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Research Article

Technical Efficiency of Vegetable Production among Wetland farmers in Southwest Nigeria

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Abstract
Due to a variety of human activities, wetland areas have come to be seen as wastelands. However, the conversion of wetland to farm lands has promise for attaining increased food production and employment generation. This study, therefore employed the Cobb-Douglas Stochastic Frontier Production function to measure technical efficiency and its determinants among dry-season vegetable farmers in selected wetland catchments in Southwest Nigeria. Multistage random sampling procedure was adopted to select 450 wetland vegetable farmers across Oyo, Ogun and Lagos States and data were collected with the aid of a structured questionnaire. Technical efficiency (TE) estimates indicated that wetland vegetable farmers operated below the production frontier with the mean technical efficiency value of 0.74 which indicates that 26.00% of production potential was still unutilized. Farm size (0.35, $p<0.01$), family labour (0.02, $p<0.10$), quantity of seed planted (0.60, $p<0.01$), and quantity of agrochemical (0.04, $p<0.10$) significantly improved the farmers' technical efficiency level. Additionally, the coefficients for extension visits, access to credit, farming experience, household size, and association membership are negative, which implies a decrease in technical inefficiency. Meanwhile, weighted average price and household size have positive coefficients implying increased in technical inefficiency. The rate of scale (RTS) was 1.012, revealing increasing return to scale. Hence, wetland vegetable farmers in the study areas could improve their production outcomes by employing more inputs such as increasing the size of farmlands, family labour, quantity of seed, fertilizer and agrochemical. It was recommended that attention should be given to improvement in the visitation by extension agent, the provision of improved seeds and affordable financial support.

Keywords Efficiency, Stochastic frontier, Vegetable, Wetland

Introduction
Households in Nigeria are experiencing acute hunger due to the startling increase in food insecurity. According to Osabohien *et al*. (2020), acute food scarcity affected 21.4% of Nigerian families in 2020. Erokhin and Gao (2020), reported that half of Nigerian population are living below the 1.9 USD poverty line. Furthermore, Nigeria scored 48.4 out of 100 on the Global Food Security Index (GFSI) in 2019, placing it 94th out of 113 countries (Ayinde *et al*., 2020).

Similarly, the National Bureau of Statistics (NBS, 2022), revealed that food prices have continued to rise in Nigeria, increasing by 17.2 per cent even presently with the removal of petrol subsidy the prices of food items are unbearable. The increase in food insecurity in Nigeria has been made worse by the rising food demand combined with seasonal variations, unpredictability, and unreliability that have characterized rainfall patterns in Nigeria (Iheanacho *et al*., 2007).

Nigeria has a large agricultural potential and an

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abundance of natural water resources, but farming households still face food shortages as a result of poor adoption of good agricultural practices (GAP) and mis-management of resources, which makes poverty and hunger serious developmental challenges (Babalola *et al*., 2020). Additionally, available opportunities in Nigeria's agricultural industry still remain untapped because most available lands suitable for agricultural production are uncultivated (*Okpe et al.*,2012). To address the issue of food insecurity, Nigeria, which a population of over 200 million people and an annual growth rate of roughly 2.6 per cent (UN, 2020), must encourage increased agricultural output.

One way to harness the agricultural potential of this country is thus, by exploiting the available, viable wetland catchments for vegetable production (Girei *et al*., 2013). Hence, efforts in the present widespread rain-fed agricultural production need to be complemented through wide and intensive practice of the wetland farming system. The availability of abundant water, rich soil organic matter, and suitability for various crops mean that wetlands are potentially valuable agricultural resource base and production environment (Jing *et al*., 2023). In addition, it provides a habitat for variety of species, wetlands also retain water, which keeps the highwater tables in these areas stable. (Olarewaju *et al.*,2022).

Farmers attempt to increase food productivity by cultivating vegetables on wetlands. Owing to the fact that vegetables production and consumption have received increased attention probably due to economic relevance, short gestation period, and awareness on nutritional importance (Ayeni, *et al* .2023). Specifically, there has not been much empirical research in the level of production efficiency for different locations or that explored the pertinent ways to improve the efficiency of seasonal wetland vegetable crop production in Southwest, Nigeria. The sustainability of wetland farming could only be assaulted or improved upon if the current levels of exploitation, and inefficiency of use in agriculture, and in particular vegetable production are known. This is very important because local vegetable producers need to be more efficient in their production activities, and also in terms of their response to market signals. A stronger focus on combining businesses and maximizing the use of existing resources in the optimal manner among wetland vegetable producers is paramount (Oluwalana e*t al*., 2019). Since low productivity remains the main issue in production, farmers' ability to utilize farm resources and the enhanced technologies at their disposal is crucial for vegetable production.

Specifically, estimating the farm-level performance in seasonal vegetable production on wetlands can furnish empirical understanding of the level of technical efficiency of the producers, and more importantly the salient factors influencing the efficiency of wetland vegetable farmers. Therefore, the increased productivity and technical efficiency that can be achieved from the production of seasonal wetlands vegetable may result in less resource waste. This study intends to determine the efficiency of wetland vegetable production in Southwest Nigeria.

Materials and Methods

The study was conducted in Southwest of Nigeria. The Southwest region of Nigeria has a population of about 38,257,260 (NBS, 2016). The study area is bounded in the East by Edo and Delta states, in the North by Kwara and Kogi states, in the West by the Republic of Benin in the south by the Gulf of Guinea. Presently, the Southwest region in Nigeria has six states, viz., Ondo, Ekiti, Lagos, Ogun, Osun and Oyo and is distinctly divided into three major agro-ecological zones (Rain Forest zone, Swamp Forest zone and Derived Savanna zone) with vary climatic conditions. The annual rainfall, which normally spread over eight months between April and November, ranges between 1000 mm to 2000 mm (Awojuola 2001). Over 75 percent of people in the region are employed and dependent on agriculture for their livelihood at the subsistence level (FAO, 2021).

Sampling Procedure and sample size: Multi-stage sampling method was employed. At the first stage, three out of the six states in the Southwest Nigeria were purposively selected (Oyo, Ogun, and Lagos States) based on wetlands resources available across the area and the level of urbanization, which favoured vegetable production and marketing in nearby urban settlements. The second stage involved the purposive selection of four Local Governments' Areas that constituted expansive wetland catchments from each State. Then, in the third stage, 50percent of the identified communities across the four Local Government Areas noted for dry season, wetlands vegetable production was selected. A total of twelve wetland communities were drawn from each State based on their dependence on wetland vegetable production and their closeness to water bodies. In the final stage, respondents were randomly selected proportionally (10 per cent) based on a list of vegetable growers gathered from the 36 locations. Consequently, 117 vegetable farmers were selected from Oyo State, 150 respondents from Ogun State and 183 respondents from Lagos State giving a total sample size of four hundred and fifty dry season vegetable farmers for this study.

Data Collection and Analysis: Primary data were used for this study. The primary data were obtained from a field survey with the use of a structured and validated questionnaire. A pre-test survey was carried out to validate the questionnaire. Data were obtained on the socioeconomic traits of the farmers, such as sex, age, marital status, family size, credit availability, farm size, level of education, and degree of farming experience, total quantity and value of the fruit and leafy vegetables produced, the quantity consumed as well as those given out as gift. The inputs data obtained for this study include land area (Ha), labour (manday), quantity of seeds (kg), quantity of fertilizers used (kg), and quantity of herbicide used (litres). All farm inputs and output data were for dry season farming operation. The primary data were analysed using stochastic frontier model.

The technical efficiency of the smallholder wetland vegetable farmers was estimated by specifying the Cobb-Douglas Stochastic Frontier Production Function (Coelli, 1994).

The model is specified explicitly as below:

$$InQ_1 = \beta_0 + \beta_1\ InX_1 + \beta_2 InX_2 + \beta_3 InX_3 + \beta_4 InX_4 + \beta_5 InX_5 + \beta_6 InX_6 + V_i - U_i. \quad (1)$$

Where,

Qi= Output of vegetable (Kg.Grain equivalent)

X_1 = Farm Size (Ha)

X_2 = Hired labour used (mandays)

X_3 = Family labour (mandays)

X_4 = Quantity of vegetable seed planted (kg)

X_5 = Quantity of fertilizer used (kg)

X_6 = Quantity of agrochemicals used (Litres)

β_0 = Intercept

$B_i - \beta_6$ = Coefficients of the independent variables estimated

V_i = Random error, which accounts for the random variations in the value of vegetable output due to factors which are beyond the control of the farm such as disease outbreak, weather, and measurement errors, among others. The V_i is thus the to be independently two -sided normally distributed random errors ($V_i \sim [0, \delta^2]$).

Ui = Non – negative error component associated with technical inefficiency of production. Specifically, U_i is the one- sided efficiency component with a half normal distribution [$U_i \sim (N/\ (0, \delta^2)$].

In order to determine the factors that directly contribute to technical inefficiency in wetlands vegetable production in each wetland location, the following model was estimated:

$$U_i = \alpha_0 + \alpha_1 z_1 + \alpha_2 z_2 + \alpha_3 z_3 + \alpha_4 z_4 + \alpha_5 z_5 + \alpha_6 z_6 + \alpha_7 z_7 + \alpha_8 z_8 + \alpha_9 z_9 \quad (2)$$

Where,

Ui = Technical inefficiency estimate of the i^{th}wetlands vegetable farmer

Z_1 = Years of formal education of the farmer (i.e years spent in school)

Z_2 = Age of the farmer (years)

Z_3 = Sex (Male=1, otherwise = 0)

Z_4 = Extension contact (Number of visits by extension agents)

Z_5 = Weighted average price of vegetables produced (₦/Kg)

Z_6 = Those that obtained credit (Yes= 1; otherwise, 0)

Z_7= Farming experience (Years)

Z_8= Household size (Number of people living in the same house)

Z_9 = Vegetable producers' association (Member =1; Otherwise=0),

μ = Random error component

STATA 15 application software was used to estimate the technical efficiency and inefficiency of wetlands vegetable production by farmers in the study area.

Results and Discussion

The maximum likelihood estimates (MLEs) of the stochastic frontier production function fitted to the data obtained on wetlands vegetable farming using the computer program STATA 15 are presented in Table 1. The stochastic frontier function and the inefficiency model were estimated simultaneously. The sigma square (0.247) is statistically different from zero at 1percent probability level. This indicates a good fit and the correctness of the specified distributional assumption of the composite error terms. Also, the variance ratio defined by gamma (γ) was estimated at 0.787 and this estimate is statistically significant at 1percent probability level. This value indicates the amount of variation arising from technical inefficiencies of the wetland vegetable farmers.

Thus, the prevailing technical inefficiency among wetlands vegetable accounted for about 79 percent of the difference in the output level. From the estimated parameters of Cobb-Douglass stochastic frontier the production function positive coefficients of the parameters showed positive relationship with output, and hence increase in wetlands vegetable production, while negative coefficients showed an inverse relationship with the output.

Among the six included variables in the technical efficiency model for wetlands vegetable production, farm size, family labour, quantity of seed planted and quantity of agrochemical indicated positive and significant (Table 1). Specifically, the result showed that the coefficient of farm size was positive and significant at one percent level of probability. Farm size was the second most significant factor after seeds in wetlands vegetable production with the coefficient of 0.35. The implication is that, rise of one percent in the size of the farmlands cultivated would increase output of vegetable by 0.35 percent. This suggests that farmers with large farm lands can produce more output, all other things being equal. The result conforms with Akpan *et al.* (2022), and Ayeni *et al* (2023) who confirmed the significant influence size of farm on output of farmers. The coefficient of family labour used was positive and significant at 5percent. Thus, 1percent increase in the mandays of family labour would result in 0.02 percent increase in the output from wetlands vegetable production. Family labour will continue to be very crucial among the wetland vegetable farmers due to the terrain of the area, which cannot support mechanization. The coefficient of seed (0.60) was positive and significant at 1percent, thus increasing quality of seed by 1 percent increased output by 0.60 percent. This suggests that planting improved viable seeds would improve output. The outcome was in agreement with Alabi *et al.* (2023) that farm output increased with increased in the use of viable seeds.

The coefficient for agrochemicals (0.040) was positive and significant at one percent meaning that 1 percent increase in agrochemicals usage will result in 0.04 percent increase in output from wetlands vegetable production. Alabi *et al.* (2022) found that the use of agrochemicals among vegetable farmers influenced output.

The result of the estimated coefficients in the inefficiency model are also presented in Table **1.** Extension contacts, weighted average price, access to credit, farming experience, household size and membership of an association are significant determinants of inefficiency among wetland vegetable farmers. In order to explain the observed degree of technical efficiency of the farmers, the sign of the variables in the inefficiency model is crucial. A positive coefficient suggests that the variable increased technical inefficiency, whilst a negative sign suggested that the variable had the impact of increasing technical efficiency.

Extension contact was (-0.019) and statistically significant at 5percent probability. This indicates that increase in extension visits would lead to a decline in technical inefficiency. The reason could be that vegetable farmers who were opportune to had contact with extension agents readily adopt new innovations which transformed the production processes.

The coefficient of weighted average price (0.001) and significant revealing that, as price increases, efficiency of vegetable production decreases. This indicates that the choice of the vegetables grown fuel technical inefficiency and hence, lead to reduced vegetable output. The reason is that farmers are not cognizant with proper vegetable combination that will result to high yield.

The coefficient associated with credit had negative sign and was statistically significant at 5 percent level. The result implies that access to credit will improve technical efficiency among farmers. Credit is essential in vegetable production particularly to purchase farm inputs as well as for meeting other exigencies.

The coefficient of farming experience was negative and statistically significant at 5percent. This indicates that as farming experience increases in vegetable production, technical efficiency also increases. Thus, farmers with more years of experience are expected to be more knowledgeable, effective and adaptive to dry season wetlands farming operations. This finding is consistent with Mairabo *et al.* (2023), that the farming experience increase efficiency level in farmers.

The coefficient of household size was negative and significant at 5percent level thus indicating reducing effect on technical inefficiency among farmers. Due to larger household size, farmers used their family members as ready source of labour thereby, reducing the labour and the total cost of production. This could bring about cordial farm work relations, quick dissemination of information and effective use of resources among family members since the farmstead belongs commonly to them. This result is in consonance with the findings of Ayeni *et al*.(2023), reported that farmers with large family size have the possibility of increasing farm output.

The coefficient of membership of farmers' association was negative as expected and significant at 5percent level. The implication of this is that joining association will enhance technical efficiency. This is because association facilitates access to relevant information on farm practice, credit availability; market information, sourcing of technical assistance, and sharing of ideas pertaining to farming activities. This agrees with the findings of Akpan *et al*. (2022), who found that being a cooperative membership significantly influenced the technical efficiency.

A crucial characteristic of the stochastic production frontier model is its ability to estimate individual or farm-specific technical efficiencies. Distribution of farmers' technical efficiency indices derived from the fitting of the Cob-Douglass stochastic frontier production function to the study data is presented in Table 2. The findings indicated that the sampled farmers' technical efficiency estimates were less than one (1.00). This suggests that the study area's vegetable producers were generating less than their maximum or frontier production.

The range of technical efficiency estimates showed that the most efficient farmer had a technical efficiency of 0.94, while the least efficient farmer had a technical efficiency of 0.27, with a mean technical efficiency value of 0.74. Further the mean technical efficiency estimates of 74 percent implies that on the average, the farmers were able to achieve about 74percent of the optimal output from a given set of inputs. The outcome matched Ayeni *et al*.(2023), which reported technical efficiency mean of 0.73 for Okra farmers in Adamawa State. Additionally, the estimate shows that for an average vegetable farmer to attain one hundred percent technical efficiency level, he/she must eliminate 25.25 percent (1-0.74/0.99) technical inefficiency in the production system.

Table 3 presents the result of elasticity and return to scale. The estimates of the elasticity of production for the explanatory variables shows that farm size, family labour, quantity of seed, fertilizer and agrochemicals were positive (i.e increase in their use will enhance output from wetlands vegetables production),while the elasticity of production with respect to the hired labour was negative (i.e increase in hired labour will lower output). Specifically, the result indicates that one percent more of the quantity of farm size, family labour, quantity of seed, fertilizer and agrochemical would give respectively 0.350, 0.015, 0.603, 0.004 and 0.040 percent increases in wetlands vegetable output. However, one percent more of mandays of hired labour would induce c a decrease in the output of vegetables by 0.001. Therefore, farmers should be mindful of excessive utilizing of hired labor as more of it could reduce output in wetlands vegetable production marginally.

Quantity of seed had the highest coefficient or elasticity value of 0.60. The high relatively elasticity value for the quantity of seed implies that a sizeable increase in vegetable output can come from the use of quality and viable seeds with appropriate spacings, and inter-cropping and inter-planting rations. Thus, farmers should be mindful of the consequence of too much seed, which could lead to overcrowding, nutrient depletion, and yellowing of leaves with possible reduction in vegetable output, and market value or a depressed market price. Therefore, the use of high yielding varieties, correct spacing and adoption of good planting method that will give maximum output with modicum seeds planted should be incorporated into vegetable cultivation practices. The results in Table 3 also indicated that all the production inputs used in wetlands vegetable production were inelastic, which implies that one percentage increase in each input result in a less than one percent change (i.e increase or decrease) in output.

Moreover, the sum of inputs elasticity of production was 1.012; indicating that stage one of the production curve, which is a zone of rising return to scale. Specifically, vegetable farmers in the research area can improve their production outcomes by employing more inputs such as increasing the size of farmlands, family labour, quantity of seed, fertilizer and agrochemical. This conclusion agrees with Alabi. *et al.* (2023), who stated that farmers can improve their output through the use of more inputs.

Conclusion

The present study examined technical efficiency of vegetable production among wetland farmers in Southwest, Nigeria. Maximum Likelihood Estimates (MLE) of the parameters of the stochastic frontier production function indicated that the coefficients of the variable inputs had the expected signs. Farm size, family labour, quantity of seeds planted, and the quantity of agrochemical had positive significant relationships with vegetable output. The mean technical efficiency for the sample was 0.74 with minimum and maximum efficiency estimates of 0.27 and 0.94 respectively. Further, 97percent of wetlands vegetable farmers had their technical efficiency indices greater than 50percent level. The inefficiency model showed that extension contact, average produce price, access to credit, farming experience, household size and membership of an association(cooperative) were the variables that had effects on the technical efficiency of the wetland vegetable farmers. The return to scale was 1.012; indicating that wetlands vegetable production in Southwest Nigeria are in stage one of production, where additional farm size, family labour, seed, fertilizer and agrochemical would enhance output. The results obtained from technical showed that vegetable farmers were moderately efficient. Therefore, efforts toward ensuring availability of extension services, provision of viable seeds, agrochemicals and easy access to finance should be promoted so as to enhance farmers' performance on their farms.

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Table 1: Maximum Likelihood Estimation (MLE) of the Cobb-Doulas Stochastic Frontier Production Function

Variables	Parameters	Coefficient	Standard Error	T-value
Constant	β_0	3.409***	0.152	22.79
Farm size	β_1	0.350***	0.059	5.86
Family Labour	β_2	0.016*	0.008	1.92
Hired Labour	β_3	-0.001	0.004	-0.31
Seed	β_4	0.603***	0.0062	9.60
Fertilizer	β_5	0.004	0.0034	1.26
Agrochemicals	β_6	0.040*	0.007	5.77
Inefficiency model				
Constant	α_0	0.118***	0.033	3.53
Education	α_1	0.003	0.001	0.37
Age	α_0	0.000	0.001	0.44
Sex	α_3	-0.001	0.008	-0.12
Extension contact	α_4	-0.019**	0.006	-2.94
Weighted average price of vegetable	α_5	0.001***	0.000	14.20
Credit availability	α_6	-0.071***	0.007	-9.54
Experience	α_7	-0.006**	0.002	-2.86
Household size	α_8	0.005**	0.002	2.80
Membership of association	α_9	-0.019**	0.007	-2.64
Diagnostic statistics				
Sigma^2	0.247	0.035***		
Gamma	0.787***			
Likelihood function	-195.42			
Mean T.E	0.74			

Source: Estimates based on analysis of the data from the field survey, 2020
Note: * , ** and * significant at 1%; 5%; and 10%.**

Table 2: Frequency Distribution of Technical Efficiency Level among Wetlands Vegetable farmers

Efficiency level	Frequency	Percentage
0.20-0.29	1	0.22
0.30-0.39	3	0.67
0.40-0.49	11	2.44
0.50-0.59	34	7.56
0.60-0.69	78	17.53
0.70-0.79	183	40.44
0.80-0.89	137	30.44
0.90-1.0	4	0.89
Mean Tech. Eff.	0.74	
Standard Deviation	0.107	
Minimum	0.27	
Maximum	0.94	

Source: Computation based on the data from the field Survey, 2020

Table 3: Inputs Elasticity of Production and Return to Scale Estimates forWetlands Vegetable Production

Input	Elasticity
Farm size	**0.350**
Family labour	**0.016**
Hired labour	**-0.001**
Quantity of seed	**0.603**
Fertilizer	**0.004**
Agrochemicals	**0.040**
Return to scale	**1.012**

Source: Field survey, 2020