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RESEARCH ARTICLE

Benefit-cost analysis of maize production in smallholder farming communities across climate-Smart agriculture technology bundles in Federal Capital Territory, Nigeria

Alabi, O. O[1*]., J. S. Aluwong[1,2], A. O. Omole[1], A. A. Yabagi[3], H. O. CHiogor[4], B. E. Okpe[4], A. F. Yusuf[3]. M. S. Bassey[3], H. N. Abubakar[3], A. P. Atteh[5]

[1]*Department of Agricultural Economics, Faculty of Agriculture, University of Abuja, PMB 117 Gwagwalada-Abuja, Federal Capital Territory, Nigeria*
[2]*Department of Agricultural-Extension and Management, School of Agricultural Technology, Nuhu Bamali Polytechnic, Zaria, Samaru Kataf Campus, Kaduna State, Nigeria*
[3]*National Cereals Research Institute, Badeggi, Niger State, Nigeria*
[4]*NIRSAL Plc, Plot 1581 Tigris Crescent, Maitama, Abuja, Nigeria*
[5]*Department of Agricultural Economics and Extension, Faculty of Agriculture, Federal University of Lafia, PMB 146 Lafia, Nasarawa State, Nigeria*

Abstract

The study analyzed the benefit-cost of maize production in smallholder farming communities across climate-smart agriculture technology bundles in Federal Capital Territory, Nigeria. A multi-stage sampling design was employed to select 220 maize farmers based on a well-structured questionnaire. The data were analyzed using descriptive statistics, four-point Likert scale, farm budgetary technique, financial analysis, and stochastic profit frontier model. The results show that maize production under CSA technologies is highly profitable with benefit cost ratio (BCR) of 1.902 and rate of return on investment of 82.05% indicating strong economic returns. Among the CSA technologies utilized by maize farmers the practices such as mulching, crop rotation and organic manure ranked highest in the adoption frequency. The stochastic frontier model shows that cost of improved seeds and manure significant increased profit, while high fertilizer costs had a negative effect on profit efficiency at 1% probability level. The inefficiency variables show that farming experience, access to credit, cooperative membership, extension services and number of CSA technologies utilized significantly reduce profit inefficiency. The average profit efficiency was 68.9%, with efficiency scores ranging from 0.21 to 0.96, suggesting a substantial gap between actual and potential profits. These findings reveal that while CSA technologies enhance efficiency and profitability, many farmers still operate below optimal efficiency levels. The study further recommends policies that promote the CSA technologies adoption, enhance access to credit, improved inputs, extension services and support farmer cooperatives.

Keywords: Benefit-Cost Ratio; Maize Production; Stochastic Profit Frontier Model; Climate-Smart Agricultural Technologies; Nigeria

1. *Introduction*

Maize (*Zea mays* L.) is a staple food crop of significant socio-economic importance in Nigeria, contributing immensely to household food security, welfare, national income, and rural livelihoods (FAO, 2021). As one of the most widely cultivated cereals, maize is integral to both human consumption and livestock feed production, making it indispensable within the country's agricultural sector. According to the National Bureau of Statistics, NBS (2020), maize accounts for about 60% of cereals grown by smallholder farmers in Nigeria. However, its production is increasingly challenged by climate variability, unpredictable rainfall patterns, declining soil fertility, poor access to inputs and poor adoption of adaptive technologies, particularly among smallholder farmers who dominate agricultural production in the country. Furthermore, Climate-Smart Agriculture (CSA) has emerged as a viable

***Corresponding author:** Olugbenga O. Alabi,
Email: omotayoalabi@yahoo.com
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approach and tool for enhancing the resilience, efficiency and productivity of smallholder farmers (FAO, 2013). More so, Climate-Smart Agriculture refers to integrated farming practices that sustainably increase productivity, enhance resilience (adaptation), reduce or remove greenhouse gases (mitigation), and enhance achievement of national food security and sustainable development goals (FAO, 2013). The CSA technologies applicable to maize production in Nigeria include the use of drought-tolerant and early-maturing varieties, conservation agriculture, crop diversification, improved water management (such as irrigation), and access to climate information services (World Bank, 2020). These interventions are particularly vital for farmers in Nigeria, where increasing weather extremes have exacerbated vulnerabilities and shocks in rain-fed farming systems. Despite the proven benefits of CSA, its adoption remains relatively low in many parts of sub-Saharan Africa, Nigeria inclusive (Ajayi *et al*., 2021). Constraints such as limited access to inputs, poor extension services, lack of credit, and low levels of awareness impede widespread implementation. More importantly, empirical evidence on the economic viability of CSA practices in maize production remains scarce, especially within Nigeria smallholder farming communities. Many policy interventions, initiatives and agricultural programs have been rolled out without rigorous benefit-cost evaluations to determine the return on investment for farmers. Consequently, there is a critical need for a systematic analysis of the costs incurred and benefits accrued from adopting CSA technologies in maize production. Such evidence is crucial for designing effective incentives, guiding policy frameworks, and promoting adoption. This study, therefore, aims to conduct a Benefit-Cost Analysis (BCA) of maize production under different CSA technology bundles adopted by smallholder farmers in the Federal Capital Territory, Nigeria. A benefit-cost analysis is a valuable tool in evaluating the economic feasibility of agricultural interventions by comparing the monetary value of benefits derived from a technology or practice to the costs associated with its implementation (Boardman *et al*., 2018). By employing this approach, the study will quantify the net economic gains or losses associated with various combinations of CSA practices such as improved seed use, conservation tillage, water harvesting, fertilizer application, and access to extension services across different farming contexts in Nigeria. Nigeria presents a suitable case study due to its diverse agro-ecological characteristics, mix of traditional and semi-modern farming practices, and increasing attention from agricultural development agencies. However, farmers often face production risks and limited access to modern inputs, exacerbating their vulnerability to climate change (IFPRI, 2022). The implications of CSA adoption in this setting will not only inform stakeholders but also contribute to broader national strategies aimed at achieving food security, rural poverty reduction, and sustainable agricultural development. Furthermore, analyzing CSA through a benefit-cost evaluation supports evidence-based decision-making and resource allocation. Policymakers and development partners often require concrete data on the economic returns of climate-smart practices to justify investments and design targeted subsidy or incentive schemes (Khatri-Chhetri *et al*., 2017). For smallholder farmers, who typically operate on thin profit margins, the perceived profitability of a technology significantly influences their willingness to adopt it. Therefore, demonstrating the cost-effectiveness of CSA practices in maize production could catalyze higher adoption rates and improve livelihoods.

Objectives and Scope of the Study

The main aim of this research is to analyze benefit-cost of maize production in smallholder farming communities across climate-smart agriculture technology bundles in Federal Capital Territory, Nigeria. Specifically, the objectives include:

(i) determine the climate smart agriculture (CSA) technologies currently being utilized by the maize farmers,

(ii) estimate the benefit-cost ratio (BCR) of maize production in smallholder farming communities across CSA technology bundles,

(iii) investigate the determinants of profit efficiency and inefficiency of maize farmers utilizing CSA technologies.

Hypotheses of the Study

This research is guided by the following null-hypotheses:
(i) The benefit-cost ratio of maize production across CSA technology bundles is less than one
(ii) There is no significant difference between CSA technologies utilized, socio-economic factors and profit inefficiency of maize farming

2. Materials and Methods

This study was carried out in Federal Capital Territory, Nigeria. This research utilized the use of a multi-stage sampling method. In the first stage, Federal Capital territory was purposively selected. The second stage involves the selection of two area councils using simple random sampling method. The third stage involves the selection of 4 villages within the two area councils using simple random sampling technique. The fourth-stage involves the use of a random sampling techniques, the total sample number of maize producers which approximately 220 respondents were selected. A multi-stage sampling design was utilized because of a variety of reasons, such as time efficiency, cost reduction, flexibility, and increase reliability. The method can be used when you have a large geographically dispersed respondents and you can get a probability sample without a complete list of samples. The method allows the researcher to obtain a more reliable estimate of population parameters like the mean. This sampling design enables you draw a respondent from a population using smaller and smaller groups (unit) at each stage. The sample frame of maize farmers approximately 489 respondents. Primary data of cross – sectional sources were used based on a well-structured questionnaire that was subjected to reliability and validity test. This sample size was estimated based on the established formula of Yamane (1967) as follows:

$$n = \frac{N}{1+N(e^2)} = \frac{489}{1+489\,(0.05^2)} = 220 \ldots\ldots(1)$$

Where,

n = The sample number

N = The total number of maize producers

e = 5%

The data obtained were analyzed using descriptive statistics, four-point Likert scale, farm budgetary technique, financial analysis, and the stochastic profit frontier model.

2.1. Four-Point Likert Scale

The perceived constraints faced by maize farmers was evaluated using a four-point Likert-type scale. The response options and values that was assigned are as follows: 4 means "frequently used," 3 means "used" 2 means "infrequently used," and 1 means "not used". A four-point Likert scale was used to rank the challenges faced by maize farmers in the study region. The average score was calculated as follows: (3 + 2 + 1)/3 = 2. This estimate was based on the work conducted by Ahaneku *et al*. (2020) and Ibeawuchi *et al*. (2020). The formula for the Likert-type measurement instrument is as follows:

$$X = \frac{\sum FX}{n} \qquad (2)$$

Where:

X = Mean Score,

Σ = Summation Sign,

F = Frequency, and

n = No of Responses.

2.2. Farm Budgetary Technique

Gross margin analysis is one of the farm budgetary method and it can be explained as the difference between the gross farm income (GFI) and total variable cost (TVC):

$$GM = \sum_{i=1}^{n} P_i Q_i - \sum_{i=1}^{n} P_j X_j \qquad (3)$$

$$GM = TR - TVC \qquad (4)$$

Where,
GM means the Gross Margin (₦)
TR means the Total Revenue (₦)

TVC is the Total Variable Cost (₦)

NFI = Gross Margin (GM) – Total Fixed Cost (TFC)

$$NFI = \sum_{i=1}^{n} P_i Q_i - \sum_{i=1}^{n} P_j X_j - K \qquad (5)$$

Where

NFI = Net Farm Income measured in Naira

GM= Gross Margin measured in Naira

P_i = Price of Maize Output ith ₦/Kg

Q_i = Quantity of Maize Output ith (Kg)

P_j = Price of Input jth (₦/Kg)

X_j = Quantity of Input jth used (Kg)

K = Total Fixed Cost (TFC)

2.3. Depreciation of Assets

The straight-line depreciation method is specified as:

$$\mathrm{D} = \frac{\mathrm{P} - \mathrm{S}}{\mathrm{N}} \qquad (6)$$

D= Depreciation of Farm Production Assets (Naira)

P= Purchase Cost of Farm Asset (Naira)

S = Salvage Value of Farm Asset (Naira)

N= Number of Years of the life span of the Farm Asset (Years)

2.4. Financial Analysis

The formula of Benefit-Cost Ratio (BCR) is stated as:

$$\mathrm{BCR} = \frac{\text{Gross Farm Income}}{\text{Total Variable Cosst}} = \frac{\mathrm{GFI}}{\mathrm{TVC}} \qquad (7)$$

The rate of return invested per naira is stated thus;

$$\mathrm{RORI} = \frac{\mathrm{NFI}}{\mathrm{TC}} \qquad (8)$$

Where, RORI means the Rate of Return per Naira Invested (Units); NFI is the Net Farm income from Maize Farming in Naira; TC is the Total Cost in Naira.

2.5. Stochastic Profit Efficiency Frontier Model

Stochastic Frontier Profit efficiency model follows the studies of Idiaye *et al*. (2022) and it is explicitly specified as follows:

$$Ln\, Z_i = \beta_0 + \sum_{j=1}^{7} \beta_i\, LnP_i + \beta_k LnP_k + v_i - u_i \qquad (9)$$

$$LnZ_i = Ln\beta_0 + \beta_1 LnP_1 + \beta_2 LnP_2 + \beta_3 LnP_3 + \beta_4 LnP_4 + \cdots + \beta_7 LnP_7 + Vi - Ui \quad (10)$$

β_1-β_7 = Regression Coefficients

V_i = Random Errors

U_i= Error Term as a result of PIE (Profit Inefficiency).

2.6. The Profit Inefficiency Model is specified as follows:

$$U_i = \propto_0 + \propto_1 Z_1 + \propto_2 Z_2 + \propto_3 Z_3 + \propto_4 Z_4 + \propto_5 Z_5 + \cdots + \propto_7 Z_7 \qquad (11)$$

Where,

U_i = Profit Inefficiency

$\propto_0$ = Constant Term

$\propto_1 - \propto_7$ = Parameters to be Estimated .

Table 1. Definition and Unit of Measurement of Variables included in the Stochastic Profit Frontier Model.

Variable Code	Variable	Definition and Unit of Measurement	Types of Variable
Y	Output of Maize	Dependent Variable in Kg	Continuous
X_1	Cost of Improved Seeds	Naira	Continuous
X_2	Manure Cost	Naira	Continuous
X_3	Labour Cost	Naira	Continuous
X_4	Fertilizer Cost	Naira	Continuous
X_5	Chemical Cost	Naira	Continuous
X_6	Transportation Cost	Naira	Continuous
X_7	Farm Size	Cost of Land in Naira	Continuous
		Profit Inefficiency Model	
Z_1	Sex	Gender of Maize Farmers 1= Male, 0 = Female	Categorical
Z_2	Experience	Number of Years in Maize Farming	Continuous
Z_3	Membership Cooperative	Membership to Farmer Group (1 = Member, 0 = Non-Member)	Categorical
Z_4	Credit	Amount of Credit Accessed in Naira	Continuous
Z_5	Extension	Number of Extension Contact per Month	Discrete
Z_6	Age	Age of Maize Farmer in Years	Discrete
Z_7	CSA Utilized	Climate Smart Agricultural Technology Utilized (Number)	Discrete

Source: Field Survey (2024).

3. Results and Discussion

3.1. The Climate Smart Agricultural Technologies (CSA) currently being utilized by Maize Growers

3.1.1. Mulching (Mean = 3.17; Rank = 1st)

Among the CSA technologies currently being utilized by maize farmers, mulching emerged as the most widely adopted practice in the study area, with a mean score of 3.17. A total of 87 respondents reported always using mulching, while only 24 reported not using it at all. Mulching helps retain soil moisture, suppress weed growth, and regulate soil temperature, thereby enhancing crop resilience to heat and drought (Lal, 2020). Its high adoption suggests farmers recognize its cost effectiveness and its immediate benefits in reducing moisture loss which is critical in rain-fed systems increasingly exposed to dry spells.

3.1.2. Crop rotation (Mean = 3.02; Rank = 2nd)

Crop rotation was ranked second with a mean of 3.02, indicating relatively high usage. Ninety-four respondents reported always using this practice, while only 25 did not. Crop rotation contributes to improved soil fertility and pest/disease control, which enhances maize yields over time (FAO, 2013). Its high ranking may reflect farmers' traditional knowledge and the ease of incorporating this method into existing cropping systems without requiring costly inputs.

3.1.3. Use of Organic Manure (Mean = 2.96; Rank = 3rd)

The use of organic manure was ranked third with a mean score of 2.96. This practice is known to improve soil structure, increase microbial activity, and enhance nutrient availability, all of which are critical for long-term soil health and productivity (Adekiya *et al*., 2019). With 96 farmers indicating they always use organic manure, the high adoption may also reflect limited access to inorganic fertilizers and the push for more environmentally friendly practices.

3.1.4. Minimum Tillage (Mean = 2.89; Rank = 4th)

Minimum tillage was moderately adopted with a mean score of 2.89, placing it fourth in the ranking. Conservation tillage reduces soil disturbance, thereby preserving soil structure, enhancing water retention, and reducing erosion (Thierfelder and Wall, 2012). Despite its benefits, the relatively moderate adoption could be due to the need for specialized tools or the perception of increased weed pressure, which may deter widespread uptake among resource-poor farmers.

3.1.5. Agroforestry (Mean = 2.83; Rank = 5th)

Agroforestry, which involves integrating trees into farming systems, had a mean score of 2.83. Although 78 farmers reported always using agroforestry, a significant number (71) reported rarely using it. The mixed responses suggest variability in farmers' knowledge, understanding and implementation of agroforestry. While it offers long-term benefits such as carbon sequestration, microclimate regulation, and diversified income, its delayed returns may reduce its attractiveness to farmers focused on short-term gains (Mbow *et al*., 2014).

3.1.6. Intercropping (Mean = 2.77; Rank = 6th)

Intercropping, the practice of cultivating multiple crops simultaneously, was sixth in adoption with a mean score of 2.77. Though 62 farmers reported always using this technique, a notable 41 did not use it at all. Intercropping can reduce the risk of total crop failure, enhance land-use efficiency, and provide complementary interactions between crops (Mucheru-Muna *et al*., 2010). Its moderate ranking might be influenced by the complexity of management, crop compatibility issues, or limited knowledge of optimal crop combinations.

***3.1.7.* Use of Improved Seeds (Mean = 2.57; Rank = 7th)**

Finally, the use of improved maize seeds ranked lowest among the CSA technologies with a mean score of 2.57. Approximately, 74 respondents always used improved seeds, while 59 did not use them. This finding aligns with existing research that highlights limited access to quality inputs as a key barrier for smallholder farmers in Nigeria (AGRA, 2021). The low adoption could stem from high seed costs, limited distribution networks, or low awareness of the benefits of improved varieties, which often offer drought tolerance, pest resistance, and early maturity.

3.2. The Net Returns and Benefit-Cost Ratio (BCR) of Maize Farming in Smallholder Communities across CSA Technologies Bundles

The gross revenue generated per hectare of maize production using CSA technologies amounted to ₦2,437,000, which includes ₦2,380,000 from grain output and ₦57,000 from stover (maize residue) (Table 3). The stover revenue highlights the multi-purpose nature of maize, as a stover can be used for livestock feed, fuel, or mulching. This outcome aligns with findings from FAO (2021), who connotes that CSA practices not only improve grain yield but also promote the efficient use of by-products for additional income and sustainability.

Table 2. The Climate Smart Agricultural Technology (CSA) Used by Maize Farmers

S/N	CSA Technology	FU (4)	U (3)	IU (2)	NU (1)	Total	Mean	Rank
1	Use of Improved Seeds	74	36	51	59	565	2.57	7th
2	Mulching	87	56	53	24	699	3.17	1st
3	Agroforestry	78	49	71	22	623	2.83	5th
4	Use of Organic Manure	96	47	48	29	650	2.96	3rd
5	Crop Rotation	94	61	40	25	664	3.02	2nd
6	Minimum Tillage	67	89	38	26	637	2.89	4th
7	Intercropping	62	86	31	41	609	2.77	6th

Source: Field Survey (2024), AU-Frequently Used, U-Used, RU-Infrequently Used, NU-Not Used.

The total variable costs amounted to ₦1,218,000. The highest contributors were labour cost at ₦277,000, chemical cost (likely for weed and pest/disease control) at ₦252,000, fertilizer cost at ₦170,000, and cost of manure ₦120,000. These figures suggest that CSA practices especially those involving organic amendments, restorations and integrated pest management are input-intensive. While, organic manure and chemical inputs both contributes significantly to soil fertility and crop protection, their costs represent a substantial proportion of total expenditure. Labour-intensive practices such as mulching, minimum tillage, and crop rotation further elevate variable costs, confirming prior researches that CSA technologies can be labor-demanding (Khatri-Chhetri *et al*., 2017). Also total fixed costs totaled ₦57,680, including depreciation (₦8,260), interest on borrowed capital (₦5,170), fees (₦4,250), and land cost (₦40,000). These were relatively low compared to variable costs, indicating that most costs in CSA maize production are operational rather than infrastructural. Furthermore, gross margin was ₦1,156,000 per hectare, while net farm income, stood at ₦1,098,320, representing the actual profit the farmer retains after all expenses. These figures indicate a high profitability of maize production under CSA, reflecting the economic viability of the practices adopted. The benefit-cost ratio (BCR) was 1.902, implying that for every ₦1 invested, a return of ₦1.90 is generated. According to Boardman *et al*. (2018), a BCR greater than 1 confirms that the investment is economically sound and generates returns exceeding costs. Similarly, the rate of return on investment (RORI) was 0.8205 (82.05%), showed a strong return and reinforces the attractiveness of CSA in maize farming. The result further suggests that the high net income and favorable BCR and RORI underscore the economic efficiency of CSA technology bundles in maize farming. Despite relatively high variable costs especially for labour, fertilizer, and pest management, the returns far outweigh the expenses, resulting in a profitable enterprise. This supports the assertion by Ajayi *et al*. (2021) who reported that CSA technologies, though sometimes capital- or labor-intensive, can deliver significant income gains if properly implemented.

3.3. The Determinants of Profit Efficiency and Inefficiency of Maize Farmers Utilizing CSA Technologies

Table 4 presents the results of maximum likelihood results from stochastic profit efficiency model. The factors influencing the profit efficiency and inefficiency are discussed below:

Cost of Improved Seed with a coefficient of 0.1135 and a p-value of 0.000. This suggests a positive and significant coefficient at the 1% level of probability. This indicates that a one unit increase in the cost of improved seeds, while keeping all other factors constant will lead to a 0.1135 increase in profit. This also reflects the value and vital role of quality seeds, which often result in better yields and higher revenues despite their higher costs (Kassie *et al*., 2011). The implication is that investing in improved seeds pays off, justifying their use in CSA bundles.

Table 3. Results of Net Returns and Benefit-Cost Analysis from CSA Technologies in Maize Farming per Hectare

Benefit-Cost Indicators	Value (Naira) per Hectare
Grain Output (Grain Output(Kg)*Unit Grain Price ($\frac{₦}{Kg}$)	2,380,000
Stover Revenue (Stover Output(Kg)*Unit Stover Price ($\frac{₦}{Kg}$)	57,000
Total Revenue/ Gross Farm Income	2,437,000
Land Preparation Cost	120,000
Fertilizer Cost	170,000
Manure Cost	120,000
Chemical Cost	252,000
Labour Cost	277,000
Transportation Cost	35,000
Maize Packaging Cost	7,000
Total Variable Cost	1,218,000
Depreciation Cost	8,260
Interest	5,170
Fees	4,250
Land Cost	40,000
Total Fixed Cost	57,680
Total Cost	1,338,680
Gross Margin	1,156,000
Net Farm Income	1,098,320
Benefit Cost Ratio (BCR)	1.902
Rate of Return on Investment (RORI)	0.8205 (82.05%)

Source: Field Survey (2024), 1 USD = 1, 500 Naira

Manure Cost with a coefficient of 0.1271and p value of 0.001. Also, positively and significantly related to profit at 1% probability level, manure costs imply that increased spending on organic soil amendments contributes to improved productivity. This supports the CSA goal of sustainable soil fertility management (FAO, 2013).

Fertilizer Cost with a coefficient of -0.1778and a p value of 0.000. This negative and statistically significant coefficient at 1% probability level implies that increasing fertilizer costs significantly reduce profit. While fertilizers boost yield, high costs may erode profit margins, particularly in the absence of subsidies or bulk purchasing schemes (Koussoubé and Nauges, 2017).

Experience had a coefficient = -0.1527, p = 0.002. This is statistically significant at ($P < 0.01$) and with negative coefficient. A unit increase in experience of maize farmers, while keeping all other variables constant will lead to 0.1527 decrease in profit inefficiency of maize farmers. This finding supports the assertion that experienced farmers are more efficient, likely due to better resource allocation, decision-making, and accumulated agronomic knowledge (Alabi *et al*., 2023).

Farmers' Cooperatives (Coefficient = -0.1807; p = 0.001): This highly significant negative coefficient at 1% probability level. A unit increase in cooperative memberships while keeping all other variables constant will lead to 0.1807 decrease in profit inefficiency of maize farmers. This suggests that cooperative membership enhances profit efficiency. Cooperatives offer access to shared inputs, credit, training, and market information (AGRA, 2021).

Credit Access with a coefficient of -0.1173 and p value of 0.000 is significant at 1% probability level. This suggests that access to credit reduces inefficiency by enabling timely input purchases and adoption of improved technologies. This outcome is in consonance with the study of Nguyen *et al*. (2021) who observed that financial inclusion is critical for CSA adoption and profitability.

Extension Services (Coefficient = -0.1675; p = 0.021) is statistically significant at 5% probability level. This result shows that extension contact improves profit efficiency, likely by enhancing farmers' technical knowledge and capacity to optimize CSA practices (Ajayi *et al*., 2021).

CSA Utilized (Coefficient = -0.2906; p = 0.000): A strongly significant and negative coefficient, confirming that farmers who adopt more CSA technologies are significantly more profit-efficient. This is in agreement with the study of FAO (2013) who reorted that CSA enhances productivity and profitability by increasing resource-use efficiency.

The Log-Likelihood of -123.7 reflects overall model fit, while sigma-squared of 0.600 measures total variance in the model. Gamma value of 0.6720 (p = 0.000) indicates that 67.2% of the total variation in profit among farmers is due to inefficiency, not random noise. This confirms the relevance of analyzing inefficiency drivers and validates the stochastic frontier model (Battese and Coelli, 1995).

Table 4. The Results of Stochastic Profit Efficiency Frontier Model

Variable	Coefficient	Standard Error	p-Value
Cost of Improved Seed	0.1135***	0.0164	0.000
Manure Cost	0.1271***	0.0219	0.001
Labour Cost	-0.1382	0.1685	0.971
Fertilizer Cost	-0.1778***	0.0189	0.000
Chemical Cost	-0.1395	0.1603	0.862
Transportation Cost	0.1461	0.1679	0.652
Cost of Land	0.1075	0.1144	0.9051
Constant	-5.206***	0.5312	0.000
Profit Inefficiency Component			
Sex	-0.4286	0.4418	0.782
Experience	-0.1527**	0.0156	0.002
Farmers Cooperatives	-0.1807***	0.0210	0.001
Credit	-0.1173***	0.0175	0.000
Extension	-0.1675**	0.0698	0.021
Age	0.1108	0.1142	0.815
CSA Utilized	-0.2906***	0.0501	0.000
Constant	2.3791***	0.3660	0.000
Diagnostic Statistics			
Log Likelihood	-123.7		
Sigma Square	0.600		
Gamma	0.6720***		

Source: Field Survey (2024)-
*Significant at($P < 0.10$), **Significant at($P < 0.05$), ***Significant at($P < 0.01$).

3.4.The Stochastic Profit Efficiency Scores among Maize Farmers

The profit efficiency scores among the respondents ranged from a minimum of 0.21 to a maximum of 0.96, with a mean efficiency score of 0.6896 and a standard deviation of 0.19061. This suggests that, on average, farmers are operating at approximately 69% of their potential profit level, implying a profit efficiency gap of about 31%. In other words, the average farmer could increase profits by approximately 31% without changing input levels or technology simply by improving management and allocative efficiency. This finding is consistent with studies of Kassie *et al*. (2011), who have found that smallholder farmers in developing countries often operate well below their optimal efficiency levels due to constraints such as poor access to credit, limited extension services, and low education levels.

Table 5. Distribution of Profit Efficiency Scores

Profit Efficiency Range	Frequency	Percentage
0.21 – 0.30	1	5.00
0.31 – 0.40	15	06.82
0.41 – 0.50	16	07.27
0.51 – 0.60	22	10.00
0.61 – 0.70	27	12.27
0.71 – 0.80	52	23.64
0.81 – 0.90	64	29.09
0.91 – 1.00	13	05.91
Total	220	
Minimum	0.21	
Maximum	0.96	
Mean Profit Efficiency	0.6896	
Standard Deviation	0.19061	

Source: Field Survey (2024)

4. Conclusion

The research analyzed benefit-cost of maize production in smallholder farming communities across climate-smart agriculture technology bundles in Federal Capital Territory, Nigeria. A simple random sampling design was used to select 220 maize farmers. The conclusion was based on the following null-hypotheses:

(i)The benefit-cost ratio of maize production across CSA technology bundles is less than one

The null hypothesis (i) is rejected because the BCR is evaluated at 1.902, this suggests that maize production using CSA technology is economically viable. Moreover, for every ₦1.00 invested, the farmers received approximately ₦1.90 in return indicating high profitability. This result is in agreement with the studies of FAO (2013) and, Ajayi *et al*. (2012). The CSA technologies when properly adopted and utilized significantly increase output, efficiency and productivity thereby boosting income.

(ii)There is no significant difference between CSA technology utilized, socio-economic factors and profit inefficiency of maize farming

The null hypothesis (ii) is rejected. There is a significant and negative relationship between socio-economic factors, CSA technology utilization and profit efficiency as farmers who utilizes more CSA technologies are more efficient, while farmers who use less CSA technologies are inefficient. The following recommendations was based on the finding of this research:

(i) Benefit-Cost Application(BCA) - Employing a BCA framework, the maize farmers can evaluate financial viability of various CSA technologies by comparing the cost (e.g seeds, fertilizer, labour, etc) with the potential benefits (e.g increased yields, higher market prices, reduced post-harvest losses)

(ii) Financial Support-The smallholder farmers often face financial constraints in adopting new technologies. Providing access to credit, grants, and other financial instruments can facilitate adoption.

(iii) Extension Services- Strengthen extension services can help maize farmers access relevant information, training, and technical support to implement CSA technologies effectively.

(iv) Policy Support- Government policies should be designed to support CSA adoption, including measures to promote access to inputs, markets, and infrastructures.

(v) Capacity Building- Training programs should focus on building farmers capacity to manage their resources effectively, adapt to climate change, and improve their overall livelihoods.

(vi) Government agencies, NGOs and development partners should promote CSA technologies. These should be tailored to local ecological conditions and made available through extension agents and advisory services.

(vii) Government should provide or made functional low interest agricultural credit schemes through cooperatives. Microfinance institutions should be also strengthened to extend financial services to smallholder farmers who engage in CSA based farming.

(viii) More extension agents, farmers should be trained specifically on CSA practices, profitability analysis and sustainable land use management, also use mass media and ICT tools to disseminate CSA knowledge, practices and market information to farmers in rural areas.

(ix) Stakeholder Involvement-The maize farmers, researchers, policy makers and other stakeholders should be engaged to ensure that the chosen CSA technologies are relevant, feasible, and acceptable. Also, factors like cost-effectiveness, sustainability, social acceptance, and the potential for long-term impact should be considered

(x) Multi-Dimensional Framework- The maize farmers should consider multiple dimensions of climate-smartness, including productivity, resilience and mitigation (eg reducing greenhouse gas emissions).

Declarations

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All authors reviewed and approved the final manuscript.

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Data presented in this study are available on fair request from the respective author.

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Not applicable

Conflicts of Interest
The authors disclosed no conflict of interest.

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