Fadama* farmers had a negative sign while the remaining five significant variables had the expected positive coefficients. Membership of cooperatives, ratio of hired to total labour, extent of farm specialisation and the number of working females had the expected positive coefficients, but were not significant in influencing the level of technical efficiency (Table 4). On the other hand, the frequency of extension contact, ownership of an irrigation device and the number of irrigation water sources had negative signs, which were contrary to the apriori expectation for these variables, though they were not significant. A possible explanation is that the farmers may not utilise the extension advice giving to them, or it may not be relevant to their needs. As for ownership of an irrigation device, some of the respondents pointed out during the field survey that the farmers who do not own the device can easily borrow or rent from others.

Table 4. Maximum likelihood estimates of the Tobit Model

Variables	Coefficients	Standard Error	t-ratio	Marginal Effects
AGE	-0.561*	0.220	-2.55	-0.001
EDU	0.055*	0.018	3.05	0.017
MOC	0.012	0.010	1.20	0.000
FSIZE	0.408**	0.190	2.14	0.103
EXTCONT	-0.009	0.022	-0.41	-0.001
LBRATIO	0.007	0.014	-0.54	0.001
IRDEVICE	-0.1563	0.016	-0.97	-0.000
NWFMALES	0.0268	0.170	0.16	0.000
FSPEC	0.0003	0.001	0.32	0.000
LTEN	0.0019 **	0.001	1.90	0.018
INT	0.146*	0.015	9.73	0.173
IRRWAT	-0.007	0.019	-0.39	-0.008
PERCULT	0.159*	0.041	3.88	0.019
Constant	0.657*	0.048	13.68	
Log likelihood function 25.71*				

Single and double asterisks (*) denote significance at 1 and 5%, respectively.

The value of the likelihood ratio was significant at 1%, implying that the model has a good fit and all the explanatory variables are jointly significant. In terms of the marginal effects, the extent of integration with output markets, farm size, and land tenure system and period of cultivation were the most important among the significant explanatory variables that would increase technical efficiency in vegetable production under *Fadama* by 17, 10, 2.0 and 2.0% if they increase by 100%, respectively. The negative sign for age, which was used as a proxy for experience, was not expected. A possible explanation is that the two effects neutralized each other, that is, older more experienced farmers had more knowledge on their land and traditional practices, but were less willing to adopt new ideas. Sometimes, one of the two effects dominates, accounting for the mixed results in literature for the effect of age. In this study, experience was not measured, so an age-experience interaction term could not be included in the model. The finding implies that the older and more experienced farmers are technically inefficient compared to the younger and more active farmers.

Furthermore, the positive sign obtained for education was expected. Studies by Oyekale (2007) and Yusuf and Malomo (2007) in south western Nigeria equally obtained a significant and positive relationship between technical efficiency and education. It is very likely that educated farmers respond readily to the use of improved technology, such as the application of fertilisers, improved seeds and insecticides, thus, achieving the expected output levels. The implication of this finding is that those *Fadama* farmers that benefit from any course or training session as obtainable under the advisory service or capacity building components of *Fadama* II are most likely to be more technically efficient.

The sign for the coefficient of farm size was also expected. It implies that technical efficiency can increase with an increase in farm size if other resources are efficiently utilised. Abrar and Morrisey (2006) equally made similar observations. The greater the farm size (less fragmentation) of a farm the greater the opportunity to apply new technologies, such as tractors and irrigation, and hence farmers with less land fragmentation could be expected to be more efficient. A likely explanation for the observed contrast is the indirect manner that farm size was measured. Underline that there is no generally accepted measure for farm size in economics literature. In addition, the effect of farm size on efficiency is highly debatable. The degree of market integration with output markets, defined as the ratio of total output sold over the total output produced, gives an idea about how much of its output the farm sells in the market. A farmer that is able to dispose off his produce at a good price is quite motivated to adopt innovations in production and marketing and thus is will be more efficient. Tenural status was positive and significant (Table 4). This is because with a secured land ownership, a farmer is able to adopt relevant innovation that span over a long period of time, hence is able to produce closer to the frontier. The finding agrees with those of Okezie and Okoye (2006) and Chavas *et al.* (2005). A likely reason for this agreement is that the above studies were conducted in countries within the West African sub region which have similar land tenure systems. However, the finding contrasts with the findings of the study by Ortega (2004) in South America. This contrast may be attributed to the differences in the research settings for the studies.

Conclusion

All the vegetable crop enterprises are clustered towards a high technical efficiency score in Kaduna State in Nigeria. This implies that the prevailing system for vegetable production in the study area requires a review because the *Fadama* farmers are not very efficient in realising the expected output levels giving the available technology and resources. Furthermore, the relevant policy variables that could be manipulated to enhance the efficiency of vegetable production under *Fadama* include; the extent of integration with output markets, farmers' education and land tenure system.

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