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Determinants of arable crop farmers' decisions to adapt to climate change risks in Nigeria

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Abstract

This study ascertained the influence of farmers' perceptions of climate change effects and their household characteristics on the choice of adaptation technologies they adopt. The survey relied mainly on institutional and primary data for its analysis. Primary data was obtained from arable crop farmers using a set of structured questionnaires administered in a multi-stage, stratified random sampling manner. Sixty (60) farmers were selected from randomly selected states for the five agroclimatic zones in Nigeria, giving a total sample size of 300 farmers. The collected data was analysed using Heckman's probit selectivity model. It was found that extension contact, gender of the head of household, temperature and rainfall levels determined the decision to adapt to climate change. The respective Z estimates of these aspects were 5.75 ($p < 0.01$), 5.30 ($p < 0.01$), 2.32 ($p < 0.01$) and -9.50 ($p < 0.01$). However, the farmers' perceptions of climate change effects were determined by education and agricultural extension access. The Z values for these were 5.42 ($p < 0.01$) and 2.86 ($p < 0.01$) respectively. The researcher recommends urgent measures to help farmers adapt to climate change, such as the establishment of weather stations and building the capacities of farmers, especially women.

Key words: climate change adaptation, Heckman selectivity model, sustainable agricultural intensification, climate smart agricultural practices, conservation practices

1. Introduction

1.1 Background

Nigeria is ranked ninth on the list of the top 10 countries globally worst hit by food crises, with over five million people affected in the country, representing 5% of the global total in 2019 (Global Network Against Food Crises [GNAFC] 2020). The food crisis is largely driven by weather extremes (climate change), conflict/insecurity and economic shocks (Food and Agriculture Organization [FAO] 2020). The crisis is expected to worsen following the Covid-19 pandemic if urgent action is not taken to build vulnerable farmers' resilience against its shock. Climate change implies variation in climate over time, either as a result of anthropogenic sources or due to human activities (McCarthy *et al*. 2001). Climate change indicated in the form of higher temperatures, reduced rainfall and increased rainfall variability reduces crop yields and threatens food security in low-income economies (FAO 2007). The specific effects of climate change risks on agriculture and natural resources include crop failures as a result of high temperature and low rainfall; and increased land degradation (erosion, desertification, leaching, flooding, poor siltation) (Margulis *et al*. 2009, 2010; World Bank 2010). The effects also include alteration of vegetation structure from thick forest to thin forest and shrubs; greater incidence of alien diseases and pests as a result of changes in temperature and humidity; persistent loss of valuable non-timber forest products; and drying out of aquatic resources, especially some rivers, thus deepening the challenge of household access to clean water.

Pachauri *et al*. (2014) warned that, if the necessary adaptation strategies are not put in place, African countries might experience a reduction in farm yields of between 10% and 25%, a situation that can become more prevalent by 2050. They note that Africa faces very challenging climatic conditions, a population that is increasing relatively fast, and a continuing loss of soil fertility. Incidents of pervasive droughts and the adoption of an unsustainable level of natural resource exploitation have aggravated deforestation and soil exposure to harsh weather (especially rainfall and wind). Recent studies confirmed Africa's status as one of the continents that are most vulnerable to climate variability and change, but it unfortunately has a very low adaptive capacity (Dunford *et al*. 2015). Dunford *et al*. (2015) state that the high dependence of Sub-Sahara African economies and farmers on rain-fed agriculture, the high rate of poverty, increasing food insecurity and the constrained development of institutional and infrastructural capacities make coping with natural climate variability a perennial challenge (Derresa *et al*. 2005; Pender *et al*. 2009). Chen *et al*. (2018) noted that smallholder farming systems remain vulnerable to a myriad challenges, ranging from population growth, rapidly increasing urbanisation, income inequalities, land degradation, decreasing farm size and productivity, all of which are exacerbated by uncertainty regarding climatic change patterns. Therefore, an understanding of the determinants of smallholder farming practices that are aimed at adapting to climate change risks would remain crucial. This is because such knowledge can inform policy design and the implementation of successful interventions, including climate change adaptation programmes, which is the thrust of this study. Some adaptations to current climate variability have been taking place; however, this may be insufficient for future changes in climate (Parry *et al*. 2007). Therefore, efforts to explore diverse adaptation technologies or strategies will continue to appeal to policy makers.

Reports from Nigeria indicate deviations of mean yearly temperature from its previous patterns (Uwejamomere & Nigerian Environmental Study/Action Team 2003; Odjugo 2010), contributing to the assertion that global warming and climate change is real. Within 108 years, according to these reports, temperatures have increased by 1.2°C in the coastal cities of the Niger Delta and 2°C in the northern extreme of Nigeria. A mean increase in air temperature of 1.7°C has been observed in Nigeria over the past 107 years. As shows by the records, the trends in Nigerian climate change indicate that, just as in some other parts of the world, Nigeria currently is under the spell of climate change, and this is in agreement with the IPCC (Parry *et al*. 2007).

Adaptation to climate change has been recognised as a viable "opportunity [that is] available for both farmers and the agencies and professionals working with them for raising farmers' yields and incomes in ways that are environmentally benign" (Abraham *et al*. 2014). The terms of the Comprehensive Africa Agriculture Development Programme (CAADP) of the New Partnership for Africa's Development (NEPAD) recommend that African governments must devote 10% of their national expenditure to agriculture "in order to support water management, intensify irrigation, reduce the continent's dependence on rain-fed agriculture and increase resilience to climate change" (Shimeles *et al*. 2018: 3).

It has been noted that only a few studies have explored farm-level adaptation methods in the rainforest zones of Africa. Some of these are Deressa (2007), Nhemachena and Hassan (2007), Deressa *et al*. (2008), Nwajiuba *et al*. (2008), Yesuf *et al*. (2008), Gbetibouo (2009) and Onyeneke and Nwajiuba (2010). In Nigeria, Enete and Amusa (2010) reviewed the existing literature on the challenges of agricultural adaptation to climate change in Nigeria. The aforementioned left room for more empirical methods of studying climate change adaptation. Even recent studies by Oluwole and Shuaib (2016) and Henri-Ukoha and Adesope (2020) did not capture the peculiar behavioural aspects of the climate change adaptation process. The current study has therefore attempted to fill this knowledge gap.

More recent studies are now recognising the relevance of behavioural change, especially in the climate change adaptation process. For instance, some scholars agree that cognitive and affective factors, in combination with social and cultural factors, are found to either motivate or inhibit adaptation behaviour in humans (Van Valkengoed & Steg 2019; Walawalkar *et al*. 2023). Thus, for adaptation to be deemed effective, it will depend heavily on the extent to which the people faced with climate change consider the risk of climate change clearly, consider climate change as serious and also agree that they perceive or think that they are capable of taking effective adaptation action. Thus, it is necessary to understand behavioural changes and community perceptions in order to support the effective implementation of climate change plans (Van Valkengoed & Steg 2019; Walawalkar *et al*. 2023).

Against the foregoing backdrop, this study was designed to ascertain the influence of climate change and other determinants on crop farmers' choices of adaptive technologies to cope.

The following null hypothesis was formulated to guide the attainment of the study's objective:

H_0: The choice of adaptation technology adopted by the farmers who perceive climate change effects is not influenced by the farmers' agroecological or climatic conditions.

1.2 Socioeconomic factors influencing choice of adaptive strategies used in adapting to the negative effects of climate change

According to the IPCC (Houghton *et al*. 2001), adaptation is defined as an adjustment in natural or human systems while responding to real or anticipated climatic effects that moderates risks or harms, or exploits beneficial opportunities. There are different forms of adaptation. These include anticipatory and reactive adaptation. Other categories include private or public adaptation and, lastly, autonomous or planned adaptation (Houghton *et al*. 2001; McCarthy *et al*. 2001). Some of the adaptation measures to climate change identified by Kaliba and Rabele (2009) included irrigation, mulching, crop rotation, terracing, contour planting, intercropping, cropping along flood plains, bonding, changing timing of planting, planting early maturing crop varieties, etc. Adaptive capacity refers to the extent to which a system is able to adjust to climate change effects (whether climate variability or climate extremes), and its ability to limit potential damages to exploit any opportunity, or rather to cope with consequences (Houghton *et al*. 2001; McCarthy *et al*. 2001).

Kaliba and Rabele (2009) found that the most common measure adopted by farmers is crop rotation (24% of respondents), fallowing (16%), waterway construction (15%), crop cover (13%) and contour cropping (12%). However, as a way of dealing with the consequences of climate change, all the farmers implemented at least one soil conservation measure on their crop farms to cope with climate change. In a study conducted in Southeast Nigeria, Onyeneke and Nwajiuba (2010) found that diversification of crops planted, soil conservation measures, changing planting dates, planting of trees, irrigation and the harvesting of rainwater were the most frequently adopted types of adaptation techniques applied by the farmers to cope with the harsh effects of climate change. They also noted that 40% of the farmers admitted to not adopting any adaptation practices at all.

Despite the availability of several choices of adaptation by farmers, their ability to adopt unfortunately still faces major constraints. For instance, a relatively recent World Bank (2007) report noted that poverty in Nigeria has continued to increase unabated. In this report, the World Bank (2007) notes that, in Nigeria, the share of individuals in the population facing extreme poverty (an income of US$1 per day) rose from 59% to 71% from 1993 to 2003. On the other hand, the proportion of individuals subsisting under conditions of moderate poverty (an income of US$2 per day) surged from 85% to 92% in the same period. Enete and Amusa (2010) postulate that, apart from poverty, the HIV pandemic as well as the brain drain have increased the vulnerability of farmers to climate change. Deressa *et al*. (2008) observed that most of the problems encountered by farmers in their adaptation to climate change were associated with poverty. This may be linked to the fact that poverty and hunger would naturally drive farmers to shift their low farm income towards a demand for the basic necessities of life, especially food and medical care, rather than spending their income on climate change adaptation practices. Enete and Achike (2008) note that urban farmers with poor access to capital fail to adopt more efficient farm inputs, and neither do they apply the recommended quantities. On the whole, they avoided innovative farming practices due to problem of poverty.

According to Madison (2006) and Onoja *et al*. (2019), some factors that influence climate change adaptation strategies, such as the age and gender of the population of farmers, are completely beyond the control of policy makers. Other factors, such as infrastructure, security of tenure, HIV infection rates, literacy and education, are much more global and related to public goods and therefore policy influence. In reality, the kind of extension services rendered regarding climate change are not the same across various locations.

1.3 Theoretical/analytical frameworks

This study largely benefits from the concepts of farm risk theory and the utility function model. Farm risk theory has a lot of empirical backing from the works of Koundouri *et al*. (2004), who demonstrated that the perception of risks by farmers affects their level of adoption of technologies. The farm risk theory is very similar to modern portfolio theory (MPT), as explained by Elton and Gruber (1997) and Chaves-Schwinteck (2011), and adopted by Omisore *et al*. (2012) and Chilokwu *et al*. (2018).These scholars hold that the MPT posits that a return on any kind of investment is largely influenced by a given risk level. The presence of risk means investors are no longer associating a single amount of payoffs with the investment in a given asset. In asset management practice, the payoff of an investment is defined by a series of outcomes, each correlated with its probability of occurring.

According to Madison (2006), theoretical research has highlighted the importance of the formation of expectations with regard to climate and whether the expectations lag behind reality in determining the transitional costs associated with climate change. He maintains that the literature on adaptation also makes it clear that perception is a necessary prerequisite for adaptation. The preliminary evidence from a number of African countries described above indicates that large numbers of agriculturalists already perceive that the climate has become hotter and the rains less predictable and of shorter duration. A study focused on the climate change risk-adaptation process and strategies therefore will offer greater insight if it is able to explain how the perceptions, in association with the realities, of climate change influences combine to determine the adapting agents' decisions.

Heckman's sample selection probit model has relatively recently been applied by Seo and Mendelson (2006) and Onoja *et al*. (2012). The model is based on the following two latent-variable models:

$$Y_1 = b'X + U_1 \quad (1)$$

$$Y_2 = g'Z + U_2, \quad (2)$$

where X represents a k-vector of explanatory variables and Z represents an m-vector of another set of explanatory variables, while including 1s for the intercepts. Meanwhile, the error terms U_1 and U_2 are jointly and normally distributed, independently of X and Z, with zero expectations. While we may be concerned primarily with the first model, the latent variable Y_1 is only observed if, and only if, $Y_2 > 0$.

The latent variable, Y_2, itself cannot be observed; rather, only its sign can. We only know that $Y_2 > 0$ if Y is observable, and $Y_2 \leq 0$ if not. Consequently, we may, without loss of generality, normalise U_2 such that its variance is equal to 1. If we ignore the sample selection problem and regress Y on X using the observed Ys only, then the OLS estimator of b will be biased, because:

$$E[Y_1|Y_2 > 0, X, Z] = b'X + rsf(g'Z)/F(g'Z), \quad (3)$$

where F is the cumulative distribution function of the standard normal distribution, f is the corresponding density, s is the variance of U_1, and r is the correlation between U_1 and U_2. Hence

$$E[Y_1|Y_2 > 0, X] = b'X + rsE[f(g'Z)/F(g'Z)|X] \quad (4)$$

If r is non-zero, then the above term induces sample selection bias. To prevent the issue of sample size selection bias, and to obtain asymptotically efficient estimators, the model's parameters would need to be estimated through the approach of maximum likelihood. Many of the farming attributes that researchers previously identified as important factors considered the farmer in deciding whether to implement new technology associated with the green revolution and could also be relevant determinants of farmers' decisions to adapt to changes to climate (Deressa 2008; Deressa *et al*. 2008). Some aspects of adaptive capacity that explains farmers' adaptation choices, according to Chen *et al*. (2018), include level of "access to information and human capital, financial considerations, assets, household infrastructure and experience". A range of variables therefore were included in the equation that describe the probability that those aware of climate change will adapt to it. Farmer experience and farmer education, both measured in years, also needed to be included. It is expected that the latter will diminish the probability that no adaptation measure is taken. Age of the respondent, gender, whether married, and whether head of the household or not were also added.

The study was conducted in Nigeria. The African Development Bank ([ADB] 2010) notes that Nigeria, a country made up of 36 states and a federal capital territory, is endowed with a total surface area of 924 000 square kilometres (i.e. approximately 92.4 million ha). According to the World Bank (2023), Nigeria's population was estimated at 213 401 323 in 2021, with an annual growth rate of 2.4% and a GDP estimated at 440.83 billion US dollars. Nigeria is bounded on the north by the Republic of Niger and Chad Republic, on the west by Benin Republic, while on the east and south it shares boundaries with the Republic of Cameroon and the Gulf of Guinea respectively.

Nigeria's climate is equatorial and semi-equatorial. About 20% of the country's land area is in the humid (swamp forest) to sub-humid forest zone (tropical forest), with annual rainfall ranging from over 3 000 mm in the coastal south to 1 150 mm in the north, with three months of dry season. The remaining 80% of the country's climate is savannah, subdivided from south to north into derived or

Guinea savannah (sometimes subdivided further into southern and northern Guinea savannah with rainfall records of between 1 000 mm to 1 500 mm, and about four and half months of dry season). In the Sudan savanna, the rainfall ranges from 500 mm to 1 000 mm, recording between five and seven months of dry season, while the Sahel savannah is situated along the north-eastern part of the country in Borno State (rainfall 250 mm to 500 mm, and seven to eight months of dry season) (see Figure 1). As can be seen in Figure 1, the Nigerian agroclimatic zones comprises five belts (Nigerian Meteorological Agency [NIMET] 2012). These includes swampy forests, the tropical forest belt, the Guinea savannah belt, the Sudan savannah and the Sahel savannah.

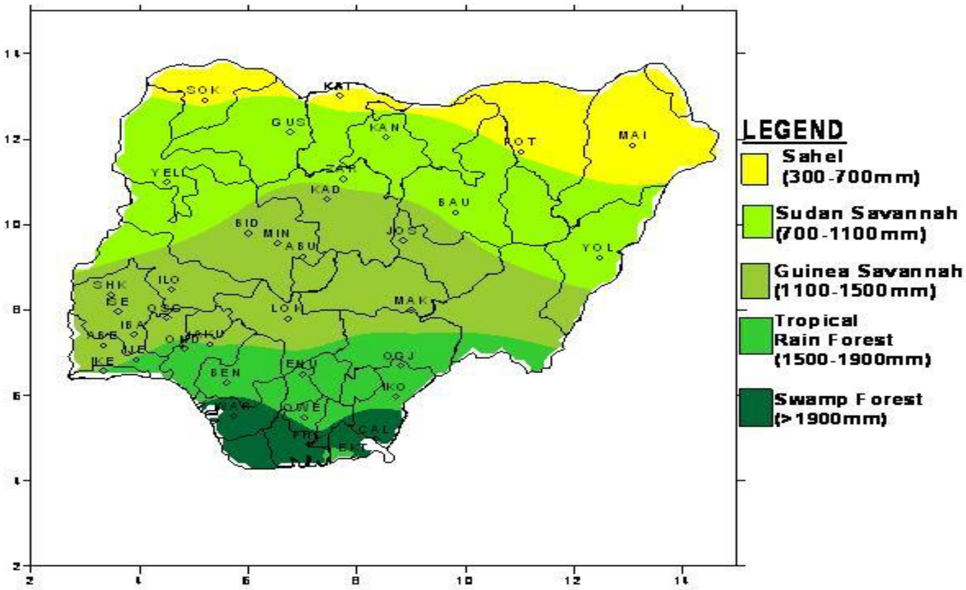

Figure 1: Map of Nigeria showing the various agroclimatic zones of the country
Source: Based on NIMET's classification (2012); Ajayi *et al*. (2020)

The study site covered one state in each of the five agroclimatic zones of Nigeria, as depicted in Figure 1. A multi-stage stratified random sampling method was used to select arable crop farmers in five agroclimatic zones, namely swampy forest, tropical forest, Guinea savannah, and the Sudan and Sahel savannahs, from a population of 4.2 million registered farmers in the country (Aiyetan & Pindiga 2013). A list of arable crop farmers (especially crops that cut across agroclimatic zones in Nigeria, such as root crops (cassava and yam), vegetables (cowpea), and cereals (maize and rice) was obtained from the Agricultural Development Projects offices in each of the five states mentioned earlier. From the lists, 60 farmers were selected in each state or agroclimatic zone, giving a total sample size of 300 farmers across all the agroclimatic zones of the country from a population of 4.2 million registered farmers in the country (Aiyetan & Pindiga 2013).

The study, a survey, relied mainly on institutional (Nigerian Meteorological Agency [NIMET]) and primary data for its analysis. This included quantitative and qualitative data gathered from government weather information agents, and from the smallholder farmers involved in the production of the major staple crops in Nigeria, including maize, sorghum, rice, cassava, yam and leguminous crops such as cowpeas. A focus group discussion (FGD) was also conducted in Abuja with the staff of the Nigerian Meteorological Agency (NIMET).

The study used quantitative methods to analyse data using the two-stage Heckman's probit selectivity model, which applies the probit function. For sample selection, the probit model implies that an underlying association exists.

The latent equation is given by:

$$y_j^* = x_j\beta + \mu_{1j} \quad (5)$$

Thus, only the binary outcome given by the probit model is observed, as

$$y_j^{probit} = (y_j^* > 0) \quad (6)$$

$$y_j^{select} = (Z_j\delta + \mu_{2j} > 0) \quad (7)$$

$$\mu_1 \sim N(0, 1) \quad (8)$$

$$\mu_2 \sim N(0, 1) \quad (9)$$

$$\text{corr}(\mu_2, \mu_{2j}) = \rho, \quad (10)$$

where x refers to a k-vector of explanatory variables, z is an m-vector of explanatory variables, and u_1 and u_2 are error terms. When $\rho \neq 0$, standard probit techniques applied yield biased results. Thus, the Heckman probit (heckprob) provides consistent, asymptotically efficient estimates of all parameters in such models (StataCorp 2009). Thus, the Heckman probit selection model was employed to analyse the perception of and adaptation to climate change in Nigerian agroecological zones following Madison (2006), Deressa (2008), Mandleni and Anim (2011) and Onoja and Ajie (2011).

In terms of variables that made up the k-vector (m-vector of regressors mentioned earlier), they included age in years, X_1, farming experience in years, X_2, nature of land tenure, X_3 (dummy 1 = privately owned land, 2 = communal land, 3 = sharecropping, 4 = government land, 5 = others), X_4 = household size (count), X_5, occupation, X_6 (full-time farmer = 1, part-time farmer with other jobs = 2), gender (0 = female, 1 = male), X_7, annual personal income in naira per month, X_8, frequency of extension contact, X_9 (count from 0.00 to n), educational attainment in terms of years spent in formal education, X_{10}, climatic factor (annual mean precipitation level in mm), X_{11}, average temperature of the area in degrees Celsius (X_{12}), level of risk rating, X_{13} (based on the farmer's risk rank as estimated as part of objective 1 in this study), and location, X_{14} (agroclimatic zones from 1 to 5).

2. Influence of climate change and socio-economic factors on crop farmers' choices of adaptive technologies to cope with perceived and actual climate change effects in Nigeria

Table 1 displays the Heckman selection model (two-step estimates). The Heckman probit model was tested for appropriateness over the standard probit model and the results indicate a sample selection problem (dependence of the error terms from the outcome and selection models), justifying the use of the Heckman probit model, with rho (-0.380) significantly different from zero (Wald $\chi^2 = 251.52$, with $p = 0.000$). Moreover, the likelihood function of the Heckman probit model was significant (Wald $\chi^2 = 52.18$, with $p < 0.000$), showing the strong explanatory power of the model, as indicated in Table 1.

The results of the regression model in Table 1 indicate that many of the explanatory variables affect the probability of adaptation, as expected, except for credit access, farm size and household size. Variables that positively and significantly influenced adaptation to climate change included extension contact, gender of the head of household, temperature and rainfall levels. An increase in the frequency of agricultural extension contact by the head of the household raised the probability of adaptation to climate change by 5.7%. Similarly, male-headed households are 5.30 times more likely to adapt to the effects of climate change than their female counterparts. It thus appears that female-headed households are more vulnerable to the effects of climate change effects, since their gender was correlated negatively with the probability of adaptation. This finding agrees with Seo and Mendelson (2006), who noted that male-headed households were 18% more likely to adapt to climate change. The result is also in line with the argument that male-headed households are often considered to be more likely to obtain information about new technologies and to take on risk than female-headed households (Asfaw & Admassie 2004).

Table 1: Heckman selection model – two-step estimates (regression model with sample selection)

Models and variables				
Adaptation model	***Coef.***	***Std err***	***Z***	***P > |z|***
Temperature	0.000	0.000	2.320**	0.020
household size	0.008	0.034	0.240	0.813
Sex	0.169	0.032	5.300***	0.000
credit access	0.005	0.011	0.510	0.607
Farmsize	0.003	0.015	0.230	0.820
Rain	-0.232	0.024	-9.560***	0.000
Landtenure	(omitted)			
Ext	0.206	0.036	5.7500***	0.000
Intercept	0.762	0.411	1.8500*	0.064
Perception of climate change effects (selectivity model)				
Educ	0.308	0.057	5.420***	0.000
Age	0.006	0.008	0.720	0.474
personalin~e	0.000	0.000	-1.490	0.135
Ext	0.542	0.189	2.860***	0.004
swampforest	-0.306	0.336	-0.910	0.363
tropical forest	0.177	0.323	0.550	0.582
guinea savanna	-0.089	0.293	-0.300	0.760
Sudan savanna	0.153	0.312	0.490	0.624
Sahel savanna	(omitted)			
Intercept	-0.098	0.423	-0.230	0.816
Number of observations	=	300		
Censored observations	=	58		
Uncensored observations	=	242		
Wald chi^2 (7)	=	251.52***		
Prob > chi^2	=	0.00		Rho = -0.380

Note: ***, ** and * indicate statistical significance at the 0.01, 0.05 and 0.10 level respectively.

An increase in annual mean temperature by 1°C raised the probability of adaptation by farm households to climate change effects by 2.32%. The fact that adaptation to climate change increased with higher temperatures is in tandem with the expectation that increased temperature could be damaging to African agriculture and that farmers respond to this through the adoption of different adaptation methods (Kurukulasuriya & Mendelsohn 2006).

Just like Seo and Mendelsohn's (2006) findings in Ethiopia, annual average precipitation was negatively related to adaptation in Nigeria. In this study, a 1 mm increase in average annual rainfall decreased the probability of farm households' adaptation to climate change effects by 9.56%. According to Seo and Mendelson, the probable reason for the negative relationship between average annual precipitation and adaptation could be the fact that, like any African country, Nigeria's agriculture is water-scarce, and higher levels of rainfall therefore would not constrain agricultural production and promote the need to adapt (at least using the main adaptation options considered in this study).

Expectedly, the likelihood of perceiving climate change is positively related to farmers' educational attainment and frequency of agricultural extension contacts in Nigeria. Increasing the years of formal education of the crop farmer thus increases the farmer's probability of perceiving a change in climate by 5.42%, whereas increasing the frequency of agricultural extension contacts with farmers by one unit increases perception of climate change by 2.86%. These results also agree with Seo and Mendelsohn's (2006) findings too. Meanwhile, Madison (2006) remarked that some factors that influence climate change adaptation strategies, such as age and gender of the population of farmers, were completely beyond the control of policy makers.

In an attempt to test the null hypothesis, it was found that the location of the agroclimatic zones in the country had no significant effect on the probability of perceiving climate change effects. None of the agroclimatic zones, as a variable, returned a significant probability. Therefore, we uphold the null hypothesis, which holds that the choice of adaptation technology adopted by the farmers who perceived climate change effects was not significantly influenced by the agroclimatic zone of the farmer.

3. Conclusion

This study has explored various prevailing climate and socio-economic factors affecting the decision-making process on adaptation of arable crop farmers in Nigeria. The results show that extension contact, gender of the head of household, temperature and rainfall levels significantly determine the decision to adapt to climate change. These variables are therefore important in policy-making aimed at boosting farmers' adaptive capacities. The perception of a climate change effect was significantly influenced by education and access to agricultural extension. Mean annual rainfall, temperature and location significantly determined the level of adoption of climate change adaptation strategies by the farmers. Gender exerted no significant effect on the level of adaptation to climate change. The author recommends that, to control other risks of climate change, such as increased temperature and drought, NIMET should be encouraged to provide farmers with early warning signals via an organised extension service programme. Agricultural development programmes (ADPs) and the FADAMA III programme should establish weather stations to aid farmers to access weather data and plan their production in a more climate-smart way. There are many indigenous technologies that can be applied in adapting to climate change effects. Through organised cooperatives, farmers can teach themselves such technologies and also recruit experts in climate change adaptation management and agricultural extension services to teach them about the new technologies available to adapt to climate change effects on their respective farms.

Gender was noted as a factor in the decision to adapt. Since the findings of this study indicate that the probability of adapting to climate change appeared to favour males more than their female partners, there is a need to mainstream women in capacity-building programmes for adapting to climate change. Such measures could be in form of the provision of free and more regular agricultural extension services to them.

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References

Abraham B, Araya H, Berhe T, Edwards S, Gujja B, Khadka RB, Koma YS, Sen D, Sharif A, Styger E, Uphoff N & Verma A, 2014. The system of crop intensification: Reports from the field on improving agricultural production, food security, and resilience to climate change for multiple crops. Agriculture & Food Security 3: Article #4. Available at http://www.agricultureandfoodsecurity.com/content/3/1/4

African Development Bank (ADB), 2010. Gender, poverty and environmental indicators on African countries. Tunis, Tunisia: Economic and Social Statistics Division, Statistics Department African Development Bank, Temporary Relocation Agency (TRA). Available at https://www.afdb.org/en/documents/document/gender-poverty-and-environmental-indicators-on-african-countries-2010-20388

Aiyetan D & Pindiga H, 2013. Fertiliser subsidy: How Nigeria short changes farmers. International Centre for Investigative Reporting. Available at http://icirnigeria.org/fertiliser-subsidy-how-nigeria-short-changes-farmers/ (Accessed 22 February 2013).

Ajayi TA, Ogunrinde TA, Yessoufou MA & Ajayi FI, 2020. Investigation of trends in agricultural and meteorological drought in Nigeria. International Journal for Research in Applied Sciences and Biotechnology 7(5): 281–94. https://doi.org/10.31033/ijrasb.7.5.37

Asfaw A & Admassie A, 2004. The role of education on the adoption of chemical fertilizer under different socioeconomic environments in Ethiopia. Agricultural Economics 30(3): 215–28.

Chaves-Schwinteck P, 2011. The modern portfolio theory applied to wind farm financing. DEWI Magazine No. 38. Available at http://www.dewi.de/dewi/fileadmin/pdf/publications/Magazin_38/02.pdf (Accessed 15 April 2012).

Chen M, Wichmann B, Luckert M, Winowiecki L, Förch W & Läderach P, 2018. Diversification and intensification of agricultural adaptation from global to local scales. PLoS ONE 13(5): e0196392. https://doi.org/10.1371/journal.pone.0196392

Chilokwu IDO, Akubuilo CJC & Agbasi OE, 2018. Effect of cooperative farmers' insurance premium on the growth of agricultural gross domestic product in Nigeria. IOSR Journal of Engineering 8(4): 58–72.

Deressa TT, 2007. Measuring the economic impact of climate change on Ethiopian agriculture: Ricardian approach. Policy Research Working Paper No. 4342, World Bank, Washington DC. https://openknowledge.worldbank.org/handle/10986/7290

Deressa TT, 2008. Analysis of perception and adaptation to climate change in the Nile basin of Ethiopia. The Journal of Agricultural Science 149(1): 21–31. https://doi.org/10.1017/S0021859610000687

Deressa TT, Hassan R & Poonyth D, 2005. Measuring the impact of climate change on South African agriculture: The case of sugar cane growing regions. Agrekon 44(4): 524–42.

Deressa TT, Hassen R, Alemu T, Yesuf M & Ringler C, 2008. Analyzing the determinants of farmers' choice of adaptation measures and perceptions of climate change in the Nile Basin of Ethiopia. IFPRI Discussion Paper No. 00798, International Food Policy Research Institute, Washington DC.

Dunford R, Harrison PA, Jäger J, Rounsevell MD & Tinch R, 2015. Exploring climate change vulnerability across sectors and scenarios using indicators of impacts and coping capacity. Climatic Change 128(3): 339–54.

Elton EJ & Gruber MJ, 1997. Modern portfolio theory, 1950 to date. Journal of Banking & Finance 21(11–12): 1743–59.

Enete AA & Achike AI, 2008. Urban agriculture and urban food insecurity/poverty in Nigeria: The case of Ohafia, South-East Nigeria. Outlook on Agriculture 37(2): 131–4. https://doi.org/10.5367/000000008784648915

Enete AA & Amusa TA, 2010. Challenges of agricultural adaptation to climate change in Nigeria: A synthesis from the literature. Field Actions Science Reports: The Journal of Field Actions 4.

Food and Agriculture Organization (FAO), 2007. The state of food and agriculture: Paying farmers for environmental services. Rome: Food and Agriculture Organization of the United Nations. Available at https://www.fao.org/3/a1200e/a1200e01.pdf

Food and Agriculture Organization (FAO), 2020. Gender and land rights database: Nigeria. Available at http://www.fao.org/gender-landrights-database/country-profiles/countries-list/national-legal-framework/rights-entrenched-in-the-constitution/en/?country_iso3=NGA

Gbetibouo GA, 2009. Understanding farmers' perceptions and adaptations to climate change and variability: The case of the Limpopo Basin, South Africa. IFRI Discussion Paper 00849, International Food Policy Research Institute, Washington DC.

Global Network Against Food Crises, 2020. 2020 Global report on food crises: Joint analysis for better decisions. Available at https://www.fsinplatform.org/sites/default/files/resources/files/GRFC_2020_ONLINE_200420.pdf

Henri-Ukoha A & Adesope OM, 2020. Sustainability of climate change adaptation measures in Rivers State, South-South, Nigeria. In Leal Filho W. (ed), Handbook of climate change resilience. Cham, Switzerland: Springer.

Houghton JT, Ding Y, Griggs DJ, Noguer M, Van der Linden PJ, Dai X, Maskell K & Johnson CA (eds), 2001. Climate change 2001: The scientific basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.

Kaliba ARM & Rabele T, 2009. Impact of adopting soil conservation practices on wheat yield in Lesotho. Research Paper 42, Aquaculture/Fisheries Centre, University of Arkansas at Pine Bluff, North University, Pine Bluff AR.

Kaliba ARM & Rabele T, 2009. Impact of adopting soil conservation practices on wheat yield in Lesotho. Research Paper 42, Aquaculture/Fisheries Centre, University of Arkansas at Pine Bluff, North University, Pine Bluff AR.

Koundouri P, Nauges C & Tzouvelekas V, 2004. Technology adoption under uncertainty: Theory and application to irrigation technology. American Journal of Agricultural Economics 88(3): 657–70.

Kurukulasuriya P & Mendelsohn R, 2006. A Ricardian analysis of the impact of climate change on African cropland. CEEPA Discussion Paper No. 8, Centre for Environmental Economics and Policy in Africa, University of Pretoria, Pretoria.

Madison D, 2006. The perception of and adaptation to climate change in Africa. Discussion Paper No. 10, Centre for Environmental Economics and Efficiency Policy for Africa (CEEPA), Special Series on Climate Change and Agriculture in Africa, University of Pretoria, South Africa.

Mandleni B & Anim FDK, 2011. Climate change awareness and decision on adaptation measures by livestock farmers in South Africa. Journal of Agricultural Science 3(3): 258–68. https://doi.org/10.5539/jas.v3n3p258

Margulis S, Narain U, Chinowsky P, Cretegny L, Hughes G, Kirshen P, Kuriakose A, De Lange G, Nelson GW, Neumann J, Nicholls, RJ, Pandey K *et al.*, 2009. The costs to developing countries of adapting to climate change – New methods and estimates. The global report on the economics of adaptation to climate change study: Consultation draft. Washington DC: World Bank. Available at http://siteresources.worldbank.org/INTCC/Resources/EACCReport0928Final.pdf

Margulis S, Narain U, Chinowsky P, Cretegny L, Hughes G, Kirshen P, Kuriakose A, De Lange G, Nelson GW, Neumann J, Nicholls, RJ, Pandey K *et al.*, 2009. The costs to developing countries of adapting to climate change – New methods and estimates. The global report on the economics of adaptation to climate change study: Consultation draft. Washington DC: World Bank. Available at http://documents.worldbank.org/curated/en/667701468177537886/The-costs-to-developing-countries-of-adapting-to-climate-change-new-methods-and-estimates-the-global-report-of-the-economics-of-adaptation-to-climate-change-study

McCarthy JJ, Canziani OF, Leary NA, Dokken DJ & White KS (eds), 2001. Climate change 2001: Impacts, adaptation, and vulnerability. A contribution of the Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.

Nhemachena C & Hassan R, 2007. Micro-level analysis of farmers' adaptation to climate change in Southern Africa. IFPRI Discussion Paper 00714, International Food Policy Research Institute, Washington DC. Available at https://www.researchgate.net/publication/5056602_Micro-Level_Analysis_of_Farmers'_Adaptation_to_Climate_Change_in_Southern_Africa

Nigerian Meteorological Agency (NIMET), 2012 Agrometeorological bulletin: A quarterly publication of NIMET (various issues of 2012). Abuja: NIMET.

Nwajiuba CU, Onyeneke R & Munonye J, 2008. Climate change: Perception and adaptation by poultry farmers in Imo State. In Nwajiuba C (ed.), Climate change and adaptation in Nigeria. Weikersheim, Germany: Margraf Publishers.

Odjugo PAO, 2010. Regional evidence of climate change in Nigeria. Journal of Geography and Regional Planning 3(6): 142–50. https://doi.org/10.5897/JGRP.9000119

Oluwole AJ & Shuaib L, 2016. Assessment of level of use of climate change adaptation strategies among arable crop farmers Oyo and Ekiti States, Nigeria. Journal of Earth Science and Climate Change 7: 369. https://doi.org/10.4172/2157-7617.1000369

Omisore I, Yusuf M & Nwufo CI, 2012. The modern portfolio theory as an investment decision tool. Journal of Accounting and Taxation 4(2): 19–28.

Onoja AO & Ajie EN, 2011. Climate change adaptation decision making among artisanal fish farmers in Rivers State, Nigeria: A Heckman two-stage selectivity model approach. Proceedings of the Nigerian Association of Agricultural Economists' (NAAE) 20th annual national conference, 4–7 November, Benin.

Onoja AO, Abraha AZ, Atkilt G & Achike AI, 2019. Climate-smart agricultural practices (CSA) adoption by crop farmers in semi-arid regions of West and East Africa: Evidence from Nigeria and Ethiopia. In Castro P, Azul AM, Leal Filho W & Azeiteiro UM (eds), Climate change-resilient agriculture and agroforestry. Cham, Switzerland: Springer. https://doi.org/10.1007/978-3-319-75004-0

Onoja AO, Usoroh BB, Ademe DT & Deedam NJ, 2012. Determinants of market participation in Nigerian small-scale fishery sector: Evidence from Niger Delta Region. Consilience: The Journal of Sustainable Development 9(1): 69–84. Available at https://journals.library.columbia.edu/index.php/consilience/article/view/4628/2069

Onyeneke R & Nwajiuba C, 2010. Socio-economic effects of crop farmers' adaptation measures to climate change in the Southeast Rainforest Zone of Nigeria. In Nmadu JN, Ojo MA, Mohammed US, Baba KM, Ibrahim FD & Yisa ES (eds), Commercial agriculture, banking reform and economic downturn: Setting a new agenda for agricultural development in Nigeria. Proceedings of 11th Annual National Conference of National Association of Agricultural Economists (NAAE), 30 November–3 December, Federal University of Technology, Gidan Kwano, Minna, Nigeria.

Pachauri RK, Allen MR, Barros VR, Broome J, Cramer W, Christ R, Church JA, Clarke L, Dahe Q, Dasgupta P, Dubash NK, Edenhofer O, Elgizouli I *et al.*, 2014. Synthesis report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva: IPCC.

Parry ML, Canziani OF, Palutikof JP, Van der Linden PJ & Hanson CE (eds), 2007. Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.

Pender J, Ringler C, Magalhaes M & Place F, 2009. The role of sustainable land management for climate change adaptation and mitigation in Sub-Saharan Africa (Land & Climate Series). Washington DC & Midrand, South Africa: TerrAfrica Secretariat.

Seo SN & Mendelsohn R, 2006. Climate change impacts on animal husbandry in Africa: A Ricardian analysis. Policy Research Working Paper No 4261, World Bank, Washington DC.

Shimeles A, Verdier-Chouchane A & Boly A (eds), 2018. Building a resilient and sustainable agriculture in Sub-Saharan Africa. Cham, Switzerland: Palgrave MacMillan. https://doi.org/10.1007/978-3-319-76222-7

StataCorp, 2009. Statistics/data analysis special edition. College Station TX: StataCorp.

Uwejamomere T & Nigerian Environmental Study/Action Team (NEST), 2003. Climate change in Nigeria: a communication guide for reporters and educators. Ibadan, Nigeria: NEST.

Van Valkengoed AM & Steg L, 2019. Meta-analyses of factors motivating climate change adaptation behaviour. Nature Climate Change 9(2): 158–63. https://doi.org/10.1038/s41558-018-0371-y

Walawalkar TP, Hermans LM & Evers J, 2023. Evaluating behavioural changes for climate adaptation planning. Journal of Environmental Planning and Management 66(7): 1453–71. https://doi.org/10.1080/09640568.2022.2028610

World Bank, 2007. World development indicators. Washington DC: World Bank.

World Bank, 2010. The social dimensions of adaptation to climate change in Ghana. Discussion Paper No. 15, World Bank, Washington DC.

World Bank, 2023. Nigeria: Overview. Available at https://data.worldbank.org/country/NG

Yesuf M, Di Falco S, Deressa T, Ringler C & G Kohlin, 2008. The impact of climate change and adaptation on food production in low-income countries: Evidence from the Nile Basin, Ethiopia. IFPRI Discussion Paper No. 828, International Food Policy Research Institute, Washington DC.