ASSESSMENT OF USAGE OF SUSTAINABLE AGRICULTURAL PRACTICES BY RICE FARMERS IN EBONYI STATE

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Abstract
The knowledge of the Sustainable Agricultural Practices (SAPs) being used by rice farmers in Ebonyi State will be beneficial especially in cases where interventions are targeted to increase rice production in a way that protects the environment. There is, however, a dearth of scientific data regarding the usage and the determinants of the use of SAPs in Ebonyi State. This study investigated the usage of SAPs by the rice farmers in Ebonyi State, and their determinants. It employed a multi-stage sampling procedure to select 120 rice farmers across the three Agricultural Development Project (ADP) zones of the state. Collected data were analyzed using both descriptive and inferential statistics. Findings revealed that most used SAPs by the farmers were; Direct-Seeded Rice (DSR) (2.17), System of Rice Intensification (SRI) (1.74), green manure (1.70), organic farming (1.52), and precision irrigation (1.48). The least used SAPs were integrated pest management (IPM) (1.41), alternate wetting and drying (AWD) (0.73), residue management and mulching (0.59), no-till farming (0.54), and composting (0.38). At 5% level of significance, farmers' age, education, income, household size, farming experience, income sources, farm size, and communication access were significant determinants of their usage of SAPs. The rice farmers had a considerable usage of SAPs, and several socioeconomic and institutional factors can ensure better use. Strengthening the farmers livelihood assets can trigger better usage of SAPs which may cascade into better sustainable rice production.
***Keyword**: Rice production; socioeconomic determinants; livelihood assets*

Introduction

The global demand for rice continues to rise, placing significant pressure on agro-ecosystems to produce more with fewer resources. Sustainable agricultural practices (SAPs), such as the System of Rice Intensification (SRI), integrated pest management (IPM), and improved water-management techniques, have been shown to enhance productivity while safeguarding environmental health and farmer livelihoods (Osuafor 2022). In sub-Saharan Africa, rice is both a staple food and a key income source, yet yield gaps persist chiefly due to low uptake of sustainable methods and inadequate extension support ((Osuafor 2022)

In Nigeria, rice production faces multiple constraints including soil degradation, inefficient water use, and pest pressures. Recent studies highlight that adoption of improved rice technologies in Ebonyi State remains suboptimal despite growing awareness: 91.7% of farmers know about improved seed varieties and 87.5% about agrochemical applications, but actual uptake across the production chain lags due to socio-economic and institutional barriers (Osuafor 2022). Meanwhile, assessments in South-east Nigeria reveal that climate-smart practices, such as alternate wetting and drying, and site-specific nutrient management, are known by only a fraction of rice farmers, underlining a critical gap between awareness and practice adoption (Igwe et al. 2019).

Within Ebonyi State specifically, sustainable agricultural land-management practices (e.g., contour farming, cover cropping, and residue mulching) have been investigated among crop farmers. A survey of 240 farmers showed that over 70% were aware of sustainable land-management techniques, with adoption significantly influenced by farm size, education level, extension contacts, and household size (Umeh & Chukwu 2014). However, these findings have not been disaggregated for rice farmers, whose unique cropping calendar and input requirements may shape their use of SAPs differently.

This study therefore investigated the usage of SAPs, and identified the socio-economic and institutional determinants of the usage of SAPs. This research will inform targeted extension strategies and policy interventions to boost both productivity and sustainability in one of Nigeria's key rice-producing regions.

Methodology

Study Area

Ebonyi State lies in southeastern Nigeria between approximately 5°22′N and 6°45′N latitudes and 7°30′E and 8°45′E longitudes, covering about 5,935 km². It shares boundaries with Enugu State to the northwest, Abia State to the southwest, Cross River State to the southeast, and Benue State to the northeast. The state capital, Abakaliki (6°04′N, 8°05′E), serves as the administrative and commercial hub. The landscape of Ebonyi is characterized by undulating highlands transitioning into broad river valleys.

Rice is grown in two main ways in the state. Mostly it is planted on low-lying valley floors that flood seasonally and are used as traditional rainfed paddy fields; additionally, there are small irrigated schemes along the Ebonyi River where farmers use simple diversion structures to grow rice in the dry season (Esheya, 2021). Upland Transition Areas Sloping fields where improved water-saving methods (e.g., alternate wetting and drying) and soil conservation practices are increasingly trialed (Chidiebere-Mark et al. 2019). The choice of this study area can, therefore, make investigations more precisely assess farmers' uptake of sustainable practices, tailor extension messages, and prioritize resource allocation for site-specific interventions.

Sampling Procedure and Sample Size

A multistage random sampling technique was used in the selection of respondents. The first stage involved a random selection of 2 Blocks from each of the Agricultural Development Project zones in the state, namely Ebonyi North, Ebonyi Central and Ebonyi South. In this stage, a total of 6 blocks were selected. The second stage involved a random selection of 2 cells from each of the selected blocks, and in this stage, a total number of 12 cells where selected. In the final stage, a proportionate sampling selection, using the Taro Yamane formula, was used to select rice farmers for this study from the identified rice farmers in each selected cell, giving a total sample size of 120 rice farmers.

Measurement of Variables and Data Analysis

Socioeconomic and institutional variables were measured at nominal and ratio levels based on the nature of the variables, and descriptive statistics was used for the analysis. The usage of SAPs was measured at ordinal level by asking the respondents their level of use of SAPs on a 4-point Likert type scale of not used (0), rarely used (1), sometimes used (2), and always used (4). The mean and standard deviation for each practice was therefore calculated. The determinants of the usage of SAPs was calculated using Multiple regression as specified below:

Model Specification

$Y=\beta_0 + \beta_1 X_1 + \beta_2 D_1 + \beta_3 D_2 + \beta_4 X_2 + \beta_5 X_3 + \beta_6 X_4 + \beta_7 D_3 + \beta_8 X_5 \ldots\ldots\ldots\ldots + u$...Eqn (1)

From Eqn (1), Y = log (usage of SAPs); β_0 =intercept; β_1- β_{11}= coefficients; X_1 = Age (Years). D_1 = Sex (Dummy variable; male = 1; female = 0), D_2 = Marital status (Married = 1; otherwise = 0), X_2 = Educational level (Number of years spent in school), X_3 = Primary occupation (Dummy variable; farming = 1; otherwise = 0), X_4 = Annual farm income (Naira), D_3 = Access to credit (Dummy variable; yes = 1; otherwise = 0), X_5 = Number of Extension contact/visits (Counts), X_6 = Farm size (hectares), D_4 = Membership of association/farmers organization (Dummy variable; yes = 1; otherwise = 0) etc.

Results and Discussion

Usage of sustainable Agricultural Practices by the farmers

Table I: Usage of sustainable agricultural practices

Sustainable agricultural practices	Mean	Std. Deviation
Direct-Seeded Rice (DSR)	2.17	0.87473
Alternate Wetting and Drying (AWD)	0.73	0.81106
Organic farming	1.52	1.10085
Integrated pest management	1.41	1.12408
System of Rice Intensification (SRI)	1.74	0.98644
Conservation tillage	1.18	0.97361
Precision Irrigation Monitoring	1.48	1.10990
Improved Grain Drying	1.42	1.03216
Use of green manure	1.70	0.90269
Composting	0.38	0.75962
No-till farming	0.54	0.85469
Residue Management and Mulching	0.59	0.83879
Precision agriculture	1.49	1.03551

Source: field survey, 2024

From Table 1, Direct-Seeded Rice was the most used SAPs by the rice farmers with a mean score of 2.17. This was followed by System of Rice Intensification which came with a mean score of 1.74. Other practices like use of green manure (1.70), organic farming (1.52), and precision irrigation monitoring (1.48) ranked 3rd, 4th, and 5th according to their usage respectively. Least used SAPs were integrated pest management (1.41), alternate wetting and drying (AWD) (0.73), residue management and mulching (0.59), no till farming (0.54), and composting (0.38), and they were 9th, 10th, 11th, 12th, and 13th according to usage.

From the table, Direct-Seeded Rice (DSR) had the highest mean usage score (2.17) among rice farmers, indicating its prominence as a Sustainable Agricultural Practice (SAP). This strong preference is consistent with evidence that DSR reduces labor and water requirements while boosting profitability through mechanization and cost savings in consistent with Chaudhary et al. (2024). System of Rice Intensification (SRI) ranked second (mean = 1.74), reflecting moderate uptake. SRI's yield gains and reduced water use are well documented, yet its labor-intensive transplanting and requirement for precise water management have constrained broader uptake, as was the case revealed by Aliyu et al. (2020).

Green manure (mean = 1.70) occupied third place, underscoring farmers' recognition of its soil-building benefits. The reason for this high usage was noted by Prajapati et al. (2023), which highlighted that green manuring can supply up to 150 kg N ha^{-1}, reduce erosion, and sequester carbon, yet limited seed availability and inadequate knowledge constrain adoption in many contexts. Organic farming also followed with a mean score of

1.52, which could be driven by the growing consumer demand for residue-free rice and policy incentives as noted by Möhring et al. (2024). Precision irrigation monitoring ranked fifth with a mean score of 1.48. Precision tools, such as soil moisture sensors and automated controllers, can cut water use by up to 50 % and boost yields, yet upfront costs and technical complexity slow farmer uptake. Van de Zande et al. (2024) demonstrate that integrated scheduling-manual-valve systems could bridge this gap by allowing resource-limited farmers to automate scheduling while retaining familiar manual interfaces.

At the lower end, integrated pest management (IPM) scored 1.41. According to FAO (2018), Farmer Field School evaluations show IPM's benefits in reducing pesticide loads and improving ecosystem health, yet farmers often lack the ecological knowledge and institutional support needed for consistent IPM uptake, keeping adoption rates modest. Alternate Wetting and Drying (AWD) recorded a very low mean (0.73), reflecting limited use. AWD can save 20–50 % of irrigation water and reduce methane emissions by 30–50 %, but its reliance on careful water-level monitoring and risk of yield loss under misapplication deter many smallholders (Yadav et al. 2025).

Residue management and mulching (mean = 0.59) and no-till farming (mean = 0.54) were also infrequently practiced. Despite their proven roles in reducing erosion and building soil organic matter, residue retention and direct seeding are constrained by lack of mechanization and entrenched tillage norms. In KwaZulu-Natal, South Africa, only 14 % of smallholders adopted no-till CA, with farm size and extension intensity emerging as key determinants of uptake (Ntshangase et al. 2018). Composting scored lowest (mean = 0.38), reflecting minimal use of on-farm organic recycling. Although farm-generated compost can reduce fertilizer expenses and enhance soil fertility, many farmers view composting as labor-intensive and slow to yield results.

Together, these findings reveal a hierarchy of SAPs usage driven by immediate economic returns and ease of integration into existing practices (Mohapatra et al. 2023). High-usage practices like DSR and SRI offer clear cost and labor savings, while water- and soil-conservation measures, such as AWD, residue retention, no-till, and composting, lag due to technical complexity, capital constraints, and knowledge gaps. To achieve holistic sustainability, policy and extension programs must not only highlight the long-term benefits of lower-adoption practices but also invest in mechanization access, risk-mitigation incentives, and tailored farmer education.

Determinants of the usage of SAPs by the farmers

Table 2: Influence of socioeconomic characteristics on the usage of sustainable agricultural practices

Variables	Parameter	Estimate	Std. Error	Z	Sig.
Age	-.002	.004	-.482	.630	-0.009*
Gender	0.105	.066	-1.579	.114	0.235
Years of education	0.002	.006	-.428	.669	0.014*
Annual income	0.000	.000	20.934	.000	0.000*
Land ownership	-.124	.073	-1.695	.090	0.268
Farm size	0.002	.022	-.111	.912	0.045*
Household size	0.005	.016	.322	.747	0.026*
Farming experience	0.003	.007	-.373	.709	0.017*
Sources of income	.045	.037	1.228	.219	0.027*
Access to market	-.049	.035	-1.384	.166	0.118
Access to transportation	-.040	.042	-.944	.345	0.122
Access to comm. networks	.044	.039	1.129	.259	0.032*

*Significant at 5%

From Table 2, the multivariate analysis identified eight socio-economic and farm-level characteristics as significant determinants of smallholder farmers' adoption of sustainable agricultural practices (SAPs) at the 5 percent level. These factors; age, education, income, household size, farming experience, income sources, farm size, and communication access; reflect both the human capital and resource endowments that shape innovation uptake in diverse contexts.

Age exhibited a small but statistically significant negative association with SAP use (p = -0.009), indicating that younger farmers were more likely to implement sustainable techniques. This inverse relationship aligns with findings in Sub-Saharan Africa, where older farmers often have more entrenched routines and perceive higher risks in changing established methods (Teklewold et al. 2013).

Years of formal schooling positively influenced SAP adoption (p = 0.014), underscoring education's role in enhancing farmers' ability to process technical information and apply new agronomic principles. Prior studies in Nigeria and Ghana have documented that each additional year of education increases the probability of adopting improved seeds, organic manures, and water-saving irrigation methods by 5–8 percent (Oyetunde-Usman et al. 2021). Household annual income emerged as the strongest predictor ($p < 0.001$), with wealthier households more readily affording the upfront costs of SAPs such as precision irrigation controllers or high-quality organic amendments. These finding echoes evidence from northern Ghana, where higher farm and non-farm incomes enabled more comprehensive SAP packages, rather than single-practice adoption, to be deployed, yielding greater farm income and food-security gains (Dope Setsoafia et al. 2022).

Larger households were more likely to adopt SAPs (p = 0.026), reflecting the labor intensity of practices like residue mulching, green manuring, and alternate wetting and drying. Amankwah et al. (2023) similarly observed that households with greater family labor capacity invested more in labor-demanding soil-conservation measures, translating into higher plot-level productivity under multiple SAP regimes.

Contrary to a purely risk-averse view, greater farming experience positively correlated with SAP use (p = 0.017). Experienced farmers may better judge the long-term benefits of soil-building and water-saving practices, having observed the diminishing returns of monocropping and continuous flooding over many seasons (Ndiritu et al. 2014). Diversified income, particularly off-farm earnings, also supported SAPs uptake (p = 0.027), by smoothing cash flows and permitting investment in inputs during lean periods. Dope Setsoafia et al. (2022) reported that farmers with multiple income streams were 30 percent more likely to adopt comprehensive SAP packages, suggesting that financial resilience catalyzes experimentation with sustainable methods.

Larger landholdings were significantly associated with SAPs use (p = 0.045). Scale economies allow farmers to allocate block areas for trial or scaled-up sustainable practices without compromising total output, a pattern documented in both Nigeria and South Africa for practices like conservation tillage and intercropping (Sithole & Olorunfemi 2024). Finally, access to modern communication, such as mobile phones, radio, and extension bulletins, was a positive determinant (p = 0.032). Reliable information flow reduces uncertainty about SAP implementation and connects farmers to weather forecasts, input suppliers, and peer networks. Sithole and Olorunfemi (2024) underscore communication infrastructure as pivotal for scaling SAPs in rural SSA, where knowledge gaps remain a principal barrier to broader adoption (Teklewold et al. 2015).

Overall, these results highlight that both human capital (education, experience), financial capacity (income, income diversification, farm size), and enabling conditions (labor availability, communication access) jointly shape sustainable practice adoption.

Conclusion

Rice farmers in Ebonyi State use SAPs considerably, and the most used SAPs by the farmers were; direct-seeded rice (DSR), system of rice intensification (SRI), use of green manure, organic farming, and precision agriculture. The least used SAPs were; conservation tillage, alternate wetting and drying (AWD), residue management and mulching, no-till farming, and composting, while precision irrigation monitoring, improved grain drying, and integrated pest management were moderately used. Furthermore, younger, better-educated farmers with higher and diversified incomes, larger households, more farming experience, and greater access to communication channels were markedly more likely to implement SAPs. Likewise, larger farm sizes facilitated experimentation and scale-up of practices, reinforcing the role of resource endowment in innovation uptakes.

Recommendations

Prioritizing the scaling of high-uptake SAPs by supporting farmer-led demonstrations and peer learning for DSR, SRI, and organic amendments to accelerate trust and local evidence of benefits is necessary. Also, investing in targeted training and extension that focuses on lower-used conservation practices (AWD, conservation tillage, residue management, no-till, composting), using hands-on field schools, pictorial guides, and season-timed sessions to overcome technical and knowledge barriers are recommended.

References

Aliyu, N. L., Bello, O. G., Olatinwo, L. K., Omotesho, K. F., & Adefalu, L. L. (2020). Farmers' adoption of System of Rice Intensification in Chanchaga Local Government Area of Niger State, Nigeria. *Nigerian Journal of Basic and Applied Science*, 28(2), 55–63.

Amankwah, A., (2023). Climate variability, agricultural technologies adoption, and productivity in rural Nigeria: A plot-level analysis. *Agriculture & Food Security*, 12(7).

Chaudhary, A. C., Mishra, A. K., Venkatramanan, V., & Sharma, S. (2024). Factors affecting farmers' acceptance and adoption of Direct seeded rice technology in developing climate resilience among rice farmers in Odisha, India. *Asian Food and Journal of Business Studies*, SI 2, 3212–3232

Chidiebere-Mark, N., Ohajianya, D., Obasi, P., & Onyeagocha, S. (2019). Profitability of rice production in different production systems in Ebonyi State, Nigeria. Open Agriculture, 4(1). https://doi.org/10.1515/opag-2019-0022

Cooreman, H., Vandenabeele, J., Debruyne, L., Ingram, J., Chiswell, H., Koutsouris, A., Pappa, E., & Marchand, F. (2018). A conceptual framework to investigate the role of peer learning processes at on-farm demonstrations in the light of sustainable agriculture. *International Journal of Agricultural Extension, 6*(3), 91-103. Retrieved from https://journals.esciencepress.net/index.php/IJAE/article/view/2682

Darji, R. K., and Yadav, M. K., (2024). Impact of mass media in agriculture: An overview. *Agricultural and Biological Research*; 40(4):1232-1233.

Dope Setsoafia, E., Ma, W., & Renwick, A. (2022). Effects of sustainable agricultural practices on farm income and food security in northern Ghana. *Agricultural and Food Economics*, 10(9).

Esheya, S. (2021). Profitability Analysis of Rice Production in Ebonyi North Agricultural Zone of Ebonyi State, Nigeria. International Journal of Agriculture and Rural Development(IJARD), 24(1).

Food and Agriculture Organization of the United Nations (FAO). (2018). Integrated Pest Management Farmer Field Schools. Rome: FAO

Igwe, A., Abor, C., & Nwose, D. I. (2019). Awareness and Determinants of Sustainable Agricultural Land Management Practices among Crop Farmers in Ebonyi State, Nigeria.Casirmediapublishing.com.

Lee-Ann Sutherland & Fleur Marchand (2021) On-farm demonstration: enabling peer-to-peerlearning, The Journal of Agricultural Education and Extension, 27:5, 573-590, DOI: 10.1080/1389224X.2021.1959716

Möhring, N., Müller, A., & Schaub, S. (2024). Farmers' adoption of organic agriculture—a systematic global literature review. *European Review of Agricultural Economics*, 51(4), 1012–1044.

Mohapatra, K. K., Nayak, A. K., Patra, R. K., Tripathi, R., Swain, C. K., Moharana, K. C., ... & Nagothu, U. S. (2023). Multi-criteria assessment to screen climate-smart rice establishment techniques in coastal rice production systems of India. *Frontiers in Plant Science*, 14, Article 1130545. https://doi.org/10.3389/fpls.2023.1130545

Msuya, C., Annor-Frempong, F., Magheni, M., Agunga, R., Igodan, C., Ladele, A., Huhela, K., Tselaesele, N., Msatilomo, H., Chowa, C., Zwane, E., Miiro, R., Bukeyn, C., Kima, L., Meliko, M., & Ndiaye, A. (2017). The Role of Agricultural Extension in Africa's Development, The Importance of Extension Workers and the Need For Change. *International Journal of Agricultural Extension*, *5*(1), 51-58. Retrievedfrom https://journals.esciencepress.net/index.php/IJAE/article/view/21

Nazari1, M. R., and Hj Hassan, M. S., (2020). The role of television in the enhancement of farmers' agricultural knowledge. *International Journal of Agricultural Extension and Rural Development* ISSN 3254-5428 Vol. 8 (3), pp. 001-006, March, 2020

Ndiritu, S. W., Ngigi, M., & Jayne, T. S. (2014). Determinants and impacts of sustainable agricultural intensification in Sub-Saharan Africa. *Journal of Development Studies,* 50(4), 512–529.

Ntshangase, N. L., Muroyiwa, B., & Sibanda, M. (2018). Farmers' perceptions and factors influencing the adoption of no-till conservation agriculture by small-scale farmers inZashuke, KwaZulu-Natal Province. *Sustainability*, 10(2), 555.

Omoghene, F., Nathaniel, A., Okome, J., and Okumagba, S. K. (2019). A Study of the Impact of Radio Agricultural Programmes on Targeted Audience in Nigeria. *African Journal ofAgricultural Economics and Rural Development* ISSN 2375-0693 Vol. 7 (7), pp. 001-005,July, 2019.

Osuafor, O. O. (2022). Level of Awareness and Climate-Smart Agricultural Technologies used by Rice Farmers in South-east, Nigeria. *Proceedings of the 54th Annual Conference of the Agricultural Society of Nigeria.*

Oyetunde-Usman, Z., Olagunju, K. O., & Ogunpaimo, O. R. (2021). Determinants of adoption of multiple sustainable agricultural practices among smallholder farmers in Nigeria. *International Soil and Water Conservation Research*, 9(3), 241–248.

Prajapati, S. K., Dayal, P., Kumar, V., & Gairola, A. (2023). Green Manuring: A sustainable path to improve soil health and fertility. *AgriSustain: An International Journal*, 1(2), 24–33.

Ramavhale, P. M., Zwane, E.M., & Belete, A.. (2024). The Benefits of Social Media Platforms Used in Agriculture for Information Dissemination. *South African Journal of Agricultural Extension* , *52*(2), 77-90. https://doi.org/10.17159/2413-3221/2024/v52n2a15342

Sen, L. T. H., Phuong, L. T. H., Chou, P., Dacuyan, F. B., Nyberg, Y., & Wetterlind, J. (2025). The Opportunities and Barriers in Developing Interactive Digital Extension

Services for Smallholder Farmers as a Pathway to Sustainable Agriculture: A SystematicReview. *Sustainability*, *17*(7), 3007. https://doi.org/10.3390/su17073007

Shodipe, O. A., Sanusi, B.,Talabi, F. O., Adelabu, O., (2024). Radio's role in agriculturaldevelopment: a review of broadcasting strategies for farmer education in South-WestNigeria. *Global Knowledge, Memory andCommunication* ; https://doi.org/10.1108/GKMC-03-2024-0163

Sithole, A., & Olorunfemi, O. D. (2024). Sustainable agricultural practices in Sub-Saharan Africa: A review of adoption trends, impacts, and challenges among smallholder farmers.*Sustainability*, 16(22), 9766.

Soulignac, V., Pinet, F., Bodelet, M., & Gross, H. (2025). The Use of Digital Social Media inAgriculture. *International Journal of Agricultural and Environmental Information Systems(IJAEIS)*, *16*(1), 1-13. https://doi.org/10.4018/IJAEIS.366308

Teklewold, H., Kassie, M., & Shiferaw, B. (2015). Information and communication technologies for agricultural knowledge management. *Journal of Agricultural Extension*, 19(3), 45–58.

Teklewold, H., Kassie, M., Shiferaw, B., & Kohlin, G. (2013). *Adoption of multiple sustainable agricultural practices in rural Ethiopia: Intentions vs. actual adoption.* Agricultural Economics, 44(5), 597–611.

Tumenta, B. F., Amungwa, F. A., & Nformi, M. I. (2021). Role of agricultural cooperatives in rural development in the era of liberalization in the North West and South West regions ofCameroon. *Journal of Agricultural Extension and Rural Development*, 13(1), 69-81.

Umeh, G., & Chukwu, V. A. (2014). Determinants of Adoption of Improved Rice ProductionTechnologies in Ebonyi State of Nigeria. *Journal of Business and Agricultural Economics*.

Van de Zande, G. D., Grant, F., Sheline, C., Amrose, S., Costello, J., Ghodgaonkar, A., & Winter,A. G. (2024). Design and evaluation of a precision irrigation tool's human–machineinteraction to bring water- and energy-efficient irrigation to resource-constrained farmers.*Sustainability*, 16(19), 8402.

Yadav, A., Mishra, A. K., & Maurya, P. K. (2025). Optimizing resource use efficiency withalternate wetting and drying: A climate-smart solution. In *Transition to RegenerativeAgriculture* (pp. 89–109). Springer.