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RESEARCH

Can Climate-Smart Agricultural Practices Improve Nutrition and Food Security? Evidence from Maize Farming Households in Southwestern Nigeria

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ABSTRACT

Purpose: *Given the threat of climate change, the study examined the factors influencing decisions to adopt climate-smart agricultural practices (CSAPs) and the impacts of their adoption on nutrition and food security among smallholder maize-farming households in Southwestern Nigeria.*

Research Method: *A multi-stage sampling procedure was used to elicit data, CSAPs were clustered into 3 components: adaptation, mitigation, and coping strategies, and food security dimensions were measured using Household-HH-Dietary Diversity (HDDS), HH-food insecurity access scale (HFIAS), and HH-food consumption score (HFCS) indices. To account for selectivity bias, data were analyzed using a two-stage multinomial endogenous switching regression (MESR) model.*

Findings and Values: *Results show that majority of farmers are young, educated and smallholders. CSAPs adoption is positive and significantly impacts nutrition and food security, which differed across sole, simultaneous and synergistic adoption with the greatest effect recorded when they use a larger package that contains all three categories of CSAPs. Consequently, farmers were 29.32%, 2.27%, and 6.02% more food secure based on HDDS, HFIAS, and HFCS indices, respectively, a potential role in adopting this package for its triple benefits of improved productivity, synergistic impacts, and enhanced household food and nutrition security. The study concludes that CSAPs adoption enhances nutrition and food security, especially, when used synergistically. The evidence can be used to deploy novel policy directions for sustained nutrition and food security attainment.*

Keywords: *Climate change, Food system, Maize farmers, Multinomial endogenous switching regression and Triple win model*

INTRODUCTION

Agriculture is known as an important contributor to food and nutrition security, which United Nations Sustainable Development Goals (SDGs) emphasized (FAO 2016). Meanwhile, empirical evidence has shown that climate change remains a great danger to agricultural productivity affecting food security (Intergovernmental Panel on Climate Change (IPCC 2014, Dube *et al.* 2016). In developing countries, the effect of climate change is more visible (Ayal *et al.* 2021), in agricultural production (IPCC 2014). It is

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known that climate threat is a primary feature of the Nigerian rain-fed agriculture (Amare *et al.* 2017, Jimoh *et al.* 2024), equally affecting maize cultivation, threatening rural household consumption and incomes (Ngoma *et al.* 2018).

Maize is a principal source of food and raw material for industry in Nigeria (World Bank 2020). In southwestern Nigeria, maize is one of the major staples cultivating under subsistence method of farming (Abdulaleem *et al.* 2019). Meanwhile, maize production and yield is highly affected by climate change as average precipitation declines referencing a unit increase in mean temperature (Tumbo *et al.* 2020, Sato *et al.* 2020). Rising sea level has submerged villages in Lagos in Southern Nigeria (Anabaraonye *et al.* 2019).

Soon, maize is becoming less suitable for cultivation as a result of rising temperatures (Chapman *et al.* 2020). Given that increase in temperature increases the production risk of smallholder maize farming households in Southwestern Nigeria (Oparinde & Okogbue 2018), there is resultant reduction in maize yields (Nwaogu *et al.* 2020, Muench *et al.* 2021).

From the foregoing, including several other studies (IPCC 2014, Asfaw *et al.* 2016), it is evident that unless farmers implement climate-smart agricultural practices (CSAPs), the livestock and crop yields in Sub-Saharan Africa (SSA) would decrease. Additionally, climate-smart agriculture is being identified as one of the most reliable approaches to achieving agricultural development sustainability for food security and nutrition amidst the threat posed by climate change (Haddad *et al.* 2015). From empirical analysis, (Ali & Erenstein 2017) show that adaption strategies improve food security and lower poverty level. If adopted more broadly and in a synergistic way, CSAPs may help reduce food insecurity among smallholder farmers (Wekesa *et al.* 2018).

Farm households in southwestern Nigeria used several adaptation and mitigation options to mitigate risks posed by climate change, including shifting to new crops, sowing time variation, and improved adoption of crop varieties (Ojo & Baiyegunhi 2020, Adeagbo *et al.* 2021). Furthermore, among the mitigation options employed by farmers include crop adjustment, soil and water management strategies (Mairura *et al.* 2021), while coping strategies farmers adopted are crop and livestock diversification, social networking, off-farm activities among others.

Meanwhile, it is necessary to investigate the extent of simultaneous and synergistic impacts of the climate-smart agricultural practices (CSAPs) on food security as regards maize farming households in Southwestern Nigeria. Many options to climate change response (IPCC 2014) have separately addressed mitigation options or incremental adaptation rather than whole inclusive transformational approach (Mapfumo *et al.* 2017, Rosenzweig & Solecki 2018). This means, transformational change requires synergized mitigation, adaptation and coping (the CSAPs) efforts within whole food system.

So far, there is dearth of information on studies that clearly analyze simultaneously and synergistic adoption impacts of the CSAPs options, particularly on food and nutrition security especially as regards maize farming households in Southwestern Nigeria. Extant literature (Ogunleye *et al.* 2021, Kehinde *et al.* 2021) have separately considered either adaptation or mitigation options in isolation, while Okoli & Ifeakor (2014) and Ajilogba & Walker (2021) considered both adaptation and mitigation scenarios but not from synergistic view point.

Additionally, none of these studies measured impacts on food security from food security pillars. Meanwhile, food insecurity is better comprehended from food security pillars dimension (Issahaku & Abdulai 2020). Considering the foregoing, this study is aimed to profile various CSAPs adopted by maize farmers, examine determinants of their adoption and investigate the impact of such practices on households' food security to ascertain the more beneficial strategy.

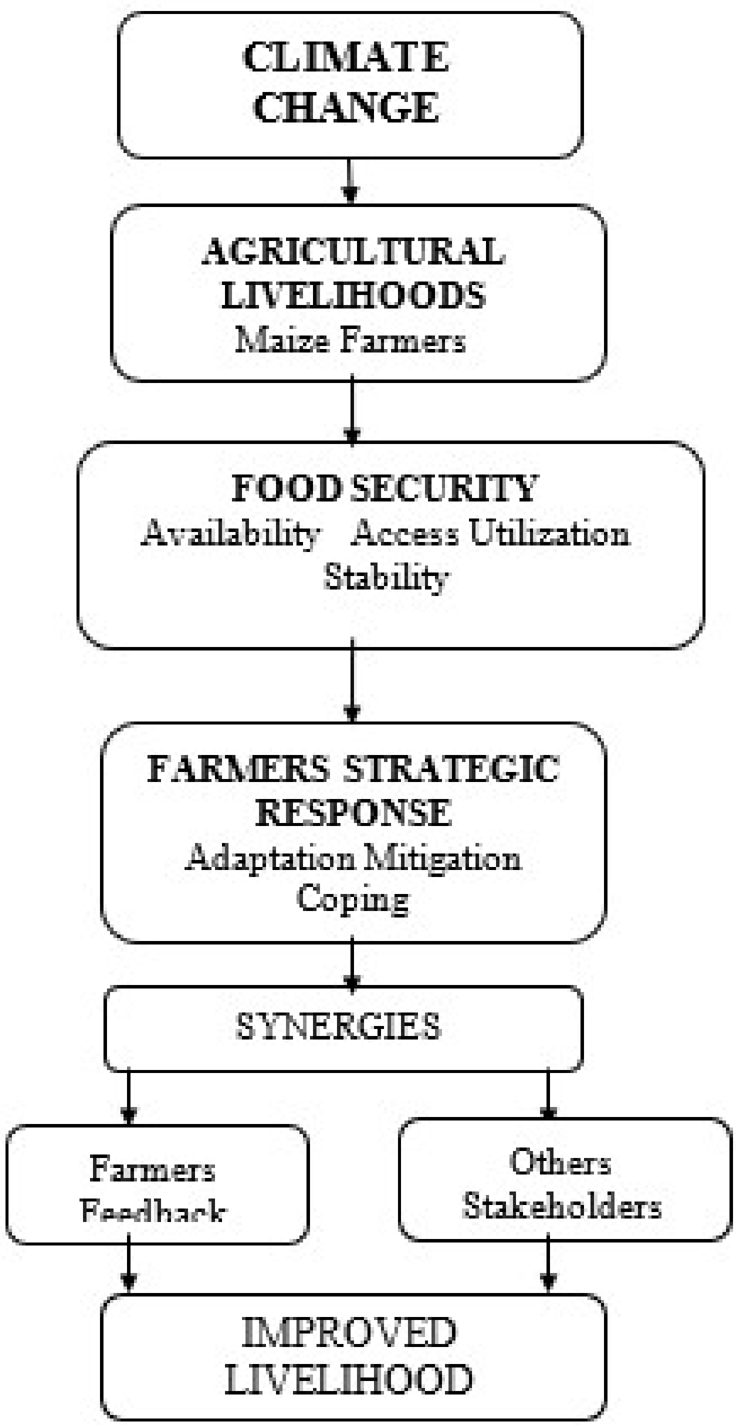

Figure 1. Methodology framework for assessing synergistic benefits of farmers' responses to climate change, the triple win model. ***Source: Authors' typology drawing from literature.***

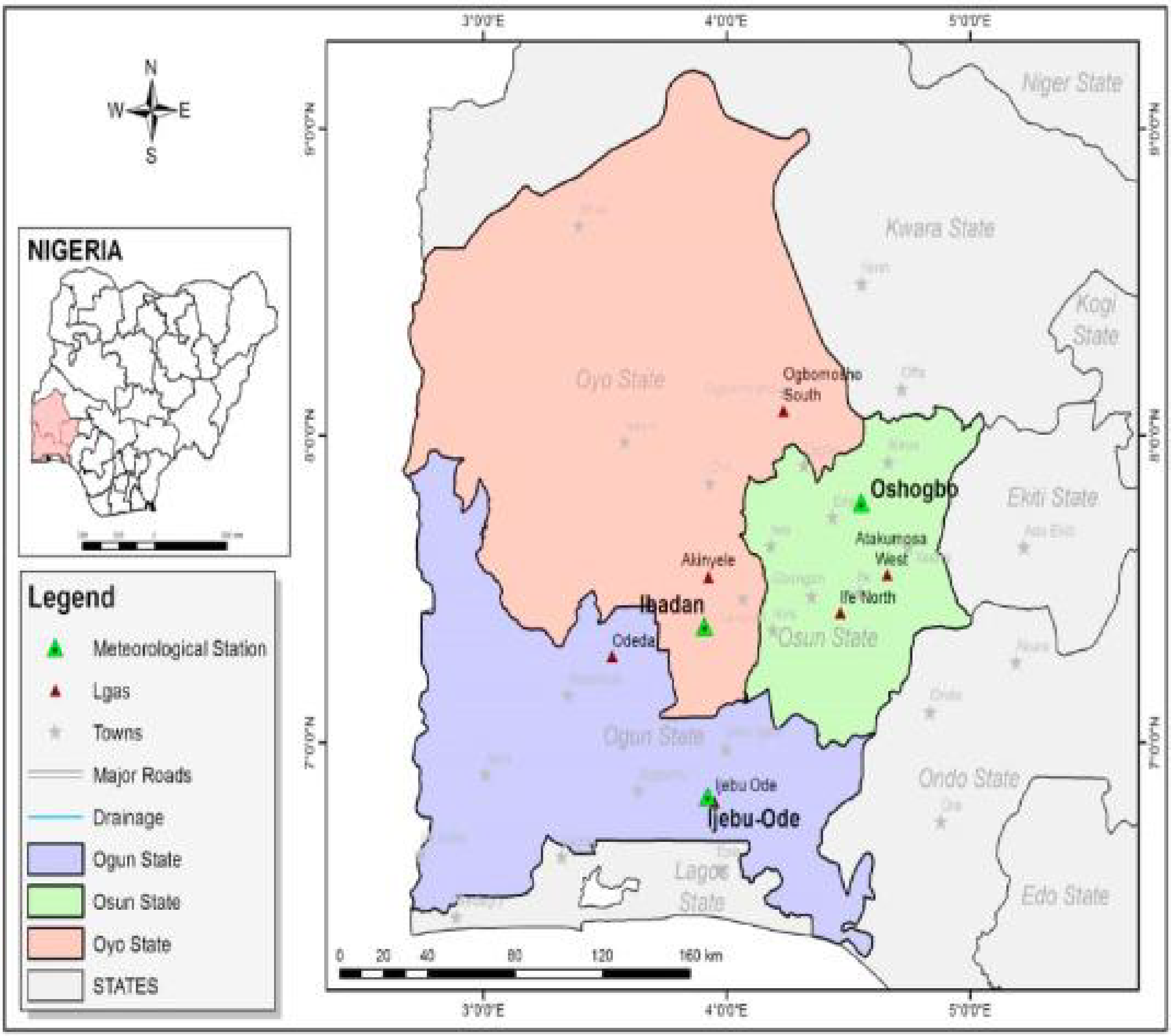

Figure 2. Map of Southwestern Nigeria showing states making the study area.

This study employed the conceptual framework depicted in Fig. 1 below, the triple win model for food system. Using a food system approach, it focused on how impactful climate change is on the four pillars of food security. It addresses the effect of farmers' climate change response on their nutritional and food security, the strategy choices available for adaptation, mitigation, and coping with climate change anomalies and their synergistic effects. The study contributed to knowledge by evidently showed how farmers' climatic response synergistically impacted on food security pillars from various indices.

MATERIALS AND METHODS

Data collection

The data used in this study were sourced from 370 maize farmers employing a validated questionnaire and focused group discussion between September and November, 2022 in Southwestern Nigeria. Multistage sampling procedure was used in the selection of the respondents. In the first stage, Oyo, Ogun and Osun States (Fig. 2), were purposively selected based on the predominance of maize farming households. In the second stage, selected states were classified into rural and urban. In the third stage, all rural local governments were stratified into rain and derived savannah based on agro ecological zones. Two derived savannah Local Government Areas (LGAs) were randomly selected from each of the three states (Table 1). The fourth stage entails the random selection of five villages from each of the six LGAs. Finally, thirteen maize farmers were randomly selected from each of the thirty villages using the list of registered maize farmers with Agricultural

Table 1. Sampled states, numbers of households, and sample size of maize farming households in Southwestern Nigeria.

No	Name of state	Household size	Sample size
1	Oyo	1625	150
2	Osun	1250	125
3	Ogun	875	95
Total		3750	370

Source: Field survey, 2022.

Development Programmes (ADPs) in the three States to make a sample of 390 maize farming households. However, for the analysis, only 370 copies of questionnaire were used. Due to inadequate data provided, the 20 copies of questionnaire remaining were not captured in the analysis.

Data analysis techniques and model specification

Adoption of CSAPs mechanisms is binary; value 1 was therefore assigned to a farmer who adopt at least one of the listed strategies and 0 for a farmer who use none in order to distinguish between adopters and non-adopters (Saguye 2016, Debela 2017). For a farmer who adopted at least one of the CSAPs, he/she was considered to have mitigated against climate change. In the study area, CSAPs that farmers adopted were classified into adaptation strategies including cropping practices (e.g. crop rotation), nutrient management practices (e.g. inorganic fertilizer), soil and water management practices (e.g. small scale irrigation farming); mitigation mechanisms (mulching/crop residues, and agroforestry), and income diversification strategies (crop and livestock diversification, off-farm activities and social networking).

Based on the review of literature concerning CSAPs mechanisms (Ojo & Baiyeghuni 2020, Jimoh *et al.* 2024), the independent variables influencing farmers' adoption of CSAPs are the joint effects of various factors, such as socioeconomic, institutional, and demographic characteristics (Table 2).

The mean age of maize farmers in the study area is 49 years, implying that most of the maize farmers are in their productive age and have the potential for productive activities and agricultural development in the area (Table 2). This is so as younger farmers are recognized for adapting to new technologies and improving their food security (Jimoh *et al.* 2025a). The mean years of formal education is 4.5, indicating low level of literacy than the national average (7.2 years) (https://www.worldeconomics.com/) among farmers. The mean farm income of the respondents was N388129, indicating capital that could be used either in the production process or be exchanged for cash or other productive assets (Akinola & Owombo 2012). The average dependency ratio is 0.63, indicating farmers had few non-productive members. The average household size is four persons, with a smallholder nature of agriculture dominant as households generally cultivate an average of two hectares or less in the study area.

Among the sampled households, food and nutrition insecurity was prevailing at some levels as HDDS of 5.2 kcal, HFIAS of 4.7 units, and HFCS of 63.53 units were reported in the past seven days, in line with (Hasan *et al.* 2018, Roba *et al.* 2019). Following Swindale & Bilisnky (2006), a household's dietary quality and nutrition security are improved when HDDS increases, while a decrease in HFIAS signals an upscaled household's access to food and improved food security. The influence of the agro-ecological zone was captured as farmers reported plot-level characteristics like drought and variation in precipitation. Precipitation variation is a pointer to climate shock to which farmers are expected to react by employing CSAPs (Di Falco *et al.* 2011).

Table 2. Summary statistics of variables used in the model.

Variable	Description	Mean	Standard deviation
Food security Index	The respondents' food security	0.38	0.214
HDDS	HH dietary diversity score, measured by the consumption of 12 categories of foods in the previous 7 days (0 to 12)	5.3	1.89
HFIAS	HH food insecurity access scale. A food secure HH has a score of 0, absolutely food insecure HH has a score of 27	4.7	3.87
HFCS	HH food consumption score is a weighted score based on dietary diversity, food frequency and the nutritional importance of food groups consumed (0 to 112)	62.53	17.82
Farm income	Monetary value of farm produce in Naira (N)	388129	296270
Adoption	Farmer adopts climate-smart agricultural Practice = 1, 0 otherwise	0.87	0.26
Gender	Male = 1, female = 0	0.78	–
Age	Age of farmer in years	49.34	10.33
Household size	Household size of respondent (number of persons)	4.14	2.48
Level of education	Years of formal education	4.52	2.95
Dependency ratio	Number of dependents in family	0.63	0.67
Farm size	Total farm size of household in hectares	1.54	2.48
Drought awareness	Farmer perceived drought occurrence (1 = yes, 0 = no)	0.76	0.44
Perceived rainfall	1 if respondent perceived rainfall to be high; 0 otherwise	0.79	0.41
Climate information	Received information on climate = 1, 0 otherwise	0.35	0.23
Terrain of the land	1 = sloppy, 0 = otherwise	0.56	0.47
Climate-smart agricultural practices	Farmer adopts climate-smart agricultural measures = 1, 0 otherwise	0.68	0.42

Source: Field survey, 2022. Note: HDDS refers to households dietary diversity on 0-12 food group scale; HFIAS refers to household food insecurity access scale on 0-27 score, HFCS refers to households food consumption score based on 0-112 score, while No. refers to number

Analytical framework

CSAPs adopted were grouped, and a two-stage multinomial endogenous switching regression (MESR) model was then used to estimate the determinants of choice and the effect of CSAPs on the food security of smallholder farmers. In the first stage, farm households were assumed to face a choice of five mutually exclusive packages for responses to climate change (changes in mean temperature and precipitation). The second stage entails using the MESR statistical model to estimate the effect of different CSAPs on household food security status. Food security status of the sampled farmers was estimated using Household Food Insecurity Access Scale (HFIAS), Household Dietary Diversity Scores (HDDS), and Household Food Consumption Score (HFCS), indicators of food accessibility, dietary diversity, and quality (Roba *et al.* 2019).

Model specification

Stage 1: Multinomial adoption selection model

Specifically, the model is adapted from Wekesa *et al.* (2018) using the multinomial logit model to determine the determinants of choice of CSA packages. Farmers were assumed to maximize their food security status Y_i by comparing the food security of five alternative CSA strategies. Y_{ij}^* is a latent variable that represents the expected food security level, influenced by observed household, climate shocks, plot characteristics, and unobserved features expressed as:

$$Y_{ij}^* = \beta_j X_{ij} + \varepsilon_{ij} \tag{1}$$

In the second step, a food security equation was used to quantify the outcome equation of the influence of adoption of mitigation and adaptation techniques on farmers' food security:

$$P_i = \beta Y_i + \delta Z_i + e \tag{2}$$

where P_i is the natural logarithm of the status of food security, Y_i is the adoption of mitigation, adaptation, and coping measures, Z_i is a collection of explanatory variables utilized in the model, and e_i stands for the error term.

Estimation of average treatment effects

Also adapted from Wekesa *et al.* (2018), a counterfactual analysis was performed to examine average treatment effects (ATET) by comparing the expected outcomes of adopters with and without adoption of a particular CSAP. ATET in the actual and counterfactual scenarios were determined as follows:

Average Treatment Effect with adoption/usage

$$\begin{aligned} ATET &= E\Big(R_{ji} \mid I = J, Z_{ji}, \hat{\lambda}_{ji}\Big) \\ &\quad - E\Big(R_{Ii} \mid I = J, Z_{Ii}, \hat{\lambda}_{Ii}\Big) \\ &= Z_{ji}(\delta_j - \delta_I) + \hat{\lambda}_{ji}\sigma_j - \hat{\lambda}_{Ii}\sigma_i \end{aligned} \tag{3}$$

RESULTS AND DISCUSSION

Synergies of CSAP combinations

The binary triplicate represents the possible strategy synergies as shown in Table 3. In the triplicate, each element is a binary variable for a CSAP combination of adaptation strategies (A), climate change mitigation practices (M), and coping/income diversification practices (C). Subscript 1 = adoption and 0 = otherwise.

The different combinations of packages whereby five mutually exclusive packages were adopted by farmers. Relatively a small fraction of farmers (12.7%) were non-adopters, $A_0M_0C_0$ of any CSAP synergy. Approximately 36.7% used all five $A_1M_1C_1$ synergy that comprised all the adaptation, mitigation, and coping/income diversification package together. About 9.5% of farmers used the $A_1M_0C_0$ package, consisting solely adaptation strategies. Another 13.5% of farmers used $A_0M_0C_1$ packages that consisted of solely coping/income diversification mechanisms. Further, 16.2% of farmers used $A_1M_0C_1$ synergy that contains joint adoption of adaptation and coping/income diversification package. Another 11.4% of farmers implemented $A_0M_1C_1$ package, which contains combination of mitigation and coping/income diversification package.

Table 3. Combination of CSAPs synergy specifications that form the packages.

Choice	Combination	Crop Mgt	Nutrient Mgt	Soil Mgt	Mitigation Strgy	Coping Strgy	Freq	%
1	$A_0M_0C_0$	✓	✓		✓	✓	47	12.7
2	$A_1M_1C_0$		✓	✓		✓	35	9.5
3	$A_0M_0C_1$	✓	✓		✓		50	13.5
4	$A_1M_0C_1$		✓		✓		60	16.2
5	$A_0M_1C_1$	✓	✓			✓	42	11.4
6	$A_1M_1C_1$		✓		✓	✓	136	36.7
						Total	370	100

Source: Field survey, 2022. Note: Comb., Mgt., and Strgy denote combination, management, and strategy, respectively.

From the above, it can be deduced that majority (61.1%) of maize farmers implement strategies relating to crop, soil, water and nutrient management (adaptation mechanisms). This indicates many smallholder farmers struggle to achieve food security through nutrient-soil based crop diversification mechanisms to mitigate rainfall anomaly patterns in agreement with observations of Hasan *et al.* (2018). Also, all users of CSAPs used a synergy of mechanisms inclusive of crop diversification mechanisms in tandem with results of Wekesa *et al.* (2018) and Getnet *et al.* (2022).

Determinants of specific CSA packages choice

Determinants of specific CSA packages choice The summary statistics shown is in Tables 4ai & 4aii. Education of farmers in non-adoption scenario is positive and statistically significant at 1% level in the study area. In the adoption situation, it is negatively correlated but statistically significant at 10% level with simultaneous adoption of $A_1M_1C_0$ packages, positive and statistically significant at 10% level with synergistic adoption of the complete package ($A_1M_1C_1$). The results show the importance of farmers' education as a deciding factor in the choice of CSAPs as more educated farmers are likely to adopt new innovation practices than their illiterate counterparts. This is corroborated by earlier study (Mairura *et.al.* 2021).

Age of farmers was negatively correlated at pre-adoption stage, but had a positive effect on the sole adoption of the income diversification package. The marginal effect implies that as the age of farmer increased by one year, the sole adoption of income diversification strategies will also increase by about 2.6% ($p< 0.1$). This follows studies by (Macharia & Pelser 2014, Musafiri *et.al.* 2020). The coefficient of gender of the farming household head in the study area was positive in all the non-adopting and CSAPs adopting situations. The marginal estimates show that male farmers were able to increase the combined adoption of $A_1M_1C_0$ package by 8.86% ($p<0.05$) and the joint adoption of the complete ($A_1M_1C_1$) package by 6.27% ($p<0.01$). This means that male farmers will adopt more CSAPs than their female counterparts. The plausible explanation to this could be that male farmers had access to farm productive resources than their female counterparts (Ibrahim & Ibrahim 2012, Coster & Adeoti 2015, Jimoh *et.al.* 2025b).

Also, the coefficient of farmers' access to credit and climate information in the study area was positive in all scenarios. The marginal results reveal that with access to credit and information, farmers were able to boost their combined adoption of ($A_1M_1C_1$) package by 20.59% ($p<0.05$) and 24.07% ($p<0.05$), respectively. This implies that farmers who can access credit and climate information are better able to plan ahead, adapt and mitigate the effects of climate change on their farms in order to maximize

Table 4ai. Determinants of specific CSA packages choice.

Variables	CSAP Models						
	No CSAP	$A_1M_0C_0$		$A_0M_0C_1$		$A_1M_0C_1$	
	dy/dx0	Coeff1	dy/dx1	Coeff2	dy/dx2	Coeff3	dy/dx3
Edu_yrs	0.0398a	0.0285	0.0478	0.0157	-0.0226	-0.0365	-0.0987b
	(0.0180)	(0.0191)	(0.5750)	(0.0202)	(0.0217)	(0.0398)	(0.0448)
Hh_gender	0.0446		0.0335		0.0178	0.0219	0.0886b
	(0.0545)	(0.0344)	(0.0251)	(0.0225)	(0.0346)	(0.0188)	(0.0421)
Credt_access	0.2107	0.3991c	0.4426		0.1071	0.2768	0.2059b
	(0.2218)	(0.2281)	(0.3794)	(0.1074)	(0.1788)	(0.4564)	(0.0980)
Clim_info	0.2708b	0.2866c	0.1838	0.43120	0.3133	0.1897	0.2407b
	(0.1128)	(0.1666)	(0.1213)	(0.3463)	(0.3516)	(0.0906)	(0.1094)
Dsmt	-0.1689a	-0.3560	-0.1180a	0.3463	0.3516	0.0906	0.1094
	(0.0544)	(0.3451)	(0.0524)	(0.2348)	(0.3975)	(0.2936)	(0.0598)

Source: Field survey, 2022. Note: [a, b, & c] are statistically significant at 1%, 5% and 10% levels, respectively. Values in parentheses are standard errors. Also, Edu_yrs, Hh_gender, Credt_access, Clim_info, Dsmt are abbreviations for education in years, household gender, credit access, climate information, and dry season mean temperature respectively.

Table 4aii. Determinants of specific CSA packages choice.

Variable	CSAP Models			
	$A_0M_1C_1$		$A_1M_1C_1$	
	Coeff4	dy/dx4	Coeff5	dy/dx5
Edu_yrs	-0.0922	0.0208	0.0693	0.4906b
	(0.1072)	(0.0305)	(0.0532)	(0.2133)
Hh_gender	0.0467	0.0329	0.2973c	0.2923a
	(0.0503)	(0.0369)	(0.1851)	(0.1092)
Credt_access	0.1439c	0.3146	0.0459	0.0627a
	(0.0082)	(0.3217)	(0.0461)	(0.0202)
Clim_info	0.1729	0.5546	0.2339	0.3107b
	(0.1671)	(0.4661)	(0.2300)	(0.1350)
Dsmt	0.1671	0.4661	2300	1350
	(0.2901)	(0.3445)	(0.3109)	(0.4153)

Source: Field survey, 2022. Note: [a, b, & c] are statistical significant at 1%, 5% and 10% levels respectively. Values in parentheses are standard errors. Also, Edu_yrs, Hh_gender, Credt_access, Clim_info, Dsmt are abbreviations for education in years, household gender, credit access, climate information, and dry season mean temperature, respectively.

Table 4bi. Determinants of specific CSA packages choice.

Variables	CSAP Models						
	No CSAP	$A_1M_0C_0$		$A_0M_0C_1$		$A_1M_0C_1$	
	dy/dx0	Coeff1	dy/dx1	Coeff2	dy/dx2	Coeff3	dy/dx3
Rsmt	0.1104a	0.2152	0.3098	0.3572	0.4226c	0.2290	0.1809b
	(0.0382)	(0.2024)	(0.2990)	(0.2874)	(0.2387)	(0.2189)	(0.0804)
Dsmp	-0.2031c	-0.3522	-0.4152	-0.2801	-0.3945	-0.2793	-0.1890
	(0.1147)	(0.2972)	(0.3891)	(0.1623)	(0.3231)	(0.3048)	(0.1281)
Luvisols	-0.4862a	-0.4936	-0.2377	-0.3766	-0.2596	-0.3325	-0.2928b
	(0.1519)	(0.3909)	(0.2645)	(0.3540)	(0.1950)	(0.2931)	(0.1273)
Nitisols	-0.3559a	-0.2943		-0.4933	-0.2505	-0.2168	-0.1545
	(0.1190)	(0.2838)	(0.3390)	(0.2406)	(0.2040)	(0.1042)	(0.3053)

Source: Field survey, 2022. Note: [a, b, & c] are statistical significance at 1%, 5% and 10% levels, respectively. Values in parentheses are standard errors. Also, Rsmt, Dsmp are abbreviations for rain season mean temperature and dry season mean precipitation.

Table 4bii. Determinants of specific CSA packages choice.

Variable	CSAP Models			
	$A_0M_1C_1$		$A_1M_1C_1$	
	Coeff4	dy/dx4	Coeff5	dy/dx5
Rsmt	0.2563	0.1994	0.5612	0.2441a
	(0.1661)	(0.1059)	(0.5149)	(0.0827)
Dsmp	-0.4214	-0.3358	-0.1853	0.1180b
	(0.3679)	(0.3055)	(0.1202)	(0.0502)
Luvisols	-0.4233	-0.3261	-0.2651	0.4398
	(0.3461)	(0.3122)	(0.1104)	(0.2484)
Nitisols	-0.6175	-0.3986	-0.3917c	0.1285c
	(0.5596)	(0.2994)	(0.2246)	(0.0694)

Source: Field survey, 2022. Note: [a, b, & c] are statistical significance at 1%, 5% and 10% levels respectively. Values in parentheses are standard errors. Also, Rsmt, Dsmp are abbreviations for rain season mean temperature and dry season mean precipitation.

Table 5. Summary MESR estimates of the impact of CSA packages on maize farming HDDS, HFIAS, and HFCS.

Package	HDDS		HFIAS		HFCS	
	ATET	% impact/Returns	ATET	% impact/Returns	ATET	% impact/Returns
$A_1M_0C_0$	0.3474* (0.1930)	7.43	0.3860*** (0.1245)	0.28	3.1098* (1.4008)	5.13
$A_0M_0C_1$	0.7164 (0.6543)	11.07	4.7123 (4.81750)	25.25	0.6106* (0.2614)	0.98
$A_1M_0C_1$	0.3997** (0.1658)	7.36	0.3019* (0.1705)	2.19	1.6304** (0.7377)	2.64
$A_0M_1C_1$	0.9575 (0.9321)	16.79	0.3200** (0.1391)	2.26	1.7540** (0.7527)	2.81
$A_1M_1C_1$	1.4554*** (0.4280)	29.32	0.3128* (0.0368)	2.27	3.5852*** (1.1381)	6.02

*Source: Field survey, 2022. Note: ***, **, * & c are statistical significance at 1%, 5% and 10% levels respectively. Values in parenthesis are standard errors.*

maize yield.

Furthermore, the coefficients of dry season mean temperature and precipitation were negative in all the adopting and non-adopting situations except in the combined adoption of ($A_1M_1C_0$) package, (Tables 4bi & 4bii). This could be explained by the fact that a temperature rise during the dry season without sufficient irrigation facilities dries up the soil and predisposes the maize crop to stress, which can lower output. The marginal effect estimates indicate that with the sole adoption of the adaptation package, farmers were able to reduce the negative effect significantly by 5.09% ($p<0.05$). This indicates that adoption of the combined ($A_1M_1C_0$) package, farmers enjoy a 10C amelioration in temperature adversity on their farm land.

The coefficient of rainy season mean temperature is positive and statistically significant ($p<0.01$) in non-adoption situation. The marginal effect results show that an increase in long term rainy temperature will significantly increase the adoption of the combined ($A_1M_1C_0$) package magnitude by 18.09% ($p<0.05$). Also, farmers adoption of the complete package ($A_1M_1C_1$) was significantly increased by 24.41% for 10C rise in rain season mean temperature.

Impact of CSA packages on maize farming households' food security using household dietary diversity score (HDDS), household food insecurity access scale (HFIAS) and households food consumption score (HFCS) indicators.

The summary statistics are shown in Table 5. It reveals that the sole adoption of adaptation mechanisms ($A_1M_0C_0$) had a positive and statistically significant impact on HDDS, HFIAS and HFCS of the adopters at the 10%, 1% and 10% levels, respectively. The ATET shows an increasing adopters' calorie intake by 0.35 kcal, reducing food inaccessibility severity by 0.31, and increasing their food consumption by 0.31 units. This is as the sole adoption that impacted on their food security positively by 7.43%, 0.28% and 5.13%, respectively. These findings are in agreement with Getnet *et.al.*, 2022, who found that farmers engage in adaptation strategies to cushion the adverse effects of climate change.

Also, simultaneous adoption of adaptation and coping/income diversification package ($A_1M_0C_1$) impacted positively and statistically significantly on HDDS, HFIAS and HFCS of the adopters at 5% 10% and 5% levels. ATET figures show an improvement in their calorie intake by 0.4 kcal, food consumption by 1.63 units and food inaccessibility reduced by 0.3 severity. Here, the highest impact on their food security was seen in HDDS (7.36%), followed by HFCS (2.64%) and the least HFIAS (2.19%). This implies that the combined strategy can reduce food insecurity through ($A_1M_0C_1$) adoption in the study area.

More importantly, a complete package ($A_1M_1C_1$) adoption of all strategies had a positive and statistically significant impact on HDDS and HFCS, each at the 1% level, except for HFIAS that is significant at the 10% level. ATETs show that the synergized adoption of the package ($A_1M_1C_i$) increases the HDDS by 1.46 kcal, food consumption by 3.58 units and reduces households' food inaccessibility by 0.31 severity. The indicator, where the food security is mostly leveraged, is when household dietary is diversified (29.32%) followed by higher consumption (6.02%) and food inaccessibility severity is reduced by 2.27%. This follows Wekesa *et.al.* (2018), who found that farmers' adoption of CSA package improves food security in their study area. On the whole, farmers had improved food security through increased food access and the ability to consume more diversified nutrient food categories by adopting mutually exclusive categories of the CSAPs with a complete package ($A_1M_1C_1$) adoption, yielding the highest impact.

CONCLUSION

Using a multi-stage sampling procedure, the study examined the factors influencing decisions to adopt and the impacts of the adoption of climate-smart agricultural practices (CSAPs) on nutrition and food security among smallholder maize farming households in Southwestern Nigeria. CSAPs were clustered into three components: adaptation, mitigation, and coping strategies.

Food security dimensions were measured using Household Dietary Diversity (HDDS), Household Food Insecurity Access Scale (HFIAS), and Household Food Consumption Score (HFCS) indices. To account for selectivity bias arising from both observed and unobserved factors, data were analyzed using a two-stage multinomial endogenous switching regression (MESR) model.

Results show that the majority of farmers are young, educated, and smallholders. CSAP adoption is positive and significantly impacts nutrition and food security. Furthermore, the adoption impacts also differed across sole, simultaneous, and synergistic adoption on nutrition and food security outcomes, with the greatest effect recorded when farmers use a larger package that contains all three categories of CSAPs. Consequently, farmers were 29.32%, 2.27%, and 6.02% more food secure based on HDDS, HFIAS, and HFCS indices, respectively. This indicates a potential benefit of adopting the complete package due to its triple advantages of improved productivity, synergized impacts, and enhanced household food and nutrition security through increased food access and the ability to consume more diversified nutrient food categories.

The study concludes that CSAP adoption enhances nutrition and food security, especially when used synergistically. Therefore, for smallholder maize farmers to achieve relatively higher nutrition and food security and reduce food insecurity, this study empirically demonstrates that adoption of CSAPs is a viable pathway.

This study facilitates the design of climate-smart agriculture policy, as understanding the determinants of adoption of these mechanisms could serve as an eye-opener to the most challenging and/or beneficial strategies in deployment stages, thereby facilitating farmers' resilience at community, state, and national levels. For instance, easy access to credit and adequate climate information dissemination could strengthen climate change sensitization among farmers and promote the adoption of

CSAPs. Finally, this study provides deeper insights into the nexus between the adoption of CSAPs and nutrition and food security.

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