Research article

Understanding the determinants of climate change adaptation strategies among smallholder maize farmers in South-west, Nigeria

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ABSTRACT

Climate is one of the most important factors in agricultural productivity, which could directly or indirectly influence productivity since the climate is linked to physiological processes. It is, therefore, essential to understanding the various strategies used by farmers to mitigate the adverse impact of climate change and the factors that influence maize farmers' adoption and intensity of climate change adaptation strategies among smallholder maize farmers in South-west Nigeria. In all, a sample of three hundred and thirty (311) smallholder maize farmers were interviewed. A double-hurdle count data model was employed to estimate the factors influencing farmers' adoption of adaptation strategies while accounting for selection bias with the plugging of inverse mill ratio (IMR) as a regressor. Significant variables such as household size, depreciation ratio, frequency of extension visits, access to extension, and non-farm income were factors influencing the adoption of climate change adaptation strategies among maize farmers. Age of the respondent, age square, household size, farm-based organization (FBO), non-farm income, climate information, access to credit, farmers residing in Osun State (location_Osun), distance to market significantly influenced the intensity of climate change adaptation strategies. This study, therefore, concluded that farm-level policy efforts that aim to improve rural development should focus on farmers' membership in FBO, increase the visits of extension agents, encourage non-farm income and access to climate change information, particularly during the off-cropping season. Policies and investment strategies of the government should be geared towards supporting improved extension service, providing on-farm demonstration training, and disseminating information about climate change adaptation strategies, particularly for smallholder farmers in Nigeria.

1. Introduction

Several households in Nigeria depend on cereals (most especially, maize) as one of the important sources of food and nutrition (CBN, 2005; Fadina and Barjolle, 2018). Maize crop production contributes to food security, which is mostly preferred to other crops such as sorghum and millet in Nigeria (Sertoglu et al., 2017). Maize is one of the important grains in Nigeria, as it creates job opportunities and contributes to the country's economic development, evidence from an increase in production (by 25.24%, from 2000-2010) (FAO, 2017). Meanwhile, maize production is found to be highly affected by climate variability and change (Sato et al., 2020). According to Tumbo et al. (2020) and Ureta et al. (2020), climate change poses a negative impact on the maize yield

when mean precipitation decreases relative to a marginal increase in mean temperature or vice versa.

The consequence of climate change on food security and poverty relies on several interacting factors such as the timing of extreme events which are predicted to become more recurring in the future (Kusangaya et al., 2014). Given the current food system, the UN Food and Agriculture Organization (FAO) estimates that there is a need to produce about 50% more food by 2050 in order to feed the increasing world population (FAO 2018a). The issue of climate change is increasingly becoming a threat not only to the sustainable development of socio-economic and agricultural activities of any nation but also to the totality of human existence (Zadawa and Omran, 2020; Rathoure and Patel, 2020). Drastic changes in rainfall patterns and rise in temperatures have introduced

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unfavourable growing conditions into the cropping calendars thereby modifying growing seasons which consequently affect the crop productivity. These changes affect food prices, food security, land use (Barnett, 2020; Sylvester, 2020) and subsequently caused uncertainty for crop managers (Hampf et al., 2020; Tumbo et al., 2020). According to Kahil et al. (2015) and Thennakoon et al. (2020), the severity of climate change impact depends on the degree of adaptation at the farm level, farmers' investment decisions and policy choices, though, these factors are interrelated and negatively affect the quantity of output most times. According to the special report of IPCC as indicated by Sinclair et al. (2019), agriculture and the food system are key to global climate change responses. Combining supply-side actions such as efficient production, transport, and processing with demand-side interventions such as modification of food choices, and reduction of food loss and waste, reduces GHG emissions and enhances food system resilience. Such combined measures can enable the implementation of large-scale land-based adaptation and mitigation strategies without threatening food security from increased competition for land for food production and higher food prices. Thus, identifying the factors that determine climate change adaptation strategies and understanding the dynamics of farmers' adaptation choice or combination of choices is necessary to sustain maize production in Nigeria.

To attain a sustainable level of output, farmers are expected to take adaptation measures to cope with risks posed by climate change on their productive activities (Pandey et al., 2017; Ojo and Baiyegunhi, 2020a). As posited by Stringer et al. (2020) and Ojo and Baiyegunhi, (2020b), there are several types of adaptation strategies available to different farmers, with the level of perception of climate change determining the type and extent to which the strategies are employed (Hasan & Kumar, 2019; Khan et al., 2020; Ojo and Baiyegunhi, 2020a). As opined by Bryan et al. (2013), adaptation to climate change at the farm level includes many possible responses, such as changes in crop management practices (e.g. planting dates, planting densities, crop varieties), livestock management practices (e.g. livestock choice, feeding and animal health practices, transhumance timing and destinations), land use and management (e.g. fallowing, tree planting or protection, irrigation and water harvesting, soil and water conservation measures, tillage practices, soil fertility management). However, some of these climate change adaptation strategies are location specific. Therefore, there is the need to understand location-specific drivers of adaptation to climate change among smallholder maize farmers in Nigeria, as varied effects of climate change on maize production has a direct bearing on choices that affect output and net revenue accruable to farming enterprises (Ayinde et al., 2010).

According to Chenu et al. (2019), Kapur et al. (2019) and Riccetto et al. (2020), maize productivity depends on climate and nature of soil among others which are regarded as the yield potentials of a certain area. The crop survives with the mean daily temperature between 16 to 19 °C and a consistently required amount of precipitation. However, this is being threatened with persistent and erratic climate change thus affecting farming within the predominantly rain-fed systems. Climate change has induced rainfall and temperature stresses, which reduced maize yields in Nigeria (Nwaogu et al., 2020; Muench et al., 2021). Furthermore, empirical evidence shows that there is a likelihood that yield will decrease by 15% and 24% by the year 2030 and 2050, respectively, compared to the baseline year 2000, implying a decline of about 1.4 million tons and 2.9 million tons, respectively (considering a mean simulated yield of 1.3 tons per hectare) (Coster and Adeoti, 2015). iAs posited by Pradhan et al. (2015), currently, crop yields vary across regions even within the same climatic zones. These variations in crop yields are related to market accessibility, purchasing power/income, agricultural work force, and terrain factors (Neumann et al., 2010). However, closing yield gaps will enhance food self-sufficiency (FSS) and enable food security at local, regional, and global scales (Pradhan et al., 2014). These changes in climate iwill in no small measure limit maize production, thus, lowering the welfare status of farming families who solely depend directly on maize cultivation as their source of food and income (Das et al., 2020).

To ensure continuous production, maize cultivators are practically taking steps to mitigate the economic losses associated with climate change (Omerkhil et al., 2020). However, it is noteworthy that these adaptation options utilized by various smallholder maize farmers do not come without costs. The effect of climate change and its cost implications on farmers have been assessed by studies (Ajetomobi *et al.*, 2010; Ojo et al., 2019; Ojo and Baiyegunhi, 2020a) on various crops but limited studies (Ayinde et al., 2010), exist on the subject matter, most especially on maize production in South-western part of Nigeria. Moreover, the determinants of adoption and intensity of adoption of climate change adaptation strategies among the smallholder maize farmers have not been adequately explored. It is therefore imperative to analyse the determinants of climate change adaptation strategies and factors that influence the intensity of adoption of adaptation options as governed by differential characteristics of the farmers of Nigeria.

2. Research methodology

2.1. Study area

The study was carried out in South-western Nigeria, which is one of the six geographical zones in the country. The zone consists of Ekiti, Lagos, Ogun, Ondo, Osun, and Oyo States as depicted in Figure 1. The zone lies between longitude $2^0 31^1$ and $6^0 00^1$ East and Latitude $6^0 21^1$ and $8^0 37^1$N with a total land area of 77,818 km^2 and an estimated population of 38,257,260 (NBS, 2016). The study area is bounded in the East by Edo and Delta States, in the North by Kwara and Kogi States, in the West by the Republic of Benin and in the South by the Atlantic Ocean.

The climate of South-western Nigeria is tropical and it is characterized by wet and dry seasons. The temperature ranges between 25 °C and 35 °C while the annual rainfall ranges between 1300 mm and 2500 mm. The wet season is associated with the Southwest monsoon wind from the Atlantic Ocean while the dry season is associated with the Northeast trade wind from the Sahara Desert (Umar et al., 2015). The ecological condition in Southwest Nigeria is made up of freshwater swamp and mangrove forest at the belt, the low land in forest stretches inland to Ogun and part of Ondo States while the secondary forest is towards the northern boundary where derived and southern Savannah exist (Bamire et al., 2010). This ecological condition encourages the cultivation of early and/or late crops such as cassava, yam, millet, rice, plantains, cocoa, palm produce, cashew and maize.

The total land areas used for maize production in 2012 and 2013 are 5 million and 5,2million hectares, respectively (Iken and Amusa, 2004). The size of the land devoted to maize in the region gives the third-highest production with an average yield of 2 tons/ha (Umar et al., 2015). The three states that were selected are Oyo, Osun and Ogun (Figure 2) as the three highest producers of maize in the region. The major source of occupation and income in the study area is agriculture. Agriculture provides income and employment for about 75% of the population and they produce both food and cash crops. Residents in these areas are also engaged in other non-farm activities like trading, commercial transport service, and some artisan activities. The artisans make hand-woven textiles, tie and dye clothes, leatherwork, calabash carving and mat-weaving among others. Some mining activities and quarry business are also carried out by people in the study area.

2.2. Procedure for data collection

The multistage sampling procedure was employed in selecting respondents for this study. In the first stage, three states (Osun, Oyo, and Ogun) were purposively selected based on the predominance of maize production in the region. In the second stage, two (2) Local Government Areas (LGAs) were purposively sampled from each of the selected states based on the concentration of smallholder maize farmers in the area. In
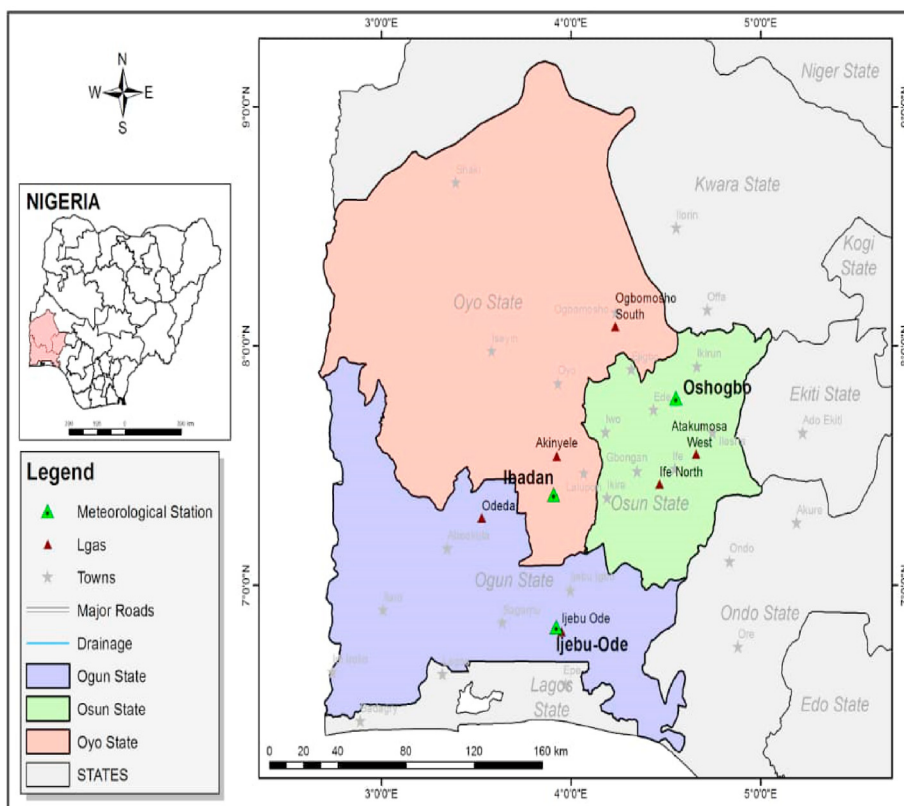
Figure 1. Map of the study area. Source: Space Applications and Environmental Science Laboratory (SPAEL), Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria, 2019.

the third stage, five (5) villages from each of the selected six LGAs were randomly selected to make a total of thirty (30) villages. The proportionality factor that was used in the selection of smallholder maize farmers was as stated in Eq. (1):

$$X_i = \left(\frac{n}{N}\right) * 30 \tag{1}$$

where

X_i = number of villages sampled from a LGA
n = number of villages in the particular LGA.
N = total number of villages in all the LGAs.

In the fourth stage, eleven (11) smallholder farmers were selected in each of the villages based on the list provided by the ADPs in the states. In all, a total of three hundred and thirty (330) smallholder maize farmers were interviewed. The primary data was collected through a cross-sectional survey of maize farmers in the study area. A semi-structured questionnaire was used to obtain data on socio-economic characteristics of the farmers, output of male and female farmers, the output of maize and corresponding inputs which include values of productive and non-productive assets, perception of climate change and adaptation strategies. However, 311 copies out of the 330 of questionnaire administered to the farmers had complete and adequate information for analysis, thus implying a response rate of 94.24%.
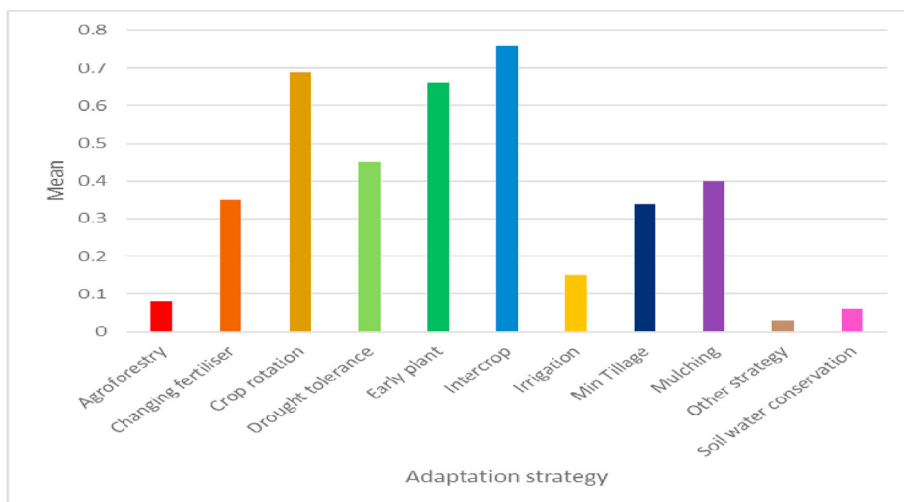

Figure 2. Distribution of adaptation strategies employed by the smallholder maize farmers in South-west, Nigeria.

2.3. The determinants of adoption of climate change adaptation strategies by smallholder maize farmers

Empirical studies have hypothesized that both adoption and intensity of climate change adaptation strategies are influenced by household socio-demographic characteristics and other forms of institutional factors (Hitayezu et al., 2017; Ojo and Baiyegunhi, 2020a). The framework of the double-hurdle model incorporates a first stage adoption of climate change adaptation strategies based on the same set of covariates determining the intensity of adoption of climate change adaptation strategies.

With the assumption of the error terms in the equations is uncorrelated conditional on all covariates, the standard errors from separate estimations are also valid for conducting statistical inference. If the conditionally uncorrelated errors assumption does not hold, coefficient estimates from separate regressions will be biased (Heckman, 1977; Harding et al., 2020). According to Wooldridge (2002), testing for conditionally uncorrelated errors follows the same method as well as the Heckman test for selection bias. Although it is not technically necessary for identification, it is standard to impose at least one justifiable exclusion restriction when estimating the second stage. The null hypothesis that the first and second stage errors are conditionally uncorrelated is tested using the standard *t*-statistic for the coefficient estimate on inverse mill ratio (*IMR*). If the coefficient estimate is statistically significantly different from zero, we reject the null hypothesis and the model must be re-estimated to conduct valid inference (De Luca and Perotti, 2011). If we fail to reject the null, we re-estimate second stage parameters excluding *IMR*. A probit model of CCAS for selection equations is estimated using a function of explanatory variables that are likely also determine CCAS intensity, vis-a-vis one or more exclusion variables. The *IMR* predicted from the first-stage probit regression is added as a regressor to account for the selection bias in the second hurdle. Following Feder et al. (1985), adoption of climate change adaptation strategies can be outlined as the stage at which a household decides to adopt one or more adaptive option in mitigating the effect of climate change. The underlying latent variable that captures the true farmers' socio-economic characteristics is hypothesized to determine the probability of adoption of climate change adaptation strategies by a smallholder farmer. The regression Eq. (2) indicates the latent variable $CCAS_i^*$:

$$CCAS_i^* = L_i\beta + e_i \quad e_i \approx N(0,1) \quad \text{(first handle)}$$
$$\text{and, } CCAS_i = 1 \text{ if } CCAS_i^* > 0 \tag{2}$$
$$CCAS_i = 0 \text{ if } CCAS_i^* \leq 0$$

where $CCAS_i$ is a categorical variable that takes the value of 1 if a smallholder farmer adopts climate change and 0 otherwise. β is a vector of parameters to be estimated. In line with Wooldridge (2002), a probit model of $CCAS_i$ which follows random utility is expressed as in Eq. (3):

$$\Pr(CCAS_i = 1|L_i, \alpha) = \Phi(L_i, \alpha) + e_i \tag{3}$$

where, $CCAS_i$ equals 1 for households that adopts climate change adaptation strategies and 0 otherwise; L_i represents the vector of independent variables; α, vector of parameters to be estimated; Φ, standard normal cumulative distribution function; e_i is a random error term hypothesized to be distributed normally with unit variance and zero mean.

2.4. The intensity of climate change adaptation strategies use among smallholder maize farmers

Count data are non-normal and hence are not well estimated by ordinary least squares (OLS) regression (Maddala, 2001). The most common regression models used to analyze count data models include the Poisson regression model (PRM), the negative binomial regression model (NBRM), the zero-inflated Poisson (ZIP) and the zero-inflated negative binomial (ZINB). The PRM and NBRM regression models have become the standard models for the analysis of response variables with

non-negative integer (Greene, 2008; Kirui, et al., 2010). The last two (ZIP and ZINB) are explicitly used to account for cases with frequent zero counts (i.e. when there are more zeros than would be expected), which is not the case in this study. Only the PRM is therefore discussed here since the response variables were non-negative integers and with only a few zero counts.

Smallholder farmers often make rational decisions when it comes to the adoption of any particular technology (Zeng et al., 2019). Since the objective of the farmer is to maximize expected (discounted) profits over time subject to input and commodity prices and technology constraint, farmers will usually weigh the benefits associated with a particular technology before they decide to adopt. Rationally, a farmer will adopt new technology if the expected (discounted) utility of profits of using that technology is greater than utility from the old technology (Adesina and Baidu-Forson, 1995; Channa et al., 2019). To estimate the determinants of intensity of CCAS, a Poisson model was employed. The Poisson model is the simplest and perhaps the most common method for modelling counts variables (Cameron and Trivedi, 1998; Siegfried and Hothorn, 2020). Poisson regression is used in this study because diagnostic tests revealed the absence of overdispersion and under dispersion. Following Wooldridge (2002) and Greene (2008), the density function of the Poisson regression model as depicted in Eq. (4) is given by:

$$\Pr(H = h) = \frac{e^{-\delta(h)}\delta_i(h)^H}{\Phi(1+H)} \tag{4}$$

where; $\delta_i = Exp(\Omega + L^i\Psi)$ and $H_i = 0,1,\ldots$, i is the number of CCAS used by the farmers and L vector of predictor variables and Ω and Ψ are the parameters to be estimated.

Greene (2003; 2008) show that the expected number of events (in this case, number of adaptation strategies adopted by the farmers) is as expressed in Eq. (5);

$$E(H_i = h_i) = Var\{H_i / h_i\} = \delta_i = Exp(\Omega + L^i\Psi) \text{ for } i = 1, 2, \ldots, n \tag{5}$$

3. Result and discussion

3.1. Descriptive statistics

The sex of farmers can be a strong determinant of their access to productive assets such as land. As this crop enterprise is dominated by male maize farmers, however, this does not preclude females from cultivating the crop. As shown in Table 1, the mean age of the sampled respondents for this study was 47.85 ± 10.26 years. This indicates that most of the maize farmers in the study area were young and have the potential for productive activities on the farm. The results bring to view the marital status of the maize farmers. On the aggregate, the majority (86.17%) of the farmers were married and 5.79, 5.47 and 5.67% were widowed, single and divorced, respectively. This finding is in line with the report of Girei et al. (2018) who opined that married farmers are likely to be committed to increasing the yield on their farms as it is critical to the sustenance of their family.

Household size can influence the household expenditure on food, clothing and shelter. However, in most agrarian communities, it is seen as an advantage to the household head as it signifies the availability of farm labour. The results in Table 1 showed that the average household size of the sampled farmers was 5.62 ± 2.06. The average dependency ratio of 0.66 ± 0.73 among the farmers shows that they have a few non-productive members. This result reveals that many of the household members were within the economically active age range while the infants and aged were few. The result in Table 1 showed that the mean number of years of formal education of the farmers in the area was 7.0 ± 4.9.

Membership of farmers' group or association is a form of social capital to farmers not only in term of accessing credit and other farm inputs but also in term of marketing and provision of opportunities to share vital information. Access to credit by smallholder maize farmers can enhance

Table 1. Definitions and summary statistics of variables used in the model.

Variable	Description of Variables	Mean	Std. Dev.
Dependnet variables			
CCAS adoption	If the household head (HH) adopted 1 and 0, otherwise	0.52	0.50
Intensity of CCAS adoption	Numbers of climate change adaptation strategies adopted by the HH	5.05	3.02
Independent variables			
Age	Age of the household head in years	47.41	10.7
Gender	1 if HH head is male, 0 if female	0.70	0.46
Education level	Years of education of HH head	7.01	4.91
Farming experience	Years of household experience in maize production	20.12	12.57
Marital status	1 if HH head is married, 0 if other/single/widowed	2.08	0.55
Household size	Number of HH size	5.57	2.06
Depreciation ratio	The depreciation ratio of HH	0.65	0.73
Farm size (hectares)	Total land cultivated for maize by HH, in hectares	1.34	1.83
Farm-based organisation association (FBO)	1 if HH belongs to a FBO, 0 if otherwise	0.36	0.48
Access to extension services	1 if HH has access to extension, 0 if otherwise	0.22	0.41
Access to credit	1 if HH has access to credit, 0 if otherwise	0.31	0.46
Climate change awareness	1 if HH is aware of climate change, 0 if otherwise	8.36	8.02
Climate information	1 if HH has access to climate change information, 0 if otherwise	0.76	0.43
Mean Temperature	Mean of annual temperature	27.09	0.02
Mean Precipitation	Mean of annual precipitation	46.43	2.61
Access to non-farm income	1 = if HH engages in any off-farm activity	0.73	0.44
Location_Oyo	1 if HH is from Oyo, 0 if otherwise	0.33	0.47
Location_Osun	1 if HH is from Osun, 0 if otherwise	0.33	0.47

their capacity to purchase improved agricultural inputs which in turn can result in increased farm-level productivity and as such improve net revenue generated from their maize farms. According to Petrick (2004), access to credit may affect farm productivity because farmers facing binding capital constraints would tend to use lower levels of improved farm inputs in their production activities compared to those are not constrained.

Farmers' access to extension service serves as a vital human capital that keeps them informed on changes and modern agricultural practices in the farming system. Access to extension service can provide farmers with quality information on how to best tackle climate change and its effects on their farms. Consistent contact between the farmers and the extension agents will provide relevant information such as farm management, planning, practices and new agricultural technologies that would assist farmers to improve yields and profitability (Oseni et al., 2014). The results on Table 3 showed that the average farm size of the farmers for this study to be 1.34 ± 1.49 ha, indicating that the farmers were mainly smallholders (Alabi and Abdulazeez, 2018). The experience of farmers in any agricultural enterprise can enhance their level of productivity on their farms. Maize farmers who are more experienced will know how best to combine agricultural inputs to maximize outputs from their farms. The results showed that an average farmer in the study area had 19.08 ± 12.56 years of maize farming experience.

3.2. List of adaptation strategies employed by the smallholder maize farmers in south-west, Nigeria

The distribution of climate change adaptation strategies employed by smallholder maize farmers is presented in Figure 2.

The level of proactive measures taken by farmers to adapt to the impacts of climate change on their farms is strongly connected with their awareness about climate change (Le Dang et al., 2014; Raworth, 2007).

A farmer that is aware of changes in climate in terms of temperature and precipitation is more likely to utilize some important adaptation strategies on his farm (Maddison, 2006). This implies that majority of the farmers were aware of climate variation in the study area and therefore, made informed decisions about climate change on their farms. This result is consistent with the findings of Adem et al. (2014) that most farmers are

conscious of the climate change taking place in their environment which influences their farming activities. Following Asfaw et al. (2019), it is imperative to understand and identify climate change adaptation strategies employed by the smallholder farmers to implement feasible adaptation strategies at the farm level. Smallholder farmers mitigated climate risks through several adaptation practices (Figure 2). In response to a changing climate, households in the study area have developed multiple adaptation strategies to adapt to climate change. The result shows that adaptation to climate conditions as an example is achieved through various methods, including mulching, varying planting date, soil and water conservation, use of improved planting materials, agroforestry, early maturing planting variety, crop rotation. Others included changing fertilizer application methods, soil and water conservation, mulching, intercropping and minimum tillage. Some of these strategies were also identified in the studies of Asfaw et al. (2019); Ojo and Baiyegunhi, (2020a), and Ojo and Baiyegunhi, (2020b).

3.3. Determinants of adoption of climate change adaptation strategies among maize farmers-probit model

This section discusses the results of the probit model. The results present the factors that significantly determine the maize farmer's probability of adopting climate change adaptation strategies in the study area. The model statistics of the probit results shows the mean independent variable 0.520; Pseudo R-squared 0.050 and the Prob > chi 2 of 0.034 indicate that the probit model is fit for the analysis. The marginal effect of the determining variables was also performed to investigate maize farmers' response to climate change adaptation strategies. The empirical findings in terms of the significant variables such as household size, depreciation ratio, frequency of extension visits, and access to extension and non-farm income are discussed.

Results show that the coefficient of household size had a positive coefficient and statistically significant, indicating that the size of maize farmer's household determines the tendency of adopting climate change adaptation strategies in the study areas. A larger household size represents an intensive labour unit which increases agricultural production and thus, influences the probability of adopting climate change adaptation strategies. This is similarly in line with the studies of Belay et al.

(2017) and Ojo and Baiyegunhi (2020a) who found that family size significantly and positively influences the likelihood of adoption of climate change adaptation. The marginal effect results in Table 2 shows that an additional household member increases the likelihood of adopting climate change adaptation by 1.6%. A significant and positive marginal effect in household size variable has also been found in the study of Debalke (2013) and Belay et al. (2017), indicating that the larger the size of family, the higher the probability of maize farmers in adopting the climate change adaptation in the study area.

According to Ingham et al. (2009), a high dependency ratio is supposedly indicative of the dependency burden on the working population, as it is assumed that the economically active proportion of the population will need to provide for the health, education, pension, and social security benefits of the non-working population, either directly through family support mechanisms or indirectly through taxation. Dependency ratio has a negative and significant effect on the probability of maize farmers to adopt climate change adaptation at. As expected, low d epre-ciation iratio reveals that many of the household members were within the economically active age range while the infants and aged were few in number. Thus, the adoption of climate change adaptation strategies by the household head increases as the dependency ration reduces. adaptation ta strategies Similarly, the marginal effect result shows that a unit increase in the dependency ratio would increase the probability of farmers to adopt climate change adaptation by 4.5%. According to Shumetie and Yismaw, 2018, the crop production sub-sector of Ethopia is the most susceptible for climate variability owing to its direct interaction and nature dependency. Therefore, dependency ratio is an important factor considered when making decisions relating to the adoption of climate change adaptation strategies by maize farmers.

The result shows that the frequency of extension visit is positively and significantly related to the adoption of adaptation strategies by maize farmers in the study area. Credible access to extension services by the maize farmers provides an opportunity for climate change-related information. This information includes changing climatic conditions and the various farming practices that could be utilized by farmers and increase the probability of farmers to adopt climate change adaptation strategies. This is also in line with the study of Mihiretu et al. (2019); Omerkhil et al. (2020) and Zakaria et al. (2020) who emphasized the importance of extension services, which positively influences farmers' probability of adopting climate change adaptation strategies. The results

of the marginal effect of frequency of extension visit indicates that a unit increase in extension visit would increase the tendency of maize farmers to adopt climate change adaptation by 1.4%. This result confirms the findings of Debalke (2013) and Talanow et al. (2021) who highlighted that an increase in extension frequency would increase farmers' prospects of adopting climate change adaptation strategies such as various farming practices against agaisnt the adverse effects of climate change.

The non-farm income variable is negative and statistically significant in influencing the decision by maize farmers to adopt climate change adaptation. Famers with other sources of income are less likely to adopt climate change adaptation methods as they could easily switch completely to off-farm employment, particularly when the cost of climate change adaptation becomes costly and unaffordable. Empirical findings have shown that non-farm income variable negatively affects adaptation decision, with the income from non-farm involvement likely not to be invested in adaptation methods (Asrat and Simane, 2018; Das et al., 2020). In line with the studies in the literature, non-farm income poses an important impact on the adoption of climate change adaptation strategies (Katengeza et al., 2012; Wollni et al., 2010; Boz and Akbay, 2005; Pandey et al., 2017; Muench et al., 2021). The results on the marginal effect of non-farm income on farmers' probability of climate change adaptation methods show that a unit increase in non-farm income would reduce the tendency of maize farmers in the study area to adopt climate change adaptation methods by 12.4%. The result suggests that farmers who solely earn income from growing maize crops are more likely to adopt climate change adaptation methods as compared to farmers with other sources of income. The findings of this study comply with that of Legesse et al. (2013) who reported that non-farm income variable had a negative impact (as well as on the marginal effect) on the potentials of farmers in adopting climate change adaptation methods.

3.4. Determinants of the intensity of climate change adaptation strategies adoption- Poisson data model

The results of the Poisson regression model are discussed in Table 3. The result discussion focuses on the significant variables which are the age of respondent, age square (age sqr), household size, membership FBO, non-farm income, climate information, access to credit, location_Osun and distance to market. The coefficient estimate for IMR is statistically significantly different from zero under the null hypothesis.

Table 2. Determinants of adoption of climate change adaptation strategies among maize farmers-Probit model.

Independnet variables	Coef.	St. Err.	P-value	Marginal effects	St. Err.	P-value
Age of the respondent	-0.011	0.009	0.221	-0.018	0.019	0.347
Educational level	0.017	0.017	0.295	0.006	0.006	0.309
Marital status	0.189	0.153	0.217	0.078	0.058	0.180
Household size	0.070	0.042	0.096*	0.028	0.016	0.079*
Dependency ratio	-0.312	0.122	0.010**	-0.124	0.045	0.006***
Membership FBO	0.250	0.231	0.279	0.093	0.087	0.282
Freq of extension visits	0.069	0.038	0.071*	0.025	0.014	0.074*
Access to extension	-0.469	0.268	0.081*	-0.181	0.099	0.068*
Non-farm income	-0.324	0.175	0.065*	-0.124	0.065	0.056*
Climate information	-0.217	0.312	0.488	-0.082	0.117	0.485
Access to credit	-0.063	0.245	0.797	-0.015	0.093	0.874
Constant	0.084	0.495	0.866			
Mean dependent variable	0.520					
Pseudo R-squared	0.050					
Chi-square	20.923					
Akaike criterion (AIC)	418.48					
Bayesian criterion (BIC)	462.93					
Number of observations	300.00					
Prob > chi 2	0.034					

***p < 0.01, **p < 0.05, *p < 0.1.

Table 3. Count data regression of the intensity of climate change adaptation strategies adoption.

Number of strategies	POISSON REGRESSION			NEGATIVE BINOMIAL		
	Coef.	St. Err.	P-value	Coef.	St. Err.	P-value
Age of the respondent	-0.042	0.019	0.028**	-0.042	0.019	0.028**
Age square	0.000	0.000	0.049**	0.000	0.000	0.049**
Educational level	0.003	0.006	0.570	0.003	0.006	0.570
Marital status	-0.069	0.062	0.269	-0.069	0.062	0.269
Household size	0.035	0.016	0.027**	0.035	0.016	0.027**
Dependency ratio	-0.057	0.047	0.225	-0.057	0.047	0.225
Membership FBO	-0.164	0.085	0.052*	-0.164	0.085	0.052*
Freq of extension visits	-0.005	0.013	0.683	-0.005	0.013	0.683
Access to extension	0.061	0.114	0.593	0.061	0.114	0.593
Non-farm income	0.135	0.077	0.080*	0.135	0.077	0.080*
Climate information	0.561	0.129	0.000***	0.561	0.129	0.000***
Access to credit	0.188	0.095	0.048**	0.188	0.095	0.048**
Main occupation	-0.099	0.073	0.176	-0.099	0.073	0.176
Location_Oyo	-0.079	0.097	0.414	-0.079	0.097	0.414
Location_Osun	0.629	0.113	0.000***	0.629	0.113	0.000***
Distance to market	0.010	0.006	0.094*	0.010	0.006	0.094*
Distance to road	0.002	0.012	0.884	0.002	0.012	0.884
IMR	-1.258	0.558	0.024**	-1.258	0.557	0.024*
Constant	2.140	0.471	0.000***	2.140	0.471	0.000***
lnalpha				-18.148	404.527	
Pseudo R^2	0.179			0.142		
Chi-square	277.953			210.915		
AIC	1311.023			1313.023		
BIC	1377.691			1383.395		
Number of obs	300.000			300.000		
Prob > chi 2	0.000			0.000		

***p < 0.01, **p < 0.05, *p < 0.1.

Hence, IMR was included in the count data model estimation and standard errors were corrected for valid inference. As depicted in Table 3, estimation of Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) are important to indicate the better model in analysing count data of the intensity of adoption of climate change adaptation strategies among smallholder maize farmers. In this study, focus is on two count models namely; the Poisson regression model and Negative binomial model regression model. Starting from the AIC values, the Poisson and negative binomial regression models show 1311.023 and 1313.023, respectively. In the same vein, for BIC values, the Poisson and Negative binomial regression models reveal 1377. 691 and 1383.395, respectively. Comparing both observations, from AIC and BIC values, Poisson regression model fits better in analysing count data of intensity of adoption of climate change adaptation strategies among smallholder maize farmers in the study area.

The result shows that the age of respondents had a negative and significant effect on maize farmers' probability to adopt climate change adaptation methods. This implies that younger farmers are less likely to intensify the adoption climate change adaptation methods than the older farmers, highlighting the fact that older farmers tend to agree that climate change poses significant effects on maize farming thus, increasing their probability to adopt adaptation methods. Also, age is a proxy for farming experience, indicating that more experienced farmers are older farmers and understand the importance of adapting to climate change. On the contrary, the younger farmers with less experience in farming, have little or no perception of climate change and therefore limit their probability of considering the adoption of climate change methods. The probability of adoption of climate change methods decreases (by 4%) with a yearly increase in the age of maize farmers in the study area. This corresponds to the studies of Ochenje et al. (2016) and Thinda et al. (2020) who found that age negatively affects climate

perception and adaptation with the younger farmers less likely to adopt climate change adaptation strategies. The result is also in consonance with the study of Denkyirah et al. (2016) who found a negative effect of age on the adoption of pesticides-a type of climate change adaptation strategies.

Similarly, to the age variable, the age squared represent an increase in the age of maize farmers over a certain period (years) which shows a positive and significant relationship, with the dependent variable showing that an increase in the age of farmers increases the intensity of adapting to climate change. The implication of the result could be attributed to the fact that the older farmers are known to have more experience in maize farming, influencing their decision making for the adoption of climate change adaptation options. The result of this study is in line with that of Tambo and Abdoulaye (2012) who showed that farmer's age squared increases with farming experience and increases the likelihood to adopt drought-tolerant maize in Nigeria.

The coefficient of household size is positive and statistically significant in influencing the adoption of climate change adaptation methods in the study area. A positive relationship between household size and the adoption of climate change adaptation strategies exists in previous studies (Deressa et al., 2009; Abid et al., 2015, Ali and Erenstein, 2016). This relationship could be ascribed to a larger labour force to farm activities and more income generated as a result of surplus labour which can be used to fund climate change adaptation strategies. This notion also complies with the study of Rahut and Micevska Scharf (2012) and that of Gautam and Andersen (2016) who emphasized that larger house of size contributes to the income generation and thus positively influences farmers' adoption of climate change adaptation.

The membership in the FBO organization shows a negative and statistically significant effect on influencing the intensity of maize farmers in adopting climate change strategies in the study areas. The negative

coefficient implies that farmers who are non-FBO member have a better level of intensity to adopt climate change adaptation method than farmers who are members of the FBO organization. This may be ascribed to that fact that FBO members tend to focus more on market integration (such as good prices and bonuses), contract arrangements, input accessibility and other social benefits attached to the members of the organization. Therefore, the intentions and focus of members of such bodies are negatively skewed towards climate change adaptation and related issues. The finding of this study is consistent with a study by Ehiakpor et al. (2016) who reported a negative relationship between FBO membership and climate change awareness, with lack of awareness likely to reduce the intensity of adoption of climate change adaptation methods.

The result shows that non-farm income positively and significantly influences the intensity of adopting climate change adaptation strategies by the maize farmers in the study area. Household non-farm income which represents earnings from other businesses by the farmers tends to contribute positively to the decisions to adopt climate change adaptation strategies. A rise in non-farm income such as petty trading, woodworking and animal bartering provides extra financial capital which could allow farmers to invest in climate change adaptation strategies. The result of this study conforms to the study of Kassie et al. (2015) who found that non-farm income provided farmers with the additional financial power to adapt to climate change strategies such as the application of improved crop varieties and fertilizers.

The result reveals that climate information is an important variable in explaining the intensity of farmers' decision to adopt climate change adaptation strategies. The coefficient of climate information is positive and statistically significant in determining the intensity of the adoption of climate change by maize farmers. Access to climate information has been found to promote farmers' investment in adaptation methods in Ethiopia (Asrat and Simane, 2018). A study by Nhemachena et al. (2014) in Zimbabwe also showed that access to weather information is crucial in improving farmers' perception of climate change, therefore increasing the possibility of adopting adaptation strategies. For instance, climate information can be communicated via mass media devices such as radio. Radio could be used as a reliable source of information among the maize farmers in the study area.

Furthermore, the study results showed that the intensity to adopt the adaptation to climate change increases with improved access to credit facilities. The coefficient of access to credit variable positive and statistically significant in influencing the likelihood of maize farmers to adopt climate change adaptation strategies. This result is consistent with previous findings that access to credit is an important variable which commonly has a positive effect on adaptation behaviour (Caviglia-Harris, 2003), and thus increases adaptation to climate change (Fosu-Mensah et al., 2012).

Location variable in this study plays an essential role in shaping the farmers' intensity to adopt climate change adaptation strategies. The result shows the coefficient for the location of Osun State is positive and statistically significant. This suggests that maize farmers in Osun State are more likely to adopt an increased numbers of climate change adaptation strategies Since some geographical locations are more exposed to climate change, this could influence how farmers perceive climate change. Therefore, farmers at such locations possess a higher intensity to adopt climate change adaptation methods than others. For example, a location such as Vietnam is reported to be exposed to climate change as a result of its geographical location along the South China Sea coastal line (Waibel et al., 2018). Previous studies such as Hinkel (2011); Below et al. (2012) and Pandey et al. (2018) have also highlighted the importance of some specific locations in influencing farmers' choice of adaptation strategies.

Farmer's distance to the market shows a positive and significant relationship with the intensity of adopting climate change adaptation strategies. This result indicates that maize farmers that are closer to the market are more likely to adopt climate change adaptation strategies. The proximity to the market is a crucial determining factor of adaptation

as the market serves as a place of products and information exchange (Maddison, 2006; Tazeze et al., 2012). A shorter distance to the market allows maize farmers to purchase new crop varieties, new soil and water conservation technologies which represent strategies needed to cope with predicted future climate change.

4. Conclusion and policy recommendations

Climate is one of the most important factors in agricultural productivity, which could directly or indirectly influence productivity since the climate is linked to physiological processes. It is, therefore, essential to understanding the various strategies used by farmers to mitigate the adverse impact of climate change and the factors that influence maize farmers' adoption and intensity of climate change adaptation strategies among smallholder maize farmers in South-west Nigeria. In all, a total of three hundred and thirty (330) smallholder maize farmers were interviewed. The primary data was collected through a cross-sectional survey of maize farmers in the study area. However, 311 copies of questionnaire out of the 330 administered to the farmers had complete and adequate information for analysis implying a response rate of 94.24%. A double-hurdle count data model was employed to estimate the factors influencing farmers' adoption of adaptation strategies and intensity of adoption at the household level. Poisson model was employed to estimate the intensity of climate change adaptation techniques while accounting for selection bias. Significant variables such as household size, depreciation ratio, frequency of extension visits, access to extension, and non-farm income were factors influencing the adoption of climate change adaptation strategies among maize farmers. Age of the respondent, age square, household size, membership FBO, non-farm income, climate information, access to credit, location_Osun, distance to market significantly influenced the intensity of climate change adaptation strategies. This study, therefore, concluded that farm-level policy efforts that aim to improve rural development should focus on farmers' membership in FBO, increased visits of extension agents, non-farm income and access to climate change information that seek to engage the farmers, particularly during the off-cropping season. The income from non-farm employment can be plough-back into farm operations such as the adoption of soil and water conservation, use of improved planting varieties, mulching, among others to mitigate climate variability and subsequently increase productivity. Policies and investment strategies of the government should be geared towards supporting improved extension service, providing on-farm demonstration training, and disseminating information about climate change adaptation strategies, particularly for smallholder farmers in Nigeria. Investment in institutions such as extension services is essential for development and might encourage farmers to adopt appropriate climate change adaptation strategies. Thus, the government, stakeholders, and donor agencies must provide capacity-building innovations around the agricultural extension system on climate change using information and communication technologies.

Declarations

Author contribution statement

O.A Adeagbo: Conceived and designed the experiments; Performed the experiments.

T. O. Ojo: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

A.A. Adetoro: Analyzed and interpreted the data; Wrote the paper.

Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

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References

Abid, M.E.A., Scheffran, J., Schneider, U.A., Ashfaq, M., 2015. Farmers' perceptions of and adaptation strategies to climate change and their determinants: the case of Punjab province, Pakistan. Earth System Dynamics 6 (1), 225–243.

Asfaw, A., Simane, B., Bantider, A., Hassen, A., 2019. Determinants in the adoption of climate change adaptation strategies: evidence from rainfed-dependent smallholder farmers in north-central Ethiopia (Woleka sub-basin). Environ. Dev. Sustain. 21 (5), 2535–2565.

Asrat, P., Simane, B., 2018. Farmers' perception of climate change and adaptation strategies in the Dabus watershed, North-West Ethiopia. Ecol. Proc. 7 (1), 7.

Alabi, O.O., Abdulazeez, I., 2018. Economics of maize (Zea mays) production in igabi local government area, Kaduna state, Nigeria. Gaziosmanpaşa Üniversitesi Ziraat Fakültesi Dergisi 35 (3), 248–257.

Ali, A., Erenstein, O., 2017. Assessing farmer use of climate change adaptation practices and impacts on food security and poverty in Pakistan. Clim. Risk Manag. 16, 183–194.

Adem, A.A., Melesse, A.M., Tilahun, S.A., Setegn, S.G., Ayana, E.K., Wale, A., Assefa, T.T., 2014. Climate change projections in the upper gilgel abay river catchment, blue nile basin Ethiopia. In: Nile River basin. Springer, Cham, pp. 363–388.

Ayinde, O.E., Ajewole, O.O., Ogunlade, I., Adewumi, M.O., 2010. Empirical analysis of agricultural production and climate change: A case study of Nigeria. J. Sustain. Dev. Africa 2, 275–283.

Adesina, A.A., Baidu-Forson, J., 1995. Farmers' perceptions and adoption of new agricultural technology: evidence from analysis in Burkina Faso and Guinea, West Africa. Agric. Econ. 13 (1), 1–9.

Bamire, S.A., Abdoulaye, T., Amaza, P., Tegbaru, A., Alene, A.D., Kamara, A.Y., 2010. Impact of promoting sustainable agriculture in Borno (PROSAB) program on adoption of improved crop varieties in Borno State of Nigeria. J. Food Agric. Environ. 8 (3), 391–398.

Barnett, J., 2020. Climate change and food security in the pacific islands. In: Food Security in Small Island States. Springer, Singapore, pp. 25–38.

Belay, A., Recha, J.W., Woldeamanuel, T., Morton, J.F., 2017. Smallholder farmers' adaptation to climate change and determinants of their adaptation decisions in the Central Rift Valley of Ethiopia. Agric. Food Secur. 6 (1), 24.

Below, T.B., Mutabazi, K.D., Kirschke, D., Franke, C., Sieber, S., Siebert, R., Tscherning, K., 2012. Can farmers' adaptation to climate change be explained by socio-economic household-level variables? Global Environ. Change 22 (1), 223–235.

Boz, I., Akbay, C., 2005. Factors influencing the adoption of maize in Kahramanmaras province of Turkey. Agric. Econ. 33, 431–440.

Bryan, E., Ringler, C., Okoba, B., Roncoli, C., Silvestri, S., Herrero, M., 2013. Adapting agriculture to climate change in Kenya: Household strategies and determinants. J. Environ. Manag. 114, 26–35.

CBN, 2005. Annual report and statement of accounts Central Bank of Nigeria. Abuja Publication, Nigeria.

Coster, A.S., Adeoti, A.I., 2015. Economic effects of climate change on maize production and farmers' adaptation strategies in Nigeria: a Ricardian approach. J. Agric. Sci. 7 (5), 67.

Channa, H., Chen, A.Z., Pina, P., Ricker-Gilbert, J., Stein, D., 2019. What drives smallholder farmers' willingness to pay for a new farm technology? Evidence from an experimental auction in Kenya. Food Pol. 85, 64–71.

Chenu, C., Angers, D.A., Barré, P., Derrien, D., Arrouays, D., Balesdent, J., 2019. Increasing organic stocks in agricultural soils: Knowledge gaps and potential innovations. Soil Tillage Res. 188, 41–52.

Cameron, A.C., Trivedi, P.K., 1998. Regression Analysis of Count Data. Cambridge University Press, New York.

Caviglia-Harris, J.L., 2003. Sustainable agricultural practices in Rondonia, Brazil: do local farmer organizations affect adoption rates? Econ. Dev. Cult. Change 52 (1), 23–49.

Das, M., Das, A., Momin, S., Pandey, R., 2020. Mapping the effect of climate change on community livelihood vulnerability in the riparian region of Gangatic Plain, India. Ecol. Indicat. 119, 106815.

De Luca, G., Perotti, V., 2011. Estimation of ordered response models with sample selection. Stata J. 11 (2), 213–239.

Debalke, N.M., 2013. Determinants of Farmers' Preference for Adaptation Strategies to Climate Change: Evidence from north Shoa Zone of Amhara Region Ethiopia. MPRA Paper, p. 48753.

Denkyirah, E.K., Okoffo, E.D., Adu, D.T., Aziz, A.A., Ofori, A., Denkyirah, E.K., 2016. Modeling Ghanaian cocoa farmers' decision to use pesticide and frequency of application: the case of Brong Ahafo Region. SpringerPlus 5 (1), 1113.

Deressa, T.T., Hassan, R.M., Ringler, C., Alemu, T., Yesuf, M., 2009. Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. Global Environ. Change 19 (2), 248–255.

Ehiakpor, D.S., Danso-Abbeam, G., Baah, J.E., 2016. Cocoa farmer's perception on climate variability and its effects on adaptation strategies in the Suaman district of western region, Ghana. Cogent Food Agric. 2 (1), 1210557.

FAO, 2017. Food and Agriculture Organization (FAO). 3.02 billion people hungry. News release. Available at: http://www.fao.org/news/story/en/item/20568/icode/.

Fadina, A.M.R., Barjolle, D., 2018. Farmers' adaptation strategies to climate change and their implications in the Zou Department of South Benin. Environments 5 (1), 15.

Feder, G., Just, R.E., Zilberman, D., 1985. Adoption of agricultural innovations in developing countries: A survey. Econ. Dev. Cult. Change 33 (2), 255–298.

Fosu-Mensah, B.Y., Vlek, P.L., MacCarthy, D.S., 2012. Farmers' perception and adaptation to climate change: a case study of Sekyedumase district in Ghana. Environ. Dev. Sustain. 14 (4), 495–505.

Gautam, Y., Andersen, P., 2016. Rural livelihood diversification and household well-being: insights from Humla, Nepal. J. Rural Stud. 44, 239–249.

Greene, W.H., 2008. The econometric approach to efficiency analysis. Meas. Prod. Effic. Prod. Grow. 1 (1), 92–250.

Greene, W.H., 2003. Econometric Analysis. Pearson Education India.

Girei, A.A., Saingbe, N.D., Ohen, S.B., Umar, K.O., 2018. Economics of small-scale maize production in Toto local government area, Nasarawa state, Nigeria. Agrosearch 18 (1), 90–104.

Hampf, A.C., Stella, T., Berg-Mohnicke, M., Kawohl, T., Kilian, M., Nendel, C., 2020. Future yields of double-cropping systems in the Southern Amazon, Brazil, under climate change and technological development. Agric. Syst. 177, 102707.

Hasan, M.K., Kumar, L., 2019. Comparison between meteorological data and farmer perceptions of climate change and vulnerability in relation to adaptation. J. Environ. Manag. 237, 54–62.

Harding, M., Lamarche, C., Pesaran, M.H., 2020. Common correlated effects estimation of heterogeneous dynamic panel quantile regression models. J. Appl. Econom. 35 (3), 294–314.

Heckman, J.J., 1977. Sample Selection Bias as a Specification Error (With an Application to the Estimation of Labor Supply Functions) (No. W0172). National Bureau of Economic Research.

Hinkel, J., 2011. "Indicators of vulnerability and adaptive capacity": towards a clarification of the science–policy interface. Global Environ. Change 21 (1), 198–208.

Hitayezu, P., Wale, E., Ortmann, G., 2017. Assessing farmers' perceptions about climate change: A double-hurdle approach. Clim. Risk Manag. 17, 123–138.

Iken, J.E., Amusa, N.A., 2004. Maize research and production in Nigeria. Afr. J. Biotechnol. 3 (6), 302–307.

Ingham, B., Chirijevskis, A., Carmichael, F., 2009. Implications of an increasing old-age dependency ratio: The UK and Latvian experiences compared. Pensions 14, 221–230.

Kassie, M., Teklewold, H., Jaleta, M., Marenya, P., Erenstein, O., 2015. Understanding the adoption of a portfolio of sustainable intensification practices in eastern and southern Africa. Land Use Pol. 42, 400–411.

Katengeza, S., Mangisoni, J.H., Kassie, G.T., Sutcliffe, C., Langyintuo, A.S., La Rovere, R., Mwangi, W.M., 2012. Drivers of improved maize variety adoption in drought prone areas of Malawi. J. Dev. Agric. Econ. 4 (14), 393–403.

Kapur, B., Aydın, M., Yano, T., Koç, M., Barutçular, C., 2019. Interactive effects of elevated CO 2 and climate change on wheat production in the mediterranean region. In: Climate Change Impacts on Basin Agro-Ecosystems. Springer, Cham, pp. 245–268.

Kahil, M.T., Dinar, A., Albiac, J., 2015. Modeling water scarcity and droughts for policy adaptation to climate change in arid and semiarid regions. J. Hydrol. 522, 95–109.

Khan, I., Lei, H., Shah, I.A., Ali, I., Khan, I., Muhammad, I., Javed, T., 2020. Farm households' risk perception, attitude and adaptation strategies in dealing with climate change: promise and perils from rural Pakistan. Land Use Pol. 91, 104395.

Kirui, O.K., Okello, J.J., Nyikal, R.A., 2010. Awareness and use of m-banking services in agriculture: The case of smallholder farmers in Kenya.

Kusangaya, S., Warburton, M.L., Van Garderen, E.A., Jewitt, G.P., 2014. Impacts of climate change on water resources in southern Africa: a review. Phys. Chem. Earth, Parts A/B/C 67, 47–54.

Le Dang, H., Li, E., Nuberg, I., Bruwer, J., 2014. Understanding farmers' adaptation intention to climate change: a structural equation modelling study in the Mekong Delta, Vietnam. Environ. Sci. Pol. 41, 11–22.

Legesse, B., Ayele, Y., Bewket, W., 2013. Smallholder farmers' perceptions and adaptation to climate variability and climate change in Doba district, west Hararghe, Ethiopia. Asian J. Empir. Res. 3 (3), 251–265.

Maddala, G., 2001. Econometrics. McGraw-Hill, New York.

Maddison, D., 2006. The perception of and adaptation to climate change in Africa (CEEPA Discussion Paper No. 10). Centre for Environmental Economics and Policy in Africa. University of Pretoria, South Africa.

Mihiretu, A., Okoyo, E.N., Lemma, T., 2019. Determinants of adaptation choices to climate change in agro-pastoral dry lands of Northeastern Amhara, Ethiopia. Cogent Environ. Sci. 5 (1), 1636548.

Muench, S., Bavorova, M., Pradhan, P., 2021. Climate change adaptation by smallholder tea farmers: a case study of Nepal. Environ. Sci. Pol. 116, 136–146.

Neumann, K., Verburg, P.H., Stehfest, E., Müller, C., 2010. The yield gap of global grain production: a spatial analysis. Agr. Syst. 103 (5), 316–326.

Nhemachena, C., Mano, R., Mudombi, S., Muwanigwa, V., 2014. Climate change adaptation for rural communities dependent on agriculture and tourism in marginal farming areas of the Hwange District, Zimbabwe. Afr. J. Agric. Res. 9 (26), 2045–2054.

Nwaogu, C., Kassahun, T., Eneche, P.U., 2020. Climate change induced soil compaction: evaluating the adaptation measures to enhance maize yields in a tropical humid

acidic soil, Nigeria. In: Climate Change, Hazards and Adaptation Options. Springer, Cham, pp. 717–739.

NBS, 2016. National Bureau of Statistics (NBS). Nigerian gross domestic product report.

Oseni, G., McGee, K., Dabalen, A., 2014. Can Agricultural Households Farm Their Way Out of Poverty? The World Bank.

Ochenje, I.M., Ritho, C.N., Guthiga, P.M., Mbatia, O.L.E., 2016. Assessment of Farmers' Perception to the Effects of Climate Change on Water Resources at Farm Level: the Case of Kakamega County, Kenya (No. 310-2016-5390).

Ojo, T.O., Baiyegunhi, L.J.S., 2020a. Determinants of climate change adaptation strategies and its impact on the net farm income of rice farmers in South-west Nigeria. Land Use Pol. 103946.

Ojo, T.O., Baiyegunhi, L.J.S., Salami, A.O., 2019. Impact of credit demand on the productivity of rice farmers in South West Nigeria. J. Econ. Beh. Stud. 11 (1), 166–180.

Ojo, T.O., Baiyegunhi, L.J.S., 2020b. Determinants of credit constraints and its impact on the adoption of climate change adaptation strategies among rice farmers in South-West Nigeria. J. Econ. Str. 9, 1–15.

Omerkhil, N., Kumar, P., Mallick, M., Meru, L.B., Chand, T., Rawat, P.S., Pandey, R., 2020. Micro-level adaptation strategies by smallholders to adapt climate change in the least developed countries (LDCs): insights from Afghanistan. Ecol. Indicat. 118, 106781.

Pandey, R., Aretano, R., Gupta, A.K., Meena, D., Kumar, B., Alatalo, J.M., 2017. Agroecology as a climate change adaptation strategy for smallholders of Tehri-Garhwal in the Indian Himalayan region. Small-scale For. 16 (1), 53–63.

Pandey, R., Kumar, P., Archie, K.M., Gupta, A.K., Joshi, P.K., Valente, D., Petrosillo, I., 2018. Climate change adaptation in the western-Himalayas: household level perspectives on impacts and barriers. Ecol. Indicat. 84, 27–37.

Pradhan, P., Lüdeke, M.K.B., Reusser, D.E., Kropp, J.P., 2014. Food self-sufficiency across scales: how local can we go? Environ. Sci. Technol. 48 (16), 9463–9470.

Pradhan, Prajal, Fischer, Günther, van Velthuizen, Harrij, Reusser, Dominik E., Kropp, Juergen P., 2015. Closing yield gaps: how sustainable can we be? PloS One 10 (6), e0129487.

Petrick, M., 2004. Farm investment, credit rationing, and governmentally promoted credit access in Poland: a cross-sectional analysis. Food Pol. 29 (3), 275–294.

Raworth, K., 2007. Adapting to Climate Change: what's needed in poor countries, and who should pay. Oxfam Pol. Pract.: Clim. Change Resil. 3 (1), 42–88.

Rahut, D.B., Micevska Scharf, M., 2012. Livelihood diversification strategies in the Himalayas. Aust. J. Agric. Resour. Econ. 56 (4), 558–582.

Rathoure, A.K., Patel, U.R., 2020. Climate conditions and biodiversity decline: impact assessment. In: Current State and Future Impacts of Climate Change on Biodiversity. IGI Global, pp. 79–94.

Riccetto, S., Davis, A.S., Guan, K., Pittelkow, C.M., 2020. Integrated assessment of crop production and resource use efficiency indicators for the US Corn Belt. Global Food Sec. 24, 100339.

Sertoglu, K., Ugural, S., Bekun, F.V., 2017. The contribution of agricultural sector on economic growth of Nigeria. Int. J. Econ. Financ. Issues 7 (1).

Shumetie, A., Yismaw, M.A., 2018. Effect of climate variability on crop income and indigenous adaptation strategies of households. Int. J. Clim. Change Strateg. Manag.

Sinclair, F., Wezel, A., Mbow, C., Chomba, S., Robiglio, V., Harrison, R., 2019. The contribution of agroecological approaches to realizing climate-resilient agriculture. GCA, Rotterdam, The Netherlands.

Sylvester, O., 2020. Achieving food security in the face of inequity, climate change, and conflict. In: The Difficult Task of Peace. Palgrave Macmillan, Cham, pp. 277–295.

Siegfried, S., Hothorn, T., 2020. Count transformation models. Meth. Ecol. Evol.

Sato, G.J., Joshua, M.K., Ngongondo, C., Chipungu, F., Malidadi, C., Monjerezi, M., 2020. Evaluation of different tillage systems for improved agricultural production in drought-prone areas of Malawi. In: Climate Variability and Change in Africa. Springer, Cham, pp. 157–167.

Stringer, L.C., Fraser, E.D., Harris, D., Lyon, C., Pereira, L., Ward, C.F., Simelton, E., 2020. Adaptation and development pathways for different types of farmers. Environ. Sci. Pol. 104, 174–189.

Tambo, J.A., & Abdoulaye, T., 2012. Climate change and agricultural technology adoption: the case of drought tolerant maize in rural Nigeria. Mitig. Adapt. Strateg. Glob. Chang. 17 (3), 277–292.

Tazeze, A., Haji, J., Ketema, M., 2012. Climate change adaptation strategies of smallholder farmers: the case of babilie district, East harerghe zone of oromia regional state of Ethiopia. J. Econ. Sustain. Dev. 3 (14), 1–12.

Talanow, K., Topp, E.N., Loos, J., Martín-Lòpez, B., 2021. Farmers' perceptions of climate change and adaptation strategies in South Africa's Western Cape. J. Rural Stud. 81, 203–219.

Thennakoon, J., Findlay, C., Huang, J., Wang, J., 2020. Management adaptation to flood in guangdong province in China: do property rights matter? World Dev. 127, 104767.

Thinda, K.T., Ogundeji, A.A., Belle, J.A., Ojo, T.O., 2020. Understanding the adoption of climate change adaptation strategies among smallholder farmers: evidence from land reform beneficiaries in South Africa. Land Use Pol. 99, 104858.

Tumbo, S.D., Mutabazi, K.D., Mourice, S.K., Msongaleli, B.M., Wambura, F.J., Mzirai, O.B.,, et al., 2020. Integrated assessment of climate change impacts and adaptation in agriculture: the case study of the wami river sub-basin, Tanzania. In: Climate Variability and Change in Africa. Springer, Cham, pp. 115–136.

Ureta, C., González, E.J., Espinosa, A., Trueba, A., Piñeyro-Nelson, A., Álvarez-Buylla, E.R., 2020. Maize yield in Mexico under climate change. Agric. Syst. 177, 102697.

Umar, S.Y., Elinwa, A.U., Matawal, D.S., 2015. Hydraulic conductivity of compacted lateritic soil partially replaced with metakaolin. J. Environ. Earth Sci. 5 (4), 53–64.

Waibel, H., Pahlisch, T.H., Völker, M., 2018. Farmers' perceptions of and adaptations to climate change in Southeast Asia: the case study from Thailand and Vietnam. In: Climate Smart Agriculture. Springer, Cham, pp. 137–160.

Wooldridge, J.M., 2002. Inverse probability weighted M-estimators for sample selection, attrition, and stratification. Portuguese Econ. J. 1 (2), 117–139.

Wollni, M., Lee, D.R., Thies, J.E., 2010. Conservation agriculture, organic marketing, and collective action in the Honduran hillsides. Agric. Econ. 41 (3-4), 373–384.

Zakaria, A., Alhassan, S.I., Kuwornu, J.K., Azumah, S.B., Derkyi, M.A., 2020. Factors influencing the adoption of climate-smart agricultural technologies among rice farmers in northern Ghana. Earth Syst. Environ. 1–15.

Zadawa, A.N., Omran, A., 2020. Rural development in africa: challenges and opportunities. In: Sustaining Our Environment for Better Future. Springer, Singapore, pp. 33–42.

Zeng, Y., Zhang, J., He, K., Cheng, L., 2019. Who cares what parents think or do? Observational learning and experience-based learning through communication in rice farmers' willingness to adopt sustainable agricultural technologies in Hubei Province, China. Environ. Sci. Pollut. Control Ser. 26 (12), 12522–12536.