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Determinants of Technical, Allocative and Economic Efficiencies among Dry Season Vegetable Farmers in Sokoto State, Nigeria

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ABSTRACT This study investigated the determinants of technical, allocative and economic efficiencies among small-scale dry season vegetable farmers in Sudan Savannah (SS) zone of Sokoto State, Nigeria, using a stochastic frontier production function. Structured questionnaires were used to collect data from 155 respondents randomly selected from designated locations in the project area. The findings revealed that four variables (extension visits, source of irrigation water, crop diversification and location of the farm), two variables (extension visits and location of the farm) and three variables (extension contact, source of irrigation water and crop diversification) were found to be significant at different levels of significance for technical, allocative and economic efficiency, respectively. These variables were therefore the important policy determinants of inefficiency in study area. These results suggest that farmers' location in vegetable farming and increased investment in extension services could jointly contribute to an improvement in efficiency of vegetable farmers in the study area.

INTRODUCTION

Nigerian agricultural sector has always been an important component of the country's economy. A sectoral analysis in 2008 of the real GDP indicated that the agricultural sector contributed about 42 percent of the GDP, with crop, livestock, forestry and fishery accounting for 37.52, 2.65, 1.37, and 0.53 percent respectively (CBN 2008). This implies that the crop sub-sector contributed 89.2 percent of agriculture GDP.

The small holders who are the back bone of the agricultural sector produce about 80 percent of the total food requirement (Fayinka 2004), mainly cultivate land by using traditional methods under rain- fed conditions. For example, Dogondaji (2005) asserted that productivity under rain- fed conditions is very low. For instance, yields of rain-fed cereals and cowpeas are about 0.5 t/ha while under *fadama* conditions productivity would increase to between one and two tonnes/ha for rice, 10 to 15 tonnes for onions, and 5 tonnes/ha for tomatoes. As a result, net farm incomes would increase from 35,000 naira under rain fed conditions to at least 80,000 naira. Consequently, future growth based entirely on rain-fed farming is likely to fall short of the needs of the rapidly growing Nigeria population which is put at 3.4 percent per annum; this is against the agricultural sector growth of 2.8 percent (PCU/FMARD 2004). Thus, the agricultural growth cannot keep pace with the population growth rate. This apparent disparity between the rate of food production and requirement in Nigeria has led to a food demand-supply gap thus leading to a widening gap between domestic food and total food requirement, an increasing resort to food importation and high rate of increases in food prices (Ojo 2003).

Sokoto state is among the northern area endowed with *fadama* areas where substantial quantities of vegetable are grown under irrigation during the dry season (Dogondaji 2005). Bello et al. (1998) observed that the *fadama* land although quite small in area, is one of the most valuable agricultural resources in the state. Despite its vast potentials, fadama productivity increase is said to be declining (Ajibola 2006). Similarly, productive efficiency for most crops still falls under 60 percent (Rahji 2005). These shortfalls are attributed to inefficiencies in production. Therefore, the need for the efficient allocation of productive resources cannot be overemphasized. Presently, there are very few firm-level studies of efficiency in the developing economies, particularly in Nigeria (Rahji 2003). As far as the researcher knows, no specific investigation into farm level productive efficiency involving vegetable production in the *fadama* is carried out in the study area, as most of these studies centre on only the resource use efficiency. To bridge the existing gap, this study examined the determinants of productive efficiencies that would help in promoting the much desired productivity and output growth in the agricultural sector, particularly among small-scale *fadama* vegetable producers in the area.

Meaning and Characteristics of Fadama Lands

Fadama land is a Hausa word already adopted by the World Bank. It simply means land that flooded during rainy season. (Baba and Singh, 1998). It refers to low lying swampy area consisting of fluvial deposits and containing extensive exploitable aquifers (Ghandi and Rajashakara, 1989). In agricultural usage, however, the word fadama commonly refers to all low lying relatively flat areas either stream less depressions or adjacent to the seasonally or perennially-flowing streams and rivers. According to Kolawole and Scoones (1994), fadama means the seasonally flooded or floodable plains along the major savanna rivers and/or depressions on the adjacent terraces. The word fadama is in contrast to tudu which means the upland.

Fadama in northern Nigeria is synonymous to bas fond in sahel, wali or khor in Sudan and dambo in southern Africa (Scoones, 1992). The fadama lands have been described by Scoones (1992) as "wetlands in dry lands" due to their moisture retention characteristics within the rhizoshere, not only in the wet but also in the dry season. Characteristically, Arnborg (1988) noted, the fadama land is marked by a flush of new vegetation at the beginning of the rainy season before the adjacent uplands turns green, but it is most conspicuous after cessation of the rains when it remains prominently green as a the surrounding upland rapidly turns brown and evenly bare. Arnborg added fadama is like "a garden, a little paradise" in the vast dry lands of northern Nigeria.

The problem is that fadama lands in most northern Nigerian states are usually small, relative to the total cultivable land area. for instance, it has been reported that fadama covers only 798,00 ha out of about five million hectares cultivated in Bauchi, Kano, Jigawa, Sokoto, Kebbi, Kaduna and Katsina states (Baba and Singh, 1998). This represents only 15.77% of the total area cultivated, with area varying from as low as 6.25% in Kano and Jigawa to as high as 39.25% in Sokoto and kebbi states. In the present Sokoto state, it is estimated that 154,524 ha of fadama land is under cultivation (SMANR, (1998).

METHODOLOGY

Area of the Study

This study was conducted in Sokoto State. The state lies within two ecological zones; the northern portion which lies largely within the Sudan savannah ecological zone, the southern portion on the other hand, lies in the northern Guinea Savanna of Nigeria. The state is located in the North West geographical zone of Nigeria within longitude $11^{o}3$-$13^{o}50$E and latitude 4^{o}-6^{o} 40^{1}N. It covers a land area of 2,648.48 square kilometers (Singh 2000). The area could be classified as one of the semi-arid regions of the world, where water is probably the most limiting factor to agricultural production. There are two distinct seasons in the state; the rainy season which starts around May and last till September and the dry season from October to April. The annual rainfall is frequently erratic, poorly distributed and varies from 500mm to 1300mm (SMANR 1998). There are two temperature extremes; the hot period (March to May) which is as high as 39^{o}C and the cold harmattan months of December to January, when cold, dust-laden winds blow from across Sahara bringing down the temperature to as low as $15^{oc,}$ averaging about 27^{o}C (SMANR 1998). There are few low-lying valleys or *fadama* which terminate to form streams at their lowest levels. The soil consists of ferruginous soil of alluvial origins, as well drained loamy sandy soil. In the *fadama*, the soil generally consists of finer sand, silt and clay. River Sokoto and River Rima are the major rivers in the state with their numerous tributaries. The major occupation of the people of the state includes arable and livestock farming.

Sampling Procedure and Sample Size

The target population for this study was the *fadama* vegetable producers in Sokoto state. Sokoto state is divided into two main agro-ecological zones by the state Agricultural and Rural Development Authority (SARDA) in consonance with ecological characteristics, cultural practices and project's policy and administrative convenience. These zones are the northern and western zones with a central headquarters in the state capital. Since vegetable is produced in virtually all the areas of the state and in order to have a representative sample in achieving the stated objectives, the sampling procedure covered the two zones equally. Accordingly, a two-stage sampling procedure was employed in selecting the sample for this study. The first stage involved the random selection of eight villages in each of agricultural zone of the state using the existing SARDA village listing. The second stage was the random selection of ten farming households in each of the already selected village. Accordingly, a sample of one hundred and sixty farming households was collected and subsequently analyzed for the study. However, one hundred and fifty- five questionnaires were found useful for the study. The sampling distribution of the respondents is shown in Table 1.

Table 1: Sampling distribution in the study area

Western zone	*Number of respondents*	*Northern zone*	*Number of respondents*
Kamata	10	Tunga	10
Wajajuke	9	Taloka	10
Jirga	10	Kwargaba	10
Kaura Kwasau	10	Sabo Dole	9
M/gari	8	Lugu	10
Shuni	10	Goronyo	10
Salla	10	Gidan AjIkwara	9
Saida	10	Gidan Kaima	10
Total	77	Total	78

Grand total = 155 Respondents
Source: Field Survey 2009

Analytical Techniques

Descriptive statistics and Cobb–Douglas stochastic production frontier approach was used to estimate the production function and the determinants of technical, allocative and economic efficiencies among vegetable farmers in the state. The stochastic function assumes the presence of technical inefficiency of production. The specification involves a function specified for cross-sectional data, which has an error term, with two components, one to account for random effects and another to account for technical inefficiency. Hence, the function is defined by:

$$Y_i = X_i\beta + (V_i - U_i),\ i = 1,..., N, \quad (1)$$

Where Y_i is the monetary value of vegetable crop per farm

X_i is a kx1 vector of (transformations of the) input quantities of the i-th firm;

β is a vector of unknown parameters to be estimated;

Where Vi are random variables, two-sided ($-\infty < vi < \infty$) normally distributed random error N ~ (0,δv2), which are assumed to be independent of the Ui that captures the stochastic effects outside the farmer's control (for example, weather, natural disasters, and luck, measurement errors in production, and other statistical noise). The two components v and u are also assumed to be independent of each other. Thus, to estimate a Cobb-Douglas production functions, we must log all the input and output data before the data is analyzed (Coelli 1995).

Thus, to estimate a Cobb-Douglas production function, we must log all of input and output data before the data is analyzed. (Coelli 1995). The estimating equation for the stochastic function is given as:

$$\ln Y = B_0 + B_1\ln X_1 + B_2\ln X_2 + B_3\ln X_3 + B_4\ln X_4 + B_5\ln X_5 + B_6\ln X_6 + V_i - U_i \quad (2)$$

In *fadama* farming, land, labour, seeds, fertilizers, agro-chemical and irrigation water are generally regarded as inputs (Tsoho 2004). On the basis of this, land (X_1) in hectare, labour (X_2) in man days, seeds in kg (X_3), fertilizer in kg (X_4), agro-chemical in litres (X_5), and quantity of irrigation water in ha-cm (X_6) was included in the stochastic frontier models. Technical efficiency of an individual firm is defined in terms of the ratio of the observed output (Y_i) to the corresponding frontier output (Y_i^*), given the available technology, conditional on the levels of input used by the firm. That is:

$$\text{Technical efficiency (TE)} = Y_i/Y_i^* \quad (3)$$

$TE = Y_i/Y_i^*$ which is obtainable by the use of Frontier 4.1 (Coelli 1996). Based on the individual farm's technical efficiency, the mean technical efficiency for the sample is obtained (Rahji 2005). The technical, allocative and economic inefficiencies are explained by:

$$U_i = \delta o + \delta i Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \delta_5 Z_{5i} + \delta_6 Z_{6i} + \delta_7 Z_{7i} + \delta_8 Z_{8i} + \delta_9 Z_{9i} \quad (4)$$

Where

U_i represents inefficiency effects;

δo represents the intercept

Farm size (Z_1): Farm size was measured in hectares.

Farming experience (Z_2): This was measured in years and will equally serve as a proxy to the age of the farmer.

Educational level (Z_3): This variable was graded for values 1, 2 and 3 to represent Quarnic, adult and western education, respectively.

Household size (Z_4): This was based on the number of direct family and dependants of the household and was adjusted to adult equivalent.

Extension contact (Z_5): Access to extension education is expected to enhance the farmer's level of adaptation to improved technologies. Access to extension was based on the number of visits by the extension agent.

Land ownership (Z_6): The mode of ownership of a fadama farmland is expected to influence the productive efficiency of a farmer. It was measured as a dummy. D= 1 if ownership by inheritance, otherwise, = 0.

Source of irrigation water (Z_7): The variable was measured as dummy. D = 1 if surface water is used, D = 0 if underground water is utilized. It is expected to have a positive effect on the farmer's efficiency.

Crops diversification (Z_8): Weather farmer practiced mixed or sole cropping system. It will be measured as a dummy. D= 1 if farmer grow more than one crop in the same piece of land, and otherwise, = 0. The variable is expected to have a positive significant effect on the farmer's efficiency.

Zonal location of the farmer (Z_9): This variable is expected to capture any variability that may exits between the two agro-ecological zones that make up the study area. The location of the farmer was measured as a dummy. D= 1, if farmer is located in northern zone of the state and otherwise, = 0.

RESULTS AND DISCUSSION

The mean age of the respondents is 43.33 years and the modal age is 41-50 years, which constituted about one-third of the total respondents (Table 2). The age of the farmer according to Adewumi and Omotesho (2002) is expected to affects his labor productivity and output. This agrees with findings of Tsoho (2004).

All the one hundred and fifty- five sampled respondents in the study area were male. This may be due to cultural and religious (Islamic) belief of the people in the area, which prohibits women to go out freely and engage in certain activities such as farming. The study revealed that more than ninety percent of the respondents were married, while the remaining were either single or widow(ers), respectively. The mean family size was 10 persons per respondent and it ranged from 1 to 40. The study also revealed that 15.49 percent have attained between primary and tertiary education. More than two-third of the respondents have had Qu'aranic education. The farmer's years of experience ranged from 5 to 45 with an average of 23.21 years. Farmers experience is expected to have a considerable effect on farmer's productive efficiency. Almost all the respondents have inherited farming as an occupation, while the remaining were introduced to farming by either friends or relatives. About Ninety percent of the respondents have farming as their main occupation and only ten percent adopts farming as their secondary occupation.

Table 2: Socio-economic characteristics of the households' heads in the study area

S. No.	*Characteristics*	*Frequency*	*Percentage*
1.	*Age of the Respondents*		
	1- 20 years	1	0.65
	21-30 years	25	16.13
	31-40 years	36	23.22
	41-50 years	54	34.84
	51-60 years	20	12.90
	61-70 years	18	11.61
	71-80 years	1	0.65
	Total	155	100.00
2.	*Marital Status of the Respondents*		
	Married	145	93.55
	Single	4	2.58
	Widower/Separated	6	3.87
	Total	155	100.0
3.	*Family Size Respondents*		
	1-10	104	67.9
	11-20	39	25.16
	21-30	10	6.45
	31-40	2	1.30
	Total	155	100.00
4.	*Education Status of the Respondents.*		
	Qu'ranic education	119	76.77
	Adult education	12	7.74
	Primary education	10	6.45
	Secondary education	12	7.74
	Tertiary education	2	1.30
	Total	155	100.00
5.	*Respondents Farming Experience*		
	1-10 years	25	16.13
	11-20 years	38	24.52
	21-30 years	64	41.29
	31-40 years	17	10.97
	41-50 years	11	7.09
	Total	155	100.00

Source: Field survey 2009

Technical Efficiency analysis

The expected parameters and the related statistical test results obtain from the analysis of the maximum likelihood estimates (MLE) of the Cobb-Douglas based stochastic frontier production function parameters for dry season vegetable farmers are presented in Table 3.

Table 3: Estimated stochastic production frontier function

Variables	*Parameters*	*Coefficient*	*t-values*
Physical inputs Constant	β_0	6.573***	12.9
Land (ha) (X_1)	β_1	0.149	1.52
Labour (man-days) (X_2)	β_2	0.181**	2.42
Seeds (Kg) (X_3)	β_3	-0.036	-0.01
Fertilizer (kg) (X_4)	β_4	0.237***	3.72
Agrochemical (litres) (X_5)	β_5	0.078	1.18
Irrigation water in ha-cm (X_6)	β_6	0.303***	3.66
Diagnostic Statistics			
Sigma square (ä^2)	($\delta u^2 + \delta v^2$)	0.253***	5.420
Gamma (ã)	($\delta u^2 / \delta^2$)	0.820***	10.20
Lambda	($\delta u/\delta v$)	4.560	
Log-likelihood function			-0.0053
Sample size (n)		155	

Source: Data Analysis*significant at 10% 2009, ***, significant at 1%, **significant at 5%

The variance parameters of the production function represented by Sigma-squared (σ^2) and Gamma (γ) are all significant even at 1%. The Lambda is greater than one (λ = 4.56). The statistical significance of Lambda showed that there exits sufficient evidence to suggest that technical inefficiencies are present in the data. Theoretically, this implies a good fit for the estimated model and correctness of the distributional assumptions for the U_i and V_i. The statistical significance of the sigma-squared also indicates a good fit for the model. The estimated gamma (0.82) shows the amount of the variation in vegetable outputs which results from technical efficiency of the sampled farmers.

The results of the estimated parameters revealed that all the coefficients of the physical variables except quantity of seeds used, conform to a priori expectation of a positive signs. The positive coefficient of land, labour, fertilizer, agro-chemical and irrigation implies that as each of these variables is increased, *ceteris paribus*, vegetable output increased. The negative sign of the seeds suggest a situation of excessive (and, hence, inefficient) use of planting material in the production of vegetable in the area. The coefficient of the variable associated with land although positive, is statistically not significant even at 10 percent level of significance. The coefficients of the three physical variables; labor, fertilizer and irrigation water are all significant even at 1 percent level of significance. Therefore, these are the major factors explaining vegetable production under fadama in the area. This findings agrees with those of Ajibefun et al. (2002) and Onyenweaku and Effiong (2005).

The Returns to Scale (RTS)

The return to scale (RTS) analysis, which serves as a measure of total resource productivity, is given in Table 4. The maximum likelihood estimates (MLE) of the Cobb-Douglas based stochastic production function parameter of 0.834 is obtained from the summation of the coefficients of the estimated inputs (elasticites). It indicated that, vegetable production in the study area was in the stage II of the production surface. Stage II is the stage of decreasing positive return-to scale, where resources and production were believes to be efficient.

Table 4: Elasticities and returns to scale of the parameters of stochastic frontier production function

Variables	*Elasticity*
Farm size	0.149
Labor	0.181
Planting materials	-0.036
Fertilizer	0.237
Agro-chemical	0.078
Irrigation water	0.303
RTS	0.834

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Multiple Regression Analysis (OLS)

Based on the literature on previous studies; nine characteristics are chosen as indicators of the farmer's socio-economic environment and are subsequently used as explanatory variables in the analysis of productive efficiency for vegetable production under *fadama* in the study area. The results of the analysis of the relationship between the farmer's characteristics and efficiency indices are presented in Table 5.

Table 5: Relationship between transformed efficiency indices and farm-farmer characteristics

Variable	*TTE*	*TAE*	*TEE*
1 Farm size (ha)	-0.017	-0.026	0.053
	(-0.197)	(-0.305)	(0.592)
2 Farming experience (years)	-0.45	0.88	-0.085
	(-0.432)	(0.818)	(-0.770)
3 Education level (graded)	0.003	-0.029	0.013
	(0.039)	(-0.350)	(0.148)
4 Household size (no of persons)	0.103	-0.079	0.154
	(1.007)	(-.725)	(1.371)
5 Extension contact (no of visits)	0.161	0.110	0.152
	(1.824)*	(1.710)*	(1.640)*
6 Land ownership (dummy)	0.025	0.119	0.044
	(0.300)	(1.484)	(0.526)
7 Source of irrigation water (dummy)	0.170	-0.006	0.196
	(2.002)**	(-0.073)	(2.273)*
8 Crop diversification (dummy)	0.209	-0.046	0.182
	(2.545)**	(-0.558)	(2.160)*
9 Zone/location of the farmer (dummy)	-0.156	-0.333	-0.112
	(-1.917)*	(-4.132)*	(-1.060)
R^2	0.42	0.31	0.21
n	155	155	155

**,* Estimates are significant at 5% and 10% levels of significance respectively.
Source: Data Analysis 2009

The results indicated that, overall, the explanatory ability of the variables included in the analysis is limited (R^2 values are generally low) and not all regressions or parameters are significant. This result agrees with the findings of several researchers who have generally obtained an R^2 value of less than 0.5 in their secondary analysis similar to this study. For example, Xu and Jeffrey (1997) obtained an R^2 value of 0.21, 0.31 and 0.19, respectively.

Extension contact has a positive sign and is statistically significant in three efficiency indices. The positive and statistically robust relationship between extension and efficiency supports the notion, which implies that farmers who had more extension visits/teachings are likely to be more successful in gathering information and understanding new practices and the use of modern inputs which in turn will improve their EE through higher levels of TE and AE. These results are consistent with the findings of Onyenweaku and Nwaru (2004) and Rahji (2005). Contrarily, the study disagreed with findings of those of Parikh et al. (1995) that have found extension to be negatively and statistically related to efficiency indices.

Source of irrigation has positive and statistically significant coefficients for both TE and EE. But, the opposite is true for the AE as its relationship is negative and non-significant. The positive coefficient suggests that farmers who use surface water to irrigate their *fadama* vegetable are technically and economically more efficient than those who use underground water. Interestingly, these same categories of farmers are however allocatively less efficient. This finding is consistent with Baba and Wando (1998) that the there is a positive and significant relationship between the source of water and the efficiency of the farmers.

The study also reveals a positive and statistically significant correlation between crops grown and TE and EE. These results indicate that as diversification increases and more crops are grown, efficiency increases. Farmers who practiced mixed cropping exhibited higher levels of TE and EE, but, surprisingly, reverse is the case for transformed AE index. The implication is that greater diversification is associated with higher relative efficiency.

The location coefficient values for the two efficiency indices (TE and AE) are negative, relatively large in magnitude and have a statistically significant effect on efficiency. The location coefficient for EE although negative is statistically not significant. The coefficients of household size, farm size, farming experience, educational status of farmers and land tenure systems are not important in explaining the variation in TE, AE and EE of farmers in the study area.

CONCLUSION

This study described the socio-economic characteristics and identifies the determinants of TE, AE, and EE of vegetable farmers in Sokoto State, Nigeria. The results indicated that while the extension contact, source of water, and crop diversification exhibited higher levels of positive significant impact on TE and EE, the location of the farm exerts a negative significant impact on TE. In addition, farm location has a statistically positive association with AE. In all, extension contact exerts a uniform impact on all the efficiency indices.

RECOMMENDATIONS

Policymakers should foster the development and provision of qualitative extension services to the farmers, while promoting the wide adoption of pumps use by the farmers.

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