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RESEARCH ARTICLE

EFFICIENCY AND PROFITABILITY ANALYSIS OF AGRO-PRODUCTION IN THE NIGER DELTA: A DATA ENVELOPMENT AND TOBIT REGRESSION APPROACH

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ABSTRACT

Agriculture remains a crucial economic activity in the Niger Delta, yet inefficiencies in resource utilization hinder its profitability and sustainability. This study applies Data Envelopment Analysis (DEA) to evaluate the relative efficiency of farm production activities for Cassava, Rice, Cocoa, Plantain, and Oil Palm in the region. The objectives of the study were to: measure the relative efficiency of different farm production activities in the Niger Delta using the DEA technique; estimate the profitability of selected crops (Cassava, Rice, Cocoa, Plantain, and Oil Palm) by analyzing yield, cost structures, and economic benefits; identify key determinants of farm efficiency using the Tobit regression model to examine the impact of cost, productivity, and other relevant factors; compare efficiency levels across different crops, determining which operate at optimal efficiency and which require resource allocation improvements; and provide policy recommendations to enhance agricultural efficiency and profitability, focusing on cost-effective solutions and productivity-enhancing techniques. Additionally, Tobit regression was used to identify key determinants of farm efficiency, focusing on the impact of cost structures, productivity, and other relevant factors. The profitability analysis reveals that Plantain and Rice exhibit the highest economic benefits, while Cassava and Oil Palm demonstrate lower profitability despite their significant production volumes. DEA findings indicate that while some crops operate at optimal efficiency, others require improved resource allocation strategies. The Tobit regression model identifies cost as a major constraint on efficiency, while increased productivity significantly enhances farm performance. Findings from this study provide empirical insights to guide policy interventions aimed at enhancing agricultural efficiency, reducing production costs, and promoting sustainable farming practices. The study contributes to evidence-based policymaking by integrating advanced quantitative techniques with practical agricultural insights, ultimately fostering economic transformation and food security in the Niger Delta.

KEYWORDS

Agricultural Efficiency, Profitability Analysis, Data Envelopment Analysis (DEA), Tobit Regression, Resource Allocation, Economic Transformation

1. INTRODUCTION

Agricultural production plays an important role in economic development, food security, and rural livelihoods, particularly in regions with vast agricultural potential such as the Niger Delta of Nigeria. The area, known for its rich natural resources and favourable climatic conditions, has a diverse agricultural sector producing key crops like cassava, rice, cocoa, plantain, and oil palm. However, despite its potential, the efficiency and profitability of agricultural production in the Niger Delta remain largely underexplored, with challenges related to resource misallocation, productivity constraints, and market inefficiencies. Understanding these dynamics is crucial for formulating effective policies that can enhance agricultural sustainability and economic growth.

Efficiency and profitability analysis is a fundamental aspect of agricultural economics, as it provides insights into how well resources are utilized and whether farming activities generate sufficient returns. Several studies have analyzed different facets of agricultural efficiency and profitability across various regions and crop types. The work by a researcher explored the digitalization of agricultural production, highlighting its efficiency-enhancing potential while cautioning against risks such as data rights issues and market concentration (Zscheischler et al., 2022). While digitalization is transforming agriculture, the extent to which such innovations influence farm efficiency in regions like the Niger Delta remains uncertain. The study examined the profit efficiency of Ghanaian maize farmers, finding a mean profit efficiency of 48.4% and identifying education, gender, and credit access as key determinants (Wongnaa et al., 2019). However, the study focused on maize farming in Ghana, leaving a research gap in assessing efficiency variations across multiple crop types in the Niger Delta.

Additionally, it assessed bioenergy production in Mediterranean regions, highlighting sustainability challenges and resource-use efficiency concerns (Pulighe et al., 2019). The study analyzed profitability in banana and sugarcane farming, respectively, emphasizing resource misallocation and input inefficiencies (Sharma et al., 2021; Pandey et al., 2020). Similarly, it investigated banana passion fruit profitability in Colombia using regression analysis, confirming the significance of key determinants (Cancino et al., 2021). These studies reinforce the need to evaluate efficiency and profitability within specific agricultural contexts, particularly in regions like the Niger Delta, where crop diversity and economic conditions vary. In Nigeria, a researcher examined yam production efficiency using the Stochastic Frontier Production Function and Gross Margin Analysis, revealing profitability constraints such as high input costs and poor storage (Idisi et al., 2024). The study analyzed agricultural efficiency in Ukraine, emphasizing the role of regional investment and innovation (Mykytiuk et al., 2019). Researchers found polarization in Ukraine's agrarian sector, with small-scale farms being

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labour-intensive but less profitable, while large enterprises achieved higher efficiency (Samarets and Nuzhna, 2018). These findings suggest that farm size and investment levels significantly influence efficiency and profitability, an aspect that requires investigation in the Niger Delta's agricultural sector.

While previous studies have extensively examined agricultural efficiency and profitability across different regions, there remains a lack of comprehensive analysis in the Niger Delta. The region presents unique agricultural and economic conditions, including smallholder-dominated farming, varying levels of mechanization, and challenges such as land degradation, poor infrastructure, and fluctuating market prices. Existing research has primarily focused on individual crops or employed limited methodological approaches. However, a holistic approach integrating Data Envelopment Analysis (DEA) and Tobit Regression can provide a more nuanced understanding of efficiency drivers and profitability trends across multiple crops.

Hence, the motivation for the current study is to look at bridging this gap by evaluating the efficiency and profitability of agro-production in the Niger Delta using DEA and the Tobit Regression approach. The specific objectives are to: measure the relative efficiency of different farm production activities in the Niger Delta using the DEA technique; estimate the profitability of selected crops (Cassava, Rice, Cocoa, Plantain, and Oil Palm) by analyzing yield, cost structures, and economic benefits; identify key determinants of farm efficiency using the Tobit regression model to examine the impact of cost, productivity, and other relevant factors; compare efficiency levels across different crops, determining which operate at optimal efficiency and which require resource allocation improvements; and provide policy recommendations to enhance agricultural efficiency and profitability, focusing on cost-effective solutions and productivity-enhancing techniques. This study is expected to contribute to evidence-based policymaking aimed at improving agricultural sustainability, resource allocation, and farmer profitability in the Niger Delta by integrating advanced quantitative techniques with practical agricultural insights.

2. Research Method

2.1 Source of Data

The data utilized in this study were primarily obtained through experimental procedures involving the anaerobic digestion of selected agro-waste types under controlled conditions. The primary data sources included measurements of biogas production volumes, feedstock input quantities, digestion retention times, and biogas quality parameters such as methane content and combustion efficiency. Specifically, data were generated from the operation of a 1-cubic-meter anaerobic digester, constructed locally for this purpose. Daily and cumulative biogas volumes were recorded using gas volume displacement methods, while methane concentration was determined via biogas analysis using a portable gas analyzer. Further data were collected during cooking tests, where the energy output of the biogas was evaluated through time-to-boil assessments using a standard single-burner biogas stove. These cooking trials provided practical insights into the thermal efficiency of the biogas produced. All data were recorded systematically over the experimental period to facilitate accurate analysis of the performance and efficiency of biogas production from the selected agro-waste feedstocks.

2.2 Area of Study

The Niger Delta is a densely populated region in southern Nigeria, covering approximately 110,624 km² (12% of Nigeria's land area). It comprises nine oil-producing states:

South-South geopolitical zone: Akwa Ibom, Bayelsa, Cross River, Delta, Edo, and Rivers.

South-East geopolitical zone: Abia and Imo.

South-West geopolitical zone: Ondo.

The region is bordered by the Atlantic Ocean to the south and Cameroon to the east and includes 184 Local Government Areas (LGAs).

2.3 LIFE-ND Project

The Livelihood Improvement Family Enterprises Project for the Niger Delta (LIFE-ND), funded by the International Fund for Agricultural Development (IFAD), aims to improve rural livelihoods through agribusiness enterprise development. The project's goal is to enhance income, food security, and job creation for rural youth and women, aligning with Nigeria's agricultural policy and Strategic Framework for Youth Employment and Job Creation. Given the Niger Delta's strong potential for agricultural-based employment, the initiative supports small agribusiness growth to drive economic transformation in the region. However, the Niger Delta is a vital economic hub, rich in oil resources but with a significant reliance on agribusiness for sustainable development.

The LIFE-ND project focuses on agricultural transformation to address youth unemployment and rural poverty.

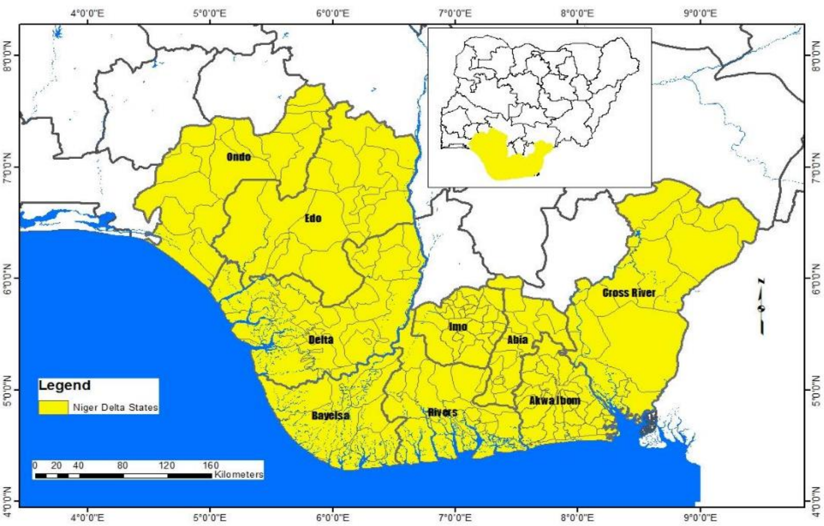

Figure 1: Map of Niger Delta Region

2.4 Method of Data Analysis

This study employs Data Envelopment Analysis (DEA) and Tobit Regression Approach to evaluate the efficiency and profitability of agro-production in the Niger Delta. The DEA technique is used to measure the relative efficiency of different farm produce, while the Tobit regression identifies key determinants of efficiency.

2.4.1 Data Envelopment Analysis (DEA)

Data Envelopment Analysis (DEA) is a non-parametric linear programming method used to evaluate the efficiency of decision-making units (DMUs), such as farms, businesses, or production processes, relative to a best-performing frontier (Charnes et al., 1978). DEA constructs an efficiency frontier by identifying the most efficient units and measuring the efficiency of all other units relative to this benchmark.

2.4.2 DEA Model Specification

Consider n decision-making units (DMUs), each using mmm inputs x_i ($i = 1,2,\dots,m$) to produce s outputs y_r ($r = 1,2,\dots,s$). The efficiency score of a DMU is computed using the Charnes, Cooper, and Rhodes (CCR) model under the assumption of constant returns to scale (CRS):

$$\max \theta_k = \frac{\sum_{r=1}^{s} u_r y_{rk}}{\sum_{i=1}^{m} v_i x_{ik}} \quad (1)$$

Subject to:

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1, j = 1,2,\cdots,n$$

$$u_r, v_i \geq 0$$

Where:

θ_k is the efficiency score of the k[th] DMU,

u_r and v_i are weights assigned to outputs and inputs, respectively,

y_{rk} and x_{ik} are the output and input values for the k[th] DMU.

A DMU is efficient if $\theta = 1$, meaning it lies on the efficiency frontier; otherwise, it is inefficient ($\theta < 1$) and has potential for improvement (Coelli et al., 1998).

The DEA model in this study evaluates the efficiency of cassava, rice, cocoa, plantain, and oil palm production by analyzing their input-output relationships. The results are then interpreted to determine which crops operate at optimal efficiency and which require resource adjustments.

2.4.3 Tobit Regression Approach

Tobit regression (Tobin, 1958) is a censored regression model designed for situations where the dependent variable is bounded or censored. In this study, DEA efficiency scores serve as the dependent variable, which are naturally censored between 0 and 1. Since ordinary least squares (OLS) regression would produce biased estimates due to the limited range of efficiency scores, Tobit regression is used to account for this censoring.

2.4.4 Tobit Model Specification

The standard Tobit model is formulated as:

$$E_i^* = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_k + \varepsilon \quad (2)$$

where:

E_i^* represents the latent (unobserved) efficiency score,

β_0 is the intercept,

$X_1, X_2, \ldots, X_k$ are independent variables such as cost and productivity,

$\beta_1, \beta_2, \ldots, \beta_k$ are coefficients,

$\varepsilon \sim N(0, \sigma^2)$is the error term.

Since the efficiency score (E_i) is bounded between 0 and 1, the observed efficiency is expressed as:

$$E_i = \begin{cases} 0, & if\, E_i^* \leq 0 \\ E_i^*, if & 0 < E_i^* < 1 \\ 1, & if\, E_i^* \geq 1 \end{cases}$$

The Tobit regression estimates the effect of explanatory variables (e.g., cost, productivity) on efficiency while accounting for the censored nature of efficiency scores. The model provides insights into which factors significantly influence farm efficiency and helps in formulating policy recommendations for improving agricultural productivity in the Niger Delta.

The combination of DEA and Tobit regression is widely used in agricultural efficiency studies (Coelli et al., 2005; Bravo-Ureta and Pinheiro, 1993). DEA quantifies efficiency scores objectively, while Tobit regression determines the drivers of efficiency, making this approach robust for policy-oriented research.

3. RESULTS AND DISCUSSIONS

This section presents the results of the study, focusing on the production efficiency and profitability of selected farm crops in the Niger Delta region. The analysis evaluates crop yield, cost structures, and economic benefits of Cassava, Rice, Cocoa, Plantain, and Oil Palm. Furthermore, efficiency scores were derived using Data Envelopment Analysis (DEA) to assess resource utilization across different crop types. A Tobit regression model was employed to identify key determinants of efficiency, with a specific focus on cost and productivity.

3.1 Farm Production and Profitability

Table 1: Production of farm produce (Cassava, Rice, Cocoa, Plantain, Oil palm)

Crop Type	Crop Yield (Metric tons)	Cost of Farm produce per metric tons	Productivity of farm produce	Benefit (N)
Cassava	75000	50,000	3,750,000,000	119,734,907.6
Cocoa	1200	2,700,000	3,240,000,000	2,595,183,934.14
Plantain	4500	2,500,000	11,250,000,000	10,605,183,934.14
Rice	7000	1,500,000	10,500,000,000	8,563,874,777.6
Oil palm	750	1,800,000	1,350,000,000	60,367,868.3

Source: Researchers computation 2024

The production analysis of farm produce in Table 1 reveals significant variations in crop yield, cost, productivity, and economic benefits. Plantain and Rice emerge as the most profitable crops, generating benefits of ₦10.61 billion and ₦8.56 billion, respectively, due to their high productivity levels. Cocoa, despite its relatively low yield (1,200 metric tons), demonstrates strong profitability with a benefit of ₦2.60 billion, attributed to its high market price per metric ton. Cassava, while having the highest yield (75,000 metric tons), records the lowest benefit (₦119.73 million), indicating inefficiencies or lower market value. Oil Palm, with the lowest yield and total productivity, also records modest profitability (₦60.37 million). These results highlight the economic potential of high-value crops like Cocoa, Plantain, and Rice while emphasizing the need for efficiency improvements in Cassava and Oil Palm production to enhance their profitability.

3.2 Efficiency Analysis of Farm Production

Table 2: Summary result of DEA Efficiency Scores

Efficiency Range	Number of Firms	Percentage (%)
0 ≤ E < 0.1	2	40%
0.1 ≤ E < 0.2	0	0%
0.2 ≤ E < 0.3	0	0%
0.3 ≤ E < 0.4	0	0%
0.4 ≤ E < 0.5	0	0%
0.5 ≤ E < 0.6	0	0%
0.6 ≤ E < 0.7	0	0%
0.7 ≤ E < 0.8	0	0%
0.8 ≤ E < 0.9	0	0%
0.9 ≤ E < 1.0	0	0%
E = 1.0	3	60%

The Data Envelopment Analysis (DEA) results presented in Table 2 indicate that three out of the five farm produce categories achieved 100% efficiency, meaning they are on the efficiency frontier and are utilizing resources optimally. However, two categories (40%) have efficiency scores below 0.1, suggesting significant inefficiencies in resource utilization. The mean efficiency is 0.609, which indicates that, on average, farms could potentially improve efficiency by 39.1% to reach the optimal performance level. These results highlight the need for improved resource allocation, cost management, and production strategies for inefficient crops to enhance overall productivity and sustainability.

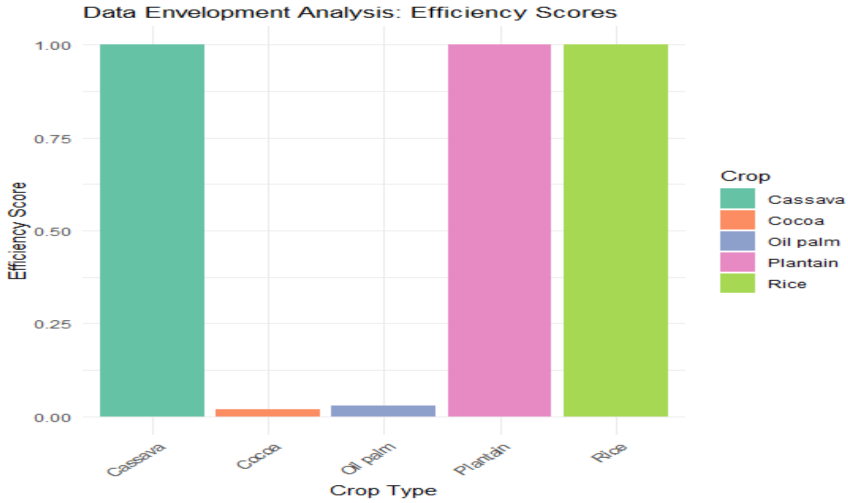

Figure 2: Plot of Data Envelopment Analysis for crop yield

Figure 2 presents the DEA efficiency scores for different crop types. The analysis indicates that Cassava, Plantain, and Rice achieved an efficiency score of 1.00, meaning they operate on the efficiency frontier and utilize resources optimally. In contrast, Cocoa and Oil Palm exhibit significantly lower efficiency scores, indicating substantial room for improvement in resource allocation and productivity.

3.3 Determinants of Efficiency in Farm Production

Table 3: Tobit Regression Results for Determinants of Efficiency					
Predictor	Estimate	Std. Error	z-value	p-value	Significance
Intercept	7.3504	6.3618	1.155	0.24793	Not Significant
log(Cost)	-1.489	0.5411	-2.752	0.00593	**Significant (p < 0.01)**
log(Productivity)	0.6719	0.1196	5.617	1.95E-08	**Highly Significant (p < 0.001)**
Log(scale)	-2.1555	0	-Inf	< 2e-16	**Highly Significant**

The Tobit regression analysis in Table 3 reveals that log(Cost) has a statistically significant negative impact on efficiency ($\beta=-1.4890$, $p=0.00593$), indicating that as production costs increase, efficiency tends to decrease. Conversely, log(Productivity) has a highly significant positive effect ($\beta=0.6719$, $p<0.001$), suggesting that greater productivity enhances efficiency. The intercept is insignificant ($p=0.24793$), meaning there is no strong baseline efficiency independent of cost and productivity.

Table 4: Model Summary	
Test Statistic	Test Value
Scale Parameter	0.1158
Log-likelihood	1.499
Wald Statistic	34.35 (*p*-value = 3.48e-08, indicating overall model significance)

The result in Table 3 found Wald statistic (34.35, $p=3.48e{-}08$) which confirms the overall model's statistical significance. These findings suggest that strategies focused on reducing costs and improving productivity could significantly enhance farm efficiency.

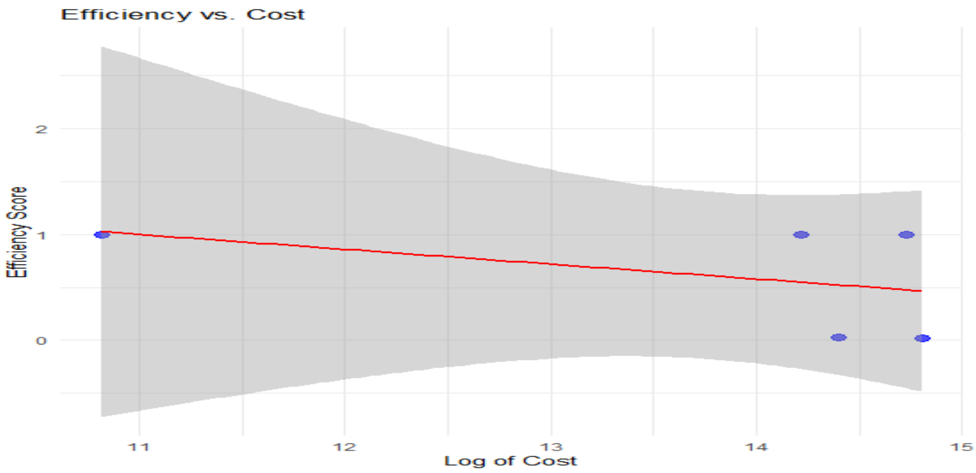

Figure 3: Plot of Efficiency and Cost

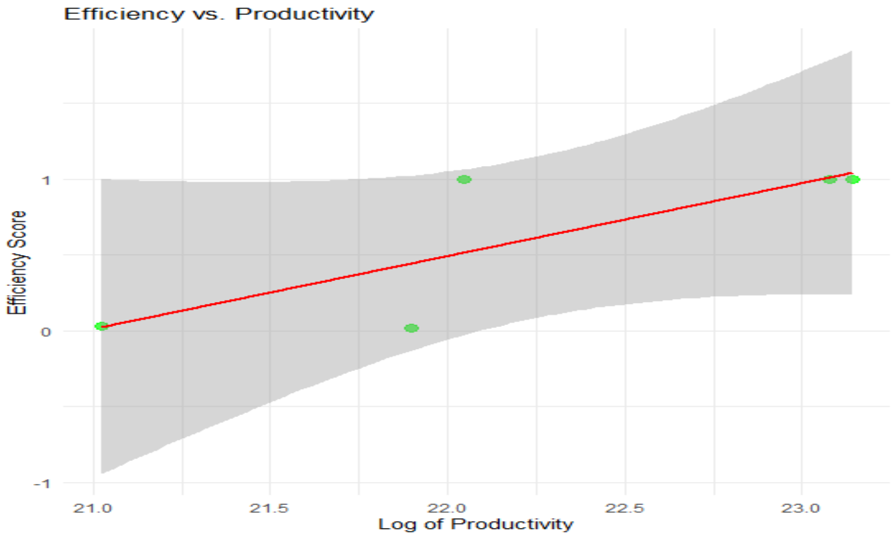

Figure 4: Plot of Efficiency and Productivity

Figure 3 presents a scatter plot of efficiency scores against the logarithm of cost, with a fitted regression line (in red) and a confidence band (in grey). The negative slope of the regression line suggests an inverse relationship between cost and efficiency, meaning that as production costs increase, efficiency tends to decline. This aligns with the Tobit regression results, where log(Cost) had a significant negative coefficient (-1.4890, $p = 0.00593$), indicating that higher costs are associated with lower efficiency scores. Moreover, the negative relationship between efficiency and cost suggests that reducing production costs can significantly improve farm efficiency. Agricultural policies should target cost-effective solutions and productivity-enhancing strategies to ensure sustainable and profitable farm production.

Similarly, Figure 4 illustrates the relationship between efficiency scores and the logarithm of productivity. The scatter plot shows a positive correlation, as indicated by the upward-sloping red regression line. This suggests that higher productivity levels are associated with greater efficiency scores. The Tobit regression results support this finding, where log(Productivity) had a significant positive coefficient (0.6719, $p < 0.001$), implying that as productivity increases, farm efficiency improves. The positive association between productivity and efficiency underscores the need for agricultural policies and investment strategies that prioritize productivity improvements as a pathway to enhancing overall farm efficiency.

4. Conclusion

This study evaluated the efficiency and profitability analysis of agro-production in the Niger Delta using Data Envelopment Analysis (DEA) and Tobit regression modelling. The findings highlight substantial variations in farm productivity, cost structures, and profitability across different crops, with Plantain and Rice emerging as the most profitable, while Cassava and Oil Palm exhibit inefficiencies that limit their economic benefits. The study establishes that production costs negatively impact efficiency, whereas productivity enhances efficiency, reinforcing the importance of cost-effective and productivity-enhancing strategies in agricultural practices.

The DEA results reveal that while some crops operate at optimal efficiency, others require significant improvements in resource allocation and farm management techniques. Also, the findings of the Tobit regression further emphasize the need for targeted policy interventions that reduce input costs, optimize resource utilization, and enhance farm productivity. These results provide valuable insights for policymakers, agribusiness stakeholders, and farmers to implement sustainable, data-driven strategies to improve agricultural performance in the Niger Delta region.

Given the Niger Delta's potential for agribusiness-driven economic transformation, the study recommends: enhancing access to improved farming technologies, including mechanization, irrigation systems, and high-yield crop varieties; reducing input costs through government subsidies, efficient supply chain management, and cost-effective production techniques; expanding agricultural extension services to educate farmers on best practices in resource allocation, productivity enhancement, and cost control; encouraging diversification into high-value crops like Cocoa and Plantain to maximize profitability and economic sustainability; and strengthening financial support systems, including credit facilities and agricultural loans, to improve smallholder farmers' ability to invest in efficiency-improving technologies.

Hence, this study was able to contribute to evidence-based policymaking for improving sustainability, resource allocation, and farmer profitability in the Niger Delta by integrating quantitative efficiency modelling with practical agricultural insights.

While the study offers significant contributions, several limitations should be acknowledged: the present study focuses on selected crops (Cassava, Rice, Cocoa, Plantain, and Oil Palm), which may not fully represent the diversity of agricultural activities in the Niger Delta. Future research should expand the scope to include other vital crops and livestock farming to provide a more comprehensive analysis of the region's agricultural efficiency. The study primarily focuses on economic and technical efficiency drivers but does not extensively analyze institutional, cultural, and policy-related constraints affecting farm operations. Future research should investigate the role of land tenure systems, access to credit, market access, and governance structures in shaping agricultural efficiency.

In conclusion, this study underscores the importance of efficiency-driven agricultural policies in enhancing profitability and sustainability in the Niger Delta. By addressing the identified limitations, future research can refine analytical frameworks and contribute to more effective agricultural strategies that foster food security, rural development, and economic resilience in the region.

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