Determinants of Adaptation Strategies to Climate Change among Rice Farmers in Southwestern Nigeria: A Multivariate Probit Approach

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Abstract:

The study analyzed the determinants of rice farmers' climate change adaptation strategies in Southwestern Nigeria. A multistage sampling technique was used to collect cross sectional data from 360 rice farmers selected from three States in the region. Out of 11 adaptation strategies identified by the farmers, the five main identified adaptation strategy options were subsequently used as the dependent variables in the multivariate probit model. The result of the Multivariate Probit Model indicated that some household characteristics, access to services and location significant and statistically influenced the choice of adaptation strategies employed by the farmers in the study area. It is obvious the farmers are aware of long-term changes in climatic factors (temperature and rainfall, for example), they are unable to identify these changes as climate change. However, the positive pair wise correlation matrix from the MVP model indicate complementarities among all the adaptation strategies used by the farmers. The government could build the capacity of agricultural extension systems and make available climate change education scheme with ICT innovations. Government policies and investment strategies must be geared towards the support of education, credit and information about adaptation to climate change, including technological and institutional methods, particularly for smallholder farmers in the country.

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1.0 Introduction

Agricultural risks, such as climate risks are dominant in both developed and developing countries, although the major sources and consequences may differ across countries, most farmers in these countries largely experience them (Harlan et al. 2015). Agriculture in sub-Saharan Africa (SSA) is an important sector of the economy serving as a stimulus for growth, assisting in poverty reduction and the provision of food security. In spite of this, food insecurity and poverty remains critical issue for most developing countries in SSA. One of the numerous reasons of food insecurity and poverty is traceable to agriculture's susceptibility to production risks, which affect farmers' income and welfare (Cervantes-Godoy, Kimura & Antón, 2013). As the African populace strive to overcome poverty and advance economic growth, these production risks portend to deepen vulnerabilities and the prospect of development is seriously undermined (Zoellick, 2009). Agricultural production activities in Africa are generally more susceptible to climate change than other socioeconomic sectors (Kurukulasuriya et al., 2006; Hassan & Nhemachena, 2008). Rural farmers in Sub-Saharan Africa are likely to be more vulnerable to climate change, particularly because of compounding challenges of poverty, low infrastructural and technological development, and high dependence on rain-fed agriculture (Ericksen et al., 2011; Lipper et al., 2014; Nelson et al., 2014; Adimassu and Kessler, 2014). Studies have shown that more than 95% of agricultural production in sub-Saharan African is rain-fed (Simelton et al. 2013; Adebisi-Adelani and Oyesola 2014; and Zake and Hauser, 2014). According to Jones & Thornton (2003), the crop yield projection for Africa may fall by 10-20% by 2050 or even up-to 50% due to climate change.

Many climate change indicators are reported in literature even though there are variations with location. Erratic rainfall often combined with intermittent dry spells, salt stress, drought, flood and change in temperature are commonly reported indicators in most studies (Adger et al., 2003; Ajetomobi., 2010; Agbo, 2013; Okonya, et al, 2013; Tripathi, et al., 2014). Farmers may thus be aware of climate change, but the degree of awareness of its short and long-term causes and consequences may vary among the farmers. In the same vein, some farmers may not perceive climate change and its effects while others may not be bothered (Deressa, et al, 2009; Okonya et al., 2013). For example, age, low level of education, ignorance, lack of information; lack of credit facilities and off-farm activities could be the reasons for farmers' low level of perception on climate change (Deressa, et al, 2011). Several studies (Agarwal, 2008; Deressa et al. 2008; Apata, 2009; Ajetomobi et al; 2010; Di Faclo et al. 2011) have examined the effects of weather variations on crop production including rice and different adaptation practices employed by farmers in SSA and beyond. However, the outcome in a given location depends on the magnitude of these changes, the response of the particular crops and location-specific management.

Despite these serious climate-related difficulties in SSA countries including Nigeria, is possible to develop adaptive responses that could mitigate these effects. Empirical evidence recognizes that adaptation to climate change can potentially reduce its adverse effects, protect the livelihoods of poor farmers and reinforce any potential advantages it may bring (Gandure et al., 2013; Wheeler et al., 2013). Adaptation refers to an adjustment in natural or human systems in response to actual or expected climatic conditions or risks and can be regarded as a policy option to contain the negative effects of climate change (Kurukulasuriya and Mendelsohn, 2008a). Agriculture is an important sector of the Nigerian economy where adaptation to climate change could be usefully applied, in particular to rice production. Despite the declining share in the gross domestic product (GDP), agriculture remains a major contributor to the Nigerian economy. It represents a critical source of income for the majority of the population, directly employing about 60% of the total labor force (Adeoti, 2002). Furthermore, rural communities, that represent the vast majority of the population, will continue to depend on agriculture even with structural change in the economy (World Bank, 2013).

Rice is one of the most important food crops in Nigeria, its economic activities related to production, processing, distribution, and consumption are widely considered a key for economic development, food security, and poverty reduction (Tollens, 2006; Velde & Maertens, 2014 and Demont and Ndour, 2015). Consumption of rice has already outpaced domestic production and as a result, Nigeria is the leading importer of rice in the world today, with an 8.2 percent share of imports in the global market (Gyimah-Brempong et al. 2016). This has made the Nigerian government to actively intervene in the rice economy over the past few decades. In November 2016, FMARD announced a plan to facilitate the procurement of 40 new large integrated rice mills. This plan would almost triple the current number of such mills that are operational in the country. Johnson and Masias (2016) found that the large integrated rice milling sub-sector had the most potential to compete with imports, but often has operated well below maximum capacity due to insufficient access to high-quality paddy which is traceable to climate change variability.

According to Manneh et al., (2007), Climate change through extreme temperatures, frequent flooding, drought and increased salinity of water supply used for irrigation in rice fields also constitute factors that affect agricultural productivity. Adoption of adaptation strategies therefore remains an imperative option to mitigate against the effect of climate change and also address its challenges prevailing on rice production (Deressa et al. 2008; Di Faclo et al. 2011). This has a laudable relevance for developing countries seeking to maintain food security if planned with the long-term policy priority among poor farmers (Di Faclo et al. 2011; Tubiello 2012).

Past studies (Pearce *et al*. 1996; McCarthy *et al*. 2001; Parry *et al*. 2004; Nkomo *et al*, 2006; Stern 2007; Deressa, *et al*, 2008; Apata *et al*, 2009), that have examined the impact of climate change on food production at the country, regional, or global level, have failed to provide critical insights in terms of the determinants of choice of adaptation strategies used by the rice farmers; although ideas from these studies created the background for the present study. Studies on the impact of climate change (particularly rainfall and temperature) and climate related adaptation measures on crop yield such as rice in Southwestern Nigeria are very scanty. A review of literature on climate change, e.g. Liu *et al*, (2004) Mendelsoln *et al,* (2004), De-wit *et al* (2006), Kurukulasuriya & Mendelsohn, (2006), Deresa (2007), Yesuf *et al* (2009), Apata *et al* (2009), Ajetomobi et al (2010) and Ayanlade et al (2017), show that more attention has been paid to climate change system modeling, climate change impacts, mitigation and risk assessment, with relatively little attention to perceptions and adaptation options for those experiencing climate change. It is against this backdrop that this study attempted to investigate the determinants of climate change adaptation strategies adoption by rice farmers in Southwestern Nigeria.

2.0 Conceptual framework

Households make adoption decisions to maximize their expected utility. Household utility is a function of expected costs and benefits of adoption as well as their preferences, which are influenced by various factors. Adaptation strategies are a form of protection measure that reduce the farmers' risk exposure by reducing the marginal effect of climate change on productivity

(Fisher-Vanden and Wing, 2011). The study used the theory of utility maximization in the presence of risk to conceptualize climate change adaptation decisions. In this case, the utility to a farmer is not defined by higher yields. In the context of adaptation, the utility derived from adopting a practice could be yield stability and the implied reduction in risk. A risk-averse farmer maximizes utility by choosing an adaptation strategy if the benefits of adaptation (risk reduction) minus the cost of adaptation are higher than the benefits realized without adapting. Following Hazell and Norton (1986), a farmers' utility function is defined as follows:

$$U_y = E_y - \alpha\omega_y \tag{1}$$

Where U_y is the perceived utility from choosing adaptation strategy y, E_y is the nonstochastic component and ω_y is the disturbance term indicating variation in yields, α is a coefficient that captures risk aversion of individual farmers which would affect the degree of the variability in the yields ω_y. Following Finger & Schmid (2007), the coefficient is expressed as;

$$\alpha = -(\partial U/\partial \omega y)\,/\,(\partial U/\partial y) \tag{2}$$

Where if $\alpha < 0$, the farmer is risk averse and thus more likely to adapt; $\alpha = 0$ indicates a risk neutral farmer and $\alpha > 0$ indicates a risk preferred. The utility of implementing an adaptation strategy y (Uy) is given by the revenue generated by the strategy less the variable costs incurred in implementation of the adaptation strategy. Given the choices of adaptation strategies, a risk-averse farmer will choose the strategy, say X that yields higher expected utility than the alternatives, say Y, i.e.

$$E(U_x) - M_x > (U_y) - M_y \tag{3}$$

Where the (U_x) is the expected utility of implementing strategy X and the associated costs Mx, while the second term U_x is the expected utility of implementing strategy Y and associated cost M_y. Assumptions about the relationship of disturbance terms of the adaptation equations i.e. whether correlated or not, determine the type of qualitative choice model to use in analysis.

2.1 Empirical MVP model for the Determinants of Adaptation Strategies to Climate Change

When farmers are faced with adverse climatic changes, they may opt to adopt a mix of strategies as a way of mitigation rather than relying on a single strategy to exploit complementarities or substitutability among alternatives. Thus, in addition to adopting a particular adaptation strategy, a farmer may choose other strategies. Adoption could be partly dependent on earlier adopted strategies informing decisions on subsequent practices in the future (Kassie et al., 2013; Lin et al., 2005). This study used a multivariate probit (MVP) econometric technique, which simultaneously models the influence of the set of explanatory variables on each of the adaptation strategies, while allowing the unobserved factors (error terms) to be freely correlated (Belderbos et al. 2004; Lin et al. 2005). The source of correlation may be complementarities (positive correlation) and substitutabilities (negative correlation) between different adaptation strategies (Belderbos et al. 2004). The study follows Lin et al. (2005) in formulating the multivariate model, the dependent variables were five dummy variables: soil and water conservation (SWC); varying planting and harvesting date (VPHDATE); agrochemicals, improved variety and mixed cropping equals to one if the household adopts the adaptation strategy option and zero if otherwise. The summary statistics of the identified major adaptation strategies are presented in Table 1

$$Y_{ik}^{*} = \beta_k X_{ik} + \alpha_k A_{ik} + \varepsilon_k \qquad \text{where } (k = 1,\dots,m) \qquad (4)$$

$$Y_{ik} = 1 \;\; if Y_{ik}^{*} > 0 \text{ and 0 otherwise}$$

Where Y_{ik}^{*}, a latent variable which captures the observed and unobserved preferences is associated with k^{th} climate change adaptation strategies and Y_{ik} denotes the binary dependent variables, $(k = 1,\dots,m)$ represents the various adaptation strategies used by the farmers. Farmers who practice adaptation strategies are adopters and non-adopters are those who did not. The adopters of these adaptation strategies take value 1 and 0 otherwise. X_{ik} is a vector of the explanatory variables which denotes the observed household and farm-specific characteristics, as well as institutional variables. Following Wooldridge (2003), A_{ik} denotes climate change variables such as annual means of temperature and precipitation to account for unobserved heterogeneity. β_k and α_k are conformable vectors to be estimated. From eq. (4), positive correlations between the error terms (ε_k) of adaptation strategies indicate complementarity between strategies, while negative correlations reveal substitutability. The error term, ε_k have multivariate normal distributions, with zero means, unitary variance and an n×n correlation matrix (Mulwa et al., 2015). Where $\varepsilon_k \approx MVN(0, \Pi)$ and the covariance matrix Π is given by:

$$\Pi = \begin{vmatrix} 1 & \rho_{12} & \rho_{13} & \cdots & \rho_{1m} \\ \rho_{21} & 1 & \rho_{23} & \cdots & \rho_{2m} \\ \rho_{31} & \rho_{32} & 1 & \cdots & \rho_{3m} \\ \vdots & \vdots & \vdots & 1 & \vdots \\ \rho_{m1} & \rho_{m2} & \rho_{m3} & \cdots & 1 \end{vmatrix} \qquad 5$$

Where ρ represents the unobserved correlation between the stochastic components of the error terms with regards to any two of the adoption equations to be estimated in the model. In Equation (5), the correlation between the stochastic components of different adaptation strategies adopted is represented by the off-diagonal elements (e.g. ρ_{21}, ρ_{12}, ρ_{31}, and ρ_{13}) in the variance-covariance matrix (Teklewold, Kassie, and Shiferaw 2013). The assumption of the unobserved correlation between the stochastic component of the k^{th} and m^{th} type of adaptation strategies means that equation (4) gives a MVP model that jointly represents decisions to adopt a particular adaptation strategy. This specification with non-zero off-diagonal elements allows for correlation across the error terms of several latent equations, which represent unobserved characteristics that affect choice of alternative adaptation strategies.

2.2 Dependent variables

The adaptation strategies farmers employed to mitigate against the effect of climate change include varying land size, sales of crops, varying the planting and harvesting dates; soil conservation techniques; mulching. Other adaptation strategies include, livestock rearing; mixed cropping, mono-cropping and no adaptation. These strategies can also be used to modify the length of the growing season, for instance by using water conservation techniques. The dependent variable in the empirical estimation for this study is the choice of an adaptation option from the set of adaptation measures listed in Table 1. Resource limitations coupled with household characteristics and poor infrastructure limit the ability of most farmers to take up adaptation measures in response to changes in climate (Kandlinkar & Risbey, 2000). For the purpose of this study, Table 1 summarizes the adaptation strategies employed by rice farmers. Out of 11 adaptation strategies identified by the farmers, the five main identified adaptation strategy options are used for empirical estimation.

Table 1: Distributions of Adaptation Strategies employed by the Rice Farmers in South western Nigeria

Variables	Percentage	SD
Land size	0.46	0.50
Sales of crop	0.58	0.49
Improved variety	**0.70**	**0.46**
Agrochemical	**0.68**	**0.47**
VPHDATE	**0.70**	**0.46**
mulching	0.59	0.49
Livestock	0.60	0.49
Mixed cropping	**0.66**	**0.47**
Mono-cropping	0.54	0.50
SWC	**0.67**	**0.47**
No adaptation	0.48	0.50

SD: Standard deviation, VPHDATE: Varying planting and harvesting date, SWC: Soil and water conservation

2.3 Explanatory variables used in the empirical model

The choice of explanatory variables is dictated by theoretical behavioral hypotheses, empirical literature and data availability. The explanatory variables considered in this study consist of seasonal climate variables and socioeconomic factors.

Age influences farmers' exposure to different farming systems, experiences and seasons. Thus, it is expected that farmers' age will positively affect his/her perception on climate change (Shiferaw & Holden, 1998). In this study, age is hypothesized to have both positive and negative impacts on the choice of adaptation strategies (or climate change adaptation adoption)

Various studies have shown that gender is an important factor affecting adoption decision at the farm level. Female farmers have been found to be more likely to adopt natural resource management and adaptation practices (Dolisca et al., 2006; Bayard et al., 2007). However, Bekele & Drake, (2003) found that household gender was not a statistically significant factor influencing farmers' decisions to adopt adaptation measures

Education and farming experience are important factors influencing farmers' decision on adopting the choice of adaptation strategy. Several studies have shown that improving education and disseminating knowledge is an important policy measure for stimulating local participation in various development and natural resource management initiatives (Glendinning et al., 2001; Dolisca et al., 2006; Anley et al., 2007; Tizale 2007). It is therefore expected that education will positively influence farmers' decisions to take up adaptation strategies.

Large household size could help harmonize, perceive, discuss and share climate related observations which could affect positively the perception of farmers on climate change. A larger household size can depend mainly on hired labour, which results in poor perception on climate change. Family size could thus influence positively or negatively the farmers' perception on climate change (Shiferaw & Holden, 1998).

The credit access variable was categorized into those farmers who accessed credit (=1) and those who did not (=0). Credit access relaxes liquidity constraints thus increasing technology adoption (Simtowe and Zeller, 2006). Thus, a positive relationship between credit access and the probability of adopting climate change adaptation strategies is expected. Access to climate information, farmer's access to regular climate information sources such as radio, television, and newspaper could improve perception on climate change and vice-versa. Better climate, and agricultural information helps farmers choose strategies that enable them to cope well with changes in climatic conditions (Baethgen et al., 2003). Accordingly and in line with technology adoption literature, farmers' access to extension contact is expected to increase their perceptions on climate change (Amsalu and de Graaff, 2007).

Location variables (Ekiti, Ondo and Osun State) were used in the MVP model to control for locational differences. These are dummy variables '1' if a farmer belongs to that location and '0' otherwise. The dummies are to account for locational differences due to agro-climatic conditions among the three regions, which are expected to have an impact on farmers' decisions to adopt the choice of adaptation strategies.

3.0 The study area and method of data collection

The study was carried out in southwestern part of Nigeria. Southwestern Nigeria consists of Lagos, Ogun, Oyo, Osun, Ondo and Ekiti States, collectively known as the South West geographical zone of Nigeria. The area lies between longitude 2^0 31^1 and 6^0 00^1East and Latitude 6^0 21^1 and 8^0 37^1N with a total land area of 77,818 km^2 and a projected population of 28, 767, 752 in 2002. It 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 Gulf of Guinea. The climate of Southwest Nigeria is tropical in nature and it is characterize by wet and dry seasons. The temperature ranges between 21^0 C and 34^0 C while the annual rainfall ranges between 150mm and 3000mm. 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. The vegetation is Southwest Nigeria is made up of fresh water swamp and mangrove forest at the belt, the low land in forest stretches inland to Ogun and part of Ondo State while secondary forest is towards the northern boundary where derived and southern Savannah exist (Agboola, 1979). The major source of occupation and income in the South West is agriculture. The food crops include maize, yam, cassava, rice and cowpea while the cash crops include cocoa, oil palm, kolanut, plantain, banana, cashew, citrus and timber.

A multistage sampling technique was used to select the respondents in the study area. The first stage involved a purposive selection of three States namely; Ekiti, Ondo and Osun and the second stage with the same technique was used to select four Local Government Areas (LGAs) from each State based on the predominance of smallholder rice farmers in these areas. The third stage involved a random selection of 5 villages each from the four LGAs selected in the second stage. While the last stage involved a random selection of 6 smallholder rice farmers in each of the villages to have a total of 360 respondents used for the study. Data were collected using a pre-tested, well-structured questionnaire on socio-economic characteristics of the respondents, adaptation strategies to climate change, determinants of adaptation strategies and as well as the costs and returns to rice production. To take advantage of the rapidly growing technological advancements that appreciates the limited available resources, an Open Data Kit (ODK) software was used to obtain data rapidly while ensuring the quality, integrity and cost implications. ODK is an open-source survey platform designed as a local application that can be installed on mobile devices on the Android operating system. ODK is widely used in field research and data collection, as it allows researchers to design surveys that enable responses to survey tasks (coded to include standard data collection inputs such as open text inputs, check boxes, dropdown menus, as well as smartphone-specific tools such as images, locations, and free-form sketches) with finger taps and swipes (Francis et al., 2010 and Brunette et al,. 2013). In respect of climate variables, January to December monthly means for precipitation and average temperature from 1970 to 2014 was specifically obtained from Nigeria Meteorological Agency at Oshodi in Lagos Nigeria and International Institute for Tropical Agriculture (IITA) in Ibadan, Nigeria

Table 2: Definitions and summary statistics of variables used in the model

Variables	Description of Variables	Mean	SD
Dependent			
Mixed cropping	Dummy = 1 if HH chooses Mixed cropping, 0 otherwise	0.66	0.47
Improved variety	Dummy = 1 if HH chooses Improved variety 0 otherwise	0.70	0.46
SWC	Dummy = 1 if HH chooses Soil and Water conservation 0 otherwise	0.67	0.47
Agrochemical	Dummy = 1 if HH chooses Agrochemicals, 0 otherwise	0.68	0.47
VPHDATE	Dummy = 1 if HH chooses Varying planting and harvesting dates 0 otherwise	0.70	0.46
Independent			
Gender	Dummy=1 if HH head male and 0 if female	0.56	0.50
Age of the HH head	Age of HH head in years	47.28	7.67
Marital Status	Dummy = 1 if HH head is married, 0 others single, widowed	0.80	0.40
Educational Status	Years of education of the HH head	6.45	5.70
Household size	Number of HH size	4.66	1.24
Off-farm income	1 = if HH engages in any off-farm activity	0.54	0.50
Farming exp.	Years of household experience in rice production	15.73	5.09
Access to credit	Dummy = 1 if HH had access to credit, 0 otherwise	0.57	0.50
Farm size	Total land owned by the HH in hectares	7.37	3.04
Acc to climate info	Dummy = 1 if HH had access to any information on climate change, 0 otherwise	0.36	0.48
Access to ext. contacts	Dummy = 1 if HH had access to government extension, 0 otherwise	0.53	0.50
Membership	Dummy=1 if HH belongs to Farmers' Association	0.54	0.50
Mean annual tempt	Mean of annual Temperature	27.66	0.05
Mean annual Ppt	Mean of annual Precipitation	111.05	16.09
Location_Ekiti State	Dummy = 1 if HH is from Ekiti, 0 otherwise	0.38	0.48
Location_Ondo State	Dummy = 1 if HH is from Ondo, 0 otherwise	0.38	0.49
Location_Osun State	Dummy = 1 if HH is from Osun, 0 otherwise	0.35	0.48

The results in Table 2 show that the average age and years of education of the household head were 47 years and six years, respectively. On extension access, about 53% of the respondents had contacts extension agents. Access to credit is a major determinants in adoption of adaptation strategies, about 57% of the sampled households had access to credit. However, there are clear differences in terms of access to information, for instance, about 36% of the farmers who adopted at least one strategy had access to climate related information.

Table 3: Correlation matrix of the choice of adaptation strategies from MVP model

	SWC	VPHDATE	Mixed cropping	Agrochemicals	Improved variety
SWC		0.409(0.110)	0.337(0.097)[c]	0.537(0.085)[c]	0.641(0.091)[c]
VPHDATE			0.738(0.070)[c]	0.839(0.048)[b]	0.787(0.069)[c]
Mixed cropping				0.754(0.061)[c]	0.746(0.084)[c]
Agrochemicals					0.928(0.042)[b]
Improved variety					
Likelihood ratio test (Chi2)		chi2(10) =	249.042		
P-value		0.000			
Joint Probability (Success)		0.458			
Joint Probability (Failure)		0.166			
Linear Predictions					
SWC		0.78			
VPHDATE		0.75			
Mixed cropping		0.68			
Agrochemicals		0.65			
Improved variety		0.79			

b, c represent significance level at 5 &10%

4.0 Determinants of Rice farmers' choice of Adaptation Strategies to Climate Change

This section discusses the results from the multivariate probit model. The likelihood ratio test (chi2 (10) = 249.042, P > 0.000) of the independence of the error terms of the different adaptation equations is rejected (Table 2). Thus, this study adopt the alternative hypothesis of the mutual interdependence among the multiple adaptation strategies. The result therefore supports the use of multivariate probit model. All the pairwise coefficients are also positively correlated indicating complementarity among these strategies. The results show that the joint probability of adopting the choice of adaptation strategies is approximately 46% while not adopting the choice is 17%. It can also be inferred from the linear predictions of the result that the likelihood of adopting SWC is 78%, while it is 75% for VPHDATE. The linear predictions for mixed cropping, agrochemicals and improved variety are 68%, 65% and 79%, respectively.

Table 4: Estimates of the MVP for the Determinants of Adaptation Strategies to Climate Change

Variables	**SWC**		**VPHDATE**		**Mixed cropping**		**Agrochemical**		**Improved variety**	
	Coef.	Std.Err	Coef.	Std.Err	Coef.	Std.Err	Coef.	Std.Err	Coef.	Std. Err
Gender	0.086	0.18	-0.033	0.189	0.049	0.17	0.038	0.178	0.097	0.197
Age of household head	0.000	0.012	0.005	0.012	**-0.029**[b]	0.011	-0.019	0.012	**-0.026**[b]	0.013
Educational status	-0.003	0.018	-0.002	0.019	-0.014	0.017	0.029	0.019	0.001	0.024
Household size	**0.180**[b]	0.075	0.027	0.075	-0.054	0.07	-0.02	0.071	0.1	0.075
Off farm income	**0.758**[b]	0.38	0.567	0.359	0.527	0.359	**0.734**[b]	0.369	**1.260**[a]	0.371
Farming experience	0.009	0.021	**-0.051**[b]	0.022	-0.013	0.02	-0.013	0.021	-0.009	0.025
Credit access	0.399	0.242	-0.302	0.231	**0.501**[b]	0.234	0.173	0.224	**0.430**[c]	0.246
Farm size	-0.053	0.033	0.032	0.036	0.02	0.032	0.027	0.034	**0.075**[c]	0.04
Acess to extenson	0.384	0.947	0.039	0.913	**1.415**[b]	0.565	-0.027	0.71	**2.470**[a]	0.541
Membership of Ass.	1.338	0.912	**2.000**[b]	0.913	0.282	0.567	**1.887**[a]	0.635	-0.668	0.527
Annual temp	**4.096**[b]	1.926	-0.926	2.61	-3.149	2.41	-3.651	2.542	-3.418	2.784
Annul ppt	0.061	0.012	0.014	0.011	**0.028**[a]	0.01	0.011	0.011	**0.034**[b]	0.014
Location_Ekiti	0.085	0.236	**0.533**[b]	0.246	**0.904**[a]	0.235	**0.472**[b]	0.234	0.166	0.266
Loc_Ondo	-0.065	0.223	-0.169	0.225	-0.07	0.216	0.093	0.221	-0.378	0.254
Loc_Osun	0.195	0.254	0.019	0.287	0.284	0.263	0.268	0.278	0.23	0.306
Constant	-121.315	53.642	23.915	72.397	84.989	66.73	99.588	70.538	90.83	77.024

a, b and c represent significance level at 1%,5% &10%

4.1 Household Characteristics

Among farmers' socio-economic characteristic variables that are statistically significant, the age of the household head exhibited a negative relationship in influencing the decision to adopt the choice of "mixed cropping and improved variety" but not significant with other adaptation strategies. The negative relationship suggests that younger farmers are more likely to adopt compared to their older counterparts possibly for being innovative and keen to try new technology and methods to improve agriculture. Older farmers could not be aware of recent innovations in agriculture and/or are reluctant to try new methods (Ali and Erenstein, 2016). The result is also in consonance with the study of Denkyirah et al. (2016) who found a negative effect of age on adoption of pesticides. The coefficient of household size is positive and statistically significant in influencing only the choice of "soil and water conservation adaptation strategy". A positive association between household size and climate change adaptation strategies has also been found in several studies (Croppenstedt et al., 2003; Deressa et al., 2009; Abid et al., 2015, Ali and Erenstein, 2016). This association could be attributed to the ability of the household to supply surplus labor to non-farm activities and the income generated could be invested in climate change adaptation strategies as found by (Lanjouw and Lanjouw, 2001; Reardon et al., 2007; Rahut and Micevska Scharf, 2012; Gautam and Andersen, 2016)

4.2 Household Assets

Recent empirical evidence has shown that household assets have a great influence on the adoption of farm technology (Mmbando and Baiyegunhi 2016). In line with Fernandez-Cornejo and Mishra, (2007), households that have access to off-farm income are likely to adapt to climate change. The coefficient of off farm activities is positive and statistically significant in influencing the choice of "soil and water conservation, agrochemicals and improved varieties". Farmers who engage in off-farm activities can purchase chemical inputs, invest in conservation of soil and also improved varieties as their financial constraints may be overcome by being involved in off-farm income activities. This is in line with study by Danso-Abbeam and Baiyegunhi (2017) who found a positive relationship between off-farm income and adoption of agrochemical management practices. Land is a major agricultural productive asset and wealth indicator. Farm size is positive and statistically significant in influencing only the choice of "planting improved varieties adaptation strategy". This is in line with the generally reported positive association between farm size and technology adoption (Tiwari et al., 2009; Bamire et al., 2010; Bryan et al., 2013; Abid et al., 2015). Farmers with large landholdings are likely to have more capacity to try out and invest in climate risk adaptation strategies through the use of improved varieties. The coefficient of years of experience in farming is negative and statistically significant in influencing the choice of "varying planting and harvesting date adaptation strategy". This implies that years of farming experience significantly decreases the probability of choosing varying planting and harvesting date adaptation strategy

4.3 Access to services

The coefficient of access to extension services is positive and statistically significant in influencing the choice of "mixed cropping and improved variety adaptation strategies", likely denoting the role of access to information and other resources which empower the farm household to adopt such climate-risk coping strategies (Abid et al., 2016). This finding aligns with other studies, including those that show positive effects of institutional membership (Adesina et al., 2000) and extension services (Deressa et al., 2009), with extension services enhancing the availability of information on climate risk and adaptation options (Maddison, 2007; Nhemachena and Nhem, 2007). The role of extension services is very critical in the perception of and adaptation to climate change. As posited by Bryan et al., (2013) farming households that did not receive extension agents' visits are more likely to either not perceive climate change or perceive it wrongly. Contact with extension represents sources of information (such as TV, radio, magazine, newspaper, personal observation, development agents, etc.) required to make decision to adopt climate change adaptation strategies. An individual exposed to climate information is more likely to take an immediate action to cope with risks related to climate change.

Empirical findings have indicated that access to credit is a major determinant of climate change adaptation decision. With resource limitations, farmers may fail to meet the costs of adaptation and at times cannot make beneficial use of available information (Kandli and Risbey, 2000). Recent studies (Gyinadu, Bakang, and Osei 2015; Mmbando and Baiyegunhi 2016) also opined that inadequate funds or a lack of funds have impeded adoption of farm management practices in developing economies. The coefficient of access to credit is positive and statistically significant for the choices of mixed cropping and use of improved varieties adaptation strategies. Adaptation strategies can be expensive with some requiring the purchase of new improved seeds while others are capital intensive. Thus, in the absence of credit, farmers may find it difficult to adopt any adaptation strategy even when provided with information on climate change, as they might not be able to purchase the requisite inputs.

The coefficient of membership of association is positive and statistically significant in influencing "varying planting and harvesting date as well agrochemical" adaptation strategies. This could be attributed to the fact that members of farmers' groups can share experiences and exchange information about new technologies when they meet (Kassie et al., 2013). Group membership can, therefore, enhance social learning and knowledge spill-over (Bandiera and Rasul, 2006) about agrochemicals. Information may shape problem awareness and attitudes important in framing the expectations of farmers towards resource problems and choice of a farming practice (Place and Dewees, 1999).

4.4 Location

Location typically plays an important role in climate change adaptation (Vincent, 2007; Tiwari et al., 2008; Hinkel, 2011; Below et al., 2012). The coefficient for the location of Ekiti State is positive and statistically significant in influencing choice of adaptation strategies through the use of "agrochemical, mixed cropping and as well as varying planting and harvesting dates".

4.5 Climate variables

As expected, the results suggest the importance of climatic variables in explaining the probability of farm households' decision to adopt adaptation strategies. The coefficient of mean annual temperature is positive and statistically significant in influencing the choice of "soil and water conservation adaptation strategy". Increasing annual temperature increases the likelihood of the farmers to adopt changes in agricultural management practices. Increasing warming is associated with reduction in water resources, high evaporation rate, this increases water scarcity and shortage of food production and other uses (Nhemachena et al. 2014). In response to increasing temperature, farmers tend to adopt the use of soil and water conservation adaptation strategy in respect to conserve the little rain received. Consequently, the coefficient of mean annual precipitation is also positive and statistically significant with mixed cropping adaptation strategy. This could be attributed to the fact that mixed farming system is already diversified and farmers have a number of alternative crop options to grow that can ensure that if one option fails, the other will thrive even if there is a change in the climatic conditions. Diversification in farming system is therefore important for farmers to adapt to climate change through mixed crop practices.

5.0 Conclusion and Policy Implications

The study analyzed the determinants of climate change adaptation strategies, using the multivariate probit model. The study rejected null hypothesis of the independence of the different adaptation strategies. Thus, the alternative hypothesis of inter-dependence among the different adaptation strategies which justifies the use of the multivariate probit for this analysis was adopted for the study. The findings from multivariate probit model revealed that the farmers' choice of adaptation strategies are statistically significantly affected by factors such farming experience, credit access, level of education, household size, age of the household head and location of the farmers. Various sources of extension information significantly inform adoption decisions. Key among these is government extension, awareness of climate change and measures to mitigate its effects is thus depicted as a key factor in the adaptation process. The study identifies credit access as a key factor to adaptation. Resource availability enables farmers to implement adaptation decisions, the lack of which presents the household with a significant challenge of adopting the adaptation measures. With the estimates of the multivariate model indicating complementarities among the adaptation strategies choices used by the rice farmers. The complementarities among these strategies shows that farm level policies that affect a choice of adaptation strategies can have a trickle-down effect on others. It is therefore, recommended for the stakeholders in the rice industry to ensure that decisions that support all the choices of adaptation strategies are put in place. Government policies and investment strategies must be geared towards the support of education, credit facilities and information about adaptation to climate change, including technological and institutional methods, particularly for smallholder farmers in the country. The government could build the capacity of agricultural extension systems and make climate change education a priority through ICT innovations. There is a need also for new institutions, such as Public-Private- Partnerships organized, which can take research findings, into the field and help smallholder farmers adapt to a changing climate. Investment in education is critical for overall development and may thus also provide a policy instrument for increasing the use of climate risk coping strategies and reducing the vulnerability of farm households.

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