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Analysis of the Determinants of Plantain Production and Profitability in Bayelsa State: Prospects for Human Nutrition

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HIGHLIGHTS

- Plantain plays a vital role both as staple food and source of income in Southern Nigeria.
- Plantain production and profitability indices were discussed in the study.
- Data were analyzed using descriptive statistics, multiple regression, logistic regression, and profitability indices.
- Farm size, planting materials, labour use, extension services, and farming experience affect plantain output.
- The profitability results confirm that plantain farming is economically viable and improve nutritional value.

Abstract

This study examines the determinants of plantain production and profitability in Bayelsa State, Nigeria, and their implications for human nutrition. Data were collected from plantain farmers using structured questionnaires and interviews with 120 farmers. The research used descriptive and inferential statistical methods, including multiple regression analysis, binary logit model, costs and returns, and profitability indices. The mean age of the farmers is 52.4 years, 81.7% are married, with a mean of six households and a mean farming experience of 19.52 years. Variance Inflating Factor and tolerance show that multicollinearity does not exist among the variables. The double-log functional model was chosen as the lead equation with an R^2 of 95.11%, where age, farm size, market accessibility, and improved variety significantly determine plantain production. The high covariance percentage (0.97) of forecasting performance indicates a great capacity to reproduce real patterns. The profitability index and return on investment show that plantain farming is profitable. Furthermore, plantain has a high nutritional value for human health, logistic regression shows that nutritional awareness of plantain is mainly driven by education and access to information. Farmers are unable to maximize their profits due to challenges such as limited market access, high input prices, and post-harvest losses. Plantain production has the potential to become a more profitable and sustainable sector, boosting economic growth, ensuring food security, and improving human nutrition in Bayelsa State and across Nigeria. To boost plantain production and nutrition, the research

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recommends investing in better road networks, storage facilities, market infrastructure, farmer education, and extension services.

Keywords: Food security; Nutrition; Plantain; Production theory; Profitability indices

1. Introduction

Plantains are perennial herbaceous plants that bear a resemblance to trees and range in height from 2 to 8 meters (Morgan and Kainga, 2024). They are members of the genus Musa and the family Musaceae, and they have an underground rhizome (Agbagwa et al., 2021). A cup of boiled green plantains contains approximately 49 grams of carbohydrates, 4 grams of fiber, 3 grams of sugar, 3.0 grams of fats, 1.7 grams of protein, 0.7 grams of carotene, 0.6 grams of potassium, 0.38 grams of folate, 0.2 grams of vitamin C, and 0.09 grams of Vitamin A, among other nutrients (U.S. Department of Agriculture, 2019; Nafack et al., 2023). In terms of gross value of production, it is the fifth most important food commodity in the world, after rice, wheat, maize, and cassava (Morgan and Kainga, 2024). More than 700 million people in numerous poor nations, particularly in Africa, consume the crop as food and beverage (FAO, 2020; Adi, 2024).

Plantain is a multipurpose food in the kitchen and raw material for many popular delicacies and snack chips (Confidence et al., 2023). Common products made from plantains include flour (for making pancakes, bread, cakes, doughnuts, biscuits, and cookies, among others), chips, ethanol, and beer (Nafack et al., 2023). The overripe plantain pulp is typically processed into flour, wine, beer, bread, cakes, and muffins, while unripe or slightly ripened plantain pulp can be fried in vegetable oil to make plantain chips (Confidence et al., 2023). Similarly, it is frequently boiled and eaten with stew or palm oil. Some consumers also cook it to make porridge, while others boil it and pound it with cassava or yam to make plantain mash. In addition, most plantains are cooked with charcoal on the roadside and sold to numerous customers (Nkwain et al., 2022).

Despite being one of the world's top producers of plantains, Nigeria does not rank among those that export them since it produces more for domestic use than for export (Okunola et al., 2022). Despite this gap, the demand for plantains has plummeted in the past ten years due to the emergence of several local food processing enterprises that use them to make bread, cakes, biscuits, cookies, and flakes, among other products (Nafack, 2023; Adi, 2024). Plantains are also gaining importance as a cash crop due to growing urbanization in major parts of the country; in certain situations, they are the only source of income for rural residents, which helps to reduce poverty (Ojediran et al., 2018; Joel et al., 2022). For instance, in the past two decades, the world's plantain production has risen by more than 21 percent to almost 53.2 million metric tonnes, with Cameroon being the largest producer (4.31 million metric tonnes), followed by Ghana (3.95 million tonnes), Uganda (3.71 million tonnes), Colombia (3.54 million metric tonnes), Nigeria (3.09 million metric tonnes), the Philippines (3.07 million metric tonnes), Peru (2.07 million metric tonnes), Cote d'Ivoire (1.59 million metric tonnes), Myanmar, and Congo (1.11 million metric tonnes) (World Maps, 2021; FAOSTAT, 2023).

The disparity in the production outlay is a sign that the plantain production process is not going well, particularly in Nigeria. Targeted changes in land policies, input subsidies, extension services, tax rebates, and market assistance are necessary to increase plantain output, ensure profitability, and improve nutritional outcomes in developing countries (Nkwain et al., 2022). This study analyzes the determinants of plantain production and profitability in Bayelsa State: implications for human nutrition. The specific objectives of the study were to: describe the socio-economic characteristics of the plantain farmers in the area, estimate the determinants of plantain production in the study area, determine the profitability of plantain production in the study area, identify the factors limiting plantain production in the area, and ascertain the level of awareness of the nutritional value of plantain in the area.

Theories that supported the study

The analysis of plantain production and profitability in Bayelsa State is founded on numerous economic and agricultural theories:

Production Function Theory: The Production Function Theory describes the quantitative link between inputs (land, labour, capital, and management) and output (plantain yield). It illustrates how varied input combinations can influence output levels (Samuelson and Nordhaus, 2001). This theory's application to plantain production is to assist in finding the best input utilization for maximum yield.

Profit Maximization Theories: According to this idea, farmers seek to maximize earnings by maximizing resource utilization in order to produce larger yields and better returns (Tey and Brindal, 2015). It posits that farmers make production decisions to increase the difference between total income and total costs. This principle applies to plantain production in the sense that farmers can boost output by using superior planting materials and effective farming procedures.

Nutrition Transition Theory: According to Mendez and Popkin (2004), the shift in eating habits is caused by changes in socioeconomic situations, urbanization, and globalization. As wages grow and lifestyles change, communities tend to shift away from traditional diets rich in whole foods (such as plantain) and toward processed energy-dense meals. This theory is relevant to plantain production because it teaches farmers that plantain can be a major crop in solving nutritional deficits during the transition by delivering critical elements such as fiber, potassium, and vitamins. Promoting plantain intake can help mitigate the detrimental health impacts of processed foods.

2. Materials and Methods

The study was conducted in Bayelsa State, Nigeria, with a total land area of 10,771 square kilometers. The State is blessed with an estimated population of 2,537,400 people (National Population Commission, 2022 projection). The State has an annual rainfall range between 2000- 3500mm and comprises eight (8) Local Government Areas. It is located within the South-South region of Nigeria between latitude 4 15' North, 5 23' 0 0 South and longitude 5 22' West and 6 45 East of the prime median (Greenwich Meridian). The temperature in the State ranges between 20 and 28 degrees Celsius with high humidity. The State is covered by tropical forest, and the main occupation of the people is farming, while their major food crops are cassava, plantain, rice, yam, and maize, with cash crops such as oil palm, cocoa among others (Morgan and Kainga, 2024).

For this study, a multi-stage sampling technique was employed. Firstly, three (3) Local Government Areas LGAs (Yenagoa, Ogbia, and Southern Ijaw) were purposively selected due to the prevalence of plantain farming in these areas. In the second stage, four (4) communities were specifically chosen from each of the three LGAs based on their prevalence in plantain cultivation. Lastly, ten (10) plantain farmers were selected from each community. Thus, a total of 120 plantain farmers were chosen at random for this study. The Agricultural Development Programme in the State provided a list of farmers. Well-structured surveys were used to get this. Both descriptive and inferential statistics were used to analyze the data using Eviews.

Table 1. Summary of the study area sampling procedure

Agricultural Zone	LGA	Community	Population of the plantain farmers	Number of respondents (Sample)
Brass	Ogbia	Kolo	187	10
		Imiringi	167	10
		Opume	154	10
		Otuabagi	174	10
Sagbama	Sagbama	Sagbama	124	10
		Ofoni	105	10
		Ebedebiri	98	10
		Toru-Orua	112	10
Yenagoa	Yenagoa	Zarama	96	10
		Igbogene	109	10
		Okolobiri	127	10
		Kalama	103	10
3	3	12	1556	120

Source: Author's Survey, 2025.

Since the population is known, Yamane's (1967) formula was used to compute the sample size:

$$n = \frac{N}{1+N.e^2} \quad (1)$$

Where n is the sample size expected, N is the population size (1556), and e^2 is the level of precision (8.7%).

$$n = \frac{1556}{1+1556*0.087^2} = 121.78$$

Hence, a sample size of 120 was used.

Model specification

Plantain production estimate is determined by using a multiple regression model as used by Oniah (2019), stated thus;

The Linear Functional form:

$$Yd = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12} + \beta_{13} X_{13} + \mu \quad (2)$$

The Semi-Log Functional form:

$$Yd = \beta_0 + \beta_1 InX_1 + \beta_2 InX_2 + \beta_3 InX_3 + \beta_4 InX_4 + \beta_5 InX_5 + \beta_6 InX_6 + \beta_7 InX_7 + \beta_8 InX_8 + \beta_9 InX_9 + \beta_{10} InX_{10} + \beta_{11} InX_{11} + \beta_{12} InX_{12} + \beta_{13} InX_{13} + \mu \quad (3)$$

The Double-Log Functional form:

$$lnYd = \beta_0 + \beta_1 InX_1 + \beta_2 InX_2 + \beta_3 InX_3 + \beta_4 InX_4 + \beta_5 InX_5 + \beta_6 InX_6 + \beta_7 InX_7 + \beta_8 InX_8 + \beta_9 InX_9 + \beta_{10} InX_{10} + \beta_{11} InX_{11} + \beta_{12} InX_{12} + \beta_{13} InX_{13} + \mu \quad (4)$$

The Exponential Functional form:

$$lnYd = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12} + \beta_{13} X_{13} + \mu \quad (5)$$

Where: Yd is the average yield (in kg), X_1 is age (in years), X_2 is gender, X_3 is marital status, X_4 is education level (years spent), X_5 is household size (in numbers), X_6 is association membership, X_7 is farming experience (in years), X_8 is extension contact, X_9 is farm size (in ha), X_{10} is weather conditions, X_{11} is market accessibility, X_{12} is planting of improved variety, X_{13} is labour, β_0 is constant, β_1 is β_{13} are the coefficient of the parameter estimates, and μ is the error term.

Plantain production profitability is determined using different profitability indices expressed thus;

TC = TVC + TFC (6)

GM = TR – TVC (7)

NFI = TR – TC (8)

ROI = NFI/TC (9)

ROCE = TR/TC (10)

PI = NFI/TR (11)

RRI = NFI/TC * 100 (12)

OR = TVC/TR (13)

Where; GM is Gross margin (profitability measurement in Naira), TR is the Total Revenue from plantain farm (unit output multiplied by unit output price in Naira), TVC is the Total Variable Costs (in Naira), TC is the Total Cost, TVC is the Total Variable Cost, TFC is the Total Fixed Cost, TR is the Total Revenue, NFI is the Net Farm Income, ROI is the Return on Investment, ROCE is the Return on Capital Employed, PI is the Profitability Index (Net Profit Ratio), RRI is the Rate of Return on Investment, and OR is the Operating Ratio.

The binary logit regression model to estimate the nutrition awareness of plantain is specified thus:

$$C_{ij} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + u \quad (14)$$

Where: C_{ij} is 1 if farmer is aware of nutritional value in plantain, and 0 otherwise (dummy), the average yield (in kg), X_1 is age (in years), X_2 is gender, X_3 is education level (years spent), X_4 is household size (in numbers), X_5 is extension contact, X_6 is market access, X_7 is association membership, β_0 is constant, β_1 is β_7 are the coefficient of the parameter estimates, and μ is the error term.

Variance Inflating Factor (VIF) was used to test the multicollinearity in the models as used by Aroyehun et al. (2024) expressed in regression form as;

$$VIF = \frac{1}{1-R^2} \quad (15)$$

Tolerance (TOL) as;

$$TOL = 1 - R^2 \quad (16)$$

Where R^2 is the coefficient of correlation for the regression of a single independent variable against the entire set of independent variables.

Rule of thumb for VIF:

- VIF > 10 means severe multicollinearity (problematic).
- VIF > 5 means moderate multicollinearity (needs attention).
- VIF < 2.5 means no serious collinearity issues.

3. Results and Discussion

This section explained the findings.

Table 2. Socioeconomic characteristics of the plantain farmers in the study area

Variables	Frequency	Percentage	Mean
Age (in years)			52.4 years
35 and below	6	5.0	
36-45	17	14.2	
46-55	58	48.3	
56-65	30	25.0	
66 and above	9	7.5	
Gender			
Male	61	50.8	
Female	59	49.2	
Marital status			
Single	9	7.5	
Married	98	81.7	
Widow/Widower	13	10.8	
Educational level			3.03
No formal education	13	10.8	
Primary completed	19	15.8	
Secondary completed	40	33.3	
Tertiary completed	48	40.0	
Household size (in numbers)			6 persons
1-3	3	2.5	
4-6	72	60.0	
7-9	45	37.5	
Membership association			
Yes	39	32.5	
No	81	67.5	
Farming experience (in years)			19.52 years
10 and below	23	19.2	
11-20	45	37.5	
21-30	45	37.5	
31 and above	7	5.8	
Extension visit (within a year)			
Yes	46	38.3	
No	74	61.7	
Landownership			
Yes	40	33.3	
No	80	66.7	
Type of landownership			
Owner of land	40	33.3	
Rent	40	33.3	
Joint ownership	8	6.7	
Family	15	12.5	
Lease	17	14.2	
Access to credit			
Yes	42	35.0	
No	78	65.0	
Amount of credit received (₦)			₦125,075.00
Non	61	50.8	
100,000-200,000	32	26.7	
200,001-400,000	21	17.5	
400,000 and above	6	5.0	

Source: Authors Field Survey, 2025.

Table 2 reveals that 48.3% of the plantain farmers were between the ages of 46 and 55, while 25.0% were between the ages of 56 and 65, with a mean age of 52.4. This reflects an aging farmer population, with low young participation, despite their active ages. This data is consistent with Confidence et al. (2023), who obtained a mean of 50 years. 50.8% were men and 49.2% were women. This data suggests that there is no gender bias in plantain production in the state, despite the fact that males outnumber females. These results are consistent with those reported by Oniah (2019) and Confidence et al. (2023). About 7.5% of plantain farmers were single, while the majority (81.7%) were married, and 10.8% were widows or widowers. This confirms that farming is mostly performed by those with family obligations. The educational level results show that 10.8% of the plantain farmers had formal education, 15.8% of the plantain farmers completed primary education, 33.3% of the plantain farmers completed secondary school education, and 40.0% of them had tertiary education, indicating a relatively educated farming community, and with a mean of 3.03, the majority of the farmers had secondary school education. Higher educational or literacy levels can lead to more widespread adoption of agricultural technology in agriculture.

Furthermore, the Table reveals that 60.0% of the plantain farmers had a household size of 4-6 individuals, 37.5% had a household size of 7-9, and 2.5% had a household size of 1-3, with a mean of 6 persons, suggesting medium-sized families. About 37.5% of plantain farmers had a farming experience of 11-20 years and 21-30 years, respectively, while 19.2% had 10 years or less, with a mean of 19.52 years, indicating an experienced agricultural labourer. Years of expertise in plantain cultivation might help growers mitigate the danger. It may be used for farm finance, product storage, and marketing, as well as sourcing farm supplies, which may result in a rise in farm profit or a decrease in farm costs (Confidence et al., 2023). The majority of plantain farmers (67.5%) did not belong to any agricultural association, while just 32.5% were members, showing low involvement in cooperative groupings. Approximately 38.3% of plantain farmers were visited by extension officials within a year, whereas the majority (61.7%) did not get extension visits, potentially limiting access to better agricultural practices.

Table 2 also reveals that 33.3% own land and 66.7% do not, reflecting a reliance on rented, leased, or family land. Approximately 35.0% had access to loans, but the majority (65.0%) did not, posing a significant impediment to farm growth and modernization. 26.7% accessed ₦100,000-₦200,000, 17.5% accessed ₦200,001-₦400,000, and just 5.0% obtained ₦400,000+, with a mean of ₦125,075.

Table 3. Plantain production factors in the study area

Variables	Frequency	Percentage	Mean
Farm size (ha)			1.38 ha
0.5 and below	14	11.7	
0.6-1.0	38	31.7	
1.1-1.5	28	23.3	
1.6-2.0	28	23.3	
2.1-2.5	5	4.2	
2.6 and above	7	5.8	
Bunches of plantain harvested (in numbers)			1053.93
500 and below	14	11.7	
501-1000	49	40.8	
1001-1500	40	33.3	
1501-2000	9	7.5	
2001 and above	8	6.7	
Type of labour			
Family	64	53.3	
Hired	10	8.3	
Both	46	38.3	
Weather effects on plantain			
Erratic rainfall	8	6.7	
Drought	93	77.5	
Both	19	15.8	
Use of improved varieties			
Yes	35	29.2	
No	85	70.8	
Easy access to the market			
Yes	75	62.5	
No	45	37.5	
Incidence of pest and disease			
Yes	101	84.2	
No	19	15.8	
Quantity of sucker planted (in numbers)			1169
500 and below	5	4.2	
501-1000	52	43.3	
1001-1500	40	33.3	
1501-2000	15	12.5	
2000 and above	8	6.7	

Source: Authors Field Survey, 2025.

Table 3 summarizes farm features and productivity parameters. About 31.7% of farms are 0.6-1.0 ha, 23.3% are 1.1-1.5 ha, and 1.6-2.0 ha, and just 5.8% have farms larger than 2.6 ha, with a mean of 1.38 ha, indicating smallholder farming. 40.8% of plantain farmers gathered between 501 and 1000 bunches, 33.3% harvested 1001 to 1500 bunches, 11.7% picked 500 or fewer bunches, and 6.7% harvested more than 2000 bunches, indicating increased output for select farmers, with a mean of 1053.93 bunches. About 43.3% of plantain farmers planted 501-1000 suckers, 33.3% planted 1001-1500 suckers (mean = 1169 suckers), and only 6.7% planted more than 2000 suckers, probably owing to financial or land restrictions. Family labour dominates (53.3%), with just 8.3% relying completely on paid labour and 38.3% combining the two. Heavy reliance on family work implies cost-cutting measures, but it may hinder scalability.

Table 3 details the problems and agronomic techniques. The majority (77.5%) of plantain farmers cite drought as a major weather effect concern, 6.7% mention unpredictable rainfall, and 15.8% suffer both drought and erratic rainfall, emphasizing climate dangers in plantain cultivation. Only 29.2% employ improved plantain cultivars, leaving the bulk (70.8%) to rely on conventional ones. This may have an impact on production potential as well as pest and climatic resistance. 62.5% of plantain growers say they have easy access to markets, while 37.5% struggle. Market problems might influence profitability and post-harvest losses. The vast majority (84.2%) of plantain growers report insect and disease problems, indicating a pervasive concern. The poor adoption of better cultivars may be a contributing cause.

Table 4. Multicollinearity statistics of multiple regression of plantain production

Variables	Tolerance	VIF	Multicollinearity issue
Age	0.687	1.456	No
Gender	0.775	1.290	No
MariStat	0.579	1.728	No
YrSch	0.705	1.418	No
HousSize	0.915	1.093	No
AssMemb	0.874	1.144	No
FrmExp	0.816	1.226	No
ExtCont	0.836	1.197	No
FrmSize	0.689	1.451	No
WeatherCon	0.928	1.078	No
MktAcces	0.677	1.478	No
ImprovVar	0.659	1.518	No
Labor	0.923	1.083	No

Source: Authors Field Survey, 2025.

Table 5. Multicollinearity statistics of nutritional awareness of plantain

Variable	Tolerance	VIF	Multicollinearity issue
Age	0.916	1.092	No
Gender	0.885	1.130	No
EduLev	0.890	1.124	No
HouseSize	0.939	1.065	No
AssMemb	0.956	1.046	No
ExtCont	0.899	1.112	No
MktAcces	0.920	1.087	No

Source: Authors Field Survey, 2025.

Tables 4 and 5 indicate the multicollinearity statistics of multiple regression and the nutritional knowledge of plantain in the study region. There are no major multicollinearity concerns because all Variance Inflating Factor (VIF) values are less than 2, which is far lower than the crucial threshold of 10. All of the tolerance values are more than 0.1, indicating that there is no significant collinearity. This implies that the independent variables are not correlated, and the regression model's predicted coefficients are statistically valid, stable, and dependable.

Table 6. Estimated Multiple Regression Functional model on plantain production

Variable	Linear	Semi-Log	Double-Log [+]	Exponential
Constant	2323.214*	13280.74***	9.2575***	7.8219***
	(1.8861)	(3.2319)	(31.7209)	(39.8932)
Age	-33.5867**	-1150.332	-0.1290*	-0.0024
	(-2.5056)	(-1.0931)	(-1.7264)	(-1.1314)
Gender	-41.8264	-45.9147	0.0011	0.0662**
	(-0.1918)	(-1.5832)	(0.5154)	(1.9072)
Maristat	661.0532**	873.1086	0.0551	0.0394
	(2.2363)	(1.0126)	(0.9000)	(0.8369)
Yrsch	-79.0169***	-133.1098***	-0.0046	0.0023
	(-3.2616)	(-3.1743)	(1.5441)	(0.6036)
Housesize	-25.4310	-1053.066	0.0285	0.0324***
	(-0.3010)	(-1.4845)	(0.5653)	92.4105)
Assmemb	313.4236	-39.9847	0.0010	0.0871**
	(1.4299)	(-1.3948)	(0.4814)	(2.4954)
Frmexp	15.7945	194.1792	0.0216	0.0010
	(1.14088)	(0.5558)	(0.8720)	(0.4460)
Extcont	-148.5091	-18.8612	-0.0019	-0.0283
	(-0.6877)	(-0.6530)	(-0.9093)	(-0.8244)
Frmsize	6383.947***	7602.729***	0.9151***	0.7097***
	(35.2692)	(22.3158)	(37.8199)	(24.6315)
Weathercon	217.1655	-314.3842	0.0478	0.0463
	(1.01429)	(-0.4896)	(1.0490)	(1.3578)
Mktacces	-828.4610***	-115.7497***	-0.0073***	-0.0258
	(-3.4375)	(-3.7955)	(-3.3625)	(-0.6737)
Improvvar	310.7937	38.8545	0.0047*	0.0456
	(1.1944)	(1.0847)	(1.8538)	(1.1008)
Labor	-168.1068*	-561.6435	-0.0548	-0.0270*
	(-1.8547)	(-1.1901)	(-1.6350)	(-1.8695)
R-squared	0.9488	0.8805	0.9511	0.8948
Adjusted R^2	0.9425	0.8658	0.9451	0.8818
Log likelihood	-997.7846	-1048.601	97.7055	51.6715
F-statistic	150.9985	60.0784	158.7052	69.3181
Prob(F-statistic)	0.0000	0.0000	0.0000	0.0000
AIC	16.8631	17.7100	-1.3951	-0.6279
Durbin-Watson	1.7553	1.3913	1.6630	2.3488

Note: ***, **, and * Significant at 1%, 5%, and 10% level of probability respectively; t-values are in parentheses, AIC is Akaike Information Criterion.
Source: Authors Field Survey, 2025.

Table 6 displays the estimated determinants of plantain output in the research. The multiple regression model predicted four functional forms: linear, semi-log, double-log, and exponential. The double-log functional model was chosen as the lead equation for discussing the findings because it has the greatest R^2 (0.9511) and Adjusted R^2 (0.9451) values, indicating that it explains the most variability in the dependent variable. Furthermore, the Akaike Information Criterion (AIC) is lowest for the double-log model (-1.3951), suggesting the best model fit, and Durbin-Watson is 1.6630, which is near 2, implying no significant autocorrelation issues in the residuals (Gujarati and Porter, 2009; Wooldridge, 2010). The double-log regression model illustrates the elements that influence agricultural production (or revenue). The double-log specification indicates that all variables are in logarithmic form, implying that the coefficients represent elasticities—that is, a 1% change in an independent variable results in a percentage change in the dependent variable. The coefficient of determination (R^2) was 0.9511, indicating that the model's independent variables explained about 95.11% of the variation in plantain production. The F-statistic (158.71, $p < 0.01$) is statistically significant at 1%, indicating the equation's overall relevance. This is consistent with the findings of Nweke (2016) and Udoh et al. (2018), who also reported that production functions in root and tuber crops are best interpreted through double-log specifications for estimating input-output elasticities and guiding resource allocation decisions.

The farmer's age coefficient was -0.1290, which was statistically significant at the 10% level of probability. The negative influence of age on plantain production implies that older farmers are less productive than younger ones; hence, younger plantain farmers were more productive than older ones, most likely due to lower adoption of new techniques. Similar studies by Oladeebo and Fajuyigbe (2010) and Olayemi et al. (2019) found that younger farmers are generally more open to adopting new farming techniques and innovations, while older farmers often stick to traditional methods, which can constrain their productivity. The coefficient of farm size (Frmsize) was 0.9151, which was significant at the 1% level of probability. This suggests that farm size has a positive and substantial association with plantain output, implying that increasing farm size by 1% results in a 0.92% rise in plantain output. This is consistent with the findings of Oniah (2019), who discovered that farm size is one of the factors influencing plantain productivity in Cross River State, Nigeria. Thus, farm size is the most important factor impacting agricultural productivity. This findings furher agreed with Oladeebo and Fajuyigbe (2010) and Adewumi and Adegbite (2015), who found that larger farms often enjoy economies of scale, make better use of labour, and use inputs more efficiently, all of which boost crop production. The finding underscores the importance of access to land and farm expansion as crucial factors for improving productivity among smallholder farmers.

The market access (Mktacces) variable was significant at the 1% level of probability, with a negative coefficient of -0.0073. The significant negative impact of market access on plantain production implies that inadequate market access affects farm productivity (revenue), maybe owing to high transportation costs, price volatility, a lack of storage facility, or a poor value addition process. This finding is consistent with Barrett (2008) and Fafchamps and Minten (2012), who emphasized that limited market access increases transaction costs and reduces incentives for farmers to expand production. Similarly, Obare et al. (2010) found that poor rural infrastructure and market inefficiencies significantly constrain agricultural productivity in developing countries. The enhanced variety (Improvvar) of plantain sucker has a positive coefficient of 0.0047, which is significant at the 1% level of probability. This means that increasing the enhanced type of plantain suckers by 1% will increase production by 0.0047%. As a result, the use of enhanced plant kinds boosts output, although the effect is minor. This tiny influence might be attributed to soil conditions and other environmental variables. This result aligns with findings by Asfaw and Admassie (2004), who emphasized that adoption of improved inputs enhances farm output, though the extent of impact often depends on complementary factors such as soil quality and farmer capacity. In addition, Evenson and Gollin (2003) noted that improved crop varieties contribute to yield growth, but their effectiveness is influenced by environmental and institutional conditions.

Figure 1 depicts the Cumulative Sum (CUSUM) test, which determines the stability of the model's coefficients over time. The blue line (CUSUM) represents the cumulative sum of the recursive residuals. The red dashed lines (5% significance level) represent the key stability boundaries. If the CUSUM line remains inside these bounds, the model is deemed stable. Throughout the sample period, the CUSUM line remained within the 5% significance level. Because the blue line does not breach the red borders, the regression coefficients are steady throughout time. As a result, the model is structurally stable at the 5% significance level. The computed regression shows no indication of structural fractures or parameter instability.

Figure 2 depicts the CUSUM of Squares test, which is used to determine the long-term stability of regression coefficients over time. It enhances the CUSUM test by detecting potential structural variance changes. The CUSUM of Squares line remains within the 5% significance range throughout the duration. The line has a consistent rising trend, showing a gradual build-up of variance but no abrupt changes. Because the CUSUM of Squares does not transcend the red borders, we infer that the model remains structurally stable over time. The regression coefficients are steady, and there is no significant indication of structural instability at the 5% level. When used with the CUSUM test, this indicates that the model does not show substantial parameter changes or breaks across the sample time.

Figure 3 depicts the residual analysis and the normality test. The mean residual (-1.52e-15) is practically zero, indicating no consistent over- or under-prediction. The median residuals (0.020468) are marginally positive but extremely tiny. The Standard Deviation (Std. Dev) (0.157970) quantifies the dispersion of residuals; the smaller the number, the more precise the model. The skewness (0.060819) value is near zero, indicating a symmetric residual distribution. Since 0.06 is so close to zero, the residuals are almost symmetric. A normal distribution has a kurtosis of 2.982525; because this is so close to 3, the residuals follow a near-normal distribution. The Jarque-Bera test (0.075505) p-value = 0.962951 > 0.05 indicates that we failed to reject the null hypothesis, implying that the residuals have a normal distribution. The model's residuals appear to be well-behaved, indicating acceptable model specification.

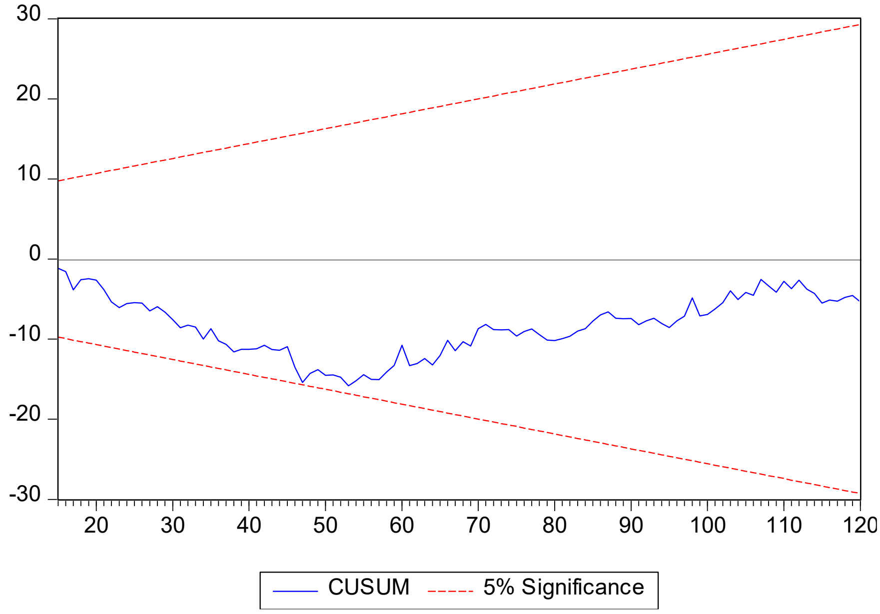

Figure 1. CUSUM stability

Source: Authors Field Survey, 2025.

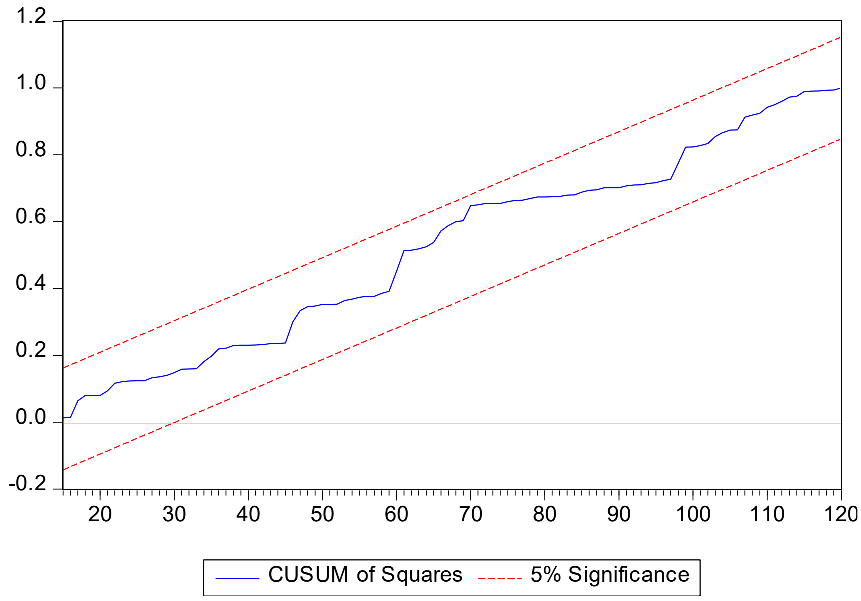

Figure 2. CUSUM of Squares stability

Source: Authors Field Survey, 2025.

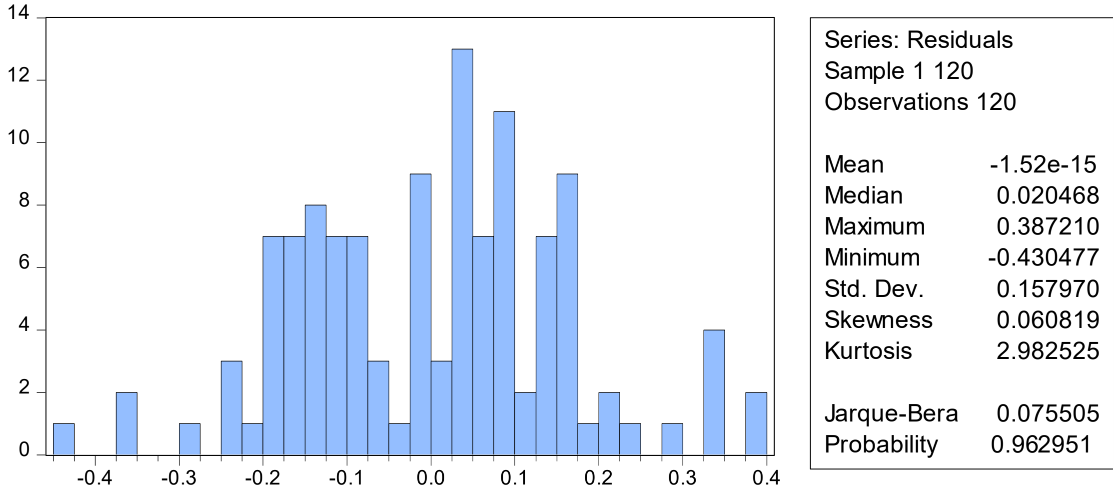

Figure 3. Residual analysis and normality test

Source: Authors Field Survey, 2025.

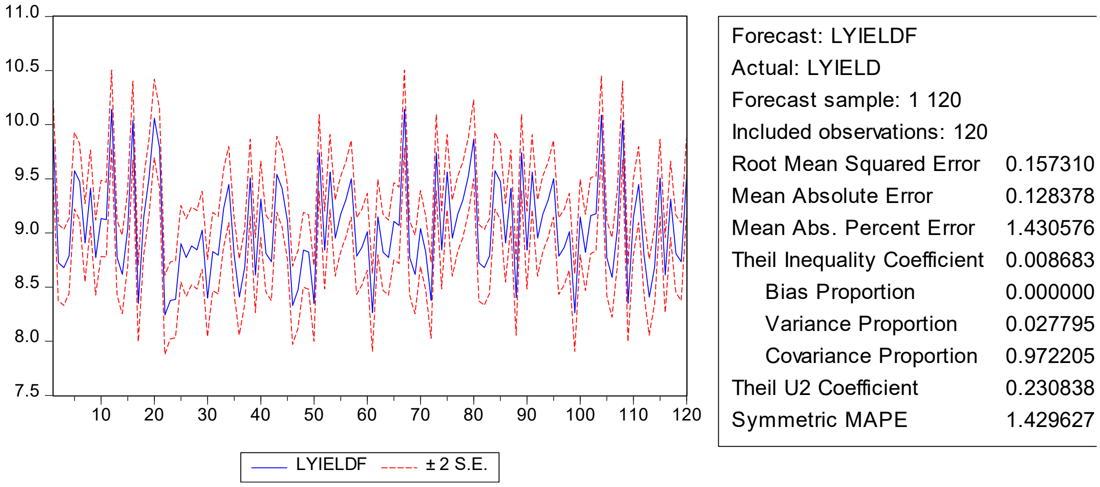

Figure 4. Forecasting performance

Source: Authors Field Survey, 2025.

Figure 4 shows a statistical model used to evaluate the forecasting ability of plantain LYIELD (log yield). The Root Mean Squared Error (RMSE) is 0.157310, which represents the standard deviation of residuals (prediction errors); a lower number implies higher predictive accuracy. The Mean Absolute Error (MAE) is 0.128378, which is the average of absolute forecast mistakes; it gives a simple measure of accuracy. The Mean Absolute Percentage Error (MAPE) is 1.430576, which shows prediction error as a percentage of actual data; a lower number (closer to zero) implies better-predicting accuracy. Theil's Inequality Coefficient (U-statistics) is 0.008683, a value around zero indicating strong predictive ability. The Theil's U2 Coefficient is 0.230383, which is closer to zero and indicates that the model outperforms a naïve forecast. The Bias Proportion is 0.000000, indicating no systematic bias in predictions (ideal case). The Variance Proportion is 0.027795, which is a minor part of the inaccuracy caused by variance variances between projected and actual values. The Covariance Proportion is 0.972205; a high number (near 1) suggests that the majority of the error is attributable to random fluctuations rather than systematic bias, implying that the model accurately reflects trends. Consequently, the model works effectively, with low error metrics and negligible bias. Random noise, rather than systematic bias, accounts for the majority of predicting mistakes. The high covariance percentage (0.97) indicates a great capacity to reproduce real patterns.

Table 7. Average annual costs and returns and profitability index on plantain farming

Items	Quantity	Unit	Price/Unit(₦)	Value (₦)	Percentage
Revenue					
Sales of plantain	1053.93	Bunch	1,554.17	1,637,986.39	100
Total Revenue (TR)				1,637,986.39	100
Variable Costs					
Plantain suckers	2169.35	Number	250.00	542,337.50	60.16
Fertilizer	5.13	Kg	7,850.88	40,275.01	4.47
Pesticides	4.36	Litre	5,268.33	22,969.92	2.55
Herbicides	2.56	Litre	5,635.83	14,427.72	1.60
Labour	4	Man-days	3,333.33	13,333.32	1.48
Transport				86,258.33	9.57
Credit				125,075.00	13.87
Total Variable Cost (TVC)				844,676.81	93.70
Fixed Costs					
Depreciation on the equipment				5,461.67	0.61
Rent on land				51,325.00	5.69
Total Fixed Cost (TFC)				56,786.67	6.3
Total Cost (TC)				901,463.48	100
Gross Margin (GM)				793,309.58	
Net Farm Income (NFI)				736,522.91	
Profitability Indices					
Return on Investment (ROI)				0.82	
Return on Capital Employed (ROCE)				1.82	
Profitability Index (PI) or Net Profit Ratio				0.45	
Rate of Return on Investment (RRI)				81.70	
Operating Ratio (OR)				0.52	

Source: Authors Field Survey, 2025.

Table 7 displays the average yearly expenses, returns, and profitability index for plantain cultivation in the research region. Cost structures demonstrate that variable costs (93.7%) dominate overall costs, with plantain suckers (60.16%) being the most expensive. Fixed costs (6.3%) are quite low, mostly due to land rent (5.69%). The average annual production cost (TC) was ₦901,463.48, with an average total revenue (TR) of ₦1,637,986.39. Plantain production had an average yearly gross margin (GM) of ₦793,309.58 before subtracting fixed expenses, while net farm income (NIF) was ₦736,522.91. This means that plantain production is lucrative, this findings is similar with Confidence et al. (2023).

Plantain farming has a Return on Investment (ROI) of 0.82, indicating that every ₦1 invested yields a profit of ₦0.82. The Return on Capital Employed (ROCE) is 1.82, indicating that every ₦1 of capital creates ₦1.82 in income. The Profitability Index (PI) of 0.45 indicates that 45% of sales are kept as net profit. The Rate of Return on Investment (RRI) is 81.70%, indicating good profitability. The Operating Ratio (OR) is 0.52, showing that 52% of revenue is spent on operating expenditures, demonstrating efficiency and efficient cost management. The farm is extremely profitable, with an 82% ROI and a net profit margin of 45%. The high cost of plantain suckers shows that bulk purchasing or alternate suppliers might increase profits.

Table 8. Challenges faced by plantain farmers in the study area

	Yes		No		
Variables	F	%	F	%	Mean
High cost of inputs	102	85.0	18	15.0	0.85
Lack of access to credit	106	88.3	14	11.7	0.88
Pest and disease incidences	29	24.2	91	75.8	0.24
Post-harvest losses	111	92.5	9	7.5	0.92
Poor road infrastructure	111	92.5	9	7.5	0.92
Lack of storage facilities	103	85.8	17	14.2	0.86
Low market price	29	24.2	91	75.8	0.24
Climate change effects (drought, flood, and erratic rainfall)	89	74.2	31	25.8	0.74
Theft	90	75.0	30	25.0	0.75
Communal clashes	41	34.2	79	65.8	0.34
Incidence oil spillage on plantain farm	22	18.3	98	81.7	0.18

Source: Authors Field Survey, 2025.

Table 8 details the difficulties encountered by plantain producers in the research region. The most urgent concerns for plantain growers include post-harvest losses (92.5%), with a mean of 0.92 classified as a significant difficulty, and farmers struggle to preserve plantains after harvest. bad road infrastructure (92.5%) was also graded high, with 0.92, implying that bad roads have an impact on transportation and market access. Lack of credit (88.3%) with a mean of 0.88 indicates that many farmers struggle to receive financial assistance. The high cost of inputs (85.0%), with a mean of 0.85, indicates that fertilizers, insecticides, and other agricultural inputs are a significant limitation. Lack of storage facilities (85.8%) with a mean of 0.86 suggests that farmers have insufficient storage alternatives, which contributes to post-harvest losses. Climate change impacts (74.2%), with a mean of 0.74, show that unpredictable weather patterns (drought, flooding, and inconsistent rainfall) affect plantain production. Theft (75.0%) with a mean of 0.75 indicates that produce theft is a serious issue, resulting in direct financial losses.

The moderate obstacles experienced by plantain producers include community confrontations (34.2%), with a mean of 0.34, indicating that conflicts within communities have an impact on farming activities. Pest and disease incidences (24.2%) with a mean of 0.24 show that fewer farmers report pest-related losses. A low market price (24.2%) with a mean of 0.24 implies that farmers face variable or low prices, which reduces profitability. Oil leakage on plantain fields is a modest problem (18.3%) with a mean of 0.18, implying that it affects a smaller population but may be severe for those who are impacted.

Table 9. Determinants factors influencing nutritional awareness of plantain

Variable	Coefficient	Std. Error	z-statistic	Sig.	Odds Ratios	Logical Remarks
Constant	-8.031	2.778	8.358	0.004	0.000	
Age	0.039	0.029	1.804	0.179	1.040	Minimal effect
Gender(1)	0.330	0.511	0.417	0.519	1.391	Weak influence
Education	0.659	0.284	5.393	0.020	1.933	Strongest driver
HouseSize	0.338	0.227	2.223	0.136	1.402	Moderate influence via shared knowledge
ExtnContact	0.670	0.497	1.819	0.177	1.954	High potential but weak delivery
MktAcces(1)	0.677	0.482	1.968	0.161	1.968	High potential via information exposure
AssMemb	-0.313	0.526	0.353	0.552	0.732	Negative, reflects weak institutions
Log likelihood		114.786				
Nagelkerke R^2		0.203				
Variables in the Equation	-1.237	0.219	32.006	0.000	0.290	Nutritional awareness is multi-dimensional

***, **, and * are Significant at 1%, 5%, and 10% levels of probability respectively.

Source: Authors Field Survey, 2025

Table 9 shows the results of the logistic regression analysis used to ascertain the level of awareness of the nutritional value of plantain. The model as a whole is statistically significant ($p < 0.01$), which means that the variables included in the analysis, when taken together, help explain why some farmers are more nutritionally aware than others. The Nagelkerke R^2 value of 0.203 indicates that about 20.3% of the variation in nutritional awareness is explained by the model. While this may seem modest, it is quite acceptable in behavioural and nutrition studies where many influencing factors—such as personal preferences and cultural habits—are difficult to measure. To better understand the results, odds ratios (OR) are used. An odds ratio greater than 1 means the variable increases the likelihood of awareness, less than 1 means it reduces it, and equal to 1 means no effect.

The age shows that older farmers are slightly more likely to be nutritionally aware (OR = 1.040, p > 0.10), with each additional year increasing awareness by about 4%. However, this effect is not statistically significant, suggesting that age alone does not strongly determine awareness. This implies that access to information may matter more than experience, which agrees with earlier findings by Ochieng et al. (2017) and Akinola et al. (2018). Gender also shows a positive but insignificant effect (OR = 1.391, p > 0.10), meaning male farmers are about 39% more likely to be aware than female farmers. However, since this result is not significant, it suggests that gender differences are not very important once other factors are considered. This supports the work of Doss (2001), who noted that differences between men and women tend to reduce when both have similar access to education and resources. Household size has a positive relationship with awareness (OR = 1.402, p > 0.10), indicating that larger households may benefit from shared knowledge and interaction among members. Still, this effect is not statistically significant. This finding is in line with Ruel et al. (2013), who explained that household dynamics can influence nutrition outcomes, though not always strongly.

Education emerges as the most important factor in this study. With an odds ratio of 1.933 ($p < 0.05$), it shows that more educated farmers are almost twice (by 93.3%) as likely to be nutritionally aware of plantain. This highlights the critical role of education in helping individuals understand and apply nutritional information. Similar conclusions have been drawn by Asfaw and Admassie (2004) and Otekunrin et al. (2021), who emphasized that education improves awareness and decision-making related to food and nutrition. Hence, nutritional awareness is largely driven by knowledge.

Extension contact also shows a strong positive effect (OR = 1.954, p > 0.10), suggesting that farmers who interact with extension agents are almost twice (95.4%) as likely to be aware. However, the result is not statistically significant, which may reflect challenges such as limited outreach or irregular contact. This supports Anderson and Feder (2007) and Davis et al. (2012), who noted that extension services are only effective when they are frequent and of good quality. Similarly, market access has a large positive effect (OR = 1.968, p > 0.10), meaning farmers with better access to markets are nearly twice (96.8%) as likely to be aware. Markets often serve as places where people exchange not just goods but also information. Although this result is not statistically significant, it aligns with Barrett (2008) and Fafchamps and Minten (2012), who highlighted the importance of markets in spreading knowledge.

Interestingly, association membership shows a negative relationship (OR = 0.732, p > 0.10), suggesting that members are less likely to be nutritionally aware than non-members. Although this finding is not significant, it may point to issues such as inactive groups or poor information sharing within associations. This contrasts with the studies of Bernard and Spielman (2009) and Fischer and Qaim (2012), which found that farmer groups usually improve access to information. In this case, it may indicate that local associations are not functioning effectively. In general, while many variables show positive effects, education is the only one that is statistically significant. This suggests that improving knowledge and access to information is more important than demographic factors in shaping nutritional awareness.

The "Variables in the Equation" result confirms that all the variables together significantly influence nutritional awareness (z = 32.006, $p < 0.01$). This means that even though some individual variables are not significant on their own, their combined effect strengthens the model. This supports the view of Hosmer et al. (2013) that a group of variables can improve model performance even when individual effects appear weak. In the context of nutrition, Ruel et al. (2013) and Otekunrin et al. (2021) also emphasize that awareness is shaped by multiple overlapping factors—such as education, access to information, and socio-economic conditions—which work better together than in isolation. Therefore, the findings show that nutritional awareness of plantain is mainly driven by education and access to information, while other factors play supporting but less decisive roles.

Figure 5 reveals that the majority (78%) are unaware of the nutritional benefits of plantain, highlighting the need for greater education and awareness campaigns. This data is consistent with Ayinde et al., (2017), who stated that rural regions are unaware that plantain is healthy, possibly due to a lack of literacy, except for people with diabetes mellitus, who use unripe plantain to cure their ailment. As a result, the consumer's nutritional understanding determines his or her plantain intake pattern.

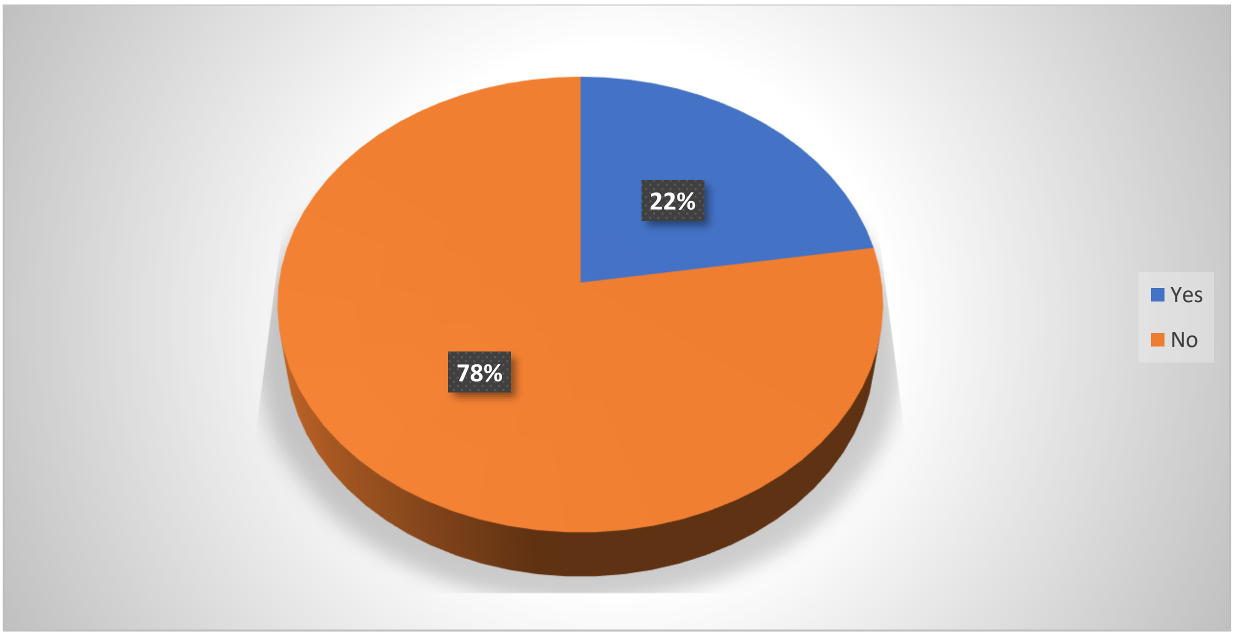

Figure 5. Nutrition of plantain awareness

Source: Authors Field Survey, 2025.

4. Conclusions and Recommendations

The examination of plantain production and profitability in Bayelsa State identifies important drivers of output and economic viability. According to the study, education, family size, and age, all have a beneficial influence on plantain nutritional knowledge, however, market availability has a negative impact. Profitability is determined by input costs, market access, extension services, and farm size. Plantain farming has the potential to improve lives and food security, but difficulties such as insufficient infrastructure, restricted access to agricultural loans, and inadequate extension services impede optimal output. In terms of nutrition, greater plantain production can greatly enhance food availability and dietary diversity in Bayelsa State. However, nutritional knowledge is still relatively poor, indicating the need for tailored interventions to optimize the health advantages of plantain intake. Plantain production has the potential to become a more viable and sustainable industry, contributing to economic growth, food security, and improved human nutrition in Bayelsa State and across Nigeria. The study therefore recommends:

i. Investing in improved road networks and storage facilities to avoid post-harvest losses. Improve market connections to help farmers achieve greater pricing and profitability.
ii. Expand extension programmes to enhance farmers' understanding of optimum agronomic practices. Increase economic returns by providing plantain processing and value-added training.
iii. Stakeholders like the Government and NGOs could create subsidized credit programmes and urge microfinance institutions to provide loans suited to plantain producers. Encourage agricultural cooperatives to increase collective negotiating strength and financial assistance.

iv. Enhance nutrition education programmes to raise knowledge of plantain's health advantages. Encourage the use of plantain-based meals in school feeding programs to increase consumption.
v. Promote organic farming and agroforestry for better soil fertility and long-term productivity. Support the use of high-yield, disease-resistant plantain cultivars to boost production.
vi. Develop strategies to encourage young participation in plantain growing through incentives and skill-building initiatives. Provide tax breaks and subsidies for agribusinesses that engage in plantain processing and distribution.
vii. To boost awareness of plantain nutrition, policies should focus on investing in both formal and informal education since it shown to be the strongest driver of nutritional awareness, enhancing agricultural extension services with clear nutrition-focused guidance, improving market infrastructure and the flow of information, and revitalizing farmer associations so they can actively support and share nutritional knowledge.

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