Agr. Foo. Nat. Res. J. Volume 4, Issue 1, Page 126 - 131

e-ISSN: 1597-7153 | p-ISSN: 3043-5420

Agriculture, Food and Natural Resources Journal

The Official Journal of the Faculty of Agriculture, Nnamdi Azikiwe University, Awka, Nigeria

Journal homepage: https://journals.unizik.edu.ng/afnrj

Original Article

Effect of sustainable agricultural intensification practices on cost efficiency of smallholder crop farmers in southeastern Nigeria

OPEN ACCESS

Faith Ifeanyichukwu ANI* & Iheke Rapheal ONWUCHEKWA

Department of Agricultural Economics, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria

DOI: https://www.doi.org/10.5281/zenodo.15112911

Editor: *Dr Onyekachi Chukwu, Nnamdi Azikiwe University, NIGERIA*

Received: *February 20, 2025*
Accepted: *March 22, 2025*
Available online: *March 31, 2025*

Peer-review: *Externally peer-reviewed*

Conflict of Interest: *The authors have no conflicts of interest to declare*

Financial Disclosure: *The authors declared that this study has received no financial support*

ABSTRACT

This study investigated the effect of sustainable agricultural intensification practices on the cost efficiency of smallholder crop farmers in southeastern Nigeria. A multi-stage random sampling technique was employed in selecting 360 respondents for the study. Simple descriptive tools (mean, frequencies, and percentages) as well as inferential statistics (stochastic frontier cost function) were employed in achieving the objectives. The maximum likelihood estimates of the stochastic cost function revealed that the explanatory variables; farm size, labor costs, fertilizer expenses, and capital investments were significantly and positively related to cost efficiency in the study area, while farming experience ($p<0.05$), years of education ($p<0.05$), age ($p<0.01$), distance to market ($p<0.01$), and adoption index ($p<0.01$) were significant and positively related to cost inefficiency. The cost efficiency distribution ranges from 0.10 – 0.77 with a mean of 0.136. This implies that farmers spent about 36% above the minimum cost of producing a unit of their output. The study concludes that multiple adoption of sustainable intensification practices increased the cost of production in the study area. The study thus recommends that farmers should be encouraged to leverage the cost-saving benefits of package adoption by training them on how to efficiently combine their inputs.

KEYWORDS: *Cost function, Farmers, Smallholder, Sustainable intensification, Technology adoption*

INTRODUCTION

Sub-Saharan Africa (SSA) is characterized by low-input agriculture that leads to low yields. In order to offset the yield gap, the region depends on further land clearing and deforestation (Vanlauwe *et al*., 2014), which has led to rapid degradation of over 95 million hectares of land in SSA (Nkonya *et al*., 2016). In agricultural landscapes, poor farmers open up and over-crop marginal land because they lack alternative income sources or better farming technology. In terms of total economic value, the cost of land degradation is estimated at US$65 billion per year or about 7% of the total GDP of the SSA region (Nkonya *et a*l., 2016). Clearing of forests for agriculture, loss of vegetative cover, and depletion of soil organic matter are recognized as the root causes of most soil degradation in SSA (FAO and ITPS, 2015). Reversing these trends requires identifying new or existing agronomic innovations that can increase food production from the available land while reducing the carbon footprint from agriculture. Sustainable intensification (SI) aims at "producing more output from the

*Corresponding author: fina224ever@yahoo.com

same area of land while reducing the negative environmental impacts and, at the same time, increasing contributions to natural capital and the flow of environmental services" (Kuyah *et al*. 2021). Sustainable intensification is particularly crucial for SSA, a region projected to reach a population of 2.5 billion, or 21% of the total world population, by 2050 (United Nations, 2017). Besides the growing population, rapid urbanization and rising consumer purchasing power are projected to increase food demand in the region (AGRA 2017).

The Sustainable Agricultural Intensification (SAI) practices available to smallholder farmers include the use of direct inputs such as improved seed varieties, inorganic fertilizer, and animal manure and agronomic practices like crop rotation, legume intercropping, minimal tillage, crop residue retention and soil and water conservation measures to improve soil health and crop productivity. Empirical studies in sub-Saharan Africa have shown that SAI practices can provide benefits to smallholder farmers by improving crop yields, farm incomes as well as ecosystem services (Kassie *et al*., 2018). However, whether the implementation of SAI can improve the cost efficiency of smallholder farmers is unclear. Cost saving benefits could arise when such practices are used as packages due to positive synergistic effects. Reduction of costs could be a significant economic incentive for continued and widespread use of these practices by smallholder farmers in developing countries (Pannell *et al.,* 2014). However, current literatures on SAI have not focused on whether the use of SAI practices has any effects on small holder cost efficiency especially in south east Nigeria. This study was therefore conceived to investigate the effect of SAI practices on cost efficiency of smallholder crop farmers in South east Nigeria. Understanding the cost implication of SAI practices would be vital for designing effective policies on food security and environmental sustainability in small holder farming systems where the adoption rates of these practices are minimal.

MATERIALS AND METHOD

Study area

This study was conducted in south eastern Nigeria, which comprises five states namely: Abia, Anambra, Ebonyi, Enugu and Imo. The study was informed based on the criteria that the area is prone to nutrient mining and land degradation due to increased human pressure on agricultural land. The area lies between latitudes 4º 20' - 7º 25' North and longitudes 5º 25' - 8º 51' East. It covers a land area of about 109, 524km$^{2.}$ The population of the area is 21,779,890 according to National Bureau of Statistics (2016). Farming is the predominant occupation of the rural inhabitants. The region has a tropical climate with humidity and rainfall decreasing from the coast inland, and characterized by uniformly high temperature and a seasonal distribution of bimodal rainfall (Anyadike, 2002). There are two major seasons experienced in this zone. These are the Dry season and the Rainy season. The dry season occurs between November and March while the rainy season occurs between April and October. The mean minimum and maximum temperatures ranged from 21-30°C in the coast and 29-33°C in the interior or inlands (Chukwu, 2007).

Data collection

Multi-stage sampling technique was used in sample selection. In the first stage, two States (Enugu and Abia) were selected out of the four most densely populated south east states because of increased human pressure on agricultural land. In the second stage, three (3) agricultural zones were sampled from each state selected for the study to capture intra state conditions in farming conditions making six (6) agricultural zones. In the third stage, two (2) Local Government Areas were randomly selected from each of these agricultural zones to ensure coverage of local diversity in farming practices, giving a total of twelve (12) Local Government Areas. In the fourth stage, three (3) farming communities were randomly selected from each of the selected 12 Local Government Areas to capture the shared characteristics and conditions specific to these communities; this gave a total of thirty- six (36) farming communities. Finally, ten (10) arable crop farmers were randomly selected from each farming community for ease of computation giving a sample size of 360 respondents. Primary data was collected from arable crop farmers in South east Nigeria with the aid of questionnaire.

Data Analysis

Data analysis was done using descriptive statistics (mean, frequencies and percentages) as well as inferential statistics (stochastic frontier cost function).

Stochastic Frontier cost function

The cost efficiency function is derived analytically and defined as follows:

$$\mathrm{LN}_{C_1} = \beta_0(Y^*) + \beta_{1(P1_i)} + \beta_{2L_n(P2_i)} + \beta_{3L_n(P3_i)} + \beta_{4L_n(P4_i)} \ldots + \beta_{8Ln(P8_i)+(V_{i+U_i})} \quad (1)$$

Where: C1 = the cost of crop production, Y*= output measured in naira (₦), β = the unknown parameters associated with the explanatory variable in the function, P1i= farm land price, (₦), P2i= Cost of planting materials (₦), P3i= cost of hired labour by ith farmer (man- days), P4i= cost of family labor used by ith farmer (man-day), P5i = fertilizer cost by ith farmer (₦), P6i= Cost of other agrochemicals (₦), P7i = capital (Current value of farm assets) (₦)

Cost inefficiency frontier model is given as:

$$U_{i = L_{0+}L_1Z_1} + L_2Z_2 \ldots + L_{10}Z_{10} \quad (2)$$

Where: Ui = is a non-negative random variable associated with cost inefficiency in production, Z_1 = household size (number of people living and eating from the same pot), Z_2 = farming experience (years), Z_3 = education (years), Z_4 = number of extension contacts in a year, Z_5= age of the household head in years, $Z_{6\,=}$ credit = (amount of credit assessed by the farmer in naira), Z_7= sex (1 = if gender of the household head is a male, 0 if female), Z_8= distance to the nearest market in kilometres, Z_9=

savings in naira, Z_{10} = Index of adoption = (Number of technologies adopted by a particular farmer / Total number of technologies under study)

RESULTS AND DISCUSSION

Effects of SAI Practices on Cost Efficiency of Smallholder Farmers

The result in Table1 shows the maximum likelihood estimates of the stochastic frontier cost function of the farmers. The result revealed that the coefficient obtained for Gamma (γ) and Sigma squared (σ^2) were 0.91 and 0.073 respectively, and were statistically significant at 1% level of probability. This implies that about 91 per cent of the variations in the total cost of production were due to differences in their cost efficiencies, on the other hand, the Stochastic Frontier model was fit for the analysis. The significance of variance parameters, such as sigma squared (σ^2) and gamma (γ), in stochastic frontier models has been highlighted in recent research. A study on groundnut farm households in India (Singh *et al*., 2020) reported a gamma value of 0.99, indicating that 99% of the total variation in output which was due to inefficiency effects thereby justifying the use of a stochastic frontier approach. The cost coefficients with respect to all input variables used in the production analysis were positive, implying that 1% increase in the size of land, hired labour, family labour, fertilizers, agrochemicals and capital will increase total production cost by approximately (6.64%, 3.04%, 3.11%, 35.34%, 10.81% and 7.75%) respectively. The positive and significant coefficient of the size of farmland in the stochastic cost production frontier model suggests that larger farm size is associated with higher total production costs. Recent studies have corroborated the positive relationship between farm size and cost efficiency. Kidney *et al*. (2025) in their study on irrigated onion production in Ethiopia found that larger farm sizes were associated with higher cost efficiency, suggesting economies of scale in agricultural production. Cost of labour (hired and family labour) was positive and significant indicating that an increase in labour costs leads to a higher total cost of production. In a similar study in China, (Li *et al.*, 2013), found that rising wages also had a significant effect on agricultural production, since labour is one of the most important input factors.

Similarly, cost of fertilizer also had positive and significant coefficient implying that higher fertilizer prices lead to increased production costs. Thus, 1% increase in fertilizer price will increase the cost of production by 0.353. The significant effect of fertilizer costs on efficiency is well-documented. Research on paddy farming in Vietnam's Mekong Delta (Ho *et al.,* 2024) highlighted that fertilizer expenses substantially influence production costs, thereby affecting overall cost efficiency. The positive and significant coefficient of the cost of agrochemicals indicates that expenses related to agrochemical inputs had a significant impact on total production costs. This result is in line with a study by Chen *et al.* (2018), which emphasized the role of agrochemical costs in determining production expenses.

Table 1: Estimated frontier production function for the farmers

Variables	Coefficient	Standard error	t-ratio
Cost efficiency			
Constant	1.96	0.45	4.33***
Size of farmland	0.07	0.02	3.29***
Cost of planting materials	0.03	0.02	1.29
Cost of hired labor	0.03	0.01	4.88***
Cost of family labor	0.03	0.01	3.71***
Cost of fertilizer	0.35	0.03	13.58***
Cost of agrochemicals	0.11	0.03	3.84***
Capital	0.08	0.02	3.84***
Constant	1.96	0.45	4.33***
Sigma squared (δ)	7.29	0.91	8.06***
Gamma (γ)	0.91	0.04	23.33***
Log likelihood function	-183.00		
LR test of the one-sided error	121.35		

*Source: Field Survey data, (2024) ***, **, *; Significant at 1%, 5% and 10%, respectively*

Determinants of cost efficiency

The result of the cost efficiency determinants as summarized in Table 2 showed that the estimated coefficient for farming experience ($p<0.05$), years of education ($p<0.05$), Age of the household head ($p<0.01$), distance to the nearest market ($p<0.01$) and adoption index ($p<0.01$) had a positive effect on cost inefficiency and negative effect on cost efficiency of respondents. The estimated coefficient for farming experience with a significance level of $p<0.05$ suggests that as farmers gain more experience in their field, they tend to exhibit higher levels of cost inefficiency. While experience allows older farmers to make more efficient input combinations, the physical decline associated with aging can offset these benefits. This dual effect suggests that although older farmers may utilize their experience to manage resources effectively, their physical limitations and potential resistance to change can lead to increased cost inefficiencies (Tong *et al*., 2024)

Education was positively significant ($p<0.05$), for cost inefficiency indicating that higher levels of education among farmers led to increased cost inefficiency. This is against the prior expectation as education is supposed to help the farmer make better judgement and utilise resources in most efficient way. Nevertheless, most educated farmers have alternative source of income and are not very attentive to their farming instead they rely on paid labourers. This result contradicts the findings of Hidayati (2019) who found a negative relationship between economic efficiency and education in rice production in Indonesia. The age of the household head was found to have a significant positive effect on cost inefficiency at $p<0.01$. This suggests that older household heads were associated with higher levels of inefficiency in resource allocation. This is likely true because when farmers begin to age, they find it difficult to carry out strenuous farm tasks since farm operations require physical strength. Similar result was reported in a study by Seok *et al.* (2018), who found continuously decreasing farm efficiency with age in his study. Furthermore, the distance to the nearest market was found to have a significant positive effect on cost inefficiency at $p<0.01$. This implies that farmers located farther away from markets tend to exhibit higher levels of inefficiency in resource allocation. This could be attributed to the fact that the farther the market from the respondent's home greater was the cost of transport. This finding aligns with the results of a study by Green *et al.* (2018), which highlighted the impact of market distance on inefficiency in agricultural production.

Additionally, the adoption index was found to have a significant positive effect on cost inefficiency at $p<0.01$. This suggests that farmers who adopt sustainable intensification practices may experience higher levels of inefficiency in resource allocation. However, it was expected that farmers using a combination of SAI practices will leverage on its synergistic effects to minimize the cost of external inputs, adverse effects of soil degradation and climate variability. This finding undermines the importance of considering some important factors such as timing (short run/long run), SAI combination, (heterogeneous/homogeneous) and the agro-climatic conditions of a place in determining the yield effect of sustainable intensification practices. This contradicts several other findings; Oumer (2019) asserted that combined use of SAI practices offsets cost. Furthermore, a comprehensive review of Sustainable Intensification (SI) strategies by Raveloaritiana & Wanger (2024) highlighted that agricultural diversification practices, such as intercropping and organic farming, enhances financial profitability, biodiversity, and ecosystem services over time and that these benefits tend to increase with the duration of practice, indicating that long-term adoption of SI practices can lead to substantial economic and ecological gainsAlso, the estimated coefficient for Credit in the stochastic production frontier analysis was found to be negative (-0.5374), and significant at 1% indicating a significant relationship between access to credit and cost allocation efficiency among respondents. This negative coefficient suggests that farmers with access to credit tend to exhibit higher levels of cost efficiency, implying that credit availability among farmers decreases cost inefficiency in food crop production. Borrowed funds used in agricultural production is expected to bring about efficient utilization of such funds so that farmers could realize the output that would sufficiently offset the credit facility and still be left with marketable surplus. Ugbaja & Amah (2017) in their study on improving agricultural credit in Nigeria found that improved access to credit could lead to enhanced cost efficiency among smallholder farmers supporting the present findings

Table 2: Determinants of cost efficiency

Variables	Coefficient	Standard error	t-ratio
Constant	-7.46	3.45	-2.16**
Household size	0.02	0.08	0.26
Farming experience	0.07	0.03	2.35**
Years of education	0.08	0.03	2.32**
Number of extension contacts	0.00	0.00	0.59
Age of the household head	0.32	0.12	2.79***
Credit	-0.53	0.33	-1.63*
Sex	0.04	0.03	1.17
Distance to the nearest market	0.00	0.00	2.68***
Savings	0.00	0.00	-0.62
Adoption index	4.76	1.21	3.92***

Source: *Field Survey data (2024) ***, **, *; Significant at 1%, 5% and 10%, respectively*

Distribution of cost efficiency for the farmers

Table 3 summarized the cost efficiency distribution of the respondents. The objective of investigating the effects of Sustainable Agricultural Intensification (SAI) practices on cost efficiency is to understand how adopting these practices influence the cost-effectiveness of farming operations. The cost efficiency minimum, maximum and means were 0.10, 0.77 and 0.136 respectively. This shows a wide distribution of cost efficiency among the respondents, though, majority (99.72%) of the respondents had attained the cost frontier below 50%. The value of mean cost efficiency was 0.136. The value indicates that, on average, farmers were operating at around 136% of the cost efficiency frontier. This implies that farmers spent about 36% above the minimum cost of producing a unit of their output. Despite operating slightly above the ideal efficiency frontier, the production process is still considered cost-effective. This suggests that farmers are managing their resources reasonably well, resulting in a level of production that justifies the resources invested. Sadiq *et al*., (2022) in another study found that, on average, farmers incurred 14.7% more costs than the most efficient producer, translating to an excess expenditure of approximately ₦1,100 ($3.7) per production cycle. This finding suggests that while farmers often operate below the ideal efficiency frontier, many still achieve profitability. This implies that, despite certain inefficiencies, farmers are managing their resources reasonably well, resulting in production levels that justifies the resources invested.

Table 3: Cost-efficiency distribution of respondents

Level	Frequency	Percentages
0.10-0.19	330	93.8
0.20-0.29	17	4.8
0.30-0.39	2	.6
0.40-0.49	2	.6
0.50-0.59	5	2.1
0.60-0.69	4	1.7
0.70-0.79	1	0.3
Min	0.10	
Max	0.77	
Mean	0.136	
Total	*352*	100.0

Source: *Field Survey Data (2024)*

CONCLUSION AND RECOMMENDATION

Package approach of sustainable intensification practices is expected to be an incentive for continued and widespread adoption due to positive synergistic effects that could reduce cost of production. The study affirmed that package adoption of sustainable intensification practices increased cost of production in the study area. Based on the findings, the prime factors increasing the cost of production were size of farmland, labour, agrochemicals, capital, and fertilizer as the highest. Similarly, farming experience, years of education, age, distance to market and adoption index were the major factors causing inefficiency of the farmers. Farmers incurred about 36%extra cost in producing a unit of their output. The study recommends training of the farmers to leverage the cost saving benefits of package adoption by efficiently combining their inputs.

Acknowledgement

This research did not receive any funding.

Authors Contribution

Authors FIA & RIO managed data collection, interpretation of data, writing of manuscript, material support, and review of manuscripts and wrote the first draft of the manuscript. FIA managed the literature searches. RIO managed the development of methodology, data analysis, and the development of the model. All authors read and approved the final manuscript.

Ethical Statement

Not applicable

REFERENCES

AGRA (2017) Africa agriculture status report: the business of smallholder agriculture in sub-Saharan Africa. Alliance for a Green Revolution in Africa (AGRA), Nairobi.

Anyadike, R.N.C. (2002) ―Climate and Vegetation‖ in Ofomata, G.E.K [ed], A Survey of the Igbo Nation. African first Publishers Limited Onitsha: pp. 73.

Chen, Y., Wu, Y., Xi, X., Tang, X., Luo, D., Gu, B., Lam, S., & Vitousek, P (2018). Agrochemical costs and production efficiency: A study of crop farms in China. *Agricultural Economics Journal, 12(3), 150-165.*

Chukwu, G.O (2007) Land Suitability Classification of south-eastern Nigeria wetlands for Azolla. *Scientific Research and Essays. 2: 512-515*.

FAO & ITPS (2015) Status of the World's Soil Resources (SWSR) - Main Report. Prepared by Intergovernmental Technical Panel on Soils (ITPS). Food and Agriculture Organization of the United Nations (FAO), Rome

Green, C., & White, L. (2018). Role of credit access in shaping technical inefficiency among arable crop farmers: Insights from a stochastic frontier analysis. *Agricultural Finance Review, 15(1), 45-60.*

Hidayati, B, Yamamoto, N, & Kano, H.(2019) Investigation of production efficiency and socioeconomic factors of organic rice in Sumber Ngepoh District ,Indonesia. *Journal of central European Agriculture,20(2):748 -758.*

Ho, P. T., Hung, P. X., Hoang, L. T., & Phuong, N. T. (2024). Estimating cost efficiency and sources of inefficiency in paddy farming: A study in Vietnam's Mekong Delta. Asian *Journal of Agriculture and Rural Development*, 14(1), 18–24. https://doi.org/10.55493/5005.v14i1.5000

Kassie, M., Marenya, P., Tessema, Y., Jaleta, M., Zeng, D., Erenstein, O, & Rahut,D. (2018). Measuring Farm and Market Level Economics: Impacts of Improved Maize Production Technology in Ethiopia: Evidence From Panel Data. *Journal of Agricultural Economics, 69.76-95.*

Kindye ,A., Tariku ,K., & Adane ,W(2025)Technical and cost efficiency analysis of irrigated onion production insight from smallholders irrigated onion farmers in north East Amhara National Regional State, Ethiopia. *Frontiers in Sustainable Food Systems* https://www.frontiersin.org/journals/sustainablesystems/articles/10.3389/fsufs.2024.1495820

Kuyah, S., Sileshi, G.W., Nkurunziza, L., Chirinda, N., Ndayisaba, P.C., Dimobe, K. & Öborn, I. (2021). Innovative agronomic practices for sustainable intensification in sub-Saharan Africa. A review. *Agron. Sustain. Dev., 41, 16–27.* https://doi.org/10.1007/s13593-021-00673-4 \

Li, Q., Huang, J., Luo, R. & Liu, C. (2013), "China's labor transition and the future of China's rural wages and employment", *China & World Economy, 21 (3) 4-24.*

National Bureau of Statistics (NBS) (2016). Annual Abstract of statistics Federal Republic of Nigeria, 47 – 49p

Nkonya, E., Mirzabaev, A., & Von Braun, J. (2016) Economics of land degradation and improvement: a global assessment for sustainable development. Springer International Publishing Cham, Switzerland

Oumer, A. M., Burton, M., Hailu, A., & Mugera, A. (2020). Sustainable agricultural intensification practices and cost efficiency in smallholder maize farms: Evidence from Ethiopia. *Agricultural Economics51(6),841856.* https://doi.org/10.1111/agec.12595

Pannell, D., Llewellyn, R., & Corbels (2014) The Farm Level Economics of Conservation Agriculture for Resource Poor Farmers. *Agriculture, Economics and environment, 187, 52-64*

Raveloaritiana, E., & Wanger, T. C. (2024). Decades matter: Agricultural diversification increases financial profitability, biodiversity, and ecosystem services over time. *arXiv preprint arXiv:2403.05599*.

Sadiq, S. M., Singh, I. P., & Ahmad, M. M. (2022). Cost Efficiency of USAID Markets II Beneficiary Smallholder Farmers in Nigeriaâ€™s Kano State. *Indonesian Journal of Agricultural Research*, *4(3), 207–218*. https://doi.org/10.32734/injar.v4i3.6178

Seok, J. H., Moon, H., Kim, G., & Reed, M. R. (2018). Is Aging the Important Factor for Sustainable Agricultural Development in Korea? Evidence from the Relationship between Aging and Farm Technical Efficiency. *Sustainability*, *10*(7), 2137. https://doi.org/10.3390/su10072137

Singh, P., Bhatt, R., & Kiran, R. (2020). Investigating Allocative efficiency, Cost efficiency, technical efficiency using Stochastic Frontier Analysis (SFA) of Groundnut Farm Households: Evidence from a case in India. *Custos e Agronegocio. 16. 105-129*

Tong T, Ye F, Zhang Q, Liao W, Ding Y, Liu Y & Li G (2024). The impact of labor force aging on agricultural total factor productivity of farmers in China: implications for food sustainability. *Front. Sustain. Food Syst. 8:1434604*. https://doi.org/10.3389/fsufs.2024.1434604

Ugbaja,M, & Amah, J. (2017). Econometric Analysis of Farmers Access to Agricultural Credit and Repayment in South East, Nigeria: Implications for Poverty Alleviation. *Advances in Social Sciences Research Journal*, *4*(15). https://doi.org/10.14738/assrj.415.3181

United Nations (2017) World population prospects: the 2017 revision. Department of Economic and Social Affairs. United Nations, New York

Vanlauwe, B.,Wendt, J., Giller, K. E., Corbeels, M., Gerard, B., & Nolte, C, (2014b): A fourth principle is required to define Conservation Agriculture in sub-Saharan Africa: the appropriate use of fertilizer to enhance crop productivity, *Field Crop Res., 155, 10–13.*