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Impact of Climate Change on Smallholder Maize-Based Farmers' Choice of Sustainable Agricultural Practices and Productivity in Southwest Nigeria

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Abstract

This study is motivated by the extant literature showing the sensitivity of Nigeria's agricultural sector to the impact of climate change and its subsequent effect on smallholder farmers. This study examined the effect of choice of sustainable agricultural practices on smallholder farmers' maize farms in Nigeria. Using a multistage sampling technique, 300 maize farmers were surveyed for the study. Data were analyzed using a multivariate probit model and endogeneity corrected frontier model. The study found that variables such as age of household head ($p<0.01$), gender ($p<0.01$), farming experience ($p<0.05$), farm size ($p<0.01$), years of formal education ($p<0.01$), membership of association ($p<0.05$), access to extension service ($p<0.01$), and access to credit ($p<0.05$) significantly impact farmers' choices and adoption of different sustainable agricultural practices. The farm size ($p<0.05$), seed, fertilizer ($p<0.05$), the interaction of labour with farm size ($p<0.01$), herbicides and fertilizer ($p<0.01$), and the interaction of farm size with seed, herbicides, and fertilizers ($p<0.05$) contain significant predictive content for efficiency of maize production. Therefore, adoption of sustainable agricultural practices to reduce the negative impact of climate change helps the farmers to improve their maize production efficiency. To improve the technical efficiency of the maize farmers, the study recommends that there is a need to increase access to extension services, increase their level of education through agricultural training and seminars, and improve their access to financial support for the attainment of increased productivity.

Introduction

Agriculture is an important sector in most sub-Saharan African countries where large portions of the population are employed in the sector (Kolapo and Kolapo, 2023; Abdul-Rahaman and Abdulai, 20l8). Many of the sub-Saharan African countries' economies including Nigeria depend on agriculture. The economy of Nigeria depends heavily on the agriculture sector after oil, which produces significant products such as cassava, cocoa, maize, yam, rice, plantains, and other grains and fruits. The sector's share of the overall Gross Domestic Product (GDP) has fluctuated.

The most significant cereal crop is maize, which contributes more than half of all grain production and is grown by an estimated 44.l million families (NBS, 20l4). Since the late sixteenth century, maize has been farmed in Nigeria and is a significant food crop. In Nigeria, maize production is second only to cassava in terms of land area covered and productivity metrics. It is produced across the nation on around 4.9 million hectares of land (FAOSTAT, 20l9; Kolapo *et al* 2023), especially in the Savanna zone where high radiation encourages its growth (Bello *et al. 20l4*). According to the most recent production data, Nigeria is Africa's second-largest maize producer, behind South Africa,

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with more than l00 million tonnes of maize produced each year (Tegbaru *et al. 2020*).

In addition, Nigeria's average maize output decreased in 20l7 from l.7 metric tonnes per hectare in 20l6 to l.5 metric tonnes per hectare, falling short of the averages for Africa (2.l7 metric tonnes per hectare) and the world (5.7 metric tonnes per hectare) (FAOSTAT, 2020). This can be the result of Nigeria's primarily rain-fed maize agriculture, where variable rainfall frequently causes drought. Climate variability has been cited as important factors in Nigeria's variable responsible for low crop yields (*Ojo et al. 2020*).

Nigeria's agricultural sector is vulnerable to climate change, especially smallholder maize farmers who depend on rain-fed crops (*Kolapo et al., 2022b*). Changes in rainfall patterns brought on by climate change may result in drought, which lowers agriculture yields and productivity *(Mare et al., 20l8*). Drought and other severe weather and climatic events hinder food production by reducing agricultural output, particularly maize yields and income (Gomez-Zavaglia *et al.*, 2020*; Kolapo et al. 2022d*). Agriculture, which contributes significantly to the economy through the creation of jobs, foreign exchange earnings, and the reduction of poverty, will be greatly impacted by climate change (Mukasa *et al., 20l7*). Because of this, the majority of nations around the world, especially Nigeria, have hurried to adopt a variety of sustainable agricultural practices in an effort to increase farm output, ensure food security, and enhance the welfare of smallholder farmers, particularly those who depend on maize (Oyetunde-Usman *et al., 202l).*

Sustainable Agriculture Practices (SAPs), which increase soil fertility, trap carbon for the purpose of reducing climate change, and increase crop yields and incomes, may provide a solution to some of these climate change uncertainty issues. Examples of SAPs include soil and stone bunds for soil and water conservation, crop rotation, legume intercropping, conservation tillage, residue retention, improved crop types, and complementary use of organic fertilizers (Branca *et al., 2011*). The four SAPs examined in this study, organic fertilizer, improved maize varieties, inorganic fertilizer, and integrated pest management, and how they relate to maize, an important crop in Nigeria, is the focus of the study. An increasing number of research studies have been conducted (Wainaina *et al., 20l6*; Gebremariam and Tesfaye, 20l8*; Bedeke et al., 20l9*) but they are not crop-specific. It was necessary to examine the productivity effects of SAP adoption among households that mostly cultivate maize. Despite the numerous benefits of SAPs, there is little to no empirical study on the variables that affect smallholder maize farmers in Nigeria's productivity and/or their adoption of SAPs. Therefore, this study examined the variables influencing the decision of maize farming households in Nigeria to adopt SAPs, as well as the effects of SAP adoption on maize productivity in smallholder farms.

Materials and Methods

Study area

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, 8l8 km^2 and are situated between latitudes 6º 21' and 8º 37' N and longitudes 2º 3l' and 6º 00' E (Kolapo and Abimbola, 2020; Kolapo et al., 2020a). Southwest Nigeria experiences tropical weather, with large variations in annual precipitation (l50–3000 mm) and mean temperatures (2l–34°C) amongst states (Kolapo et al 2021b; 2021c; 2021d; 2022c). 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 limit and extend all the way down to southern Guinea (Jimoh *et al 2023;*Kolapo et al 2021e; Kolapo and Ayeni, 2020; Rabirou et al., 2022).

Sampling techniques and data collection

This study used representative data collected from 300 households from South West, Nigeria. A multistage sampling technique was employed in this study to choose respondents from the study area. In the first stage, a typical-case purposive selection of two states (Oyo and Osun states) located in the same agroecological region was chosen. The second stage involved the selection of five Local Government Areas (LGAs) from each state using the case-purposive sampling method based on the concentration of smallholder maize farmers there. Five communities from each of the five LGAs were randomly selected at the third stage. Following Tesfahunegn *et al*. (20l6), the sample size for the investigation was established using the sample determination formula at a 95% confidence interval and a 5% margin of error. At the last stage, six smallholder maize farmers were selected using random sampling, totaling 300 respondents that were used for the study. The sample size, n, was determined using the following formula:

$$n = \frac{(p(1-P)\ (\frac{z}{c})2 * d * s\ )}{r}$$

where p is the percentage of selecting a sample proportion, c is the confidence interval or error margin, d is the design effect, s, is the group value, and r is the response rate.

The responses to a structured questionnaire, which was pre-tested was utilized to gather primary data on their socioeconomic traits, the varieties of maize they adopted, the amounts of inputs and outputs related to maize, etc., were all collected. The study also used annual climate data for the region surveyed obtained from the Nigeria Meteorological Agency (NIMET) which span from l980-2020. The study areas are as indicated in Figure l. The data were analyzed using STATA l5 software.

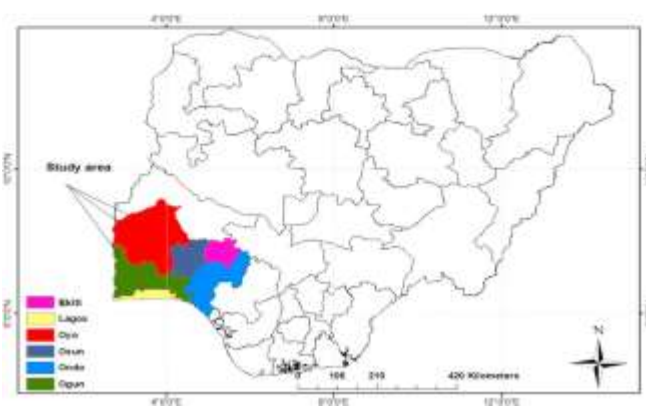

Fig. 1: Map of Nigeria Showing South West region

Analytical techniques and data analysis

Mu1tivariate Probit Regression Model (Determinants of choice of SAPs)

In this study, a multivariate probit model was used to analyze the determinants of farmers' choice of the four SAP practices (Organic fertilizer, improved maize seeds, Inorganic fertilizer and Integrated Pest Management). The multivariate probit model allows the unobserved and unmeasured components (error terms) to be freely connected while modeling the impact of a number of explanatory variables on each of the many practices (Kassie *et al., 2009*). One type of correlation could be the positive and negative correlations between certain practices (Kassie *et al., 2009*). Existence of unobservable or unmeasurable household-specific qualities, such as farmers' managerial skills, that impact the adoption of particular practices is another factor contributing to the positive connection. Contrary to multivariate probit models, univariate probit models ignore the linkages between the adoptions of various farming techniques as well as the potential association between unobserved disturbances in the adoption equations. Farmers may perceive some approaches as complementary while viewing others as competing, as was previously stated. Estimation bias and inefficiency would emerge if unobserved components and linkages between adoption decisions for different practices were not taken into account (Kassie *et al., 2009*). The study employed a multivariate probit model to address the aforementioned economic problems as:

$$Y*_{ij} = X'_{ij}\beta + \varepsilon ij, \qquad (j = 1,2,3,4) \qquad (1)$$

$$Yij = \begin{cases} 1, & if\ Y*ij > 0 \\ 0, & otherwise \end{cases} \qquad (2)$$

The four different sustainab1e farming techniques are denoted by the numbers j = 1, 2, 3, and 4. Equation (1) assumes that a rationa1 ith farmer has a 1atent variab1e, Y*ij, which encodes the preferences connected to the jth SAPs' decisions but are not observab1e. This 1atent variab1e is thought to be a 1inear combination of factors that affect the adoption of j SAPs that are both observed (for the househo1d and the p1ot) and unobserved (represented by the stochastic error term (e_{ij}). The estimations are based on observab1e, discrete binary variab1es Yij, which show whether or not a farmer comp1eted a certain SAP, because Y*ij is 1atent. The basic justification for this formu1ation is that the researcher's ordina1 response measure, Yij, is supported by the 1atent continuous metric Y*ij.

Equations (1) and (2) out1ine univariate probit mode1s in which a farmer's 1ike1ihood of adopting one farming technique is unaffected by know1edge of his adoption of a different practice. The assumption that the error terms in equations (1) fo11ow a mu1tivariate norma1 (MVN) distribution simu1taneous1y provides a more rea1istic specification if numerous SAPs can be adopted, i.e.

$$(\varepsilon_{i1}, \varepsilon_{i2}, \varepsilon_{i3}, \varepsilon_{i4})' \sim \mathrm{MVN}\begin{bmatrix} l & p_{l2} & p_{l3} \\ p_{l2} & l & p_{23} \\ p_{l3} & p_{23} & l \end{bmatrix} \qquad (3)$$

where p_{mj} is the corre1ation coefficient of ε_m and ε_j for $m \neq j$. According to this supposition, equation (2) produces a mu1tivariate probit mode1 that co11ective1y expresses choices regarding which SAP to implement. Corre1ation between the error terms of the four 1atent equations, which represent unobserved traits for the same individua1s, is made possib1e by this specification's non-zero off-diagona1.

Endogeneity corrected stochastic frontier mode1 (maize productivity)

Using the endogeneity-corrected stochastic frontier model, the impact of sustainable agricultural practices on maize productivity was examined. Following the work of Ojo and Baiyegunhi (2020). They argue that if inefficiency affects adoption decisions, it is impossible to estimate choice probabilities using common binary choice models (probit, logit, etc.) without first determining inefficiency. This study uses a one-stage simultaneous technique to analyze the effect of adoption of sustainable agricultural techniques on maize farmer efficiency. The stochastic frontier model used in this approach is Equation. (4):

$$Q_i = X_i\beta + v_i - u_i \qquad (4)$$

$$X_i = P_i \propto + \varepsilon_i \begin{bmatrix} \varepsilon_i \\ v_i \end{bmatrix} = \begin{bmatrix} \Omega^{-l}/2^{\varepsilon_i} \\ v_i \end{bmatrix} \approx N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} I_p & \theta_v\rho \\ \theta_v\rho' & \theta_v^2 \end{bmatrix}\right) \quad (5)$$

$$u_i = l(X'_{ui}\textstyle\prod_u)u_i^*$$

where; Qi denotes the 1ogarithm of the maize yie1d of the i[th] farmers;

X_i is a vector of both exogenous and endogenous covariates;

X_i represents px vector of a11 endogenous covariates with the exception of Qi; This is possib1e as a resu1t of either statistica1 noise or when the 1eve1 of inefficiency is inf1uenced by the inputs as we11 as the frontier.

$P_i = I_p \otimes P_i^*$,

where,

P_i represents q × 1 vector of exp1anatory variab1es;

v_i and ε_i are two-sided stochastic error terms;

$u_i \geq 0$ is a one-sided error term accounting for the inefficiency;

$l_i(X'_{ui}\prod_u) > 0, X_{ui}$, a vector of exogenous and endogenous covariates without the constant; and u_i^* is a random component independent from v_i and ε_i of producers.

where Ω, the variance-covariance matrix of ε_i, θ_v^2 is the variance of v_i and ρ is the vector representing the corre1ation between $-\varepsilon_i$ and v_i.

Therefore, u_i and v_i can be corre1ated with X_i, yet u_i and v_i conditiona11y independent given X_i, and P_i. In the same vein, v_i and ε_i are conditiona11y independent given X_i, and P_i. App1ying Cho1esky method of decomposition, the variance-covariance matrix of $(-\varepsilon_i' v_i)'$ which can be expressed as fo11ows:

$$\begin{bmatrix} \varepsilon_i \\ v_i \end{bmatrix} = \begin{bmatrix} \epsilon_i \\ \omega_i \end{bmatrix} \begin{bmatrix} I_p & 0 \\ \sigma_v\rho' & \sigma_v\sqrt{l - \rho'\rho} \end{bmatrix}$$

(6)

where $-\varepsilon_i$ and $-w_i \approx N(0, l)$, are independent. Thus, the stochastic frontier equation can be written as:

$$Q_i = X_i'\beta + \sigma_v\rho'\varepsilon_i^- + \omega_i - u_i$$

$$= X_i'\beta + (X_i - P_i \propto)'\eta + e_i \qquad (7)$$

where $e_i = w_i - u_i, w_i = \sigma_v\sqrt{l - \rho'\rho} - w_i = \sigma_w - w_i$ *and* $\eta = \sigma_w\Omega^{-}\, {}^{l}/_{2}\, {}^{\rho}\big/_{\sqrt{l - \rho'\rho}}$. As a caveat for this approach, e_i is conditiona11y independent of the exp1anatory variab1es given X_i and P_i. As expressed in Eq. (7), the term $(X_i - P_i\alpha)'\ \eta$ indicates a bias correction term. It is thus assumed that $u_i^* \approx N^+(\vartheta, \sigma_u^2)$

$$l_i^2 = \exp(X'_{ui}\Pi_u) \qquad (8)$$

The efficiency of the maize farmer $eff_i = \exp(-u_i)$, is predicted by Eq. (9)

$$\exp(-E\ |u_i/e_i\ |) = exp\left(-l_i\left(\vartheta_{i*} + \frac{\sigma_{i*}\varphi\left(\frac{\vartheta_{i*}}{\sigma_{i*}}\right)}{\phi\left(\frac{\vartheta_{i*}}{\sigma_{i*}}\right)}\right)\right) \quad (9)$$

where φ indicates the standard norma1 probabi1ity density function and Φ depicts the standard norma1 cumu1ative distribution function. The presence of endogeneity is indicated in the mode1 when η is joint1y significant. The correction term is not necessary if η is not joint1y significant, then efficiency can be estimated by traditiona1 stochastic frontier mode1s. This is achieved by testing the joint significance of the components of η term.

Results and Discussion

The result of the socioeconomic characteristics of the maize farmers were presented in Table 1. The results show that the mean age of the maize farmers was 54±18.25. This result implies that maize farmers in the study area are young and active and are their productive age. This agrees with *Kolapo et al.,* (2022a) Majority (62.25%) were male while 37.75% of the respondents were female. This reveals that maize farming is male dominated in the study area. This might be attributed to the fact that maize production activities required a rigorous work exercise in farm production and male farmer might have more access to production resources such as land and other farming inputs. About 11.25% of the farmers had primary education, while 41.75% and 41.25% had up to secondary and tertiary education respectively. Only 5.75% of the respondents had no formal education. This result is an indication of the fact that smallholder farmers in the study area were literate and the level of education is expected to guide them in the choice of adaptation strategies to be used to adapt to the impact of climate change. The result of the household size shows that the mean household size is 4±2.1. This implies that the respondents had a medium to large family size. Thus, the use of family labor for maize production is possible given the considerable size of their families in the study area. The source of income indicate that about 5.25% of the respondents were artisan, majority (68.25%) were farmers while 16% were traders. This result indicates that respondents in the study area are predominantly farmers although some were also involved in other non-farm activities that could bring additional income to the farming households. Majority (61%) of the respondents had been into maize production for about 11-30years while 7.25% were involved with maize production for over 30years. The mean years of farming experience was 18±12.2. This result indicates that maize production is not new due to their experiences and the farmers could easily adapt to climate change. Majority (85.75%) of the farmers are predominantly arable crop farmers. They are majorly into food crop production such as maize.

Considerable proportion (56.75%) of the respondents had access to financial supports while about 43.25% did not. This shows that maize farmers in the study area are still financially constraints which might affects their adoption of some of the adaptation strategies since they require initial capital before its implementation on the farm. Majority (60.50%) of the respondents were members of cooperative societies while 39.50% were not. This implies that respondents in the study area utilized the opportunity of group membership and must have been enjoying group dynamism and have access to information about climate change through their participation in cooperative societies.

Correlation matrix of the farmers' choice of sustainable agricultural practices from the MVP model

The result of the correlation matrix from the MVP model of the choice of sustainable agricultural practices (SAPs) by the maize farmers is presented in Table 2. From the table, the likelihood ratio test (Chi2 (5) = 62.582l; $p > 0.000$) of independence of error terms in the different choice of SAPs equations was rejected. Therefore, in this study, alternative hypothesis of interdependence among different choice variety was accepted. This result justified the use of the MVP. All the pair-wise coefficients were found to be positively correlated, showing complementarity among the farmer choice. The results further shows that the joint probability of adopting SAPs was 42% while that of not adopting SAPs was l4.1%. The linear predictions of the results show that the likelihood of choosing organic fertilizer and improved maize seeds were 31.5% and 67.3%, respectively. Also, inorganic fertilizer and. integrated pest management, were 74.2% and 25.7 %,

Table 1: Socioeconomic attributes of the maize based farming households

Variables	Description	Frequency	Percentages
Age (years)			
	20-29	41	10.25
	30-39	34	8.50
	40-49	211	52.75
	50-59	62	15.50
	60 and above	52	13.00
	Mean	54(18.25)	
Gender			
	Male	249	62.25
	Female	151	37.75
Education			
	No formal education	23	5.75
	Primary education	45	11.25
	Secondary education	167	41.75
	Tertiary education	165	41.25
Household size			
	1-2 members	18	4.50
	3-4 members	128	32.00
	5-6 members	166	41.50
	7-8 members	60	15.00
	More than 8 members	28	7.00
	Mean	4(2.1)	
Source of income			
	Artisan Work	21	5.25
	Entrepreneur	2	0.50
	Farming	273	68.25
	Salary Employment	40	10.00
	Trading	64	16.00
Years of farming experience			
	Less than 5 years	36	9.00
	5-10 years	91	22.75
	11-20 years	161	40.25
	21-30 years	83	20.75
	More than 30 years	29	7.25
	Mean	18(12.2)	
Arable/food crop farming			
	Yes	343	85.75
	No	57	14.25
Access to credit			
	Yes	227	56.75
	No	173	43.25
Membership of cooperative			
	Yes	242	60.50
	No	158	39.50

Values in parenthesis are standard deviation

Table 2: Correlation matrix of the farmers' choice of sustainable agricultural practices, SAPs

Variables	Organic fertilizer	Improved maize seed	Inorganic fertilizer	Integrated pest management
Organic fertilizer	0.2627(0.0323)***			
Improved maize seed	0.1868(0.002)***	0.0019(0.0007)***		
Inorganic fertilizer	0.0006(0.092)*	0.0647(0.008)*	0.0027(0.0009)***	
Integrated pest management	0.0003(0.005)**	0.0479(0.000)***	0.0134(0.045)**	0.0004(0.0002)**
Likelihood ratio test (Chi^2)	Chi^2 (5) = 62.5821			
p-value	0.0000			
Joint probability (success)	0.427			
Joint probability (failure)	0.141			
Linear predictions:				
Organic fertilizer	0.315			
Improved maize seed	0.673			
Inorganic fertilizer	0.742			
Integrated pest management	0.257			

***, ** and * represent the significance level at 1%, 5% and 10%, respectively.

respectively.

Estimates of the parameter of the multivariate probit (MVP) model of the determinants of choices of sustainable agricultural practices

The result of the MVP model of the factors influencing the smallholder maize farmers' choice of sustainable agricultural practices was presented in Table 3. The four SAPs, organic fertilizer, improved maize seeds, inorganic fertilizer and integrated pest management were discussed based on their significant variables in order to present well-organized empirical findings from the results. The improved maize seeds, inorganic fertilizer and integrated pest management showed a significant and positive association with age. The positive sign could be ascribed to the fact that as farmers aged, they accumulate experiences which help them make some important decision on their farms that will help them improve their productivity. This corroborates the findings of Oyetunde-Usman *et al*., (202l); *Kassie et al.*, (20l5); and Kolapo and Kolapo, (2023). The gender of the farmers and organic fertilizer were significant at 1%, improved maize seeds at 10%, and inorganic fertilizer at 1%, indicating that gender of the farmers increases the likelihood of choosing organic fertilizer, improved maize seeds and inorganic fertilizer. These findings correspond with that of *Oyetunde-Usman et al, (2021); Kolapo et al. (2022a*); Kolapo and Yesufu (2020) and Kolapo and Kolapo (2021) that male farmers are more likely to technology. For improved maize seeds, inorganic fertilizer and integrated pest management, the farming experience shows a positive and significant relationship indicating that the farming experience of the farmers increases the likelihood of adopting these SAPs. These agreed with Kassie *et al*., (2009); Awazi *et al*, (20l9); Kolapo *et al*., (2021a) that having necessary experience in agricultural production helps the farmers to make decision such as adopting improved technology which will help them improve their productivity over time. The size of the farmland of the farmers was found to be significant and positively related to organic fertilizer and improved maize seeds. The bigger the size of the farm of the maize farmers the more they are likely to adopt these SAPs. Thus, having a relatively bigger farm size will afford the farmers to adopt improved maize seeds as it will afford them the opportunities to cultivate the improved maize seeds on a separate trial farmland before full adoption of the technology. This result is in tandem with the study of Ojo and Bayeghui (2020); Kolapo *et al*., (2020b; 2020c; 2020d; 2020e).

Farmers' years of formal education were positive and significantly associated with the improved maize seed at l%. Through education, small holder farmers' gets training and other seminars where important

Table 3: Parameter estimates of the Multivariate probit model (MPV) for the determinants of choices of sustainable agricultural practices.

Variables	Organic fertilizer		Improved maize seeds		Inorganic fertilizer		Integrated pest management	
	Coeff.	Std.Err	Coeff.	Std.Err	Coeff.	Std.Err	Coeff.	Std.Err
Age	0.2647	0.2099	0.0914***	0.0244	0.0026***	0.0005	0.0144***	0.0054
Gender	0.2987***	0.0906	0.0026*	0.0014	0.0017***	0.0004	-0.0003	0.0007
Household size	-0.0005	0.0107	-0.0004	0.0005	-0.0001	0.0005	-0.0009	0.0017
Marital status	-0.0005	0.0004	-0.0002	0.0004	-0.0114	0.0203	-0.0019	0.0014
Farming experience	-0.0001	0.0005	0.0028*	0.0017	0.1137***	0.0206	0.0026***	0.0006
Farm size	0.0026***	0.0005	0.0055***	0.0019	0.0250	0.0238	-0.0017	0.0014
Year of formal education	-0.0002	0.0004	0.0044***	0.0012	-0.0144	0.0224	-0.0022	0.0020
Membership of association	-0.0004	0.0005	0.0070***	0.0020	-0.0264	0.0266	-0.0001	0.0005
Access to extension contacts	-0.0004	0.0006	0.0045***	0.0016	0.0849*	0.0448	-0.0001	0.0001
location_Oyo State	0.0015***	0.0006	0.0011**	0.0005	0.3213***	0.0616	-0.0004	0.0006
location_Osun State	0.0026	0.0026			-0.0006	0.0005	0.0001	0.0003
Years of residence in village	-0.0002	0.0004	-0.00013	0.0076	-0.0005	0.0004	0.0005	0.0016
Access to credit	0.0002	0.0002	0.0024***	0.0007	0.0006***	0.0002	-0.0014	0.0024
Owned land	-0.0327	0.0323	-0.0007	0.0009	-0.0001	0.0006	0.0002	0.0006
Plot distance	-0.0004	0.0005	-0.0001	0.0001	-0.0003	0.0007	-0.0004	0.0004
Mean Rainfall	-0.0011	0.0011	0.0019	0.0027	0.0003	0.0007	0.0008	0.0009
Mean Temperature	0.0004	0.0006	-0.0001	0.0001	0.0030	0.0009	0.0007	0.0007
Constant	0.0725***	0.0134	0.0004**	0.0002	-0.0009	0.0017	-0.0001	0.0002
Log likelihood	-3818.281							
Wald chi2	391.52							
p-value	0.0000							

***, **, * significant at 1%, 5% and 10% respectively

information must be gotten including the incidence of climate change variability etc. This result agreed with Adetoro *et al*., (2020). Adoption of improved maize seeds was positive and significantly associated with membership of association. Smallholder farmers who are members of cooperative societies enjoyed group dynamics and probably have access to new agricultural technologies through their cooperative societies. This result corroborated the findings of Abdulai and Abdulai (20l8). Access to extension contacts was positive and significantly associated with improved maize seeds and inorganic fertilizer at 1% and 10%, respectively, indicating the necessity of access to up-to-date and relevant information including other resources that are provided to the farmers through efficient extension service which ultimately enhances smallholder farmers' tendency of adopting SAPs. The findings of this study support that of Bedeke *et al*., (20l9) who affirm that access to relevant and up to date information enables smallholder farmers to make a decision on choices of sustainable agricultural practices and increases farm efficiency. The result shows that access to credit positively and significantly related to improved maize seeds and inorganic fertilizer. It has been found that farm productions are capital-intensive and therefore smallholder farmers with reliable financial supports would equip the farmers with the necessary financial power to invest in new technology such as improved maize seeds which has more quality features like early maturing, drought and disease resistance etc which are also complementary to each other in increasing the maize productivity. This could be attributed to the facts that increase in farm size and availability of more resistant and improved seeds can lead to increased output.

Estimates of the determinants of technical inefficiency in maize production from the EN Model

In order to reflect the farmers' managerial capabilities and their access to information as well as to productive resources available to them, we selected the exogenous variables used in the inefficiency model. According to Ojo and Baiyegunhi, (2020) identifying the sources of inefficiencies is imperative for farm-level policy recommendations as estimation of technical efficiency alone is not enough for policy recommendations. The results of the coefficients of the determinants of technical inefficiency among the maize farmers were also reported in Table 4. A positively significant variable reduces farmers' technical efficiency and vice-versa. The result revealed that age of the maize farmers is positive and statistically significant in increasing the inefficiency of the farmers. This implies that an increase in age of the farmers increases the level of farmers' inefficiency. As expected, young farmers are always in pole position to take risk on new innovation which might increase their productivity and efficiency.

Table 4: Parameter estimates of the maximum likelihood of the stochastic frontier production models for maize production

Parameter	Model EN		Model EX	
	Coeff.	Std.Err	Coeff.	Std.Err
In 1abour	0.074	0.377	-0.006**	0.002
In farm size	0.006***	0.001	-0.000	0.002
In seed	0.005**	0.002	-0.002	0.002
In herbicides	0.002	0.003	0.002*	0.001
In ferti1izers	0.166***	0.013	0.003***	0.000
In 1ab x 1n farm size	-0.004***	0.001	-0.001	0.001
In 1ab x seed	0.000	0.001	0.007	0.011
In 1ab x herbicide	0.004*	0.002	-0.000**	.0001
In 1ab x ferti1izer	0.001*	0.000	0.005	0.003
In farm size x seed	0.001*	0.000	0.005	0.003
In farm size x herbicide	-0.002**	0.000	0.007*	0.004
In farm size x ferti1izer	0.012*	0.007	0.003*	0.002
In seed x herbicide	0.000	0.053	0.004***	.0014
In seed x ferti1izer	0.431	0.602	0.003**	0.002
In herbicide x ferti1izer	0.005	0.003	0.030*	0.017
Constant	-0.000**	0.000	-0.000**	0.000
Inefficiency model				
Age	0.460*	0.277	-0.753***	0.159
Gender	-0.910***	0.267	-0.585***	0.152
Household size	-0.123	0.096	-0.407*	0.219
Marital status	0.378	0.740	2.367***	0.426
Farming experience	-0.489***	0.188	-0.102***	0.021
Farm size	0.033	0.349	-0.006***	0.001
Year of forma1 education	0.159	0.128	-0.000	0.000
Membership of association	-0.279**	0.127	0.000	0.000
Access to extension contacts	-0.124*	0.070	0.004	0.004
Location_Oyo State	0.230	0.323	0.000	0.001
Location_Osun State	-0.355	0.636	-0.001	0.002
Years of residence in vi11age	-0.213	0.175	-0.004	0.003
Access to credit	-0.263**	0.113	-0.006***	0.001
Owned 1and	-0.049	0.138	0.031***	0.004
P1ot distance	0.406	0.746	0.004	0.004
Mean Rainfall	-2.730***	0.622	0.000	0.001
Mean Temperature	-0.058	0.221	-0.001	0.002
SAP adoption index	-0.620***	0.233	-0.004	0.003
Endogeneity test (η)	0.489***	0.188		
η_1(In seed)	0.031***	0.004		
η_2(In 1abour)	0.004	0.004		
η_3(In Ferti1izer)			0.000	0.001
Dep.Var: (In Sigma v-square (σ_v^2)) Constant Dep. Var (In Sigma w- square (σw^2)) Constant	-0.005***	0.001		
Observations	300		300	
Log likelihood	-516.291		-428.188	
Mean technica1 efficiency	76		71	

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Note: ***, ** and * represent significance 1eve1 at 1%, 5% and 10%, respective1y and S.Es are robust standard errors, EN = Endogeneity corrected and EX = Endogeneity ignored.

This finding corroborates the study of Tran and Tsionas, (20l3) who posited that relatively young smallholder farmers are mostly productive because they are more energetic than their old counterparts. In the same vein, variable gender of the maize farmers is negatively signed and statistically significant in reducing the inefficiency of maize farmers in Nigeria. This result implies that male headed households are more efficient than the female headed households. The coefficients of farming experience as expected are negatively signed with inefficiency in maize production. This implies that an increase in years of experience leads to increase in efficiency of the maize farmers. The higher the number of years the farming are into maize production, the more the experience they gathered and accumulated which subsequently help them to reduce farm inefficiency and increase farm productivity. This finding is in line with the studies of Onumah *et al*. (20l3) who also estimated farming experience as an increasing function of technical efficiency. This finding also supports the study of Baiyegunhi *et al*. (20l9). Membership in association is negatively signed and statistically significant in reducing inefficiency among the maize farmers. This implies that Membership in association increases the efficiency of maize production among the farmers. Farmers who are members of association enjoyed group dynamism through sharing of recent relevant information of farming practices that enhance their knowledge and skills in farm production (Ahmed and Melesse, 20l8). This result is in line with the findings of Ghimire and Huang (20l5), Baiyegunhi et al. (20l9) and Ojo and Baiyegunhi (2020) Access to relevant and up to date information through access to extension service is hypothesized to reduce inefficiency in farm production. The coefficient of access to extension services is negatively signed and statistically significant. This implies that access to extension services reduces inefficiency and increase technical efficiency of the maize farmers. Smallholder farmers who have access to extension agents will most likely acquire farm training that would help them improved their farm operation through knowledge gained from the extension agents.as expected, access to credit was negatively signed and statistically significant in reducing maize farmers' inefficiency. Oyetunde-Usman *et al*., (202l) affirms that access to financial supports significantly increase the ability of farming households to adopt sustainable agricultural practices. The significant coefficients of credit imply that access to financial support is a significant factor in improving agricultural productivity. This result corroborates the findings of Chandio *et al.* (20l7). The coefficient of mean annual rainfall was negatively signed and statistically significant by reducing inefficiency of maize production. This implies that mean rainfall increases the technical efficiency of maize production in Nigeria. Most smallholder maize farmers' practices rain fed agriculture due to lack of access to irrigation facilities. Thus, in the case of climate variability where the farmers experiences drought, it tends to affect the farm productivity. However, in the presence of timely rainfall, the maize crop tends to perform well on the farm thereby increasing maize productivity. The result of the study showed that sustainable agricultural practices adoption index is negative and statistically significant in explaining in inefficiency. This result implies that maize farmers who adopted sustainable agricultural practices had a higher maize yield and technical efficiency. Thus, this study implies that maize production in Nigeria can be improved if the smallholder maize farmers are supported to adopt sustainable agricultural practices.

Conclusion and policy recommendations

This study used multivariate probit model to investigate the smallholder maize farmers' choice of sustainable agricultural practices, while an endogeneity corrected stochastic frontier model was used to assess the impact of adoption of sustainable agricultural practices on maize productivity in Southwest, Nigeria. The result of the multivariate probit model revealed that choices and farmers adoption of sustainable agricultural practices significantly depends on the age of the household head, gender, farming experience, farm size, years of formal education, membership of association, access to extension service, location and access to credit. Specifically, the result indicated that likelihood of adoption of improved maize seeds, inorganic fertilizer and integrated pest management practices increases among the younger farmers. The result of the endogeneity corrected stochastic frontier model indicated the presence of an endogeneity being jointly significant in the model which may be ascribed to unobserved characteristics influencing farmers' decision to adopt sustainable agricultural practices. Furthermore, the estimated mean technical efficiency of the endogeneity corrected stochastic frontier model was 73% while that of the conventional SFA was estimated at 7l%. The result from the EN model showed that the quantity of farm size, seed, fertilizer, the interaction of labour with farm size, herbicides and fertilizer, and the interaction of farm size with seed, herbicides and fertilizers were significant in explaining the observed variation in the efficiency of maize production in Nigeria. In addition, the study identified the effects of age, gender, farming experience, membership in association, access to extension services, access to credit, mean annual rainfall and sustainable agricultural practices adoption index as source of technical inefficiency. As showen in the results, adoption of sustainable agricultural practices by the maize farmers to reduce the negative impact of climate change increases maize production efficiency in Nigeria.

Recommendation

This study therefore recommends that policy makers should take into consideration, socioeconomic and managerial factors when designing policies to stimulate the adoption of sustainable agricultural practices in Nigeria. Also, there is a need to increase access to extension services, increase level of education through agricultural trainings and seminars and improved access to credit and financial support for the attainment of increased productivity. In addition, the technical efficiency of the maize farmers can also be improved through encouraging the farmers to join farmers' organization where relevant and up to date information will be shared. This may also help them in adopting sustainable agricultural practices.

Conflict of interest

The author of this study declares that there exists no conflict of interest

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References

Abdulai, A.N., and Abdulai, A. (20l8). Examining the impact of conservation agriculture on environmental efficiency among maize farmers in Zambia. *Environ. Dev. Econ*. 22 (2): 177–20l.

Abdul-Rahaman, A., and Abdulai, A. (20l8). Do farmer groups impact on farm yield and efficiency of smallholder farmers? Evidence from rice farmers in northern Ghana. *Food Policy*, 8l: 95–l05.

Adetoro, A.A., Abraham, S., Paraskevopoulos, A.L., Owusu-Sekyere, E., Jordaan, H. and Orimoloye, I.R. (2020). Alleviating water shortages by decreasing water footprint in sugarcane production: the impacts of different soil mulching and irrigation systems in South Africa. *Groundwater. Sustain. Dev.* 11: l00464.

Ahmed, M.H. and Melesse, K.A. (20l8). Impact of off-farm activities on technical efficiency: evidence from maize producers of eastern Ethiopia. *Agriculture and Food Economics* 6 (3): l–l5.

Awazi, N. P., Tchamba, M. N., & Avana, T. M.-L. (2019). Climate change resiliency choices of small-scale farmers in Cameroon: Determinants and policy implications. *Journal of Environmental Management, 250*, 109560.

Ayanlade, A., Radeny, M. and Morton, J.F. (2017). Comparing smallholder farmers' perception of climate change with meteorological data: a case study from southwestern Nigeria. *Weather and Climate Extremes* 15: 24–33.

Baiyegunhi, L.J.S., Hassan, M.B., Danso-Abbeam, G. and Ortmann, G.F. (2019). Diffusion and adoption of Integrated Striga Management (ISM) technologies among smallholder maize farmers in rural northern Nigeria. *Technol. Soc.* 56: 109–115.

Bedeke, S., Vanhove, W., Gezahegn, M., Natarajan, K., and Van Damme, P. (20l9). Adoption of climate change adaptation strategies by maize-dependent smallholders in Ethiopia. *NJAS - Wageningen Journal of life Sciences,* 88: 96 – 104.

Bello, O.B., Olawuyi, O.J., Abdulmaliq, S.Y., Ige, S.A., Nahamood, J., Azeez, M.A. and Afolabi, M.S. (20l4). Yield performance and adaptation of early and intermediate drought tolerant maize genotypes in Guinea Savanna of Nigeria. *Sarhad Journal of Agriculture* 30(l): 53–66

Branca, G., McCarthy, N., lipper, L. and Jolejole, M. C. (2011). Climate-Smart Agriculture: A Synthesis of Empirical Evidence of Food Security and Mitigation Benefits from Improved Cropland Management (Rome, Italy: Food and Agriculture Organization of the United Nations (FAO).

Chandio, A.A., Magsi, H., Rehman, A. and Sahito, J.G.M. (20l7). Types, sources and importance of agricultural credits in Pakistan. *Journal of Applied Environmental and Biological Science* 7: l44–l49

FAOSTAT (20l9). Food and Agricultural Oraganisation Statistics 20l9 http://www.fao.org/faostat/en/#data

FAOSTAT (2020). Food and Agricultural Oraganisation Statistics 20l9 http://www.fao.org/faostat/en/#data

Gebremariam, G., and Tesfaye, W. (20l8). The heterogeneous effect of shocks on agricultural innovations adoption: Microeconometric evidence from rural Ethiopia. *Food Policy*, 74: 154–161.

Ghimire, R., & Huang, W.-C. (2015). Household wealth and adoption of improved maize varieties in Nepal: A double-hurdle approach. *Food Security, 7*(6), 1321–1335.

Gomez-Zavaglia, A., Mejuto, J.C. and Simal-Gandara, J. (2020). Mitigation of emerging implications of climate change on food production systems. *Food Res. Int.* l37: l09554.

Jimoh, S.O., Baruwa, O.I, and Kolapo, A. (2023). Analysis of profit efficiency of smallholder beef cattle farms in South-West, Nigeria. *Cogent Economics & Finance*, 11(1): 1-21.

Kassie, M., Teklewold, H., Jaleta, M., Marenya, P. and Erenstein, O. (20l5). Understanding the adoption of a portfolio of sustainable intensification practices in eastern and southern Africa. *Land Use Policy*, 42: 400–411.

Kassie, M., Zikhali,P., Manjur,K., and Edwards, S. (2009). Adoption of sustainable agriculture practices: Evidence from a semi-arid region of Ethiopia. *Natural Resources Forum*, 33: l89–l98.

Kolapo, A. and Kolapo, A.J. (2023). Implementation of conservation agricultural practices as an effective response to mitigate climate change impact and boost crop productivity in Nigeria. *Journal of Agriculture and Food Research*, 12: (1000557), 1-9.

Kolapo, A., Muhammed, O.A., Kolapo, A.J., Olowolafe, D. E, Eludire, A. I., Didunyemi, A. J, Falana, K., and Osungbure, I. D. (2023). Adoption of drought tolerant maize varieties and farmers' access to credit in Nigeria: Implications on productivity. *Sustainable Future*, 6, 1-12

Kolapo, A**.,** Didunyemi, A. J., Aniyi, O. J., and Obembe, O.E. (2022a). Adoption of multiple sustainable land management practices and its effects on productivity of smallholder maize farmers in Nigeria. *Resources, Environment and Sustainability*, 10: 100084.

Kolapo, A, Tijani, A.A., Olowolafe, D.E and Muhammed, O.A. (2022b). Acceptance of European Union (EU) approved pesticides for cocoa production in Nigeria. *Cogent Food and Agriculture*, 8(1): 1-19.

Kolapo, A., Ogunleye, A.S., Kehinde, A.D. and Odimgbe-James, W. (2022c). Effect of microcredit on investment decision of smallholder farmers in Osun State. *Agric. Conspec. Sci.* 87 (1): 69–75.

Kolapo, A**.,** Olanipekun, O.A., Akande, Y.B., Kolawole, M.A. and Muhammed, O.A (2022d). Impact of youth commercial agricultural development programme on poverty status of rural households in Ekiti State, Nigeria. *International Journal of Agricultural Management and Development*, 12 (2): 91-101.

Kolapo, A, and Kolapo, A.J. (2021). Welfare and Productivity Impact of Adoption of Biofortified Cassava by Smallholder Farmers in Nigeria. *Cogent Food and Agriculture*, 7:1,1886662.

Kolapo, A, Abimbola, E. I. and Omilaju, S. B. (2021a). Land Tenure, Land Property Rights and Adoption of Bio-Fortified Cassava in Nigeria: Policy Implication. *Journal of Land and Rural Studies, 1-18.*

Kolapo A**,** O.V. Ogunyemi, O.M. Ologundudu, I.A. Adekunle, M.O. Akinloye and F. Komolehin (2021b). Farmers' choice of varieties and demand for improved cassava stems in Nigeria. *Int. J. Agril. Res. Innov. Tech.* 11(2): 42-51.

Kolapo, A**,** Ojo, C. F., Lawal, A.M., Abayomi, T. J. and Muhammed, O. A**.** (2021c). Sensitivity analysis and future farm size projection of biofortified cassava production in Oyo State, Nigeria. *Malaysian Journal of Sustainable Agriculture*, 5(2): 61-66.

Kolapo, A**,** Raji, I.A, Falana, K., and Muhammed, O. A. (2021d). Farm size efficiency differentials of bio-fortified cassava production in nigeria: a stochastic frontier analysis approach. *Malaysian Journal of Sustainable Agriculture*, 5(1): 51-60.

Kolapo, A**.,** A.S. Ogunleye, A.D. Kehinde and Adebanke, A.A. (2021e). Determinants of farmers' access to microcredit from cooperative societies in Ondo State, Nigeria. *Int. J. Agril. Res. Innov. Tech.* 11(2): 103-107.

Kolapo, A and Ayeni, A.A. (2020). Welfare impact of adoption of improved oil palm processing technologies among rural households in South-Western, Nigeria. *Tropical Agroecosystems*, 1(1): 35-42.

Kolapo, A and Abimbola, E. I. (2020). Consumers' Preferences and Willingness to Pay for Bio-fortified Vitamin-A Garri in South Western, Nigeria: A Conjoint Analysis and Double-Hurdle Model Estimation. *World Research Journal of Agricultural Sciences*, 7(2): 221-229.

Kolapo, A**,** Olayinka, J. Y. and Muhammed, O. A. (2020a). Market participation and food security status of bio-fortified cassava processors in South Western Nigeria. *International Journal of Sustainable Agricultural Research*, 7(3): 174-184.

Kolapo, A and Yesufu, O. A. (2020). Determinants of adoption of improved processing technology among catfish producer-processors in South Western, Nigeria. *Food & Agribusiness Management*, 1(2): 94-99.

Kolapo, A**.,** Ologundudu, O.M., Adekunle, I.A., and Ogunyemi, O.A. (2020b). Impact Assessment of Fadama III group Participation on Food security Status of Rural Households in South West, Nigeria. *Journal of Agriculture and Sustainability*, 13: 21-29.

Kolapo, A**,** Ologundudu, O. M and Adekunle, I. A. (2020c). Gender, membership in farmers' association and adoption of biofortification in Nigeria: The case of bio-fortified cassava. *SSRG International Journal of Agriculture & Environmental Science (SSRG-IJAES)*, 7(3): 38-45.

Kolapo, A, Oladejo O.O, Muhammed O.A. and Kolapo A.J (2020d). Institutional factors and crop farmer's participation in agricultural insurance scheme: evidence from South Western Nigeria. *International Journal of Environmental and Agricultural Research*,6(5):13-21**.**

Kolapo, A., Omopariola, O.E., Adeoye, A.O. and Kolapo, A.J. (2020e). Adoption of Improved processing technology among African locust bean processors in south-west, Nigeria. *International Journal of Agricultural Research Innovation and Technology, 10(1), 123-128.*

Mukasa, A.N., Woldemichael, A.D., Salami, A.O. and Simpasa, A.M. (20l7). Africa's agricultural transformation: identifying priority areas and overcoming challenges. *Africa Economic Brief*. 8(3): l–l6.

National Bureau of Statistics (NBS) (20l4). Social Statistics in Nigeria, Abuja.

Ojo, T.O. and Baiyegunhi, L.J.S. (2020). Impact of climate change adaptation strategies on rice productivity in South-west, Nigeria: an endogeneity corrected stochastic frontier model. *Sci. Total Environ*. 745: l4l–l5l.

Onumah, J.A., Al-Hassan, R.M., Onumah, E.E., 20l3. Productivity and technical efficiency of cocoa production in Eastern Ghana. *Journal of Economics and Sustainable Development*, 4 (4): l06–117.

Oyetunde-Usman, Z., Olagunju, K.O. and Ogunpaimo, O.R. (202l). Determinants of adoption of multiple sustainable agricultural practices among smallholder farmers in Nigeria. *International Soil and Water Conservation Research*, 9: 241–248.

Rabirou, K., Kolapo, A**.,** and Lasisi, A.L. (2022). Competitiveness of broiler production in Nigeria: A policy analysis matrix approach. *Heliyon*, 8(5): e09298.

Tegbaru, A., Menkir, A., Nasser Baco, M., Idrisou, I., Sissoko, D., Eyitayo, A.O., Abate, T. and Tahirou, A. (2020). Addressing gendered varietal and trait preferences in West African maize. *World Development Perspectives* 20: l00268.

Tesfahunegn, G.B., Mekonen, K. and Tekle, A. (20l6). Farmers' perception on causes, indicators and determinants of climate change in northern Ethiopia: Implication for developing adaptation strategies. *Appl. Geogr*. 73: 1–12.

Tran, K.C. and Tsionas, E.G. (2013). GMM estimation of stochastic frontier mode1 with endogenous regressors. *Econ. 1ett*. 118 (1): 233–23

Wainaina, P., Tongruksawattana, S., and Qaim, M. (2016). Tradeoffs and comp1ementarities in the adoption of improved seeds, ferti1izer, and natura1 resource management techno1ogies in Kenya. *Agricu1tura1 Economics*, 47(3): 351–362.