



EFFECTS OF CLIMATE-SMART AGRICULTURAL (CSA) TECHNOLOGIES ON MAIZE PRODUCTION IN NIGER STATE, NIGERIA

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ABSTRACT

This study examined the effects of Climate-Smart Agricultural (CSA) technologies on maize production in Niger State, Nigeria. Using a multi-stage sampling technique, 232 maize farmers were selected, and primary data were collected through structured questionnaires administered in field surveys in 2025. Data were analysed using descriptive statistics and multiple regression models. Awareness of CSA technologies was generally high, but adoption varied widely across practices. High adoption rates were observed for direct seeding, mixed cropping, mixed farming, bush burning, and drought-tolerant crop varieties, while adoption of capital-intensive water management technologies such as drip irrigation and water harvesting structures remained low. Regression results showed that adoption of water-use and management practices, farm size, production risk management strategies, livestock ownership, extension contact, training received on CSA, and access to credit had significant positive effects on maize yield, while the cost of CSA technologies adoption had a significant negative effect. The study concludes that CSA technologies significantly enhance maize yield and sustainability, and recommends strengthened extension services, improved access to affordable credit, and development of low-cost CSA technologies.

Keyword: Climate smart; Maize; Production; Regression; Agriculture

INTRODUCTION

Agriculture plays a vital role in Nigeria's economy, contributing substantially to the country's Gross Domestic Product (GDP) and serving as a primary source of employment for a substantial portion of the population. In Nigeria, agriculture accounted for approximately 28.65% of the real gross domestic product in the third quarter of 2024 (National Bureau of Statistics [NBS], 2026). However, despite the high level of involvement of Nigerians in agricultural activities, the sector faces numerous challenges in meeting the increasing food demands of the growing population. Nigeria's population is rapidly expanding, and it is projected to become the world's third most populous country by 2050 (United Nations, 2023). This population growth, coupled with urbanization and changing dietary preferences, places immense pressure on the agricultural sector to produce more food. However, the sector struggles to meet the national food demands due to various agronomic challenges, including climate factors which tend to limit production potential, especially for maize crops.

Maize (*Zea mays*) is one of the most widely grown cereal crops in Nigeria and forms a significant part of the daily diet for many Nigerians. It is not only a food crop but also a source of income and employment, particularly for smallholder farmers. According to the National Bureau of Statistics (NBS, 2026), maize is cultivated across all ecological zones in Nigeria, with the highest production levels recorded in states like Kaduna, Niger, Taraba and Benue. In terms of consumption, maize is used for preparing local dishes, livestock feed and as a raw material in food processing industries.

Despite its importance, the current average maize yield in Nigeria is relatively low compared to its potential. In 2024, maize output stood at approximately 2.3 tons per hectare (t/ha), which is below the global average of 5.8 t/ha (Food and Agriculture Organisation (FAO), 2024). This gap is attributed to a range of factors that undermine production. These include poor soil fertility, limited access to quality seeds and fertilizers, pests and diseases, and low-level mechanization. Additionally, inadequate extension services and weak infrastructure further exacerbate the problem, leaving farmers unable to adopt best agronomic practices or access timely market information. The declining production of maize farming in Nigeria is further worsened by the growing effects of climate change. Rising temperatures, erratic rainfall patterns, droughts, and floods have disrupted the traditional agricultural calendar, reduced arable land and increased the

risk of crop failure. According to the Intergovernmental Panel on Climate Change (IPCC, 2023), climate change poses a significant threat to food security in sub-Saharan Africa, and maize is among the most vulnerable crops. This situation calls for urgent and innovative solutions that enhance resilience, increase production and ensure environmental sustainability.

In response to these challenges, Climate Smart Agriculture (CSA) has emerged as a transformative paradigm approach to agricultural development. CSA is defined by FAO (2023a) as agricultural practices that sustainably increase productivity and resilience (adaptation), reduce or remove greenhouse gases (mitigation) and enhance the achievement of national food security and development goals. It encompasses a range of practices and technologies that have the potential to increase agricultural productivity, enhance the resilience of farming systems, and reduce greenhouse gas emissions (De Pinto *et al.*, 2022).

Studies have highlighted the adoption of CSA practices among maize farmers in Nigeria (Ogunniyi *et al.*, 2020; Ajani *et al.*, 2022; Ogunjimi *et al.*, 2020), but empirical evidence on the level of adoption of CSA practices among maize farmers in Niger State is limited. The effect of CSA practice adoption on sustainable maize production in Niger State also remains largely unexplored. The near-absence of documented evidence on these effects means that CSA practice adoption has received little attention and requires investigation to guide the State's policy thrust in mitigating the adverse consequences of climate change. These gaps in the literature necessitated this research. Based on the foregoing, the study aimed to achieve the following objectives;

1. ascertain the types and level of adoption of CSA technologies in maize production;
2. examine the effects of CSA technologies on maize yield in the study area.

METHODOLOGY

The study was conducted in Niger State, Nigeria. Niger State is located between Latitudes 8°22'N and 11°30'N and Longitudes 3°30'E and 7°20'E. The population of the State is 3,950,249, comprising 2,082,725 males and 1,867,524 females (National Population Commission (NPC), 2006). The projected population of the State as at 2025 was 7,495,547 at 3.4% population growth (National Bureau of Statistics (NBS), 2026).

A three-stage sampling technique was employed to select maize farmers in the study area. The first stage involved random selection of two extension blocks from each of the three (3) Agricultural zones in Niger State. These are Katcha and Lapai in Agricultural Zone (I), Bosso and Paikoro in Agricultural Zone (II) and Wushishi and Kontagora LGAs in Agricultural Zone (III). The second stage involved random selection of twelve (12) extension cells from each of the selected extension blocks. The final stage involved random selection of maize farmers in each of the selected extension cells using the Yamane formula and proportionate allocation technique. Upon discussion with Niger State Agricultural Mechanisation and Development Authority (NAMDA), Community heads and extension agents from each Agricultural zone, the Sampling frame of 1,439 was obtained. Thus, a total number of 232 respondents was used as the sample size. The sampling distribution of farmers is presented in Table 3.1. The formula is given in Equation 3.1:

$$n = \frac{N}{1+N(e)^2} \quad (1)$$

Where: n= Sample size; N= Total sampling frame;

e = Limit of tolerable error at 0.06 probability level; and 1= unity.

The proportion allocation technique formula is stated in equation 3.2 as follows:

$$S_h = \frac{n \times N_h}{N_T} \quad (2)$$

Where: S_h = Number of farmers selected;

n = Total sample size;

N_h = Sampling frame of each village; and

N_T = Total sampling frame

Multiple regression model

This model was used to determine the effects of CSA Technologies on maize yield. It was hypothesized that some farmer-specific socio-economic, socio-demographic and institutional variables influence maize farmers' yield. Multiple regression is a statistical tool that uses several explanatory variables to predict the outcome of a response variable. In this case, the value of the dependent variable is predicted based on the values of two or more independent variables. The

value being predicted is termed the dependent variable; its outcome or value depends on the behavior of other variables. Various functional forms were fitted to the data. The “lead equation”, otherwise referred to as the “equation of best fit”, was chosen based on the normal economic, econometric and statistical criteria, which include:

1. The number of significant explanatory variables,
2. The explanatory power of the model (given by the coefficient of multiple determination (R² value)
3. Relative magnitude of estimated regression coefficient
4. Conformity of signs of estimated regression coefficients with *a priori expectation*, and the overall significance of the model (given by F-statistics/ratio).

Table 1: Sampling distribution of respondent

Agricultural Zone	Extension Blocks	Selected Extension Cells	Sampling frame	Sampled size
Zone I	Kacha	Assanyi	104	17
		Babagi	109	18
	Lapai	Gulu	116	19
		Evuti	121	20
Zone II	Bosso	Kampala	120	19
		Kodo	150	24
	Paikoro	Kwakuti	142	23
		Tunga Gana	120	19
Zone III	Wushishi	Bankogi	123	20
		Danku-wagi	95	15
	Kontagora	Tungan wawa	108	17
		Nagwamatse	131	21
Total	6	12	1439	232

Source: Niger State Agricultural Mechanisation and Development Authority (NAMDA), (2023).

The explicit form of the model is expressed in four functional forms as given in the equation below, as adopted from Kalu *et al.* (2023);

$$\text{Linear: } Y = a + b_1x_1 + b_2x_2 + \dots \dots b_{14}x_{14} + e \quad (3)$$

$$\text{Semi - } \ln Y = a + b_1\ln x_1 + b_2\ln x_2 + \dots \dots b_{14}\ln x_{14} + e \quad (4)$$

$$\text{Cobb-Douglas: } \ln Y = a + b_1\ln x_1 + b_2\ln x_2 + \dots \dots b_{14}\ln x_{14} + e \quad (5)$$

$$\text{Exponential: } \ln Y = a + b_1x_1 + b_2x_2 + \dots \dots b_{14}x_{14} + e \quad (6)$$

Where;

Y = Maize output (kg)

$b_1 - b_{14}$ = Vector of the parameter estimated hypothesized to influence the depending variables

$x_1 - x_{14}$ = The vector of explanatory variables.

Log= Logarithm

X_{1i} = Farming experience (years)

X_{2i} = Adoption of water use and management Technologies (total no. adopted)

X_{3i} = Farm size (hectares)

X_{4i} = Type of farm labour (family labour=1 otherwise=0)

X_{5i} = Adoption of production risk management Technologies (total no. adopted)

X_{6i} = Education (years spent in school)

X_{7i} = Adoption of conservation farming Technologies (total no. adopted)

X_{8i} = Distance to the source of farm inputs (Kilometer)

X_{9i} = Livestock ownership status (Total Livestock Unit, TLU)

X_{10i} = Extension contacts on CSAT (No. of visits in the last cropping season)

X_{11i} = Trainings received on CSAT (Number)

X_{12i} = Cost of adoption of CSAT (₦)

X_{13i} = Amount of credit received for maize farming (₦)

X_{14i} = Adoption of soil/land management Technologies (total no. adopted)

e = Error term

term

RESULTS AND DISCUSSION

Types and Level of Adoption of CSA Technologies in Maize Production

Table 2 presents the types and stages of adoption of Climate-Smart Agricultural (CSA) technologies among maize farmers in Niger State. The results reveal considerable variation in the level of adoption across different CSA practices. Under water use and management practices, awareness levels were generally high for capturing and storing water (93.5%), construction of wetlands (72.8%), drip irrigation (67.2%) and subsurface drainage (50.0%). However, actual adoption was relatively low for most practices, except subsurface drainage (35.3%) and drought-tolerant crops (56.0%). The low adoption of drip irrigation (6.9%) and zero adoption of wetland construction may be attributed to high capital requirements, technical complexity and limited access to irrigation infrastructure. In contrast, drought-tolerant crop varieties recorded high adoption due to their affordability, ease of use and compatibility with existing farming systems, making them attractive to smallholder farmers facing climate-induced rainfall variability.

For risk management practices, awareness was moderate for use of improved seeds (29.7%), soil-friendly farm machinery (48.7%) and organic fertilizer (13.8%). Adoption of these practices was higher relative to awareness, with improved seeds (49.1%), soil-friendly farm machinery (36.2%) and organic fertilizer (44.0%) being implemented by a significant proportion of farmers. This suggests that farmers tend to adopt practices that are perceived to improve productivity and manage production risks directly, even if formal awareness levels are initially low.

Among conservation agriculture practices, awareness was very high for zero tillage (92.7%) and green manure (88.8%), yet adoption remained extremely low (1.3% each), which can be attributed to technical and labour constraints. In contrast, direct seeding was practiced by all maize farmers in the study area, with 100% adoption. This high adoption can be attributed to the simplicity, ease of implementation and proven effectiveness of the practice within local farming systems. Taungya/afforestation had moderate awareness (17.2%) but relatively high adoption (58.2%), indicating successful promotion through extension programmes or community initiatives. Conservation tillage showed moderate awareness (23.3%) with 34.9% adoption, reflecting partial adoption of practices requiring incremental changes to traditional farming methods.

Table 2: Level of awareness and adoption of CSA Technologies

Practice / Measure	Not Aware Freq. (%)	Aware Freq. (%)	Trial Freq.(%)	Adopted Freq. (%)
Water use and Management				
Drip Irrigation	2 (0.9)	156 (67.2)	58 (25.0)	16 (6.9)
Terracing	17 (7.3)	92 (39.7)	92 (39.7)	31 (13.4)
Contouring	13 (5.6)	109 (47.0)	108 (46.6)	2 (0.9)
Construction of Wetland	56 (24.1)	169 (72.8)	7 (3.0)	0(0.0)
Subsurface Drainage	2 (0.9)	116 (50.0)	32 (13.8)	82 (35.3)
Planting Drought-Tolerant Crops	5 (2.2)	48 (20.7)	49 (21.1)	130 (56.0)
Capturing and Storing Water	6 (2.6)	217 (93.5)	6 (2.6)	3 (1.3)
Rotational Grazing	0(0.0)	81 (34.9)	41 (17.7)	110 (47.4)
Compost & Mulch Use	4 (1.7)	86 (37.1)	50 (21.6)	92 (39.7)
Planting Cover Crops	0(0.0)	47 (20.3)	65 (28.0)	120 (51.7)
Risk Management				
Use of Improved Seed	0(0.0)	69 (29.7)	49 (21.1)	114 (49.1)
Soil-Friendly Farm Machinery	0(0.0)	113 (48.7)	35 (15.1)	84 (36.2)
Organic Fertilizer Use	2 (0.9)	32 (13.8)	96 (41.4)	102 (44.0)
Conservation Agriculture				
Conservation Tillage	0(0.0)	54 (23.3)	97 (41.8)	81 (34.9)
Planting Seed Directly	0(0.0)	0(0.0)	0(0.0)	232 (100.0)
Zero Tillage	0(0.0)	215 (92.7)	14 (6.0)	3 (1.3)
Taungya / Afforestation	0(0.0)	40 (17.2)	57 (24.6)	135 (58.2)

Green Manure	7 (3.0)	206 (88.8)	16 (6.9)	3 (1.3)
Soil/land Management				
Crop Rotation	0(0.0)	30 (12.9)	155 (66.8)	47 (20.3)
Mulch Application	28 (12.1)	195 (84.1)	6 (2.6)	3 (1.3)
Mix-Farming	0(0.0)	24 (10.3)	27 (11.6)	181 (78.0)
Crop-Slope Farming	76 (32.8)	89 (38.4)	37 (15.9)	30 (12.9)
Strip Cropping	63 (27.2)	40 (17.2)	20 (8.6)	109 (47.0)
Mix Cropping	0(0.0)	0(0.0)	12 (5.2)	220 (94.8)
Shifting Cultivation	0(0.0)	149 (64.2)	29 (12.5)	54 (23.3)
Bush Burning	0(0.0)	43 (18.5)	12 (5.2)	177 (76.3)

Source: Field survey, 2025.

In soil and land management practices, awareness levels were generally low to moderate for crop rotation (12.9%), mulch application (12.1%), mixed farming (10.3%), crop-slope farming (38.4%), and strip cropping (17.2%). Despite these relatively low awareness levels, adoption varied considerably across practices. Mixed cropping (94.8%), mixed farming (78.0%), and bush burning (76.3%) recorded high adoption rates, indicating that many farmers had already progressed beyond the awareness stage. This suggests that these practices are largely traditional and locally adapted, and therefore widely implemented even without formal awareness campaigns.

The findings from this study indicate a persistent gap between awareness and adoption. Practices that are affordable, easy to implement and compatible with local farming systems tend to have higher adoption. In contrast, practices that require significant investment, specialised knowledge or substantial labour input remain underutilized. This pattern is consistent with the findings of Akinyele *et al.* (2020), Ogbole *et al.* (2020) and Nwachukwu *et al.* (2020), who agreed that smallholder farmers in Northern Nigeria preferentially adopt climate-smart practices that are affordable, simple to implement and capable of delivering immediate productivity gains.

Level of adoption of CSA technologies in maize production

Table 3 presents the level of adoption of Climate-Smart Agricultural (CSA) technologies among maize farmers in Niger State. Under water use and management practices, adoption was generally low. Drought-tolerant crops recorded the highest adoption rate (56.0%), followed by cover crops (51.7%), rotational grazing (47.4%) and subsurface drainage (35.3%). In contrast, drip irrigation (6.9%), contouring (0.9%), capturing and storing water (1.3%) and construction of wetlands (0.0%) recorded very low adoption. The relatively higher adoption of drought-tolerant crops may be attributed to their affordability, ease of use and direct response to rainfall variability, which is a major constraint to maize production in Niger State. However, the low adoption of irrigation-based practices is likely due to high investment costs, inadequate technical know-how, and limited access to irrigation infrastructure. Akinbile *et al.* (2020) reported that the adoption of drought-resistant maize varieties has significantly increased in northern Nigeria, where the dry season is longer and rainfall is less predictable.

Table 3: Level of adoption of CSA technologies in maize production

Practice	Adopted Freq	Adopted %
Water use and Management		
Drip irrigation	16	6.9
Terracing	31	13.4
Contouring	2	0.9
Construction of wetland	0	0.0
Subsurface drainage	82	35.3
Drought-tolerant crops	130	56.0
Capturing & storing water	3	1.3
Rotational grazing	110	47.4
Compost & mulch	92	39.7
Cover crops	120	51.7
Risk Management		
Improved seed	114	49.1

Soil-friendly farm machinery	84	36.2
Adequate Organic fertilizer	102	44.0
Conservation Agriculture		
Conservative tillage	81	34.9
Direct seeding	232	100.0
Zero tillage	3	1.3
Taungya/afforestation	135	58.2
Green manure	3	1.3
Soil/land Management		
Crop rotation	47	20.3
Mulching	3	1.3
Mixed farming	181	78.0
Crop-slope farming	30	12.9
Strip cropping	109	47.0
Mixed cropping	220	94.8
Shifting cultivation	54	23.3
Bush burning	177	76.3

Source: Field survey, 2025.

With respect to risk management practices, moderate adoption levels were observed for improved seed varieties (49.1%), improved farm machinery (44.0%) and adequate organic fertiliser application (34.9%). The adoption of improved seeds reflects sustained intervention by government agencies, extension services and development partners promoting climate-resilient maize varieties. However, financial constraints and limited mechanisation support may explain the relatively lower adoption of farm machinery and organic fertiliser. Under conservation agriculture, direct seeding recorded complete adoption (100.0%), making it the most widely adopted CSA practice in the study area. This is likely due to its simplicity, low cost and compatibility with traditional planting methods. Taungya/afforestation also recorded a relatively high adoption rate (58.2%), possibly due to its perceived long-term benefits for soil fertility and

land productivity. However, zero tillage (1.3%) and green manure (1.3%) recorded extremely low adoption, which may be attributed to limited technical awareness and delayed yield benefits associated with these practices.

In the soil and land management category, mixed cropping (94.8%), mixed farming (78.0%) and bush burning (76.3%) recorded high adoption levels. Mixed cropping and mixed farming are traditional risk-spreading strategies that enhance resilience to climate shocks and ensure household food security. However, the high prevalence of bush burning raises sustainability concerns, as it contradicts CSA principles and may contribute to soil degradation and greenhouse gas emissions.

Overall level of adoption of CSA technologies in maize production

Table 4 summarises the overall adoption levels of CSA technologies across the four practice categories. The findings indicate that the soil and land management subsection recorded the highest adoption level, with three practices (37.5%) classified under high adoption. This relatively higher adoption may be attributed to farmers' familiarity with traditional land management practices such as mixed cropping, bush burning, and mixed farming, which require minimal financial investment and align with existing production systems. The conservation agriculture subsection followed with one practice (25.0%) under high adoption, primarily driven by the widespread use of direct seeding, which fits easily into farmers' current farming practices and does not require specialised equipment. The risk management subsection recorded moderate adoption levels, with two practices (50.0%) falling within the moderate adoption category. This reflects the gradual acceptance of improved seeds and mechanisation technologies, although adoption remains constrained by access to credit and input affordability.

The water uses and management subsection recorded the lowest adoption level, with none of the practices falling within the high adoption category and 70.0% classified as low adoption. The low adoption of these practices is largely associated with the high cost of irrigation infrastructure, limited technical knowledge required for installation and maintenance and inadequate institutional support for water resource management. The findings suggest that maize farmers in Niger State predominantly adopt CSA technologies that are low-cost, labour-based and consistent with existing farming practices, while technologies requiring substantial investment and technical expertise record low adoption. This pattern is consistent with the

findings of Akinyele *et al.* (2020), who reported that smallholder farmers in Northern Nigeria are more likely to adopt climate-smart practices that offer immediate and tangible benefits with minimal financial risk.

Table 4: Overall level of adoption of CSA technologies in maize production

Subsection	No. of Practices	High Adoption (70–100%)	Moderate Adoption(40–69%)	Low Adoption (<40%)
Water Use and Management	10	0(0.0)	3(30.0)	7(70.0)
Soil/Land Management	8	3(37.5)	1(12.5)	4(50.0)
Conservation Agriculture	5	1(20.0)	1(20.0)	3(60.0)
Risk Management	3	0(0.0)	2(66.7)	1(33.3)

Source: Field survey, 2025.

Effects of CSA Technologies on Maize Yield

Table 5 presents the multiple regression estimates examining the effects of CSA technologies on maize yield in the study area. Four functional forms were estimated, namely linear, semi-log, double-log and exponential models. Based on the magnitude of the coefficient of determination (R^2), the number of statistically significant explanatory variables and conformity with *a priori* expectations, the double-log functional form was selected as the lead equation. The model produced an R^2 value of 0.906, indicating that approximately 90.6% of the variations in maize yield were explained by the included explanatory variables. In comparison, the remaining 9.4% could be attributed to omitted variables and random disturbances. The probability value of the F-statistic ($\text{Prob} > F = 0.0000$) confirms that the overall model was statistically significant at the 1% probability level, implying that the explanatory variables jointly influenced maize yield in the study area.

The coefficient of adoption of water uses and management practices (0.086) was positive and statistically significant at the 5% probability level, suggesting that increased adoption of water-related CSA practices significantly enhanced maize yield. Specifically, the elasticity estimate implies that a 1% increase in the adoption of water use and management practices led to an estimated 0.086% increase in maize output, holding other factors constant. The study earlier revealed that maize farmers were highly aware of water use and management practices such as capturing and storing water, construction of wetlands, drip irrigation and subsurface drainage; however, actual adoption was generally low. This low adoption suggests that there is substantial potential for yield improvement if farmers implement these practices more widely. Water use and management techniques enhance crop growth by ensuring adequate moisture availability, reducing water stress and improving nutrient uptake, which ultimately results in higher and more stable yields. This result is consistent with the findings of Chikowo *et al.* (2023), who reported that improved water management technologies significantly increased crop productivity among smallholder farmers due to enhanced moisture conservation and improved efficiency of resource utilisation.

Farm size exhibited a positive and highly significant coefficient (0.135) at the 1% probability level. This suggests that, holding all other factors constant, a 1% increase in farm size is associated with a 0.135% increase in maize output. Large farm sizes enable farmers to expand production scale, adopt improved mechanisation practices, and efficiently allocate resources such as labour and capital inputs. Farmers with large holdings are also more likely to diversify production activities and experiment with climate-smart technologies because they possess relatively greater risk-bearing capacity compared with small-scale farmers. Furthermore, economies of scale associated with large farm sizes may reduce average production costs and enhance overall productivity. The result corroborates the study of Olanrewaju *et al.* (2020), which found that farm size significantly influenced agricultural productivity among smallholder farmers, as larger landholdings allowed farmers to optimise input utilisation and expand production capacity.

The coefficient of adoption of production risk management practices (0.164) was positive and statistically significant at the 1% probability level. This indicates that, holding other factors constant, a 1% increase in the adoption of risk management strategies corresponds to a 0.164%

increase in maize output. Production risk management practices, such as the use of improved maize seeds, adequate organic fertilisers, and mechanised farm equipment, as reported earlier, help mitigate the effects of biotic and abiotic stressors, including pests, diseases, and erratic rainfall, which are common challenges in Niger State. The earlier descriptive analysis showed that maize farmers were aware of and had partially adopted risk management practices, though the level of full-scale adoption varied across practices. By implementing these strategies, farmers are better able to stabilise yields, reduce losses, and maximise returns on investment. Risk management practices also encourage farmers to be more confident in experimenting with other CSA technologies, as they provide a buffer against potential negative outcomes. This creates a synergistic effect, whereby the adoption of multiple CSA practices enhances overall farm productivity.

Additionally, production risk management increases the predictability of farm outcomes, which is crucial for decision-making, planning, and accessing credit. Farmers who actively manage risks are more likely to produce surplus maize that can be sold or stored for future use, thereby enhancing both food security and income. This finding corroborates the study of Adebayo *et al.* (2025), who reported that the adoption of improved input and risk management practices significantly increased maize yield among smallholder farmers in Nigeria. The positive relationship underscores the importance of promoting production risk management strategies as integral components of climate-smart maize production.

Table 5: Regression Estimates on the Effects of CSA technologies on maize yield

Variable	Linear Model Coeff. (T-value)	Semi-log Model Coeff. (T-value)	Double-log Model Coeff. (T-value)	Exponential Model Coeff. (T-value)
Farming experience	-0.0001 (-0.88)	-0.00003 (-1.03)	0.045 (0.93)	0.215 (1.06)
Adoption of water use & management	0.229 (1.42)	0.073 (1.80)	0.086 (2.38)**	0.259 (1.73)
Farm size	0.116 (3.57)***	0.025 (2.97)***	0.135 (3.65)***	0.611 (3.97)***
Type of farm labour	-0.044 (-0.28)	-0.013 (-0.32)	0.011 (0.31)	0.037 (0.25)
Adoption of production risk management	0.450 (2.85)***	0.108 (2.69)***	0.164 (3.25)***	0.551 (2.62)***
Education (years)	0.379 (1.99)**	0.101 (2.09)**	0.044 (1.02)	0.206 (1.14)
Adoption of conservation farming	0.009 (0.41)	0.003 (0.55)	0.064 (0.77)	0.175 (0.50)
Distance to input source	0.078 (2.03)**	0.019 (1.91)*	0.073 (1.39)	0.290 (1.33)
Livestock ownership	0.107 (0.55)	0.053 (1.07)	0.086 (1.93)*	0.193 (1.04)
Extension contacts	0.457 (2.95)***	0.141 (3.57)***	0.244 (3.30)***	0.666 (2.16)**
Trainings received	0.369 (1.73)*	0.137 (2.53)**	0.111 (2.29)**	0.297 (1.46)
Cost of CSAT adoption	-0.089 (-4.79)***	-0.021 (-4.36)***	-0.914 (-6.42)***	-3.657 (-6.16)***
Credit received	4.258 (6.87)***	1.333 (8.44)***	0.766 (8.66)***	2.250 (6.10)***
Soil & land management adoption	0.046 (0.77)	0.017 (1.12)	0.009 (0.68)	0.016 (0.28)
Constant	1.764 (2.16)**	0.435 (2.09)**	3.900 (9.48)***	14.332 (8.35)***
R ²	0.757	0.773	0.906	0.829
Adj. R ²	0.715	0.732	0.874	0.792
Prob > F	0.0000	0.0000	0.0000	0.0000

Source: Field survey, 2025

Note: *,**,*** = 0.10,0.05 and 0.01 significant level.

Extension contacts had a positive and highly significant coefficient (0.244) at the 1% probability level, indicating that increased interaction with extension agents significantly improved maize yield among farmers. The elasticity estimate suggests that a 1% increase in extension contact frequency resulted in approximately a 0.244% increase in maize output, *ceteris paribus*. Extension services play a critical role in disseminating knowledge about improved agronomic practices, climate-smart technologies, pest management strategies, and efficient input utilisation. Farmers who frequently interact with extension personnel are more likely to access updated technical information, receive training on CSA practices, and adopt improved production techniques, which ultimately enhance productivity. Effective extension systems also strengthen farmers' capacity to make informed production decisions under changing climatic conditions. This result underscores the importance of strengthening agricultural advisory services to improve technology adoption and productivity outcomes. The finding supports the study of Ikenna *et al.* (2021), which reported that access to extension services significantly increased smallholder farmers' productivity through improved knowledge dissemination and enhanced adoption of agricultural innovations.

Training received by farmers recorded a positive coefficient (0.111) and was statistically significant at the 5% probability level, indicating that participation in agricultural training programmes significantly enhanced maize yield. The elasticity estimate suggests that a 1% increase in training exposure increased maize output by approximately 0.111%, holding other factors constant. Training programmes improve farmers' technical competence, managerial skills, and understanding of climate-smart agricultural technologies, thereby facilitating more efficient resource utilisation and improved production practices. Farmers who participate in training are better equipped to apply recommended practices such as soil conservation techniques, improved input application methods, and climate adaptation strategies, which collectively contribute to higher yields. Training also enhances farmers' awareness of production risks and appropriate mitigation measures, thereby improving overall farm performance. This result implies that expanding farmer training initiatives can serve as an effective policy instrument for increasing agricultural productivity. The finding is consistent with the study of Okali and Uwagboe (2022), who reported that farmer training significantly increased crop productivity by improving knowledge acquisition and adoption of improved agricultural technologies.

The cost of CSA technology adoption had a negative and highly significant coefficient (-0.914) at the 1% probability level, indicating that higher adoption costs significantly reduced maize yield. The elasticity estimate implies that a 1% increase in the cost associated with adopting CSA technologies decreased maize output by approximately 0.914%, holding other factors constant. High adoption costs often limit farmers' ability to invest in improved technologies such as irrigation equipment, improved seed varieties, soil conservation structures, and mechanised tools. Financial constraints may lead farmers to adopt suboptimal input levels or delay adoption altogether, thereby reducing productivity gains associated with CSA technologies. The strong negative coefficient highlights the importance of reducing financial barriers through subsidies, credit facilities, and cost-sharing programmes to encourage wider adoption of climate-smart technologies. Lower adoption costs can significantly enhance farmers' willingness to invest in productivity-enhancing practices. This finding corroborates the study of Yusuf *et al.* (2021), which reported that high technology adoption costs significantly constrained farmers' ability to implement climate adaptation practices, thereby negatively affecting agricultural productivity.

Credit received exhibited a positive and highly significant coefficient (0.766) at the 1% probability level, indicating that access to credit substantially increased maize yield. The elasticity estimate suggests that a 1% increase in credit access resulted in approximately a 0.766% increase in maize output, holding other factors constant. Access to credit enhances farmers' liquidity and enables them to purchase improved inputs such as fertilisers, certified seeds, irrigation equipment, and labour services promptly. Credit availability also allows farmers to adopt climate-smart technologies that require initial investment but yield long-term productivity benefits. Farmers with better access to financial resources are more capable of scaling up production and managing production risks effectively. The strong positive relationship observed emphasises the importance of strengthening rural financial institutions and credit delivery mechanisms to support agricultural transformation. This finding agrees with the results of Amadu *et al.* (2020), who found that improved access to agricultural credit significantly enhanced farmers' productivity by facilitating timely input acquisition and increased technology adoption.

Livestock ownership showed a positive coefficient (0.086) and was statistically significant at the 10% probability level, suggesting that farmers who owned livestock achieved higher maize yields compared with those without livestock assets. The elasticity estimate indicates

that a 1% increase in livestock ownership increased maize yield by approximately 0.086%, holding other factors constant. Livestock contribute to crop production through the provision of organic manure, which enhances soil fertility and improves soil structure, thereby increasing crop productivity. In addition, livestock ownership serves as a source of income diversification and financial security, enabling farmers to finance crop production activities and adopt productivity-enhancing technologies. Animal traction may also facilitate timely land preparation and cultivation, particularly among smallholder farmers operating under limited mechanisation conditions. The complementary relationship between livestock and crop production underscores the benefits of integrated farming systems in improving agricultural productivity. This finding is consistent with the study of Daudu *et al.* (2020), which reported that integrated crop–livestock systems significantly enhanced farm productivity through improved nutrient recycling and resource complementarities.

CONCLUSION AND RECOMMENDATION

Based on the findings of the study, it was concluded that despite these favourable conditions, adoption of CSA technologies remains uneven and selective, with farmers more inclined to adopt practices that are low-cost, familiar, and immediately beneficial, such as mixed cropping, bush burning, drought-tolerant crops and direct seeding. In contrast, capital-intensive and technically demanding practices, particularly those related to water management, recorded very low adoption levels. It was also concluded that adoption of CSA technologies had a statistically significant positive effect on maize yield.

Since the study revealed low adoption of advanced water-saving technologies compared to traditional practices, it is recommended that simple, low-cost and locally adaptable water management technologies be promoted to enhance gradual adoption and ease of use among farmers.

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