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RESOURCE USE EFFICIENCY IN IMPROVE HYBRID TOMATO PRODUCTION IN AKWA IBOM STATE, SOUTHERN REGION OF NIGERIA

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Abstract
The study estimates the technical efficiency of tomato farmers in Akwa Ibom State in the Southern Region of Nigeria. One hundred and twenty tomato farmers were randomly selected using multistage sampling technique. Descriptive statistics and maximum likelihood estimation of the stochastic Cobb-Douglas production function were used to analyze the collected data. The results of socioeconomic characteristics showed that male farmers dominated tomato cultivation in the region. The majority of farmers were relatively young, educated, and had moderate household size but low social capital accumulation. The empirical results identified seeds, manure, fertilizer, farm size, hired labour and family labour as significant inputs in tomato production. The study found decreasing return to scale in tomato production in the region. An average technical efficiency index of 0.797 was estimated, which corresponds to an efficiency gap of approximately 20.30%. Determinants of technical efficiency were: farming experience, socialization, education, training, farm income, household size and non-farm income. To increase the technical efficiency of tomato farmers, it is recommended that they should be encouraged to join existing cooperatives to obtain production information that would improve their technical efficiency; and providing formal education, especially in rural areas, would encourage tomato farmers to update their knowledge and acquire more skills necessary for efficient management of farm resources.
Keywords: Tomato, farmers, rural area, technical efficiency, resources

Introduction

Tomato *(Lycopersicom esculentum)* is one of the most popular and highly consumed vegetables grown in Nigeria (Amurtiya & Adewuyi 2020; Norbert, Kaka & Gona, 2023; Bolarinwa, Olubanjo, Otunaiya & Idowu 2024). The vegetable is consumed in a variety of ways and it constitutes a significant proportion of daily vegetable consumption among Nigerians (Raaijmakers, Snoek, Maziya-Dixon & Achterbosch 2018; Snoek, Raaijmakers, Lawal & Reinders 2022; Adeosun, Salman, Chukwuone, Ume, Chukwuone & Ezemaaa 2022). According to statistics, Nigeria is a prominent producer of fresh tomato in sub-Saharan Africa and ranks 14th in the world and second in Africa (FAO, 2024). The country produces 3.47 million tons of fresh tomatoes in 2021 and 3.68 million tons in 2022, with an estimated land area of 809,602 ha and 702,275 ha, respectively (FAO, 2024). The country's annual yield was 4.29 tons/ha and 5.25 tons/ha in 2021 and 2022, respectively. These yields were relatively low compared to 42.61 tons/ha and 43.69 tons/ha for Egypt and 67.34 tons/ha and 67.18 tons/ha for South Africa in 2021 and 2022 respectively (FAO, 2024). Despite the low yield, farmers in the country are currently struggling with about 60.00% post-harvest losses, equivalent to 2.21 million tons/year, caused by multiple factors (Business Day Newspaper, 2023, FAO, 2024). However, the country's annual tomato consumption was estimated at 3.25 million tons in 2021, with a consumption gap of 1.78 million tons per year. This created an incentive for importation, which has a huge financial impact on Nigeria's economy (Balogun, 2020).

The medicinal quality of the tomato shows that the vegetable is rich in vitamins, minerals, fibre, antioxidants and beta-carotene, among other things (Ali, Sina, Khandker, Neesa, Tanvir, Kabir, Khalil & Gan 2020; Campestrini, Melo, Peres, Calhelha, Ferreira & De Alencar 2019). In Nigeria, tomato cultivation is predominantly carried out in the northern region of the country. However, increasing insecurity in the northern region recently has slowed down tomato production, widening the consumption deficit gap and correspondingly stimulating the desire of other regions to grow tomatoes. Due to the continued rising prices of fresh tomatoes and other vegetables in the country, there has been a massive response from farmers to invest in tomato production in the southern region of the country (Business Day newspaper 2017, Akpan, Okon & Ernest 2019a; Bolarinwa *et al.*, 2024). The region's government has motivated farmers to grow tomatoes through repeated awareness programmes, provision of farm inputs, farm demonstrations and the provision of processing facilities, among other measures (Michael, Tashikalma & Maurice 2018; Ogwu, Chime & Oseh 2018; Tawo, 2019). Hence, currently there is a massive boom in tomato production in the southern region of the country. For example, tomato production has been included in various youth development programs while grants, input subsidies and special consideration have been given to tomato production in the region to sustain this developing agribusiness in the region (Akwa Ibom State Government, 2024). Despite various interventions from the sector's stakeholders, tomato farmers are often faced with a variety of challenges that exacerbate post-harvest losses. For example, there are poor resource base, inadequate processing facilities, frequent terrorist/herdsman attacks on farmers, soil infertility, conflicts between farming communities, poor road infrastructure, youth migration, rising transportation costs, and increasing rural poverty, among others (Ofuoku & Aganagana 2018; Akpan and Udoh 2016; Obaniyi, Kolawole, Ajala, Adeyonu & Oguntade 2020; Akintobi 2020; Adisa, Famakinwa, Adeloye, & Adigu 2022). Therefore, addressing these challenges is critical to the survival and sustainability of tomato production in the country (Akpan & Okon 2019; Adeloye, Torimiro & Oladejo 2023).

Smallholder farmers, who typically represent around 90% of the agricultural sector and cultivate less than 2 hectares of land (Olugbire, Sunmbo & Olarewaju 2021; Dhillon & Moncur, 2023; Onoja, 2023), play a significant role in vegetable production within the country. However, sustainable tomato cultivation necessitates various farm resources, which are often in short supply (Akpan, Monday, & Okon 2018; Akpan, Monday 2021; Akpan**,** Antia, Nkanta 2022; Bolarinwa *et al.*, 2024). Consequently, the effective management of these resources is crucial for achieving agricultural sustainability (Tahir, Ghide, Ibrahim, Mohammed & Abba 2021; Akpan & Monday, 2021; Mulaudzi, Oyekale & Ndou 2019; Alabi, Abdulazeez, Anekwe, Sambo, Alabuja, Drisu, Safugha, Obinna-Nwandikom, Abdullahi & Aluwong 2023a).

Consequently, the ability of tomato farmers to combine the available farm resources in an efficient mix to achieve maximum production levels is crucial to the survival of tomato production in the country (Akpan, Antia, Nkanta 2022; Alabi *et al.*, 2023a). One way for small-scale farmers such as tomato farmers to achieve sustainability in farm production is to increase farm productivity by improving the efficiency of farm factors within the existing resource base and technology (Akpan et al., 2022; Alabi *et al.*, 2023a; Alabi, Jeremiah, Aluwong, Atteh, Dirisu, Yusuf, Popoola, Agada & Haruna, 2023b; Bolarinwa et al. 2024). The sustainability of tomato farms in the southern region is crucial and necessary to meet the nutritional needs of consumers (Akpan & Okon, 2019). Given the increasing importance of tomato in the nutritional composition of citizens in the region and the comparative advantage of tomato production over other vegetables, there is an overwhelming need to assess and determine the level of factor productivity in this enterprise. In addition, since tomato cultivation has a short maturation period, requires less drudgery and has a simple cost-return structure, it is a real means of attracting young people to agricultural production in the region (Haruna, Asogwa & Ezhim 2019; Akpan, Udoh & Nkanta 2023a; Oyibo & Odebode 2024). In this light, the current efforts of tomato farmers in the region need to be reassessed to identify factors that would promote the technical efficiency of farm resource use and improve sustainable tomato production.

Several authors have addressed the issue of technical efficiency of vegetable crops in developing countries. Mulaudzi *et al.*, (2019) analyze the technical efficiency of African indigenous vegetables (AIVs) production in Vhembe District of Limpopo Province, South Africa. The results showed that cultivated land area, fertilizers, seeds, labour and tractor days have a significant impact on the production of AIVs. Additionally, an average technical efficiency of 0.79% was found, while years in formal education, access to extension services, gender and access to irrigation system were identified as significant factors affecting the technical efficacy of AIVs production. Mwangi, Ndirangu & Isaboke (2020) assessed agricultural productivity and factors affecting its technical efficiency of smallholder tomato farmers in Kenya. The results showed an efficiency gap of 39.55%. Household size, production systems, seed type, fertilizer, cropping and market information significantly and positively influenced technical efficiency, while land size was significant and inversely influenced technical efficiency. Khan, Wotto, Liaqat, Khan, Rasheed, Rafiq & Xiangyu (2020) found an average Technical Efficiency (TE) of 85% among tomato farmers in Balochistan, while age, education and farming experience had a significant impact on the TE of tomato farmers. Asfaw (2021) studied the factors affecting the TE of tomato farmers in Ethiopia. The results showed that male farmers accounted for about 70.75% of tomato farmers. Farm inputs, namely land, labour, tomato seeds and oxen, had a significant impact on tomato production. Also, farmers' education, extension contacts, training and access to credit have a significant positive impact on technical efficiency, while household size, off-farm income, livestock, distance to market and pesticides have a significant negative impact. The study also found a mean TE of 80.9%. Alabi *et al.*, (2023a) worked on technical efficiency differences of tomato production in two different environments in Nigeria. The results showed that farm size and labour factors were significant factors affecting the production of traditional tomato farming, while farm size, fertilizer use, seed use, chemical use and labour factor were significant factors affecting the technical efficiency of improved tomato production technologies. However, the TE for the traditional farms was influenced by age, household size and farming experience. On the other hand, age, gender, educational level, marital status, household size and experience in farming influenced the TE of an improved tomato farm. The average technical efficiencies were 0.39 and 0.57 for traditional and improved tomato production technologies, respectively. Also, Alabi *et al.,* (2023b) examined factors affecting allocative efficiency of small-scale tomatoes (Lycopersicum species) in northern Nigeria. The results suggest that the following factors influence the allocative efficiency of tomato production: age, farm size, household size, gender, marital status, education level, access to extension services and membership in a cooperative organization. Bolarinwa *et al.,* (2024) analyze the technical efficiency of vegetable production among wetland farmers in southwest Nigeria. The results showed a mean technical efficiency of 0.74, indicating that 26.00% of the production potential was still unused. An increase in farm size, family labour, amount of seeds planted, and amount of agrochemicals significantly improved vegetable production. On the other hand, an increase in agricultural extension visits, access to credit, farming experience, household size and association membership reduces the technical inefficiency of vegetable farmers.

The literature provided lacks of information on the technical efficiency of vegetable farmers in the southern region of Nigeria. Additionally, sparse information from other regions of the country may not be fully applicable to the southern region due to differences in climatic factors, farmers' income, poverty rates, and consumer priorities, among others (Akpan, Uwemedimo & Ima-abasi 2019b; Akpan, Udo & Akpan 2019c). As a developing agricultural enterprise, tomato production has enormous potential to promote employment and improve the region's food self-sufficiency. Therefore, sustainability must be ensured by providing information about the enterprise's technical efficiency. Based on these facts, the study was specifically designed to examine the social and economic characteristics of tomato farmers, evaluate the factor productivity of tomato farms, and estimate the technical efficiency indices as well as factors affecting the technical efficiency of resource use in tomato farms in the region.

METHODOLOGY

Study Area

The study was carried out in the two agricultural zones of Akwa Ibom State, namely: Abak and Ikot Ekpene agricultural zones. Ikot Ekpene Agricultural Zone consist of five (5) local government areas namely: Ini, Obot Akara, Ikot Ekpene, Ikono and Essien Udim. Abak agricultural zone is made up of five local government areas namely; Abak, Etim Ekpo, Ika, Oruk Anam and Ukanafun. The people are predominantly farmers producing food crops and vegetables such as pepper, tomato, cucumber, fluted pumpkin, melon, sweet potatoes among others.

Sampling Techniques and Sample Size

A multistage sampling procedure was adopted in selecting tomato farmers in the study area. A list of registered tomato farmers was obtained from Akwa Ibom State Agricultural Development Programme (AKADEP) office in both agricultural zones selected. In the first stage, Abak and Ikot Ekpene Agricultural Zones were purposively selected from the existing six Agricultural Zones because they are the major centers for commercial tomato production in the State. In the second stage, a sample frame of one hundred and seventy-three tomato (173) farmers from the two zones were obtained from the list of registered tomato farmers. In the next stage, the representative sample size (Sn) was obtained using the formula developed by Yamane, (1967) as thus:

$$S_n = \frac{N}{1+N(e^2)} = \frac{173}{1+173(0.05^2)} = 120 \ldots\ldots\ldots\ldots (1)$$

Where; Sn = representative sample size; N = sample frame; e = absolute error at 5% probability level of type 1 error

Hence, a total of one hundred and twenty (120) registered tomato farmers were needed for the study. The third stage involved a random selection of one hundred and twenty (120) tomato farmers from the merge list using a ballot system. In the final stage, the selected tomato farmers were contacted and interviewed to obtain the necessary data for the study.

Data source

The data for this study was collected through the use of a well-designed and structured questionnaire. A cross-sectional data was collected from small-scale tomato farmers. The data collected includes; social and economic data, farm specific and production data.

Analytical Techniques

Descriptive statistics (consisting of percentages, tables, mean, and frequencies), and stochastic Cobb Douglas production model was used to analyze data collected. The assumption of constant input substitution inherent in the Cobb Douglas production function was presumed. Implicitly, the Cobb Douglass production function is specified as thus:

$$TOM_i = f(X_i, \beta_i)e^{V_i - U_i} \ldots\ldots\ldots\ldots (2)$$

$$TOM = f(LAN, HHL, HIL, FER, CAS, CAP, MAN, (V_i - U_i)) \ldots\ldots (3)$$

Note, variables are expresses in logarithm.
Explicitly, the specified Cobb Douglas production function is shown as thus:

$$LogTOM = \delta_0 + \delta_1 LogLAS + \delta_2 LogHIR + \delta_3 LogFAL + \delta_4 LogFER + \delta_5 LogMAN + \delta_6 LogSED + \delta_7 LogAGC + \delta_8 LogWAT + (V_1 - U_1) \ldots\ldots (4)$$

Where, TOM = Output of tomato in one production cycle in (kg); LAS = land size of a tomato farm in hectare; HIR = hired labour used in the tomato farm in one cycle (man day); FAL = family labour used in the tomato farm in one production cycle (man days); FER = amount of fertilizer used in one production cycle (Kg); MAN = quantity of manure applied in one production cycle (kg); SED = quantity of seed planted in one production cycle (kg); AGC = volume of agrochemical used in one production cycle (litres); (Vi –Ui) = composite error term.

Note, the marginal physical product (MPP) and average physical product (APP) were estimated with respect to each farm factor and used to explain the productivity of factors of production. The elasticity of production (EP) with respect to each factor generated from the stochastic frontier was used to determine the return to scale value. The estimation of the stochastic production function specified in equation 4 equally generated the inefficiency function simultaneously with the production function. Explicitly, the determining factor of technical inefficiency of tomato farmers are specified as thus:

$$TEE = \beta_0 + \beta_1 AGE + \beta_2 EDU + \beta_3 GEN + \beta_4 EXP + \beta_5 HHS + \beta_6 FAS + \beta_7 SOC + \beta_8 TRA + \beta_9 CRE + \beta_{10} EXT + u_i \ldots\ldots\ldots\ldots (5)$$

Where, TEE = Technical inefficiency of tomato farmers; AGE = represents tomato farmers' age (years); EDU = formal education level of tomato farmer (year); GEN = farmers' gender (a dummy, 1 for male farmer and 0 represents female farmers); EXP = tomato farmers' years of experience (years); HHS = family size of tomato farmers (number); FAS

= farm area in hectare, SOC = membership in a social organization (Number of years); TRA = number of trainings received by tomato farmer (number); CRE = access to credit (amount of credit received in naira), EXT = access to extension services (number of times in a year).

Results and Discussion

Socioeconomic Characteristics of Tomato Farmers

The socioeconomic characteristics of tomato farmers are presented in Tables 1 and 2. The result showed that the majority (70.80%) of tomato farmers are male. The result could be attributed to the labour-intensive production system prevalent among tomato farmers in the region. In addition, financial involvement in tomato cultivation promotes male dominance because they have better access to production resources compared to women. The finding corroborate Asfaw (2021).

The age distribution of tomato farmers revealed that majority (61.70%) were in the age group of 30 to 40 years, 35.80% were in the age group of 40 to 50 years, 1.70% were under 30 years old and 0. 80% were over 50 years of age. The average age of farmers was 39.00 years. The age distribution suggests that tomato farmers in the region are in their active age range. This means that tomato farmers in the region have a high level of resilience and ability to adopt and utilize new technologies in the production, marketing and processing of tomatoes.

The marital status of the tomato farmers revealed that majority of them were married (61.70%), 35.80% were divorced, 1.70% were single and 0.80% were widowed. These results suggest that most tomato farmers participated in the business to increase income to support the family. The distribution of farming experience showed that majority (80.80%) of tomato farmers had years of experience ranging from 5 to 10 years, 12.50% had less than 5 years, and 6.70% had more than 10 years of farming experience.

Table 1: Socioeconomics Characteristics of Tomato Farmers

Socioeconomic characteristics	Frequency	Percentage	Mean
Gender			
Male	85	70.80	
Female	35	29.20	Dummy
Total	120	100.00	
Age (years)			
< 30.00	2	1.70	
30.00 – 40.00	74	61.70	39.00
40.00 – 50.00	43	35.80	
> 50.00	1	0.80	
Total	120	100.00	
Marital Status			
Single	2	1.70	
Married	102	61.70	
Divorced	6	35.80	Dummy
Widow	10	0.80	
Total	120	100.00	
Farming experience (years)			
< 5.00	15	12.50	
5.00 – 10.00	97	80.80	7.20
> 10.00	8	6.70	
Total	120	100.00	
Farm Income (₦) (one production cycle)			
<50,000	16	5.00	60,325.00
50,000 – 100,000	95	79.20	
>100,000	9	15.80	
Total	120	100.00	

Source: Field survey, 2024.

The average farming experience was 7.20 years, indicating that tomato production in the region is an evolving agro-business and has great potentials. The income of tomato farmers in a single production cycle showed that majority (79.20%) of them earned in the range of ₦50,000 to ₦100,000, only 15.80% earned above ₦100,000 per production cycle while 5.00% earned less than ₦50,000 per production cycle. The average income from a single production cycle was ₦72,083.3, indicating that the majority of tomato farmers are smallholders. Perhaps this explains the reason why all tomato farmers have a part-time job or secondary occupation. The accumulation of social capital among tomato farmers was low as the majority (74.20%) did not belong to any social organization while 25.80% were members of a farm-related social organization. The formal education level of tomato farmers shows that majority (75.83%) have acquired secondary education while 19.17% had up to tertiary education. Only 5.00% of farmers received up to six years of formal education (i.e. primary education). However, the average duration of formal education was 12.88 years, indicating that most tomato farmers in the region are literate and have secondary education.

Table 2: Socioeconomics Characteristics of Tomato Farmers

Socioeconomic Characteristics	Frequency	Percentage	Mean
Household Size (number of persons)			
<7.00	32	26.70	
7.00 – 8.00	62	51.70	7.00
>8.00	26	21.60	
Total	120	100.00	
Land Acquisition (dummy)			
Inheritance	41	34.20	
Leased	28	23.30	Dummy
Purchase	12	10.00	
Community	39	32.50	
Total	120	100.00	
Farm Size (ha)			
< 0.50	44	36.70	0.55
0.50 – 1.00	46	38.30	
> 1.00	30	25.00	
Total	120	100.00	
Secondary Occupation (dummy)			
Civil servant	50	41.70	
Pensioner	8	6.70	Dummy
Okada/Bus driver	33	27.50	
Petty trader	29	24.10	
Total	120	100.00	
Membership of Social Organization			
Yes	31	25.80	
No	89	74.20	Dummy
Total	120	100.00	
Educational level (years)			
No schooling	0	0.00	
Primary school	6	5.00	12.88
Secondary school	91	75.83	
Tertiary school	23	19.17	
Total	120	100.00	

Source: Field Survey, 2024.

The household size distribution result revealed that majority (51.70%) of farmers had a household size in the range of 7 to 8 people, 26.70% had less than 7 people and 21.60% had more than 8 people. The average household size was 7 people, suggesting that family labour is important in tomato production in the region. Land ownership is crucial for tomato cultivation as population density increases in the region. The results showed that about 34.20% of tomato farmers acquired land through inheritance, 32.50% grew tomatoes on communal land, 23.30% acquired farmland through rent or leasing arrangement and only 10.00% cultivated on purchased land.

Since it is a small agricultural business in the region, tomatoes are grown on small areas of land. For example, about 38.30% of the farmers had a farm size in the range of 0.5 ha to 0.9 ha, 36.70% had a size of less than 0.5 ha and 25.00% had a size of more than 1 ha. The average farm size was 0.55 ha, which confirms the small-scale nature of the business in the region. Income diversification among tomato farmers in the region is increasing. For example, about 41.70% of farmers were civil servants, 27.50% were engaged in a mass transit system called okada or minibus driving, while 24.10% were small traders and 6.70% were pensioners or retirees.

Estimates of Stochastic Production Function of Tomato Farms

The stochastic Cobb Douglas production estimates for tomato farms are shown in Table 3.

Table 3: Cobb-Douglas Stochastic Production Function for Tomato Farms

Variable	Coefficient	Std. error	Z-value	Probability
Constant	7.8976	0.8828	8.9464***	0.000
Hired labour	0.0928	0.0550	1.6872*	0.078
Family labour	0.5641	0.0787	7.1696***	0.000
Fertilizer	0.2083	0.0484	4.3052***	0.000
Manure	0.1069	0.0513	2.0838**	0.044
Seed	0.5531	0.2201	2.5127**	0.012
Chemicals	-0.4047	0.6609	-0.6123	0.438
Farm size	-0.2288	0.0749	-3.0554***	0.002
			Inefficiency model	
Age	0.3212	0.2389	1.3445	0.3489
Marital status	-0.7634	0.5689	-1.3419	0.3457
Farm experience	-0.0345	0.0014	-24.643***	0.0000
Socialization	-0.0033	0.0012	-2.7500***	0.0034
Education	-0.9876	0.2389	-4.1339***	0.0000
Training	-0.4567	0.1209	-3.7775***	0.0009
Credit access	-0.2345	0.4932	-0.4755	0.7845
Extension	-0.0034	0.3487	-0.0097	0.9056
Dependent ratio	0.0027	0.0017	1.5882	0.1298
Farm income	-0.1256	0.0023	-54.609***	0.0000
Household size	0.8752	0.3983	2.19734**	0.0543
Non-farm income	-0.0913	0.0211	-4.3270***	0.0000
Sigma squared	0.1199	0.0157		
lambda	0.7791	0.2296		
Log likelihood	-42.9732			
Wald chi2 (7)	133.54 (0.000)***			

Source: From data analysis, 2024. Note: Asterisk *, ** and *** represent 10%, 5% and 1% significance levels respectively.

The diagnostic statistics revealed that, the coefficient of the sigma square (0.1199) is statistically significant at 1% probability level. This indicates a good fit and correctness of the specified distribution assumption of the composite error term in the production model. The estimated variance ratio coefficient of 0.7791 is statistically significant at a 1% level. The result suggests that the systematic effect that is not captured in the estimated production model is relatively the dominant factor in the random error sources. The finding implies that, the occurrence of inefficiency in the specified farm resources of tomato farmers' is responsible for approximately 77.91% of the fluctuations in the output of tomato. The remaining 22.09% is attributed to the normal random stochastic error sources. By this result, the presence of a dominant one-sided error component in the specified production model is therefore confirmed. The implication of the result is that, the Ordinary Least Squares (OLS) estimation method would provide insufficient representation of the production model specified. Hence, the diagnostic test justified the specification of the stochastic production frontier model and the choice of maximum likelihood estimation method.

The coefficient of factors of production exhibited a *priori* expectations. The coefficient with respect to each production input represents production elasticity of the corresponding inputs. The estimated production function reveals that hired labour, family labour, fertilizer, seed and farm size significantly affected the farm level production of tomato farmers in the study area. The empirical results revels that the coefficients of hired labour (0.0928), family labour (0.5641), fertilizer (0.2083), tomato seed (0.5531) and manure (0.1069) have a positive significant relationship with tomato output. This means that, a unit increase in these farm inputs would induce tomato output growth by the value equivalent to the respective input elasticity.

On the contrary, the coefficient of farm size (-0.2288) and agrochemicals (-0.4047) have a negative relationship with tomato output. This connotes that as these factors is increased, tomato output would decrease correspondingly. The findings are in agreement with Mulaudzi *et al.*, (2019); Mwangi *et al.*, (2020); Asfaw (2021); Alabi *et al.* (2023a); and Bolarinwa *et al.*, (2024).

Farm Factor Productivity of Tomato Farmers

The results presented in Table 4 shows the factor productivity indices of tomato farms. The production elasticity with respect to hired labour, family labour, fertilizer, manure, and tomato seed are positive and less than unity (inelastic). This means that a unit change in these inputs is greater than a corresponding unit change in tomato output. Also, the APP of these inputs are greater than their respective MPP, denoting they are in stage II in the classical production surface.

Table 4: Production Parameters of Tomato Farm

Inputs	Elasticity	APP	MPP	Input utilization stage
Hired labour	0.0928	0.4146	0.0385	II
Family labour	0.5641	1.2071	0.6809	II
Fertilizer	0.2083	8.8338	1.8401	II
Manure	0.1069	3.3953	0.3629	II
Tomato seed	0.5531	16.1431	8.9287	II
Chemicals	-0.4047	26.0394	-10.538	III
Farm size	-0.2288	591.1781	-135.26	III
Return to scale		0.8917		Decreasing returns to scale

Source: Field Survey Data, 2024.

By implication, these factors of production are rationally utilized and are in the rational stage in the classical production surface. An increase in the used of these factors of production will increase the quantity of tomato output but at a decreasing rate. Hence, it is advisable to maintain the level of utilization of these inputs given the level of tomato output and technology as well as the level of utilization of other factors of production. On the contrary, the elasticity with respect to farm size and agrochemical is negative. This means that the use of these inputs is irrational and occur in stage III in the classical production surface. It is advisable to reduce the use of these inputs as increase in the use would reduce the total physical product of tomato farms.

The returns to scale in tomato production in the southern region of Nigeria connotes decreasing returns to scale situation. This implies, that increase in the use of factors of production will increase tomato outputs in a decreasing manner. Alternatively, tomato outputs increase by a smaller proportion relative to the increase in farm resources.

Technical Efficiency Indices of Tomato Farms

The distribution of technical efficiency indices of tomato farms is shown in Table 5. The results showed that tomato farmers had different technical efficiencies ranging from 0.010 to 0.980, with a mean of 0.797. The efficiency distribution shows that only a small proportion of tomatoes are not produced due to the inefficient use of the specified farm resources. The results revealed that only 8.33% of tomato farmers operated in the efficiency range of 0.101 to 0.200 and 0.601 to 0.700 respectively. The majority (37.50%) of tomato farmers operated in efficiency range of 0.501 to 0.600.

Table 5: Frequency Distribution of Technical Efficiency Indices of Tomato Farms

Efficiency category	Frequency	Percentage
0.001 – 0.100	5	4.17
0.101 – 0.200	10	8.33
0.201 – 0.300	9	7.50
0.301 – 0.400	10	8.33
0.401 – 0.500	5	4.17
0.501 – 0.600	45	37.50
0.601 – 0.700	10	8.33
0.701 – 0.800	15	12.50
0.801 – 0.900	10	8.33
0.901 – 1.000	1	0.84
Total	**120**	**100.00**
Mean	0.797	
Minimum	0.010	
Maximum	0.980	

Source: From data analysis, 2024.

About 0.84% of tomato farms were close to the efficient frontier, while only a few farmers (4.17% of farms) were very far from the efficient frontier. However, the least technically efficient farmer needs an efficiency gain of 98.98% (i.e. 1.0 ─ 0.010/0.980) (100) in resource use if he wants to reach the efficiency level of the most technically efficient farmer. While an average farmer in technical efficiency needs a gain of 18.67% (i.e. (1.0 ─ 0.797/0.980) (100) to reach the level of most efficient farmers in resource use.

With efficiency gap of 20.30%, the findings revealed that tomato farms in the region still have opportunity to increase the level of farm resource use available to them. This suggests that, if tomato farms in the region avail themselves with improved technologies, given a stable macroeconomic environment, they still have opportunity to expand production, through increase in farm resource productivity.

Determinants of Tomato Farm Technical Efficiency

The estimated coefficients or parameters of the technical inefficiency model are shown in the lower part of Table 3. The result of the inefficiency model shows that farming experience has a significant negative relationship with the technical inefficiency of resource use. This implies that the farming experience of tomato farmers is positively correlated with the technical efficiency of resource use. Alternatively, increasing farmers' experience would increase the technical efficiency index or decrease the technical inefficiency index. The result meets the expectations, since increase in farming experience reduces risk situations during production. The finding confirms Khan et al., (2020); Alabi *et al.,* (2023a); and Bolarinwa *et al.,* (2024).

Membership in a social organization has a significant positive association with the technical efficiency index. Socialization helps build social capital and creates opportunities for increased access to productive resources that promote efficiency in resource use. Cooperation between farmers and between farmers and buyers is improved as farmers become increasingly socialized. The exchange of information, particularly about means of production, price movements and marketing issues, is motivated by the increasing socialization of farmers. Similar result is reported by Alabi *et al.,* (2023b), but contradicts Bolarinwa *et al.,* (2024).

Years of formal education have a significant negative association with technical inefficiency, but on the contrary, a positive association with technical efficiency. This implies that the technical efficiency of tomato farmers increases with increasing formal education. It is known that longer formal training of farmers has a positive effect on the adoption of innovations. In addition, improving education increases farmers' analytical ability and provides them with a better market for inputs and outputs, as well as financial and non-financial incentives such as credit, access to information, training and research, and others. Therefore, improving the training of tomato farmers promotes farmers' management skills, resulting in efficiency in agricultural resource management. The finding is consistent with Mulaudzi *et al.,* (2019); Khan *et al.,* (2020); Asfaw (2021); Alabi *et al.,* (2023a); and Alabi *et al.,* (2023b).

Farmer training has a significant negative association with technical inefficiency. This means that tomato farmers' technical efficiency increases the more training they receive. Training helps to improve production technology and the skills and knowledge required in production processes. By providing repeated training opportunities, farmers' production capacity will be regularly updated and this will increase the efficiency of farm resource use. The result is supported by Asfaw (2021).

Farm income has a significant negative relationship with technical inefficiency of resource use. This means that the technical efficiency of tomato farmers increases as farm income increases. Increased farm income can provide farmers with the financial resources necessary to invest in modern technology, equipment and inputs that can increase productivity and efficiency. This includes adopting precision farming techniques, automation and other advanced technologies that optimize resource use and increase production. In addition, increased income allows farmers to access training programs, extension services and research initiatives that improve their technical skills.

The coefficient of non-farm income has a significant negative impact on the technical inefficiency of tomato farms. Alternatively, there is a significant positive relationship between tomato farmers' non-farm income and the technical efficiency of resource use. This means that diversifying sources of income through non-farm activities can provide farmers with financial stability and resilience, allowing them to invest in modern technologies, equipment and training that can improve the technical efficiency of their farm resources. A further implication would be that non-farm income can serve as an additional source of financing for farm activities, enabling farmers to afford inputs, machinery and infrastructure that improve productivity and efficiency. Asfaw (2021) has reported a similar result.

Household size has a significant positive association with the technical inefficiency of tomato farms. This implies that the household size of tomato farmers has a significant negative association with technical efficiency. The instability of family labour composition due to constant human development effort in farming families may help explain this relationship. For example, as family members gain skills and acquire higher education, they migrate in search of greener pastures, creating a gap or shortage in the supply of farml labour which often impacted negatively on farm resource efficiency. The finding is consistent with Mwangi *et al.,* (2020); Asfaw (2021); Alabi *et al.,* (2023a); Alabi *et al.,* (2023b); a Bolarinwa *et al.,* (2024).

Conclusion and Recommendations

Smallholder farming is the core of the agricultural system in sub-Saharan Africa. Therefore, the sustainability of small-scale agriculture depends on the efficient use of farm resources. In Nigeria, the need for efficient use of farm resources is even more urgent due to rampant poverty, increasing malnutrition, increasing price volatility of agricultural products, farm insecurity and high youth unemployment, among others. In this context, the study focused on determining the technical efficiency of tomato farms by applying the stochastic parametric estimation method. Maximum likelihood estimates of the Cobb-Douglas production function and inefficiency estimates as well as indices of technical efficiency of farm resources were obtained. The estimated parameters were unbiased, efficient and consistent. The diagnostic statistics confirmed the superiority of the stochastic production frontier and the use of the maximum likelihood estimation method over the OLS estimation method. The study showed that the majority of tomato farmers in the region were male, married and have moderate household size. In addition, all tomato farmers had training and a secondary occupation. The empirical results showed that seed quantity, hired labour, family labour, farm size, manure and fertilizer are significant factors that influence tomato production in the region. A mean technical efficiency index of 79.70% was determined for tomato farmers. This means that tomato production has not yet reached the production frontier and therefore production can still be increased by about 20.30% with the available resources and improved technology. However, the determining factors of technical efficiency were: farming experience, membership in a social organization, formal education, years of formal training, farm income, non-farm income, and household size. It is recommended that tomato farmers in the region receive more trainings and should be encouraged to improve their formal education and join social organizations to improve their technical efficiency. Tomato farmers' involvement outside of farm income should also be encouraged to create an incentive to increase the technical efficiency of their farms.

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