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Adaptation and Farm Income: Insights from the Savanna Region of Togo

Mikémina Pilo[1*] and Komlan Ametowoyo Adeve[1]

[1]*Department of Economics, University of Kara, Togo.*

Authors' contributions

This work was carried out in collaboration between both authors. Author MP designed the study, performed the econometric analysis, discussed the results and wrote the first draft of the manuscript. Author KAA managed the literature searches and improved the analyses. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: The Savanes region of Togo is characterized by frequent droughts and floods which adversely affect farming, the primary source of livelihood for majority of households in the region. Given the rapidly changing climate, these adverse shocks are expected to become more pervasive. This situation seriously threatens the structural transformation of agriculture in the region. Adaptation adoption is therefore important for farm households to be able to withstand any future climatic shock. However, it is doubtful whether farmers are able to identify practices and measures that constitute the appropriate response to climate as such adjustments are beyond their range of experience. Consequently, the aim of this study is to understand how adaptation strategies used by farm households in the Savanes region of Togo shape the impact of climate change on agricultural income.

Place and Duration of Study: The study was conducted at the University of Kara in Togo between April and September 2015.

**Corresponding author: Email: pilomikemina15@gmail.com;*

Methodology: We estimate an Endogenous switching Regression (ESR) model to account for the heterogeneity in the decision to adapt based on household survey data.
Results: Two main results come out of this study. First adaptation enhances farm income for the farm households that adapted. Second the decision not to adapt is rational for famers who did not adapt since they would have been 13.24 percent worse off in terms of farm income if they were to adapt. The policy message drawn from this study encourages adaptation policies which build on indigenous knowledge since farm household that did not adapt may be using some indigenous practices not recognized as adaptation strategies.

Keywords: Adaptation; climate change; endogenous switching regression model; Savanes region of Togo.

1. INTRODUCTION

Human activities have contributed to a rapid and unprecedented increase in greenhouse gas (GHG) emissions in the atmosphere. As a result, the average global temperature has increased by 0.2ºC per decade and is predicted to increase between 1.1ºC and 6.4ºC over the next century [1]. Global sea level has grown at a faster rate over the period of 1993-2003 compared to the period of 1961-2003 [1]. Change in the state of the climate is seriously damaging the planet and the life of creatures that is strongly related to a fragile ecosystems' balance between soil and climate.

Agricultural production, which highly depends on environmental conditions, remains the main source of livelihoods for most rural communities in developing countries and sub-Saharan Africa in particular. In this part of Africa, agriculture provides a source of employment for more than 60 percent of the population and contributes about 30 percent of Gross Domestic Product (GDP) [2]. The farming condition in the region is characterized by low land productivity, low input use, harsh weather conditions (erratic rainfall and frequent drought spells mainly), soil erosion resulting in low crops yield [3]. Climate change will worsen these challenges. Indeed, climate change will have greater negative impacts on poorer farm households as they have the lowest capacity to adapt to changes in climatic conditions. It is therefore no doubt that adaptation strategies are crucial to support farm households' livelihood.

Indeed, adaptation literature make it clear that adaptation measures are important to help developing rural communities to better face extreme weather conditions and associated climatic variations [4]. Thus, many authors support the idea that adaptation has the potential to significantly contribute to the reduction of the negative impacts from changes in climatic conditions as well as other changing socioeconomic conditions, such as volatile short-term changes in local and international markets [1,3,5]. Also the positive link between adaptation strategies and food productivity is well documented [e.g: 1,3,5-7].

However, it is doubtful whether farmers are able to identify practices and measures that constitute the appropriate response to climate as such adjustments are beyond their range of experience [8]. "This situation may results in maladaptation leading to a period of transitional losses of unknown duration as a result of adapting to climate change" [8]. Indeed, despite the use of a variety of strategies to adapt to climate change, studies on climate change vulnerability reveal that farmers remain highly vulnerable to changes in climate attributes, especially in Africa [5,9]. Studies of adaptation to current climate also make it clear that human activities are not always as well adapted to climate as they could be. The mounting losses from great natural disasters, for example, are in substantial part associated with extreme atmospheric events. However, it has been shown that these losses cannot be ascribed to these events alone but are also due to lack of appropriate human adaptation and that losses are in some cases being increased by maladaptation [10]. Also, a study by Tambo and Wünscher (2014) reveals that in the north-East Ghana the farm household that did not adapt to climate change would have been about 2-3 percent worse off in terms of resilience to climate shocks if they were to adapt.

Consequently, the impact of climate change adaptation on farm household welfare is therefore a local-specific phenomenon. Adoption of adaptation strategies, when not appropriately implemented, may increase farm households' vulnerability to climate change and shocks instead of reducing it. Thus, the main objective of this study is to understand how adaptation strategies used by farmers in the Savanes region of Togo shape the impact of climate change on agricultural income. Nationally, the link between climate change and agricultural production is widely recognized, but little is known about how climate change adaptation strategies affect farm income. This information is particularly important for the design of effective adaptation strategies policy for coping with climate change adverse impacts. Although [11] looked at the impact of adaptation strategies in the Savanes region of Togo, they did not account for interactions among existing adaptation measures. This study aims to fill this paramount drawback. The remaining of the paper is organized as follow: The next section presents the detailed methodology applied in this study while the section 3 presents and discusses the results. The paper ends with a conclusion.

2. MATERIALS AND METHODS

2.1 Study Site

The study focuses on farmers of the Savanes region of Togo which covers 15% of the country's land mass. The Savanes Region, the northernmost of the country, is located between longitudes 0º and 1º E and latitudes 10º and 11º N and covers two agro-ecological zones. The region is characterized by less than 1100 mm mean annual rainfall. A short rainy season (June to October) alternates with a long dry season of 7 months (November- May) annually. The growing season is about 80-110 days. Agriculture is the main activity which supports the livelihood in the region. The dry spells are common in the growing season often resulting in crop failures. Agriculture in this zone is characterized by traditional bush-fallow shifting cultivation of arable crops; pastoral herding and irrigation farming. Constraints facing farmers, (in their agricultural activities) among others include: low rainfall, dry spells, low fertility of the sandy and rocky soils. Several reasons explain the choice of the Savanes region in Togo. Indeed, the Savanes region is the poorest region despite its related market access. Its agriculture is typical of the constraints on agriculture in the country. Located in the driest part of the country, climatic risk is very high in agricultural activity.

2.2 The Model

The decision to adapt to climate change can be modelled in this study in the setting of a two-stage framework. The first stage is represented by a selection model for climate change adaptation. In that stage, a representative farmer chooses to adapt to climate change if adaptation generates net benefits. Let's note A^* denotes the latent variable which represents the expected benefits from the decision to adapt compare to not adapting. We then specify this latent variable as:

$$A^* = Z_i\alpha + \eta_i \quad (1) \quad \text{With} \quad A_i = \begin{cases} 1 \text{ if } A^* > 0 \\ 0 \quad \text{otherwise} \end{cases}$$

Thus, the farm household i will decide to adapt (i.e Ai=1) through the adoption of a panel of strategies in response to climate change and variability as long as $A^* > 0$ and will not adapt otherwise. The vector Z represents variables that are posit to affect the expected befit of the decision to adapt. These factors are retained based on the theory and the literature on the topic. The operating farm characteristics such as soil fertility represent the first factors. Farms that are more fertile might be less affected by climate change, consequently less likely to adapt. Second we account for current climatic factors as well as the experience of previous extreme events such as droughts and floods. In order to have consistent estimates, we address the role of access to credit. Farm households with limited access to credit have less capital available to invest in the implementation of costly adaptation strategies such as soil conservation strategy. Farmers' access to information about adaptation strategies is important for implementing them. Extension services improve farm households' access to information on adaptation. Their importance mainly comes from the fact that farmers receive information on climate change. Farm household head and farm household characteristics (e.g, age, gender, education, marital status, if the farmer head has an off-farm job, farm household size) affect farmers' decision to adapt. The presence of assets in principle affect the likelihood of adaptation to climate change. The Table 1 gives the summary of the variables used in this study.

The second stage estimates the effect of adaptation on farm income. This is modelled through a representation of the production technology. We did not explore different functional forms in order to choose the most robust one as required. Instead, we choose the

Table 1. Variables description

Variables	Description	Mean	Standard deviation	Minimum	Maximum
Age	Number in years	49.50	14.70	20,00	99,00
Sex	Dummy variable (1 if male headed household and 0 otherwise	0.15	0.32	0	1
Literacy	In number of validated years	2.27	3.62	0	15
Married	Dummy variable (1 if yes and 0 if no)	0.69	0.46	0	1
Off-Farm job	Dummy variable (1 if yes and 0 if no)	0.49	0.50	0	1
Household size	In number of persons	7.72	3.78	1	22
Relatives	In number of persons	2.12	2.01	0	23
Access to credit	Dummy variable (1 if yes and 0 if no)	0.36	0.27	0	1
Fertility	Dummy variable (1 if yes and 0 if no)	0.33	0.23	0	1
Use tractor	Dummy variable (1 if yes and 0 if no)	0.15	0.35	0	1
Flood experience	Dummy variable (1 if yes and 0 if no)	0.65	0.47	0	1
Drought experience	Dummy variable (1 if yes and 0 if no)	0.70	0.45	0	1
Access to river	Dummy variable (1 if yes and 0 if no)	0.19	0.39	0	1
Fertilizer	In kg	56.85	5.85	0	800
Government extension services access	Dummy variable (1 if yes and 0 if no)	0.42	0.40	0	1
Have heard about climate change	Dummy variable (1 if yes and 0 if no)	0.76	0.42	0	1
Rainy season rainfall	In mm	503,7	199.0	450.4	937.1
Dry season rainfall	In mm	78.56	56.99	123.0	265.9
Rainy season temperature	In degree Celsius	27	0.90	24.5	32.0
Dry season temperature	In degree Celsius	28.3	0.82	27.0	32.3
Farm income	In CFA	100,849	28,877	63,995	8,567,456

Source: Authors from [12]

most robust form used in a similar study in Ethiopia by [3]. A quadratic specification was consequently adopted. A single output production function hardly captures the possibility of switching crops and, therefore the estimation of climate variables' impact is biased [13]. This is particularly true when considering a very limited specialized agriculture such as the one of the United States. However, in Togo agriculture is highly diversified as each farmer produces a relatively large number of different. Considering the total farm income implicitly deals with these alternatives.

One can assess the impact of adaptation by including a dummy variable taking the value of 1 in the farm household adapted to climate change and then, regressing the ordinary least squares (OLS). This technique, however, might potentially lead to misleading results because it assumes that adaptation to climate change is exogenously determined while it is potentially endogenous. Indeed, the adaptation decision is voluntary and may be based on individual self-selection. Differences may exist between adaptation adopters and the non-adopters. Adopters may have decided to do so based on expected outcome (farm income). They may have decided to adapt based on expected benefits. Unobservable characteristics of farmers and their farm may affect both the adaptation decision and farm income, resulting in inconsistent estimates of the effect of adaptation on farm income from cropping. For example, if only the most skilled or motivated farmers choose to adapt and we fail to control for skills, then we will incur upward bias. This study follows [3] to account for the endogeneity of the adaptation decision by estimating a simultaneous equations model of climate change adaptation and farm income with endogenous switching regression model by full information maximum likelihood (FIML). For the model to be identified it is important to use as exclusion restrictions, thus as selection instruments, not only those automatically generated by the nonlinearity of the selection model of adaptation (1) but also other variables that directly affect the selection variable but not the outcome variable.

We adopt an endogenous switching regression model of farm income where farmers face two regimes: regime 1 to adapt and 2 not to adapt defined as follows to account for selection:

Regime 1: $y_{1i} = X_{1i}\beta_1 + \varepsilon_{1i} \quad if\ A_i = 1$ (2a)

Regime 2: $y_{2i} = X_{2i}\beta_{2i} + \varepsilon_{2i} \quad if\ A_i = 0$ (2b)

Where yi is the farm income level per hectare in regimes 1 and 2, and Xi represents a vector of inputs and of the farmer head's and the farm household's characteristics, soil's characteristics, assets, and the climatic factors included in Z.

Finally, the error terms in equations (2a), and (2b) are assumed to have a trivariate normal distribution, with zero mean and covariance matrix Ω.

$$\Omega = \begin{bmatrix} \sigma_\eta^2 & \sigma_{\eta 1} & \sigma_{\eta 2} \\ \sigma_{1\eta} & \sigma_1^2 & . \\ \sigma_{2\eta} & . & \sigma_2^2 \end{bmatrix}$$

where $\sigma_\eta^2$is the variance of the error term in the selection equation (1), which can be assumed to be equal to 1, since the coefficients are estimable only up to a scale factor [14], σ_1^2 and σ_2^2 are the variances of the error terms in the productivity functions (2a) and (2b), and σ1η and σ2η represent the covariance of ηi and ε_{1i} and ε_{2i} Since y_{1i} and y_{2i} are not observed simultaneously the covariance between ε1i and ε2i is not defined (reported as dots in the covariance matrix)[1].

2.3 Conditional Expectations, Treatment, and Heterogeneity Effects

We utilized the endogenous switching regression model to measure the expected farm income from cropping of the farm households that adapted (a) with respect to the farm households that did not adapt (b), and to investigate the expected farm income in the counterfactual hypothetical cases (c) that the adapted farm households did not adapt, and (d) that the non-adapted farm household adapted. The conditional expectations for farm income in the four cases are presented in the Table 2. Cases (a) and (b) along the diagonal of Table 2 represent the actual expectations observed in the sample. Cases (c) and (d) represent the counterfactual expected outcomes.

To determine the effect of the treatment "to adapt" on the treated (ATT) as the difference between (a) and (c) we follow [15], ATT =E (y1i|Ai =1) – E (y2i|Ai =1) which represents the effect of climate change adaptation on the farm income of the farm households that actually adapted to climate change. Similarly, we calculate the effect of the treatment on the untreated (ATU) for the farm households that actually did not adapt to climate change as the difference between (d) and (b), ATU =E (y1i|Ai =0) – E (y2i|Ai =0). We can use the expected outcomes described in (a) – (d) to calculate also the heterogeneity effects. For example, farm households that adapted may have produced more than farm households that did not adapt regardless of the fact that they decided to adapt but because of unobservable characteristics such as their skills. We follow Carter and [16] and define as "the effect of base heterogeneity" for the group of farm households that decided to adapt as the difference between (a) and (d), BH1 =E (y1i|Ai =1) − E(y1i|Ai =0).

Similarly for the group of farm households that decided not to adapt, "the effect of base heterogeneity" is the difference between (c) and (b), BH2 =E (y2i|Ai =1) – E(y2i|Ai =0). Finally, we investigate the "transitional heterogeneity" (TH), that is whether the effect of adapting to climate change is larger or smaller for farm households

[1] The discussion in this section is drawn from Maddala (1983, 223–224)

Table 2. Conditional expectations, treatment, and heterogeneity effects

Sub-samples	Decision stage		Treatment effect
	Adapt	Not to adapt	
Farm households that adapted	(a) E (y1i|Ai =1)	(c) E (y2i|Ai =1) TT	TT
Farm households that did not adapt	(d) E (y1i|Ai =0)	(b) E (y2i|Ai =0) TU	TU
Heterogeneity effects BH2 TH	BH1	BH2	TH

Note: (a) and (b) represent observed expected farm income level per hectare in CFA; (c) and (d) represent counterfactual expected farm income level per hectare in CFA; Ai=1 if farm household adapted to climate change and Ai=0 if farm households did not adapt; Y1i: Farm income level if farm households adapted; Y2i: Farm income level if farm household did not adapt; ATT: The effect of adaptation (treatment) on the farm households that adapted (the treated); ATU: The effect of adaptation (treatment) on the farm households that did not adapt (the untreated); BHi: The effect of base heterogeneity for farm households that adapted (i=1), and did not adapt (i=2); TH=(ATT-ATU), i.e., transitional heterogeneity

that actually adapted to climate change or for farm households that actually did not adapt in the counterfactual case that they did adapt, that is the difference between ATT and ATU.

2.4 Data

This research used cross-sectional data from the farm household survey collected in 2013 in the Savanes region of Togo on 450 farm households. It is the part of the dataset that included farmer perception on climate change, adaptation strategies developed by farmers and farm income that is used in this research. Climatic data on rainfall and temperature come from the National Meteorological Service. Because we needed household specific rainfall and temperature data, we use the technique known as Thine Plate Spline method to derive them. This method computes the village specific values using latitude, longitude and elevation information. Then we used the computed values to approximate household specific climate data.

3. RESULTS AND DISCUSSION

3.1 Descriptive Statistics

This section presents brief summaries of the strategies farmers use for adapting to climatic change. The study focuses on private adaptation measures adopted in farming practices. In the survey which data is used in this study's questionnaire farmers were asked questions about their perceptions of long-term climate changes as well as about which measures and practices they have typically adopted in order to cope with such changes over the years. The question asked was "What have you done to reduce the impact of the changes in weather patterns on your farm or crop yield/livelihood?" Interviewers had a list of possible adaptation options, but to avoid framing bias, they did not present it to the respondents. Instead, the respondents verbally described their adaptation measures and the Interviewers checked the corresponding options in the list. The results show that the majority of farmers correctly perceive that long-term temperatures are rising (72.4%) and precipitation is declining (76.3%).

Farmers' adaptation strategies in responding to the changing climate include crop diversification, changing planting dates, use of irrigation, use of soil and water conservation techniques (stone bunds use), farm to livestock shift, increase in farm size, off-farm activities (Fig. 1).

As mentioned previously we used the technique known as Thin Plate Spline to derive villages specific climate data that were further used as proxy of households' specific climate data. The Table 3 presents the result of the Thin Plate Spline estimates. A closer look of the Table 3 reveals that higher rainy season precipitations level is associated with lower level of rainy season temperature. Similarly, a higher level of dry season precipitations implies lower dry season temperature.

3.2 Test on the Validity of the Selection Instruments

In this case study, we use as selection instruments in the income equation the variables related to the information sources specifically government extension and climate information. When a variable stands for a valid instrument, it will impact on adaptation decision but will not affect the farm income per hectare among farmers that did not adapt. Table 4 supports the idea that the information sources chosen can be considered as valid selection instruments: They are jointly statistically significant drivers of the decision to adapt or not to climate change (Model 1, $\chi2$ =63.88; p= 0.00) but not of the farm income from cropping per hectare for the farm households that did not adapt (Model 2, F-stat.=2.25, p=0.23).

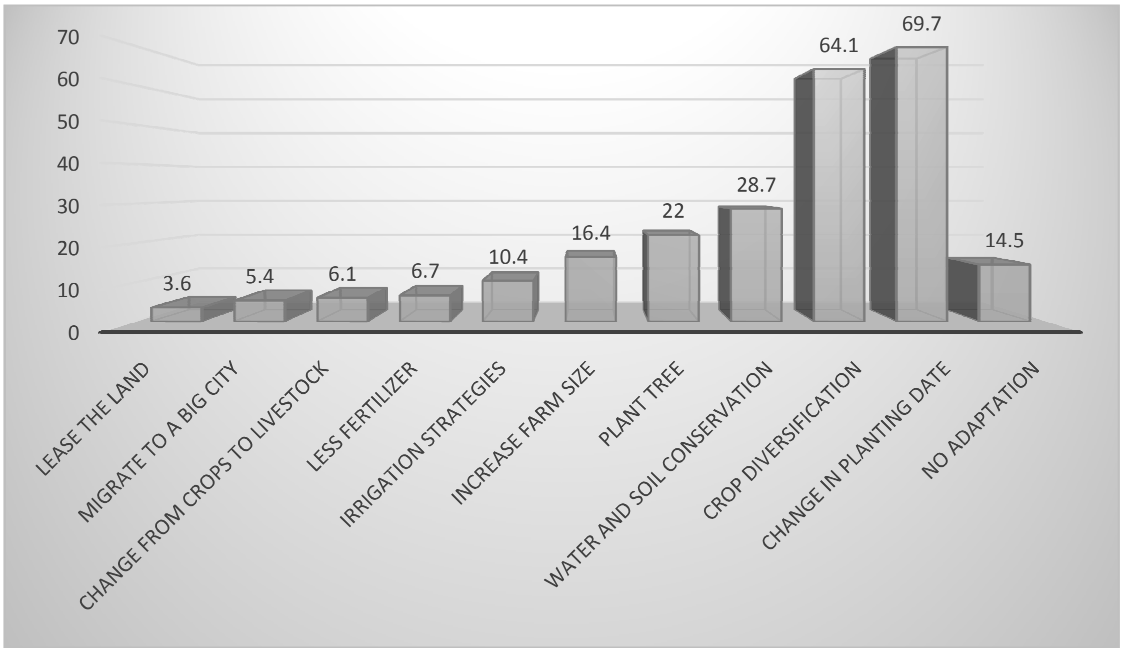

Fig. 1. Adaptation strategies used by farmers in the Savanes region (% of respondents)
Sources: Authors from Mikemina P., 2014

Table 3. Results of the thin plate spline estimates

Villages	Precipitation (In mm)		Temperature (In degree Celsius)	
	Rainy season	Dry season	Rainy season	Dry season
Galbagou	447,01	70.34	26.17	27.46
Tambimongue	448.00	55.50	26.99	29.67
Tintoangbangue	434.16	34.12	27.89	32.65
Konkomoni	567.09	80.40	24.17	27.29
Djambangou	430.90	74.3	26.35	28.70
Patebogou	399.08	79.15	30.4	28.45
Koumbeloti	501.14	90.7	25.45	27.74
Payoka	429.03	69.09	27.89	28.90
Mandouri	498.2	77.12	27.00	28.30
Bagre	532.2	99.00	24.89	27.70
Gando	507.34	90.23	25.36	26.37
Djesserabou	508.13	80.12	25.70	27.09
Tanbangou	489.2	78.03	27.90	28.34
Konkogue	500.00	70.40	26.34	29.02
Pokpielok	532.2	45.90	28.18	32.30
Nadjir	456.60	56.55	27.50	30.14
Baniam	455.20	79.60	27.00	26.17
Tidonti	520.14	75.50	25.10	27.89

Source: Authors from thin plate spline estimates

3.3 Endogenous Switching Regression Model Results

The Table 5 reports the estimates of the endogenous switching regression model. The first column presents the estimation of the coefficients of the selection equation on adapting or not to climate change. The second and third column report the estimation of the coefficients of the farm income equation (2a) and (2b) for the farm households that did and did not adapt to changing climate.

The estimation presented in the first column suggest the main drivers of farm households' decision to adopt some adaption options in response to climate change.

First the characteristics of the household head play important role in adapting to climate change. Indeed, the male headed farm households are more likely to take up adaptation compare to their counterpart female. This result may be due to the fact that the male headed households are more willing to take risk. His level of education also positively affects the farm household's likelihood to adapt. This is so because better educated farmers are more skilled to transform information into knowledge.

Farmers with access to credit have higher chances of adapting to changing climatic conditions. Access to affordable credit increases the financial resources of farmers and their ability to meet transaction costs associated with the various adaptation options they might want to take. With more financial and other resources at their disposal, farmers are able to change their management practices in response to changing climatic and other factors. They are better able to make use of all the available information they might have on changing conditions, both climatic and other socioeconomic factors. For instance, with financial resources farmers are able to buy new crop varieties, new irrigation technologies, and other important inputs they may need to change their practices to suit the forecasted and prevailing climatic conditions.

Access to Government extension services significantly increases the probability of taking up adaptation options. Extension services provide an important source of information on climate change as well as agricultural production and management practices. Farmers who have significant extension contacts have better chances of being aware of changing climatic conditions and of the various management practices that they can use to adapt to changes in climatic conditions. Improving access to extension services for farmers has the potential to significantly increase farmers' awareness of changing climatic conditions as well as adaptation measures in response to climatic changes.

We now turn on the productive implication of adaptation. The correlation coefficient rho_1 and rho_2 are both positive but are significant only for the correlation between the adaptation equation and the farm income for farm households that adapted. Although we could not have known it a priori, this implies that the hypothesis of sample selectivity bias may not be rejected.

The difference in the coefficients of the farm income equation between farm households that adapted and those that did not adapt illustrate the presence of heterogeneity in the sample. The farm income equation of farm households that adapted to climate change is significantly different from the farm income equation for those that did not adapt. The level of income in the both equations is simultaneously explained by education, household size, access to credit, tractors use, fertilizers and climate variables. This is quite consistent with what agricultural household model theory predicts in a context such as the one prevailing in the Savanes region of Togo. It is worth underling the effect of climate extreme events (floods and droughts) on these equations. Flood and drought have both negative impact on farm income for farm households that adapted and positive impact on farm income for farm households that adapted. This can be interpreted as follow: Droughts and flood negative impact on farm income is well known. However, once adaptation strategies are appropriately put in place, farm household can take up the opportunities offered by these events. The positive values of the coefficients of the extreme events is pointed the fact that farm households that adapted are benefiting from the strategies put in place. However, at this stage one cannot say anything about what would have happened if the farm households that did not adapted had adapted. To analyze that situation we have to turn onto the treatment effect. The next section deals with that.

Table 4. Test on the validity of the selection instruments

	Model 1	Model 2
	Adaptation 1/0	**Farm income per hectare by farm household that did not adapt**
Government extension	0.531*** (0.129)[2]	76.449 (40.09)
Climate information	0.891*** (0.149)	32.125 (46.29)
Constant	-0.706*** (0.142)	29.86 (43.25)
Wald test on information sources	χ^2 = 63.88	Fstat =2.25
Sample size	445	65

Note: Model 1 =Probit model (Pseudo R2 = 0.1074); Model 2 = Ordinary Least Square (Adj R-squared = 0.0056)

Table 5. Results of the Endogenous Switching Regression (ESR) model

Independent variables	1	2	3
	Adaptation 1/0	**Adaption=0 (Farm households that adapted)**	**Adaptation =1 (Farm household that did not adapted)**
	Adaptation 1/0	**Farm income per hectare**	**Farm income per hectare**
Age	0.0004 (0.0039)	-0.1177 (0.5361)	-0.5187 (2.1604)
Sex	0.3300 (0.1867)*	46.1059* (25.7582)	68.2424 (93.3464)
Education	0.0424 (0.0231)*	6.0385*** (1.8753)	15.4494 (8.6309)*
Married	0.0003 (0.0773)	1.1742 (10.6996)	-32.9707 (39.4609)
HH size	0.0323** (0.0161)	3.9022*(1.2111)	14.8796* (8.2986)
Off-farm job	0.8169*** (0.2222)	21.9949 (18.7252)	33.6520**(16.4325)
Relatives	-0.2887 (0.1180)	-16.3362 (17.2057)	-14.9787 (23.7419)
Access to credit	0.2869** (0.1182)	39.5256** (16.4994)	56.8059*** (22.0368)
Fertility	0.0233 (0.2356)	2.8906 (3.1768)	16.4509 (22.1314)
Tractor use	0.8147*** (0.2223)	117.2099*** (31.1761)	71.0280*** (23.8970)
Flood experience	0.1596* (0.0656)	-17.7663 (17.2212)	57.4839** (31.8456)
Drought experience	0.0191*** (0.0006)	-30.4684(40.4882)	20.0989 (26.9956)
Access to river	0.1719** (0.0686)	-25.7963 (23.2851)	25.7815* (14.4123)
Fertilizers	0.1569* (0.0921)	123.2340*** (40.2333)	200.2199*** (56.7779)
Government extension	0.0276*** (0.0016)		
Head climate change	0.0411*** (0.0024)		
Rainy season rainfall	0.0100 (0.0040)	2.124 (0.0140)***	0.0210(0.0001)**
Rainy season rainfall square	133.567 (233.980)	-234.232(130.726)*	-278.345 (155.500)*
Dry season rainfall	0.3334 (2.354)	3.1788 (2.8963)	-6.900 (10.234)
Dry season rainfall square	122.333 (200.12)	230.567 (234.678)	117.2122 (200.1923)
Constant	-0.6798*** (0.0395)	74.8045 ** (42.0227)	85.2343 (28.4114)***
Sigma_1		789.345 (90.456)***	
Sigma_2			578.908 (100.456)***
Rho_1		0.1459 (0.4539)	
Rho_2			0.8758 (0.0171)***
LR test	Chi2=112.87; Prob>=0.000		

Source: Authors estimates from STATA 12

[2] The number in parentheses indicate standard errors

Table 6. Average expected income per hectare and treatment and heterogeneity effects

Sub-samples	**Decision stage**		**Treatment effect**
	Adapt	**Not to adapt**	
Farm households that adapted	(a) 800,835	(c) 607,970	ATT=192,865**
Farm households that did not adapt	(d) 512,202	(b) 590,345	ATU=-78,143*
Heterogeneity effects BH2 TH	BH1=228,633	BH2=-17,375	TH=246,258**

Source: Authors' estimates in STATA 12

3.4 Average Expected Income per Hectare, Treatment and Heterogeneity Effects

Table 6 depicts observed and expected income of the both groups of farm households (Those who adapted and those who did not adapted). Cell (a) and (b) represent the observed income from cropping. One can notice that the farm households that adapted present a higher income than those who did not adapt (800, 835 CFA against 607, 970 fcfa). However this comparison is misleading as the farm households that did adapt may not have the same characteristics that those who did not adapt have. To have an accurate idea on whether it is worth adapting for non-adapters, let's look in the fourth column of the Table 6. That column presents the treatment effects of adaptation on farm income per hectare in CFA. In the counterfactual case (c), farm households who actually adapted would have earned about 192,865 (24.08%) less if they have not adapted. This confirms the previous findings in a similar study by [3]. In the counterfactual case (d) that farm households that did not adapted have adapted, they would have earned about 78,133 fcfa (13.24%) less if they had adapted. Thus, the results of the treatment effect (ATT) indicate that adaptation significantly enhance households' farm income for adapters. However, the ATU results indicate that the non-adopters' decision not to adopt appear to be rational as they would have been 13.24 percent worse off in terms of farm income if they were to adapt. This situation may be due to the fact that farm household that did not adapt utilize some indigenous strategies ("farmer innovation") not classified as adaptation option to cope with climate change.

4. CONCLUSION

Through this paper, our main objective was to analyse farm income implications of the decision to adapt to climate change. In addition to this primary objective, we investigated the factors driving farm household decision to adapt. We used survey that collected data at households' level in the study area during the agricultural year 2013. We complemented these data by climate data collected from the national meteorological service. The analyses are based on the results of the estimates from the Endogenous Switching Regression (ESR) model. Prior to the ESR model estimation, the climate data (rainfall and temperature) at communities level were computed using the Thine plate Spline method.

The analysis of the determinants of adaptation reveal that both access to credit and information about climate change provision have a positive effect on the probability of adaptation. Extension services also play a crucial role in determining farm households' decisions to adapt.

The results also reveal that adaptation to climate change increases farm income for farm household who adapt. However, the decision of farm household that did not adapt not to adapt appear to be rational since they would have been 13.24 percent worse off in terms of farm income if they were to adapt. This last result appear to be quite surprising. However, this can be understood. Indeed, this situation might be due to the fact that farm households that are considered as non-adapters use some indigenous practices ("farmer innovation") not classified as adaptation to cope with climate change. The policy message drawn from this study first support adaptation strategies which build on indigenous practices. Second, policies aiming to enhance adaptation to climate change adoption have to be based on strategies designed to improve access to credit market and information about climate change.

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DISCLAIMER

This manuscript was presented in the conference "7th African Population

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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