



Awareness, Adoption Intensity and Institutional Determinants of Climate-Smart Agricultural Practices among Crop Farmers in Ebonyi State, Nigeria

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ABSTRACT

Background: Ebonyi State's predominantly rain-fed crop production exposes farmers to rainfall variability and flooding, yet empirical evidence on climate-smart agriculture (CSA) within the State remains limited.

Objective: This study assessed farmers' awareness of CSA practices, identified practices adopted, determined adoption intensity, examined associated socioeconomic and institutional factors, and identified major constraints to adoption.

Method: A cross-sectional survey of 302 crop farmers across the Abakaliki, Onueke and Afikpo Agricultural Development Programme zones was conducted using a structured questionnaire; data were analysed with descriptive statistics and multinomial logistic regression.

Results: Overall awareness was moderate ($M = 2.19$, $SD = 0.91$). Adoption was highest for irrigation (91.2%), organic manure (87.9%) and early planting (83.8%), and lowest for agroforestry (36.8%); 74.5% of farmers recorded high adoption intensity. Extent of use was highest for early planting ($M = 3.20$, $SD = 0.77$) and lowest for agroforestry ($M = 1.84$, $SD = 0.95$). High input cost ($M = 2.67$), lack of awareness ($M = 2.66$) and poor credit access ($M = 2.59$) were the leading constraints. The multinomial model was significant, $\chi^2(28) = 101.15$, $p < .001$, Nagelkerke $R^2 = .372$; credit access was positively associated with high adoption intensity ($OR = 9.56$, $p < .001$), while association membership was negatively associated ($OR = 0.42$, $p = .035$).

Conclusion: Current approaches appear more successful at encouraging simpler, low-cost practices than at facilitating systemic integration of technically demanding ones, underscoring the need to address financial and informational constraints.

Unique Contribution: The study contributes empirical evidence to SDG 2 (Zero Hunger) and SDG 13 (Climate Action), informs state-level adaptation planning and extension targeting, and integrates the Diffusion of Innovations with the Theory of Planned Behaviour in explaining adoption intensity in sub-Saharan Africa.

Key Recommendation: Extension agencies should establish demonstration plots within existing farmer groups that bundle widely adopted practices with underutilised ones such as agroforestry, while policymakers link microfinance schemes to registered farmers' associations to reduce input costs and expand credit access.

Keywords: climate-smart agriculture; adoption intensity; awareness; agricultural credit; farmers' associations; Ebonyi State



INTRODUCTION

Climate change increasingly affects agricultural production through rainfall variability, flooding, dry spells and temperature changes that disrupt planting decisions and crop performance. Rain-fed systems are especially exposed because production depends heavily on rainfall timing and soil moisture (Food and Agriculture Organization of the United Nations [FAO], 2023; Intergovernmental Panel on Climate Change [IPCC], 2022). In sub-Saharan Africa, these pressures occur alongside constraints in finance, infrastructure, extension and markets (Campbell et al., 2014; Manono et al., 2025).

Climate-Smart Agriculture (CSA) provides a framework for improving productivity and incomes, strengthening adaptation and resilience, and reducing or removing greenhouse-gas emissions where feasible (FAO, 2013; Lipper et al., 2014). CSA is context-specific rather than a universal technology package; practices are considered climate-smart according to their contribution to these objectives within particular agro-ecological and socioeconomic settings (Gemtou et al., 2024). Farmers' movement from information to implementation is shaped by resources and institutions. Awareness introduces an innovation, but adoption decisions are affected by perceived benefits, technical complexity, risk, finance, labour, land security and institutional support (Dessart et al., 2019; Meijer et al., 2015). Nigerian evidence similarly links agricultural technology adoption to socioeconomic and resource conditions (Awotide et al., 2016; Oyetunde-Usman et al., 2021).

Adoption intensity adds an important dimension. A binary measure identifies whether a farmer uses a practice but does not show the extent to which several practices are integrated. Multiple-practice research therefore uses counts, indices and graded measures to distinguish limited uptake from broader implementation (Feder et al., 1985; Basiru et al., 2024). Ebonyi State is an appropriate setting because crop production is strongly rain-fed and the state is an important producer of rice, yam, cassava and maize. Studies in Southeast Nigeria and Ebonyi State document climate-smart practices and exposure to climate risks, but practice-specific uptake and institutional relationships vary across settings (Onyeneke et al., 2018, 2021; Mbanasor et al., 2024; Njoku et al., 2024).

A central issue is whether awareness is accompanied by actual practice use and intensive implementation. Credit may enable farmers to purchase inputs and meet seasonal production costs, while farmer organisations may facilitate information exchange and collective action; however, institutional effects are not necessarily uniform across contexts (Balana & Oyeyemi, 2022; Kahsay et al., 2024). This study consequently assesses awareness, identifies specific CSA practices adopted, determines adoption intensity, examines socioeconomic and institutional factors associated with intensity, and identifies major constraints among crop farmers in Ebonyi State.

STATEMENT OF THE PROBLEM

Climate variability poses an increasing challenge to agricultural production in Ebonyi State, where many crop farmers depend on rain-fed systems that are vulnerable to irregular rainfall, flooding and declining soil quality. Although climate-smart agriculture (CSA) provides a framework for improving agricultural resilience, productivity and sustainability, the uptake of CSA practices among farmers remains uneven. The existence of individual CSA practices does



not necessarily indicate broad or intensive adoption, as farmers may adopt some practices while using others infrequently or not at all.

Existing studies in Nigeria have largely focused on farmers' perceptions of climate change, general adaptation strategies or the determinants of adopting individual practices. Consequently, limited empirical evidence exists on the combined dimensions of CSA awareness, types of practices adopted, adoption intensity and the constraints shaping uptake among crop farmers in Ebonyi State. In particular, insufficient attention has been given to how institutional factors such as access to agricultural credit, extension services and membership of farmers' associations are associated with differences in adoption intensity.

This evidence gap limits a comprehensive understanding of the factors that enable or constrain the implementation of CSA at the farm level. Without such evidence, agricultural extension programmes, financial interventions and farmer-support institutions may not adequately address the specific conditions influencing CSA adoption in Ebonyi State. The present study therefore assesses farmers' awareness and adoption of CSA practices, determines the intensity of adoption, identifies major constraints, and examines the socio economic and institutional factors associated with adoption intensity among crop farmers in the state.

RESEARCH OBJECTIVES

The general objective is to assess climate-smart agricultural practices among crop farmers in Ebonyi State, Nigeria. Specific objectives are:

1. To determine level of awareness of CSA practices among crop farmers in Ebonyi State
2. To identify specific CSA practices adopted by crop farmers.
3. To assess the intensity of adoption of CSA practices among crop farmers in Ebonyi State.
4. To examine the socio-economic and institutional factors associated with the intensity of CSA adoption among crop farmers in Ebonyi State.
5. To identify major challenges constraining CSA adoption.

RESEARCH HYPOTHESES

H01: Socio-economic characteristics of crop farmers are not significantly associated with their CSA adoption intensity.

H02: Access to agricultural credit is not significantly associated with CSA adoption intensity.

H03: Membership in farmers' associations is not significantly associated with CSA adoption intensity.

LITERATURE REVIEW



Concept of Climate-Smart Agriculture

Climate-Smart Agriculture is an approach to managing agricultural systems in ways that pursue sustainable productivity and income, adaptation and resilience, and mitigation where feasible (FAO, 2013; Lipper et al., 2014). Its context-specific character is important because a practice that contributes to resilience in one location may not produce the same benefits elsewhere. The classification of practices in this study therefore follows their documented contribution to productivity, adaptation or resource management in crop systems rather than treating CSA as a fixed package (Gemtoui et al., 2024). For the present study, the CSA practices examined included early planting, improved seed varieties, irrigation, organic manure or fertiliser use, mixed cropping, mulching, cover cropping, crop rotation, minimum tillage and agroforestry. These practices signify adjustments in crop timing, genetic material, water management, soil management, diversification and landscape management. Their potential benefits include improved soil moisture, reduced erosion, better use of rainfall, risk diversification and greater resilience to climatic stress (Mbanasor et al., 2024; Njoku et al., 2024).

Awareness of CSA Practices

Awareness is an important cognitive component of agricultural innovation adoption. Within the innovation-decision process, farmers need to encounter and understand an innovation before they can evaluate whether it is relevant to their circumstances (Rogers, 2003). Awareness can be generated through extension services, farmer-to-farmer communication, mass media, digital platforms, input suppliers and community organisations. The growing use of ICT in African agriculture also expands the range of channels through which agricultural information is circulated (Ayim et al., 2022).

Awareness should not, however, be equated with adoption. Farmers may understand the potential value of a practice but lack credit, inputs, labour, land security or technical assistance. Reviews of sustainable agricultural adoption consistently show that behavioural and structural conditions operate alongside knowledge and attitudes (Dessart et al., 2019; Gemtoui et al., 2024). This distinction is central to the present study because it permits assessment of whether moderate or high awareness is accompanied by actual practice use and intensive implementation.

Intensity of CSA Adoption

Adoption intensity captures a dimension that binary adoption cannot provide. A farmer classified as an adopter may use one practice once or combine several practices across the farm and season. The two situations have different implications for production, resilience and resource use. Multiple-practice studies have therefore measured adoption using counts, indices, proportions or graded scales (Basiru et al., 2024; Oyetunde-Usman et al., 2021).

In this study, binary adoption was used to establish whether each of ten CSA practices was currently used. Adoption intensity was measured separately across seven practices for which the questionnaire collected graded extent-of-use responses. The binary section provides a broad practice typology, whereas the intensity section provides a comparable graded measure for



practices with sufficient response detail to support an intensity index. The approach avoids treating a simple yes/no response as if it contained information about degree of use.

Institutional Determinants of CSA Adoption Intensity

Institutional conditions determine whether farmers can convert information into action. Credit can relax seasonal liquidity constraints and allow farmers to purchase inputs, hire labour or invest in water-management and soil-improvement practices (Awotide et al., 2016; Balana & Oyeyemi, 2022). Extension services can reduce information gaps and provide demonstrations, while farmer organisations can facilitate information exchange, collective procurement and social learning (Ayim et al., 2022; Manda et al., 2020).

The expected effect of institutional participation is not necessarily positive in every setting. Organisations differ in their capacity, services, leadership and relationship with members. Membership alone may, therefore, be an imperfect substitution for effective institutional support. This is particularly important for interpreting a negative association between membership and adoption intensity without assuming that farmer organisations are inherently harmful. The present study accordingly tests association membership and credit access separately as institutional determinants.

Theoretical Framework

The study is anchored on Rogers' Diffusion of Innovations theory and Ajzen's Theory of Planned Behaviour. Diffusion of Innovations explains adoption as a process involving knowledge, persuasion, decision, implementation and confirmation, with communication channels and perceived innovation attributes influencing the process (Rogers, 2003). The theory is useful for explaining why awareness and communication precede adoption and why practices with greater compatibility, observability or relative advantage may diffuse differently.

The Theory of Planned Behaviour complements this perspective by emphasising attitudes, subjective norms and perceived behavioural control as determinants of behavioural intention (Ajzen, 1991). In farming, perceived control is relevant to access to capital, land, inputs, labour and technical support. The two perspectives, therefore, provide a useful framework for examining a transition from awareness and practice recognition to actual implementation under different socioeconomic and institutional conditions (Dessart et al., 2019).

Empirical Review and Research Gap

Empirical studies consistently show that CSA adoption varies with farmer characteristics, institutional access and practice attributes. Abegunde et al. (2020) and Oyetunde-Usman et al. (2021) demonstrate the importance of socioeconomic and resource conditions, while Awotide et al. (2016) show how agricultural technology adoption in Nigeria is linked to resource conditions. Nigerian studies likewise report variation across locations and practices (Daudu et al., 2025; Saadu et al., 2024).



Evidence from Southeast Nigeria is relevant. Onyeneke et al. (2018, 2021) documented the regional and Ebonyi State context, while Mbanasor et al. (2024) reported practice-specific CSA patterns and Njoku et al. (2024) linked CSA practices with cassava production outcomes in Ebonyi State. However, available studies often emphasise individual practices or adoption status rather than the combined relationship between awareness, practice-specific adoption, adoption intensity and institutional factors.

This study addresses that gap by examining awareness, ten-practice binary adoption, seven-practice adoption intensity, perceived constraints, and socioeconomic and institutional correlates within one quantitative framework. The distinction between binary adoption and intensity provides a clearer basis for determining whether farmers merely use a practice or integrate a wider portfolio at different levels of implementation.

Research Design

The study employed a cross-sectional quantitative survey design within a post-positivist framework. Data were collected from crop farmers during the study period using a structured questionnaire. The design was appropriate for describing awareness, practice-specific adoption, adoption intensity and perceived constraints and for estimating statistical associations between farmer characteristics, institutional factors and adoption-intensity categories. Because the data were collected at one point in time, the reported relationships are associative rather than causal (Creswell & Creswell, 2018).

Study Area

The study was conducted in Ebonyi State, southeastern Nigeria. The state lies approximately between latitudes 5°40'N and 6°45'N and longitudes 7°30'E and 8°30'E and has a tropical climate with a bimodal rainfall pattern (Osuji et al 2025). Agriculture is an important livelihood activity, with rice, yam, cassava and maize among major crops. The state is also exposed to rainfall variability and flooding, making it a relevant setting for examining CSA practices (Onyeneke et al., 2018, 2021; Njoku et al., 2024). For agricultural administration, the state is divided into the Abakaliki, Onueke and Afikpo ADP zones.

Sample Size Determination

Cochran's (1977) formula for a large or unknown population was used with a 95% confidence level, $p = .50$, $q = .50$ and a 5% margin of error. The calculation produced a minimum sample of approximately 384 respondents. To accommodate non-response and unusable questionnaires, 400 questionnaires were administered. Of these, 302 were correctly completed and retrieved, giving a usable response rate of 75.5%. The final sample of 302 was retained for analysis and the shortfall from the initial Cochran estimate is recognised as a limitation. For the multiple-response typology module, five incomplete records were excluded listwise, yielding 297 valid cases.

Sampling Procedure

A multistage procedure was used. First, the three ADP zones: Abakaliki, Onueke and Afikpo were included to provide coverage of the state's agricultural zones. Second, one LGA was selected by simple random balloting from each zone: Izzi from Abakaliki, Ikwo from Onueke and Ohaozara from Afikpo. Third, eight farming communities were randomly selected within



each sampled LGA, producing 24 communities. Fourth, respondents were selected by proportional allocation and simple random sampling from farmer lists supplied by community heads and local extension agents. The farmer lists were screened to confirm active crop farmers, compared across available local lists to identify duplicate names, and checked with community and extension personnel before selection. This procedure was used to reduce duplication and improve coverage of eligible farmers.

Research Instrument

Data were collected with a structured questionnaire administered through face-to-face interviews by trained enumerators. Interviewer administration was used consistently to accommodate differences in literacy and to ensure that response categories were understood in the same way. The instrument had five sections. Section A collected socioeconomic and farm-enterprise characteristics. Section B measured awareness of CSA practices on a four-point scale: 1 = Not Aware, 2 = Slightly Aware, 3 = Moderately Aware and 4 = Highly Aware. Section C measured binary adoption of ten practices as Yes = 1 and No = 0. Section D measured intensity of adoption for seven practices on a four-point scale: 1 = Not Adopted, 2 = Low Extent, 3 = Moderate Extent and 4 = High Extent. Section E measured eight perceived challenges on a four-point scale from Not a Constraint to Very Serious Constraint.

The ten-practice binary section and seven-practice intensity section were deliberately treated as different measures. The ten practices were retained for the broad adoption typology because the objective of the binary measure was to establish which CSA practices farmers currently used across a wider practice set. The intensity measure was restricted to seven practices for which the questionnaire collected graded intensity-of-use responses that were directly comparable and could therefore be aggregated into an intensity measure. The three additional practices in the binary section were not assigned graded extent scores and were excluded from the composite intensity measure. This separation prevents the binary presence/absence responses from being treated as if they contained information on degree of implementation.

Validity and Reliability

Content and face validity were assessed through expert review by three university professors with expertise in agricultural extension, rural sociology and agricultural statistics. The instrument was reviewed for clarity, relevance, domain coverage and contextual suitability to crop farming in Ebonyi State, and the recommended revisions were incorporated. A pilot test involving 40 crop farmers in a comparable non-sampled community was used to assess internal consistency. Cronbach's alpha coefficients were .87 for awareness, .82 for intensity of adoption and .79 for perceived challenges. All exceeded the conventional .70 benchmark (Nunnally & Bernstein, 1994). Alpha was not calculated for demographic variables or binary adoption items because internal consistency statistics are not appropriate for those categorical measures.



Measurement of Variables

The dependent variable was CSA adoption intensity, defined as the degree or extent to which farmers implemented selected CSA practices. Seven practices: early planting, organic fertiliser use, supplementary irrigation, mulching, improved seed varieties, crop rotation and agroforestry were scored from 1 = Not Adopted to 4 = High Extent. Item scores were averaged to obtain a composite score from 1.00 to 4.00 and classified into low, moderate and high intensity using equal-width intervals on the four-point continuum. The resulting categories were low ($n = 53$, 17.5%), moderate ($n = 24$, 7.9%) and high ($n = 225$, 74.5%).

The explanatory variables were age, gender, education, farming experience, farm type, farmers' association membership and agricultural credit access. These predictors were selected a priori to represent human capital, production structure, social organisation and resource access identified in the adoption literature.

DATA ANALYSIS

Data were coded, cleaned and analysed in IBM SPSS Statistics version 26. Frequencies and percentages summarised demographic characteristics and binary adoption; means and standard deviations summarised awareness, practice-specific intensity and perceived constraints. Adoption intensity was analysed with multinomial logistic regression using low intensity as the reference category.

The model estimated the log odds of moderate and high adoption intensity relative to low intensity. Odds ratios, 95% confidence intervals and two-tailed p-values were reported at $\alpha = .05$. Multinomial regression was selected a priori because the study sought category-specific contrasts without imposing a common proportional-odds restriction.

The seven predictors were retained because they were part of the prespecified instrument and theoretical framework. Variables such as farm size, annual farm income, extension-visit frequency, household size, land tenure and risk perception were not included because they were not measured within the final questionnaire/model specification and could not be introduced retrospectively without changing the completed study design. Multicollinearity was considered during model preparation, and model fit was assessed using the omnibus likelihood-ratio test and pseudo- R^2 statistics.



Socioeconomic Characteristics of Crop Farmers

Table 1: Socioeconomic Characteristics of Respondents (N=302)

Variable	Category	n	%
Age	20–30	60	19.9
	31–40	96	31.8
	41–50	93	30.8
	≥51	53	17.5
Gender	Male	158	52.3
	Female	144	47.7
Education	No formal	20	6.6
	Primary	24	7.9
	Secondary	124	41.1
	Tertiary	134	44.4
Experience	0–5	12	4.0
	6–10	23	7.6
	11–15	89	29.6
	16–20	111	36.9
	≥21	66	21.9
Farm type	Smallholder	122	40.4
	Commercial	180	59.6
Association	Member	119	39.4
	Non-member	183	60.6
Credit access	Access	123	40.7
	No access	179	59.3

Table 1 outlines the demographic profile of respondents. A majority of respondents were aged 31 to 40 years (31.8) and 41 to 50 years (30.8), with males comprising 52.3% of the sample. Educational attainment was relatively high, as 44.4% held tertiary qualifications and 41.1% completed secondary education. Most respondents possessed substantial experience, predominantly within 16 to 20 years (36.9%) and 11 to 15 years (29.6). Additionally, commercial operations constituted 59.6% of farm types. Conversely, non-membership in associations (60.6%) and lack of credit access (59.3%) were prevalent across the population.



Level of Awareness of CSA Practices

Table 2: Awareness of Selected CSA Practices (N = 302)

CSA practice	M	SD	Interpretation
Improved seed varieties	2.66	0.85	Moderate
Irrigation/water management	2.32	1.02	Moderate
Agroforestry	2.29	0.90	Moderate
Organic fertiliser use	2.20	0.90	Moderate
Crop rotation	2.03	1.00	Low
Mulching	1.96	0.75	Low
Conservation tillage	1.82	0.88	Low
Overall awareness	2.19	0.91	Moderate

Overall awareness was moderate ($M = 2.19$, $SD = 0.91$). Improved seed varieties recorded the highest awareness ($M = 2.66$, $SD = 0.85$), followed by irrigation/water management ($M = 2.32$, $SD = 1.02$), agroforestry ($M = 2.29$, $SD = 0.90$) and organic fertiliser use ($M = 2.20$, $SD = 0.90$). Awareness was low for crop rotation ($M = 2.03$, $SD = 1.00$), mulching ($M = 1.96$, $SD = 0.75$) and conservation tillage ($M = 1.82$, $SD = 0.88$). The results indicate that awareness was not uniform across practices.

Binary Adoption of CSA Practices

Table 3: Binary Adoption of CSA Practices (N = 297)

Practice	Adopted n	Adopted %	Not adopted n	Not adopted %
Irrigation	271	91.2	26	8.8
Organic manure	261	87.9	36	12.1
Mixed cropping	255	85.9	42	14.1
Early planting	249	83.8	48	16.2
Mulching	211	71.0	86	29.0
Cover cropping	162	55.3	135	44.7
Crop rotation	152	51.1	145	48.8
Improved seed varieties	150	50.5	147	49.4
Minimum tillage	128	43.0	169	56.9
Agroforestry	111	37.4	186	62.6

Table 3 presents the distribution of Climate-Smart Agriculture (CSA) practices among respondents ($N = 297$). Irrigation recorded the highest adoption rate (91.2%), followed by organic manure (87.9%), mixed cropping (85.9%), early planting (83.8%), and mulching (71.0%). Moderate implementation was observed for cover cropping (55.3%), crop rotation



(51.1%), and improved seed varieties (50.5%). But, non-adoption predominated for capital-intensive practices, particularly for minimum tillage (56.9%) and agroforestry (62.6%).

Adoption Intensity of CSA Practices

Table 4. Adoption Intensity of CSA Practices (N = 302)

Practice/category	M or n	SD or %	Interpretation
Early planting	3.20	0.77	High extent
Organic fertiliser	2.97	1.04	Moderate/high extent
Irrigation	2.45	1.00	Moderate extent
Mulching	2.24	1.02	Moderate extent
Improved seed varieties	2.21	1.00	Moderate extent
Crop rotation	2.15	0.89	Moderate extent
Agroforestry	1.84	0.95	Low extent
Low intensity	53	17.5	
Moderate intensity	24	7.9	
High intensity	225	74.5	

The seven-practice intensity measure classified 74.5% of respondents as high intensity, 17.5% as low intensity and 7.9% as moderate intensity. Early planting had the highest extent-of-use score (M = 3.20, SD = 0.77), followed by organic fertiliser (M = 2.97, SD = 1.04). Irrigation (M = 2.45, SD = 1.00), mulching (M = 2.24, SD = 1.02), improved seed varieties (M = 2.21, SD = 1.00) and crop rotation (M = 2.15, SD = 0.89) were in the moderate range. Agroforestry recorded the lowest extent (M = 1.84, SD = 0.95).

Challenges Constraining CSA Adoption

Table 5: Challenges to CSA Adoption (N = 302)

Challenge	M	SD	Interpretation
High cost of inputs	2.67	0.95	Serious
Lack of awareness	2.66	0.85	Serious
Poor access to credit	2.59	0.92	Serious
Climate variability	2.35	1.04	Moderate
Land tenure issues	2.30	0.81	Moderate
Labour shortage	2.21	0.95	Moderate
Lack of technical knowledge	2.13	0.91	Moderate
Inadequate extension services	1.82	0.88	Less serious

High cost of inputs was the most severe perceived constraint (M = 2.67, SD = 0.95), followed by lack of awareness (M = 2.66, SD = 0.85) and poor access to agricultural credit (M = 2.59, SD = 0.92). Climate variability (M = 2.35, SD = 1.04), land-tenure issues (M = 2.30, SD = 0.81), labour shortage (M = 2.21, SD = 0.95) and lack of technical knowledge (M = 2.13, SD = 0.91)



were rated as moderate constraints. Inadequate extension services recorded the lowest severity ($M = 1.82$, $SD = 0.88$).

Socioeconomic and Institutional Factors Associated with Adoption Intensity

Table 6. Multinomial Logistic Regression Estimates for Adoption Intensity

Comparison / predictor	B	OR	95% CI	p
High vs. Low: Gender (male)	0.80	2.22	[1.09, 4.54]	.028
High vs. Low: Primary vs. tertiary education	2.45	11.61	[1.28, 104.88]	.029
High vs. Low: Association member	-0.86	0.42	[0.19, 0.94]	.035
High vs. Low: Credit access	2.26	9.56	[3.70, 24.68]	<.001
Moderate vs. Low: Age 31–40	-2.39	0.09	[0.02, 0.55]	.009
Moderate vs. Low: Age 41–50	-2.93	0.05	[0.01, 0.38]	.003
Moderate vs. Low: Experience 6–10 years	3.00	20.11	[1.34, 302.24]	.030
Moderate vs. Low: Smallholder	1.28	3.58	[1.14, 11.20]	.029
Moderate vs. Low: Association member	-3.31	0.04	[0.01, 0.21]	<.001

The multinomial logistic regression model was statistically significant, $\chi^2 (28) = 101.15$, $p < .001$. The model produced Cox and Snell $R^2 = .285$, Nagelkerke $R^2 = .372$ and McFadden $R^2 = .231$. Likelihood-ratio tests showed significant overall effects for age ($\chi^2 = 14.82$, $p = .022$), gender ($\chi^2 = 8.40$, $p = .015$), education ($\chi^2 = 14.48$, $p = .025$), farmers' association membership ($\chi^2 = 19.85$, $p < .001$) and access to agricultural credit ($\chi^2 = 37.48$, $p < .001$). Farming experience ($\chi^2 = 14.12$, $p = .079$) and farm type ($\chi^2 = 5.00$, $p = .082$) were not significant at the .05 level in the overall likelihood-ratio tests.

4.6.1 High versus Low Adoption Intensity

Male farmers had higher odds of high rather than low adoption intensity than female farmers ($B = 0.80$, $OR = 2.22$, 95% CI [1.09, 4.54], $p = .028$). Farmers with primary education had higher odds of high rather than low intensity relative to tertiary-educated farmers ($B = 2.45$, OR

= 11.61, 95% CI [1.28, 104.88], $p = .029$). Association membership was negatively associated with high rather than low intensity ($B = -0.86$, OR = 0.42, 95% CI [0.19, 0.94], $p = .035$). Access to agricultural credit was strongly positively associated with high rather than low intensity ($B = 2.26$, OR = 9.56, 95% CI [3.70, 24.68], $p < .001$).

Moderate versus Low Adoption Intensity

Farmers aged 31–40 years had lower odds of moderate rather than low intensity than those aged ≥ 51 years ($B = -2.39$, OR = 0.09, 95% CI [0.02, 0.55], $p = .009$). The corresponding result for farmers aged 41–50 years was also negative ($B = -2.93$, OR = 0.05, 95% CI [0.01, 0.38], $p = .003$). Farmers with 6–10 years of farming experience had higher odds of moderate rather than low intensity relative to those with ≥ 21 years ($B = 3.00$, OR = 20.11, 95% CI [1.34, 302.24], $p = .030$). Smallholders had higher odds of moderate rather than low intensity than commercial farmers ($B = 1.28$, OR = 3.58, 95% CI [1.14, 11.20], $p = .029$). Association membership was negatively associated with moderate rather than low intensity ($B = -3.31$, OR = 0.04, 95% CI [0.01, 0.21], $p < .001$). The wide confidence interval for the 6–10-year experience category reflects the relatively small number of respondents in the moderate-intensity group.

Summary of Hypotheses Testing

H01 was partially rejected because some socioeconomic characteristics: gender, education and selected age, experience and farm-type contrasts were significantly associated with adoption-intensity categories, while the overall effects of farming experience and farm type were not significant at the .05 level. H02 was rejected because access to agricultural credit was significantly and positively associated with high rather than low adoption intensity. H03 was rejected because farmers' association membership was significantly associated with both moderate and high intensity relative to low intensity, with the observed association being negative.

DISCUSSION

Awareness of CSA Practices

Overall awareness was moderate, $M=2.19$, $SD=0.91$, suggesting partial exposure rather than comprehensive knowledge. This is consistent with Gabriel et al. (2023) in North-Central and North-West Nigeria and Otitoju et al. (2023), who found awareness moderate but uneven across practices.

Awareness was highest for improved seed varieties, $M=2.66$, $SD=0.85$, followed by irrigation/water management, $M=2.32$, $SD=1.02$, agroforestry, $M=2.29$, $SD=0.90$ and organic fertiliser use, $M=2.20$, $SD=0.95$. This aligns with Babaji et al. (2025) in Bauchi and Saadu et al. (2024) in North-Western Nigeria, where improved varieties and water management were most recognised. The higher awareness of improved seeds may reflect longstanding promotion of certified seeds.

In contrast, awareness was lower for crop rotation, $M=2.03$, $SD=1.00$ and mulching, $M=1.96$, $SD=0.75$, with conservation tillage lowest, $M=1.82$, $SD=0.88$. This contrasts with Babaji et al. (2025), who reported high awareness of crop rotation, and differs from Mbanasor et al. (2024) in Southeast Nigeria.



Specific CSA Practices Adopted

Irrigation, organic manure, mixed cropping and early planting were each adopted by 91.2%, 87.9%, 85.9%, and 83.8% of the farmers respectively. This pattern is consistent with Saadu et al. (2024) and Mbanasor et al. (2024) in Southeast Nigeria, reflecting compatibility with existing systems and low technical complexity. Early planting and mixed cropping require minimal financial investment while offering visible benefits under variable rainfall.

Adoption was moderate for mulching, 71.0%, covers cropping, 55.3%, crop rotation, 51.1% and improved seed varieties, 50.3%. The near-equal split for improved seeds suggests variability in access, cost and risk perception, implying need to strengthen input distribution and demonstrations.

Lower adoption was observed for minimum tillage, 43.0% and agroforestry, 37.4%, with agroforestry lowest. This aligns with Diro et al. (2022) in Ethiopia, where technically demanding practices requiring longer-term investment and changes to traditional land preparation showed limited uptake.

Adoption Intensity of CSA Practices

The finding that 74.5% of respondents were classified as having high adoption intensity is interpreted alongside the practice-specific scores. Early planting and organic fertiliser recorded the highest extent of use, whereas agroforestry recorded the lowest. Thus, the composite category reflects the breadth of practices across the intensity index and does not mean that every practice was used at a high level. The result supports the value of measuring intensity in addition to binary adoption because farmers can differ substantially in the depth of implementation (Basiru et al., 2024; Oyetunde-Usman et al., 2021).

Constraints and the Awareness-to-Action Gap

High input cost ($M = 2.67$, $SD = 0.95$), lack of awareness ($M = 2.66$, $SD = 0.85$) and poor access to credit ($M = 2.59$, $SD = 0.92$) were the leading perceived constraints. The convergence between the credit constraint and the regression result is important: farmers identified credit as a problem, and those with credit access were more likely to be in the high-intensity category. The finding supports the view that information is more actionable when farmers have the resources required for implementation (Awotide et al., 2016; Balana & Oyeyemi, 2022).

Institutional Determinants

Credit access had the strongest positive association with high rather than low adoption intensity ($OR = 9.56$, $p < .001$). This is consistent with the resource requirements of many CSA practices and evidence that financial constraints can limit agricultural technology adoption (Saadu et al., 2024). Because the design was cross-sectional, the result indicates association rather than causation.

Farmers' association membership was negatively associated with both moderate and high intensity relative to low intensity. This differs from the expectation that organisations automatically promote technology diffusion through social learning. Institutional effects depend on organisational capacity and the services actually provided to members (Kahsay et al 2025).



Membership status alone cannot establish whether an association offers technical training, input services or finance linkages; the observed negative association therefore requires further investigation rather than a conclusion that farmer organisations are inherently detrimental.

Socioeconomic Factors

Male farmers had higher odds of high rather than low adoption intensity, consistent with evidence that differences in access to land, finance, labour and productive assets can shape CSA adoption (Daudu et al., 2025). Primary education was positively associated with high rather than low intensity relative to tertiary education, but the wide confidence interval calls for caution.

The moderate-versus-low comparison also showed lower odds for farmers aged 31-40 and 41-50 relative to those aged ≥ 51 , while the 6-10-year experience group and smallholders had higher odds of moderate rather than low intensity. These differences illustrate the value of category-specific estimation when adoption intensity is not uniform across farmer groups.

CONCLUSION

Overall, 74.5% of farmers recorded a high extent of CSA adoption, despite uneven awareness ($M = 2.19$, $SD = 0.91$) and marked variation in adoption intensity across practices. Credit access ($OR = 9.56$) and association membership ($OR = 0.42$) were significantly associated with adoption levels. Current approaches appear more successful at encouraging simpler, low-cost practices than facilitating systemic integration of technically demanding ones, highlighting the need to address financial and informational constraints.

RECOMMENDATIONS

1. Extension services in Ebonyi should integrate practical demonstration plots combining high-adoption practices early planting and organic manure with lower-adoption agroforestry and conservation tillage within existing farmer groups.
2. State and federal policymakers should link microfinance schemes directly to registered farmers' associations to reduce high input costs and improve credit access.
3. Agricultural communication units should redesign campaigns to emphasise interconnected benefits of CSA practices rather than isolated technologies.
4. Local government agricultural departments should establish monitoring systems to track intensity changes and evaluate bundled interventions involving credit, training and market support.
5. Strengthen farmer associations through transparent resource allocation, demonstration plots, gender-inclusive leadership and co-financing mechanisms.



Ethical approval

The study involved adult farmers and was conducted under the institutional research procedures applicable to the study. Participation was voluntary and respondents were informed about the purpose of the study before data collection.

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Conflict of interest

The authors declare no conflict of interest.

Data availability

The dataset on which conclusions drawn for this study are available on reasonable request

Authors' Contributions

Ogodo Monday Ogodo conceptualised, designed, drafted the first copy and data analysis, Elechi Joseph conducted the Literature review; while Ugbo Ejike and Chidozie-Omi Mercy surveyed the field for Data collection, data coding and general proofreading.

All authors read and approved manuscript for publication and conferred rights to corresponding author to make necessary changes required by editorial team and act as guarantor.

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AI tool (ChatGPT) was used for language editing and structural planning; all scientific content was verified by the authors.

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