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Impact of Climate Change Adaptation on Household Food Security in Nigeria—A Difference-in-Difference Approach

Oyinlola Rafiat Ogunpaimo ^{1,2,*} , Zainab Oyetunde-Usman ³  and Jolaosho Surajudeen ²

¹ Rural Economy & Development Programme, Teagasc, Mellows Campus, Athenry, Co., Galway H65 R718, Ireland

² Department of Agricultural Economics and Farm Management, Federal University of Agriculture, Abeokuta 112251, Nigeria; surajudeenjolaosho@yahoo.com

³ National Resources Institute, University of Greenwich, Chatham Maritime ME4 4TB, UK; zainabus23@gmail.com

* Correspondence: oyinlolaadams@gmail.com

Abstract: Studies have shown that climate change adaptation options (CCA) are implemented to buffer the unfavorable climatic changes in Nigeria causing a decline in food security. Against the background of measuring the impact of CCA options using cross-sectional data, this study assessed how CCA had affected food security using panel data on farming households from 2010–2016 obtained from Nigerian General Household Survey (GHS). Data were analyzed using the Panel probit model (PPM), Propensity Score Matching (PSM), and Difference-in-Difference (DID) regression. PPM showed that the probability of adopting CCA options increased with farm size ($p < 0.01$), extension contact ($p < 0.01$), and marital status ($p < 0.01$), but decreased with the age of the household head ($p < 0.01$). Credit facilities ($p < 0.05$), ownership of farmland ($p < 0.01$), household size ($p < 0.01$), years of schooling ($p < 0.01$), household asset ($p < 0.01$), and location ($p < 0.05$) also had a significant but mixed effect on CCA choices. PSM revealed that farming households that adopted CCA strategies had 9% higher food security levels than non-adopters. Furthermore, the result of the DID model revealed a significant positive effect of CCA on household food security ($\beta = 5.93$, $p < 0.01$). It was recommended that education and provision of quality advisory services to farmers is crucial to foster the implementation of CCA options.

Keywords: developing countries; welfare; panel probit model; adoption; propensity score matching



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1. Introduction

The agricultural practices in African nations especially Nigeria largely rely on the natural weather conditions of the locality. Changes in the climatic condition of the country are evident in increased desert encroachment and extreme droughts in the Northern region [1,2], likewise the problem of persistent flood and erosion occurrence in the Southern region. Climatic variability and changes have been linked to erosion, increased flooding, environmental degradation [3], and a decrease in agricultural productivity [4,5].

Frequent and intense weather events as a result of climate change are likely to impact the welfare and food security status of both the rural and urban populace through poor food production, poor land availability, and reduced opportunities [6]. The optimal usage of land for crop and animal production, biodiversity restoration, health, and well-being can also be negatively impacted by increased temperature and precipitation changes, and increased weather fluctuations [7–9].

In accordance with the 2020 global food security index, Nigeria's food insecurity status is considered serious in the severity chart [10]. The Federal Ministry of Agriculture of Nigeria in 2014 estimated that 65% of the population is food insecure despite having more than half of all employments dependent on agriculture [5]. Among several other factors, heightened food insecurity among farm households is caused by limited access to

credit, poor storage and improved agricultural facilities, and negative environmental influences such as erosions and floods [5]. Other reasons include the lower household income necessary for food purchases needed to attain food security [11], increased population growth [12,13], and a huge reliance on imported food items [14]. The 2030 United Nations Sustainable Development Goals are new global policies with the objective to restructure regional and national development plans over the next 10 years. The global policy aims to put an end to poverty and hunger, food insecurity, sustaining natural resources and the environment, and promote food and agriculture sustainability [15].

The International Symposium on Climate and Food Security (ISCFS) and Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) also recognized three critical global problems of poverty and hunger, increased population growth, and unfavorable weather and climate [16]. Agricultural production and climate change exhibit a feedback relationship, while agricultural activities may result in increased emissions and pollutions leading to climatic changes, climate change also influences agricultural output. Research has indicated that by 2030, the negative consequence of climate change on agriculture will be more severe across all the countries of the world [17]. Climatic changes already have an antagonistic influence on food security with the number of chronically undernourished people in the world estimated to have increased by 38 million in 2016, in addition to 777 million recorded in 2015 [18], thus, without proper implementation of adaptation and mitigation measures, climate variability and change will threaten the achievements of the SDG goals in eradicating poverty and hunger [17].

As stated by the United Nations Framework Convention on Climate Change (UNFCCC, 2007) AR4 and buttressed by Field [19] and Steynor and Pasquini [20], Africa is predicted to be the continent most susceptible to climate change and variability; adverse climatic impacts are worsening the livelihoods, welfare, and regional and household food security in tropical developing regions [17]. Consensus exists that climate change and variability will have a significantly negative impact on all these aspects of food security in Africa [21]. Like other African countries, studies such as Ebele and Emodi [22] reported that the projected impact of climate change on West Africa's agricultural productivity could lead to a 4% reduction in the region's GDP; in Nigeria, the adverse influence of climate change on food security is evidenced by the changes in plant duration and output of cereal crops, reductions in aquatic life [23], and livestock failure [24]. In tackling climate change and variability, studies [25,26] indicate that CCA can promote household food security. While research had been conducted on factors influencing the choice of CCA by farming households and the impact of CCA options on household food security, very few studies if any had applied a panel data analysis approach to investigate the influence of CCA options on household food security in Nigeria.

Morland [27] stated that small scale farmers in Africa experience weather variability and other climate-change-related events. Among farm households, varieties of climate-adaptation methods abound and this includes diversification and crop rotation, engaging in non-agricultural income-generating activities, practicing soil and water conservation techniques, adjusting the times they sow their lots, use of irrigation and creation of flood barriers, adopting improved seed varieties and fertilizers, tree-planting, and integrating crop production with livestock.

Adaptation to climate change and variability means anticipating the adverse effects of climate variability and taking appropriate action to prevent and or minimise the damage they cause or taking advantage of opportunities that may arise [28]. It involves the use of climate sustainable practices to reduce the negative consequences of climate change.

In many African countries, especially Nigeria, access to food will be severely affected by climate change. Africa is the region where climate change and variability have had the biggest impact on acute food insecurity and malnutrition, affecting 59 million people in 24 countries [7]. Given these discouraging prospects, it is no surprise that the adaptation strategies are vital to support the climate effects on food security. These strategies can indeed buffer against climate variability and play a crucial role in promoting the food

security of farm households, thereby reducing the negative effect of climate variability on food security.

Thus, this research sought to investigate the impact of climate change adaptation on farm households' food security status by providing answers to the following questions: (1) What are the factors affecting climate adaptation strategies employed by farm households in Nigeria? (2) What is the impact of climate change adaptation on household food security?

2. Materials and Methods

This section describes the study area, the data source, a summary of farm household characteristics, the description of variables, and the method of data analysis.

2.1. Study Area

The study area is Nigeria situated 4° and 14° N, and longitudes 2° and 15° E. Nigeria is located in West Africa with its capital at Abuja created in 1976 having a total area of 923,769 km² (356,669 sq mi) [29], making it the world's 32nd largest country. Nigeria is bordered to the north by Niger, to the east by Chad and Cameroon, to the south by the Gulf of Guinea of the Atlantic Ocean, and the west by Benin [29].

Like most countries in sub-Saharan Africa, the climatic condition in Nigeria is tropical with varying rainy and dry seasons. The Nigeria vegetation belts, also known as the agroecological zones range from the mangrove, freshwater swamps, and tropical rainforest which extends from the South-South, South-East to South-West regions. The tropical savanna grasslands zone is dominant in the middle belts with Sudan and Sahel Savanna in the Northern regions. Agricultural production is dominant in the northern agroecological zones, however, climatic changes and human activities such as continuous cropping, overgrazing, and bush burning especially in densely populated areas have highly impacted the agricultural vegetation.

Specifically, in the far northern areas, the nearly total disappearance of plant life has facilitated a gradual southward advance of the Sahara [29]. The map of Nigeria showing the different regions and states is illustrated as shown in Figure 1.

2.2. Data Source

Panel data on relevant socioeconomic, demographic, consumption, and production data of farming households from 2010–2016 were obtained from the World Bank and the Nigeria Bureau of Statistics (NBS) General Household Survey (GHS). The GHS is a nationally representative survey with respondents obtained from the 36 states of Nigeria including the Federal Capital Territory. Three waves of the Living Standard Measurement Survey (First wave—2010/2011 Ref. NGA_2010_GHSP-W1_v03_M [30], Second wave—2012/2012 Ref. NGA_2012_GHSP-W2_v02_M [31] and the Third-wave—2015/2016 Ref. NGA_2015_GHSP-W3_v02_M [32]) was employed such that there are six-period panel data for the farm households from which 3500 farm households were used for this study.

2.3. Summary of Characteristics of Farm Households in the Study Area

The summary of farm households' characteristics is shown in Table 1. Age is an important determinant of farm activities. It is believed that younger people commit more energy to production activities, while older farmers are likely to be more experienced. The mean age of respondents was 50.4 and 53.2 years in 2010 and 2016 respectively. In relation to the gender of the household head, the majority of family households were male-headed. Male household heads accounted for 88.36% in 2010 to a slight reduction of 84.14% in 2016. This report buttresses the dominance of males in farming activities in Nigeria as reported by [33]. However, the decline in the proportion of male-headed households in the study area may be due to increasing awareness of female empowerment and capacity building in the area.

Table 1. Summary of Farm Households' Characteristics in the Study Area.

Characteristics		Year			
		2010		2016	
		Percentage	Mean	Percentage	Mean
Gender of HH	Female	11.64		15.86	
	Male	88.36		84.14	
Marital status	Single	15.00		20.43	
	Married	85.00		79.57	
Accessed credit	Yes	2.94	-	24.01	
	No	97.06		75.99	
Extension contact	Yes	14.38		86.79	
	No	85.62		13.21	
Ownership of land	Yes	29.07		1.24	
	No	70.93		98.76	
Age of HH			50.4		53.2
HH SIZE			6		8
Years of schooling			6		7
Household asset			11		41
Plot size			11,372.38		10,264
Secondary income			13,465.25		5672.59
Total food expenditure			16,382.38		21,867.58
Total non-food expenditure			7137.23		8350.23
Total expenditure			23,519.61		30,217.83

Author's Computation from LSMS Data 2010:2016.

As illustrated in Table 1, the majority (85%) of farming households in 2010 were married, this came down to 79.57% in 2016. In terms of educational level, the average years of schooling were 6 years with no significant change in 2016 implying that although farm households have access to formal education, the level of education among farming households in Nigeria is still low. However, by 2016 the average years of schooling had increased by a year in the country due to various campaigns and probable enlightenment on the need for female education in the region. Following apriori expectation education is likely to increase the probability of farming households adapting to climate changes because it can be assumed that education will increase farm household's awareness of CCA.

The size of households is also shown in Table 1. It is evident that the average household size for the sampled farm households' was approximately six persons in 2010 to eight persons in 2016. Previous literature [35–37] argued that the probability of adopting labour-intensive adaptation measures increases with family size due to the availability of free or inexpensive man-power. Also, large families divert part of their labour force into non-farm activities to generate more income [38,39].

From Table 1, the majority of respondents (85.62%) had no access to extension contact in 2010, however, in 2016 the majority (86.79%) had access to extension contact. This showed the intensification of extension services contact increased over the years within the study area. For access to formal credit, the majority (97.5%) of the respondents did not have access; this may limit the ability of the farmers to expand their scale of production. This result is buttressed by the findings of [40] who assessed the trend of formal credit allocation to food crop production in Nigeria; their results showed that there was a decreasing trend in the credit allocation to the food crop production since 2011. It can be argued that agriculture production is constrained in Nigeria by poor credit delivery; the delivery of credit facilities in the country is largely in favour of the wealthy farmers as opposed to poor farmers; the wealthy farmers may utilize the loan acquired for ulterior motives rather than the initial function of agricultural production [40,41]. This limited access to credit facilities may be as a result of high-interest rates credit facilities provided by financial institutions among other bureaucratic delays inherent in loan assessment, acquisition, and disbursement in Nigeria.

Ownership of land can serve as an indicator of the wealth status of farming households [25], and thus it can be expected that the increased wealth status of farming households leads to increased food security of farm households. The distribution of the ownership of land is illustrated in Table 1; the result obtained showed that the majority (98.76%) of farm-households owned land compared to 2010 where the majority (69.96%) of farm households had no access to land.

The summary of average food expenditures and, by extension, food security of farm households, is presented in Table 1. A household is categorized to be very vulnerable to food insecurity if more than 75% of its total expenditure is spent on food items whereas people spending 65–75% are considered to have high food insecurity [11,42]. Following Engel's law, the higher the food expenditure share, the lower the food security of farm households. Thus, the food security status of farm households measured as household food expenditure share slightly reduced in 2016 with average farm households spending approximately 72% of their expenditure on food compared to 2010 when an average farm household spent about 69.6% of their expenditures on food.

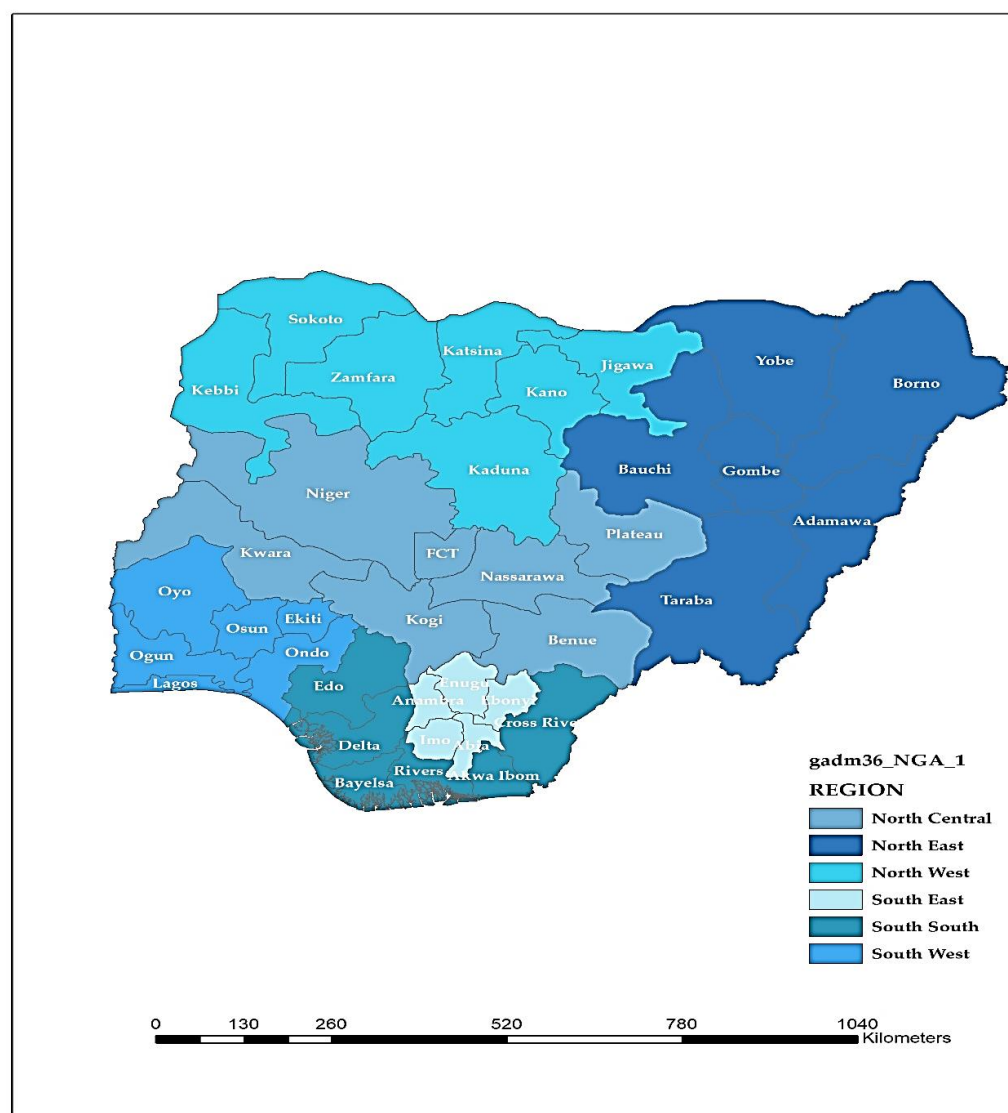


Figure 1. Geographical subdivisions of Nigeria showing the 36 states, Federal Capital Territory, and the six geo-political regions of the country obtained by computation of GADM [34] geo package Data.

2.4. Analytical Techniques

The method of data analysis adopted in this study to achieve the stated objectives includes:

2.4.1. Panel Probit Model

The pooled probit model specification of the panel data model was employed to evaluate the factors affecting CCA strategies employed by farm households for this study [43,44]. Following Akerele et al. [43], the panel probit model is expressed as follows:

$$y_{jit}^* = a + X_{jt}\beta + e_{jit} \quad (1)$$

where

y_{jit}^* = the latent (underlying) variable that determines whether farm household j would be classified as an adopter of CCA measure i at time t ;

β = a vector coefficient;

X_{jt} = a matrix of explanatory variables;

a = the constant term; and

e_{jit} = the idiosyncratic errors assumed to have zero mean and unit variance. The relationship between the latent variable y_{jit}^* and the observed outcome y_{jit} is represented as

$$y_{jit} = \begin{cases} 0 & \text{if } y_{jit}^* < 0 \\ 1 & \text{if } y_{jit}^* > 0 \end{cases} \quad \text{for } i = 1, \dots, n \quad \text{and } j = 1, \dots, p-1 \quad (2)$$

where $y_{jit} = 1$ if a farm household adopts a CCA strategy for each adaptation strategy.

The selection of the variables was motivated by previous literature [4,25,45–47], availability of data [48], and economic theories [4] on factors influencing the choice of CCA and are presented in Table 2. Farm and household attributes were included as explanatory variables for assessing determinants of CCA options. Ownership of land or tenancy status was used as a determinant mainly because these can act as proxies for the wealth status of the farm households [25].

Table 2. The Description Measurement and A Priori Expectation of the Variables.

Variable	Description	Measurement	A Priori Expectation
X1	Age of household head	Years	±
X2	Accessed credit	Dummy: 1 for yes; 0 no	+
X3	Tenancy status	Dummy: 1 for farm owner; 0 otherwise	+
X4	Farm size	Hectares	+
X5	Accessed extension contact	Dummy: 1 for yes; 0 no	+
X6	Household size	Number	±
X7	Gender of the HH	Dummy: 1 for male; 0 otherwise	±
X8	Marital status	Dummy: 1 for married; 0 otherwise	±
X9	Educational level of HH	Years	+
X10	Secondary occupation income	Naira	+
X11	Quantity of household asset	Number	+
X12	North Central	Dummy: 1 for yes; 0 otherwise	+
X13	North East	Dummy: 1 for yes; 0 otherwise	+
X14	North West	Dummy: 1 for yes; 0 otherwise	+
X15	South East	Dummy: 1 for yes; 0 otherwise	+
X16	South West	Dummy: 1 for yes; 0 otherwise	+
Reference category	South-South		

Following Teklewold et al. [4], socio-demographic characteristics of farm households important in implementing CCA options were controlled for, these factors include age, gender, household size, gender, and educational level of the household head. Resource constraint was also considered while accounting for the factors influencing CCA options. Quantity of household assets can act as a proxy in measuring the wealth status of farm households [4]; access to credit facilities extension services was included as one of the

explanatory factors since extension services provide crucial education and information needed to adopt CCA options [25,46].

Following from this, the four categories of adaptation strategies were considered in this study, these measures were selected based on the popularity of these measures amongst farm households across all the geo-political zones in Nigeria considered in this study:

- Diversify more into other crops
- Used Irrigation facilities
- Diversify into off-farm activities
- Implement soil conservation techniques

Adoption of crop diversification is a CCA method that may involve the planting of high yield variety and drought-resistant crops or intercropping [48], which has been extensively identified from previous studies as an option that can help farmers and farming households buffer the negative effects of climate change. Planting of crops such as cereals that are highly affected with sporadic fluctuations in weather patterns along with turgid crops such as cassava will minimize crop losses due to weather events [33,49].

Implementation of soil conservation techniques such as fallowing and practicing alley cropping can aid in the restoration of soil nutrients, minimize nutrient loss, protects the vegetation cover, and also reduces organic matter oxidation in the soil [49]. Alley cropping can aid in reducing soil erosion while also serving as windbreaks.

Water as a resource is crucial for optimal crops and livestock cultivations [48]. Several studies such as [48–51] documented the importance of implementation of irrigation facilities especially in regions prone to drought or low rainfall occurrences. The adoption of irrigation is encouraged to augment the rainfall amount required for optimal crop cultivation.

Off-farm diversification has been extensively used as a CCA strategy as evidenced by previous literature [51,52]. Farming households may undergo off-farm activities or other occupation during the dry season, unfavourable climate conditions [51] or mainly to complement income sources in order to meet household food security status.

Estimating the impact of climate change adaptation on household food security in Nigeria was achieved in two stages using a combination of two analytical tools, which were described as 2.4.2 (Propensity Score Matching) and 2.4.3 (Difference-In-Difference).

2.4.2. Propensity Score Matching

This study employed PSM to estimate the impact of the adaptation strategies on farm household food security status. The PSM is defined as the conditional probability that a farm household adopts the new adaptation strategies, given pre-adoption characteristics [53]. To mimic a typical randomized controlled experiment, the PSM assumes the unconfoundedness assumption, also known as conditional independence assumption, which implies that once Z is controlled for, technology adoption is random and uncorrelated with the outcome variables. The PSM also accounts for this sample selection bias [25,54].

Following the framework of Ali and Erenstein [25], the PSM was used to estimate the impact of climate change adaptation on farm households' food security. After investigating the choice determinants of CCA practices using PPM, a propensity score matching approach was employed to analyse the impact of adaptation practices on food security.

The farm households were classified as food secure or food insecure based on their share of total household expenditure spent on food. Following Ali and Erenstein [25,42], Smith, et al. [55], households spending more than 75% of their expenditures on food were categorized as food insecure households and were assigned a dummy value of zero; while farm households were categorized as food secure and assigned a value of 1 when the food expenditure is below the threshold level (75%) of total expenditure.

A risk-averse farm F_i opts for a few strategies (S_i). It is assumed that households that have opted for adaptation strategies have higher utility levels compared to those that have not: [25].

$$U[F(S_1)] > U[F(S_0)] \quad (3)$$

The PSM can be expressed as according to Ali and Erenstein [25]:

$$P(Z) = \Pr\{I = 1|Z\} = E\{1|Z\} \quad (4)$$

where I = is the indicator for adoption and

Z = the vector of pre-adoption characteristics.

The conditional distribution of Z , given $p(Z)$, is similar in both groups of adopters and non-adopters.

The expected treatment effect for the treated population is of primary significance and is given as

$$\tau_{|I=1} = E(\tau|I = 1) = E(R_1|I = 1) - E(R_0|I = 1) \quad (5)$$

where τ = the average treatment effect for the treated (ATT),

R_1 = denotes the value of the outcome for adopters of the adaptation, and

R_0 is the value of the same variable for non-adopters.

As noted above, the major problem is that we do not observe $E(R_0|I = 1)$, in other words, it is potentially a biased estimator.

After estimating the propensity scores, the average treatment effect for the treated (ATT) can then be estimated as [25,56]

$$\begin{aligned} \tau &= E(R_1 - R_0|I = 1) = E\{E\{R_1 - R_0|I = 1, p(Z)\}\} \\ &= E\{E\{R_1|I = 1, p(Z)\} - E\{R_0|I = 0, p(Z)\}\} \end{aligned} \quad (6)$$

PSM is based on two underlying assumptions, that is: the common support and the conditional independence assumption [25]. A diagnostic test of matching quality must be carried out after matching to estimate the standard errors and treatment effects. Some balancing tests were to be carried out to access the matching quality, mean absolute bias, t-statistics, and the bias reduction before and after matching [57,58].

2.4.3. Difference-in-Difference

DID was also used to assess the impact of CCA on household food security; unlike the PSM which estimates the impact of CCA on household food security between adopters of CCA and non-adopters, DID evaluates the impact of CCA over time, that is from 2010 to 2016.

Difference-in-difference (DID) methods, compared with PSM, assume that unobserved heterogeneity in adoption is present but that such factors are time-invariant. With data on project and control observations before and after the CCA adoption, therefore, this fixed component can be differenced out. Some variants of the DID approach have been introduced to account for potential sources of selection bias. Combining PSM with DID methods can help resolve the problem of selection bias, by matching units in the common support [56]. The propensity score can be used to match participant/adopters and control/non-adopters units in the base year, and the CCA impact is calculated across adopters and matched control units within the common support. For two time periods $t = \{1, 2\}$, the DID estimate for each adoption area i will be calculated as

$$DID_i = (Y_{i2}^T - Y_{i1}^T) - \sum_{j \in C} \omega(i, j) (Y_{i2}^C - Y_{i1}^C) \quad (7)$$

where

$\omega(i, j)$ is the weight (using a PSM approach) given to the j th control area matched to adoption area i .

Y_{i2}^T = Farm household food security status of CCA adopters in 2016.

Y_{i1}^T = Farm household food security status of CCA adopters in 2010

Y_{i2}^C = Farm household food security status of non-adopters of CCA in 2016

Y_{i1}^C = Farm Household food security status of non-adopters of CCA in 2010.

3. Results and Discussion

The findings of this research work, interpretations, and also discussion of the result are presented in this section.

3.1. Determinants of Farm Households Climate Change Adaptation Options

A panel probit model was used in this study to estimate the factors affecting adaptation strategies employed by farming households. Adaptation options identified include

Irrigation

Soil conservation

Crop diversification

Diversification into non-farm activities

The likelihood ratio test from the Panel probit model showed the overall significance of the models at ($p < 0.01$) probability level, which signified that the model is useful in explaining factors influencing decisions of farming households to adapt to climate change.

Age of Household Head: As shown in Table 3, the age of the household head is an important determinant in the decision of farming households to use irrigation ($p < 0.01$), and diversify into non-farm activities ($p < 0.01$). The sign of the parameter is negative, implying that the older the household head, the less likely their probability to adopt irrigation and diversify into non-farm activities. It can be deduced from the result that with a year increase in the age of farmers the probability of implementing irrigation facilities and practicing non-farm diversification decreases by 1% and 0.4% respectively. These findings suggest that younger farmers are more likely to adopt these CCA strategies compared to their older counterparts, possibly because they are innovative and keen to try new technology and methods to improve agriculture, whereas older farmers through years of experience may understand the negative economic implications of practicing such strategies. These findings are in support of Ali and Erenstein [25]; where the age of the household head had a negative relationship with CCA adoption, they claimed that older farmers may be conservative about trying new and innovative agricultural practices despite increased awareness. However, the result was against the findings of [59–61] who found that age had a positive association with CCA adoption among farming households.

Access to Credit Facilities: Access to credit facilities was positively significant ($p < 0.01$) for practicing soil conservation and off-farm diversification (shown in Table 3), which is in support of Hassan and Nhemachena [62] and Ojo and Baiyegunhi [63]. In their study, they opined variations to farmers' adaptation options, which are largely dependent on their access to credit and information on credit. On the other hand, access to credit facilities has a negative but significant ($p < 0.10$) effect on the probability of using irrigation facilities. This may be due to the cost implication attached to the use of irrigation and the predictive risk of being unable to refund the credit owed when due. The effect on irrigation facilities is in line with [59] but opposed to findings in [64]. Hisali et al. [59] reported that households without credit have a greater likelihood of implementing CCA options, the suggested situations like this may occur where repayment of credit leads to resource constraint needed for CCA adoption or that credit can be used for other purposes other than climate change adaptation.

Table 3. Parameter Estimates of Panel Probit Model of Determinants of Farming Households CCA Strategies.

	Irrigation	Soil Conservation	Crop Diversification	Diversify into Other Occupation
Credit	−0.14 * (−1.82)	0.13 *** (2.61)	−0.20 (−0.38)	0.23 *** (5.30)
Tenancy Status	0.05 (1.19)	0.10 *** (39.49)	0.26 *** (7.97)	−0.08 *** (−2.99)
Farm size	0.02 *** (3.55)	0.03 * (1.86)	0.03 *** (4.10)	0.08 (1.62)
Extension contact	0.17 *** (2.89)	−0.09 * (−1.61)	0.24 *** (4.07)	−0.07 (−1.64)
Household size	0.02 * (1.90)	0.06 *** (9.17)	0.01 (0.68)	0.04 *** (6.27)
Age of HH	−0.01 *** (−3.03)	0.01 (0.69)	−0.01 (−0.11)	−0.004 *** (−4.74)
Gender of HH	−0.07 (−0.75)	0.30 *** (4.69)	−0.02 (−0.38)	−0.11 ** (−2.38)
Marital status	0.24 ** (2.19)	−0.16 ** (−2.55)	0.28 *** (5.17)	0.26 *** (5.13)
Years of schooling	−0.01 (−0.04)	−0.04 *** (−12.35)	−0.02 *** (−6.29)	0.02 *** (7.27)
HH asset	−0.01 *** (−3.16)	−0.09 *** (−15.66)	−0.01 *** (−7.12)	0.003 *** (3.79)
North Central	0.35 ** (2.23)	0.49 *** (7.65)	0.28 *** (3.80)	−0.54 *** (−7.51)
North East	−0.03 (−0.17)	0.56 *** (8.68)	0.15 ** (2.10)	−0.42 *** (−5.88)
North West	0.56 *** (3.71)	0.48 *** (7.37)	1.12 *** (12.35)	−0.18 *** (−2.52)
South East	−0.01 (−0.04)	0.55 *** (8.48)	1.43 *** (15.11)	−0.25 *** (−3.52)
South West	−0.35 (−1.62)	0.50 *** (6.38)	0.06 (0.99)	0.47 *** (5.37)
Constant	−2.12 (−9.79)	−1.99 (−19.02)	0.38 (3.50)	−0.16 (−1.70)
Number of Observations	18,873	18,873	18,873	18,873
Log-Likelihood	−0.07 ***	−4262.18 ***	−6173.30 ***	−9332.21 ***
Wald Chi2(14)	0.21 ***	2371.78 ***	745.85 ***	431.58 ***
p-Value	−0.05 **	0.000 ***	0.000 ***	0.000 ***

*, ** and *** represents statistical significance at 10%, 5% and 1% respectively. Authors computation of LSMS data 2010–2016.

Tenancy Status: The influence of ownership of farmland is reported in Table 3. As indicated ownership of farmland has a mixed effect on adaptation options, it has a direct and significant relationship with soil conservation ($p < 0.01$) and crop diversification ($p < 0.01$). With ownership of land, the decision on the usage of land rests solely on the farmer, due to the availability of lands, it is easier for the farmer to leave some portion of his land for fallowing and also utilize the farm for the cultivation of crops with varying lifecycles since he does not have to fear he may lose his tenancy status. The cost of incurring land is null, therefore, there are more funds available to go into planting various crops. Quan [65] and Kokoye, et al. [66] concluded that land ownership availability can be an incentive for farmers to invest in resources for farming because farmers can pass their land on to the next generation; therefore, they are more willing to care for the land by adopting practices that can aid to maintain its productivity and food security in the context of climate change. Conversely, ownership of farmland has a negative and significant relationship in practicing alley cropping and diversifying into non-farm activities. The relationship between ownership of farmland and diversifying into nonfarm activities is expected because farmers may have invested so much in their farming business; another reason is that owning land may increase the profitability of the business. Previous studies, however, showed mixed results for the relationship between tenancy status and adoption of CCA options. While some studies [67,68] posit a direct relationship between land ownership and adoption of CCA options, other studies such as [25,69–73] reported a negative correlation. The latter are

variously associated with the need for farmers in this category to have more agriculturally reliant livelihoods.

Farm size: Farm size has a significant influence on CCA options. An increase in farm size increases the probability of farmers adopting irrigation ($p < 0.01$), implementing soil conservation techniques ($p < 0.01$), and practicing crop diversification. From Table 3, a 1 hectare increase in farm size increases the likelihood of farm households implementing irrigation, soil conservation techniques, and crop diversification by 2%, 3%, and 3% respectively. Findings are in support of several studies that generally reported a positive association between CCA adoption and farm size [25,70,74,75]. Farmers with large land possessions are likely to have more capacity to try out and invest in climate risk-coping strategies. As reported by Arunrat et al. [64], an increase in farm size and land ownership reduces bureaucratic delays with regards to decisions about CCA adoption, mainly because of their ability to procure the high capital and landholdings, and the freedom required to implement innovative practices on their land.

Extension Contact: Studies such as Adams [39], Tambo [51], Boansi, Tambo and Müller [61], and Gbetibouo [76] have shown significant effects of access to extension contact on adopting CCA options. The result of the PPM confirmed that access to the extension has a positive and significant ($p < 0.01$) impact on irrigation use and crop diversification; from Table 3, it can be inferred that a unit increase in farm households' access to extension contact increases the likelihood of implementing irrigation and crop diversification by 17% and 24% respectively. The reason behind it is that extension services help disseminate innovations likely denoting the role of advisory services, and access to information among other resources may motivate the farm household to implement such CCA strategies [70,71]. These findings support those of Tambo [51], Boansi, Tambo and Müller [61], and Gbetibouo [76], which showed that extension services enhanced the availability of information on CCA options.

Household Size: It is positive and significant ($p < 0.01$) for the probability of households to diversify into non-farm activities and implement soil conservation techniques. Increasing household size results in an increase in food expenditure and the compulsion to meet this need comes from non-agricultural income sources. Ali and Erenstein [25], Deressa, Hassan and Ringler [45], and Arshad, et al. [77] revealed similar results of the increase in household size, which increases the probability of adopting a strategy. This is likely due to the prevalence of family labour, which makes task achievement more effective, especially during peak periods. Adams [39], Temesgen, Hassan, Tekie, Mahmud and Ringler [47], and Le Dang, et al. [78] contradict the positive influence of household size; they opined that household size has a negative and significant impact on the probability of choosing adaptation strategies.

Gender of Household Head: Results obtained in Table 3 are partially in tandem with previous findings [46,50,79,80] that male-headed households often have a higher likelihood of adopting agricultural innovations and thus are better adapted to climate change. Being a male-headed household increases the chances of practicing soil conservation compared to their female counterparts. However, the likelihood to diversify into other occupations increases with being a female-headed household because females in the household especially in Nigeria are found to play supportive roles (such as processors and traders) in the households by diversifying the household income, thus easing the financial burden of the family. Females in households also tend to make financial plans for unforeseen circumstances. Adams [39] and Ogunpaimo, et al. [81] shared a similar view on females tilting towards the adoption of occupation diversification compared to the males.

Marital status: Table 3 showed that married farmers have the likelihood to use adaptation strategies such as irrigation facilities, crop diversification, and nonfarm diversification compared to singles. This is likely because more efforts come into making decisions when being married compared to being single. On the other hand, being married has a negative but significant influence on implementing soil conservation techniques.

Years of schooling: From Table 3, it is shown that the years of schooling of the farm household head have mixed effects on the choice of CCA. This variable significantly and positively affected practicing diversification into non-farm activities ($p < 0.01$); this result shown in Table 3 supported the work of Ali and Erenstein [25], Alam [48], Gebrehiwot and Van Der Veen [49], and Alam, Alam and Mushtaq [60]. The papers all agreed that educated farmers may be more aware and perceive climate change, as they can easily understand and interpret information compared to farmers with a lower level of education. However, this philosophy did not work for the adoption of some strategies; years of schooling negatively influenced the probability of practicing soil conservation ($p < 0.01$) and crop diversification ($p < 0.01$).

Quantity of Household Asset: The quantity of household assets, which is a proxy of the wealth status of farming households, is an important variable that reflects farmers' choice of climate change adaptation options. Results shown in Table 3 contradict Ali and Erenstein [25] in that quantity of household assets enacted a negative influence on climate change adaptation options except for non-farm diversification ($p < 0.01$). It can be implied that income from the use and sale of household size is diverted mainly into non-farm diversification with non-farm diversification serving as secondary income to the farming households.

Location: Location typically plays an important role in CCA adoption [25,82–85]. In this study, we included dummies for agroecological zones to control for the location effect on adaptation strategies, with South-South being the base for the model. The result indicated a significant positive and significant probability of farm households in North-Central and North-West to implement irrigation facilities compared to farm households in the South-South region. The likelihood of adopting soil conservation techniques increases with residing in all other regions of the country in relation to the South-South zone. The findings in Table 3 also highlighted that all the zones, except for the South-West zone, negatively affect the probability of farming households to diversify into non-farm activities concerning those in the South-South region.

3.2. Impact of Climate Change Adaptation on Household Food Security

A combination of PSM and DID was used to evaluate the impact of CCA adoption on household food security. It is therefore imperative to discuss the result of the impact of CCA options on household food security between adopters and non-adopters from 2010 to 2016.

3.2.1. PSM Result of Impact of CCA on Household Food Security

The with and without effect of climate change adaptation options is explained by PSM. Table 4 presents the impacts of adaptation methods used on household food security based on propensity score matching. The impact of climate change adaptation on household food security was significant with adopters having 9% higher food security than non-adopters in 2010. This result is in support of Ali and Erenstein [25], but against Weldegebriel and Prowse [86] who found that the adaptation strategy reduced farm income and, with that, food security due to the exclusion of important variables. Ali and Erenstein [25] stated that CCA practices help to enhance the food security and welfare of rural households. Thus, farm households should be encouraged to adopt a few CCA practices to improve welfare outcomes. Farm households not adopting CCA practices are more likely to be food insecure. Shiferaw, et al. [87] also opined that the average treatment effect on the treated (ATT) of adaptation on household food security was positive and significant, which implied that CCA options foster household food security.

Table 4. PSM Showing the Impact of CCA Adoption on Household Food Security.

Outcome Variable	ATT	t-Values	Mean Bias	Median Bias	Bias Reduction
Food security	0.09 **	2.15	4.2	4.3	83%

Authors computation of LSMS data 2010–2016. ** represents statistical significance at 5% respectively.

Table 5 shows the covariate balancing tests before and after matching. As indicated in the table, the balancing test revealed that the bias was relatively higher before matching.

Table 5. Covariate Balancing test for the difference between CCA Adopters and non-adopters.

Variable	Before Matching-Mean Absolute Bias	After Matching Mean Absolute Bias	t-Vals of Covariates before Matching	t-Vals of Covariates After Matching	% Reduction Bias
Credit	0.001	0.01	0.15	1.63	75.8
Tenancy Status	0.06	0.01	1.90	1.13	74.7
Farm size	0.07	0.01	0.11	1.44	70.4
Extension contact	0.06	0.002	2.82	0.13	97.2
Age of HH	1.62	0.28	1.49	0.41	82.6
Gender of HH	0.07	0.002	3.94	1.39	97.2
Years of Schooling	0.49	0.09	2.07	0.25	82
Marital Status	0.03	0.01	1.19	0.69	65
HH SIZE	0.08	0.01	0.41	1.33	88.7
HH ASSET	0.516	0.112	0.87	0.41	78.1

Authors computation of LSMS data 2010–2016.

For instance, before matching tenancy status ($p < 0.10$), extension contact ($p < 0.05$) and gender of the household head ($p < 0.01$) could cause selection bias when assessing the influence of CCA options on household food security status. The percentage bias reduction is between 65–97.2%. These indicators of covariates balancing showed the results obtained satisfied the balancing of covariates following matching and the application of the common support condition. The result implied no selection bias when matching adopters and non-adopters, thus differences in food security levels are mainly due to the adoption of CCA measures.

3.2.2. DID Result of Impact of CCA on Household Food Security

The true impact of CCA on household food security over time can be measured by looking at the effects of adaptation options between adopters and non-adopters, which was illustrated by the result of the PSM and then measuring the impact of the adaptation measures over the period of adoption using the DID. The adopter and the non-adopter groups within the same common support in the PSM analysis for the base period were appended, after which the DID analysis was carried out.

The difference in difference (DID) estimation combined with propensity score matching (PSM) was used to evaluate the average impact of the CCA options on household food security. The average treatment effects of CCA options were evaluated, which compares food security in the adoption state (Y_1) with the outcomes in the control or the counterfactual (Y_0) conditional on receiving treatment.

Contrary to previous studies [25,88], which used cross-sectional data to assess the impact of CCA options, this study used panel data for six time periods to assess the impact of CCA options on household food security. Similar to Kangmennaang et al. [26] and Kabunga, et al. [89], this approach allowed for the combination of propensity score matching with DID estimation to control for selection bias and temporal impact variability. The estimated results showed that adopting CCA options intervention positively influenced household food security.

As shown in Table 6, the F-value is significant at ($p < 0.01$), which indicated that the model was useful in assessing the impact of CCA on household food security over

time. The result in Table 6 showed that the coefficient of time trend (y16) was significant ($\beta = -4.02$, $p < 0.01$); this implied that household food security was trending down with time. The result of the DID is positive and significant ($\beta = 5.93$, $p < 0.01$), which reveals that the impact of the CCA options increases household food security between adopters and non-adopters. This finding confirms that CCA options had a significant positive impact on farm households' food security status. This finding shared similar results with Noltze, et al. [90], and Kangmennaang et al. [26] who found that agroecological practices in the form of CCA promote food security after 2 years. However, while this study adopted the use of HFES as a measure of food security, Kangmennaang et al. [26] used the Household Food Insecurity Access Scale (HFIAS).

Table 6. DID Showing the Impact of CCA Options on Household Food Security Without Covariates.

Household Food Expenditure	Coefficient	Robust Standard Error	t-Values
Adapt	4.86 ***	1.09	4.45
y16	−4.02 ***	0.50	−8.06
DID	5.93 ***	0.68	8.73
Constant	76.00	0.91	83.29
F-value	33.85 ***		
Prob > F	0.000		

Authors computation of LSMS data 2010–2016. *** represent statistical significance at 1% respectively.

It must be noted that CCA adoption may be implemented by farming households before the year 2010, however, 2010 was used as the baseline due to data availability. The findings in this study also support the result of other studies that confirmed the direct effects of CCA options on household food security. Becerril and Abdulai [91] reported that increased farm output can lead to higher consumption, off-farm diversification, and increased farm incomes. Surpluses from farm yield may also be used to increase the household quantity of assets increasing the adaptive capacity of households to climate change, thus promoting households' food security status [92,93]. Khonje, et al. [94] also reported that sustainable practices such as crop diversification and other CCA options can lead to improved welfare and food security outcomes. Other effects of adopting CCA options reported may include promoting women empowerment, capacity-building, and knowledge exchange within the community, which may further lead to increased food production at the community level, increased consumption, and better living standard conditions [26]. Adopting CCA options can also foster collective relationships among farming households within the communities, allowing for the sharing of risks and burdens associated with farm activities.

To control for any selection bias between the adopters and non-adopters of CCA, the results obtained in Table 6 were controlled for covariates influences on the impact of CCA on household food security status, as shown in Table 7. The result obtained indicated that even after controlling for potential covariate influence, DID had a positive and significant ($\beta = 4.15$, $p < 0.01$) effect on household food security status. This result was corroborated by [26] who found that covariates control does not influence the outcome of the DID result or the influence of CCA on the household food security status.

Table 7. DID Showing the Impact of Adaptation Options on Household Food Security with Covariates.

Food Security Outcome	Coefficient	Robust Standard Error	t-Values
Adapt	4.34 ***	1.22	3.55
Time	−3.13	3.17	−0.99
DID	4.15 ***	1.01	4.11
Constant	79.90	2.90	36.36
F-value	13.55 ***		
Prob > F	0.000		

Authors computation of LSMS data 2010–2016. *** represent statistical significance at 1% respectively.

4. Conclusions

This study assessed the impact of climate change adaptation (CCA) on household food security among farm households in Nigeria. Against previous works of literature that adopted cross-sectional approaches to investigate CCA impacts on welfare outcomes, this research work adopted a panel data analysis, thus measuring the impacts of CCA on household food security across space and time. We recognized that there are other CCA options not considered in this study mainly due to lack or limited data of such CCA strategies in the LSMS data. However, this study has provided useful insights and information on the relationship between CCA options and household food security in Nigeria. Based on the aforementioned findings, this study confirmed the need for adaptation to climate change by farming households, which increase with an increase in farm size, extension contact, and marital status, with access to credit, ownership of farmland, household size, the gender of household size, years of schooling, household asset and location having mixed effects on the choice of adaptation strategies. From the study, it was shown that climate change adaptations have helped farming households improve their food security status in the face of prevalent climatic conditions. Therefore, the study recommends that farming households should practice continual implementation of CCA options to foster improvement in household food security status. Also, access to credit facilities and extension contacts remains a catalyst for implementing adaptation measures, thus constant and quality extension contacts and credit facilities with low-interest rates should be provided to farming households to enable them to adapt better to climate changes and improve household food security status.

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