Production of Talinum fruticosum **(waterleaf) for sustainable household income and livelihoods in Akwa-Ibom State, Nigeria**

***[1ab]Ayojimi, W., [1]Ake-Abasi, E., [1]Bamiro, O.M., [2]Kehinde, M.O., [3]Toromade A.S., [4]Okon E.M., [5]Kolawole, A.E., [6]Joseph, A., [5]Obaniyi, K.S., [5]Alade, Babafemi Theophilus**

[1]Agricultural Economics Program, Landmark University, Omu-Aran, Kwara State, PMB 1001, Nigeria.

[2] Faculty of Agriculture, Federal University of Agriculture, Mubi, Adamawa State, PMB 2025, Nigeria.

[3] Department of Agricultural Economics, Ladoke Akintola University of Technology, 4000, Ogbomoso, Nigeria.

[4] Department of Animal Sciences and Aquatic Ecology, Faculty of Bioscience Engineering, Ghent University, Ghent, Belgium.

[5] Agricultural Extension Program, Landmark University, Omu-Aran, Kwara State, PMB 1001, Nigeria.

[6] Crop and Soil Program, Landmark University, Omu-Aran, Kwara State, PMB 1001, Nigeria.

[a] Landmark University SDG 2: Zero Hunger

[b] Landmark University SDG 12: Responsible Consumption and Production.

[*]Corresponding author: ayojimi.wale@lmu.edu.ng

https://orcid.org/0000-0003-0038-3462

ABSTRACT

Unstable income and displaced livelihoods are pervasive issues in emerging economies, like Nigeria. The production of *Talinum fruticosum* (Tf) is a secret weapon for sustainable rural and peri-urban household income and livelihoods, driving the attainment of SDGs 2 (Zero Hunger) and 8 (Decent Work). This study delved into the profitability, drivers, and constraints of sustainable waterleaf production in Akwa-Ibom State, Nigeria. This study elicited responses from sixty-one surveyed Tf producers using a multi-stage sampling technique and analyzed them using descriptive and inferential statistics. Findings revealed that Tf is grown majorly (64%) on <1 ha farmland and is driven by young (57%, 25-44 age range) females (85%) who are married. Tf generates a high profitability index (80%) and profit (₦90,165.88/acre/Waterleaf production cycle). Labor was the primary cost (51.42%), indicating a labor-intensive venture. The low fixed cost suggests accessibility to smallholder farmers. ₦3.81 is earned for every ₦1 invested in Waterleaf production. Additionally, larger farm sizes drive larger outputs. Most respondents either agreed or strongly agreed that low educational status, soil degradation, insufficient water supply, and theft impeded optimal production. Policy directives that simplify land ownership, promote Waterleaf as a viable crop, subsidize land preparation costs, and enhance market access and value chains to increase income and improve livelihoods should be implemented. Capacity-building programs tailored to best farming practices, climate resilience, and organic inputs should be implemented.

Keywords: *Waterleaf, Talinum fruticosum (Tf), Sustainable, Economics, Livelihood, Production.*

1. Introduction

As food remains the primal fuel for human existence, embracing sustainable food production is quintessential if we must meet the growing demand of a global population and prevent the planet from going desolate. With the rapid growth in the global population, the fight against hunger and malnutrition is backsliding. Approximately 733.4 million people were undernourished in 2023 [1]. This issue is severe in sub-Saharan Africa (SSA), where dietary deficiencies and dependence on imported food highlight the need for resilient, locally adapted agri-food systems [2]. The FAO recommends integrating indigenously grown vegetables, like Waterleaf, to enhance dietary diversity and support sustainable farming [3]. Consequently, the demand for nutritious and easily cultivable vegetables has made *Talinum fruticosum* (Tf) a priority, especially in SSA, where it is a staple food and an income source.

Commonly known as Waterleaf, Tf is a flowering plant belonging to the Talinaceae family [4]. It thrives in warm climates with moderate rainfall and uses water efficiently [5]. It is rich in iron, zinc, and molybdenum; thus, it is widely cultivated in tropical regions. The Tf value chain can generate income and reduce poverty and unemployment [6]. Originating from Africa, Waterleaf has spread to Asia and Central and South America [7]. It matures in 30-45 days, tolerates different climates and low-fertility soils, and has a high health value. It helps manage diabetes and hypertension, combat malnutrition, and support sustainable agriculture [8]. Waterleaf production is economically significant locally and globally because of its low input costs for seeds, pesticides, and herbicides, thriving in home gardens [9].

In Nigeria, Tf is cultivated widely and is crucial for many unemployed women and youth in rural and peri-urban areas [10]. It is a common vegetable in traditional dishes and is valued highly in Nigerian food markets, gaining attention for its broad appeal and export potential. This has increased the production of leafy vegetables transported to urban centers like Uyo, Calabar, Port Harcourt, Umuahia, Aba, Owerri, Enugu, and Onitsha [11].

Some initiatives in continental space have aimed at promoting the cultivation of leafy vegetables, including Waterleaf. A 1996 project by Biodiversity International and partners addressed malnutrition and livelihoods in SSA by promoting African leafy vegetables (ALVs) in Botswana, Cameroon, Kenya, Senegal, and Zimbabwe. The 1996 & 2001 projects improved production, processing, and market linkages for ALVs [12]. A horticultural Collaborative Research Support Program (CRSP) project on Indigenous African Leafy Vegetables (ALV) for Enhancing Livelihood Security of Smallholder Farmers in Kenya also aimed at improving resources, practices, farmers' knowledge, and market access for sustainable ALV cultivation and consumption [13]. Research has shown that NGOs and international organizations have actively promoted ALVs through media campaigns [14]. An impact assessment study showed a positive impact, with increased ALV production, consumption, and marketing, benefiting women financially [15]. Awareness of their health increased, with consumption rising by 45% in some households. Cascading to the national level, initiatives such as the Agricultural Transformation Agenda (ATA) and NIHORT programmes aim to boost agricultural productivity, including the promotion of indigenous crops like Tf [16]. A recent initiative reported the significance of community engagement in promoting these vegetables, including Waterleaf, within the local market [17]. These efforts provide farmers with improved seedlings, training, market information, and research on sustainable practices.

Scores of research studies have established the potential of Tf to contribute significantly to the health and economic livelihood of engaging households [18]. Studies from the Philippines and Nigeria highlight its use in traditional menus and its high soluble dietary fiber content ([1,19]. Research in Akwa-Ibom State, Nigeria, shows the economic benefits of Waterleaf farming, with significant revenue despite production costs [20]. Studies also highlight the impact of climate change, pests, and organic manure on Waterleaf yield [21, 22]. Research by ref. [23] highlighted farm size, the quantity of manure used, and non-farm income as negative determinants of labor productivity in Waterleaf production in Akwa-Ibom State, Nigeria. In a related study, ref. [24] concluded that pests contribute to yield loss in Waterleaf production. Sustainable food availability and affordability are crucial to prevent hunger and malnutrition. Despite the benefits of Tf, problems remain in achieving food security, affecting social and economic development [25]. Studies show Nigerians' fruit and vegetable intake falls short of the WHO recommendation of 400 grams per day [26; 27], with lower consumption in the North than in the South (160 grams vs. 179 grams) [16]. The demand for Waterleaf is rising due to urbanization and new settlements [28], widening the domestic demand-supply gap [29]. Small-scale farmers in densely populated South-South Nigeria face limited farmland access due to land fragmentation and urbanization [23]. In Akwa-Ibom State, farming is often not business-oriented, with poor practices and limited modern farming knowledge. Through this lens, this study estimated the cost structure of Waterleaf production, investigated the drivers of Waterleaf production, and identified some factors limiting Waterleaf production in the study area.

The paucity of recent empirical studies on the economics of Waterleaf farming in Nigeria is a recognized gap, justifying this study. Unless for a few recent studies [30], studies on the economics of Waterleaf production date to a decade ago and beyond. Therefore, this study addresses a critical gap and uniquely provides up-to-date data on economic viability (using the cost structure approach), production drivers (using the Ordinary Least Squares to quantify key socioeconomic and farm-level factors that determine production), and constraints (using a Likert-scale approach) to Waterleaf production in Akwa-Ibom State. These research approaches provide statistical and qualitative evidence to inform policy and intervention. Akwa-Ibom is a major hub for Waterleaf production in Nigeria; therefore, there is a need to investigate how its production has fared to improve the livelihood income of engaging households. In addition, if the health safety of Nigerians is to be improved, insufficient intake of vegetables is estimated to cause around 14% of gastrointestinal cancer deaths, about 11% of ischemic heart disease deaths, and about 9% of stroke deaths [31], necessitating a careful assessment of Tf production capacity.

2.0 Materials and Methods

2.1 Study Area

The study was conducted in Akwa-Ibom State, Nigeria. This study was carried out between 2021 and 2022. In Akwa-Ibom State, agriculture is a pivotal part of the economy, and the State is a leading producer of leafy vegetables in Nigeria [32]. The state has six (6) agricultural zones, namely Oron, Abak, Ikot Ekpene, Etinan, Eket, and Uyo, and has a very high potential for agriculture. It is suitable for food crops, tree crops, fish, and livestock farming. Crops widely grown are leafy vegetables like Waterleaf, fluted pumpkin, and garden egg. Other crops are yams, swamp rice, cassava, etc.

2.2 Sampling Technique and Procedure

A multi-stage sampling technique was used. The state has six Agricultural Development Project (ADP) zones: Uyo, Oron, Abak, Etinan, Eket, and Ikot Ekpene. In the first stage, Oron, Abak, and Etinan were purposively selected because more rural farming households are concentrated there. In the second stage, a simple random sampling technique was used to select four (4) villages from each of these zones, totaling 12 villages. The third stage involved the snowball sampling of six Waterleaf farmers across the sampled villages. As participants were identified through referrals, sampling continued until no new Waterleaf farmers could be found. Of the 72 sampled farmers for this study, only 61 across the 12 selected villages were found to be analysable. It is important to note that this data set represents the study area, Akwa-Ibom State, being a leading producer of Tf in Nigeria, from which generalizable inferences can be made at the State level, but not applicable for a larger (national) population. Although the use of the snowballing technique may introduce selection bias, triangulation with other sampling methods can mitigate this, ensuring robust and representative findings. Thus, generalizable inferences are made only at the State level but do not apply to a larger (national) population.

Enumerators and extension agents were involved in this study to facilitate interviews. There was no direct or indirect use of animal subjects or human clinical trials involved in arriving at the findings of this article. Respondents gave written consent after the aim and objectives of the study were disclosed, as well as assurance of anonymity and confidentiality of information.

2.3 Data Analytical Technique

Table 1 presents the research objectives for this study and the corresponding analytical techniques adopted.

Table 1: Presentation of Research Objectives and Analytical Techniques

S/No	Objective	Analytical Technique
1.	Describe the socio-economic characteristics of waterleaf farmers	Descriptive Statistics
2.	To estimate the costs and returns from waterleaf production	Budgetary technique
3.	Examine the drivers of waterleaf production in Akwa-Ibom State	Multiple regression
4.	Describe the constraints faced by waterleaf farmers	Descriptive Statistics

2.3.1 Descriptive Statistics

The socio-economic and farm-level characteristics of the Waterleaf farmers were described using tables, frequency counts, class intervals, and percentages, while the constraints encountered by the farmers were described with the aid of a five-point Likert scaling procedure viz. Strongly Agree (score 5), Agree (score 4), Undecided (score 3), Disagree (score 2), Strongly Disagree (score 1), and Mean.

2.3.2 Budgetary Technique

The Budgetary Technique was employed to analyze the profitability of Waterleaf production in the study area. The gross margin and profitability ratios were some of the metrics used. These are as stated below.

i. Total Cost will be obtained using

$$TC = TVC + TFC \quad (1)$$

Where:

TC= Total Cost (N)

TVC = Total Variable Cost (N), which includes the costs of seeds, fertilizer, transportation, etc.

From equation (1), TFC = Total Fixed Cost (N), which includes the costs of fixed inputs such as machete, weeding hoe, cutting knife, basin, shovel/spade, etc.

NOTE: The fixed items are depreciated using the annual depreciation value method.

$$ADV = \frac{\text{Cost Price - Salvage or Scrap value}}{\text{Estimated useful life}} \quad (2)$$

The scrap value of an asset, as stated in equation (2), may be zero if the asset can no longer be disposed of at any price.

ii. Total Revenue will be obtained using

$$TY = P_y Q_y \quad (3)$$

Where:

From equation (3), TR = Total Revenue (N) from the sale of fresh Tf

P = Unit Price per bundle

Q = Quantity per cutting

iii. Profit will be estimated using

π= TR –TC (4)

Where,

π = Profit (N)

iv. Profit Ratio/Profitability Index = NI/ TR (5)

v. Fixed Ratio = TFC/TR (6)

vi. The Rate of Return on Investment (RRI) = NI/TC *100 (7)

vii. Operating Ratio = TVC/TR (8)

2.3.3 Ordinary Least Squares (OLS) Regression Model Specification

The implicit form of the production function from the study is stated as:

$$InY_i = \beta_0 + \beta_1 X_{1i} + \beta_2 + \beta_3 X_{3i} + \cdots . \beta_{12} X_{12} + u_i \quad (9)$$

Where:

Y = Net Farm Income (Naira/acres) from Waterleaf production

X_1 = Cost of Planting materials/stem cuttings (Naira/Kg)

X_2 = Cost of Fertilizer (Naira/acres)

X_3 = Labor (in man-days/acres)

X_4 = Age (in years)

X_5 = Educational level (years of schooling)

X_6 = Marital Status (Married=1, 0 otherwise)

X_7 = Household size (number of persons)

X_8 = Farming as a major Livelihood Source (Yes=1, 0 otherwise)

X_9 = Farming experience (in years)

X_{10} = Farm size (in acres, 1ha≈2.5 acres)

X_{11} = Cost of bush clearing (Naira/acres)

X_{12} = Cost of land tillage (Naira/acres)

U = Error term

3.0 Results and Discussion

3.1a Socio-economic Features of Sampled Farmers

The result in Table 2 provides the basic socio-economic profile of Waterleaf farmers in the study area.

Table 2: Socio-economic features of the respondents

Variables	Frequency	Percentage (%)
Age		
<25	3	4.9
25-34	20	32.8
35-44	15	24.6
45-54	9	14.8
>54	14	22.9
Sex		
Male	9	14.8
Female	52	85.2
Marital Status		
Single	3	4.9
Married	37	60.7
Divorced	5	8.2
Widowed	4	6.6

Separated	12	19.6
Household Size		
1-4	54	88.5
5-8	7	11.5
Level of Education		
No formal Education	11	18.0
Primary Education	41	67.2
Secondary Education	6	9.9
Tertiary Education	2	3.3
Others	1	1.6
Major Occupation		
Farming	57	93.5
Trading	1	1.6
Civil service	1	1.6
Others	2	3.3
Non-Farm Income ₦		
≤ 50,000	11	50.0
50,001-100,000	8	36.4
100,001-150,000	1	4.5
150,001-200,000	0	0.0
>200,000	2	9.1
Livelihood source: Water leaf Farming		
Yes	21	34.4
No	40	65.6

Source: *Author's computation from 2021 field survey*

Waterleaf production in Akwa-Ibom State is predominantly female-driven (85%), and producers are within the 25-44 age range (57%). They mostly (67%) have primary education and rely more (about 94%) on farming as their primary occupation. Moreover, most of the sample respondents (89%) have a household size of 1-4 members. This socioeconomic profile underscores the relevance of Waterleaf production for household-level livelihood security in Akwa-Ibom State.

3.1b Farm-level Characteristics of Sampled Farmers

Table 3 delves deeper into the characteristics of waterleaf producers in the study area, focusing on their farm experience, income, etc.

Table 3: Farm-level characteristics of Waterleaf farmers

Variables	Frequency	Percentage
Farming experience		
1-5	11	18.0
6-10	28	45.9
11-15	18	29.5
16-20	3	4.9
>20	1	1.7
Monthly Income (₦)		
≤ 50,000	39	63.9
50,001-100,000	17	27.9
100,001-150,000	5	8.2
Farm Size (Acres)		
1-2	39	63.9
3-4	18	29.5

>4	4	6.6
Non-Farm Income (₦)		
≤ 50,000	11	50.0
50,001-100,000	8	36.4
100,001-150,000	1	4.5
150,001-200,000	0	0.0
>200,000	2	9.1
Farming type		
Mono-cropping	21	35.0
Mixed cropping	37	61.6
Farming Association		
Yes	2	3.3
No	59	96.7
Member of Cooperative Society		
Yes	0	0.0
No	61	100.0
Farm Labor Type		
Hired	7	11.5
Family	4	6.6
Both	50	81.9

Source: *Author's computation from 2021 field survey*

According to Table 3, most *Talinum fruticosum* (64%) producers have between 1 and 10 years of farming experience, and over two-thirds (64%) fall within the category of those who earn a monthly farm income of NGN ₦50,000 or less. Many Waterleaf farmers (93%) operate smallholdings (≤ 4 acres). Importantly, many of the surveyed respondents (62%) engage in mixed crop farming practices and are mostly non-members of farming associations and cooperatives (97% and 100%, respectively).

3.2 Profitability of sampled Waterleaf Farms

Table 4 presents the budgetary analysis cum breakdown of the economic performance of sampled Tf farms in Akwa-Ibom State.

Table 4: Costs and Returns on Waterleaf Production in Selected Zones of Akwa-Ibom State.

Variable	***(₦/acre)**	**%**
A. Revenue		
Revenue from the sale of Tt	113,819.67	100.00
Total Revenue	113,819.67	100.00
B. Variable costs		
Cost of Seed	4,817.21	20.37
Cost of Fertilizer	2,237.71	9.46
Cost of Transportation	963.93	4.08
Cost of Labor	12,164.75	51.42
Total variable cost	20,183.60	
C. Fixed cost (Depreciated)		
Cost of rented farmland	1,075.82	4.55
Cost of working tools (hoes, machetes, cutting knife, basin, shovels)	2,394.37	10.12
Total fixed cost	3,470.19	100.00
D. Total Cost (B+C)	23,653.79	
E. Gross Margin (A--B)	93,636.07	
F. Net returns/Profit (A—D)	90,165.88	

Profitability Analysis	
G. Profit Margin (F/A)	0.792
H. Gross Ratio (D/A)	0.208
Return per naira spent in Tt production =F/D	3.812
I. Operating Ratio (B/A)	0.177
J. Fixed Ratio (C/A)	0.030

Source: *Author's computation from 2021 field survey *USD = ₦403.9 (As of 2021).*

The revenue generated from the sale of *Talinum fruticosum* is NGN ₦113,819.67 per acre per Waterleaf production cycle, based on a total investment cost of NGN ₦23,653.79, indicating a single-source product revenue. Labor accounts for over half (51.42%) of the total variable cost. Fixed costs are relatively low compared to variable costs, with working tools representing the larger portion (10.12%) of fixed costs, just as the cost of rented farmland (NGN ₦1,075.82 per acre) is also low (4.55%). The profitability index of 0.79 implies that approximately NGN ₦ 0.79 is earned as profit per NGN ₦1 revenue generated. The rate of return on investment indicates that farmers earn approximately NGN ₦ 3.81 for every NGN ₦1 spent, suggesting high short-run profitability. The gross ratio (0.208) indicates that total costs account for about 21% of the total revenue.

3.3 Drivers of Waterleaf Production in Akwa-Ibom State, Nigeria.

The factors that influence net gains in Waterleaf production are explained in Table 5.

Table 5: Factors influencing Waterleaf production in Akwa-Ibom State, Nigeria

Variable	Coeff.	Std. Err.	P>t
Planting materials/stem cuttings	-3062.6267	7753.028	0.696
Fertilizer	-1.2910	1.0200	0.219
Labor	2.6670	1.7600	0.142

Age	-401.4323	475.143	0.406
Education	-773.2576	827.853	0.359
Marital Status	4188.3124	5936.233	0.487
Household Size	-7496.6365*	3863.770	0.063
Livelihood Source	2.3570**	1.0700	0.037
Farming Experience	968.5624	942.972	0.314
Farm Size	0.27179***	0.06888	0.001
Cost of Bush Clearing	-5.4550***	1.7400	0.004
Land tillage	2.7790*	1.3900	0.056
_cons	-9.6850	3.5600	0.011

R-squared: 0.973, Adj R-squared: 0.938, Prob (F-stat): 1.61e-13, No of Observations: 61

Source: *Author's computation from 2021 field survey* *** = Significant at 1%, ** = Significant at 5%, * = Significant at 10%.

The R-squared value of 0.973 indicates that approximately 97% of the variability in the outcome variable can be explained by the independent variables that are included in the model. The F-statistics are significant (p-value < 0.01), suggesting that the model is statistically significant and a good fit for the data. Among the variables analyzed, household size, livelihood source, farm size, costs of bush clearing, and tillage are the only statistically significant factors that drive Waterleaf production in Akwa-Ibom State, Nigeria.

The coefficient of household size (-7496.6365) is negative and significant at the 10% level, indicating that for every unit increase in the number of persons within the household, the returns (in Naira) from Waterleaf production decrease by about 7497 units, holding all other factors constant. Households whose primary livelihood source is Waterleaf farming tend to experience a 2.357 unit increase in production net income, at a 5% probability level. The positive and statistically significant result for the respondents' farm size ($p<0.01$) suggests a direct relationship between farm size and Waterleaf profitability, confirming that land expansion increases profitability through scale effects. Furthermore, a unit increase in the cost of bush clearing decreases farmers' income by 5.46 units and is significant at a 1% probability level. Finally, farmers' increased expenditure on land tillage increases production net returns by 2.78 units.

3.4 Variance Inflation Test (VIF)

Table 6 shows the VIF result. VIF is a test used to detect the presence of multicollinearity in a regression analysis. Generally, VIF values below 10 are acceptable, suggesting the absence of multicollinearity [33]. However, ref. [34] opines that more stringent assessments can include a lower VIF threshold.

Table 6: Result of the Variance Inflation Test

Variable	VIF	1/VIF
Planting materials/stem cuttings	1.29	0.776512
Fertilizer	1.31	0.764860
Labor	1.48	0.673773
Education	1.25	0.798371
Household Size	1.68	0.594185
Farming Experience	1.44	0.692434
Farm Size	1.81	0.552763
Age	2.12	0.472704
Livelihood	1.17	0.852814
Mean VIF	1.51	

Source: *Author's computation from 2021 field survey*

The VIF values across all the variables in the regression model are below the critical threshold of 10, and even the stricter threshold of 5. The highest VIF value is Age (2.12), which falls within acceptable limits. This implies that there is no significant multicollinearity among the independent variables included in the regression model and that the independent variables are sufficiently independent of one another. The low VIF values indicate that the independent variables are not highly correlated with each other, ensuring that the regression coefficients will be stable and reliable. Additionally, the mean VIF of 1.51 is relatively low, suggesting that, on average, the independent variables exhibit low multicollinearity. Overall, these findings support the robustness of the regression model.

3.5 Constraints faced by the sampled waterleaf Farmers

Table 7 ranks various constraints encountered by the surveyed respondents. The ranking is based on the mean score, with higher scores indicating a greater constraint.

Table 7: Constraints Encountered by Waterleaf Producers

Variable	1	2	3	4	5	Mean	Rank
Poor education level	1(1.7)	14(23.3)	5(8.3)	13(21.7)	27(45.0)	3.29	1st
Poor soil	0(0)	1(1.7)	0(0)	46(76.7)	13(21.7)	3.00	2nd
Inadequate water availability	0(0)	0(0)	0(0)	56(93.3)	4(6.7)	2.97	3rd
Rampant incidence of theft	0(0)	17(28.3)	0(0)	9(15.0)	34(56.7)	2.79	4th
High cost of inputs	2(3.3)	31(51.7)	0(0)	13(21.7)	14(23.3)	2.47	5th
Markets for vegetables	7(11.6)	22(36.7)	0(0)	28(46.7)	3(5.0)	2.43	6th
Low price of the product	1(1.7)	53(88.3)	0(0)	4(6.7)	2(3.2)	2.12	7th
Unstable market price	7(11.6)	51(85.0)	0(0)	2(3.3)	0(0)	1.97	8th
Pests and diseases	31(51.7)	16(26.7)	0(0)	3(5.0)	10(16.7)	1.82	9th
High cost of labor	25(41.7)	30(50.0)	0(0)	0(0)	5(8.3)	1.77	10th
High cost of land	29(48.3)	23(38.3)	0(0)	3(5.0)	5(8.3)	1.76	11th
Insufficient capital	24(4.0)	34(56.7)	0(0)	1(1.7)	1(1.7)	1.73	12th
Land availability	41(68.2)	14(23.3)	0(0)	3(5.0)	2(3.2)	1.53	13th
Lack of credit facility	39(65.0)	19(31.6)	0(0)	2(3.3)	0(0.0)	1.51	14th

Lack of storage facilities	55(91.7)	4(6.7)	0(0)	1(1.7)	0(0)	1.26	15th
Inadequate extension visits	59(98.3)	1(1.7)	0(0)	0(0)	0(0)	1.19	16th

1= Strongly Disagree, 2= Disagree, 3= Undecided, 4= Agree, 5= Strongly Agree

Source: *Authors' computation based on the 2022 field survey*

Waterleaf farmers in the study area observed poor educational levels (mean score of 3.29) as the major besetting challenge in Tf production. Soil degradation, with a mean score of 3.00, was ranked as the second primary challenge in Tf cultivation by most of the respondents. All the sampled respondents faced the challenge of insufficient water availability (mean score of 2.97). A significant proportion of the surveyed Tf farmers (72% with a mean score of 2.79) highlighted the high prevalence of theft (ranked 4th), as a notable concern in Waterleaf production. Conversely, an inadequate extension visit was observed as the least (ranked 16th) of the problems Waterleaf farmers faced during production. Lack of storage facilities was ranked 15th among all the constraints encountered by the surveyed farmers.

4.0 Discussion

The 25-44 age bracket of most respondents may infer that Waterleaf farming is more attractive to young, energetic individuals who possess the physical strength to sustain the rigorous tasks required for farming activities. This is supported by the study of Akpan et al. (2019), which states that Waterleaf farming is a crucial source of livelihood for many unemployed youth and women among the rural and peri-urban population. Having most of the sampled participants being married may mean a higher family responsibility, and equally, the engagement of family labor in their farming activities. Ref. [35] reported that most arable crop farmers are married people. This resonates with ref. [36] that the sample respondents are mostly farmers. Most households having 1 to 4 members could imply lower labor costs for farming activities, which is essential for subsistence farming systems in Nigeria. Additionally, smaller households may have become increasingly common due to urban migration and changing farming structures. This conflicts with an earlier study by ref. [37] that most crop farmers have between 6 and 10 household members.

The respondents' farming experience shows that they have practiced farming for a considerable time, thus endowed with the necessary practical knowledge to gain mastery. This corroborates ref. [38] findings that the years of experience could help farmers make expert decisions on farming practices. The farming experience could also influence the adoption of innovation and technology. According to ref. [39], farmers who embrace innovation and technologies, in most cases, are influenced by their farming experience. The small farm holdings may be implicated in their farm income; thus, small farms may mean small income earnings. This agrees with ref [20] and ref. [29]. A significant percentage of farmers engaging in mixed cropping portrays potential diversification strategies. The dominance of mixed crops may also indicate some level of agricultural knowledge. However, these cases of non-membership in both associations and cooperatives suggest a wide knowledge-sharing gap, poor resource access, or collective bargaining opportunities.

A high revenue figure may underscore good returns and the potential economic viability of the Waterleaf business in the study area. This may further imply that Waterleaf farming is a lucrative business that supports household livelihood, health, and food security. It can also serve as a key income source for women and youth with limited resources, reinforcing its role in achieving SDG 2 (Zero Hunger) and SDG 8 (Decent Work and Economic Growth). These results corroborate the findings of Nya et al. (2010) that Waterleaf can be a profitable business, with high yields and good market demand. However, the average profit margin (approximately 79%) surpasses earlier studies [20], possibly due to the underestimation of opportunity costs. Labor is the most significant variable cost component in Waterleaf production that boosts income, but with diminishing returns. Meanwhile, from the result, the low drudgery, implying low labor cost, and low production cost requirement for vegetable production may inform the high profit margin. The low fixed costs may suggest potentially small landholdings or low rent rates. The low fixed costs may suggest that initial capital investment in the Tf business is modest. However, family labor costs and opportunity costs of land may not be fully accounted for.

The inverse relationship suggests that higher household size is associated with reduced agricultural returns. Smallholder farming is typically characterized by limited resource availability, such as land. Therefore, this aligns with the economic theory of diminishing marginal returns in that more dependents can strain limited resources, lowering per-capita output. Furthermore, larger households may exert pressure on household resources, divert resources from market-oriented farming to subsistence needs, and shift labor from productive farming to domestic tasks (childcare, food preparation), resulting in a dilution of per capita farm inputs and reduced marketable surplus. Thus, this negative association highlights the consumption-production trade-off in peasant households, echoing Chayanov's peasant economy theory that posits that smaller households optimize labor-to-land ratios more effectively. The statistical significance of farmers' primary livelihood source may suggest that specialization in Waterleaf farming enhances production performance. Primary engagement in Waterleaf production may lead to greater efficiency, focused knowledge, and improved input utilization. Additionally, this may be connected to the shorter production cycles, stable market demand, and low input costs associated with water leaf farming. The positive association between farm size and Waterleaf net returns implies that larger farms may benefit from economies of scale, better technology use, or more efficient input allocation. This finding aligns with ref [29], who found that farm size is a major determinant of Tf output. Although bush clearing is a critical land preparation step, high costs may reduce the cultivable land area or delay production activities, thus hampering profitability. On the other hand, excessive land preparation costs erode farm profitability. The findings of ref [40] on the cost of bush clearing as a major factor influencing farm productivity. Subsidies or community-led clearing initiatives could mitigate this. Finally, Proper tillage improves soil aeration and moisture retention, increasing productivity. This finding agrees with ref. [41] that tillage plays a crucial role in crop yield.

In terms of production constraints, farmers with lower years of schooling (primary education) may struggle to adopt the best practices in areas such as crop management and pest control. This can lead to reduced yields and cost inefficiencies. This finding aligns with relevant studies that found that farmers need to enhance their knowledge and skills in Waterleaf production. Degraded soil can negatively affect nutrient uptake and water retention, leading to sub-optimal production. As a critical input for crop growth, an insufficient water supply can severely constrain Tf yield and quality. A high prevalence of theft can lead to direct financial loss and operational disruption. Theft poses a substantial disincentive and security challenge to investment among farmers, impacting crop security and overall profitability. Ref [42] reported that inadequate storage facilities were a major constraint faced by vegetable farmers.

5.0 Conclusion

This study investigated the economic viability and constraints faced by Waterleaf producers in the study area. The findings suggest that a total cost of ₦23,653.79 was expended on Waterleaf production, generating a high gross margin (₦93,636.07) and profit (₦90,165.88) per acre per Waterleaf production cycle, indicating an economically viable enterprise. However, this result reflects a decline in profitability compared to 2010. Labor was identified as the major variable cost component (51.42%), highlighting the labor-intensive nature of production. These findings are further supported by the low operating cost, suggesting that variable costs represent a small portion of the total income. Similarly, fixed costs were relatively low, suggesting potential accessibility for small-holder farmers. Additionally, Waterleaf farming as a principal livelihood source emerges as a statistically and economically significant driver of farm performance, showing evidence of improving household welfare. However, several constraints militate against the optimal production and profitability of *Talinum fruticosum*, key among which are the low educational level of farmers, poor soil quality, insufficient water availability, and high prevalence of theft. A government policy initiative that encourages land consolidation vis-à-vis land access and security, in the study area, to boost Tf production for sustained income, health security, and meet export needs, should be underway. Government policy directives should frame profitability not only as a household benefit, but also as a pathway for urban food supply security. Such policies should promote Waterleaf as a viable livelihood crop through extension services, especially in areas where it is agroecologically suitable, and should be underway. Market access and value chain links for Waterleaf farmers to ensure price stability and post-harvest handling should be implemented. ADP should develop and implement capacity-building programs for Waterleaf farmers tailored to best practices, including crop management, pests and disease control, and soil health improvement, climate-resilient farming techniques and organic fertilizer use, should be considered. Encourage local processing or preservation initiatives that could add value and reduce perishability, enhancing farmers' income. Subsidized land clearing services or community-led labor arrangements can lower this cost and encourage cultivation. Farmers should be trained by extension experts on sustainable tillage practices to improve soil quality and crop yields. Public-private initiatives can invest in the development of water management infrastructure, including the sinking of boreholes to improve water availability for farmers. At the communal level, community policing programs and other security measures to deter theft should be implemented.

Although *Talinum fruticosum* in the study area has export potential, this research is, however, limited by its small sample size, and therefore, the conclusions drawn from this study may not be generalizable or applicable to a larger population. Also, the study highlights the need for further research to validate the findings on the factors influencing Waterleaf's profitability, using other econometric approaches like the Cobb-Douglas production function

Conflicts of interest

The Authors declare that they have no conflicts of interest.

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