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Effect of adoption of Sustainable Agricultural Practices (SAP) on profit efficiency among cassava farmers in Ogun State, Nigeria

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Abstract

Background and Objective: Despite cassava's many benefits to the world, many farmers still embrace unsustainable farming methods, which frequently lead to pest infestations, degraded soil, and low profits. Adopting Sustainable Agricultural Practices (SAP), such as integrated pest management, organic manuring, and agroforestry systems, could undoubtedly improve the profitability of cassava production. Nevertheless, there is still a shortage of empirical evidence regarding the economic impacts of these practices, particularly concerning profit efficiency. The study was conducted in Ogun State, Nigeria, to assess the adoption of SAP and its impact on profit efficiency among cassava farmers. The study described the farmers' socio-economic characteristics, identified the adopted SAP, determined the profitability of cassava production, and examined the determinants of profit efficiency.

Methodology: The study's data set was primary. It was obtained from 120 farmers using a questionnaire. The farmers were selected via a multi-stage sampling procedure. Data analysis methods include descriptive statistics, budgetary analysis, and the Cobb-Douglas stochastic frontier profit function.

Main Results: The results revealed that the cassava farmers were predominantly male (79.20%), with an average farmer being 45 years old.

SAP adopted includes soil enrichment (65.00%), integrated pest management (63.30%), intercropping (59.30%), crop rotation (55.80%), and mixed farming (54.20%), among others. Furthermore, given the profitability indices, cassava production is profitable in the study area. Determinants of profit efficiency include farm size, labour cost, cost of cassava stem, age, education, extension contact, mixed farming, and integrated pest management.

Conclusions: The study's findings suggest that cassava farming is profitable and SAP, like mixed farming and integrated pest management, influences profit efficiency. Farmers also need increased extension services to increase their knowledge and awareness of SAP.

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INTRODUCTION

Agriculture contributes substantially to economic growth, progress, and industrialization, especially in developing nations like Nigeria (Pawlak and Kołodziejczak, 2020). Crop production plays a dominant role, contributing 86.85% of the sector's total nominal value in the first quarter of 2023 (National Bureau of Statistics, 2023). Trentinaglia *et al.* (2023) emphasize that meaningful development in any developing country is unattainable without an adequately developed agricultural sector, as it ensures self-reliance in food production and reduces dependence on food imports. Cassava, as one of the staple crops, is gaining widespread acceptance and quickly replacing other crops like yams due to its resilience and role as an insurance crop against hunger (Food and Agriculture Organization, 2022). However, despite its increasing relevance, cassava production in Nigeria is hindered by poor farming practices, pest infestations, soil degradation, and limited access to inputs, particularly among smallholder farmers (Akpan and Effiong, 2022). This results in inefficient resource usage and, eventually, reduced profitability. To address these constraints, Sustainable Agricultural Practices (SAPs) have emerged as an essential strategy.

SAPs are ecologically sound, economically viable, and socially acceptable techniques that include organic manuring, crop rotation, intercropping, integrated pest management (IPM), agroforestry, and mixed farming (Pretty *et al.*, 2011; Van Thanh and Yapwattanaphun, 2015). These practices aim to increase productivity while preserving environmental quality and supporting rural livelihoods. Evidence shows that SAPs can enhance soil fertility, stabilize yields, reduce input costs, and improve food security and farm incomes (Ghimire *et al.*, 2012; Fanadzo, 2013; Khatri-Chhetri *et al.*, 2016; Latati *et al.*, 2016). Additionally, Tilman *et al.* (2002) found that adoption of integrated pest management techniques improved profit efficiency. Also, Reganold and Wachter (2016) found that soil health maintenance through organic manuring enhances stable yields and profit efficiency over time as farmers are shielded from synthetic inputs price volatility.

While many studies (Hennessy *et al.*, 2013; Ettah and Nweze, 2016; Mathieu *et al.*, 2019; Oyewo and Oladeebo, 2023) highlight the yield or food security benefits of SAPs, empirical evidence on their impact on profit efficiency remains limited, particularly in the Nigerian context. Profit efficiency refers to a farm's ability to generate the maximum profit given prevailing input prices and production technology (Farrell, 1957). Understanding how SAPs affect this efficiency is essential for aligning sustainability goals with farm-level profitability.

The theoretical foundation of this study draws from both the Resource-Based View (RBV) Theory and Production Theory. The RBV theory posits that farm enterprises can achieve a sustainable competitive advantage by developing and utilizing unique, valuable, and inimitable resources. In the context of smallholder agriculture, SAPs represent strategic resources that improve productivity, reduce costs, and enhance environmental resilience (Barney, 1991). Similarly, Production Theory provides a framework for understanding how farmers maximize outputs relative to inputs under given resource constraints. According to this view, SAPs can help farmers shift their production frontier outward by enhancing technical and allocative efficiency (Farrell, 1957; Aigner *et al.*, 1977).

Despite the theoretical promise, relatively few empirical studies in Nigeria have specifically examined how SAP adoption influences profit efficiency among cassava farmers. Most existing works focus broadly on agricultural productivity or food security without isolating cassava or profitability metrics. Addressing this gap is vital for informing policy and guiding resource allocation to practices that simultaneously improve sustainability and economic outcomes. Therefore, this study bridges that gap by empirically examining how the adoption of SAPs influences profit efficiency among cassava farmers in Ogun State, Nigeria. Grounded in these theoretical perspectives, the study not only investigates the adoption and types of SAPs used but also quantifies their contribution to profit efficiency using a Cobb-Douglas stochastic frontier approach. In doing so, it tests theoretical assumptions in a real-world context of smallholder farming, offering insights that are both academically relevant and practically actionable. These specific objectives were considered: i) to describe the farmers' socio-economic characteristics, ii) to identify the SAP adopted among the cassava farmers, iii) to estimate the profitability of cassava farming, and iv) to examine the effect of SAP on profit efficiency among cassava farmers (Figure 1).

The hypothesis for the study is:

H_0: There is no relationship between SAP adoption and profit efficiency among cassava farmers

H_a: There is a relationship between SAP adoption and profit efficiency among cassava farmers

MATERIALS AND METHODS

The Abeokuta Agricultural Development Programme (ADP) Zone in Ogun State was the study area. It lies between latitude 7.1475^o N and longitude 3.3619^o E. The study area's land size is 879 km^2. In Ogun State, farming is the most common economic activity and is pivotal in the state's economy. Other economic activities include fishing, apparel, and textile industries. This location was chosen for its rich agricultural heritage and potential to provide valuable insights into farming practices and profit efficiency.

Sampling Procedure

The study's population comprises all smallholder cassava farmers in the Abeokuta Agricultural Development Programme (ADP) Zone of Ogun State. 120 cassava farmers were selected using a multi-stage sampling procedure. In stage one, 2 blocks were chosen randomly from the 6 blocks in the ADP zone. In stage two, 2 cells were randomly selected from each block to give 4 cells. In stage three, proportionate sampling across the 4 cells was done

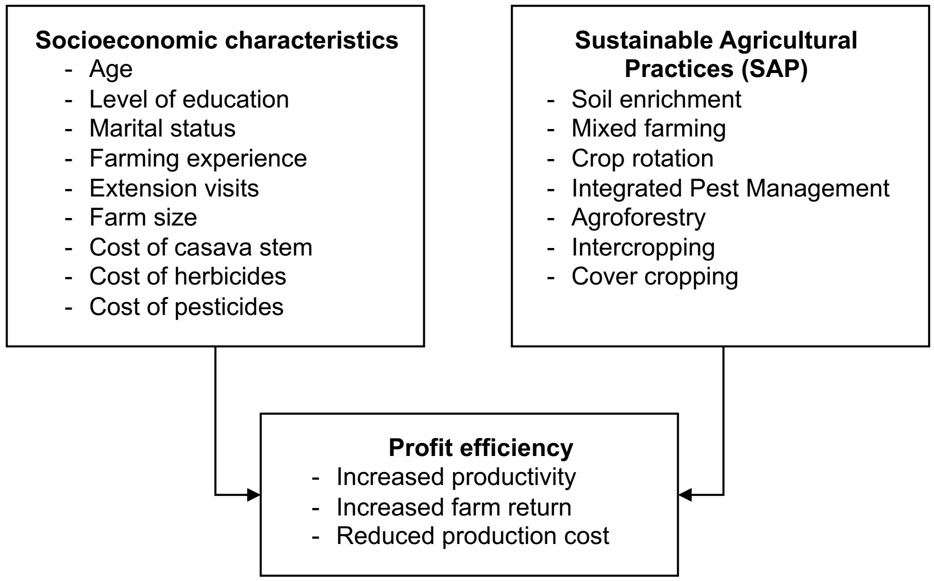

Figure 1 Conceptual framework

to select 120 cassava farmers. Primary data was collected between April 2023 and March 2024 with a questionnaire designed to capture the study's objectives. Four senior colleagues in this field of study validated this instrument (questionnaire), and a reliability test was conducted using the test and re-test method. Furthermore, the questionnaire's face validity was measured by pretesting it with small farmer groups to ensure easier understanding and correct interpretation of the questions. For clarity, a pilot test was also carried out among twenty farmers, who were randomly selected from the target population. Feedback from the pilot testing was improved upon.

The study's sample size is justified in that similar studies (Ettah and Kuye, 2017, used n = 108; Edeoghon *et al.*, 2008, used n = 96; Onuk *et al.*, 2017, used n = 90) on sustainable agriculture and profit efficiency have used comparable or smaller sample sizes, which produced meaningful and statistically significant results, thus, reinforcing the validity of n = 120 for this study.

This suggests that n = 120 aligns with standard research practices in this field. Also, the chosen sample adequately represents the diversity within the target farming population, capturing variations in farm size, production methods, and economic conditions. In addition, given the study's budget and logistical constraints, n = 120 allows for a thorough yet manageable data collection process without compromising the reliability of the findings. Considering these factors, the sample size is justified as methodologically sound and practically feasible. External factors in the data collection process were minimized by ensuring that the data were collected within a consistent time frame to prevent time-related bias, and potential outliers were statistically controlled.

Furthermore, to strengthen the sample size of 120 respondents, a power analysis was conducted. The sample size calculation was based on detecting a moderate effect size (Cohen's d = 0.5) with a confidence level of 95% ($\alpha = 0.05$), margin of error (set at 0.10 for practical field conditions) and a power of 80% ($\beta = 0.20$), which represent standard thresholds for agricultural and social science research (Cohen, 1988). Using the standard formula for sample size determination for proportions, a minimum of 96 respondents was obtained to achieve statistically reliable results. However, a total of 120 cassava farmers were selected to strengthen the representativeness of the findings and to allow for better subgroup analysis across the study communities. Thus, the final sample size exceeds the minimum required for statistical reliability, ensuring that the study's conclusions are both robust and generalizable.

Data on cassava farmers' socio-economic characteristics, SAP adopted, input costs, and output were collected. The collected data were analyzed using descriptive statistics (mean, mode, frequency, and percentage) to describe the cassava farmers' socio-economic characteristics and examine the various SAPs adopted. The profitability of cassava farming was examined via budgetary analysis, while the Cobb-Douglas stochastic frontier profit function was utilized to investigate the factors influencing profit efficiency among cassava farmers.

SAP adoption was modelled using binary indicators (1 = adopted; 0 otherwise). This approach was chosen for its clarity in identifying the adoption status of individual practices and for maintaining comparability with previous empirical studies.

Model Specification

Budgetary analysis

Profit level determination in cassava farming involves estimating costs and returns. This includes the costs of each input used (variable and fixed), the amount of output (cassava) produced in kg/ha, and the price per unit of output produced. The cost and return (budgetary) analysis yielded the following mathematical notations for profitability ratios: net farm income (NFI), gross margin (GM), and benefit-cost ratio (BCR). This can be expressed mathematically below:

Net farm income (NFI) = Profit (π) = TR - TC ---[1]

Gross margin (GM) = TR - TVC ---[2]

Benefit-cost ratio (BCR) = TR/TC ---[3]

Rate of return on investment (ROI) = NFI/TC ---[4]

where Total cost (TC) = Total fixed cost (TFC) + Total variable cost (TVC)

TR = Total revenue (₦/ha)

= Output (Q) × Price (P) = PQ

TVC = Total variable cost (₦/ha)

TFC = Total fixed cost (₦/ha)

P = Unit price of output (₦/kg)

Q = Cassava total output (kg)

Following the earlier documentation of Oke *et al.* (2022), an agricultural enterprise is profitable if the following conditions are satisfied: TR is greater than TC, BCR value exceeds 1, ROI value is above zero, and GM and NFI (profit) values are positive.

Cobb-Douglas stochastic frontier profit function

The Cobb–Douglas functional form of the stochastic frontier profit function was used to ascertain profit efficiency among cassava farmers. Following the earlier study of Akpan *et al.* (2013), the frontier model was specified as follows:

$$\ln C = ß_0 + ß_1 \ln X_1 + ß_2 \ln X_2 + ß_3 \ln X_3 + ß_4 \ln X_4 + ß_5 \ln X_5 + V_i – U_i \quad ---[5]$$

where ln = logarithm to base, C = profit of the cassava farmers (N/ha), X_1 = farm size (ha), X_2 = hired labour cost (N/ha), X_3 = cost of cassava stem cuttings (N/ha), X_4 = cost of pesticide (N/L), X_5 = cost of organic fertilizer (N/kg), U_i = error term, $ß_0$ = constant term, $ß_1$ - $ß_5$ = regression coefficients. U_i are random independent variables with a normality assumption of mean zero and constant variance, N $(0,\delta^2)$. The non-negativity assumption of these random variables has been established to be crucial in understanding and addressing profit inefficiency in production (Aigner *et al.*, 1977).

Profit inefficiency determinants are modeled as:

$$U_i = \alpha_0 + \alpha_1 Z_1 + \alpha_2 Z_{2i} + \alpha_3 Z_{3i} + \alpha_4 Z_{4i} + \alpha_5 Z_{5i} + \alpha_6 Z_{6i} + \alpha_7 Z_{7i} + \alpha_8 Z_{8i} + \alpha_9 Z_{9i} \quad ---[6]$$

where U_i = profit inefficiency, Z_1 = intercropping as SAP (adopted = 1; 0 otherwise), Z_2 = mixed farming as SAP (adopted = 1; 0 otherwise), Z_3 = crop rotation as SAP (adopted = 1; 0 otherwise), Z_4 = integrated pest management as SAP (adopted = 1; 0 otherwise), Z_5 = farmers' age (year), Z_6 = farmers' level of education (years), Z_7 = marital status (married = 1; 0 otherwise), Z_8 = farming experience (year), Z_9 = extension contacts (yes = 1; 0 otherwise), α_0 - α_9 = parameters.

The Cobb-Douglas stochastic frontier profit function was selected for this study due to its simplicity, interpretability, and well-established use in agricultural economics research. The Cobb-Douglas form enables the direct estimation of input elasticities and profit efficiencies with relatively few parameters, making it particularly suitable for studies with moderate sample sizes. Additionally, it imposes constant elasticity of scale and monotonicity assumptions that align with typical smallholder farming conditions in developing countries, where proportional relationships between inputs and outputs are commonly observed (Battese and Coelli, 1995).

RESULTS AND DISCUSSION

Socio-economic Characteristics of Cassava Farmers

The socio-economic profiles of cassava farmers in the study area, as shown in Table 1, depict that 79.20% of the farmers were male, while 20.80% were female. This suggests that more men than women are into cassava farming in the study area. In contrast, females tend to engage in value-added activities, such as processing and marketing. The age distribution of the farmers showed that very few (7.50%) were less than 30 years of age, while a large number (43.30%) were between 41 and 50 years, with an average farmer being 45 years old. This situation might have a positive effect on labour supply in the study area. Agricultural production necessitates physically fit and active individuals; an unskilled labour supply may, to some extent, may not be a major hindrance to the production activities of cassava farmers in the study area. This aligns with the findings of Mgbada *et al.* (2016) regarding their investigation of SAP and its determinants among cassava farmers in Southeast Nigeria. A related study conducted by Onuk *et al.* (2017) regarding the economics of maize-cowpea intercropping production in Kokona Local Government Area of Nasarawa State revealed that labour supply was not an issue because most farmers were in their economic prime.

The result in the table also revealed that 97.50% were married, while 2.50% were single. This result aligns with that of Girei *et al.* (2020), who reported that marital status plays an essential role in farm business if both males and females get involved with agricultural activities. Married couples contributed significantly to the overall growth of farm enterprises, and increased output was observed when wives were given separate portions of farmland for farming. It was found that 7.50% of cassava farmers had primary education, 83.30% had secondary education, and 9.20% had tertiary education. This could enhance the adoption and application of innovative technology in cassava production. This is crucial to increased cassava output. Farmers with more education would find it easier to implement the latest technology in the study area. Education had a favorable impact on the adoption of innovation that could increase farmers' production output, as Onuk *et al.* (2017) reported in their research. In addition, this result was also consistent with a study conducted by Bassey *et al.* (2014), which found that a high rate of education had a positive impact on cassava yield. The result also depicted that 50% of the farmers had between 1 and 5 persons in their households. Furthermore, 49.20% had between 6 and 10 persons in their households, while only 0.80% of the farmers had households made up of more than 10 persons. Household size could be essential in cassava production as households with more individuals can supply more family labour.

Table 1 Distribution of cassava farmers by socio-economic characteristics

Variables	Frequency	Percentage	Mean/Mode
Sex			
Male	95	79.20	
Female	25	20.80	
Total	120	100.00	Male
Age (year)			
≤ 30	9	7.50	
31–40	33	27.50	
41–50	52	43.30	
51 and above	26	21.70	
Total	120	100.00	45 years
Marital status			
Married	117	97.50	
Single	3	2.50	
Total	120	100.00	Married
Educational qualification			
Primary	9	7.50	
Secondary	100	83.30	
Tertiary	11	9.20	
Total	120	100.00	Secondary education
Household size (number of persons)			
1–5	60	50.00	
6–10	59	49.20	
> 10	1	0.80	
Total	120	100.00	6 persons
Farm size (ha)			
≤ 1.0	12	10.00	
1.1–2.0	65	54.20	
2.1–3.0	43	35.80	
Total	120	100.00	2 ha
Farming experience (year)			
< 10	6	5.00	
10–20	71	59.20	
> 20	43	35.80	
Total	120	100.00	18 years
Group membership			
Cooperative society	94	78.30	
Farmers association	14	11.70	
Social group	12	10.00	
Total	120	100.00	Cooperative society
Access to extension services			
Yes	110	91.70	
No	10	8.30	
Total	120	100.00	Yes

This result was consistent with that of Vihi *et al.* (2017), who found that large households are important for labour supply, which raises the productivity of low-income resource farmers. According to the farm size distribution, more than half (54.20%) of the farmers had between 1.1 and 2.0 ha of farmland, while 35.80% had between 2.1 and 3.0 ha of farmland.

The mean farm size of the cassava farmers in the study area was 2 ha. Cassava farmers were mostly small-scale farmers due to the small size of their farm holdings, and as a result, their output level was inevitably low. This finding aligns with that of Mgbada *et al.* (2016), who found that cassava farmers in Southeast Nigeria were small-scale holders. In addition, more than half (59.20%) of the farmers had between 10 and 20 years of experience in farming, whereas just 5% had below 10 years of experience in farming. 35.80% had more than 20 years of farming experience. This suggests that most farmers in the study area are experienced in cassava production. Also, experience and agricultural output are positively correlated, as Edeoghon *et al.* (2008) documented. Membership in various groups revealed that the majority (78.30%) were members of cooperative societies, 11.70% were members of farmers' associations, and 10% were members of social groups. This may enhance access to credits that could improve the current scale of production. The result further showed that 91.70% of the farmers could access extension services, whereas very few (8.30%) could not. Access to extension services could provide farmers with recent production techniques that can improve their production status.

Sustainable Agricultural Practices (SAP) Among Cassava Farmers

SAP adoption among the cassava farmers, in ranking order as shown in Figure 2 revealed that soil enrichment is mostly (65%) adopted, followed by integrated pest management (63.30%), intercropping (59.30%), crop rotation (55.80%), mixed farming (54.20%), agroforestry (45.80%) and cover cropping (38.50%). Adoption of soil fertility maintenance was also found in the study of Rigby *et al.* (2001) as the most common sustainable agricultural practice among cassava farmers.

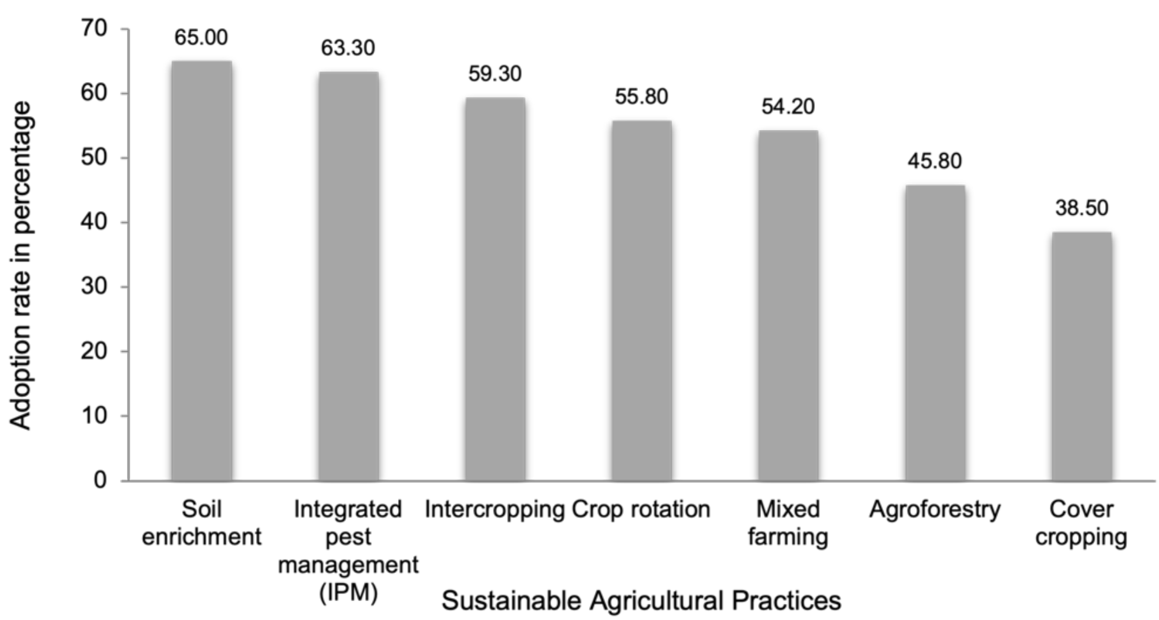

Figure 2 Sustainable Agricultural Practices (SAP) among cassava farmers

Profitability of Cassava Farming

The budgetary analysis showing the costs and returns to cassava farming is presented in Table 2. This result indicates that cassava farming is a worthwhile venture in the study area, considering the various profitability indices previously stated. The total revenue exceeds the total cost; net farm income and gross margin have positive values. Also, the rate of return on investment was more than zero. The result showed that the revenue generated from cassava farming is N301,069 ($187.35). The total fixed cost expended was N26,481 ($16.48), which accounted for 17.20% of the total production cost. The total variable cost expended was N127,591 ($79.40), and this accounted for 82.80% of the total production cost. The total production cost of cassava per hectare was N154,072 ($95.88). The result also showed that the costs expended on labour accounted for the largest share (50.10%) of the total cost of cassava production. Organic fertilizer, cassava stems, and the cost of pesticides accounted for 15.42%, 12.28%, and 3.46% of the total production cost, respectively. This clearly showed that a large sum of money was spent on labor and the acquisition of organic fertilizer in the production of cassava. Depreciation on fixed assets, such as land, cutlass, hoe, wheelbarrow, and file, represented 17.20% of the total cost of production. The gross margin from cassava farming is N173,478 ($107.95) while the profit or Net farm income was N146,997 ($91.47). In addition, the rate of return on investment in cassava farming, with a value of 0.95, means that for every one naira invested, a return of N1.95k is obtained, resulting in a profit of N0.95k.

Profit Efficiency Among Cassava Farmers

The profit efficiency of cassava farmers is presented in Table 3. As shown in the table, 4.10%

Table 2 Average costs and returns for cassava production per hectare among the respondents

Items	Average value (N)	% of TC
A. Total revenue (TR)	301,069.00	
Sales of cassava tubers (ton)	6.02	
Price per ton (naira)	50,000.00	
Variable costs		
Hired labor	77,195.00	50.10
Cassava stem	18,925.00	12.28
Fertilizer (organic)	23,762.00	15.42
Herbicides	2,372.00	1.54
Pesticides	5,337.00	3.46
B. Total variable costs (TVC)	127,591.00	82.80
Fixed cost (depreciated)		
Land, cutlass, hoe, file, wheelbarrow		
C. Total fixed cost (TFC)	26,481.00	17.20
D. Total cost (TC) = B + C	154,072.00	100.00
E. Gross Margin = A - B	173,478.00	
F. Net Farm Income = A - D	146,997.00	
G. Rate of return on investment (ROI) = F/D	0.95	
H. Benefit-cost Ratio (BCR) = A/D	1.95	

Note: 1 USD for Naira (N) = 1,607, 1 ton = 1,000 kg.

Table 3 Distribution of cassava farmers according to profit efficiency

Profit efficiency range	Frequency	Percentage
≤ 0.20	5	4.10
0.21–0.40	35	29.20
0.41–0.60	50	41.70
0.61–0.80	18	15.00
0.81–1.00	12	10.00
Total	120	100.00
Minimum	0.13	
Maximum	0.95	
Mean	0.64	

of the farmers had a profit efficiency value of 0.20 or below. 29.20% had a profit efficiency value between 0.21 and 0.40. A large number (41.70%) had profit efficiency values between 0.41 and 0.60, while 15% and 10% had profit efficiency values of 0.61–0.80 and 0.81–1.00, respectively. The mean profit efficiency was 0.64, whereas 0.13 and 0.95 represented the minimum (lowest) and maximum (highest) profit efficiency among the farmers, respectively. A mean profit efficiency value of 0.64 suggests that the cassava farmers could acquire 64% of their profit expectation from a unit combination of inputs.

In contrast, management inefficiencies accounted for roughly 36% of the profit lost among the farmers. This finding suggests that cassava farmers are operating 36% below the optimal profit frontier, indicating substantial inefficiencies in resource utilization, input management, or farming decisions. The practical consequence is reduced farm income and suboptimal returns on both private and public investments in cassava production. This finding aligns with that of Ettah and Kuye (2017), who reported a 0.35 likelihood increase in profit efficiency among farmers in Nigeria.

Stochastic Frontier Result of Profit Efficiency Determinants Among Cassava Farmers

The parameter estimates of profit efficiency determinants among cassava farmers are shown in Table 4. The estimated gamma parameter (γ) is 0.813 ($P < 0.01$). This implies that about 81.30% of the deviation in real profit from the maximum profit (profit frontier) among farmers can be attributed to dissimilarities in farmers' methods of operation rather than random error. The estimated coefficients' signs and significance levels in the inefficiency model also provide crucial insights into the profit efficiency of farmers. The estimated parameter for farm size is positively associated with profit at $P < 0.01$. The implication of this is that an increase in the size of the farmland cultivated will bring about an increase in profit efficiency. Specifically, a unit increase in farm size cultivated will increase profit efficiency by 18.80%. The practical implication of this is that if a farmer operating at a profit efficiency level of 0.60 expands his cassava farm size by 1 hectare, his expected profit efficiency could increase to 0.788. This means the farmer captures more of the potential maximum profit by better utilizing economies of scale, spreading fixed costs, and accessing better markets or production support. This supports policies that enable access to more land. This further agrees with the earlier findings of Oyewole and Oyewole (2023), who documented a positive relationship between profit and farm size cultivated. The costs of hired labour and cassava stems exhibited a significant negative relationship with

Table 4 Factors influencing profit efficiency among cassava farmers

Variables	Co-efficient	Standard error	t-value	P-value
Stochastic frontier profit model				
Constant	9.024***	2.160	4.18	0.003
Farm size	0.188***	0.030	6.27	0.000
Hired labour cost	-0.120**	0.061	1.97	0.040
Cassava stem cost	-0.020***	0.005	4.00	0.000
Pesticide cost	0.003	0.060	0.05	0.857
Fertilizer cost (organic)	-0.092	0.076	1.21	0.217
Inefficiency model				
Constant	2.753***	0.589	4.67	0.000
Intercropping	0.463	0.783	0.59	0.548
Mixed farming	-1.436**	0.656	2.19	0.031
Crop rotation	0.695	0.783	0.89	1.116
Integrated pest management	-0.496*	0.280	1.77	0.061
Farmers' age	-0.506*	0.300	1.69	0.058
Level of education	-0.184***	0.042	4.38	0.001
Marital status	0.097	0.242	0.40	1.986
Farming experience	-0.844**	0.415	2.03	0.033
Extension contacts	-0.994***	0.151	6.58	0.001
Sigma squared (δ^2)	10.471***	2.385	4.39	0.000
Gamma (γ)	0.813***	0.215	3.78	0.002
Log-likelihood function	-198.43			
Observations	120			

Note: ***, **, and * denote significance at 1%, 5%, and 10% probability levels, respectively. Agroforestry and cover cropping were excluded from the model because their empirical adoption rates were low among the respondents.

profit efficiency at P < 0.05 and P < 0.01, respectively. This implies that a unit increase in the price of these variables will lower the cassava farmers' profit efficiency by 12% and 2%, respectively. This result agrees with the earlier result of Oke *et al.* (2021a), who reported that the higher the cost incurred in the production process, the lower the expected returns in the form of profit.

The study also addressed the role of non-significant variables, such as pesticide and organic fertilizer costs, which were retained in the model for theoretical completeness and balanced interpretation. Their insignificance may be attributed to low variability or underreporting in input usage, indirect effects that are not fully observable in a single-season cross-sectional study, and potential substitution effects, such as reduced pesticide use resulting from the adoption of IPM. Despite their lack of statistical significance, these inputs may still have a significant influence on long-term profit efficiency and should be explored further in panel or longitudinal studies.

For the profit inefficiency model, the coefficient for age was significant at P < 0.10 but had a negative relationship with inefficiency. The negative sign indicates that as farmers age, inefficiencies in profit decrease, thereby increasing profit efficiency. This means that the older the farmer becomes, the more efficient he becomes, probably owing to the mastery of the intricacies involved in cassava production, which will not allow for the wastage of resources. This further corroborates the earlier documentation of Oke *et al.* (2022), who reported age as a positive contributor to profit efficiency among maize growers in Oyo State, Nigeria. An inverse and significant association was found between the level of education and profit inefficiency at $P < 0.01$ probability level. This result suggests that increasing educational attainment decreases profit inefficiency (i.e., increases profit efficiency). Specifically, education improves profit efficiency by 18% among farmers in this study's location, possibly due to better resource management, increased market access, and financial resources. This result is in tandem with that of Oke *et al.* (2021b) where education increases profit efficiency cum output in catfish farming. The educational attainment of the farmers affects the productivity of farmers as it is also expected to reduce the level of profit inefficiency, as educated farmers would find it easier to understand information on innovations with farm practices like the adoption of SAP and production technologies that can improve crop yield (Osun *et al.*, 2014).

The farming experience estimated coefficient was negative and significant at a $P < 0.05$ probability level, suggesting that an increase in farming experience tends to reduce profit inefficiency. Farming experience can increase profit efficiency by applying the practical knowledge and skills acquired by farmers over time, which allows for the optimization of agricultural operations, such as those using SAP, and the efficiency of resource use. This result aligns with the earlier report by Abu *et al.* (2012), who found that increased farming experience decreases the profit inefficiency of female smallholder farmers in the Atiba Local Government Area of Oyo State, Nigeria. A significant negative relationship was found between extension contacts and profit inefficiency at a $P < 0.01$ level of significance in this study. Contact with extension services or agents reduces profit inefficiency and improves profit efficiency. Extension contact with farmers creates opportunities for interaction, leading to the exchange of knowledge and information on improved farming technologies, such as SAP, which protects the environment through input cost reduction. These findings align with those of Oyewole and Oyewole (2023), who documented that extension services provide farmers with the necessary technical support and resources that contribute to improved profit efficiency.

The SAP variables influencing profit inefficiency were mixed farming and integrated pest management. These variables were found to reduce profit inefficiency among the farmers at $P < 0.05$ and $P < 0.10$ significant levels, respectively. This suggests that the higher the adoption of the two SAPs, the higher the profit efficiency. Specifically, as found in this study, profit efficiency is expected to increase substantially among farmers who adopt mixed farming and by 49.60% among those who adopt integrated pest management. Mixed farming, which involves combining livestock farming with crop production on the same piece of land, offers farmers an additional income source rather than relying on a single income source. Additionally, there is also an efficiency in resource use; for instance, the residues from cassava farming can be used as livestock feed, thereby reducing the cost of buying feed for the animals. Also, the animal's waste can serve as manure to enrich the soil nutrients. This resource recycling reduces cost and waste, thereby improving profit efficiency. This result aligns with an earlier study documented in Kenya, as reported by Greenlife Crop Protection Africa (2024). In the study, agroforestry and crop diversification are two sustainable farming strategies that Kenyan smallholder farmers have embraced. According to the study, during three years, farmers who adopted sustainable agricultural practices saw a 30% increase in net income compared to those who adopted traditional methods. Higher profits were attributed to better soil health and more resilience to shocks caused by climate change.

Integrated pest management as a SAP reduces the need for chemical pesticides on the farm. This reduces the cost of production and eventually improves profit efficiency among farmers as found in this study. This finding aligns with that of Tilman *et al.* (2002), who reported improved profit efficiency among adopters of the integrated pest management technique. A reduction in expenditure on pesticides was reported, which ultimately lowered production costs and directly contributed to higher net returns.

Additionally, research consistently demonstrates that farmers who employ sustainable farming methods tend to have larger profit margins than those who do not. Reduced input costs, improved market accessibility, premium pricing for commodities produced, and increased resilience to market and environmental variations are some factors that have led to this increased efficiency. For instance, in a study carried out in Ghana among smallholder farmers by Ehiakpor *et al.* (2021), it was found that integrated pest management, crop rotation, and mixed cropping, among others, are some of the SAP adopted by the farmers. Farmers who adopted sustainable practices achieved higher profit efficiency and higher returns on investment compared to those who did not.

Limitation of the Study

Due to financial and logistical constraints, the study aims to investigate the impact of SAP on food security and poverty. In addition, the cross-sectional design of this study also restricts the ability to capture the long-term effects of SAP adoption, particularly for practices such as agroforestry and organic fertilization, which have delayed benefits. Future research could utilize panel data to assess dynamic efficiency changes over time and incorporate adoption behavior models to explore the socio-economic and psychological drivers of SAP uptake. Additionally, mixed-method approaches could enrich the analysis by addressing contextual factors such as risk perception, gender, and institutional barriers. Further studies should also examine interaction effects among SAPs, explore broader outcomes such as food security or environmental efficiency, and investigate scalable adoption mechanisms, including cooperatives or public-private partnerships. These directions provide a more comprehensive understanding of SAP impacts and inform more effective policy interventions.

Cassava farming is a prominent activity among highly productive farmers, as it is both profitable and has been adopted by the farmers. Furthermore, SAP, like mixed farming and integrated pest management, has a positive impact on profit efficiency. The findings also showed that the mean profit efficiency of cassava farmers was 0.64. This suggests the potential for further profit optimization. The significant role of SAPs found in this study is consistent with results from similar contexts beyond Nigeria. For example, a study conducted in Kenya by Greenlife Crop Protection Africa (2024) revealed that smallholder farmers who adopted sustainable practices, including agroforestry and mixed farming, experienced a 30% increase in net income over three years compared to those using conventional methods. In Ghana, Ehiakpor *et al.* (2021) found that farmers who implemented interrelated SAPs such as integrated pest management and crop rotation recorded higher profit efficiency and improved returns on investment. Likewise, Van Thanh and Yapwattanaphun (2015) reported from Southeast Asia that the adoption of SAP among upland banana farmers in Vietnam enhanced both yield stability and profitability, mainly where extension support was available. These international comparisons suggest that the efficiency improvements and profitability gains observed among cassava farmers in Ogun State reflect a broader global pattern. The results demonstrate that promoting SAPs not only enhances farm profitability but also contributes to the sustainability and resilience of farming systems.

CONCLUSIONS

In conclusion, promoting the adoption of SAPs among cassava farmers offers a dual benefit of enhancing farm-level profitability while advancing broader goals of environmental conservation and food security.

Based on the findings of this study, several key recommendations are proposed: (i) provision of regular support to farmers to improve access to inputs such as organic fertilizers, improved cassava varieties, and affordable agroecological technologies; (ii) demonstration plots establishment to facilitate hands-on training and build farmer confidence in the long-term benefits of SAPs; (iii) training extension agents in participatory approaches that actively engage farmers and strengthen their capacity for adaptive SAP adoption; (iv) integrating SAPs into national and subnational agricultural development strategies, climate-smart agriculture plans, and food security programs; (v) strengthening farmer associations and cooperatives as platforms for technology dissemination, input procurement, and collective action; and (vi) recognition of the heterogeneity among farmers particularly in terms of education, land access, and market exposure when designing adoption support programs to ensure inclusive and scalable SAP implementation.

Furthermore, accelerating the adoption of SAPs requires coordinated efforts through technical assistance, institutional support, and evidence-based policymaking. By addressing economic, informational, and systemic barriers, stakeholders can drive a transition toward more profitable, sustainable, and climate-resilient cassava farming systems in Nigeria and other similar agroecological contexts.

CONFLICT OF INTEREST

The authors have no relevant financial or non-financial conflicts of interest to disclose.

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