

# Analysis of Cost Efficiency and Profitability of Integrating Climate-Smart Technologies in Cassava Production in Anambra State Nigeria

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## ABSTRACT

The study used stochastic frontier cost function to analyze cost efficiency of cassava farmers and ascertained variation in cost efficiency due to inefficiency effects on cassava production in the study area. Data were collected from 135 randomly selected cassava farmers. Data were analyzed using descriptive statistics and stochastic cost function. Results showed that the mean age of cassava farmers was 41 years. Cost of organic manure, labour, improved cassava stem and agro chemicals were significant factors that are determinants of total cost associated with cassava production in the study area. That is, 1% increase in the cost of organic manure, labour, improved cassava stem and agro chemicals will increase total production cost by approximately 0.86%, 0.56%, 0.32% and 0.68% respectively with the value of the sigma squared ( $\delta^2$ ) being

0.95 indicating a good fit. The maximum likelihood estimates for the Stochastic cost function used in explaining the inefficiency parameters for cassava farmers showed that the coefficient of age, household size and level of education all had the *a priori* expected signs and statistically significant showing that an increase in any of them decreases cost inefficiency. The mean cost efficiency was 0.62, meaning that an average cassava farmer in the study area has the scope for increasing cost efficiency by 38%. It was concluded that farmers are not cost efficient from their cost efficiency indices. Extension agents should design structured training modules focusing on efficient use of organic manure (application rates, composting methods) and adoption and management of improved cassava varieties.

**Key words:** Cost, Efficiency, Cassava Farmers, Profitability, Climate-smart

## INTRODUCTION

Cassava (*Manihot esculenta*) is one of the leading food crops of the world and a major source of carbohydrate. It ranks fourth among staple crops, with a global production of about 160 million tons per year with Nigeria producing approximately 63 million tonnes per year (Otekunrin, 2024). Cassava's ability to flourish in various soil types, including those with low fertility and high acidity that are unsuitable for many other crops, is further enhanced by its climate resilience, tolerance to drought, and resistance to pests and diseases consisting of essential micronutrients, such as vitamins A, B and C, iron and Zinc (Shilpa *et.al.*, 2023).

Climate-smart agriculture (CSA) is an integrated approach to managing landscapes—cropland, livestock, forests, and fisheries—that addresses the interlinked challenges of food security and climate change. According to Onyewuchi *et.al.*, (2025) there are a lot of CSA technologies that are practiced in many countries, Nigeria inclusive example conservation agriculture, agro-forestry, soil management, water management, irrigation, improved crop variety and diversification, integrated pest management, manure management, livestock management, intercropping, conservation tillage etc. CSA aims to achieve three main objectives: sustainably increasing agricultural productivity and incomes, adapting and building resilience to climate change, and reducing and/or removing greenhouse gas emissions, where possible.

Cost efficiency (CE) of cassava production refers to the ratio of minimum production costs that allows the level of inefficiency to the actual total cost (observed cost) (Alabi, *et.al.*, 2023). Profitability of cassava production is the difference between the value of the produce by the farm business and the associated costs for producing them (Stuttgen, *et.al.*, 2020). One of the Climate-smart Agriculture practices is the use of improved

crop variety in other to achieve efficiency and profitability in production. Unfortunately researchers like Gbigbi & Chuks-Okonta (2021) and Ogunleye *et.al.*, (2025) that worked on efficiency and profitability of cassava failed to capture improved cassava stem variety. Organic manure have been known to boost the fertility of the soil naturally in carrying out any type of agricultural production unfortunately, most researchers (Bello, *et.al.*, 2025; Eze & Nwibo, 2014) who worked on efficiency of cassava production failed to capture the use of organic manure. This study addressed it. In line with the stated problems, the broad objective of this study was to analyse the cost efficiency and profitability of integrating climate smart technologies in cassava production. Specifically, the study identified the socio economic factors, analyzed the cost and returns and determined the cost efficiency of cassava production. This study will be of immense relevance to farmers particularly the rural farmers who are yet to embrace the climate-smart agricultural techniques with a hypothesis that Cassava farmers in the study area are not cost efficient.

## MATERIALS AND METHODS

The study was carried out in Anambra State. The predominant occupations in these areas include farming, fishing, trading, craft, etc. The annual rainfall ranges from 1400 mm in the North to 2500 mm in the south with temperature of 250C- 350C. The population of the State is 4,182,232 with 863 Sqkm density (NPC, 2006). It consists of twenty-one (21) Local government areas (LGAs) and four agricultural zones. According to the Anambra State Agricultural Development Programme, the state has eight thousand five hundred (8500) registered cassava producers. Multi-stage sampling technique was adopted in selecting sample for the study. The first stage, purposive sampling technique was used to select three agricultural zones from the four agricultural zones of the state due to the predominance of cassava farmers. Second stage, simple random selection technique was used to select five Local Government Areas from each of three agricultural zones totaling fifteen LGAs. Third stage, simple random technique was used to select three communities from each of the fifteen LGAs making a total of forty five communities. Fourth stage, three respondents were randomly selected from each of the forty five communities making a total of one hundred and thirty five respondents (135) which formed the sample size.

### Analytical Tools and Model Specifications.

Cost and return analysis was applied to evaluate the profitability of cassava production using the formular:

$$GM = TR - TVC \dots (1)$$

$$TC = TVC + TFC \dots (2)$$

$$NFI = TR - TC \dots (3)$$

$$ROI = NFI/TC \times 100 \dots (4)$$

Where: TR = Total revenue, TVC = Total variable cost, TC = Total cost (₦), TFC = Total fixed cost (depreciation on fixed assets), and ROI = Return on investment

### The Stochastic Frontier model specification

In this study Battese and Coelli (1995) model, as used by Zalkuwi, Dia & Dia (2010) was used to specify a stochastic frontier cost function with behaviour inefficiency component and to estimate all parameters together in one step maximum likelihood estimation. This model implicitly expressed as:  $L_n C_i = g(P_i, Y_i, \beta) + (V_i - U_i) \dots (5)$

Where  $C_i$  = the total production cost,  $g$  = suitable functional form such as Cobb Douglas,  $P_i$  = vector variable input prices (organic manure, labour, improved cassava stem, land and agrochemicals)  $Y_i$  = the value of cassava produce in kg,  $V_i$  = the systematic component which represents random disturbance cost due to factors outside the scope of the farmers.  $U_i$  is the non-negative random variables associated with inefficiency which are assumed to be independent and normally distributed with zero mean and constant variance. The cost

efficiency of an individual farm is define in terms of the ratio of the observed cost ( $C_b$ ) to the corresponding minimum cost ( $C_{min}$ ) given the available technology.

$$\text{That is cost efficiency (CEE)} = \frac{C_b}{C_{min}} \frac{g(P_i, Y_i, \beta) + (V_i + U_i)}{g(P_i, Y_i, \beta) + (V_i)} = \exp(U_i) \dots (6)$$

Where:  $C_b$  = the observed cost represents the actual total production cost.  $C_{min}$  = minimum cost and represents the frontier total production cost or least cost total production level.

$$CEE = \exp(U_i) \dots (7)$$

CEE takes the values of 1 or higher with 1 defining cost efficient farm. And following the adoption of Battese and Coelli (1995) framework for the analysis of data, the explicit Cobb Douglas functional form for cassava farm in the study area is therefore specified as follows;

$$L_n C_i = \beta_0 + \beta_1 + L_n P_{1i} + \beta_2 L_n P_{2i} + \beta_3 L_n P_{3i} + \beta_4 L_n P_{4i} + \beta_5 L_n P_{5i} + (V_i + U_i) \dots (8)$$

Where:  $C_i$  = Total production cost (₦/ha) of the  $i$ th farmer,  $P_1$  = Cost of organic manure (₦/ha),  $P_2$  = Cost of labour (₦/ha),  $P_3$  = Cost of improved cassava stem (₦/ha),  $P_4$  = Cost of Land (₦/ha),  $P_5$  = Cost of herbicides (₦/ha),  $\beta_0$  = Constant,  $\beta_1 - \beta_5$  = Parameters to be estimated

$$\text{The inefficiency model is define by } U_i = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} \dots (9)$$

Where:  $U_i$  is the cost inefficiency of the  $i$ th farmer,  $Z_1, Z_2, Z_3,$  and  $Z_4$  represents age, Household size, farming experience, and level of education. These socio-economic variables are included in the model to indicate their possible influence on the cost efficiency of the cassava farmers. The result from the stochastic frontier analysis was used to test the hypothesis. The null hypothesis will be rejected if cassava farmers are cost efficient

## RESULTS AND DISCUSSION

The socio-economic characteristics of the respondents are presented in Table 1 below. The result shows that majority (53.3%) of the cassava farmers were between the ages 36-50 with mean age of 41 years and mean household size was 8 persons showing that cassava production in the area is mainly done by young and vibrant farmers as also confirmed by Oshioriamhe, *et.al.*, (2025) Younger farmers are typically more open to adopting CSA practices such as improved crop varieties,. Most (45.9%) attained secondary education (Kundiri, *et.al.*, 2022) which will enable them adopt new innovation easily to improve efficiency in resource pricing with 6 years of farming experience and mean farm size of 2ha showing they have appreciable knowledge about the improved cassava variety (Omodara, *et.al.*, 2023). The cost and return analysis in table 2 shows that the total cost was ₦815,000 with total revenue of ₦1,278,500 and return on investment of 57% meaning that for every ₦1 spent, they cassava farmers gets ₦57 showing that cultivation of improved cassava variety is profitable which also corresponds with the findings of Nzeakor and Ume (2021). This profitability demonstrates that adopting improved cassava varieties is not only financially viable but also aligns with CSA’s first pillar: increasing productivity and incomes.

The maximum likelihood estimate presented in Table 3 showed that all parameter estimates have the expected sign, where cost of organic manure (₦/ha) ( $P_1$ ), cost of labour (₦/ha) ( $P_2$ ), cost of improved cassava stem (₦/ha) ( $P_3$ ), and cost of agro chemicals (₦/ha) ( $P_5$ ) are statistically significant at 1%, meaning that these factors are important determinants of total cost associated with cassava production in the study area. Cost of land ( $P_4$ ) on the other land is not significant because variations in land cost contribute very little to overall cost production. Furthermore, in many agricultural settings (especially cassava farming in Nigeria), land is often inherited, rented informally, or accessed through communal arrangements. Due to this, actual monetary expenditure on land may not reflect its true economic value, weakening its statistical impact. The insignificance of land cost underscores CSA’s emphasis on optimizing productivity per unit of land rather than expanding land area, which helps reduce deforestation and land degradation. The cost elasticities with respect to all input variables used in the production analysis are positive, implying that an increase in the costs of organic manure, labour, improved cassava stem and agro chemicals <by 1% increases total production cost by

approximately 0.86%, 0.56%, 0.32% and 0.68% respectively which further strengthens the findings of Nwosu *et al.*, (2021). The value of the sigma squared ( $\delta^2$ ) was 0.950 and is statistically significant at 1% level. This indicates a good fit and correctness of the distributional form assumed for the composite error term in the model. It also indicates moderate variance in the error term. This means there is noticeable unexplained variation in cassava production costs across farms. The fact that  $\sigma^2$  is statistically significant ( $p < 0.05$ ) implies that the error variance is not zero. In other words, inefficiency and random shocks are real and measurable in the data. Since  $\sigma^2$  is significant, the stochastic frontier model is appropriate and confirms that cassava production costs are influenced not only by observable inputs (like labour, manure, agrochemicals) but also by inefficiency effects and random noise. The log likelihood of -117.477 indicates a reasonably good fit of the stochastic frontier cost function to the data. The likelihood ratio chi-square statistic of 72.366 with 5 degrees of freedom is highly significant ( $p < 0.01$ ), confirming that the included cost factors and inefficiency variables jointly explain variations in cassava production costs. Although some individual variables (such as cost of land and farming experience) were not significant, the overall model is statistically robust. The maximum likelihood estimates (MLE) for the stochastic cost function used in explaining the inefficiency parameters for cassava farmers is presented in Table 3. The coefficients of variables had *a priori* expected signs and significant at 1% and 5% respectively. The coefficient of age, household size and level of education is estimated to be negative and statistically significant at 1% and 5% level, indicating that increase in any of them decreases cost inefficiency in cassava production. According to Alabi, *et al.*, (2023), as age, household size of cassava farmers increases inefficiency reduces and as they acquire an additional education, this will lead to 54% decrease in inefficiency of cassava production (Ewekhare *et al.*, 2026). Farming experience (0.023) was not significant. This may be due to the fact that in cassava production, efficiency may depend more on access to improved stems, agrochemicals, and labour management than on years of farming. This reduces the explanatory power of experience. This suggests that efficiency depends more on access to modern inputs and innovations than on years of traditional practice. This aligns with CSA's focus on innovation-driven adaptation rather than reliance on past methods. The cost efficiency indices which measure the cost of resources is presented in Table 4. The cost efficiency of the sampled farmers ranged from 0.45 to 0.95. The mean cost efficiency was 0.62, meaning that an average cassava farmer in the study area has the scope for increasing cost efficiency by 38% in the short run by adopting fully climate-smart techniques such as the use of organic manure and improved cassava variety as noted by Oduntan, *et al.*, (2021). The mean cost efficiency of 0.62 also signals that while cassava farming is profitable, there is significant potential to enhance productivity and resilience through deeper CSA integration, ensuring both economic gains and climate sustainability.

### Test of Hypothesis

From the result of the cost efficiency indices, cassava farmers are not cost efficient (0.62) leading to the acceptance of the null hypothesis.

### CONCLUSION/ RECOMMENDATION

The results has shown that farmers are not cost efficient from their cost efficiency indices. Particular attention should be paid to the inefficiency effects to boost cassava production. From the results above, the following recommendations are made:

- Extension agent should design structured training modules focusing on efficient use of organic manure (application rates, composting methods) and adoption and management of improved cassava varieties.
- Governments at local, state, and federal levels should provide transport allowances, performance-based bonuses, and digital tools to help extension workers reach rural cassava farmers.
- Encourage cassava farmers to form cooperatives that negotiate fair prices for cassava products, improving profitability and efficiency.
- Government should provide subsidies or credit facilities for farmers who adopt CSA practices (e.g., organic manure use, improved varieties).

## Implications Of The Findings For CSA Adoption

The findings reveal that cassava farmers benefit from significant cost drivers such as organic manure, labour, and improved stems all of which align with climate-smart agriculture practices. Profitability, with a 57% return on investment, shows CSA adoption can be financially attractive. Socio-economic factors like age, household size, and education reduce inefficiency, supporting resilience and knowledge-driven adaptation. The insignificance of land cost highlights intensification over expansion, consistent with CSA's sustainable land use. Overall, the results imply that cassava farmers are well-positioned to adopt CSA, ensuring productivity, resilience, and environmental sustainability.

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Table 1: Socio Economic Characteristics of the Respondents

Age (Years)	Frequency	Percentage
21-35	44	32.6
36-50	72	53.3
51-75	19	14.1
<b>Total</b>	<b>135</b>	<b>100</b>
<b>Mean age</b>	<b>41 Years</b>	
<b>Level of Education (Yrs)</b>		
0 (None)	13	9.6
1-6 (Primary)	43	31.9
7-12 (Secondary)	62	45.9
13-18 (Tertiary)	17	12.6
<b>Total</b>	<b>135</b>	<b>100</b>
<b>Mean Edu Level</b>	<b>7 Years</b>	
<b>Household size</b>		
1-5	33	24.4
6-10	81	60.0
11-15	21	15.6
<b>Total</b>	<b>135</b>	<b>100</b>
<b>Mean</b>	<b>8 persons</b>	
<b>Years of Experience</b>		
1-5	78	57.8

6-10	35	25.9
11-15	13	9.6
16-20	9	6.7
<b>Total</b>	<b>135</b>	<b>100</b>
<b>Mean</b>	<b>6 Years</b>	
<b>Farm size (ha)</b>		
0.5-1	31	23.0
1.5-2	91	67.4
2.5-3	13	9.6
<b>Total</b>	<b>135</b>	<b>100</b>
<b>Mean</b>	<b>2 ha</b>	

Source: Field survey data, 2025.

Table 2: Cost and Return Analysis in Cassava Production

Items	Unit of Measurement	Unit Cost (₦)	Total Quantity/ha	Total Value (₦)	Standard Deviation (SD)
<b>Variable Cost</b>					
Cassava Stem	Bundle	3500	130	455,000	250
Labour	Manday	7,000	5	35,000	500
Fertilizer	50kg/bag	12,500	11	137,500	1,000
Herbicide	Litre	4,500	2	9,000	400
pesticide	Litre	4,500	2	9,000	400
Transportation	Lump sum			22,500	2,000
<b>Total Variable Cost</b>				<b>668,000</b>	
<b>Fixed Cost</b>					
Farm tools	Lump sum			47,000	3,000
Land	Rent			100,000	10,000
<b>Total Fixed Cost</b>				<b>147,000</b>	
<b>Total Cost</b>				<b>815,000</b>	

<b>Revenue</b>					
Sale of Cassava Tuber	50kg	13,000	92	1,196,000	1,500
Sale of Cassava Root	Bundle	2500	33	82,500	500
<b>Total Revenue</b>				<b>1,278,500</b>	
Gross Margin				<b>610,500</b>	
Net Farm Income				<b>463,500</b>	
Return on Investment				<b>57%</b>	

**Field Survey Data, 2025**

Table 3: Maximum Likelihood Estimate of the Stochastic Cost Function

Variable	Parameter	Coefficient	Standard Error	t-value	P-Value/ Significance
<b>Cost Factors</b>					
Constant	$\beta_0$	16.004	2.520	6.354	P < 0.01 ***
Cost of Organic manure (P <sub>1</sub> )	$\beta_1$	0.864	0.212	4.084	p < 0.01 ***
Cost of labour (P <sub>2</sub> )	$\beta_2$	0.560	0.204	2.745	p < 0.05 **
Cost of improved cassava stem (P <sub>3</sub> )	$\beta_3$	0.318	0.082	3.887	p < 0.01 ***
Cost of land (P <sub>4</sub> )	$\beta_4$	0.031	0.071	0.436	ns (p > 0.10)
Cost of agrochemicals (P <sub>5</sub> )	$\beta_5$	0.676	0.120	5.624	p < 0.01 ***
Sigma Squared		0.950	0.376	2.526	p < 0.05 **
Log likelihood		- 117.477	-		-
Chi-Square		72.366	-		<b>p &lt; 0.01 ***</b>
<b>Inefficiency effects</b>					
Constant	$\delta_0$	- 0.442	0.068	-6.543	p < 0.01 ***
Age (Z <sub>1</sub> )	$\delta_1$	-0.215	0.075	-2.852	p < 0.05 **
Household size (Z <sub>2</sub> )	$\delta_2$	-0.526	0.231	-2.279	p < 0.05 **
Farming experience (Z <sub>3</sub> )	$\delta_3$	-0.022	0.958	0.023	ns (p > 0.10)
Level of Education (Z <sub>4</sub> )	$\delta_4$	-0.543	0.258	-2.10	p < 0.05 **

\* Significant @ 1% \*\*Significant @ 5% **Field Survey Data, 2025**

Table 4: Cost Efficiency of sampled Cassava farmers

Cost Efficiency	Class	Frequency	%
0.45-0.55		27	20.0
0.56-0.65		82	60.7
0.66-0.75		12	8.9
0.76-0.85		9	6.7
0.86-0.95		5	3.7
<b>Total</b>		135	100
<b>Mean</b>			0.62
Maximum			0.95
Minimum			0.45

Source: Field Survey Data, 2025.