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ARE SMALL-SCALE ORGANIC MAIZE FARMERS TECHNICALLY EFFICIENT? EVIDENCE FROM NIGERIA

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Abstract

The paucity of information on the efficiency of organic food crops deters relevant interventions to enhance their production in order to address the health risks associated with inorganic food items. This study, therefore, investigated the technical efficiency, identified the factors influencing the productivity of organic maize farming, and measured the factor efficiency or resource productivityof organic maize farming in Nigeria. This study used data obtained from 480 organic maize farmers and analysed it using descriptive statistics, a stochastic frontier production function, and return to scale. The results revealed that organic maize farms had an average technical efficiency of 0.76, showing there is room for improvement. Organic manure, labour, seeds, education, extension contacts, and farm size significantly contributed to the technical efficiency of organic maize farming production. To improve and maintain the continuity of organic maize farming practices, farmers need to form and belong to farm-based organisations, where government and non-government organisations can support them, to facilitate the promotion of organic-based farming knowledge and obtain financial assistance.

Key words: *food safety, maize production, Nigeria, organic agriculture, technical efficiency*

INTRODUCTION

The use of agrochemical farming inputs such as inorganic fertilizers, herbicides, fungicides, and pesticides in conventional agriculture to increase agricultural output increases soil acidity and poses serious threats to humans, animals, natural resources, and the environment [7, 12, 16]. The use of inorganic inputs in conventional agriculture results in the poisoning of about 30 million people, leading to the death of 220,000 people yearly [31]. This increases the consumers' and policymakers' interest in safe and healthy foods. Organically produced food is thus an important solution to this menace. Organic foods are produced using methods of production that minimize human, animal, and plant health risks and have no negative impact on the environment [24].

The demand for organic foods has increased due to an increase in awareness of environmentally friendly and healthy foods [37, 43]. Organic farming in developing countries is growing due to increasing demand in European and North American markets [6] and an increase in organic food consumption globally [13]. Therefore, there is a need to increase organic farming to meet the demand for healthy foods with low risk. One of the most widely consumed food crops by humans and animals is maize. It is the leading cereal in Nigeria and its production serves as a means of livelihood for many people, especially rural dwellers.

Due to the economic value of maize to humans, for instance, as food, livestock feed and raw materials for industries, more attention has to be given to its method of organic cultivation to achieve its quality and healthy output. There is a need for organic maize farming to curb the health and environmental issues in the use of chemical inputs. Many organizations like the Food and Agricultural Organization, the International Federation of Organic Agricultural Movements, and the Organic Farmers Association advocate the use of organic materials for farming because of its economic value.

The benefits of organic practices have been proved in many ways. The use of organic manure, under organic farming, tends to increase soil pH. Organic materials also serve as the essential constituent of the soil, which is present in a variety of forms, ranging from animal and plant material. Effective use of organic manure enhances fruiting in maize, increases maize curb size and optimal yield will be achieved [39, 40]. Generally, organic farming reduces the risk of crop failure that can occur due to adverse weather conditions and advent of climate change [27, 41].

Despite the importance of organic maize to human health, most studies have concentrated on maize production from conventional agriculture [2, 10, 17, 18, 23, 26, 28, 29,34, 35, 36, 44]. The technical efficiency of organic maize farms is less documented as the available studies on the technical efficiency of organic farming did not focus on maize, thus creating a gap in the technical efficiency of organic maize farming, especially in Nigeria. For instance, Gogoi et al. [25] assessed the technical efficiency of tea farming in Assam, India. However, the few available studies on organic maize production were on experimental farms which were viewed from the agronomic point of view. For instance, Adamteya et al. [1] used established trials in a field experiment to compare the yield of organically produced maize and conventionally produced maize in Kenya. Similarly, Mucheru-Muna et al. [30] established experimental trials at two sites in Kenya to examine the effects of various organic nutrient sources on maize revenue and yield. Choudharya & Kumar [15] also set an experiment using a randomized block design with six treatments to examine the influence of organic nutrients on the yield and growth of maize in India. Therefore, this study intends to fill this gap and add to the existing knowledge on organic farming.

From the foregoing, the present study adds to literature by using data from organic maize farmers to assess the technical efficiency of the farms. Specifically, the study assessed the technical efficiency of organic maize farming, identified the factors influencing the productivity of organic maize farming, and measured the factor efficiency or resource productivity of organic maize farming. These would help farmers, researchers, extension agencies, government parastatals, as well as various policymakers with empirical evidence on technical efficiency of organic maize farming. This will, in turn, serve as a policy material for organizations and the government at large to enhance organic farming and food safety. It will also serve as a reference material for individuals willing to undertake research into the efficiency of organic maize farming.

MATERIALS AND METHODS

Study area

The study area is Nigeria. Nigeria lies between longitudes 3^0 and 14^0 East and latitudes 4^0 and 14^0 North and has a total land area of 923.768 km^2 [32]. Agriculture is the major source of employment and livelihood, employing 70% of the population.

Samplingtechnique and data collection

The respondents were selected using a multi-stage sampling technique. It involves a purposeful selection of two leading states (Niger and Kaduna) in maize production, in stage one. After this, a random selection of four local government areas (LGAs) was done from each state. This is followed by selection of three communities from each LGA, randomly. In the fourth stage, twenty organic maize farmers were selected from each rural community using the snowball technique; this gave a total of 480 respondents.

Data was collected through the administration of questionnaires to the organic maize farmers. Data was collected on socioeconomic and production characteristics. The data includes age, gender, monthly income, primary and secondary occupation, household size, level of education, marital status, membership of farmer-based organization, years of farming experience, total farm size for organic maize cultivation, and access to extension services by the farmers. The variables were selected based on the design of the research and literature. Also, information regarding organic maize farming was sought from the respondents. It includes the quantity of inputs used in its production. Data was collected in February and March 2021 by the researchers and trained research assistants.

Methods of data analysis

Descriptive statistics, stochastic frontier production function (SFPF), and return to scale (RTS) were means of data analyse.

Descriptive statistics

Descriptive statistics is a statistical technique that produces figures or numbers that describe or summarize a set of data. The descriptive statistical analyses used were the measure of dispersion and a measure of central tendency such as percentage, frequency distribution table, and mean. This was used to present the findings of organic farmers' technical efficiency.

Stochastic frontier production function (SFPF)

To investigate the productivity of organic maize farming and determinants of its efficiency, the Cobb-Douglas form of the SFPF was used. This has been widely used in previous studies as it meets the requirement of being self-dual [8, 9, 17,19, 25, 38, 42]. It can also be used to estimate the returns to scale in a production function.

The model is implicitly specified as:

$$Y = f(X_i, \beta_i) + V_i - \mu_i$$
....(1)

The technical efficiency model is explicitly represented as:

$$lnY = \beta_0 + \beta_1 lnX_1 + \beta_2 lnX_2 + \beta_3 lnX_3 + \beta_4 lnX_4 + V_i - \mu_i$$
....(2)

where:

In = natural logarithm

Y = Yield of organic maize (kg)

X_1 = labour (man/days)

X_2 = seed (kg)

X_3 = quantity of organic manure used (kg)

X_4 = farm size (hectares)

B_1-β_4 = coefficients

B_0 = constant

Vi-Ui = composite error terms

Vi is the random variables that are consideredindependent of ui. It is normally distributed with constant variance and a zero mean N (0, δ v^2). It accounts for error measurement and other factors which are not under the control of the organic farmer such as disease and weather.

Ui = non-negative random variables that are considered to be independent of vi. They account for the technical inefficiency in organic maize farming. The inefficiency of organic maize farming, Ui, is modelled in terms of the factors related to socioeconomic features of the organic maize farmers assumed to influence the efficiency of organic maize farming. The model was jointly estimated with equation (3) and is expressed as:

$$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5$$
....(3)

where:

U_i = technical inefficiency

Z_1 = Farming experience in years

Z_2 = Farmers' age in years

Z_3 = Household size (number)

Z_4 = Education (years)

Z_5 = Contact of extension agent (number of contacts)

δ_0 (intercept) and δ_{1-5} (coefficients) are parameters to be estimated.

The gamma (γ) will be determined. This is the percentage of output divergence from the frontier caused by technical inefficiency. The sigma square (δ^2) will also be estimated. It indicates the model's goodness of fit and the correctness of the distributional assumption.

Returns to scale (RTS) in organic farming production

Measurement of factor efficiency or resource productivity was done using RTS. A measure of RTS is calculated by summing the regression coefficients of the predicted functions of all independent variables in the frontier production function. It is expressed as:

$$RTS = \sum \beta_i$$
....(4)

where:

RTS = Returns to scale

β_i = regression coefficient.

If RTS > 1, it suggests an increasing RTS

If RTS < 1, it suggests decreasing RTS

If RTS = 1, it suggests a constant RTS.

RESULTS AND DISCUSSIONS

Technical efficiency levels of organic maize farms

Table 1 presents the level of technical efficiency of the organic maize farmers. The value ranged between 0.47 and 0.95 with an average of 0.76. The average technical efficiency implies that there is still a gap of 0.24 (or 24%) between the current organic farmers' technical efficiency and the production frontier. This suggests that if the efficiency of input usage by organic farmers is increased by 24%, the organic maize farmers will be operating on a production frontier. Further analysis revealed that 60.8 per cent of the farmers were operating above this average, while 39.2% were operating below it.

Table 1. Distribution of the organic farmers by technical efficiency

Technical efficiency	Frequency	Percentage	Minimum	Maximum	Mean
0.41 - 0.50	10	2.1	0.47	0.50	0.49
0.51 - 0.60	45	9.4	0.57	0.60	0.59
0.61 – 0.70	101	21.0	0.63	0.68	0.66
0.71 - 0.80	185	38.5	0.74	0.79	0.77
0.81 - 0.90	91	19.0	0.86	0.90	0.88
0.91 - 1.00	48	10.0	0.91	0.95	0.93
Sample	480	100	0.47	0.95	0.76

Source: Field survey, 2021.

Productivity of organic maize farming

Efficiency estimation

The maximum likelihood estimates of the organic farmers is presented in Table 1. The estimated variance (δ^2) was significant. This indicates the correctness of the specified distribution assumption of the composite error term and the goodness of fit. In the same vein, the estimated gamma (0.9532785) was significant. This indicates that 95.3% of the total difference in the farm yield of the organic farmers was due to technical inefficiency. Furthermore, the coefficients of organic manure, labour, and farm size were positive and significant, while that of seed was negatively significant.

The positive coefficient of organic manure indicates that it has a direct relationship with organic maize output. This implies that a proportionate increase in the use of organic manure while other explanatory variables remain constant will result in an increased organic maize output level. The result indicates that the use of organic manure would result in a higher yield of organic maize farming production, all things being equal. This could be because the output of crops depends on the soil nutrients; thus, the use of organic manure will enhance soil nutrients and consequently increase the organic maize yield. This conforms to the findings of Gogoi et al. [25] that organic manure increases the total output. Anang et al. [5] and Uuld et al. [38] also stated that crop output is heavily dependent on manure.

The estimated positive coefficient of labour shows a direct relationship between labour and organic maize output. This result shows that an increase in labour usage will increase organic maize farming output. Labour is crucial in agriculture, especially in developing nations where the most farmers use crude implements [14, 33]; thus, as efficient labour usage increases, farmer efficiency and output increase. This supports Bozoglu and Ceyhan [11], Anang et al. [5], and Uuld et al. [38].

The negative coefficient of seed implies that an increase in seed usage by farmers will not necessarily increase the output of organic maize. As the farmers increase the quantity of seed used per hectare, a diminishing marginal return sets in. This could be because organic maize farming has a specific planting space (75cm by 50cm) which is being used in the study area. Thus, any increase in seed rate per hectare will cause overpopulation of the crop and competition for space and nutrients, which, in turn, may lower the efficiency and productivity of organic maize farming. A similar finding was also reported by Bairagi and Mottaleb [8] that seed negatively affected farm production efficiency.

The positive sign of the farm size shows that farm size contributes immensely to the technical efficiency of organic maize production. An increase in farm size will increase the efficiency level of organic maize production. This could be due to the enjoyment of economies of scale, which is possible at large farm sizes. Farmers will buy the required inputs at a cheaper rate, which will, in turn, enhance their production efficiency. This supports Bidzakin et al. [9] and Uuld et al. [38] that farm size (land) enhances productivity.

Table 2. Maximum likelihood estimates of the SFPF of organic maize production

Variables	*Coefficient*	*Standard Error*	*z*	*P>|z|*
Efficiency model				
Constant	10.3581	1.2863	8.05	0.000
Labour	0.2109**	0.0833	2.53	0.012
Seed	-0.4496***	0.0988	-4.55	0.000
Organic manure	0.0011**	0.0005	2.23	0.026
Farm size	0.2037***	0.0349	5.84	0.000
Inefficiency Model				
Constant	1.0927	0.9883	1.11	0.269
Age	0.0647	0.2999	0.22	0.829
Household size	0.3401	0.2218	1.53	0.125
Farming experience	-0.1703	0.1085	-1.57	0.177
Level of education	-0.1644***	0.0596	-2.76	0.006
Extension contacts	-0.0371**	0.0371	-2.15	0.042
Sigma-squared (δ^2)	0.9298***	0.2227	4.17	0.000
Gamma (γ)	0.9533***	0.2749	3.47	0.006

Wald chi2(3) = 7.92 Prob > chi2 = 0.0477 Log likelihood = -132.3770
**p*< 0.1; ***p*< 0.05; ****p*< 0.01
Source: Survey data, 2021.

Inefficiency estimation

The inefficiency factors were chosen to reflect the farmers' unique socio-economic conditions. Negative coefficients imply that the variables increase the efficiency of organic maize production, whereas a positive coefficient indicates the opposite, that is, it reduces the efficiency. As shown in Table 2, educational level and extension contacts were negatively significant. The estimated coefficient of the educational level was negative concerning the inefficiency of organic maize production. This suggests that the technical efficiency of organic maize farming increases as the educational level increases and vice versa. Thus, educated farmers were more efficient in organic maize farming. This could be due to educated farmers being well informed on technical know-how, adopting innovation, and obtaining agricultural information [20, 21, 22], resulting in production near the frontier. This agrees with Gogoi et al. [25], and Wu [42] that formal education increases crop production efficiency.

Contacts with extension agents influenced organic maize farming inefficiency negatively. This implies that access to extension services increased the technical efficiency of organic maize production. Farmers who had access to extension services were more efficient in organic maize farming than those without extension contact. This could be a result of information on best farming practices, innovation, training, and technical support gotten from the extensionists [3, 4]. This supports Falola et al. [19] that extension contacts increased production efficiency.

Returns to scale in organic farming production

The result of returns to scale used to measure resource productivity or factor efficiency of organic maize production is presented in Table 3. The return to scale was -0.0339. The negative sign of the computed RTS indicates a decreasing return to scale. This shows that organic maize farmers stopped their production when the average productivity of variable resources was declining and total physical product reached its peak but increased at a decreasing rate. This is a rational, optimal, and economical stage of production. The result implies that the organic maize production resources were efficiently utilized by the farmers.

Table 3. Returns to scale of organic maize production

Variables	*Elasticity*
Labour	0.2109
Seed	-0.4496
Organic manure	0.0011
Farm size	0.2037
RTS	-0.0339

Source: Survey data, 2021.

CONCLUSIONS

This study investigates the technical efficiency of organic maize farming. The study showed that organic maize farms had an average technical efficiency of 0.76, showing that there is room for improvement on the part of the farmers. The analysis of the drivers of productivity of organic maize farming reveals that the use of organic manure increases maize yield, whereas increasing labour and seeds does not necessarily increase organic maize output per hectare. In addition, farmers' educational level, extension contacts, and farm size enhance the technical efficiency of organic maize farming.

This study recommends the encouragement of farmers to form and belong to cooperatives or farm-based organizations to facilitate the promotion of organic-based farming knowledge among themselves. Adequate funding should be provided by governments and NGOs to enhance judicious research in developing feasible and sustainable organic agricultural practices. They could also, through relevant ministries, assist in efficient monitoring and evaluation of the production systems in organic farming. Also, efforts should be geared towards improving the educational level of the farmers, as this will increase their level of technical efficiency. This could be done through organizing literacy programs for the farmers.

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