

Original Research Article

Climate change adaptation mechanisms for smallholder farmers in Côte d'Ivoire

ABSTRACT

The aim of this paper is to analyse smallholder farmers' adaptation mechanisms to climate change in Côte d'Ivoire. The Heckman's probit model with sample selection was adopted to account for farmers' level of perception of climate change. The study used data from the World Bank survey (CGAP, 2016) of small agricultural households in Côte d'Ivoire carried out in 2016. The results of our econometric estimations confirm the relevance of perception in the process of identifying adaptation factors and meteorological information is decisive in improving the degree to which farmers perceive climate change. Furthermore, access to agricultural information, membership of a cooperative, subscription to agricultural insurance, gender, level of education and level of income have all been shown to be relevant to adaptation to climate change. Consequently, a policy to strengthen the adaptive capacity of smallholders requires advisory support (agricultural advice and meteorological information), the promotion of agricultural organizations (cooperatives), the availability of financial resources, and the extension of risk coverage to the agricultural sector. All these measures must be part of a framework that not only strengthens the capacities of small-scale farmers through education and training, but also promotes gender equality by facilitating women's access to the productive resources they need to effectively meet their food production requirements.

Keywords: Côte d'Ivoire, climate change, adaptation, perception, smallholder farmers, Heckman's probit model with sample selection.

1. INTRODUCTION

Adaptation remains the preferred option for countering the adverse effects of climate change, Barnabàs et al. [1], Mustapha et al. [2], Traoré [3], Sissoko et al. [4], Traoré et al. [5], El Bilali

H.[6] and Niang and Ruppel[7]. According to IPCC[8], adaptation is defined as an adjustment in natural or human systems in response to present or future climatic stimuli or their effects in order to mitigate adverse effects or exploit beneficial opportunities. In agriculture, these adaptation strategies take several forms, including new crop varieties and animal species better suited to drier conditions, irrigation, crop and livestock diversification and changes to the cropping calendar, Deressa et al.[9] and Di Falco et al.[10].

In countries with agricultural economies, such as those in Africa, the implementation of these strategies is of the utmost importance, as the social and economic well-being of the population depends on them. The agricultural sector, dominated by rain-fed agriculture, plays a key socio-economic role, contributing between 30% and 60% of GDP and employing 2/3 of working population, FAO [11] and World Bank [12]. Studies show that the impact of climate change will be severe in Sub-Saharan Africa in general and in the Sahel and West Africa in particular, Baarsch et al.[13], Bakshi et al.[14], Bornemann et al. [15], Hassan[16], Lokonon et al.[17], Sultan and Gaetani[18] and Egbebiyi et al. [19], given that these countries are already experiencing low agricultural yields that are worsening their food situation, World Bank[12] and Sawadogo et al. [20]. Unfortunately, the sector is dominated by smallholders who, despite accounting for 80% of food production, Poole[21] and sometimes representing 75% of the workforce, World Bank[22], do not always have the necessary means to cope with climatic hazards.

Although adaptation strategies are important and are being adopted by farmers to varying degrees, their effectiveness has yet to be demonstrated, Below et al.[23], Steward et al.[24], Dimon[25], Bello et al.[26], Traoré et al. [5] and Adou et al.[27]. This situation translates into either, a low level of adoption, or inappropriate strategies. Hence, we need to identify the factors behind the adoption of appropriate and effective strategies.

The literature highlights several factors linked to adoption. Some authors point out financial and technological constraints, Garcia de Jalon et al.[28] and Kalame et al.[29], that limit the choice of adaptation strategy. Others mention factors linked to human and social capital (Jones et al.[30] and Garcia de Jalon et al.[31]. Furthermore, selected authors point out governance problems, in general, and in particular, the failure to take local knowledge into account in the design of adaptation strategies, Dimon[25], Bello et al.[26], Kanté[32], Traoré et al.[5] and Bambara et al.[33]. Thus, several studies neglect the farmers' perception dimension in the identification of factors favourable to the adoption of adaptation strategies, Mustapha et al.[2] and Traoré et al. [5]. However, it is the driving force behind the adoption process, Agossou et al.[34], Ruault[35] and Ban van den et al.[36]. Indeed, the nature of adaptation and its effectiveness depend on how danger or risk is perceived. Farmers' behaviour is shaped more by their perceptions of climate change than by actual climate trends, De Longueville et al. [37], Adger et al.[38], Mertz et al.[39], Deressa et al. [40], Maddison[41] and Gbetibouo[42]. Further to the above, authors indicate that the incidence of climate change is not a determining factor in the adoption of adaptation strategies, Schlenker and Lobell [43] and Garcia de Jalon et al.[28]. For example, Garcia de Jalon et al. [28] show that countries most exposed to the effects of climate change have a low probability of adopting adaptation strategies. Similarly, climate change adaptation measures differ according to the realities of each area, Chemura et al.[44] and Rippke et al.[45]. It is therefore necessary to have clear understanding of smallholder farmers' perceptions of climate change and the factors driving their decision to adapt, Esham and Garforth[46].

In Côte d'Ivoire, where changes in climatic conditions, characterised in particular by variations in the dates of the seasons and rainfall amounts, Ochoy[47], Goroza[48], Brou and Chaléard[49] and Goula et al.[50], have already been observed, MEDD[51], smallholder rural farmers, the main producers, have only partial knowledge, Isbell et al.[52] and little capacity to adapt, CDN[53]. Although, studies have been carried out on perception and adaptation in Côte d'Ivoire, not only they have done little to explore the link between the two phenomena, Kouassi et al.[54] and Attoumane et al.[55] but those studies also have been partial as they are specific to a given study area, Brou et al.[56], Timité et al.[57], Boko et al.[58] and Bodji et al.[59].

This paper aims to fill this gap with the main objective of analysing the adaptation mechanisms of smallholder farmers in Côte d'Ivoire to climate change. The contribution of this paper is twofold. The first relates to the modelling of the adaptation process, which takes account of farmers' perceptions in the form of a two-stage econometric estimation technique. Indeed, most studies do not link the two phenomena. Those that do, study the two phenomena separately as in the case of Kaboré et al.[60]. The second concerns the inclusion of all smallholder farmers throughout the country, in contrast to the partial studies that have been carried out to date. In this way, a better understanding of adaptation factors would help guide decision-making with a view of promoting rapid and effective adaptation by smallholder farmers.

The rest of the paper is structured as follows. Section 2 describes the methodology and data. Section 3 presents the results and section 4 discusses them. The final section concludes the study and draws out the economic policy implications.

2. METHODOLOGY AND DATA

This section presents the modelling and data sources in turn.

2.1 Presentation of the theoretical and empirical model

The strategy for identifying the determinants of climate change adaptation by smallholder farmers is based on random utility models. A representative farmer i decides to implement an adaptation strategy if his expected utility, in case of adaptation, U_1 is higher than that without adaptation U_0 . In other words, if $A^* = U_1 - U_0 > 0$ corresponding to a net gain from adoption, then the farmer adopts the adaptation strategy. Also, as A^* it is not observable, it is specified as follows:

$$A_i^* = X_i\alpha + \varepsilon_i \text{ with } A_i = \begin{cases} 1 & \text{if } A_i^* > 0 \\ 0 & \text{if } A_i^* \leq 0 \end{cases} \quad (1)$$

where $\varepsilon_i \sim N(0, \sigma^2)$

A_i being the observed behaviour of farmer i and X_i the vector of characteristics of farmer i with α and ε_i respectively the vector of parameters and the error term. Thus equation (1) states that farmer i will choose to implement the adaptation strategy ($A_i = 1$) if his net utility is positive ($A_i^* > 0$).

Estimation of equation (1) by a standard binary probit model would give unbiased estimators. However, adaptation follows from the perception of climate change. According to Maddison[41] and Gbetibouo[42], perception is a prerequisite for adaptation. In other words, perception precedes adaptation. Consequently, omitting this step undoubtedly leads to selection bias and biased estimators. In fact, estimating equation (1) using a probit poses a problem of sample selection insofar as farmers who adopt an adaptation strategy are only those who have a good perception of climate change.

Adaptation to climate change is therefore a two-stage process. In the first stage, the farmer perceives climate change, and in the second stage he decides whether to adapt by adopting a particular measure or not. This reality is taken into account using a probit or logit model with sample selection, and the two dependant variables are binary. The final model is as follows:

$$A_i^* = X_i\alpha + \varepsilon_i \quad (1)$$

$$P_i^* = Z_i\beta + \mu_i \quad (2)$$

$$\text{with } P_i = \begin{cases} 1 & \text{if } P_i^* > 0 \\ 0 & \text{if } P_i^* \leq 0 \end{cases}$$

$$\text{and } A_i = \begin{cases} 1 & \text{if } A_i^* > 0 \text{ and } P_i = 1 \\ 0 & \text{if } P_i \leq 0 \text{ and } P_i = 1 \\ 0 & \text{if } P_i = 0 \end{cases}$$

where $\begin{pmatrix} \varepsilon_i \\ \mu_i \end{pmatrix} \sim N_2 \left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma^2 & \rho\sigma \\ \rho\sigma & \sigma^2 \end{bmatrix} \right)$

Equation 2 is the perception equation (being the latent variable) explaining the level of perception of climate change from characteristics Z relating to farmer i . μ_i is the error term. If $P_i = 1$, the farmer has a good perception of climate variability and 0 otherwise. The parameters α and β are estimated by maximizing the following likelihood function:

$$L = \prod_i \Phi_2(Z_i\beta, X_i\alpha; \rho)^{1(y_i=1)} x \Phi_2(Z_i\beta, -X_i\alpha; -\rho)^{1(y_i=0 \& P_i=1)} x \Phi(-Z_i\beta)^{1(p_i=0)}$$

Φ is the normal distribution function; $1(A)$ is the indicator function taking the value 1 if event A is true and 0 otherwise; and ρ measures the degree of correlation between the error terms ε_i and μ_i . When $\rho \neq 0$, standard probit techniques applied to the first equation give biased results. Empirically, the model is as follows:

$$\text{Equation 1 : } A_i = \alpha_0 + \alpha_1 \text{Sex}_i + \alpha_2 \text{Coop}_i + \alpha_3 \text{Exp}_i + \alpha_4 \text{Educ}_i + \alpha_5 \text{Agri}_{ad}_i + \alpha_6 \text{Age}_i + \alpha_7 \text{Rev}_i + \alpha_8 \text{HHsize}_i + \alpha_9 \text{Info}_i + \alpha_{10} \text{Loan}_i + \alpha_{11} \text{Land}_i + \alpha_{12} \text{Insur}_i + \varepsilon_i \quad (3)$$

$$\text{Equation 2 : } P_i = \beta_0 + \beta_1 \text{Sex}_i + \beta_2 \text{Coop}_i + \beta_3 \text{Exp}_i + \beta_4 \text{Educ}_i + \beta_5 \text{Age}_i + \beta_6 \text{Info}_i + \beta_7 \text{Loan}_i + \beta_8 \text{Land}_i + \beta_9 \text{Insur}_i + \beta_{10} \text{Area}_i + \mu_i \quad (4)$$

A_i is the adaptation decision of head of household i ; Sex_i gender of head of household i ; $Coop_i$ agricultural cooperative membership status of head of household i ; Exp_i agricultural experience of head of household i ; $Educ_i$ education level of head of household i ; $Agri_ad_i$ access to agricultural advices of head of household i ; Age_i age of head of household i ; Rev_i income of head of household i ; $HHsize_i$ size of household i ; $Info_i$ access to agricultural information of head of household i ; $Loan_i$ access to credit of head of household i ; $Land_i$ type of ownership of plot farmed by head of household i ; $Insur_i$ agricultural insurance status of head of household i ; $Area_i$ place of residence of head of household i and P_i the level of perception of climate change by household i .

Details of the description of the study variables are given in Table A0 in Appendix. The Stata Heckprobit command provides consistent and asymptotically efficient estimates for all the parameters of this model. However, for the model to be properly identified, the selection equation (the perception equation) must include at least one variable that does not appear in the outcome equation (the adaptation equation). Otherwise, the model is identified only by its functional form, and the coefficients have no structural interpretation. To interpret the coefficients, marginal effects are calculated.

2.2 The data

This paper uses data from the Consultative Group to Assist the Poor (CGAP) survey of small farm households in Côte d'Ivoire conducted by the World Bank in 2016. This survey was based on three questionnaires. The first questionnaire focuses on the household as a whole, with the head of household or a knowledgeable adult as the respondent. It deals with basic information about the household (assets and characteristics of the dwelling). The second questionnaire was sent to multiple respondents, i.e. all household members over the age of 15 who participate in the household's agricultural activities. This questionnaire covers demographic data, agricultural activities and household economic data. The third questionnaire was sent to a randomly selected adult in the household and covers farming activities and formal and informal financial instruments. For this study, we reconciled these 3 databases using the household identifier. This enabled us to obtain a database with all the questions/answers from respondents unique to each household, in this case the heads of household.

3. RESULTS AND DISCUSSION

3.1 Descriptive statistics

The characteristics of the sample are presented in Table A1 in appendix. The sample comprised 11674 smallholder farmers, 43% of whom were men and 57% women, with an average household size of around 6 members. They were almost equally distributed between the three zones studied, i.e. 38.76% in the western forest zone, 31.72% in the savannah zone and 29.52% in the eastern forest zone. Around 43% of households surveyed were between 30 and 50 years old. Over 70% of farmers have no more than primary education. On the other hand, over 90% of farmers have more than 10 years' farming experience. Unfortunately, few farmers belong to agricultural cooperatives (3.14%) and receive advice on farming techniques (6.30%). Only 0.44% of respondents have access to agricultural information (prices of inputs, agricultural products on the market, etc.).

In terms of perception of climate change, Table 1 shows that over 80% of farmers do not have a good perception of climate change. Only 1,875 respondents, or 16% of those surveyed, said that they had observed and noticed changes in climatic phenomena over the past 3 years.

Table1: Producers' perception of and adaptation to climate change

	Adaptation No use of strategies	Use of strategies	Percentage (%)	Total
<i>Perception</i>				
No perception	9799	0	83.94	9799
Perception	1033	842	16.06	1875
Percentage (%)	55.09	44.91	100	-
<i>Total</i>	10832	842	-	11674

Source: authors based on World Bank survey data (CGAP, 2016)

For the latter, weather is the most important risk for agricultural activities with a percentage of 77.2% as shown in Table 2. The parameters or variables measured are weather-related factors i.e. changes in climatic variables (drought, floods and late rains). Despite the concerns raised by the respondents on the effects of climate change on their livelihoods, only 45% of farmers adopted strategies to cope with the adverse effects of climate variability on their crops. In fact, in addition to adaptation strategies, resilience measures have been adopted, including the development of secondary activities, the sale of livestock, and the use of savings or even loans where appropriate.

Table2: The most important risks for farming according to producers

<i>The most important risks</i>	<i>Nber of producers</i>	<i>Totalnber of producers</i>	<i>Percentage(%)</i>
Weather-related risks	9013	11674	77.2
Health and market imperfections	1705	11674	14.61
Input prices and risks	907	11674	07.77
Others	49	11674	00.42

Source: authors based on World Bank survey data (CGAP, 2016)

According to Table 3, most producers drew on their savings to overcome the difficulties associated with poor harvests.

Table 3: The various resilience factors used by farmers following their perception

<i>Strategies</i>	<i>Secondaryactivities</i>	<i>Loans</i>	<i>Sale of livestock</i>	<i>Savings</i>	<i>Total</i>
<i>Nber of producers</i>	135	251	47	409	842
<i>Percentage (%)</i>	16.03	29.81	5.58	48.57	100

Source: authors based on World Bank survey data (CGAP, 2016)

3.2 Econometric results

We present the results for the whole sample and those taking account of the heterogeneities in the sample. Farm size and crop type are the forms of heterogeneity considered in this study.

3.2.1 Factors favouring adaptation to climate change by smallholder farmers

Table 4 presents the results of the estimation of the probit model with Heckman sample selection, which includes the selection equation and the outcome equation. The model is globally significant at the 1% level. The Heckman approach is appropriate because rho is significantly different from zero. In other words, the adoption of adaptation strategies by small-scale farmers is conditioned by their level of perception of climate change. Several variables in the model are also significant. These include membership of an agricultural cooperative, gender, household size, access to agricultural information, possession of agricultural insurance, age, level of education, agricultural experience and type of land ownership.

Among the above variables, those favouring the adoption of coping strategies were membership of an agricultural cooperative, male gender, large household size, access to agricultural information, and possession of agricultural insurance. Farmers benefiting from cooperative services, agricultural information and insurance were 7.9%, 5.5% and 5.6% respectively more likely to adapt to climate variability. On the other hand, farmers who are older, more experienced, have no education and do not own land are less likely to adopt adaptation strategies. Thus, age, experience, illiteracy and common ownership of land are factors that reduce the incentive for farmers to adapt to climate change. Furthermore, the adoption of adaptation strategies depends on small-scale farmers having a good perception of climate change. In this respect, the results show that factors such as membership of a cooperative, access to agricultural information and subscription to insurance improve farmers' perceptions.

All these results show that being male, young, a member of a cooperative, having access to agricultural information, taking out insurance and having a private title to land encourage the adoption of adaptation strategies.

Table 4. Results of the estimation of the probit model with Heckman sample selection

Explanatory variables	Outcome model		Selection model	
	Regression	Marginal effects	Regression	Marginal effects
	Coefficient	dy/dx	coefficient	dy/dx
Age (base : <31 years old)				
From 51 and over	-0.091***	-0.013	-0.116***	-0.021***
31 to 50 yearsold	-0.192***	-0.028	-0.455**	-0.071***
Coop				
yes	0.546***	0.079	1.078***	0.247***
Educ(base :primary)				
secondary	0.010	0.001	0.023	0.006
superior	-0.066	-0.009	0.063	0.019
No level	-0.576***	-0.079*	-0.987***	-0.223***
Sex				
male	0.201***	0.031	0.286	0.045***
Exp(base: <6 years)				
From 6 to 10 years	0.100***	0.015	0.045***	0.014***
Over 10 years	-0.706***	-0.097*	-1.094***	-0.256***
Hhsize(base: <6pers)				
From 6 to 10 pers	-0.26	-0.024		
Over 10 pers	3.291***	0.847***		
Agri_ad				
yes	0.047	0.007		
Info				
yes	0.373*	0.055	0.635***	0.125**
Rev(base :<52M)				
52 000M to 110 000M	0.041	0.005		
110 000M to<600 000M	-0.0006	-0.001		
600 000M to< 1 200 000M	-0.135	-0.019		
> 1 200 000M	-0.126	-0.018		
Land(base :private)				
community or State	-0.227**	-0.032	-0.001	-0.001
others	-0.371***	-0.054	-0.609***	-0.104***
Loan				
yes	0.249	0.037	0.118	0.191
Insur				
yes	0.383***	0.056	0.483	0.090***
Area(base :Easternforest)				
West forest zone			0.151***	0.022***
Savannah zone			0.222***	0.033***
_cons	-0.247		0.891***	
Number of obs	11 674			
Selected	1875			
Not selected	9799			
Prob > chi2	0.0000			

Source: authors based on World Bank survey data (CGAP, 2016)

Notes: ***, **, * = significant at 1%, 5%, and 10% probability level, respectively.

3.2.2 Sensitivity analysis (robustness tests)

The above results (in table 4) assume that the entire sample is homogeneous. However, not all growers are confronted with the realities with the same intensity. These differences in exposure to climatic realities may result in different reactions from producers. We tested heterogeneities relating to farm size and crop type. For farm size, we consider farms of less than five hectares (small farms) and farms of more than five hectares (large farms). In terms of crop type, we distinguish between food crops and perennial crops.

Table 5 presents the results for farm size. Overall, the models are significant at the 1% level. However, there are differences in the results for the two farm categories. The first difference is the independence of the outcome and selection equations. Unlike small farms, the adoption of adaptation strategies by producers on large farms is not linked to their perception, as rho is not statistically different from zero (prob > chi2=0.377). The second difference is linked to the variables that were found to be decisive in explaining the adoption of adaptation strategies. Unlike large farms, where age and household size were found to be relevant, the adoption of coping strategies by smallholders was linked to membership

of a cooperative, access to agricultural information, subscription to insurance and, above all, income level. The results also showed that, in addition to the factors identified above, household income proved to be a relevant factor to consider when designing adaptation policies for smallholder farmers. Regarding crop type, the results in Table 6 reveal different determinants. Although the significant variables are virtually the same for the two types of crops, their signs are opposite. Thus, while belonging to a cooperative and being a man significantly and positively affected the probability of adopting strategies among food crop producers, these same variables negatively affect that of perennial crop producers. The same was true for the education and work experience variables.

Table 5. Results of the estimation of the probit model with Heckman sample selection according to farm size

Explanatory variables	Farmers with less than 5 hectares		Farmers with more than 5 hectares	
	Outcome model (adaptation) Coefficient	Selection model(perception) coefficient	Outcome model (adaptation) Coefficient	Selection model (perception) Coefficient
Age(base :<31years old)				
From 51 and over	0.058	0.009	-0.009	-0.234***
31 to 50 yearsold	0.075	-0.054	0.424**	-0.628***
coop				
yes	0.476***	0.884***	-0.656	1.205***
Educ(base :primary)				
secondary	-0.064	0.019	0.026	0.031
supérieur	-0.394	-0.017	0.276	0.067
No level	-0.459***	-0.714**	0.610	-1.205***
Sex				
male	0.121**	0.187***	-0.117	0.330***
Exp(base : <6 years)				
From 6 to 10 years	0.253	-0.042	-0.253	0.317
>10 years	-0.423*	-0.993***	0.150	-0.958***
Hhsize(base : <6pers)				
6 to 10 pers	-0.128		-0.496	
>10pers			5.620***	
Agri_ad				
yes	0.029		0.071	
Info				
yes	0.775***	0.932***	-0.444	0.516
Rev(réf :<52M)				
52M to 110M	0.019		0.054	
110M to 600M	-0.078		0.079	
600M to<1200M	-0.052		-0.032	
>1200M	2.402***		-0.068	
Land(base :private)				
community or State	-0.133	-0.011	-0.407*	0.048
others	0.065	-0.029	0.257	-0.608**
Loan				
yes	0.195	-0.028	-0.006	0.210
Insur				
yees	0.514***	0.794***	0.178	0.010
Area(base :Easternforest)				
West forest zone		0.216***		-0.127
Savannah zone		0.346***		-0.135
_cons	-0.607**	0.533*	0.208	1.124**
Number of obs	2 973		8 701	
Selected	1 004		871	
Notselected	1 969		7 830	
Prob > chi2	0.0000		0.0000	

Source: authors based on World Bank survey data (CGAP, 2016)

Notes: ***, **, * = significant at 1%, 5%, and 10% probability level, respectively.

In addition, other variables are decisive on both sides of the two crop groups considered. These are access to information and income in the case of perennial crop farmers, on the one hand, and age, form of land ownership and household size in the case of food crop promoters, on the other.

Table 6: Results of estimating the probit model with Heckman sample selection according to crop type

Explanatory variables	Food cropfarming		Perennialcropfarming	
	Outcome model(adaptation) Coefficient	Selection model(perception) coefficient	Outcome model(adaptation) Coefficient	Selection model(perception) Coefficient
Age(base :<31yearsold)				
From51 to over	0.044	0.004***	-0.026	-0.041
31 to 50 yearsold	0.383***	0.032***	0.131	-0.045
coop				
yes	-0.811***	1.259***	0.428***	0.819***
Educ(base :primary)				
secondary	-0.111	0.168	-0.049	-0.146
supérieur	-0.242	0.119	0.059	-0.222
No level	0.636***	-0.988***	-0.445**	-0.858***
Sex				
male	-0.201***	0.282***	0.174	0.144**
Exp(base: <6years)				
From6 to 10 years	0.250	-0.017	0.098	0.376
>10 years	0.847***	-1.224***	-0.539*	-0.559*
Hhsize(base : <6pers)				
From 6 to 10	-0.334		-0.109	
>10pers	6.332***			
Agri_ad				
yes	0.032		0.126	
Info				
oui	-0.337	0.250	0.828***	1.238
Rev(base :<52M)				
52M to 110M	-0.003		0.080	
110M to 600M	-0.027		0.038	
600M to<1200M	-0.719**		0.076	
>1200M	-0.353		2.077***	
Land(base :private)				
community or State	-0.445***	0.084	-0.024	-0.040
others	0.443***	-0.708***	0.116	0.026
Loan				
yes	0.030	0.414**	-0.264	-0.507
Insur				
yes	-0.148	0.436**	0.292	0.429
Area(base :Easternforest)				
West forest zone		-0.191***		0.213
Savannah zone		-0.176***		0.361
_cons	-0.167	1.277***	-0.603*	0.249
Number of obs	9 654		2 020	
Selected	1 188		687	
Notselected	8 466		1 333	
Prob > chi2	0.0000		0.0000	

Source: author based on World Bank survey data (CGAP, 2016)

Notes: ***, **, * = significant at 1%, 5%, and 10% probability level, respectively.

3.3 Discussion

Analysis of the determinants of smallholder farmers' adaptation to climate change in Côte d'Ivoire revealed several factors, including membership of an agricultural cooperative, gender (male), large household size, access to agricultural information, possession of agricultural insurance, level of education and experience.

As expected, membership of a cooperative has a positive influence not only on farmers' perception of climate change but also on their willingness to adopt adaptation strategies. This result is corroborated by several authors including Parcell and Gedikoglu[61], who show that considering cooperation between farmers helps to better explain adoption behaviour. Farmers' organisations are places where information about the agricultural sector is shared, Donahue and Miller[62], Jones et al.[30] and Polyzou et al.[63]. According to Jones et al.[30], there is a link between the density of the social network, representing the amount of information held by members, and awareness of environmental problems. In addition, these cooperatives also receive technical training from government and non-governmental organisations (NGOs) as part of agricultural development projects and programmes that include components on climate change in relation to agricultural activities, Yegbemey et al.[64] and Kaboré et al.[60]. The significance and sign of the "access to agricultural information" variable confirms this result. Certainly, one of the objectives of agricultural cooperatives is to facilitate the

sharing of information and experience between members for good practices. By reducing uncertainty, information enables farmers to better perceive new practices and the associated risks. In addition to information sharing, the association plays a supervisory role and acts as a guarantor for access to finance, Below et al.[23], Hammill et al.[65] and McLeman et al.[66]. The result obtained confirms those contained in Table 2 (small versus large) insofar as this variable is a determining factor for smallholders, whereas it is not for large farms. In fact, thanks to their organisation and financial resources, large farms have access to high-quality strategic information that enables them to make better decisions, unlike small farms. So, for smallholders, associations are sources of information with low transaction costs. Furthermore, the mutual supervision of members facilitates the adoption of innovative strategies, Thiombiano and Ouoba[67]. The effects of information are similar to those of education insofar as our results show that a low level of education (no level of education) reduces the probability of adopting adaptation strategies. Thus, the higher the level of education of the head of household (large stock of knowledge), the more willing he or she is to adopt new agricultural strategies, as highlighted by several authors including Garcia de Jalon et al.[31], Deressa et al. [40], Salhi et al.[68], Goulden et al. [69], Roussy et al. [70] and Iglesias et al. [71]. On the contrary, experience in agriculture considered as an accumulation of knowledge and know-how reduces the producer's incentive to adopt adaptation strategies. Although surprising, this result can be explained by the fact that a good control of the production system acquired through experience leads the producer to minimise the associated risks by not adopting adaptation strategies. Similar results have been highlighted by Kebede et al.[72] and Belay et al.[73]. Age has the same effect as the above but can be explained differently. Indeed, with a shorter planning horizon, older farmers do not adopt agricultural innovations that offer only long-term benefits. Several studies confirm this result, D'Souza et al.[74], Foltz and Chang[75], Anderson et al.[76], Abdulai and Huffman[77], Featherstone and Goodwin[78] and Soule et al., [79].

Moreover, contrary to several authors such as Denton F. [80], Hassan and Nhemachena [81], Bello et al.[26], Traoré et al.[5] and Chimi et al.[82], adaptation to climate change has a gender effect. Men are more willing to adopt adaptation strategies than women. The result above, corroborated by Below et al. [23] and Kaboré et al.[60] can be linked to land access rules. Indeed, in most African communities in general and in Côte d'Ivoire in particular, women have limited access to land resources; this reduces their incentive to invest in farms. Similarly, the socio-cultural status¹ that society attributes to women does not allow them to be always available for associative activities in which information on new practices circulates. This reality is confirmed by the results relating to the sub-sample of food crop growers dominated by women. At this level, the type of land ownership, particularly communal ownership, has a negative impact on the adoption of adaptation strategies by producers, unlike private ownership, Schuck et al.[83], Thiombiano and Ouoba[69]. In reality, women generally do not have ownership rights to land, even though they are the main producers of food crops. Under these conditions, they cannot adopt an adaptation strategy, either because they lack the financial resources or because they have no assets (land) to use as collateral to obtain loans from financial institutions.

Household size seems to have an indirect effect on adaptation through the size of the farm. In fact, the number of people in the household (the workforce) contributes to large farms, which are favourable to the adoption of adaptation strategies. Table 6 confirms these facts insofar as household size is only relevant to adaptation on large farms. The relevance of this determinant is also highlighted by Traoré et al. [5] who obtained similar results.

The importance of income or financial capital in adaptation strategies has been confirmed in several studies, Mertz et al.[84], Adou et al.[27], Belay et al.[73], Negash[85], Beyé[86], Campbell[87], Osbahr et al.[88] and Thomas et al.[89]. Financial constraints are a major obstacle to the adoption of new practices, which often require a significant amount of capital. For example, agricultural equipment (irrigation systems) and improved seeds. The level of income or availability of financial resources has two effects. The first is to reduce the degree of risk aversion and the second is about the capacity to finance the investment. In line with the relevance of financial resources in the adaptation process, the "access to credit" variable shows a positive sign, even though it is not significant for the sample in hand. At this level, some authors found significant results, Boansiet al.[90], Jahel et al.[91], Zampaligré & Fuchs[92] and Kaboré et al.[60].

4. CONCLUSION AND POLICY IMPLICATIONS

¹ Socio-cultural practices mean that women do not have access to productive assets (land, bank loans, etc.) and their main activity is housework.

Although Africa makes a marginal contribution to greenhouse gas emissions, which are responsible for climate change, it is strongly affected by it. In Côte d'Ivoire, climate change is manifesting itself in droughts, floods and late rains. Climate change is disrupting farmers' cropping calendars and threatening Côte d'Ivoire's economy, which is fundamentally based on agriculture. The main objective of this paper is to analyse the mechanisms by which smallholder farmers are adapting to climate change in Côte d'Ivoire. To achieve this, we adopted Heckman's probit model with sample selection to consider farmers' level of perception of climate change. The data used come from the survey of small agricultural households in Côte d'Ivoire conducted, in 2016, by the World Bank (CGAP, 2016). The results of our econometric estimations confirm the relevance of perception in the process of identifying adaptation factors for smallholder farmers and meteorological information is a determining factor in adaptation by improving the degree to which farmers perceive climate change. Furthermore, access to agricultural information, membership of a cooperative, subscription to agricultural insurance and the level of income have a positive influence on the probability of adapting to climate change. In addition, the level of education and gender were also found to be relevant in the adaptation process. Consequently, the means of strengthening small farmers' ability to adapt involve advisory support (agricultural advice and meteorological information), the promotion of agricultural organisations (cooperatives), the availability of financial resources through the establishment of guarantee funds and the extension of risk cover to the agricultural sector. All these measures must be part of a framework that not only builds the capacity of smallholder farmers through education and training, but also promotes gender equality by facilitating women's access to productive resources (land, financial loans) to enable them to effectively meet their food production needs.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Authors hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

REFERENCES

1. Barnabás B, Jäger K, Fehér A. The effect of drought and heat stress on reproductive processes in cereals. *Plant, Cell & Environment*. 2008; 31:11-38.
2. Mustapha S, Sanda A, Shehu H. Farmers' perception of climate change in central agricultural zone of Borno State, Nigeria. *Journal of Environment and Earth Science*. 2012;(2): 21-27.

3. Traoré B. Climate change, climate variability and adaptation options in smallholder cropping systems of the sudano-sahel region in West Africa. PhD thesis. Wageningen University, Pays-Bas;2014.
4. Sissoko P, Aune JB, Senneväg G, Teme B and Lebailly P. Vulnerability evaluation of Millet and sorghum cropping system to climate change and adoption of new technologies in Mali. *Asian Journal of Science and Technology*.2017; 8: 4176-4182.
5. Traoré L, BelloOD, Togola A, Balogoun I, Chabi F, Yabi I, Ahoton ELand SaïdouA. Farmers' perceptions of climate change and adaptation strategies on sorghum productivity in the sudanian and sahelian zones of Mali. *African Crop Science Journal*.2021;29(1): 157-175.
6. El Bilali H. Climate change and agriculture in Burkina Faso. *Journal of AridlandAgricultur*. 2021; (7): 22-47.
7. Niang I, Ruppel OC. Africa, in: *Climate Change 2014: Impacts, Adaptation and Vulnerability. IPCC 5th Assessment Report. Working Group II*. 2014.
8. IPCC. *Climate change 2001:synthesis report*. Cambridge : CambridgeUniversityPress ;2001.
9. Deressa TT, Bryan E, Gbetibouo GA, Ringler C. Adaptation to climate change in Ethiopia and South Africa: options and constraints. *Environmental Science & Policy*. 2009;12 (4): 413-426.
10. Di Falco S, Veronesi M, Yesuf M. Does Adaptation to Climate Change Provide Food Security? A Micro-Perspective from Ethiopia. *American Journal of AgriculturalEconomics*. 2011; 93(3): 825-842
11. FAO. The role of agriculture in the development of the least developed countries and their integration into the world economy; 2001.<https://www.fao.org/3/Y0491f/y0491f01.htm>
12. World Bank. West Africa food insecurity demands climate-smart response amid multiple crises. (visited on 17 November 2023) <https://www.worldbank.org/en/news/feature/2022/09/08/west-africa-food-insecurity-demands-climate-smart-response-amid-multiple-crises>
13. Baarsch F, Granadillos JR, Hare W, Knaus M, Krapp M, Schaeffer M and Lotze-CampenH. The impact of climate change on incomes and convergence in Africa. *World Development*.2020; 126:104699
14. Bakshi B, Nawrotzki RJ, Donato JR, Lelis LS. Exploring the link between climate variability and mortality in Sub-Saharan Africa.*International Journal of Environment and Sustainable Development*.2019; 18(2): 206.
15. Bornemann FJ, Rowell DP, Evans B, Lapworth DJ, Lwiza K, Macdonald DMJ, Marsham, JH, Tesfaye K, Ascott MJ and Way C. Future changes and uncertainty in decision-relevant measures of East African climate. *Climatic Change*. 2019; 156(3): 365-384. <https://doi.org/10.1007/s10584-019-02499-2>.
16. HassanRM.The double challenge of adapting to climate change while accelerating development in sub-Saharan Africa. *Environment and Development Economics*.2010; 15(6): 661-685.
17. Lokonon BOK, Egbendewe AYG, Coulibaly N andAtewambaC. The Potential Impact of Climate Change on Agriculture in West Africa: A Bio-Economic Modeling Approach.*Climate Change Economics*.2019; 10(4): 1950015.
18. Sultan B, GaetaniM. Agriculture in West Africa in the Twenty-First Century: Climate Change and Impacts Scenarios, and Potential for Adaptation. *Frontiers in Plant Science*. 2016; 7: 1262.

19. Egbebiyi TS, Crespo O, Lennard C. Defining Crop–climate Departure in West Africa: Improved Understanding of the Timing of Future Changes in Crop Suitability. *Climate*.2019; 7(9): 101.
20. Sawadogo M, Pam Z, SawadogoJPW. Analysis of factors explaining crop association in Burkina Faso. *Rural Economy*.2022 ;380: 87-101.
21. Poole N. *Smallholder Agriculture and Market Participation*. Rugby : Practical Action Publishing ; 2017.
<https://www.developmentbookshelf.com/doi/book/10.3362/9781780449401> (accessed on 27 August 2021) ISBN 978-1-85339-940-4.
22. World Bank. *Unlocking Africa’s Agricultural Potential: An Action Agenda for Transformation*. Africa Economic Brief. 2013; 75(3): 372-384.
<https://openknowledge.worldbank.org/bitstream/handle/10986/16624/769900WP0SDS0A00Box374393B00PUBLIC0.pdf?sequence=1>
23. Below TB, Mutabazi KD, Kirschke D, Franke C, Sieber S, Siebert R and Tscherning K. Can farmers’ adaptation to climate change be explained by socio-economic household-level variables? *Global environmental change*.2012; 22(1): 223-235.
24. Steward PR, Dougill AJ, Thierfelder C, Pittelkow CM, Stringer LC, Kudzala M and Shackelford GE. The adaptive capacity of maize-based conservation agriculture systems to climate stress in tropical and subtropical environments: A meta-regression of yields. *Agriculture, Ecosystems & Environment*.2018; 251: 194-202.
25. Dimon R. *Adapting to climate change: perceptions, local knowledge and adaptation strategies developed by farmers in the communes of Kandi and Banikoara, Northern Benin*. Doctoral Thesis, University of Abomey-Calavi, Benin;2008.
26. Bello D, Ahoton L, Saidou A, Akponikpè I, Ezin V, Balogoun I and Aho N. Climate change and cashew (*Anacardium Occidentale L.*) productivity in Benin (West Africa): Perceptions and endogenous measures of adaptation. *International Journal of Biological and Chemical Sciences*. 2017;11: 924-946.
27. Adou AG, N’da KC, KouassiGN. Resented impacts of climate variability and adaptation strategies for farmers in the locality of brizeboua (ivoirian centre-west). *Revue EspacesAfricains*. 2022; 1(2):109-122.
28. García de Jalón S, Iglesias A, Barnes AP. Drivers of farm-level adaptation to climate change in Africa: an evaluation by a composite index of potential adoption. *Mitigation and Adaptation Strategies for Global Change*. 2016; 21(5): 779-798.
29. Kalame FB, Kudejira D, Nkem J. Assessing the process and options for implementing National Adaptation Programmes of Action (NAPA): a case study from Burkina Faso. *Mitigation and Adaptation Strategies for Global Change*. 2011; 16(5): 535-553.
30. Jones N, Evangelinos IK, Iosifides T, Halvadakis PC and Sophoulis CM. Social factors influencing perceptions and willingness to pay for a market-based policy aiming on solid waste management. *Resources, Conservation and Recycling*. 2010; 54(9): 533-540.
31. García de Jalón S, Iglesias A, NeumannMB. Responses of sub-Saharan smallholders to climate change: Strategies and drivers of adaptation. *Environmental Science & Policy*. 2018; (90): 38-45.
32. Kanté S. *Soil fertility management by farm class in Southern Mali*. PhD Thesis, University of Wageningen, Netherlands;2001.
33. Bambara D, Bilgo A, Hien E, Masse D, Thiombiano A and Hien V. Farmers’ perceptions of climate change and its socio-environmental consequences in Tougou and Donsin, sahélian and sahélo-sudanian climates of Burkina Faso. *Bulletin of Agricultural Research in Benin*. 2013; 74: 8-16.

34. Agossou DSM, Tossou CR, VissohVP and Agbossouh KE. Perception of climatic disturbances, local knowledge and adaptation strategies of agricultural producers in Benin. *African Crop Science Journal*. 2012; 20(2), 565-588.
35. Ruault C. The socio-technical survey from a comprehensive perspective: methodological foundations and principles. Course Notes for the Master's module supagro IRC-GERDAL-IRAM, comprehensive survey of action or evaluation; 2007.
36. Ban Van Den AW, Hawkins HS, Brauwers JHAM and Boon CAM. Rural extension in Africa. Paris: Editions Karthala; 1994.
37. De Longueville F, Ozer, P., Gemenne, F., Henry S, Mertz O, & Nielsen JØ. Comparing climate change perceptions and meteorological data in rural West Africa to improve the understanding of household decisions to migrate. *Climatic Change*. 2020; 160(1): 123-141.
38. Adger WN, Dessai S, Goulden M, Hulme M, Lorenzoni I, Nelson DR, Naess LO, Wolf J, and Wreford A. Are there social limits to adaptation to climate change? *Climatic Change*. 2009; 93:335-354.
39. Mertz O, Mbow C, Reenberg A. Farmers' Perceptions of Climate Change and Agricultural Adaptation Strategies in Rural Sahel. *Environmental Management*. 2009; (43): 804-816.
40. Deressa TT, Hassan MR, Ringler C, Alemu T and Yesuf M. Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global Environmental Change*. 2011; 19(2): 248-255.
41. Maddison D. The perception and adaptation to climate change in Africa. World Bank Publications, 4308; 2007.
42. Gbetibouo GA. Understanding Farmers Perceptions and Adaptations to Climate Change and variability: The case of the Limpopo Basin farmers South Africa. IFPRI Discussion. 2009; Paper 849.
43. Schlenker W, Lobell DB. Robust negative impacts of climate change on African agriculture. *Environmental Research Letters*. 2010; 5(1): 014010.
44. Chemura A, Kutwayo D, Hikwa D and Gornott C. Climate change and cocoyam (*Colocasia esculenta* (L.) Schott) production: assessing impacts and potential adaptation strategies in Zimbabwe. *Mitigation and Adaptation Strategies for Global Change*. 2022; 27(6): 42.
45. Rippke U, Ramirez-Villegas J, Jarvis A, Vermeulen SJ, Parker L, Mer F, Diekkrüger B, Challinor AJ and Howden M. Timescales of transformational climate change adaptation in sub-Saharan African agriculture. *Nature Climate Change*. 2016; 6(6): 605-609. <https://doi.org/10.1038/nclimate2947>
46. Esham M, Garforth C. Agricultural adaptation to climate change: Insights from a farming community in Sri Lanka. *Mitigation and adaptation strategies for global change*. 2013; (18): 535-549.
47. Ochou A. Global warming: origins, manifestations and impacts', Communication Ministry for the Environment and Sustainable Development, Republic of Côte d'Ivoire; 2011.
48. Goroza G. Impacts of climate change in the different wetland agroclimatic zones of West Africa: the case of Côte d'Ivoire. National Meteorology of Côte d'Ivoire; 2012.
49. Brou Y, Chaléard J. Peasant Perceptions and Environmental Changes in Côte d'Ivoire. *Annales de géographie*. 2007 ; 653 : 65-87.
50. Goula BTA, Soro GE, Kouassi W, Srohourou B. Trends and breaks in extreme daily rainfall in Côte d'Ivoire (West Africa). *Hydrological Sciences Journal*, 57(6), 1067-1080.
51. MESD (Ministry for the Environment and Sustainable Development) (2011): National environmental Policy, Republic of Côte d'Ivoire.

52. Isbell T, Kone J, Silwe KS. Despite threat to cocoa and reforestation response, only half of Ivoirians aware of climate change. *Afrobarometer*. 2018; 221: 1-9.
53. Côte d'Ivoire's Nationally Determined Contributions (NDC) (2022). https://unfccc.int/sites/default/files/NDC/2022-06/CDN_CIV_2022.pdf
54. Kouassi JL, Wandan N, Mbow C. Observed climate trends, perceived impacts and community adaptation practices in Côte d'Ivoire. *Environmental & socio-economic Studies*. 2022; 10(3): 43-58.
55. Attoumane A, Dos Santos S, Kacou M, Della André A, Karamoko AW, Seguis L & Zahiri EP. Individual perceptions on rainfall variations versus precipitation trends from satellite data: An interdisciplinary approach in two socio-economically and topographically contrasted districts in Abidjan, Côte d'Ivoire. *International Journal of Disaster Risk Reduction*. 2022;81:103285.
56. Brou YT, Akindès F and Bigot S. Climate variability in Côte d'Ivoire : between social perceptions and agricultural responses. *Cahiers Agricultures*. 2005 ; 14(6) : 533-540.
57. Timité N, Kouakou ATM, Bamba I, Barima YSS and Bogaert J. Climate Variability in the Sudanian Zone of Côte d'Ivoire: Weather Observations, Perceptions, and Adaptation Strategies of Farmers. *Sustainability*. 2022; 14(10410): 1-21.
58. Boko AA, Cissé G, Koné B and Dedy SF. Local beliefs and strategies for adapting to climatic variations in Korhogo, Côte d'Ivoire. *Tropicultura*. 2016; 34(1): 40-46.
59. Bodji NC, Koutouan PF, Kouadio KB, Traoré K, Wandan EN. The perception of climate change and coping strategies among rural farming households in Bouaflé area, Côte D'Ivoire. *International Journal of Development Research*. 2017; 7(7): 13753-13759.
60. Kaboré PN, Barbier B, Ouoba P, Kiema A, Some L and Ouedraogo A. Perceptions of climate change, environmental impacts and endogenous adaptation strategies by producers in the North-central Burkina Faso. *Vertigo*. 2019, 19(1): 1-28.
61. Parcell JL, Gedikoglu H. A Differential Game Approach to Adoption of Conservation Practices. *Agricultural and Applied Economics Association, 2013 Annual Meeting, August 4-6, 2013, Washington, DC; 2013*.
62. Donahue AK, Miller JM. Experience, attitudes and willingness to pay for public safety. *The American Review of Public Administration*. 2006; 36(4): 395-418.
63. Polyzou E, Jones N, Evangelinos IK, Halvadakis CP. Willingness to pay for drinking water quality improvement and the influence of social capital. *Journal of SocioEconomics*. 2011; 40(1): 74-80.
64. Yegbemey RN, Kabir H, Awoye OHR, Yabi JA and Paraïso AA. Managing the agricultural calendar as coping mechanism to climate variability: a case study of maize farming in Northern Benin, West Africa. *Climate Risk Management*. 2014; 3:13-23.
65. Hammill A, Matthew R, McCarter E. *Microfinance and climate change adaptation*. Oxford: Blackwell Publishing Ltd; 2008.
66. McLeman R, Mayo D, Strebeck E, Smit B. Drought adaptation in rural eastern Oklahoma in the 1930s: lessons for climate change adaptation research. *Mitigation and Adaptation Strategies for Global Change*. 2008; 13: 379-400.
67. Thiombiano N, Ouoba Y. Factors affecting farmer participation and willingness to pay for farmland conservation and protection programs in Burkina Faso. *International Journal of Agricultural Resources Governance and Ecology*. 2021; 17(1): 81-98.
68. Salhi S, Imache A, Tonneau JP, Ferfera MY. Determinants of the adoption of drip irrigation by Algerian farmers in the Mitidja plain. *Cahiers Agricultures*. 2012; 21(1): 417-426.
69. Goulden M, Adger NW, Dessai S, Hulme M, Lorenzoni I, Donald R, Naess LO, Wolf J and Wreford A. Are there social limits to adaptation to climate change? *Climate Change*. 2008;(93): 335-354.

70. Roussy C, Ridier A, Chaib K. Innovation adoption by farmers: the role of perceptions and preferences. Working Paper Smart Lereco. 2015; 15(3): 1-33.
71. Iglesias A, Juan-Carlos C, Szabo L, RegemorterVD. Physical and economic consequences of climate change in Europe. Potsdam Institute for Climate Impact Research;2011 (visited on 18 November 2023)
72. Kebede Y, Gunjal K, CoffinG. Adoption of new technologies in Ethiopian agriculture: The case of Tegulet-Bulga district Shoa province. *Agricultural Economics*.1990; (1): 27-43.
73. Belay A, Recha JW, Woldeamanuel T, Morton JF. Smallholder farmers' adaptation to climate change and determinants of their adaptation decisions in the Central Rift Valley of Ethiopia. *Agriculture & Food Security*. 2017; 6(1): 1-13.
74. D'Souza G, Cyphers D, PhippsT. Factors affecting the adoption of sustainable agricultural practices. *Agricultural and Resource Economics Review*.1993;22(2): 159-165.
75. Foltz JD, Chang HH. The adoption and profitability of rbST on Connecticut dairy farms. *American Journal of Agricultural Economics*. 2002; 84(4): 1021-1032.
76. Anderson JB, Jolly DA and Green RD. Determinants of farmer adoption of organic production methods in the fresh market produce sector in California: A logistic regression analysis. Western Agricultural Economics Association, Annual Meeting, July 6-8, 2005. San Francisco: California; 2005
77. Abdulai A, Huffman WE. The diffusion of new agricultural technologies: the case of crossbred-cow technology in Tanzania. *American Journal of Agricultural Economics*. 2005;87(3):645-659.
78. Featherstone AM, Goodwin BK. Factors Influencing a Farmer's Decision to Invest in Long-Term Conservation Improvements. *Land Economics*. 1993: 69(1): 67-81.
79. Soule MJ, Tegene A and WiebeKD. Land Tenure and the Adoption of Conservation Practices. *American Journal of Agricultural Economics*.2000; 82(4): 993-1005.
80. Denton F. Gender and climate change: giving the latecomer a head start. *IDS Bulletin-Institute of Development Studies*. 2004; 35 (3): 42-49.
81. Hassan RM and Nhemachena C. Determinants of African farmers' strategies for adapting to climate change: Multinomial choice analysis. *African Journal of Agricultural and Resource Economics*. 2008;2: 83-104.
82. Chimi PM, Mala WA, Fobane JL, Essouma FM, Mbom II JA, Funwi FP and Bell JM. Climate change perception and local adaptation of natural resource management in a farming community of Cameroon: A case study. *Environmental Challenges*. 2022; (8):100539.
83. Schuck EC, Nganje W, Yantio D. The role of land tenure and extension education in the adoption of slash and burn agriculture. *Ecological Economics*. 2002; 43(1): 61-70.
84. Mertz O, Mbow C, Nielsen JØ, Maiga A, Diallo D, Reenberg A. and Dabi D. Climate factors play a limited role for past adaptation strategies in West Africa. *Ecology and Society*. 2010; 15(4): 1-15.
85. Negash M. Analysing the determinants of farmers' preference for adaptation strategies to climate change: evidence from north Shoa zone of Amhara region. PhD Thesis, Addis Ababa University, Ethiopia; 2011
86. Beye A. Improving rice-growing productivity under climate change in Senegal : what adaptation strategy ? *Rural Economy*.2021; 377(3): 125-141.
DOI:<https://doi.org/10.4000/economierurale.9228>
87. Campbell JH, Pounds AJ, Fogden M. Biological response to climate change on tropical mountain. *Nature*. 1999;398 (6728): 611-615.

88. Osbahr H, Twyman C, Adger WN, Thomas D. Effective livelihood adaptation to climate change disturbance: scale dimensions of practice in Mozambique. *Geoforum*. 2008;39(6): 1951-1964.
89. Thomas D, Twyman C, Osbahr H and Hewitson B. Adaptation to climate change and variability: farmer responses to intra-seasonal precipitation trends in South Africa. *Climatic Change*. 2007; 83: 301-322.
90. Boansi D, Tambo JA, Müller M. Analysis of farmers' adaptation to weather extremes in West African Sudan Savanna. *Weather and Climate Extremes*. 2017; (16): 1-13. <https://doi.org/10.1016/j.wace.2017.03.001>
91. Jahel C, Baron C, Vall E, Karambiri M, Castets M, Coulibaly K, Bégué A and Lo Seen D. Spatial modelling of agro-ecosystem dynamics across scales: A case in the cotton region of West-Burkina Faso. *Agricultural Systems*. 2017; 157: 303-315.
92. Zampaligré N, Dossa LH, Schlecht E. Climate change and variability: perception and adaptation strategies of pastoralists and agro-pastoralists across different zones of Burkina Faso. *Regional Environmental Change*. 2014; 14(2): 769-783.

Table A0: Description of variables

<i>Variables</i>	<i>Description</i>	<i>Coding</i>	<i>Min</i>	<i>Max</i>
Age	Age of head of household	1= if the head of household is under 31 years of age 2= if the age of the head of household is between 31 and 50 3= if aged over 50	1	3
Exp	Agricultural experience of the head of household	1= if the head of household has less than 6 years' experience 2= if he has between 6 and 10 years' experience 3= if he has more than 10 years' experience	1	3
HHsize	The size of household	1= if the household has more than 6 members 2= if the size of the household is between 6 and 10 members 3= if the household has more than 10 members	1	3
Rev	Average household income	1= if the household income is less than 52,000f 2= if income is between 52,000f and 110,000f 3= if income is between 110,000f and 600,000f 4= if income is between 600,000f and 1,200,000f 5= if income exceeds 1,200,000f	1	5
Coop	Head of household's membership of an agricultural cooperative	1= if he belongs to 0= otherwise	0	1
Educ	Level of education of the head of household	1= no level 2= primary 3= secondary 4= superior	1	4
Sex	gender of head of household	1= male 0= female	0	1
Agri_ad	The farm manager's access to agricultural advice	1= if he has access to farm advisory services 0= otherwise	0	1
Area	Where the household lives	1= if the household belongs to the East Forest zone 2= if the household belongs to the West Forest zone 3= if the household belongs to the Savannah zone	1	3
Info	access to agricultural information	1= whether the head of household has access to agricultural information 0= otherwise	0	1
Land	the form of plot ownership	1= if the plot is individually owned 2= if the plot belongs to the community or the State 3= other forms of ownership	1	3
Loan	Household heads' access to agricultural credit	1= whether the head of the household has access to agricultural credit 0= otherwise	0	1
Insur	Possession of agricultural insurance by the head of household	1= if he has agricultural insurance 0= otherwise	0	1

Table A1 : Descriptive statistics for explanatory variables

<i>Variables</i>	<i>Observation</i>	<i>Proportion</i>	<i>Std.Dev</i>	<i>Min</i>	<i>Max</i>
<i>Quantitative variables</i>					
Age	11674	2.221	0.77	1	3
Exp	11674	2.867	0.447	1	3
Hhsize	11674	1.988	0.995	1	3
Rev	11674	4.153	1.49	1	5
<i>Qualitative variables</i>					
Coop	11674	0.031	0.174	0	1
Educ	11674	2.547	0.776	1	3
Sex	11674	0.429	0.495	0	1
Agri_ad	11674	0.063	0.243	0	1
Area	11674	2.022	0.782	1	3
Info	11674	0.004	0.066	0	1
Land	11674	2.311	0.936	1	3
Loan	11674	0.011	0.099	0	1
Insur	11674	0.008	0.092	0	1

Source: authors based on World Bank survey data (CGAP, 2016)

UNDER PEER REVIEW