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Implementation of conservation agricultural practices as an effective response to mitigate climate change impact and boost crop productivity in Nigeria

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ABSTRACT

Conservation agricultural practices aims to concurrently improve climate resilience, improve agricultural productivity and rural livelihood. This study examined the determinants of adoption and implementation of alternative package of conservation agricultural practices using household level survey data in Nigeria. A Multinomial endogenous switching regression (MESR) model was employed to estimate the factors influencing the adoption of conservation agricultural practices and productivities of adopters and non-adopters of alternative package of conservation agricultural practices. Significant variables such as age, gender, farming experience, farm size, formal education, access to extension services and membership in association were factors influencing the adoption and implementation of alternative package of conservation agricultural practices among the farmers. The result of the MESR-ATT indicates that adoption of alternative package of conservation agricultural practices to mitigate the negative impact of climate change improves the productivity of the farmers in the study area. To ensure effective implementation of alternative package of conservation agricultural practices among the farmers, the study suggest that stakeholders and government need to take the lead in the promotion of alternative package of conservation agricultural practices while creating enabling environment for effective participation of the other stakeholders.

1. Introduction

It is becoming more and more obvious that climate change and rural livelihoods are closely related. In most developing nations, especially rural Sub-Saharan Africa (SSA), climate change will deepen multidimensional poverty and generate new poor, according to the Intergovernmental Panel on Climate Change's fifth assessment report (AR5) [1]. Since the majority of rural communities in these areas rely on rainfed farming for their livelihoods, agriculture is the main sector having an impact on the climate in these areas [2,3]. Food security, agricultural revenues, and the capacity of the poor to overcome poverty are all directly impacted by climate change. Climate change indirectly affects factor pricing ratios, which impacts the direction of technological advancement and entire food systems [1,4].

Less rainfall is anticipated in SSA, which will have a detrimental impact on the region's long-term agriculture productivity [5,6]. By 2050 and 2100, rainfall in Nigeria is expected to decrease by 3 and 0.6% respectively, while the country's temperature is expected to rise by 1.9 and 2.3 °C [7]. According to Hamudu and Ngoma [7], the country's water availability will probably decrease by 13% by 2100, with considerable regional variations (the southern part likely to become the most affected). There are two challenges for the area: (i) to increase agricultural production in order to accommodate shifting dietary choices and a growing population that is expected to reach 2 billion people by 2050 [8] and (ii) to improve the region's agrifood systems' resilience and mitigate the negative effects of recent and future climate change. The collection of conservation agriculture (CA) techniques is seen as a component of the solution that might lessen crop output losses due to adverse weather occurrences, and may therefore contribute to the climate smart agriculture (CSA) objectives of increasing output and income for households, improving resilience and climate adaptation and lowering agricultural greenhouse gas (GHG) emissions [9].

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Conservation agriculture (CA) has been widely advocated as a substitute for tillage-based conventional agriculture and as a method of crop husbandry that can reconcile these frequently conflicting objectives in response to the harsh climate change impact on agriculture [10]. Conservation Agriculture is defined as a set of agricultural technologies, which includes minimum soil disturbance, zero tillage, permanent soil cover, diversified crop rotations, and integrated weed management [11], aimed at reverting the many negative effects of conventional farming practices such as soil erosion, soil organic matter decline, water loss, soil physical degradation, and fuel use [12]. CA is an agronomic technology management method that enables minimal soil disturbance, upkeep of a permanent soil cover, and spatiotemporal diversification of crop species [13]. According to research, CA has a variety of advantages, including reduced greenhouse gas emissions due to reduced labor, energy, and mineral nitrogen use in farming [14], increased biological activity in soils [15], and an increase in long-term yield and productivity as a result [16]. Some studies claim that if CA is not done properly, it provides no yield gains in the short term and in irrigated areas [13]. Comparatively to temperate countries and South America, the area covered by CA in SSA is also quite limited [17]. Around 2.5 million ha, or 1% of all arable land, are thought to be covered by partial CA-based systems (at least one crop with no-till, with or without residue retention) in SSA [10], which is still far below the percentage in America, Europe, Australia, and China [18].

The peasant production system in Nigeria's agricultural system is due to the country's traditional land tenure structure, low productivity brought on by the dramatic effects of climate change, slow adoption of new technologies, and use of rain-fed and primitive crop husbandry techniques [19]. Rural farmers are known to employ a variety of traditional agricultural methods, including basic agronomic procedures, centuries-old soil amendment management strategies, and antiquated mechanical soil management techniques. Nevertheless, the use of these techniques has kept up production, at least at a subsistence level, though not without some negative side effects, such as the destruction of the environment and a fall in productivity after a certain point or threshold [20]. Therefore, conservation efforts to lessen the effects of climate change, increase the production of food crops, and improve soil quality remain a crucial component of conservation efforts to increase farmers' productivity in Nigeria. One such practice is conservation agriculture (CA), which is more environmentally friendly.

In other scholarly publications, sustainable intensification through CA agricultural methods has been proposed as a means and approach to increase smallholder output, particularly in SSA, according to Brown, Nuberg, and Llewellyn [21]. Many African governments and development professionals have firmly embraced CA [22]. A review of the literature [22–25] revealed that the use of CA in SSA was less than what is available in many developed nations. The underutilization of CA is linked to the lack of access to land and hurdles to customary land tenure, as well as to inadequate information dissemination regarding CA, which, by extension, reflects farmers' limited trust, interest, and low rate of adoption [26].

Ojo et al. [27] have previously reaffirmed that the use of soil conservation technology in Nigeria and other SSA countries may increase farmers' profitability through high yield, minimize labor-intensive activities, and improve soil quality as well as the resulting deteriorating environment. However, scaling up the usage of these technologies has remained unexplored and poorly documented in many SSA nations, including Nigeria in particular, despite the immense advantages. Kenya, South Africa, Mozambique, Zambia, Malawi, Zimbabwe, Lesotho, and Ethiopia stand out as exceptions to this rule because they are currently leading the way in Africa in terms of CA practices and its documentation. The adoption of CA is driven by a number of dynamics, including agronomic, socioeconomic, and cultural variables; how well it succeeds depends largely on how these dynamics interact [28]. Farmers' productivity goals, limitations, and risk tolerance are key considerations in the adoption process, along with the anticipated advantages and up-front expenses of CA. Farmers in SSA frequently prioritize current related costs and anticipated future returns when considering their options when choosing an adoption strategy, according to Corbeels et al. [28]. In light of this, it is essential to give this topic the attention it deserves because it pertains to reducing the harsh effects of climate change and increasing farm output by encouraging policies to support the uptake, implementation, and scaling up of agricultural technology like CA in Nigeria which will help to achieve one of the sustainable developmental goals of combating climate change impact. Specifically, the study examined the factors influencing the adoption and implementation of conservation agricultural practices while also assessing the effect of the implementation of the CA practices on farmers' productivity (yield and income).

2. Conceptual framework

The study employed the random utility framework, following prior studies [29–31] in adopting agricultural technology. The study regarded the adoption of CA farming techniques as a decision issue. If the overall benefit of adoption is greater than zero, the random utility predicts that a utility-maximizing farmer will adopt any combination of CA techniques. Rural farming households in several developing nations, including Nigeria, rarely adopt a single technology. Instead, they consider a range of technologies and select a particular technology package that maximizes their predicted usefulness [32]. In this framework, predicted utility maximization or net return are used to explain the adoption decisions of innovations. In this study, it is assumed that CA techniques will only appeal to farming households if they provide the greatest positive net return after accounting for socioeconomic factors, resource endowments, and other determining factors. A resource-poor farmer that prioritizes utility will adopt CA techniques if $L^* = U_{iA}$ - $U_{iN} > 0$, where L^* is a hidden (latent) variable that reflects the difference between the benefits/returns from adopting CA methods (Ui_A) and non-adopting (Ui_N). L^* can be represented as a function of the following observable variables:

$$L_i^* = \beta X_i + \varepsilon_i \ \ with\ L_i = \begin{cases} 1 & if\ L_i^* > 0 \\ 0\ otherwise \end{cases} \tag{1}$$

L is a two-fold variable with a value of one (1) if a farming household uses CA practices and zero (0) otherwise. Any farmer that adopted at least one CA practice during the 2019–2020 growing season is referred to as an adopter in this study. β is an estimated trajectory of constraints (parameters); X is a trajectory of explanatory factors (such the socio-economic variables of the farmer and agricultural characteristics); ε is the stochastic error term. Adoption of CA is thought to have a significant impact on farm productivity, yield, and net farm income. The linear regression equation can be represented as follows if we believe that rising farm productivity and net farm income are linear functions of CA adoption (Li) and a trajectory of certain explanatory variables (Xi):

$$W_i = \varphi X_i + \delta L_i + \mu_i \tag{2}$$

Wi stands for yield or net farm income, φ are estimation-restrictions, and δ is the stochastic error term. The productivity and financial effects of CA adoption are measured by these parameters. Nevertheless, random assignment of agricultural households to the treatment (CA adopters) and control groups is necessary for balanced identification of (non-adopters of CA practices). Farming households with a relative advantage in terms of visible and unobserved attributes may implement CA methods without the random appointments and hence experience more welfare gains than a randomly chosen farmer. Due to unobservable features that are related to the adoption decision and welfare outcome variable (productivity/yield or net farm income), δ in Eq. (2) would be biased. Propensity score matching (PSM) is typically used in impact assessment studies to correct for self-selection biases in impact evaluations. Although this method eliminates a higher proportion of the reference point differences between the two sets of farming households (adopters and non-adopters), their ability to take into account hidden factors such farmers' inherent skills is constrained. King and Nielsen [33] also shown that PSM can increase imbalance and bias due to simulating an entirely randomized trial, even when the selection process is fair and inclusive. As a result, the multinomial endogenous switching regression (MESR), which offers a solution to endogeneity issues from self-selection and assesses the effects of both individual and combination of technologies, was used to determine the welfare impact of CA adoption among smallholder farmers using methods from prior empirical studies [34,35].

3. Econometric framework

In this study, the multinomial endogenous switching regression (MESR) analysis was used because it employs a selection bias correction method by computing an inverse mill ratio (IMR) using a shortened normal distribution. The goal was to assess the factors influencing the implementation of CA practices to mitigate the impact of climate change and its subsequent effect on productivity [36]. In comparison to other impact approaches, such as the propensity score matching (PSM) technique, this approach has an advantage since it enables the creation of a counterfactual based on advantages to adopters' and non-adopters' attributes [37]. This shows that the influence of strategy choice is not limited to the intercept of the result equations, but can also have a slope effect. It also allows the strategy set choices (treatment variables) to interact with noticeable variables and unseen variability. The MESR analysis is done concurrently in two parts. In the first step, the multinomial logit (MNL) model is used to estimate the alternative complementary technology package that farming families choose while taking unobserved heterogeneity into account. The predicted probabilities in the MNL model are also used to calculate the IMR concurrently. The influence of the various complementing technology packages of CA techniques is assessed using the ordinary least square (OLS) estimator in the second stage, with IMRs introduced as additional covariates to account for selection bias resulting from temporally varying undetected heterogeneity. The next parts go into the specific econometric estimate strategy and estimation of average treatment effects.

4. The multinomial logit regression (MNL) model

An analytical methodology used to evaluate the selection of various technique combinations in smallholder farming systems is the multinomial logit (MNL) regression [38]. The selection of several technologies from a choice set that includes all likely combinations is studied in this technique. Based on estimates from an MNL choice model, the marginal effects of farmer and farm attributes on choice probabilities are evaluated. The functional form of this econometric framework suggests that the choice probabilities ratio is independent of the presence of other substitutes in the choice set; if choice A is preferred over choice B in the choice set (A, B), then the addition of a third alternative C (A, B, C) should not make B preferred over A. This is a limitation of this econometric framework. Even if the independence of immaterial alternatives (IIA) assumption does not apply, Bourguignon et al. [36] determined that the parameter estimations from the MNL model are accurate and dependable. Let's take a look at a rational farmer named i whose major objective is to maximize utility T_i by weighing the advantages brought about by alternate strategy P. If there is a related positive net benefit, this rational farmer will pick bundle a over any alternative bundle p. Thus, $\Delta T_{ip} = T_{ia} - T_{ip} > 0$ $p \neq a$. As a result, the index function for adopting the bundle can be specified as;

$$T_{i\alpha}^{*} = X_{ip}\beta_p + \varepsilon_{ip} \tag{3}$$

where $T_{i\alpha}^{*}$ is the latent variable that describes the expected net gains a farmer would receive from implementing the bundle a, Experiential covariates are denoted by Xip (socioeconomic, farm-specific, etc.), and β_p is the Xp-related parameter p that is constant across all choices. The parameter ε_{ip} is a stochastic error term that captures the unobserved characteristics of the other options as well as the dimensions of inherently random choosing behavior. If C represents a farmer's preference for CA practices, then;

$$C = \begin{cases} 1 \text{ if } Ti_1^{*} > 0 \max\left(T_{ip}\right) or\ \lambda_{i1} < 0 \\ \quad for\ all\ p \neq \alpha \\ \alpha \text{ if } T_{i\alpha} > 0 \max\left(T_{ip}^{*}\right) or\ \lambda_{i\alpha} < 0 \end{cases} \tag{4}$$

According to the index function in Eq. (4), if bundle an offers the ith farmer the highest substantial anticipated profit compared to alternative combination or bundle p, he will choose to use it. $p \neq a$; $\lambda_{ia} = \max(T_{i\alpha}^{*} - T_{ip}^{*}) < 0$ if the error term (ε_{ip}) is identical and independently Gumbel distributed [36].

According to McFadden [39], the multinomial logit model, which is denoted as follows, can be used to demonstrate the possibility that an ith farmer will select bundle a:

$$P_{i\alpha} = P_r(\lambda_{i\alpha} < 0 / z_i) = \frac{\exp(z_i\beta_\alpha)}{\sum_{p=1}^{A} exp(z_i\beta_p)} \tag{5}$$

With the use of Stata Statistical Software's "mlogit" tool, the MNL model in Eq. (5) was predicted (STATA 14).

5. Multinomial endogenous switching regression (MESR) model

To investigate the relationship between productivity and net farm income variables and a group of covariates (α) for a particular technology choice, the MESR model entails estimating an Ordinary Least Squares (OLS) regression with selectivity adjustment, i.e. ($RT_0SC_0CR_0$), p = 1 (non-adoption as a base category); Reduced Tillage (RT) ($RT_1SC_0CR_0$), p = 2; Soil cover (SC) ($RT_0SC_1CR_0$), p = 3; Crop Rotation (CR) ($RT_0SC_0CR_1$), p = 4; Reduced Tillage and Soil cover (RT& SC) ($RT_1SC_1CR_0$), p = 5; Reduced Tillage and Crop Rotation (RT&CR) ($RT_1SC_0CR_1$), p = 6; Soil cover and Crop Rotation (SC&CR)($RT_0SC_1CR_1$) = 7 and both Reduced Tillage, Soil cover and Crop Rotation ($RT_1SC_1CR_1$), p = 8. The productivity equation for specific likely regime p is specified as:

$$\begin{cases} Regime\ 1: A_{1i} = \beta_1\alpha_1 + \partial_j\theta_{1i} + \varphi_{1i}\ if\ j = 1 \\ \qquad p = 2,3,4 \\ Regime\ P: A_{pi} = \beta_p\alpha_{ji} + \partial_p\theta_{pi} + \varphi_{pi} if\ j = p \end{cases} \tag{6}$$

where (Api's) are the regime-p farmers' productivity indicators, The parameter vectors are denoted by β′s. (φ_{1i}) and (φ_{pi}) are the stochastic error terms. These error terms ($\varphi_{pi}{}'s$) have distributions $E(\varphi_{pi}\,|X,\alpha) = 0)$ and var $(\varphi_{pi}\,|X,\alpha) = \sigma 2_p)$. In this case, A_{pi} is observed if only bundle p is adopted, wherein $\pi^*_{ip} > \max_{p \neq a} (\pi^*_{ia})$. In order to reduce the unobserved heterogeneity restrictions, Wooldridge (2002) states that Eq. (6) is supplemented with the mean plot changing covariates (∂) (fertilizer use, labor use, etc.). The stochastic error term (φ_{pi}) consists of a random error term with unobserved particular effects. Therefore, if the error terms of the adoption (ε_{pi}) and outcome (φ_{pi}) equations are dependent, the OLS estimates in Eq. (6) will be biased. Therefore, the inclusion of the choice correction factors is necessary for consistent estimations of β_p and ∂_p in Eq (5). There are p - 1 choice correction terms in the multinomial choice situation, one for each replacement adoption bundle. The second MESR phase with accurate estimates is written as:

$$\begin{cases} Regime\ 1: A_{1i} = \beta_1\alpha_1 + \sigma_1\bar{\lambda}_{1i} + \partial_j\theta_{1i} + \varphi_{1i}\ if\ j = 1 \\ \qquad p = 2,3,4 \\ Regime\ P: A_{pi} = \beta_p\alpha_{pi} + \sigma_p\bar{\lambda}_{pi} + \partial_p\theta_{pi} + \varphi_{pi}\ if\ j = p \end{cases} \tag{7}$$

where the disturbance term with an expected value of zero is represented by φ_{1i}, σ is the covariance amongst (ε_{pi}) and (φ_{1i}), while $ƛ_{pi}$ is the IMR calculated from predicted probabilities in Eq. (6). The IMR ($ƛ_{ai}$) is given as follows:

$$ƛ_{ai} = \sum\nolimits_{p\neq\alpha}^{\alpha} \rho_\alpha \llbracket \frac{\rho_{ip}\ \ln(\hat{P}_{ip})}{1-P_{ip}} + \ln(\widehat{P}_{\alpha i}) \rrbracket \tag{8}$$

where the correlation between (ε_{pi}) and (φ_{1i}). is denoted by ρ. The zero value of the error terms is predicted. The Inverse Mills Ratio regressor, $ƛ_{ait}$, has a high likelihood of heteroscedasticity, as was indicated by the use of bootstrap standard errors. Teklewold et al. [40] advise adding selection instruments to the choice model (equation (6)), which is created automatically by the non-linearity of the selection model, in order to obtain accurate estimates of β_p. In order to determine the selection equation, this study employed three instrumental variables: interactions with extension agents (yes = 1), participation in farmers associations (yes = 1), and Access to credit (yes = 1). It is presumable that the instrumental factors included directly affect the adoption of CA practices, but that CA practice adoption is the primary way to influence the outcome indicators.

6. Average treatment effects (ATT)

The average treatment effect (ATT) on the treated was calculated using the multinomial endogenous switching regression (MESR) by comparing the anticipated values of the outcomes of the treated (adopters) and untreated (non-adopters) in real (actual) and unreal (counterfactual) situations. The change in the outcome variable of interest that can be solely attributable to the adoption of CA procedures is known as the ATT. The restrictive expectations for the productivity variables in both the actual and their counterfactual setups are defined as follows by Khonje et al. [41]:

Adopters with adoption (actual),

$$E\left(A_{pi}\ \middle|\mathrm{U}=\mathrm{p}, \alpha_{pi}, \theta_{pi}, ƛ_{ai}\right) = \beta_p\alpha_{ji} + \partial_p\theta_{pi} + \sigma_pƛ_{ai} \tag{10a}$$

Adopters had they decided not to adopt (counterfactuals),

$$E\left(A_{1i}\ \middle|\mathrm{U}=\mathrm{p}, \alpha_{pi}, \theta_{pi}, ƛ_{ai}\right) = \beta_1\alpha_{ji} + \partial_1\theta_{pi} + \sigma_1ƛ_{ai} \tag{10b}$$

If the coefficients on the features of adopters (α_{pi}; θ_{pi}; $ƛ_{ai}$) had been identical to the coefficients on the features of non-adopters, the adopters' outcome variable values would have been as shown in Eq. (10b), [37]. For the purpose of estimating ATT, the MESR estimation in Eq. (8) was used to forecast the real (counterfactual) Eq. (10b) predicted values of productivity outcome for a farmer who adopted technology p and the unreal (counterfactual) Eq. (10a) predicted values. The difference between the two equations is given as follows:

$$\begin{aligned} ATT &= E\left(A_{pi}\ \middle|\mathrm{U}=\mathrm{p}, \alpha_{pi}, \theta_{pi}, ƛ_{ai}\right) - E\left(A_{1i}\ \middle|\mathrm{U}=\mathrm{p}, \alpha_{pi}, \theta_{pi}, ƛ_{ai}\right) \\ &= \alpha_{pi}\left(\beta_p-\beta_1\right) + \theta_{pi}\left(\beta_p-\beta_1\right) + ƛ_{ai}\left(\sigma_p-\sigma_1\right) \end{aligned} \tag{11}$$

The first term (α_{pi}), in Eq. (11)'s right side will represent the predicted change in the average outcome variable assuming adopters and non-adopters shared identical characteristics. On the right-hand side of Eq. (11), the third term ($ƛ_{ai}$) and the Mundlak method (θ_{pi}), account for selection bias and endogeneity resulting from unobserved heterogeneity.

7. Research methods

7.1. Area of study

The study was carried out in the southwest of Nigeria, which is made up of the six geopolitical states of Lagos, Osun, Ogun, Oyo, Ekiti, and Ondo. The research locations cover an area of roughly 77, 818 km^2 and are situated between latitudes 6° 21′ and 8° 37′ N and longitudes 20 31′ and 6° 00′ E. Southwest Nigeria experiences tropical weather, with large variations in annual precipitation (150–3000 mm) and mean temperatures (21–34 °C) amongst states. While the north-eastern trade wind from the Sahara desert is connected with the dry season, the monsoon wind from the Atlantic Ocean is associated with the rainy season. The research regions, which span the states of Ogun and Ondo, are covered with swamp, deep forest, as well as woodlands. Forests cover the northern 1imit and extend all the way down to southern Guinea [56]. Ayan1ade et al. (2017) [56] claim that there are a variety of difficulties with agricultural output in the Southwest region of Nigeria, including ongoing crop losses from poor weather and pest outbreaks. Over the past few decades, droughts and floods as well as other extreme weather events have had a detrimental impact on agricultural output, farmer income, and food security in this region. In drier regions where there are more newly emerging farmers, the effects of climate change on the weather are more noticeable.

7.2. Sampling techniques and sample size

A multistage sampling technique was employed in this study to choose participants from the study area. In the first step, a typical-case selection of two states (Oyo and Osun) located in the same agro-eco1ogica1 region was chosen. The second phase involved selecting five local government areas (LGAs) from each state using the conventional case-purposive sampling method based on the presence of smaller maize growers there. Five participants from each of the four LGAs were randomly selected for the third round. According to Tesfahunegn et al. (2016) [57] the sample size for the investigation was established using the sample determination formu1a at a 95% confidence interval and a 5% margin of error. From each of the five vi11ages included in this framework, six smaller maize producers were selected for the study's interviews, totaling 300 respondents. The responses to a well-structured questionnaire, was utilized to collect primary information. Data on their socioeconomic attributes, the varieties of maize they adopted, the amounts of inputs and outputs related to maize, etc., were all obtained. The community leaders of the chosen communities in the Local Government Areas in Oyo and Osun State provided their approval. Throughout the duration of the study, the ethical norms of respect for persons, anonymity and confidentiality, beneficence, and the principle of fairness were all observed. For instance, the respondents' informed consent was only requested before data collection. Irrespective their race or religious beliefs, every respondents was treated fairly and equally during the course of the survey.

8. Empirical results and discussion

8.1. The summary of the descriptive statistics of the farmers

We presented the resu1t of the descriptive statistics of the sma11-ho1der farmers in Table 1 and Table 2. Based on the survey resu1t, 11% did not implement any of the CA practices on their farm, 12%, 13.7% and 14.3% had implemented reduced tillage, maintenance of soil cover and crop rotation respectively as climate change mitigation strategies. About 11.3% had combined reduced tillage and soil cover, 14.7% had combined soil cover and crop rotation, 12.3% had combined reduced tillage and crop rotation while 10.7% had combined and implemented all the three CA practices on their farm as climate change mitigation strategies. The mean age of the farmers was found to be 53 years indicating that they are sti11 active and productive. We a1so found that the average years of farming experience, size of farm 1and for maize production and years of forma1 education was 18 years, 6.7ha and 8years respective1y. About 63% of the farmers be1onged to farmers association, whi1e on1y 48% of the farmers had contact with extension agents in the time past. Furthermore, about 47% of the farmers had gained financia1 support through a re1iab1e credit access which might have contributed to them adopting the CA practices.

The combinations represent the possible package adoption of CA

Table 1
Specification of CA practices combinations that form the packages.

CA choice (j)	Combinations	RT = Reduced Tillage		Soil Cover Maintenance		Crop rotation		Sample observation	%
		RT_0	**RT_1**	**SC_0**	**SC_1**	**CR_0**	**CR_1**		
1	RT_0 SC_0 CR_0	✓		✓		✓		33	11
2	$RT_1SC_0CR_0$		✓	✓		✓		36	12
3	$RT_0SC_1CR_0$	✓			✓	✓		41	13.7
4	$RT_0SC_0CR_1$	✓		✓			✓	43	14.3
5	$RT_1SC_1CR_0$		✓		✓	✓		34	11.3
6	$RT_1SC_0CR_1$		✓	✓			✓	37	12.3
7	$RT_0SC_1CR_1$	✓			✓		✓	44	14.7
8	$RT_1SC_1CR_1$		✓		✓		✓	32	10.7
TOTAL								300	100

Tab1e 2
Summary statistics and definition of variab1es used in the mode1.

Variab1e	Description of variab1es	Mean	S.D	Max	Min
Dependent variab1es					
Maize yie1d	Log of maize yie1d (kg)	8.382	.074	8.618	8.152
Exp1anatory variab1es					
Age	Age of HH head (years)	53.371	8.312	34	68
Gender	1 if HH head is ma1e, 0 if fema1e	.677	.381	1	0
Househo1d size	Number in HH	5.236	1.573	10	2
Marita1 status	1 if HH head is married, 0 if otherwise	0.792	.429	1	0
Farming experience	Number of years into maize farming	18.492	6.384	31	12
Farm size	Size of farm1and into maize farming (ha)	6.711	3.217	8	1
Year of forma1 education	Years of education of househo1d head	8.562	4.319	16	0
Membership of association	1 if HH be1ongs to an association	.637	.472	1	0
Access to extension contacts	1 if HH has access to extension, 0 if otherwise	.484	.41	1	0
1n_1abour	1og of hired and fami1y 1abour in man-days	68.572	27.382	129	48
1n_fertilizer	1og of quantity of ferti1iser app1ied per ha in 1itres	6.316	.33	7.103	5.228
Access to credit	1 if HH has access to credit, 0 if otherwise	.473	.412	1	0

practices. Each element is a binary variable of their combination: Subscript 1 = adoption and 0 = otherwise. Source: Field survey, 2021.

9. Factors influencing the implementation of conservation agricultural practices

Presented in Table 3 is the regression result of the multinomial logit model of factors influencing the implementation of conservation agricultural practices among the farmers as climate change mitigation strategies. The non-adopters of conservation agricultural practices (RT_0 SC_0 CR_0) was the base category in the multinomial logit model. The marginal effects were generated through STATA 14 for the multinomial logit model and were presented in Table 3. The marginal effects refer to the change in the forecasted probabilities that accompanied a unit change in the explanatory variables. The sign and magnitude of the marginal effect indicates the direction of covariates effect and probability effect on outcome variables respectively [42,43]. The Wald test ((χ^2 (54) = 76.26; p = 0.000) that all regression co-efficients are jointly equal to zero was rejected. The parameter estimates of the marginal effects vary across the alternative bundles of CA practices.

10. Age

The coefficients of the age of the farmers was positive and statistically significant with alternatives of reduced tillage, maintenance of soil cover and crop rotation packages indicating that the probability of adopting and implementing reduced tillage only ($RT_1SC_0CR_0$), maintenance of soil cover only ($RT_0SC_1CR_0$), reduced tillage and crop rotation ($RT_1SC_0CR_1$), maintenance of soil cover and crop rotation ($RT_0SC_1CR_1$), reduced tillage, maintenance of soil cover and crop rotation ($RT_1SC_1CR_1$) as climate change mitigation strategies increases as farmers get older. This might be unconnected with the fact that as farmers get older, they accumulate experience over time which helps them to try new technologies based on past experiences. As they advance in age, their level of aversion to taking risk increases mostly due to their past accumulated experiences thus suggesting that older farmers may not be averse to new farming practices and accept risk associated with adoption of new technologies. This result agrees with those of [44–46] that older farmers are more likely to adopt conservation agricultural farming systems.

11. Gender

The estimates of the marginal effect indicate a positive and statistically significance association between gender and alternatives of conservation agriculture packages. Thus, the likelihood of adopting and implementing reduced tillage only ($RT_1SC_0CR_0$), maintenance of soil cover only ($RT_0SC_1CR_0$), reduced tillage and crop rotation ($RT_1SC_0CR_1$), maintenance of soil cover and crop rotation ($RT_0SC_1CR_1$), reduced tillage, maintenance of soil cover and crop rotation ($RT_1SC_1CR_1$) as climate change mitigation strategies increases with male farmers. In Nigeria, access to agricultural inputs such as land is mostly common among the male farmers. Practice of conservation agriculture requires considerable land size which might only be available to male farmers, hence the probability that male farmers are more likely to implement conservation agriculture since they have access to land. This result agree with that of [47,48] that majority of the implementers of conservation agriculture are men.

12. Farming experience

The parameter estimates of the marginal effect shows a statistically significant and positive relationship with alternatives of conservation agriculture packages. That is, a year increase in farming experience increases the likelihood of adopting and implementing reduced tillage only ($RT_1SC_0CR_0$), maintenance of soil cover only ($RT_0SC_1CR_0$), crop rotation only ($RT_0SC_0CR_1$), reduced tillage and soil cover ($RT_1SC_1CR_0$), soil cover and crop rotation ($RT_0SC_1CR_1$), and reduced tillage, maintenance of soil cover and crop rotation ($RT_1SC_1CR_1$) as climate change mitigation strategies. This result revealed the significance of accumulation of years of experience in farming activities as it helps farmers to make decisive decisions in mitigating the impact of climate change through the implementation of alternatives conservation agricultural

Table 3
Factors influencing the implementation of CA practices.

Variables	$RT_1SC_0CR_0$		$RT_0SC_1CR_0$		$RT_0SC_0CR_1$		$RT_1SC_1CR_0$		$RT_1SC_0CR_1$		$RT_0SC_1CR_1$		$RT_1SC_1CR_1$	
	ME	Sd.Er	ME	Sd.Er	ME	Sd.Er	ME	Sd.Er	ME	Sd.Er	ME	Sd.Er	ME	Sd.Er
Age	0.2987***	0.0906	0.1894***	0.0684	0.2647	0.2099	0.0025	0.1729	0.6904***	0.2560	4.7080***	0.4333	0.3218***	0.1018
Gender	0.4705***	0.1089	0.2385***	0.0809	0.5714	0.7580	−1.8995	0.9862	0.6205***	0.0863	0.4489***	0.1561	−1.2451***	0.4518
Househo1d size	0.0005	0.0004	−0.0002	0.0004	−0.0004	0.0005	−0.0004	0.0006	0.0026	0.0019	0.0001	0.0005	−0.0009	0.0008
Marita1 status	0.0001	0.0005	−0.0011	0.0015	−0.0009	0.0007	0.0028	0.0037	0.0004	0.0006	0.0001	0.0004	−0.0005	0.0006
Farming experience	0.0029*	0.0017	0.0016***	0.0005	0.0018***	0.0006	0.0019***	0.0006	0.0007	0.0009	0.0007*	0.0004	0.0028*	0.0017
Farm size	0.0085*	0.0050	0.00013***	0.0004	0.0002**	0.0001	0.0001	0.0002	0.0004	0.0006	0.0002	0.0002	0.0035*	0.0021
Year of forma1 education	0.0004	0.0006	0.0001	0.0006	0.0007	0.0009	0.0007*	0.0004	0.0036**	0.0018	0.0030*	0.0018	0.0085*	0.0050
Membership of association	0.0018***	0.0005	0.0016*	0.0009	0.0024***	0.0007	0.0001	0.0001	0.0006	0.0005	0.0004	0.0005	0.0012***	0.0004
Access to extension contacts	0.0114	0.0203	0.0351	0.0243	0.0250	0.0238	0.0124	0.0184	−0.0264	0.0266	0.2286***	0.0503	0.3204***	0.1028
Access to credit	0.0065	0.0083	0.0080	0.0341	0.0533	0.0721	0.0144	0.0554	0.0124	0.0184	−0.0264	0.0266	0.0018	0.0312
Annual rainfall	0.0250	0.0238	0.0144	0.0224	−0.0264	0.0266	0.0249	0.0448	0.0351	0.0243	0.0114	0.0203	0.0124	0.0184
Temperature	0.0001	0.0005	−0.0001	0.0001	0.0007	0.0005	0.0011	0.0046	−0.0002	0.0011	0.0002	0.0031	0.0062	0.0420
Wald test ($X^2(54)$)	76.26													
P	0.000													

$RT_0SC_0CR_0$ is the base category. ME and SE represents marginal effects and robust standard errors respectively. ***,**,* represents significant level at 1%, 5% and 10% respectively.

farming. This is in agreement with [44,49] who all reported a positive and statistically significant relationship between years in farming experience and conservation agriculture implementation.

13. Farm size

The coefficient of the marginal effect showed a positive and statistically significant relationship between farm size and alternatives of conservation agricultural packages. That is, an increase in farm size by one ha increases the likelihood of adopting and implementing reduced tillage only ($RT_1SC_0CR_0$), maintenance of soil cover only ($RT_0SC_1CR_0$), crop rotation only ($RT_0SC_0CR_1$), and reduced tillage, maintenance of soil cover and crop rotation ($RT_1SC_1CR_1$) as climate change mitigation strategies. Adoption of conservation agricultural practices requires extra land area for implementation and only farmers who have relatively large farm size are more likely to implement the different conservation agricultural practices, hence, as farm size increases, implementation of conservation agricultural practices also increase. It could also reflect the fact that larger farm holdings give farmers leverage to experiment with conservation agricultural practices on some parts of their land, while maintaining the low-risk, low-return conventional methods on the rest of their land. This result corroborates the results of [50,51] that optimum farm size is required for implementation of conservation agricultural practices.

14. Education

The estimates of the marginal effect showed a positive and statistically significant relationship between years of formal education and adoption of alternatives of conservation agricultural packages. An increase in the years of education increases the likelihood of adopting and implementing of reduced tillage and soil cover ($RT_1SC_1CR_0$), reduced tillage and crop rotation ($RT_1SC_0CR_1$), soil cover and crop rotation ($RT_0SC_1CR_1$), and reduced tillage, maintenance of soil cover and crop rotation ($RT_1SC_1CR_1$) as climate change mitigation strategies. Education informs of training, acquisition of skills and sensitization programs are all forms of education have encouraged farmers to adopt new technologies that will help them increase productivity. Education help farmers to develop skills that improve their technical know how about new technology such as conservation agricultural practices that help them mitigate the impact of climate change. This notion agrees with [42,43] that education increase the change of new technology adoption among farmers.

15. Membership in association

Our result found a positive and statistically significant relationship between membership in farmers association and adoption of alternatives of conservation agricultural packages. That is, being a member of farmers organization could increase the likelihood of adoption and implementation of reduced tillage only ($RT_1SC_0CR_0$), maintenance of soil cover only ($RT_0SC_1CR_0$), crop rotation only ($RT_0SC_0CR_1$), and reduced tillage, maintenance of soil cover and crop rotation ($RT_1SC_1CR_1$) as climate change mitigation strategies. It has been found that social networks inform of association encourage the dissemination of information among farmers as farmers tends to trust their fellow farmers who have tried and adopts a new technology. Farmers always perceive new technology to be riskier, thus, if the new technology is introduced to them by another farmer especially those that they belong to same association, it will facilitate the speedy adoption and implementation of the technology. Similar result was observed by Baiyegunhi et al. [52] and Ghimire and Huang [53].

16. Access to extension services

The result of the estimate of the marginal effect showed a statistically significant and positive relationship between access to extension services and adoption of alternatives of conservation agricultural packages. An increase in the number of times a farmers has access to extension services increases the probability of adoption and implementation of soil cover and crop rotation ($RT_0SC_1CR_1$) and reduced tillage, maintenance of soil cover and crop rotation ($RT_1SC_1CR_1$) as climate change mitigation strategies. Access to up to date information is an important aspect of technology adoption process. Farmers who have access to timely information are more likely to adopt new technology because they would be informed of the availability of the technology and even have access to on-farm trials thus increasing the likelihood of adopting the technology. This result agrees with that of Baiyegunhi et al. [52,54].

17. Average treatment effects (ATT) of conservation agricultural practices

The MESR average treatment effects (ATT) of the alternative package of conservation agricultural practices adoption and implementation were quantifies under this section. We computed the ATT by comparing the outcome variables of the adopting households with same outcome variables had they not adopt. Rosenbaum [55] ascertained that the measure of treatment effect is a better approach to estimating usefulness of innovation to among farming households. We presented in Table 4, the result of the MESR-ATT of adopting alternative package of conservation agricultural practices.

18. Effect on crop productivity (yield)

The result from this study on crop productivity showed that farmers obtained significant yield in kg/ha from implementation of alternative package of conservation agricultural practices. The estimated result of the ATT presented in Table 4 indicated that farmers who implemented alternative package of conservation agricultural practices who have obtained lower yield on average had they not implemented conservation agricultural practices. It was found that farmers who implemented the combination of reduced tillage and maintenance of soil cover ($RT_1SC_1CR_0$) had the highest yield gain of 1246 kg/ha closely followed by the combination of maintenance of soil cover and crop rotation ($RT_0SC_1CR_1$) with a yield gain of 1245 kg/ha. This implies that the implementation of the combination of alternative package of reduced tillage and maintenance of soil cover ($RT_1SC_1CR_0$) to mitigate the impact of climate change brings about significant increase in crop yields. This results agrees with [44–46] that conservation agriculture increase farm productivity.

Table 4
ATT effects of the conservation agricultural practices on smallholder farmers productivity.

Outcome variables	Technology choice (j)	Adoption status		ATT
		Adoption	**Non-adoption**	
		j=(2,3,4,5,6,7,8)	**j=(1)**	
		(1)	**(2)**	**(3)=(1)-(2)**
Crop yields (kg/ha)	$RT_1SC_0CR_0$	8995(58)	7904(25)	1091***
	$RT_0SC_1CR_0$	11345(47)	10287(46)	1058**
	$RT_0SC_0CR_1$	6189(43)	5615(37)	574*
	$RT_1SC_1CR_0$	7132(74)	5886(42)	1246
	$RT_1SC_0CR_1$	8361(39)	7116(17)	1245**
	$RT_0SC_1CR_1$	9102(28)	8207(33)	895**
	$RT_1SC_1CR_1$	8564(26)	7352(56)	1239***
Net farm income (N′ 000/ha)	$RT_1SC_0CR_0$	7472(47)	6452(36)	1020**
	$RT_0SC_1CR_0$	3618(58)	2590(23)	1028***
	$RT_0SC_0CR_1$	2638(18)	1946(37)	692*
	$RT_1SC_1CR_0$	4910(37)	3554(29)	1356**
	$RT_1SC_0CR_1$	4184(36)	2912(19)	1272***
	$RT_0SC_1CR_1$	5728(15)	4913(35)	815**
	$RT_1SC_1CR_1$	4510(35)	3579(25)	931***

***,**,* represents significant at 1%, 5% and 10% respectively. Figures in parenthesis are standard error.

19. Effect on net farm income

We presented the unconditional average treatment effects of implementation of alternative package of conservation agricultural practices on the income of farmers in Table 4. It was found that adopters of alternative package of conservation agricultural practices received more income than non-adopters. We note that increased yields from the implementation of alternative package of conservation agricultural practices translated to increased income of the farmers. The results of the ATT showed that the income effect of N1,356/ha for the adoption and implementation of reduced tillage and maintenance of soil cover ($RT_1SC_1CR_0$) followed by N1,272/ha for the adoption and implementation of maintenance of soil cover and crop rotation ($RT_0SC_1CR_1$). The lowest income effects of N692 N/ha was recorded for the adoption of crop rotation ($RT_0SC_0CR_1$) only. This result corroborates the results of [50,51] that adoption of conservation agricultural practices significantly improves farm incomes.

20. Conclusion and policy recommendations

In this study, we assessed the factors that influencing the implementation of alternative package of conservation agricultural practices to mitigate climate change impact while boosting farm productivity (yield and net farm income) of the famers in Nigeria. The results of the multinomial logit model showed that adoption and implementation of alternative package of conservation agricultural practices is influenced by age, gender, farming experience, farm size, formal education, access to extension services and membership in association. Findings from the study also showed that the MESR-ATT results revealed that alternative package of conservation agricultural practices increases farmers' productivity in terms of yields and net farm income. Based on the findings of the study, it is important that efforts to mitigate the negative impact of climate change through adoption and implementation of alternative package of conservation agricultural practices should focus on improving the significant variables of interest affecting its adoption. For example, there is a need to improve the provision of extension services to the farmers through recruitment of qualified extension agents while also training them to equip them with necessary skills. Farmers are also encouraged to join farmers organization for them to enjoy group dynamism and have access to farm inputs including new technology that would help them improve their farm productivity.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jafr.2023.100557.

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