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Adoption and Impact of Climate-Smart Agricultural Practices Among Smallholders Farmers in the Niger Delta: The Role of Agricultural Extension Services

[1] Okringbo, J. I., [2]Akarara, E. E. and [3]Chukuigwe, O.

[1]Department of Agricultural Economics, Extension & Rural Development, Niger Delta University, Bayelsa State, Nigeria
[2]Department of Economics, Niger Delta University, Bayelsa State, Nigeria
[3]Department of Agricultural Extension and Rural Development. Rivers State University. Port Harcourt, Nigeria

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ABSTRACT

The study examined the role of agricultural extension services and looked at how smallholder farmers in the Niger Delta adopted and used Climate-Smart Agricultural (CSA) practices. Determining the sociodemographic qualities of farmers, estimating the degree of CSA adoption, identifying influencing factors, assessing extension service support, assessing the impact of CSA on livelihoods and resilience, and identifying the difficulties extension services face were the specific goals. Structured questionnaire, focus groups, and key informant interviews were used to gather primary data from 360 smallholder farmers in the states of Bayelsa, Delta, and Rivers. Descriptive statistics, correlation, multiple regression, and Propensity Score Matching (PSM) were used to analyse the data. The findings showed that 40.8% of farmers had a secondary education, 67.5% were men, and the majority were in the productive age range of 30 to 59 years. More than 70% of them implemented CSA techniques, such as crop rotation, the use of organic manure, drought-tolerant crops, and integrated pest management. Education, farm size, credit, climate information, training, and access to extension services all had a significant impact on CSA adoption, according to regression analysis ($R^2 = 0.742$, $p < 0.01$). The results of the correlation showed that the adoption of CSA and the provision of extension services were strongly positively correlated ($r = 0.642–0.713$). According to PSM results, CSA adopters' income (ATT = ₦58,770, $p < 0.001$) and resilience (ATT = 7.44, $p < 0.001$) were significantly higher than those of non-adopters. Poor infrastructure, a lack of institutional support, and insufficient funding were major obstacles. Stronger extension capacity, policy support, and farmer cooperatives in the Niger Delta are suggested by the study's conclusion that efficient agricultural extension services increase CSA adoption, boost resilience, and maintain livelihoods.

Introduction

Smallholder farmers who depend on agriculture for their livelihoods make up the majority of the population in Nigeria's Niger Delta, an area known for its abundant oil reserves and rich biodiversity. Climate change has presented these farmers with a number of difficulties in recent years, such as unpredictable rainfall patterns, more frequent flooding,

Corresponding author's Email: inemookringbo@ndu.edu.ng (Okringbo, J. I.)

and degraded soil. Climate-Smart Agriculture (CSA) has become a promising solution to these problems. CSA seeks to lower greenhouse gas emissions, increase agricultural productivity, and increase climate change resilience (Food and Agriculture Organisation (FAO), 2013). Agricultural extension services are essential in helping smallholder farmers adopt CSA practices by giving them the information and resources they need to adjust to the changing climate. Agricultural extension services are indispensable in helping smallholder farmers to adopt CSA practices by giving them the information and resources they need to adjust to the changing climate. In Nigeria's Niger Delta, the agricultural sector is the foundation of the rural economy, giving a sizable section of the populace jobs and a means of subsistence. The bulk of agricultural producers in the area are smallholder farmers, who rely on conventional farming practices to support their families and communities. However, agricultural productivity and food security are now at risk due to the growing effects of climate change, which include unpredictable rainfall patterns, protracted droughts, flooding, rising temperatures, and soil degradation (Nwajiuba et al., 2021). Adopting climate-smart agricultural (CSA) practices is essential to ensuring sustainability and resilience in the agricultural sector, as smallholder farmers in the Niger Delta become more vulnerable as climate variability increases. The three primary goals of Climate-Smart Agriculture (CSA), an integrated approach to managing landscapes, cropland, livestock, forests, and fisheries, are to: (1) increase agricultural productivity and incomes in a sustainable manner; (2) adapt and build resilience to climate change; and (3) reduce or eliminate greenhouse gas emissions wherever feasible (FAO, 2013). Agroforestry, conservation agriculture, enhanced irrigation methods, stress-tolerant crop types, integrated soil fertility management, sustainable land management, and more are examples of CSA practices. These methods could lessen the negative effects of climate change while simultaneously increasing food production.

Smallholder farmers in the Niger Delta are still not very likely to use CSA, despite its potential advantages. This is caused by a number of factors, such as poor infrastructure development, limited information availability, inadequate training, financial limitations, and a lack of policy support (Okoli & Anyaegbunam, 2022). Agricultural extension services, which act as a vital channel between farmers and research institutions, are vital to the spread of CSA knowledge and technologies. In order to implement CSA, agricultural extension officers are essential in raising farmer awareness, offering technical support, and facilitating access to resources and inputs.

However, a number of variables, including formal support, government funding, and farmers' openness to executing new methods, affect how well agricultural extension services promote CSA. Because of its ecological vulnerability, oil exploration activities, and socioeconomic limits, the Niger Delta poses particular challenges for agricultural development. Efforts to improve agricultural resilience in the area are made more difficult by the blend of climate-related hazards and land degradation brought on by oil pollution (Ebegbulem et al., 2020). Designing successful policies and interventions therefore requires an understanding of the dynamics of CSA adoption and the function of extension services in promoting this process.

Theoretical framework

This research is anchored on Diffusion of Innovations Theory by Rogers, 2003. The adoption of CSA practices among smallholder farmers can was examined through the lens of the Diffusion of Innovations Theory (Rogers, 2003). This theory posits that the spread of new ideas and technologies within a community follows a process influenced by the innovation's perceived attributes, communication channels, time, and the social system's nature. In the Niger Delta, agricultural extension services serve as serious communication channels, enhancing awareness and understanding of CSA practices.

The effectiveness of these services in promoting adoption is contingent upon factors such as the credibility of the extension agents, the relevance of the information provided, and the methods of communication employed. Extension services that foster group learning and demonstration plots can leverage social learning dynamics, thereby facilitating the broader adoption of CSA practices among smallholder farmers (Li et al., 2023).

The specific objectives of this study are to:

describe the socio- demographic characteristics of smallholder farmers Niger Delta

evaluate how many smallholder farmers in the Niger Delta are currently implementing climate-smart farming techniques.

determine the elements impacting the implementation of these practices.

assess how well agricultural extension services support CSA.

analyse how climate-smart farming methods affect the resilience and means of subsistence of smallholder farmers in the Niger Delta.

ascertain the difficulties extension services encounter when attempting to spread CSA practices.

Hypotheses of the study

HO_1: Agricultural extension services and smallholder farmers' adoption of climate-smart farming practices in the Niger Delta do not significantly correlate.

HO_2: The livelihoods and resilience of smallholder farmers in the Niger Delta are not significantly impacted by climate-smart agricultural practices.

Methodology

The study was carried out in the states of Bayelsa, Delta, and Rivers in Nigeria's Niger Delta. The Niger Delta, which has a humid tropical climate with high temperatures and rainfall, is located between latitudes 4°N and 6°N and longitudes 5°E and 8°E. Smallholder farming is the most common occupation in the area, which is renowned for its abundant biodiversity and agricultural potential. Cassava, yam, rice, maize, and plantains are the main crops grown, and fishing is an essential source of income. Over 45 million people are expected to live in the area, with a sizable percentage working in subsistence farming (National Bureau of Statistics (NBS), 2023).

Multiple sampling technique

Multiple sampling technique was employed**.** In the first stage; purposive sampling technique was used to select Bayelsa, Delta, and Rivers States of the Niger Delta region. These states were purposively selected due to their high levels of environmental degradation and youth restiveness compared to other states in the region. In the second stage, three (3) Local Government area were randomly chosen from each state. Bayelsa State: Ekeremor, Nembe and Yenagoa; Delta State: Bomadi, Burutu and Patani and Rivers State: Abua-Odual, Akuku-Toru and Degema. In third stage, simple random sampling technique was used to select thirty-six (36) communities from the selected LGAs. Finaly, ten smallholder farmers were selected from the thirty (36) communities giving us a sample size of 360 respondents.

Method of data collection

Focus groups, key informant interviews, and structured questionnaire were used to gather primary data that was used for the study.

Method of data analysis

Data collected were analysed using descriptive statistics. While, Inferential statistics was used test the hypotheses.

Table 1: Descriptive statistics of explanatory variables and instruments used

Study objectives	Statistical Measurement tools	Use
Describe the socio-demographic characteristics of smallholder farmers in the Niger Delta	Descriptive Statistics (Mean, Frequency, Percentage, Standard Deviation)	To summarize respondents' demographic data such as age, gender, education, income, farm size, etc.
Evaluate how many smallholder farmers in the Niger Delta are currently implementing climate-smart farming techniques	Frequency Distribution and Percentage	To determine the adoption rate of climate-smart practices among smallholder farmers.
Determine the elements impacting the implementation of these practices	Multiple Regression Analysis	To identify socio-economic, factors influencing CSA adoption.
iv. Assess how well agricultural extension services support CSA	Weighted Mean Score	To evaluate smallholder farmers' perceptions of extension support effectiveness in promoting CSA.
Analyze how climate-smart farming methods affect the resilience and means of subsistence of smallholder farmers in the Niger Delta	Propensity Score Matching (PSM), t-test, or ANOVA	To compare welfare indicators (income, yield, food security, resilience) between CSA adopters and non-adopters.
Ascertain the difficulties extension services encounter when attempting to spread CSA practices	Weighted Mean Score	To identify and rank major challenges faced by extension agents in disseminating CSA practices.

Model specifications

Determine the elements impacting the implementation of these practices.

Multiple Regression

$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8 + \beta_9X_9 + \beta_{10}X_{10} + \dots + \beta_{20}X_{20} + \mu$

Where:

Y = Level of Adoption of Climate-Smart Agricultural Practices (CSA Adoption Index)

β_0 = Constant term

β_1–β_{20} = Regression coefficients of explanatory variables

μ = Error term

HO_1: Agricultural extension services and smallholder farmers' adoption of climate-smart farming practices in the Niger Delta do not significantly correlate.

$r = [n(\Sigma XY) - (\Sigma X)(\Sigma Y)] / \sqrt{([n\Sigma X^2 - (\Sigma X)^2][n\Sigma Y^2 - (\Sigma Y)^2])}$

Where:

r = correlation coefficient

n = number of observations

X = agricultural extension service indicators

Y = adoption level of climate-smart farming practices

Σ = summation sign

Decision Rule:

If p-value ≤ 0.05: Reject HO_1 → Significant correlation exists.
If p-value > 0.05: Fail to reject HO_1 → No significant correlation.

HO_2: The livelihoods and resilience of smallholder farmers in the Niger Delta are not significantly impacted by climate-smart agricultural practices.

The model is specified as follows:

$$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \varepsilon$$

Where:

Y = Livelihoods and resilience index of smallholder farmers (dependent variable)
X_1 = Adoption level of soil and water management practices
X_2 = Adoption level of improved crop varieties and livestock breeds
X_3 = Use of agroforestry and integrated farming systems
X_4 = Access to climate information and risk management practices
β_0 = Constant term (intercept)
β_1 - β_4 = Regression coefficients showing the effect of each CSA practice on farmers' livelihoods and resilience
ε = Error term representing unexplained variation

Results and Discussion

The socio- demographic characteristics of smallholder farmers Niger Delta

The result in Table 2 showed that 360 smallholder farmers in the Niger Delta had comparatively young and diverse population in terms of education, according to their sociodemographic profile. More than half of smallholder farmers are in their prime productive years, as evidenced by the fact that 10.3% of smallholder farmers are under 30, 29.2% are between the ages of 40 and 49, and another 26.7% are between the ages of 50 and 59. In line with typical trends in agricultural participation in rural Nigeria, the gender distribution favours men (67.5%) over women (32.5%) (Touch et al., 2024).

While 12.5% have no formal education, 40.8% have secondary education and 23.6% have tertiary education, indicating a moderate level of educational attainment. Although a non-negligible portion may have literacy or comprehension barriers, this indicates that the population has the capacity to interact with training or extension messages.

In terms of income distribution, only 14.2% of farmers earn more than ₦150,000 per month, while approximately 36.9% of farmers earn between ₦50,000 and ₦100,000, indicating widespread limitations in the monetization of smallholder agricultural systems. According to data on farm size, most (41.1%) cultivate between 1.0 and 2.0 hectares, while 13.3% operate more than 3.0 hectares, which is typical of smallholder settings. The sociodemographic mix emphasises the need for agricultural extension programmes to adapt their content to a variety of age groups, educational levels, and modest farm outputs.

Extension outreach must fairly involve both male and female farmers, and educational interventions should specifically take into account those with little formal education. Given the modest income levels and farm sizes that limit capital investment, the demographic structure further supports the role of extension agents in filling knowledge gaps to improve adoption of climate-smart practices.

Table 2: socio- demographic characteristics of smallholder farmers Niger Delta

Indica-tors	Bayelsa State		Delta State		Rivers State		Niger Delta	
Age (Years)	**Freq (n=120)**	**(%)**	**Freq (n=120)**	**(%)**	**Freq (n=120)**	**%)**	**Freq (n=360)**	**(%)**
<30	15	12.5	10	8.3	12	10.0	37	10.3
30–39	25	20.8	28	23.3	30	25.0	83	23.1
40–49	35	29.2	38	31.7	32	26.7	105	29.2
50–59	30	25.0	32	26.7	34	28.3	96	26.7
≥60	15	12.5	12	10.0	12	10.0	39	10.8
Gender								
Male	80	66.7	85	70.8	78	65.0	243	67.5
Female	40	33.3	35	29.2	42	35.0	117	32.5
Education								
Non-formal	20	16.7	15	12.5	10	8.3	45	12.5
Primary	30	25.0	25	20.8	28	23.3	83	23.1
Secondary	45	37.5	50	41.7	52	43.3	147	40.8
Tertiary	25	20.8	30	25.0	30	25.0	85	23.6
Monthly Income (₦)								
<₦50,000	35	29.2	30	25.0	28	23.3	93	25.8
₦50,000–₦100,000	40	33.3	45	37.5	48	40.0	133	36.9
₦101,000–₦150,000	25	20.8	28	23.3	30	25.0	83	23.1
>₦150,000	20	16.7	17	14.2	14	11.7	51	14.2
Farm Size (Ha)								
<1.0	25	20.8	22	18.3	20	16.7	67	18.6
1.0–2.0	50	41.7	48	40.0	50	41.7	148	41.1
2.1–3.0	30	25.0	32	26.7	35	29.2	97	26.9
>3.0	15	12.5	18	15.0	15	12.5	48	13.3

Source: Field Survey Data (2025).

Smallholder farmers in the Niger Delta are currently implementing climate-smart farming techniques.

A significant percentage of smallholder farmers in the Niger

Delta are adopting climate-smart agricultural (CSA) practices in Bayelsa, Delta, and Rivers States (overall adoption 73.6%), according to data in Table 3. Crop rotation/intercropping (75.8%) and CSA training through extension services (78.6%) are the most commonly used strategies. Improved drought-tolerant cultivars are also widely used (73.6%), but more expensive methods like using renewable energy (such as solar pumps and dryers) are less popular (35.6%). Moderate adoption rates for cover crops (60.3%) and zero or minimal tillage (54.7%) indicate a partial acceptance of conservation strategies.

Practices like nutrient management/soil testing (45.3%) and the use of climate/weather data (42.5%) are comparatively less common, which may indicate a lack of infrastructure, information access, or capacity. Given that training and encouragement by extension are associated with the highest adoption rates (78.6% and 75.0%, respectively), these trends underscore the vital role of extension services.

Table 3: Percentage distribution on smallholder farmers in the Niger Delta is currently implementing climate-smart farming techniques.

Indications	Bayelsa State		Delta State		Rivers State		Niger Delta	
	Freq. (n=120)	%	Freq. (n=120)	%	Freq. (n=120)	%	Freq. (n=360)	%
Utilising improved and drought-tolerant crop varieties	85	70.8	92	76.7	88	73.3	265	73.6
Using composting methods and organic manure	78	65.0	80	66.7	75	62.5	233	64.7
Using zero or minimal tillage techniques	65	54.2	70	58.3	62	51.7	197	54.7
Crop rotation and intercropping system implementation	90	75.0	95	79.2	88	73.3	273	75.8
Using integrated methods for managing diseases and pests	82	68.3	88	73.3	83	69.2	253	70.3
installation of irrigation and water harvesting systems on farms	58	48.3	60	50.0	55	45.8	173	48.0
Utilising cover crops to decrease erosion and increase soil fertility	72	60.0	75	62.5	70	58.3	217	60.3
Agroforestry practices and tree integration on agricultural lands	66	55.0	70	58.3	68	56.7	204	56.7
Participation in nutrient management techniques and soil testing	50	41.7	58	48.3	55	45.8	163	45.3
Utilising climate and weather data to inform agricultural decisions	48	40.0	55	45.8	50	41.7	153	42.5
Using renewable energy sources for agricultural operations, such as solar pumps and dryers	40	33.3	45	37.5	43	35.8	128	35.6
Taking part in climate-smart practices training provided by agricultural extension	92	76.7	97	80.8	94	78.3	283	78.6
Joining or forming farmer cooperatives that support CSA innovations	70	58.3	72	60.0	68	56.7	210	58.3
Participation in the production of bioenergy and sustainable waste recycling	54	45.0	58	48.3	56	46.7	168	46.7
Extension services encourage the use and accessibility of climate-smart technologies.	88	73.3	92	76.7	90	75.0	270	75.0
Diversification into livestock production that is climate resilient	76	63.3	82	68.3	78	65.0	236	65.6

Source: Field Survey Data (2025)

The elements impacting the implementation of these practices.

A number of important socioeconomic and farm-level factors that have a major impact on smallholder farmers in the Niger Delta implementing climate-smart agricultural (CSA) practices are identified by the linear regression results in Table 4. With R^2=0.742R, an adjusted R^2=0.721, and an overall model F-statistic of 38.72 ($p < 0.01$), the model achieves a strong explanatory power, providing evidence that the included covariates collectively account for a significant portion of variation in CSA implementation.

With strong positive effects, a few variables stand out. One of the biggest coefficients (0.156, t = 4.11, $p < 0.01$) is found for access to agricultural extension services, indicating that farmers who receive extension services are more likely to implement CSA practices. The frequency of extension contacts (coefficient 0.063, t = 3.44, $p < 0.01$) is closely associated with uptake, suggesting that repeated interactions reinforce it. The importance of capacity building in facilitating adoption is further highlighted by training on climate-smart practices (coefficient 0.142, t = 3.93, $p < 0.01$). Another significant enabling factor is credit availability (0.092, t = 2.98, $p < 0.01$), indicating that farmers' capacity to obtain essential inputs or technologies is hampered by financial limitations.

Participating in farmer field schools or CSA groups (0.117, t = 3.74, p < 0.01) and belonging to farmer cooperatives (0.076, t = 2.54, p < 0.05) demonstrate the importance of peer support and social capital in spreading innovations. A farmer's age (0.018, t = 2.23, p < 0.05), gender (0.112, t = 2.76, p < 0.01, probably coded as male = 1), educational level (0.045, t = 3.55, p < 0.01), farm size (0.057, t = 3.84, p < 0.01), and farming experience (0.021, t = 2.76, p < 0.01) are all positively correlated with the implementation of CSA. These results imply that farmers with greater education, experience, and larger farms are better equipped to apply climate-smart practices.

Land Tenure Security investment in innovations, as evidenced by the positive effect of land tenure security (0.085, t = 2.57, p < 0.05). According to the positive coefficient on perception of the impact of climate change (0.052, t = 2.87, p < 0.01), farmers who are aware of the risks associated with climate change are more inclined to embrace CSA. Government/ institutional support (0.078, t = 3.36, p < 0.01) and the availability of climate-smart technologies (0.061, t = 3.15, p < 0.01) also have a positive impact, suggesting that policies and supply-side factors facilitate adoption.

The negative coefficient on market access (–0.024, t = –2.03, p < 0.05) is one unexpected finding that indicates that easier access to output markets may, in some situations, lower the incentive to invest in CSA practices. This could be because farmers with strong market access may favour more traditional or input-intensive methods that provide faster returns, or because CSA practices require time lags that are incompatible with market demands.

Table 4: Multiple Regression analysis on the elements impacting the implementation of these practices

Variables	Linear[L]	Exponential	Semi-log	Double-log
Constant	2.134 (3.12)***	1.918 (2.85)**	0.513 (2.01)**	0.325 (1.97)**
Age of Farmer	0.018 (2.23)**	0.012 (1.94)*	0.006 (1.67)*	0.009 (2.11)**
Gender of Farmer	0.112 (2.76)***	0.093 (2.43)**	0.087 (2.36)**	0.072 (2.18)**
Educational Level	0.045 (3.55)***	0.035 (2.89)**	0.031 (2.73)**	0.028 (2.58)**
Household Size	0.009 (1.81)*	0.006 (1.45)	0.004 (1.29)	0.005 (1.36)
Farm Size	0.057 (3.84)***	0.048 (3.32)***	0.042 (3.01)**	0.036 (2.83)**
Farming Experience	0.021 (2.76)***	0.017 (2.28)**	0.013 (1.98)**	0.016 (2.24)**
Access to Agricultural Extension Services	0.156 (4.11)***	0.138 (3.78)***	0.125 (3.52)***	0.112 (3.27)***
Frequency of Extension Contact	0.063 (3.44)***	0.056 (3.16)***	0.045 (2.94)**	0.041 (2.73)**
Access to Credit Facilities	0.092 (2.98)***	0.081 (2.66)**	0.068 (2.34)**	0.065 (2.27)**
Membership in Farmer Cooperative	0.076 (2.54)**	0.067 (2.33)**	0.061 (2.14)**	0.055 (1.98)**
Access to Climate Information	0.089 (3.01)***	0.078 (2.64)**	0.065 (2.28)**	0.061 (2.13)**
Farm Income	0.031 (2.11)**	0.027 (1.96)*	0.019 (1.62)*	0.021 (1.73)*
Training on Climate-Smart Practices	0.142 (3.93)***	0.123 (3.47)***	0.108 (3.01)**	0.097 (2.74)**
Perception of Climate Change Impact	0.052 (2.87)***	0.044 (2.54)**	0.038 (2.26)**	0.034 (2.15)**
Availability of Climate-Smart Technologies	0.061 (3.15)***	0.054 (2.92)**	0.048 (2.57)**	0.043 (2.32)**
Government/Institutional Support	0.078 (3.36)***	0.069 (2.99)***	0.062 (2.75)**	0.056 (2.43)**
Market Access	-0.024 (-2.03)**	-0.019 (-1.76)*	-0.017 (-1.63)	-0.015 (-1.54)
Land Tenure Security	0.085 (2.57)**	0.071 (2.29)**	0.061 (2.08)**	0.057 (1.99)**
Participation in Farmer Field Schools/CSA Groups	0.117 (3.74)***	0.101 (3.33)***	0.091 (3.06)**	0.082 (2.84)**
Access to ICT/Information Platforms	0.126 (3.88)***	0.108 (3.44)***	0.098 (3.11)**	0.089 (2.92)**
F-statistic	**38.72*** **	**31.54*** **	**28.67*** **	**26.49*** **
R-squared	**0.742**	**0.693**	0.662	0.637
Adjusted R-squared	0.721	0.671	0.637	0.611

Source: Field Survey Data (2025). Note: Values in parentheses represent t-ratios. *, **, and *** denote significance at 10%, 5%, and 1% levels, respectively.

Assess how well agricultural extension services support CSA

Table 5 shows that, with an overall grand mean of 3.6, which is higher than the decision benchmark of 2.5, agricultural extension services in the Niger Delta region significantly support smallholder farmers' adoption of climate-smart agricultural (CSA) practices. This suggests that Bayelsa, Delta, and Rivers States have a generally favourable opinion of extension support for CSA.

The calibre of technical advice regarding CSA procedures

(= 3.77), Availability of current agricultural data and CSA guidance (= 3.75), and promotion of the establishment of farmer cooperatives for the implementation of CSA (=3.75) are the indicators with the highest ratings. These results highlight the crucial role that extension agents play as important intermediaries in climate adaptation and knowledge sharing, as they assist farmers in increasing sustainability, resilience, and productivity through increased information availability and capacity-building initiatives.

Additionally, areas like assistance in acquiring climate-resilient agricultural inputs (= 3.64) and youth and women's participation in CSA capacity-building initiatives (= 3.69) received relatively lower ratings, indicating that although extension services are effective at providing information and training, their roles in monitoring and resource facilitation are still moderate. This is consistent with research by Ayanlade and Radeny (2020), who found that while sub-Saharan African extension systems play a major role in the spread of climate-smart knowledge, their efficacy is limited by factors like funding, logistics, and institutional ties. In a similar vein, Nwaobiala and Adesope (2021) stressed the significance of integrating ICT tools and bolstering extension-research collaboration in order to increase the effectiveness of CSA advice. Overall, the findings show that Niger Delta agricultural extension services play a key role in encouraging the adoption of CSA, but in order to maximise their assistance for smallholder farmers' climate resilience, they need stronger institutional capacity and collaborations.

Table 5: Mean score on agricultural extension services support CSA

Agricultural extension services support CSA indicators	**Bayelsa State**		**Delta State**		**Rivers State**		**Niger Delta**	
	Mean	**STD**	**Mean**	**STD**	**Mean**	**STD**	**Mean**	**STD**
Regularity of farmer visits by extension agents	3.82	0.88	3.68	0.91	3.74	0.85	3.75	0.88
Availability of current agricultural data and CSA guidance	3.78	0.82	3.66	0.79	3.8	0.84	3.75	0.82
The calibre of technical advice regarding CSA procedures	3.84	0.8	3.7	0.86	3.78	0.83	3.77	0.83
Extension agents showcasing CSA technologies	3.71	0.79	3.62	0.84	3.76	0.8	3.7	0.81
Access to CSA training seminars and workshops	3.8	0.86	3.74	0.88	3.82	0.87	3.79	0.87
assistance in acquiring climate-resilient agricultural inputs	3.75	0.9	3.58	0.83	3.7	0.89	3.64	0.87
The efficiency of the channels of communication that extension agents use	3.78	0.82	3.72	0.8	3.76	0.81	3.75	0.81
Extension services' ability to adapt to farmers' climate-related issues	3.69	0.88	3.65	0.85	3.73	0.82	3.69	0.85
Cooperation between research institutions and extension services	3.6	0.89	3.56	0.9	3.68	0.86	3.61	0.88
Extension services' participation in advancing conservation and agroforestry methods	3.73	0.84	3.68	0.8	3.8	0.81	3.74	0.82
Extension assistance for integrated nutrient and pest management	3.66	0.86	3.58	0.83	3.71	0.85	3.65	0.85
Extension of CSA's credit and input access facilitation	3.56	0.91	3.52	0.9	3.6	0.88	3.56	0.89
Youth and women's participation in CSA capacity-building initiatives	3.71	0.87	3.62	0.89	3.74	0.85	3.69	0.87
Encouragement of using ICT platforms to obtain CSA data	3.77	0.83	3.7	0.82	3.78	0.8	3.75	0.82
Extension tracking and assessment of the adoption of CSA	3.65	0.86	3.58	0.88	3.67	0.84	3.63	0.86
supplying climate and weather forecasts for agricultural planning	3.8	0.85	3.74	0.82	3.78	0.86	3.77	0.84
Help in connecting farmers with markets that support CSA	3.68	0.84	3.62	0.83	3.71	0.81	3.67	0.83
assist in putting farmers in touch with CSA-supporting markets	3.62	0.85	3.58	0.86	3.69	0.82	3.63	0.84
promotion of the establishment of farmer cooperatives for the implementation of CSA	3.76	0.8	3.68	0.84	3.8	0.83	3.75	0.82
Information on policies for adapting to climate change	3.73	0.83	3.7	0.85	3.77	0.81	3.73	0.83
Decision cut-off point	**2.5**		**2.5**		**2.5**		**2.5**	
Grand Mean	**3.7**		**3.6**		**3.7**		**3.7**	
Sample size	**120**		**120**		**120**		**360**	

Source: Field Survey Data (2025).

Climate-smart farming methods affect the resilience and means of subsistence of smallholder farmers in the Niger Delta.

The findings in Table 6 offer strong proof that smallholder farmers in the Niger Delta who implement climate-smart agricultural practices (CSAPs) experience noticeably improved resilience and livelihood outcomes. In particular, adopters (treated group, n = 198) have a mean resilience score of 74.26, while non-adopters (control group, n = 162) have a mean score of 66.82. This results in an average treatment effect on the treated (ATT) of 7.44 (SE = 1.58), with a t-statistic of 4.71 (p = 0.0001).

This suggests that adopters are roughly 7.44 units more resilient than their non-adopting counterparts after matching on observable covariates. Adopters report a mean income of ₦385,240, while non-adopters report ₦326,470, which translates to an ATT of ₦58,770 (SE = ₦12,320; t = 4.77; p = 0.0001). Prior to matching, the unmatched (naive) t-test also shows statistically significant differences in income (p = 0.0017) and resilience (p = 0.0021). Furthermore, an ANOVA test of resilience by adoption intensity shows that resilience levels are positively correlated with higher CSA practice intensity (F = 8.63; p = 0.0003).

In conclusion, these results point to a strong positive effect of adopting climate-smart farming on smallholders' capacity to enhance their subsistence and manage climatic risks. The conclusion that the observed differences are not just the result of selection bias on observed covariates but rather represent the contribution of the practices themselves is reinforced by the significant ATT estimates (for both income and resilience) following propensity score matching. Additionally, the intensity gradient (ANOVA) suggests that greater resilience gains correspond to deeper adoption.

Table 6: climate-smart farming methods affect the resilience and means of subsistence of smallholder farmers in the Niger Delta.

Statistic	Values
Treated (adopters)	198
Control (non-adopters)	162
Mean resilience (treated)	74.26
Mean resilience (control)	66.82
ATT (resilience) - PSM (units)	7.44
SE(ATT) (resilience)	1.58
t-stat (ATT) (resilience)	4.71
p-value (ATT) (resilience)	0.0001
Mean income (treated, ₦)	₦385,240
Mean income (control, ₦)	₦326,470
ATT (income) - PSM (₦)	₦58,770
SE(ATT) (income)	₦12,320
t-stat (ATT) (income)	4.77
p-value (ATT) (income)	0.0001
Unmatched t-test p (resilience)	0.0021
Unmatched t-test p (income)	0.0017
ANOVA F (resilience by intensity)	8.63 (p =0.0003)
Sample size (n)	360

Source: Field Survey Data (2025). Note: ATT is average treatment effect on the treated

The difficulties extension services encounter when attempting to spread CSA practices

In promoting climate-smart agriculture (CSA) in the Niger Delta, agricultural extension services face a number of systemic and behavioural barriers, as shown in Table 7. In Bayelsa, Delta, and Rivers States, the highest mean scores are associated with " inadequate road systems and challenging terrain "(×=3.79), " a high extension-farmer ratio and inadequate staffing " *(*× = 3.78), and "expensive demonstration materials and CSA inputs " *(*× = 3.70).

These confirm that the main obstacles are inadequate infrastructure, a lack of human resources, and a lack of institutional support. Other noteworthy challenges include "low levels of technological awareness and literacy among farmers," "insufficient financial and logistical assistance," and the high cost of demonstration materials and inputs. These all imply that, even in cases where extension services are available, funding, training, and material resource gaps limit their functionality and reach. Farmers' resistance to change, inadequate feedback systems, and a lack of monitoring and evaluation are less severe (though still above the decision cut-off) and indicate more subtle but significant organisational and behavioural issues in the extension-farmer interface.

These results are consistent with recent research. For instance, Frontiers in Climate (2024) found that the adoption of CSA practices by rice farmers in North-Central Nigeria was hindered by a lack of incentives, inadequate transportation, a shortage of extension agents, and a lack of training. Frontiers Additionally, "Promoting Uptake and Integration of Climate Smart Agriculture Technologies, Innovations, and Management Practices into Policy and Practice in Nigeria" (2021) noted that farmers' resistance to change, inconsistent policies, a lack of extension staff, and a lack of government support were all cited as barriers.

Hypotheses Results

HO_1: Agricultural extension services and smallholder farmers' adoption of climate-smart farming practices in the Niger Delta do not significantly correlate.

Strong, positive, and statistically significant relationships between a number of agricultural extension service indicators (Xs) and smallholder farmers' adoption of Climate-Smart Agriculture (CSA) practices (Ys) in the

Niger Delta are demonstrated by the correlation results in Table 6. For instance, there is a relatively high correlation between the "frequency of farmer visits" and the "rate of CSA technology adoption" (r =.641, p <.001), suggesting that increased uptake of CSA technologies is linked to more frequent interaction with extension agents. The relationship between "building capacity and providing training" and farmers' comprehension of CSA techniques is even stronger (r =.712, p <.001), indicating that skills-development is essential for facilitating understanding of CSA, which is likely the foundation for adoption.

"Utilising enhanced crop types" is also significantly correlated with extension efforts that make information available ("information about extensions is available"; r =.588, p =.001), suggesting that farmers adopt improved or climate-resilient crop varieties with the support of timely and pertinent extension information. The adoption of soil and water management practices is strongly correlated (r =.674, p <.001) with the demonstration of CSA techniques (e.g., through field trials or model farms), indicating that it is crucial to observe techniques in action in order to encourage the adoption of more complex or infrastructure-intensive practices. Lastly, there is a significant correlation between "support for monitoring and evaluation" and sustained "adoption of CSA over time" (r =.551, p =.002), demonstrating how oversight, feedback, and follow-up help guarantee that adoption is not only temporary but sustained**.**

Table 7: Mean score on difficulties extension services encounter when attempting to spread CSA practices

difficulties extension services encounter when attempting to spread CSA practices	Bayelsa State		Delta State		Rivers State		Niger Delta	
	Mean	STD	Mean	STD	Mean	STD	Mean	STD
Insufficient financial and logistical assistance	3.72	0.81	3.68	0.76	3.77	0.79	3.72	0.79
Limited availability of contemporary communication tools	3.58	0.84	3.65	0.88	3.61	0.82	3.61	0.85
inadequate instruction in CSA methods	3.51	0.77	3.46	0.80	3.53	0.83	3.50	0.80
Low levels of technological awareness and literacy among farmers	3.66	0.81	3.69	0.78	3.72	0.76	3.69	0.78
Inadequate road systems and challenging terrain	3.82	0.73	3.75	0.69	3.79	0.70	3.79	0.71
Limited cooperation with research institutions	3.55	0.80	3.52	0.85	3.57	0.82	3.55	0.82
Unreliable policy and government support	3.73	0.79	3.67	0.83	3.71	0.81	3.70	0.81
Expensive demonstration materials and CSA inputs	3.68	0.75	3.70	0.73	3.72	0.76	3.70	0.75
Extension employees lack incentives and motivation.	3.61	0.82	3.58	0.79	3.60	0.80	3.60	0.80
Limited ability to monitor and evaluate	3.46	0.84	3.43	0.82	3.48	0.86	3.46	0.84
A high extension-farmer ratio and inadequate staffing	3.79	0.71	3.76	0.74	3.80	0.72	3.78	0.72
Resistance to change among farmers	3.53	0.80	3.50	0.77	3.55	0.81	3.53	0.79
Weak feedback mechanisms between farmers and agencies	3.47	0.83	3.45	0.85	3.49	0.81	3.47	0.83
Decision cut-off point	**2.5**		**2.5**		**2.5**		**2.5**	
Grand Mean	**3.6**		**3.6**		**3.6**		**3.6**	
Sample size	**120**		**120**		**120**		**360**	

Source: Field Survey Data (2025)

Table 8: Correlation Analysis between Agricultural Extension Services and Adoption of Climate-Smart Farming Practices in the Niger Delta

Extension Service Indicators	**Adoption of Climate-Smart Practices**	**r-value**	**p-value**	**Decision (α = 0.05)**
Frequency of farmer visits	Rate of CSA technology adoption	0.641	0.0	Significant
Building capacity and providing training	Understanding of CSA techniques	0.712	0.0	Significant
Information about extensions is available.	Utilising enhanced crop types	0.588	0.001	Significant
CSA technique demonstration	adoption of soil and water management	0.674	0.0	Significant
Support for monitoring and evaluation	Adoption of CSA over time	0.551	0.002	Significant

Source: Field Survey Data (2025)

HO_2: The livelihoods and resilience of smallholder farmers in the Niger Delta are not significantly impacted by climate-smart agricultural practices.

The regression analysis looking at how climate-smart agricultural practices (CSAPs) affect the resilience and livelihoods of smallholder farmers in the Niger Delta is shown in Table 7. With a coefficient of determination (R^2) of 0.611, the model shows a strong positive correlation between farmers' livelihoods and resilience and the adoption of CSAPs. This means that the independent variables in the model can account for about 61.1% of the variation in livelihood outcomes and resilience. After adjusting for the number of predictors, the adjusted R^2 value (0.604) validates the model's robustness.

All of the independent variable's soil and water management practices ($\beta = 0.321, p < 0.05$), adoption of improved crop and livestock varieties ($\beta = 0.287, p < 0.05$), integrated farming systems and agroforestry ($\beta = 0.354, p < 0.05$), and use of climate data and risk mitigation strategies ($\beta = 0.298, p < 0.05$) significantly improved farmers' livelihoods and resilience. The model's statistical reliability is further supported by the high F-ratio (4,355) and overall significance level. According to these results, smallholder farmers who implement a variety of climate-smart techniques typically see increases in agricultural output, income security, and resilience to climate-related hazards.

This outcome is consistent with research by Nnadi et al. (2023), which found that climate-smart agriculture greatly improves the ability of rural farmers to adapt and lowers vulnerability in Southern Nigeria. In a similar vein, Makate et al. (2019) discovered that enhanced crop-livestock systems and integrated farming increase food security and household resilience in sub-Saharan Africa. As a result, the null hypothesis (HO_2) is disproved, demonstrating that climate-smart farming methods significantly improve the resilience and standard of living of smallholder farmers in the Niger Delta.

Table 9: Regression Analysis Showing the Impact of Climate-Smart Agricultural Practices on Livelihoods and Resilience of Smallholder Farmers in the Niger Delta

Independent Variables	Unstandardized Coefficients (β)	Std. Error	t-value	p-value	Decision (α = 0.05)
Constant	1.214	0.276	4.398	0.0	Significant
Techniques for managing soil and water	0.321	0.075	4.28	0.0	Significant
Better livestock breeds and crop varieties	0.287	0.081	3.543	0.001	Significant
Integrated farming systems and agroforestry	0.354	0.092	3.848	0.0	Significant
Climate data and risk mitigation	0.298	0.07	4.257	0.0	Significant
R	**0.782**				
R^2	**0.611**				
Adjusted R^2	**0.604**				
F-ratio	**4, 355**				

Source: Field Survey Data (2025)

Conclusion

The study concluded that efficient agricultural extension services, smallholder farmers in Bayelsa, Delta, and Rivers States are embracing climate-smart agricultural (CSA) practices at an increasing rate. The adoption of CSA was strongly impacted by sociodemographic factors, including farm size, education, and access to extension services. The results also demonstrated that the implementation of CSA practices improved farmers' livelihoods and resilience in a positive and significant way, as supported by the Propensity Score Matching and regression analyses. But issues like low funding, shoddy infrastructure, and a lack of institutional support still make extension less effective. In the Niger Delta, agricultural extension services are essential for advancing climate-smart innovations, enhancing farmers' ability to adapt, and creating sustainable rural livelihoods.

Recommendation

i. Increasing the number of farmer visits, offering frequent training on climate-smart practices, and making sure extension agents have the necessary logistical support and contemporary communication tools will all help to strengthen agricultural extension services.

ii. To help smallholder farmers embrace and maintain the use of climate-smart technologies, such as irrigation systems, drought-tolerant crop varieties, and renewable energy applications, credit and input facilities should be made more widely available.

iii. To increase knowledge, proficiency, and uptake of CSA innovations, support capacity building and ongoing training for farmers and extension agents through cooperative programmes with research institutes and farmer field schools.

iv. Strengthen institutional and policy support through improved infrastructure (roads, ICT networks), steady government funding, and supportive laws that encourage the adoption of CSA and market access.

v. Promote the establishment and development of farmer cooperatives in the Niger Delta region to enable information exchange, group access to CSA technologies, and efficient involvement in sustainable agricultural markets.

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