

COMPARATIVE TECHNICAL EFFICIENCY OF WATERLEAF (*Talinum triangulare*) PRODUCTION BY RURAL AND URBAN FARMERS IN UYO AGRICULTURAL ZONE, AKWA IBOM STATE, NIGERIA

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Abstract

*This study compared the technical efficiency of waterleaf (*Talinum triangulare*) production among urban and rural farmers in Uyo Agricultural Zone of Akwa Ibom State, Nigeria. Using a stochastic frontier production function and Cobb-Douglas specification on primary data from 80 waterleaf farmers (40 urban, 40 rural), the technical efficiency levels, production determinants, and key socioeconomic influences were assessed across both group of farmers. The results showed that waterleaf farmers in rural Uyo exhibits higher technical efficiency ($\bar{x} = 0.867$) compared to their urban counterparts ($\bar{x} = 0.733$), with 85% of rural farmers operating in the high-efficiency range (0.71–1.00) versus 70% of urban farmers. Production elasticities showed that farm size had the most substantial impact on output across both groups, although the elasticity was higher in rural areas (0.843) than in urban areas (0.549). Family and hired labour contributed positively to output, particularly in urban settings. Conversely, planting material had a negative effect in urban areas but was strongly positive in rural areas. Social organisation, extension services, and credit access were identified as key drivers of efficiency among urban farmers, while farming experience played a significant role in improving efficiency in rural areas. Factor productivity analysis showed decreasing returns to scale in urban settings (0.572) but increasing returns in rural areas (1.737). Based on these findings, it is recommended that policymakers promote improved access to quality planting materials and cultivable land for urban farmers, while simultaneously enhancing rural farmers' access to market infrastructure, technical training, and improved resource management to ensure balanced productivity growth across both farming environments.*

Keywords: Stochastic Frontier Analysis, Resource Use Efficiency, Urban Agriculture, Rural Farmers

Introduction

Agriculture remains fundamental to Nigeria's economy and food security, contributing 26.46% to the national GDP in 2022, with crop production as the dominant subsector (NBS, 2023). Despite this significance, Nigeria faces persistent challenges in domestic food production (Okon, Frank, Etowa and Nkeme, 2017), particularly in rapidly urbanizing regions like Akwa Ibom State. To reduce food insecurity and poverty, many urban dwellers in the state have resorted to using vacant plots and roadsides for food crops production. Urban agriculture has emerged as a critical strategy to enhance food access, income generation, and nutritional security for urban households (Yuan *et al.*, 2022). In Akwa Ibom State, especially within the Uyo metropolis, urban agriculture involving leafy

vegetables like waterleaf is increasingly vital for livelihoods (Akpan, Okon and Ernest, 2019a).

Waterleaf, a member of the Portulacaceae family, is one of the most widely cultivated leafy vegetables in Akwa Ibom State, Nigeria. Its popularity stems from its culinary versatility and industrial applications, making it a staple in nearly every household across the state (Akpan *et al.*, 2019a). The crop is a short-lived perennial herb, typically reaching a height of 30 to 60 cm. Its attractive agronomic characteristics, including a short growth cycle and ease of cultivation, make it particularly appealing to small-scale farmers and household gardeners. Waterleaf can be harvested within 35 to 45 days of planting, offering a relatively quick return on investment (Okon and Idiong, 2016). The leaves possess a succulent stalk and a greenish hue (Tindall, 1983), with a high water content that

contributes to their widespread appeal among various ethnic groups in Nigeria. Locally, waterleaf is known by different names, such as *gare* among the Yoruba and *mmon-mmong ikong* among the Efik/Ibibio, further reflecting its cultural integration and year-round demand (Akpan, Akpan and Ernest, 2019band). While often regarded as a weed in urban areas due to its adaptability to wet conditions, waterleaf remains predominantly consumed in the southern regions of Nigeria, where it plays a critical role in household nutrition and food security (Ossai, Morakinyo, Azeez and Akpeji, 2022).

Nutritionally, waterleaf is a rich source of calcium, phosphorus, iron, protein, and essential vitamins, contributing significantly to efforts aimed at reducing malnutrition in Africa (Tata *et al.*, 2016). Its composition includes water, calories, ash, protein, lipids, carbohydrates, crude fibre, thiamine, riboflavin, niacin, and ascorbic acid (Tindall, 1983; Enete and Okon, 2010; Akpan *et al.*, 2019a).

In Nigeria, waterleaf cultivation is predominantly carried out by rural farmers in the South-South, South-East, and South-West geopolitical zones. Its increasing demand in local food markets and rapid maturity have led to its widespread adoption among farmers nationwide (Akpan *et al.*, 2019a). Additionally, the crop serves medicinal purposes in southern Nigeria, where it is used to treat gastrointestinal disorders, measles, and other infections. It also serves as a viable feed option for snail farming (Ossai *et al.*, 2022). In the peri-urban, urban, and rural areas of southern Nigeria, particularly the South-South region, waterleaf cultivation has become a vital livelihood strategy, especially among unemployed women and youths (Okon and Idiong, 2016). Vegetable consumption in Nigeria has been increasing, with recent estimates ranging between 22 and 47.5 kg per person annually (Obisesan, 2021). Given its high acceptability across different social groups and its comparatively high profitability, waterleaf has gained prominence as a component of urban agriculture, as it is a source of income for urban households who are producers (Okon and Enete, 2010). This trend has been particularly

beneficial to unemployed youth and women, who have increasingly engaged in its production as a source of income and food security (Akpan *et al.*, 2019a; Ossai *et al.*, 2022).

Sustainable waterleaf production in southern Nigeria, however, depends largely on the availability and efficient use of agricultural inputs. Enhancing productivity in this sector requires strategic allocation and management of farm resources (Akpan, 2021). In comparison to other vegetable and arable crop enterprises, waterleaf production is characterized by affordability, low input requirements, a short gestation period, and quick financial returns. Its leaves are also commonly used as softeners in the preparation of fibrous vegetables such as *Gnetum africanum* (Afang), *Heinsiacrinata* (Atama), and *Telfairia occidentalis* (fluted pumpkin) (Akpan *et al.*, 2019) among others. There is hardly any traditional soup in Akwa Ibom State that waterleaf is not included, and this make it extremely popular (Enete and Okon, 2010). Despite its growing popularity, a widening gap exists between the domestic supply and demand for waterleaf in Nigeria, necessitating the need for expanded production and improved value chain development (Okon and Idiong, 2016). Furthermore, waterleaf farming presents a significant opportunity for income diversification, particularly among female and youth farmers in rural communities.

However, waterleaf farmers in Uyo are faced with significant constraints, including limited access to quality inputs, soil fertility decline, high production costs, and land competition due to urban sprawl (Ossai *et al.*, 2022; Akpan and Ebong, 2021). These factors exacerbate technical inefficiencies, hindering productivity and profitability. Given the limited existing evidence comparing the technical efficiency of waterleaf production in urban and rural areas, this study seeks to address the question: What is the difference in technical efficiency between urban and rural waterleaf farmers in Uyo Agricultural Zone of Akwa Ibom State?

Theoretical Framework and Literature Review

The theory of production explains how various inputs are transformed into outputs within the

technical constraints of a given technology. In agricultural production, this relationship is represented by the production function, typically expressed as $Y=f(X)$, where Y is the output and X is a vector of inputs such as land, labour, and capital. Productivity indicators derived from this function include the Average Physical Product ($APP = \frac{Y}{X}$) and the Marginal Physical Product ($MPP = \frac{\Delta Y}{\Delta X}$), which measure average and incremental contributions of inputs, respectively. The Elasticity of Production ($EP = \frac{\Delta Y}{\Delta X} \cdot \frac{X}{Y}$) reflects how responsive output is to changes in input use (Manglik, 2024). This technical relationship forms the basis for assessing input-output dynamics in farming systems.

Efficiency theory complements this by evaluating how close observed production is to optimal output levels. According to Farrell (1957), efficiency comprises technical and allocative components, and their combination defines economic efficiency. Technical efficiency (TE) is the ratio of observed to maximum feasible output, given input levels, expressed as:

$$TE = \frac{Y_i}{Y_i^*} = \exp(-U_i)$$

Where U_i is the non-negative inefficiency term. This study adopts the stochastic frontier model, proposed by Aigner, Lovell and Schmidt, (1977) and Meeusen and Van den Broeck (1977), which distinguishes between inefficiency and random error. The model is specified as:

$$Y_i = f(X_i; \beta) \exp(V_i - U_i)$$

Where V_i captures exogenous shocks and measurement error, and U_i captures technical inefficiency. Udoh (2006) emphasised that efficiency entails deriving the most from an undertaking, particularly when marginal value product exceeds marginal factor cost. The foundation laid by Farrell, allows for both input- and output-oriented assessments, which are vital in identifying areas of underperformance. By applying this framework, the present study evaluates the technical efficiency of waterleaf farmers, identifying the extent to which resource

inputs are optimally utilised in their production processes and quantifying inefficiencies that hinder productivity improvement in the Uyo Agricultural Zone.

Previous studies in southern Nigeria highlight suboptimal technical efficiencies among vegetable farmers, often attributed to socioeconomic factors (e.g., education, credit access) and agronomic challenges (Edet, Agbachom, and Uwah, 2019; Ogunmodede and Awotide, 2020). Research by Akpan *et al.*, (2019a) and Igbinidu and Egbodion (2023) documents consistent socioeconomic patterns among Nigerian vegetable farmers, with mean ages spanning 42.94 to 53 years and female dominance (74–84%) in waterleaf cultivation. Educational attainment remains modest, as Igbinidu and Egbodion (2023) report primary education completion rates of 56–58%, while Akpan *et al.* (2019a) confirm that formal schooling enhances input adoption. Household composition varies, with Okon and Idiong (2016) noting 55.3% of households having 11–15 members, contrasting Akpan *et al.*,’s (2019b) finding of smaller units ($\bar{x}=4$ members), where larger size reduced fertilizer investment. Land access constraints manifest in small operational holdings (0.04 ha; Akpan *et al.*, 2019b) and prevalent tenancy (66%; Okon and Idiong 2016).

Technical efficiency analyses reveal critical insights. Akpan *et al.*, (2022) report a baseline technical efficiency of 52.23% for waterleaf farmers using stochastic frontiers, rising to 87.77% under sustainability adjustments, indicating significant improvement potential. Determinants include positive effects from farm size, experience, and social capital, countered by negative impacts from advanced age and excessive experience. Comparatively, Agza *et al.*, (2021) find non-migrant Ethiopian households achieve 45.5% efficiency versus 72.3% for migrant-sending households, attributing gains to migratory experience and market access. Ogunmodede and Awotide (2020) identify farm size, education, and input costs as efficiency drivers, with a mean score of 80.4%. Input management emerges as pivotal; Amadi-Roberts (2024) notes the positive output elasticity of labour but seed and manure inefficiencies, while

stochastic frontiers confirm systematic inefficiency. Profitability varies by crop, with Igbidun and Egbodion (2023) reporting fluted pumpkin's superiority (\$324 vs. waterleaf's \$177 net profit).

Systemic constraints recur across studies. Onyia, Chiemala, Ujah, and Onah, (2021) and Amadi-Roberts (2024) identify high input costs, credit inaccessibility, and transportation inefficiencies as primary barriers. Okon and Idiong (2016) noted that 55% of farmers prioritize organic inputs where accessible, yet Akpan *et al.*, (2019a) found that distance to markets suppresses adoption. Extension deficiencies persist despite theoretical benefits (Onyia *et al.*, 2021). Biotic pressures and land fragmentation compound these issues, though enterprises remain viable, with Amadi-Roberts (2024) confirming profitability (rate of return=1.39).

While research exists on efficiency of waterleaf production in Akwa Ibom State, studies comparing the technical efficiency of waterleaf production in urban and rural areas of Uyo Agricultural Zone are scarce. Urban farmers may leverage proximity to markets but face land scarcity, whereas rural farmers often have larger plots but poorer market access (Akpan *et al.*, 2022). There is little or no information on studies comparing the technical efficiencies of urban and rural waterleaf production. This study seeks to bridge this information gap by comparing the technical efficiencies of urban and rural waterleaf farmers in Uyo Agricultural Zone of Akwa Ibom State, Nigeria.

Research Methodology

Study Area

The study was conducted in Uyo Agricultural Zone of Akwa Ibom State, Nigeria comprising of Uyo, Uruan, Itu, Ibiono Ibom and Ibesikpo Asutan local government areas. It is located between latitudes 4°30'N and 5°30'N, and longitudes 7°30'E and 8°20'E (Akpaeti, Okon and Ekpo, 2019), placing it within two major ecological regions of Southern Nigeria: the coastal swamp and the moist lowland regions. The climate is humid tropical with mean annual temperature between 27 – 28°C, relative humidity between 75 – 80%, and a bimodal rainfall pattern, with a rainy season spanning

approximately 7 – 8 months with annual rainfall between 2,500 to 3,000mm. The soil pH across the zone ranges between 4.9 to 5.8 and soil textures include loamy sand, sandy clay loam, and clay suitable for a diverse range of crops majority of which includes cassava, plantain, waterleaf, fluted pumpkin, yam, cocoyam, maize, rice, oil palm, and banana. Major livestock include poultry, goats, sheep, pigs, and fisheries (Akpan *et al.*, 2022). The estimated population of the zone is 1,480,822 (AKSG 2014, World Population Review, 2025). Ibibio is the major language spoken across the zone and the economic activities are farming, trading, fishing, crafts, transportation, and civil service.

Sampling Technique and Sampling Size

The sample size for this study was determined using Cochran's (1963) formula, which is appropriate when the population size is large or undetermined. The formula was expressed as:

$$n_o = \frac{Z^2 pq}{e^2}$$

where n_o is the required sample size, Z is the standard normal deviate corresponding to the desired confidence level (1.96 at 95% confidence), p is the estimated proportion of the population with the desired attribute (assumed to be 0.5 in the absence of prior information, thereby maximizing variability), $q=1-p$, and e is the acceptable margin of error.

Substituting into the formula with $p=0.5$, $q=0.5$, $Z=1.96$, and a margin of error of 10% ($e=0.10$), the computation is as follows:

$$n_o = \frac{(1.96)^2 \times (0.5) \times (0.5)}{(0.10)^2} = \frac{0.9604}{0.01} \approx 96$$

Thus, a sample size of ninety-six respondents was required to achieve a 95% confidence level with a 10% margin of error. To ensure robustness and account for nonresponse, the study adopted a slightly smaller sample size of eighty respondents, which was distributed thus:

A multistage sampling technique was adopted for the study. In the first stage, four cells were randomly selected from the urban areas (Offot, Etoi, Mbierebe and Nwaniba) and rural areas (Ibiaku, Ididep, Mbiabo and Afaha), respectively,

of the study area, giving a total of eight cells. In the second stage, ten waterleaf farmers were randomly selected from each of the cells, giving a total of 40 urban farmers and 40 rural farmers (80 farmers) for the study.

Method of Data Collection

Primary data was collected for the study through the aid of a well-structured questionnaire that was complemented with personal interviews to suit the intended objectives and to ensure consistency and accuracy of data collected.

Analytical Techniques

Following Battese and Coelli (1995), the Stochastic Production Frontier (SPF) is defined as:

$$Y_j = f(X_j - \beta) \exp(V_j - U_j) \dots (1.1)$$

Where Y_j is the output of firm j , X_j is a vector of factor inputs, V_j is the stochastic error term, and U_j is a one-sided error representing the technical inefficiency of firm j . Both V_j and U_j are assumed to be independently and identically distributed with constant variance and zero mean. Technical efficiency (TE) of a firm using the Stochastic Production Frontier is given as:

$$\begin{aligned} TE = \frac{Y_i}{Y_i^*} &= \frac{\text{Observed output}}{\text{Frontier output}} \\ &= \frac{f(X_j - \beta) \exp(V_j - U_j)}{f(X_j - \beta) \exp(V_j)} \\ &= \exp(-U_j) \dots (1.2) \end{aligned}$$

Implicitly, it is shown as thus:

$$\begin{aligned} \text{LogOutput} = & \delta_0 + \delta_1 \text{LogHHL} + \delta_2 \text{LogHIL} \\ & + \delta_3 \text{LogMAN} + \delta_4 \text{LogPTM} \\ & + \delta_5 \text{LogCAP} + (V_1 \\ & - U_1) \dots (1.3) \end{aligned}$$

Output = Quantity of Waterleaf harvested (kg)

HHL = Household labour used throughout the production cycle (man-days)

HIL = Hired labour used throughout the production cycle (man-days)

MAN = Quantity of manure used throughout the production cycle (Kg)

PTM = Cost of planting materials used throughout the production cycle (naira)

CAP = Depreciation value of farm asset as a proxy of farm capital (Naira)

$(V_i - U_i)$ = Composite error term

Note that variables were expressed in logarithms.

The technical efficiencies of waterleaf were computed respectively for urban areas and rural areas of the study area. This objective was further analysed using the t-test to compare and test for the difference among the mean efficiencies of waterleaf cultivated in the study area.

The Cobb–Douglas production function is employed in this study because it offers a balance of theoretical soundness, empirical simplicity, and policy relevance. Its coefficients are directly interpretable as elasticities, providing clear insights into the contribution of each input to the output. Unlike more complex functional forms such as the Translog or CES, the Cobb–Douglas requires fewer parameters, making it suitable for datasets that are often limited in scope, as is common in smallholder farming systems. It also facilitates the estimation of returns to scale and integrates effectively within the stochastic frontier analysis framework for assessing technical efficiency. By capturing the essential relationships between inputs and output while avoiding the challenges of overparameterization, the Cobb–Douglas form provides a robust and widely comparable approach to analyzing waterleaf production.

Assessing the total factor productivity of waterleaf in the study area

The Cobb–Douglas production function specified was used to relate fluctuation in the output of waterleaf and farm resources. The production parameters, such as APP, MPP and production elasticity generated from the production function, were used to analyse the level of resources used among waterleaf farmers. Implicitly, the Cobb–Douglas production

function envisaged in the research is specified thus:

$$OUT = f(LAN, HHL, HIL, PTM, CAP, MAN) \dots \quad (1.4)$$

Implicitly, it is expressed as;

$$\ln OUT = \partial_0 + \partial_1 \ln LAN + \partial_2 \ln HHL + \partial_3 \ln HIL + \partial_4 \ln PTM + \partial_5 \ln MAN + \partial_6 \ln CAP + u_i \dots \quad (1.5)$$

Note: The model is adopted on the assumption of constant factor productivity, i.e.

$$\begin{aligned} \partial_1 + \partial_2 + \partial_3 + \partial_4 + \partial_5 + \partial_6 \\ = 1 \text{ (constant return to scale)} \\ \partial_1 + \partial_2 + \partial_3 + \partial_4 + \partial_5 + \partial_6 \\ > 1 \text{ (increasing return to scale)} \\ \partial_1 + \partial_2 + \partial_3 + \partial_4 + \partial_5 + \partial_6 < 1 \text{ (decreasing return to scale)} \dots \quad (1.6) \end{aligned}$$

Where:

OUT = Output of waterleaf of the i^{th} farmer (kg)
 ∂_0 = Total factor productivity
 LAN = Land size of farmers (ha)
 HIL = Quantity of hired labour used by the farmer (man-days)
 HHL = Quantity of household labour (man-days)
 PTM = Quantity of waterleaf cuttings used in the current farming season (kg)
 MAN = Quantity of manure used (kg)
 CAP = Depreciation cost (₦)

Determinants of Technical Efficiency in Waterleaf Production among Farmers in Urban and Rural Akwa Ibom State

The stochastic frontier production specified in equations 1.1 and 1.2 was used to generate indices of technical efficiency and determinants of technical inefficiency simultaneously. Stata 15 was used to generate these indices in a single-stage maximum likelihood estimation procedure. The interpretation of the determinants of technical efficiency was the opposite of the result of the determinants of technical inefficiency. Implicitly, the determinants of technical inefficiency are specified thus:

$$U_i = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \delta_5 Z_{5i} + \delta_6 Z_{6i} + \delta_7 Z_{7i} \dots \quad (1.7)$$

Where:

U_i – Technical inefficiency of waterleaf
 Z_1 – Age (years)
 Z_2 – Household Size (numbers)
 Z_3 – Education (years)
 Z_4 – Farming experience (years)
 Z_5 – Membership of cooperative (dummy)
 Z_6 – Access to credit (dummy)
 Z_7 – Access to extension services (dummy)

Results and Discussion

Summary Statistics of Socioeconomic Characteristics of Waterleaf Farmers in the Study Area

The result presented in Table 1 shows that female (90%) dominates the study area. This suggests that waterleaf production in Uyo is predominantly managed by women, implying that both urban and rural waterleaf farming are crucial income sources for women, contributing to household food security and economic empowerment. This is in line with the findings of Udoh (2007); Enete and Okon (2010); Akpan, Okon and Ernest (2019a), and Igbinidu and Egbodion (2023), and Amadi-Roberts (2024), but contrasts with the finding of Ogunmodede and Awotide (2020) who report a male-dominated population in Ogun State.

The age distribution shows that urban farmers have a mean age of 39.95 years, while their rural counterparts are slightly older, with a mean of 44.45 years. The t-value -1.362 indicates that there is no significant difference between the age of urban and rural farmers in the study area. This age variation may imply that younger individuals are more engaged in urban farming, possibly due to proximity to markets, higher adaptability to space-limited production, or greater willingness to participate in alternative urban livelihoods. Okon *et al.*, (2017) reported a mean age of 44.38 years, Akpan *et al.* (2019) 42.94 years, Ogunmodede and Awotide (2020) 50 years, and Igbinidu and Egbodion (2023) 52 years.

Table 1. Summary Statistics of Socioeconomic Characteristics of Waterleaf Farmers in the Study Area (n=80)

Characteristic	Urban Uyo Mean	Uyo Std. Dev.	Min	Max	Rural Uyo Mean	Uyo Std. Dev	Min	Max	t- value	P
Gender										
Male	10%				10%					
Female	90%				90%					
Age (years)	39.95	11.5	22	63	44.45	9.276	29	62	-1.362	0.181
Farming Experience (years)	13.7	8.492	3	30	15.05	7.416	5	31	-0.535	0.595
Soc. Org. (years)	6.5	7.037	0	25	5.5	4.274	0	16	0.543	0.59
Education (years)	10.5	3.426	0	14	8.9	5.24	0	15	1.143	0.26
Household Size (persons)	5	2.026	1	9	4	1.559	2	8	1.224	0.228
Farm Size (ha)	0.104	0.166	0.004 8	0.7	0.112	0.074	0.025 5	0.24	-0.196	0.845
Secondary Income (₦)	45,125	39175. 68	0	125,0 00	29,650	12724.9 2	0	50,00 0	1.680	0.101

Source: Field Survey, 2025

The rural farmers were more experienced in waterleaf farming with a mean of 15.05 years, compared to 13.7 years for urban farmers. The t-value of -0.535 suggests this difference is not statistically significant. Nonetheless, the higher experience level among rural farmers is consistent with the older age profile and the likelihood of longer-term land access or more extensive farming engagement in rural communities. Furthermore, years of participation in social organizations are higher for urban farmers at 6.5 years, compared to 5.5 years for rural farmers. With a t-value of 0.543, this difference is not statistically significant, but it reflects slightly greater involvement in social networks within urban areas. Such networks may facilitate access to information, group input purchases, and shared marketing activities, especially in more structured urban agricultural settings. Okon and Idiong (2016) reported an average of 13 years of experience, and Akpan *et al.*, (2019a) had 11.77 years of farming experience. Furthermore, the years of education attained are higher among urban farmers ($\bar{x}$ = 10.5 years) compared to rural farmers ($\bar{x}$ = 8.9 years), with a t-value of 1.143. Although the difference is not significant, it reflects the

broader trend of higher educational attainment in urban environments. Education is a crucial factor in technology adoption, record keeping, and engagement with formal markets, suggesting that urban farmers may have a slight advantage in accessing improved agricultural practices. This is in line with the findings of Okon and Idiong (2016), Akpan *et al.* (2019a), Ogunmodede and Awotide (2020), Igbinidu and Egbodion (2023), and Amadi-Roberts (2024), who all reported that most of the respondents have received at least primary education.

Household size differs modestly between groups. Urban farmers report an average of five persons per household, while rural farmers report about four persons. Larger household sizes in urban areas could provide additional family labour, although the marginal nature of the difference may limit its practical implications. Nonetheless, household size remains an important consideration in labour availability for waterleaf cultivation, especially given its labour-intensive nature. This falls largely within the range of findings from Akpan *et al.*, (2019a) and Amadi-Roberts (2024), but differs from the findings of Okon and Idiong (2016), who reported

household size within the range of 11 – 15 persons. Additionally, the average farm size of urban areas ($\bar{x} = 0.104$) and rural areas ($\bar{x} = 0.112$) indicates that most of the waterleaf farmers in Uyo Agricultural Zone are smallholder farmers cultivating less than 1ha of land. These small plot sizes reflect the intensive nature of waterleaf production and the space limitations associated with both urban and rural agriculture in the zone, which could diminish the advantage of economies of scale. This is in line with the findings of Akpan *et al.* (2019a), who reported a mean farm size of 0.04ha, also Enete and Okon, 2010, reported a mean farm size of 0.33ha.

Finally, income from secondary sources shows that urban farmers report an average secondary income of ₦45,125, compared to ₦29,650 for rural farmers. The t-value of 1.680, though not statistically significant, suggests that urban farmers are more engaged in diversified income-generating activities. This higher secondary income may provide urban farmers with more financial stability, enabling greater investment in inputs, production efficiency, or household welfare. Akpan *et al.*, (2019a) reported a mean income of ₦65,872.

Technical Efficiency of Waterleaf Farmers in Akwa Ibom State

Table 2: Estimation of the Cobb-Douglas Production Function of Waterleaf Farmers in Uyo Agricultural Zone

Variable	Urban Uyo			Rural Uyo		
	Coefficient	Std. Err.	Z	Coefficient	Std. Err.	Z
Constant	6.151	2.165	2.84***	-2.298	1.1747	-1.96**
Hired labour	0.0913	0.0474	1.92*	0.03	0.0121	0.25
Family Labour	0.0614	0.0275	2.23**	0.0343	0.0075	4.58***
Planting material	-0.3583	0.2365	-1.510	0.745	0.0587	12.69***
Depreciation	0.1913	0.2597	0.740	0.0496	0.1278	0.39
Farm Size	0.5494	0.1236	4.450***	0.8434	0.0498	16.94***
Manure	0.0367	0.1407	0.260	0.0617	0.0247	2.49**
Diagnostics						
Sigma squared	1.85	0.62		0.06	0.02	
Gamma	0.35	0.12		0.653	0.15	
Log Likelihood	-14.9714			15.6742		
Wald chi2 (5)	58.77***			701.66***		
LR test	17.01***			13.65**		
Inefficiency Model						
Variable	Urban Uyo			Rural Uyo		
	Coefficient	Std. Err.	Z	Coefficient	Std. Err.	Z
Constant	-47.973	34.628	-1.390	-18.175	16.463	-1.1
age	0.563	0.397	1.420	0.497	0.392	1.27
Social Organization	-5.705	3.076	-1.86*	2.709	4.657	0.58
Experience	-0.392	0.492	-0.800	-0.473	0.243	-1.94**
Education	2.546	1.826	1.390	0.006	0.165	0.04
Family size	1.661	1.189	1.400	-0.249	0.871	-0.29
Extension access	-7.231	4.103	-1.76*	0.380	1.353	0.28
Credit access	-5.290	2.993	-1.77*	-0.195	1.61	-0.12

Source: Author's estimation using Stata 15, 2025

Note: Asterisks ***, **, *, indicates significance at 1%, 5%, and 10% level of probability respectively

The stochastic frontier analysis presented in Table 2 shows the assessment of the technical efficiency and production determinants among waterleaf farmers operating in urban Uyo and rural Uyo. The diagnostic statistics support the robustness and validity of the stochastic frontier specification in both models. For urban Uyo, the log-likelihood value is -14.9714, and the Wald chi-square statistic is 58.77 ($p < 0.01$), indicating that the explanatory variables collectively provide a statistically significant explanation of waterleaf output. Similarly, in Rural Uyo, the log-likelihood is 15.6742, and the Wald chi-square is significantly higher at 701.66 ($p < 0.01$), indicating a good model fit. The likelihood ratio (LR) test statistics further affirm the relevance of the stochastic frontier specification over a traditional OLS model. The LR test value for urban Uyo is 17.01 ($p < 0.01$), while that for rural Uyo is 13.65 ($p < 0.05$), both of which confirm the presence of inefficiency effects in the model. However, the gamma (γ) value, which measures the proportion of the total variance attributed to inefficiency rather than random noise, differs notably between locations. In urban Uyo, the gamma value ($\gamma = 0.35$) suggests that 35% of the variation in output is attributable to technical inefficiency. Conversely, in rural Uyo, gamma is higher ($\gamma = 0.653$), indicating that about 65.3% of output variability can be explained by technical inefficiency. The constant is significant in both models, but with differing signs.

The elasticity of farm size is positive and statistically significant in both urban (0.5494, $p < 0.01$) and rural (0.8434, $p < 0.01$) areas of Uyo Agricultural Zone. These positive and highly significant elasticities imply that an increase in the area of land cultivated leads to a substantial increase in output, holding all other factors constant. Specifically, a 10% increase in farm size is associated with approximately a 5.49% increase in output in urban areas and an 8.43% increase in output in rural areas. This suggests that an increase in cultivated land directly correlates with higher waterleaf output, with a greater elasticity in rural areas. This difference in magnitude reveals a key structural distinction between urban and rural waterleaf farming systems. In Urban Uyo, limited land availability

constrains the extent to which farmers can expand production. The positive coefficient nonetheless affirms that where land is accessible, such as in peri-urban plots, backyards, or shared community spaces, expansion has the potential to significantly improve output. However, the urban context presents challenges such as land tenure insecurity, high competition for space, and fragmentation, which can limit the scalability of urban farms, in contrast to rural farmers who may benefit from greater land availability and possibly more secure land tenure systems, allowing for broader and more consistent cultivation of waterleaf. The higher coefficient in the rural model reflects this reality, indicating that rural farmers are able to better capitalise on increases in farm size due to lower population pressure, traditional land inheritance systems, and the relative abundance of cultivable land. Economically, larger farm sizes enhance not only total output but also economies of scale. Farmers operating larger plots can more efficiently allocate labour, justify investment in inputs or tools, and reduce average costs of production. This is in line with the findings of Ogunmodede and Awotide (2020) and Akpan *et al.*, (2022) but contrasts with the findings of Onyia *et al.*, (2021), who noted a negative relationship between farm size and output.

The result further shows that manure use had insignificant elasticity in urban Uyo but statistically significant returns in rural Uyo (0.0617, $p < 0.05$). This implies that manure is more effectively utilized or of higher quality in rural areas, possibly due to access to livestock and organic farming practices. Rural farmers may often have direct access to livestock, providing a consistent supply of dung and organic matter. Moreover, rural households tend to have traditional knowledge of composting and manure management, passed down through generations, which helps optimize nutrient retention and application timing. This agrees with the findings of Akpan *et al.*, (2022) but differs from the findings of Onyia *et al.*, (2021) and Amadi-Roberts (2024), who reported a negative influence of organic manure on waterleaf output in Rivers State.

Determinants of Technical Efficiency of Waterleaf Farmers in Uyo Agricultural Zone

The results in Table 2 also indicate the determinants of technical efficiency among waterleaf farmers in Uyo Agricultural Zone, offering insight into how various socioeconomic and institutional factors influence farmers' ability to maximize output given available resources. In this inefficiency effects model, negative coefficients suggest factors that enhance technical efficiency (i.e., reduce inefficiency), while positive coefficients imply increased inefficiency.

In Urban Uyo, three variables significantly reduce technical inefficiency at the 10% level of probability. First, social capital, with a coefficient of -5.705 ($p < 0.1$), suggests that belonging to social or cooperative groups significantly increased technical efficiency of waterleaf farmers in Uyo urban. This aligns with the view that social networks provide farmers with shared knowledge, access to pooled resources, and stronger bargaining power, all of which contribute to better resource use. Second, extension access also demonstrates a significant negative effect (-7.231 , $p < 0.1$), indicating that contact with extension agents helps farmers adopt more efficient production practices, hence making them more efficient in waterleaf production. This reflects the critical role of information dissemination in urban agricultural settings, where formal training is often limited.

Third, access to credit significantly reduces inefficiency (-5.290 , $p < 0.1$), reinforcing the importance of financial support in enabling farmers to acquire timely inputs and invest in productivity-enhancing tools. In urban settings where land is scarce and the cost of living is higher; credit may also help stabilize production and reduce inefficiencies arising from undercapitalization. Akpan *et al.*, (2022) reported that social capital formation and extension access had a significant negative relationship with technical inefficiency.

In Rural Uyo, the most influential determinant of technical efficiency is experience, which is negatively and significantly associated with inefficiency (-0.473 , $p < 0.05$). This suggests that years of farming experience contribute to better management practices, more effective input use, and a deeper understanding of environmental and market conditions. In contrast to the urban context, other variables do not show statistically significant relationships with efficiency. This may reflect the more informal and subsistence-based structure of rural farming systems, where knowledge is largely acquired through experience rather than external institutions.

Akpan *et al.*, (2022) reported that social capital formation and extension access had a significant negative relationship with technical inefficiency, whereas Onyia *et al.*, (2021) reported a positive relationship between years of farming experience and technical inefficiency.

Table 3: Estimation of Technical Efficiency Indices of Waterleaf Farmers in Uyo Agricultural Zone

Efficiency	Urban Uyo		Rural Uyo	
	Frequency	Percentage	Freq	Percentage
0 – 0.05	6	15.0	0	0.0
0.05 – 0.1	2	5.0	0	0.0
0.1 – 0.4	0	0.0	0	0.0
0.41 – 0.7	4	10.0	6	15.0
0.71 – 1	28	70.0	34	85.0
Mean	0.7328		0.8671	
Min.	0.0223		0.5871	
Max.	0.9992		0.9931	
t-value	-1.5564	p = 0.1196		

Source: Author's Estimation using Stata 15, 2025

The results presented in Table 3 show that waterleaf farmers in Rural Uyo exhibit significantly higher technical efficiency than their urban counterparts. The mean technical efficiency score in Rural Uyo is 0.8671, while that of Urban Uyo stands at 0.7328. Although the difference in means, tested with a t-value of -1.5564, is not statistically significant at conventional thresholds, the pattern is nonetheless meaningful and consistent with other indicators of efficiency observed in the study.

In terms of distribution, the result indicates a more favourable and consistent efficiency profile among rural farmers. Specifically, 85% of Rural Uyo farmers fall within the highest efficiency range (0.71–1.00), compared to 70% in Urban Uyo. Notably, no rural farmers were found in the lower efficiency categories (below 0.4), indicating that virtually all participants in the rural sample operate above a moderate efficiency threshold. In contrast, Urban Uyo demonstrates a broader and more skewed efficiency distribution, with 15% of farmers operating at extremely low-efficiency levels (0.00–0.05) and another 5% falling within the 0.05–0.10 range. This finding suggests that a considerable proportion of urban farmers are severely inefficient in their use of resources.

The minimum efficiency score in Urban Uyo is 0.0223, reflecting the existence of farmers who

are only 2.23% efficient relative to their best-performing peers. In contrast, the lowest observed efficiency in Rural Uyo is 0.5871, indicating a floor level of technical competence and consistency in input utilization. Meanwhile, the maximum efficiency scores are nearly equal across both groups, 0.9992 in Urban Uyo and 0.9931 in Rural Uyo, demonstrating that both urban and rural environments host individual farmers capable of operating at near-optimal efficiency. Ogunmodede and Awotide (2020) reported a mean efficiency of 0.804, Agza, Alamirew, and Shibru (2021) had a mean efficiency of 57.4%, and Akpan *et al.* (2022) reported 52.23%.

These disparities in efficiency levels between urban and rural farmers may be attributed to a range of contextual and structural differences. Rural farmers, who typically possess more experience and may benefit from more stable agronomic practices, appear to demonstrate a higher baseline of technical competence. Conversely, the lower efficiency levels observed in Urban Uyo may reflect constraints such as limited land access, poor-quality inputs, inadequate technical training, or fragmented institutional support systems.

Factor Productivity of Waterleaf Production in Uyo Agricultural Zone

Table 4: Factor Productivity of Waterleaf Production in rural and urban areas of Uyo Agricultural Zone

Factors	Urban Uyo				Rural Uyo			
	APP	MPP	EP	Stage of Production	APP	MPP	EP	Stage of production
Hired labour	25.33	1.547	0.061	II	83.6	3.14	0.003	II
Family labour	31.85	2.898	0.091	II	51.13	1.74	0.034	II
Planting materials	3.27	-1.17	-0.358	III	3.98	2.97	0.745	II
Depreciation	8.01	1.53	0.191	II	56.36	2.80	0.05	II
Farm size	17.89	9.822	0.549	II	2.45	2.07	0.843	II
Manure	49.73	1.47	0.037	II	62.26	3.86	0.062	II
Return to Scale			0.572				1.737	

Source: Author's estimation, using STATA 15, 2025

The factor productivity analysis of waterleaf production in the Uyo Agricultural Zone, as presented in Table 4.7, indicates how various inputs influence output across urban and rural farming contexts. The productivity measures allow for the classification of each input into various stages of production. Except for planting material in urban Uyo, which falls in Stage III (irrational stage), all inputs in both locations operate within Stage II, where diminishing but positive returns are observed. This implies that most inputs are being used efficiently, though not optimally, and that further gains in productivity can be achieved through improved resource management.

Urban production achieves a notably higher Average Physical Product (APP) for household labour (25.33) relative to rural production (8.36), suggesting greater average output per unit of this input. However, rural areas demonstrate a higher Marginal Physical Product (MPP) for hired labour (3.14) compared to the urban figure (1.547), indicating stronger immediate productivity gains from additional labour units. The Elasticity of Production (EP) for hired labour remains low in both zones (urban: 0.061; rural: 0.003), confirming its limited proportional impact on output. For family labour, rural areas achieve a higher APP (51.13) than urban areas (31.85), while urban areas show a higher MPP (2.898) than rural areas (1.74). Both maintain low EP values (urban: 0.091; rural: 0.034), with all labour operating within Stage II, the rational production stage.

Critical divergences appear in the utilisation of planting materials utilization. Urban production exhibits negative MPP (-1.17) and negative EP (-0.358), placing it in Stage III, where additional units reduce total output. This contrasts sharply with rural production, which shows positive MPP (2.97) and high EP (0.745), reflecting efficient utilization within Stage II. Capital inputs show further differentiation: Rural depreciation achieves a higher APP (56.36) than urban depreciation (8.01), but its EP (0.05) is lower than the urban EP (0.191), suggesting weaker marginal returns to capital investment. Farm size demonstrates higher APP (17.89) and MPP (9.822) in urban areas relative to rural APP

(2.45) and MPP (2.07). Yet rural areas achieve significantly higher EP for farm size (0.843) compared to the urban EP (0.549), indicating land's stronger proportional influence on output. Manure application proves efficient in both zones (Stage II), though rural production shows superior performance across APP (62.26), MPP (3.86), and EP (0.062), outperforming urban APP (49.73), MPP (1.47), and EP (0.037).

The return to scale estimates further reveals the contrast between the two zones. Urban Uyo shows decreasing returns to scale (0.572), meaning that increasing all inputs leads to less than proportional increases in output. This implies the need for optimization of resources in urban farming. Expansion alone is not sufficient without improving input quality and application efficiency. Conversely, rural Uyo exhibits increasing returns to scale (1.737), suggesting that input expansion can yield more than proportional gains in output. The results suggest a strong justification for promoting the expansion of rural waterleaf production through increased provision of inputs, infrastructure development, and enabling services.

The findings from Akpan *et al.* (2022) show that the returns to scale were 0.285, farm size was at stage I, and family labour, hired labour, manure, planting materials, and capital depreciation were at stage II in the production curve, respectively.

Conclusion

This study provides empirical evidence of distinct technical efficiency patterns in waterleaf production between urban and rural contexts in Uyo Agricultural Zone. Rural farmers demonstrate superior technical efficiency, attributable to greater land availability, experiential knowledge, and more effective input utilization. Urban farmers face pronounced constraints, including land scarcity, inefficient planting material use, and labour saturation, which suppress productivity despite advantages in education and secondary income. The significant positive elasticity of farm size in both zones confirms land as the paramount production factor, though its impact is magnified in rural areas. Furthermore, the findings demonstrate that institutional factors such as social organisation, extension access, and credit

facilities enhance urban farmers' efficiency, while farming experience remains pivotal in rural areas. Collectively, these findings emphasize that enhancing waterleaf productivity requires tailored strategies addressing the unique socioeconomic, agronomic, and institutional challenges inherent to each production environment.

Recommendations

1. Urban farmers should be trained to rationalize planting material use, avoiding inefficiency from over-application.
2. Strengthening farmers' social networks and cooperative organisations is essential, as participation in such groups was found to

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- enhance technical efficiency through knowledge sharing and resource pooling.
3. Extension services should be expanded and tailored to meet the distinct needs of both urban and rural waterleaf farmers, providing training on improved agronomic practices, input management, and sustainable production techniques.
 4. Facilitating access to affordable credit for smallholder farmers, particularly in urban areas, will enable the timely acquisition of inputs and reduce inefficiencies arising from undercapitalisation.
 5. Provide women farmers with better access to inputs, markets, and training since they dominate waterleaf production.
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