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Emerging climate-smart-agriculture strategies: Determinants to adoption by Nigerian arable crop farmers

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ABSTRACT

Climate change is a major threat to Nigeria's food security because of its human population. This research assessed the determinants of Nigerian arable crop farmers adopting emerging climate-smart agriculture strategies. Specifically, it investigated the respondents' awareness of signs of climate change, identified the human contributions to climate change, its effect on agricultural production, and the determinants of respondents' adoption of emerging climate-smart agricultural strategies. Respondents were 120 arable crop farmers randomly selected from 4 communities in Akinyele LGA, Oyo State, Nigeria. Primary data collected with a structured questionnaire was analysed using descriptive statistics and binary logistic regression. Findings indicate respondents had experienced signs of climate change, notably poorer yield (mean=4.15), unpredictable weather patterns (mean=3.95), and intense heat (mean=3.88). Respondents strongly agreed on human contributions to climate change such as deforestation, agrochemical use, continuous cropping, and overgrazing. Challenges posed by climate change to production identified by respondents were reduced yield, erosion, pest infestation, poor soil moisture, and decreased work hours. The most significant determinant of the adoption of the emerging climate-smart agricultural strategies was agronomic strategies ($p = 0.008$), while environmental strategies were marginal determinants ($p = 0.072$). The research concluded that the respondents recognized signs of climate change and were aware of humans' contributions to it and its consequences on their production. Their choice of strategy was significantly determined by the agronomic strategy. The research recommends integrating indigenous and modern emerging climate-smart agricultural strategies and bolstering farmers' awareness, technological expertise, and financial resources through comprehensive awareness and training programs.

KEYWORDS: *Anthropogenic, Arable crop farmers, Climate action, Climate change adaptation, SDG 13*

INTRODUCTION

Climate change is a global emergency that demands everyone's attention because the earth, our common home and that of our future generations, as well as all living and non-living things globally, are under its scourge. Field & Barros (2014) explained that climate change is one of the most complex environmental and societal issues facing the world today. This issue has become of great interest to local, national, international, and global discourse, transcending regional, political, social, and religious horizons. The Intergovernmental Panel on Climate Change (IPCC, 2001) defines climate change as any change in climate over time, whether due to natural variability or as a result of human activities. NASA (2023) described climate change as a long-term change in the average weather patterns that have come to define Earth's local, regional and global

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climates. These changes have a broad range of observed effects that are synonymous with the term. Changes observed in Earth's climate since the mid-20th century were driven by human activities, particularly fossil fuel burning, which increases heat-trapping greenhouse gas levels in Earth's atmosphere, raising Earth's average surface temperature. The root cause of climate change has been narrowed to the phenomenon known as the greenhouse effect. Scientists used the term greenhouse effect to describe the way that certain atmospheric gases "trap" heat that would otherwise have radiated from the planet's surface, upwards, into outer space. The causes of the greenhouse effect can be categorized into two broad components; the natural cause and the human-driven causes. The natural causes to a large extent can be attributed to natural phenomena that affect the planetary cooling and warming patterns, such as volcanic eruptions, fluctuations in solar radiation, tectonic shifts, and even small changes in our orbit. Human-driven or anthropogenic causes include transportation, electricity generation, industry and manufacturing, agriculture, building, deforestation, and lifestyle choices. Olaniyi *et al.* (2013) pointed out that Africa, which is not historically responsible for global warming, will be hit the hardest by the effects of climate change (African Union (AU), 2023).

It is paradoxical that while agriculture contributes to climate change, it is also worst affected by climate change. The effects of climate change on agriculture include an increase in temperature, decreased rainfall, drought, desertification, melting ice, extreme weather, floods, sea level rise, sinking of islands, water scarcity, and health problems (Ikumbur & Iornumbe, 2019). Other obvious effects of climate change are increased irregularity and inconsistency in rainfall patterns, severe floods, frequent droughts, increased insect and disease rates and irregular agricultural planting seasons resulting in higher production costs, which have adversely affected crop and livestock output (Shrestha, 2019; Kangogo *et al*., 2021; Andati *et al*., 2022).

Akoso *et al*. (2017) highlighted a major concern regarding climate change in Nigeria: the increasing problem of subsistence farming, which is particularly evident in the dry and semi-dry areas of northern Nigeria, which are becoming even drier, while the southern regions are experiencing more rainfall. The unpredictable rainfall patterns negatively impact farming practices, particularly for smallholder farmers who rely solely on rain-fed agriculture. Adedugbe (2023) therefore attributed the looming food crises in Nigeria to two major factors, climate change and insecurity because most of the food supply within Nigeria is from the smallholder farmers' rain-fed agricultural production.

Climate-smart-agriculture (CSA) is a farming approach targeted at supporting food security under the new realities of climate change by delivering positive outcomes on three impact pillars, namely, intensification, adaptation, and mitigation, (Lipper *et al*., 2014). CSA aims to achieve three main objectives: sustainably increasing agricultural productivity and incomes; adapting and building resilience to climate change; and reducing and/or removing greenhouse gas emissions, where possible (Lipper *et al*., 2014). Adedugbe (2023) defined the concept of CSA as a process of climate responsiveness, development, and agricultural integration aimed at achieving food security amidst changing climate and rising new dietary and food demands. It entails a series of technologies and practices that have the potential to increase resilience, adaptation to climate change, sustainable agricultural production, food security, and income for farmers (FAO, 2018). CSA strengthens adaptation and resilience to climate change, thereby increasing the farmers' income, living standards, and productivity. Some commonly practiced CSA are intercropping/multiple cropping, agroforestry, conservation agriculture, etc.

Arable crop production is a type of farming that cultivates a wide range of annual crops that complete their life cycle within a year. Because of the seasonality of arable crops, climate change will alter the planting and harvesting calendars. Solomon & Edet (2018) opined those farmers with better information on the changing climate are likely to adopt climate change adaptation measures. However, the majority of the population of smallholder arable crop farmers in Nigeria are rural dwellers who cannot access information and hold strongly to their traditional agronomic practices. Adedugbe (2023) explained that a farmer's choice to reject or accept a technology or adaptation model for farming is based on his or her perception, thus, a farmer may decide to use a particular CSA strategy of farming only if he is aware and sure of it and develops interest as well. Most arable crop farmers are not oblivious to climate change because they employ strategies like relocation from climate-risk areas, prayers to God, recycling of waste, and multiple cropping. However, employing modern CSA strategies has been limited to younger, educated farmers who are technologically and information savvy. Adedugbe (2023) explained that in this group of modern farmers, there is a remarkable improvement in their productivity. These emerging CSA strategies in Nigeria include the greenhouse farm model; the integrated farming system, which promotes zero waste production by the recycling of agricultural waste on farmland for the benefit of other segments of the farm; sac farming, which involves the bagging of rich soil in sacs which are used as a medium for planting; and hydroponic farming. It is against this background that this research ascertained the awareness of the respondents on signs of climate change, identified the respondents' level of human contributions to climate change, examined the effects of climate change on agricultural production and investigated the determinants of respondents' choice of CSA strategies in the study area.

MATERIALS AND METHOD

The study was conducted in Akinyele Local Government Area (LGA), Oyo State. Akinyele LGA is bordered by Afijio Local Government to the north, Lagelu Local Government Area to the east, Ido Local Government Area to the west, and Ibadan North Local Government Area to the south. It is located at approximately 7.5237°N latitude and 3.9147°E, with its headquarters at Moniya. The area is known for its agricultural activities, mainly crop cultivation such as cocoa, palm products, plantain, banana, cassava, yam, maize, and citrus.

A three-stage sampling technique was used to select 120 respondents for this study. The first stage was the purposive selection of Akinyele LGA due to its large population of arable crop farmers. The second stage was the purposive selection of four districts from the nine districts in the Local Government Area, namely Moniya, Ijaye, Akinyele, and Onidundu, because they are dominated by arable crop farmers who have access to the International Institute of Tropical Agriculture (IITA) in Moniya. The third stage was the random sampling of 30 farmers from each of the selected districts.

Table 1: Strategies adopted by respondents to mitigate climate change

AGRONOMIC
Adjusting the timing of farm operations in response to weather variation.
Multiple / Intercropping.
Soil conservation (mulching/cover crops);
Zero or minimum tillage.
Early Planting.
Planting at shallow or deeper depths
Use of early maturing variety.
TECHNOLOGICAL
Groundwater harvesting (use of boreholes).
Irrigation.
Construction of drainage and water paths.
Efficient water harvesting and storage techniques.
Sack farming
Hydroponic farming
Integrated farming (Zero waste)
The greenhouse farming
Application of indigenous or scientific methods in managing pests and disease (Biotechnology).
ENVIRONMENTAL
Agroforestry.
Planting of trees.
Destruction of infected farms.
Reduction in the use of inorganic chemicals and fertilizers.
INSTITUTIONAL
Use of weather forecast.
Government programs and policies.
Extension programs.
Crop insurance
SOCIAL
Diversification from farming to non-farming practices.
Prayers.
Migration or movement to another site.
Forming farmers associations or cooperative societies

Primary data on their socio-economic characteristics, their awareness of climate change, human contribution to climate change, the effect of climate change on the respondent's agricultural production, and adaptation strategies adopted to mitigate climate change, were collected using structured questionnaire. Data on the strategies were categorized into five broad categories, as shown in Table 1.

Data obtained were analysed using descriptive statistics, with the cut-off point obtained using the 5-point Likert scale set at 3.0. The cutoff of 3.0 was used because it represents the middle point of the scale, which corresponds to a "Neutral" response. So mean scores of 3.0 and above were considered strongly agreed or most aware, while scores below 3.0 were considered otherwise.

The non-parametric method of binary logistic regression was used to determine the CSA strategies used. The binary logistic regression model was stated as follows:

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \varepsilon_i \quad (1)$$

Where Y_i = adoption of climate change mitigation strategy (0 = not adopting; 1 = adopting), β_0 = intercept, X_1 = agronomic strategies expressed mean of agronomic factors (obtained from a five-point Likert scale), X_2 = technological strategies expressed mean of technological factors (obtained from a five-point Likert scale), X_3 = environmental strategies expressed mean of environmental factors (obtained from a five-point Likert scale), X_4 = institutional strategies expressed mean of institutional factors (obtained from a five-point Likert scale), X_5 = social strategies expressed mean of social factors (obtained from a five-point Likert scale), $\beta_1, \ldots, \beta_5$ = Regression parameters $X_1 \ldots X_5$, ε_i = error term

RESULTS AND DISCUSSION

Socioeconomic characteristics

The socioeconomic characteristics of the respondents displayed in Table 2 showed that the majority of the respondents (60.8%) were males; the mean age was 43 years, with the majority of the respondents falling within the age ranges of 30-39 years (29.2%) and 40-49 years (30%). The average household size in the study area was 5 people. Respondents' average number of years of formal education attained was 13.6 years, showing that they must have respondents. The respondents do not have large farmland; about 35.8% had less than a hectare, while about 39.2% had 1 to 3 hectares of farmland. This may be because the majority of the farmers (49.2%) have minimal farming experience of 1 to 5 years.

Table 2: Socioeconomic characteristics of the respondents

Socioeconomic characteristics		Frequency (n=120)	Percentage (%)
Sex	Male	73	60.8
	Female	47	39.2
Age (years)	≤19	1	0.8
	20-29	8	6.7
	30-39	35	29.2
	40-49	36	30.0
	50-59	26	21.7
	60-69	8	6.7
	≥70	6	5.0
Mean = 45; Std. dev. =12.35			
Household size (people)	≤ 2	14	11.7
	3-5	71	59.2
	6-8	32	26.7
	9-11	2	1.7
	≥12	1	0.8
Mean =5; Std. dev. =±1.92			
Formal education (years)	0	3	2.5
	1-6	2	1.7
	7-12	12	10.0
	≥12	103	85.8
Mean =13.6; Std. dev. =±4.4			
Farm size (hectares)	< 1	43	35.8
	1-3	47	39.2
	3.1-5.0	16	13.3
	> 5	14	11.7
Mean =2.6; Std. dev. =±1.2			
Farming experience (years)	1-5	59	49.2
	6-10	31	25.8
	>10	30	25.0
Mean = 1.8; Std. dev. =± 0.9			
Annual income (₦’000)	200-400	31	25.8
	401-600	27	22.5
	601-800	30	25.0
	≥801	32	26.7
Mean = 804000.6; Std. dev. =± 4.6			
Major crops grown	Cucumber	2	1.7
	Maize	35	29.1
	Pepper	1	0.8
	Potatoes	2	1.7
	Tomatoes	1	0.8
	Tubers	2	1.7
	Vegetables	18	15.0
	Cassava	47	39.1
Extension services	No access	47	39.2
	Access	73	60.8
Credit facilities	No access	35	42.0
	Access	65	78.0
Ownership and/or usage of heavy farm machinery	Non-ownership/usage	79	65.8
	Ownership/usage	41	34.2

Perceptions of respondents on signs of climate change

Table 3 shows the respondents have observed all the signs of climate change in the study area. The respondents strongly agreed that they had prolonged rainfall and a prolonged dry season (3.26). According to Marie *et al*. (2020), frequent floods and droughts are among the manifestations of climate change that cause productivity losses. Respondents are also in strong agreement that changes in weather (3.95) and the inability to predict weather (3.75) were a result of climate change, as were the scorching sun (3.88) and the short rainy season (3.33). This is in agreement with Gebremichael *et al.* (2014) opinion that inadequate rainfall and intense sunshine were the main causes of famine and food shortages. The respondents also agreed that climate change affected agriculture (4.12) in the study area, farmers need agricultural protection (4.15). This result shows that farmers' level of awareness about climate change is high and it is an important determinant in adopting methods to cope with its effect.

Table 3: Perception of respondents on the signs of climate change

Respondents’ perception of climate change	Mean	Std. Deviation
Prolonged rainy season	3.21	1.34
Prolonged dry season	3.26	1.18
Reduction of water level of the streams	3.10	1.24
Change in weather	3.95	1.02
Inability to predict weather	3.75	1.04
Thunderstorms and heavy rains	3.52	0.94
Scorching sun	3.88	1.04
Short rainy season	3.33	1.00
Unpredictable rainfall pattern	3.60	1.04
Climate change affects agriculture	4.12	1.05
Farmers are experiencing poorer yield	4.15	0.90

Cut off point = 3.0

Human activities contributing to climate change

The respondents identified the following human activities displayed in Table 4 that contribute to climate change in the study area. The respondents strongly agreed that deforestation (3.35), use of agrochemicals (3.63), continuous cropping (3.56), and overgrazing (3.03) can contribute to climate change in the study area. This supports the claim made by Chinwoke *et al.* (2012) that deforestation contributes significantly to carbon emissions because trees absorb carbon dioxide as they grow, but as fewer trees are left, the carbon dioxide in the atmosphere will build up. Respondents were in strong disagreement that the burning of petrol, diesel and kerosene (2.66), quarrying (2.23), cement production (1.57), and exhaust fumes from automobiles (2.92) were part of the human contribution to climate change in the study area. This may be because the study area was not known for quarrying and no cement industry was situated there also the study area was a rural area with minimal commercial activities and vehicular movements. Furthermore, disagreement over the contribution of exhaust fumes and fossil fuel combustion indicates that the study area was not heavily industrialized.

Table 4: Human activities contributing to climate change

Human contribution to climate change	Mean	Std. Deviation
Deforestation	3.35	1.28
Use of agrochemicals	3.63	0.88
Continuous cropping	3.56	1.01
Overgrazing	3.03	1.26
Burning of petrol diesel and kerosene	2.66	1.09
Bush burning	2.85	1.19
Exhaust fumes from automobiles	2.92	1.04
Urine and animal droppings on the soil	3.28	1.12
Industrialization	2.61	1.10
Quarrying	2.23	1.09
Cement production	1.57	0.88

Cut off point = 3.0

Effect of climate change on agricultural production

The multiple linear regression output showing the effect of climate change on agricultural production in the study area is displayed in Table 5. The R-square value of 0.836 indicates that about 83.6% of the variability in the dependent variable (effect of climate on agriculture) can be explained by the independent variables in the model. The adjusted R-square value of 0.699 means that about 69.9% of the variance is still explained after accounting for the number of predictors. Although this is also a solid value but it is lower than the R-squared, indicating that while the model is good, not all predictors might be significantly contributing to it.

As indicated by the p-values (Sig.), the following variables were statistically significant predictors of the dependent variable:

- Reduced yield or harvest: The coefficient is 0.117, and the p-value is less than 0.001 (indicated by ***), which is less than 0.05. This suggests that reduced yield or harvest is a statistically significant predictor of the effect of climate change on agriculture.
- Loss of agricultural land due to erosion: The coefficient is 0.101, and the p-value is less than 0.001 (indicated by ***), which is less than 0.05. This suggests that loss of agricultural land due to erosion is a statistically significant predictor of the effect of climate on agriculture.
- Increase in pest infestation: The coefficient is 0.092, and the p-value is 0.002 (indicated by ***), which is less than 0.05. This suggests that increase in pest infestation is a statistically significant predictor of the effect of climate change on agriculture.
- Poor soil moisture: The coefficient is 0.052, and the p-value is 0.040 (indicated by **), which is less than 0.05. This suggests that poor soil moisture is a statistically significant predictor of the effect of climate change on agriculture.
- Reduced hours of work on the farm: The coefficient is 0.080, and the p-value is 0.001 (indicated by ***), which is less than 0.05. This suggests that reduced hours of work on farms is a statistically significant predictor of the effect of climate change on agriculture.

The other variables were not statistically significant at the 0.05 level, as their p-values were greater than 0.05.

Table 5: Effect of climate change on agricultural production

Model	B	t	Sig.
(constant)	-1.283	-8.772	0.000
Reduced yield or harvest	0.117	3.709	0.000***
Loss of agricultural land due to erosion	0.101	3.736	0.000***
Reduction in soil fertility	0.019	0.536	0.593
Increase in pest infestation	0.092	3.189	0.002***
Increase in disease infestation	0.008	0.277	0.782
Increase in weed infestation	0.027	0.858	0.393
Premature ripening of fruit	0.011	0.405	0.686
Poor soil moisture	0.052	2.081	0.040**
Irregular rainfall distribution	0.039	1.308	0.194
Decline in vegetative cover	0.030	1.129	0.262
Decay of crops on the farm	-0.012	-0.475	0.636
Reduced hours of work on the farm	0.080	3.558	0.001***
Delayed ripening of fruit	-8.000e-005	-0.003	0.998
Delayed maturity of crops	0.012	0.415	0.679
Frequent illness among workers	0.020	0.870	0.386

R-square = 0.836; Adj.R^2 = 0.699
****sig at 1%; ** sig at 5%; * sig at 10%*

Determinants of Respondents' choice CSA strategies

Table 6 shows the findings of a binary logistic regression used to evaluate determinants of choice. The output showed that;

- Agronomic strategy: The coefficient was -1.424, and the p-value was 0.008 (indicated by ***), which is less than 0.05. This suggests that the agronomic strategy was statistically significant in predicting the respondents' choice of CSA strategies. The odds ratio is 0.241, which means that for each unit increase in agronomic strategy, the odds of the outcome occurring are multiplied by 0.241 (or decrease by about 76%, since 1 - 0.241 = 0.759), holding all other variables constant.
- Technological strategy: The coefficient was 0.178, but the p-value is 0.511, which was greater than 0.05. This suggests that the technological strategy was not statistically significant in predicting the respondents' choice of CSA strategies. The odds ratio is 1.195, which would mean that for each unit increase in technological strategy, the odds of the outcome occurring are multiplied by 1.195, holding all other variables constant. However, because the p-value was not significant, no definitive conclusions can be made from the odds ratio.

- Environmental strategy: The coefficient was 0.864, and the p-value was 0.072 (indicated by *), which is greater than 0.05 but less than 0.1. This suggests that the environmental strategy might be marginally significant in the choice of respondents CSA strategies. The odds ratio was 2.372, which means that for each unit increase in environmental strategy, the odds of the outcome occurring are multiplied by 2.372, holding all other variables constant.
- Economic strategy: The coefficient was 0.544, but the p-value was 0.153, which is greater than 0.05. This suggests that the economic strategy was not statistically significant in predicting the respondents' choice of CSA strategies. The odds ratio is 1.722, which would mean that for each unit increase in economic strategy, the odds of the outcome occurring are multiplied by 1.722, holding all other variables constant. However, because the p-value was not significant, no definitive conclusions can be made from the odds ratio.

Table 6: Determinants of respondents' choice CSA strategies

CSA Strategies	B	S.E.	Wald	Sig.	Exp (B)
Agronomic strategy	-1.424	0.534	7.113	0.008***	0.241
Technological strategy	0.178	0.271	0.431	0.511	1.195
Environmental strategy	0.864	0.481	3.226	0.072*	2.372
Economic strategy	0.544	0.381	2.037	0.153	1.722
Social strategy	0.267	0.322	0.691	0.406	1.307
Institutional strategy	-0.069	0.281	0.061	0.805	0.933

****sig at 1%; ** sig at 5%; * sig at 1%*

CONCLUSION AND RECOMMENDATION

The research illuminated the significant signs, causes, and effects of climate change on the agricultural activities of arable farmers in Akinyele Local Government Area of Oyo State, as well as the determinants of their adoption of climate-smart strategies to mitigate the effects of climate change. The research concluded that the respondents were aware of climate change as they have experienced firsthand signs of climate change notably a decline in yield, diminishing river water levels, unpredictable weather patterns, intense heat, and declining soil fertility, among other substantial challenges posed by climate change. The respondents were aware of how humans contribute to the menace of climate change recognized by the use of agrochemicals, deforestation, continuous cropping and overgrazing of land by livestock. The respondents have also identified the immediate consequences of their actions, which include reduced yield or harvest, erosion, increased pest attack, reduced hours of farm work, and poor soil moisture. However, the choice of the respondents' climate-smart strategy was significantly determined by the agronomic strategy.

Based on these findings, the following recommendations are proposed:

1. Farmers should embrace emerging strategies and synergize local knowledge with modern practices such as sac farming, integrated farming, and hydroponic farming to effectively combat the adverse effects of climate change in the region.
2. Recognizing the hesitance of smallholder rural farmers to adopt technological climate-smart agriculture, there is an urgent need to bolster their awareness, technological expertise, and financial resources through comprehensive awareness programs and targeted training initiatives.
3. The optimal benefits of emerging strategies can only be realized if their costs are feasible for farmers and do not compromise their profits. By reducing the costs of strategies such as greenhouse farming and hydroponic farming through the use of locally sourced construction materials, these solutions will be more accessible. Encouraging research and production with locally available materials is pivotal in achieving this objective.

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Authors' Contributions

CFA conceptualized and supervised the research, analyzed and interpreted the data and wrote the manuscript. IVO co-supervised the research, complied relevant literatures and reviewed the manuscript. OEO managed the data collection and coded the questionnaires.

Ethical Statement

Not Applicable

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