Farmers' perceptions of climate change and farm-level adaptation strategies: Evidence from Bassila in Benin

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Abstract

Very few studies of the agricultural sector's adaptation to climate change have been conducted in Benin. This paper focuses on farmers' perceptions and adaptation decisions in relation to climate change. A double hurdle model that includes a logit regression and a truncated negative binomial regression was developed using data from a survey of 200 farmers located in northern Benin. The results show that farmers' perceptions of climate change support the macro-level evidence. The econometric results reveal that the most effective ways to increase the probability of adaptation are to secure land rights and support the creation and strengthening of local farm organisations. The most effective ways to increase the intensity of adaptation are to improve access to agricultural finances and extension. The findings of this study have several public policy implications for creating an enabling environment for adaptation to climate change in Benin.

Keys words: decision to adapt; intensity of adaptation; climate change; double hurdle model; Benin.

1. Introduction

Climate change has had a significant affect on the pattern of precipitation and has caused frequent extreme weather events, leading to natural disasters such as droughts and floods (IPCC 2007, 2014a; Schlenker & Lobell 2010).

Benin's crop production and food security are beginning to be threatened by climate change (Gnanglé *et al*. 2011; Vodounou & Doubogan 2016; Awoye *et al*. 2017; Padonou *et al*. 2017; Duku *et al*. 2018). To cope with the adverse effects of these changes, farmers have adopted adaptation practices and technologies. The modification of cultural practices, the development of new agricultural activities and extensification are among the climate change adaptation practices used in Benin (Agossou *et al*. 2012; Yegbemey *et al*. 2013). More generally, the adaptation literature identifies innovation, adaptation, crop selection and migration as key strategies (Zilberman *et al*. 2012). Farmers adopting various adaptive practices are influenced by a set of determinants, the analysis of which is essential to identify the appropriate options to improve adaptation.

Obtaining better knowledge of these determinants has been the subject of renewed interest in the economic literature (Hisali *et al*. 2011; Zhang *et al*. 2012; Yegbemey *et al*. 2013; Alauddin & Sarker 2014; Wood *et al*. 2014; Tessema *et al*. 2018). Nevertheless, this work is confronted with three major shortcomings that motivate the present study. First, these studies fail to draw conclusions about determinants that are common to all situations, particularly because of the heterogeneity of farmers and of production contexts (Roussy *et al*. 2015). These works are indeed divided according to how these adaptive practices are likely to be adopted by different communities around the world whose livelihoods are dependent on highly dynamic and heterogeneous resources (Reed *et al*. 2013). Indeed, although there are some generalities between regions, many factors influencing change and adaptation vary across regions (Wood *et al*. 2014). Second, compared to several African countries, Benin has

received very little attention from researchers. An analysis of Google Scholar search results, both general and within leading climate change-related journals, confirms this situation (Hendrix 2017). Third, while several studies have focused on the conditions for adopting practices to adapt to climate change, most studies have used econometric regression models with binary variables. The adoption of adaptive practices is modelled as a one-step decision. These models assume that any variable that increases the likelihood of adopting an adaptation practice also increases the intensity of adaptation. However, this hypothesis is not always true because the decision to adapt and the intensity of adaptation can be explained by different factors (Roco *et al*. 2014; Boansi *et al*. 2017). Simultaneous exploration of factors is rare in the economic literature. However, it is essential for the formulation and implementation of an effective and sustainable adaptation policy in Benin.

We therefore focused on the choice of adaptation to climate change made by farmers in the Bassila area in Benin. It is currently poorly understood what determines farmers' adaptation in Benin. Benin is an interesting area to study in sub-Saharan Africa, given its high vulnerability to extreme weather events such as droughts, floods and heat waves. In addition, the occurrence of these extreme events is a challenge for agricultural production in the Bassila area. The aim of this research was to better understand the determinants of the decision to adapt and the adaptation intensity of agricultural producers in Bassila to climate change, and to express support for public policies in favour of the adoption of adaptive practices. Therefore, the study aimed to answer the following questions: (i) What are the perceptions of farmers in the Bassila area regarding climate change? (ii) What main adaptation strategies do these farmers adopt to address the negative effects of such changes? (iii) What are the determinants influencing their decisions and their adaptation intensity? This research provides information on the perceptions of farmers and on local climate change adaptation strategies, providing new insights into the determinants of the adaptation choices of farmers and the policies to be implemented.

The rest of this paper is organised as follows: Section 2 presents a review of the relevant empirical evidence. It specifies certain concepts mobilised in this study and reports the determinants that emerge in the literature. A brief description of the study area and data collection is provided in section 3. In section 4, we examine the econometric estimation model used. The collected data were analysed using a double hurdle model, and the model's estimated results are presented in section 5. Finally, section 6 discusses the conclusions and policy implications of the findings.

2. Literature review

This section provides a summary of the research findings on the factors influencing the adaptation of rural communities to climate change.

Adaptation is defined as the response of economic agents and societies to major environment changes (e.g. global warming) and/or political and economic shocks (e.g. famine or war) (Zilberman *et al*. 2012). Adaptation to climate change is a process that allows communities or individuals to adjust in response to changes in their environment in order to limit the negative impacts of climate change or to benefit from the positive impacts (Adger 2003; IPCC 2007). Thus, adaptation strategies aim to increase the resilience and reduce the vulnerability of environments, communities and individuals to the known or anticipated effects of climate change. Tessema *et al*. (2018) distinguish between two types of adaptation strategies used by farmers. These authors differentiate the strategies that mainly use existing technologies ("non-technological") and those that adopt new technologies ("technological"). The former are adjustments made on the farm to allow the use of technologies or inputs traditionally used by a community for generations. Examples include changes in crop type and planting period, crop rotation, and crop diversification. These adjustments depend mainly on local knowledge accumulated over generations, and the resources available in the community. Technological strategies are similar to the adjustments that have been studied in the literature on

adopting farming technology. Examples include the adoption of fertilisers, irrigation technologies, pesticides and farming machinery.

Different adaptation practices, whether technological or non-technological, are likely to reduce vulnerability to climate change (Smit & Skinner 2002; IPCC 2014b; Tessema *et al*. 2018). Understanding the determinants of adaptation practices is essential to explain and enhance the local adaptation process. These determinants can be classified into three categories: household and farm characteristics, social capital, and institutional variables (Alauddin & Sarker 2014; Alam *et al*. 2016). Household and farm characteristics include the farmer's age, sex and level of education, farm and non-farm income, household size, farm size, and land tenure status. Social capital encompasses contacts with extension services and farmers' participation in a local social group. Institutional variables comprise access to climate change information, loan facilities and markets.

With regard to household and farm characteristics, Yegbemey *et al*. (2013) conclude that land ownership has a positive effect on the decision of farmers in Benin to adapt to climate change. Thus, securing farmers' property rights most likely contributes to enhancing their capacity to adapt to climate change. Other socio-economic and demographic factors, such as educational attainment, age, gender, number of household assets and non-farm income could also support the adoption of some coping strategies. Randell and Gray (2016) show that, in Ethiopia, education improves the capacity of farmers to learn and apply complex technologies. In the West African Sudan Savanna, older farmers, with sufficient years of experience in farming to recognise changes in their environment, are more likely to adopt adaptation strategies (Boansi *et al*. 2017). It also appears that climate change adaptation options are closely related to the roles and responsibilities of male and female farmers (Ngigi *et al*. 2017). These authors show that male farmers in nine East and West African countries are more likely to use adaptive practices than female farmers. A high number of active household members is also associated with the greater availability of labour, all of which favour the adoption of certain practices in Chile (Roco *et al*. 2014). In their work, Roco *et al*. (2014) also note that intensive crop farmers in Chile are more likely to adopt several adaptive practices than grain farmers. Zhang *et al*. (2012) found that Chinese farmers with large farms are most in favour of adopting adaptation strategies related to land degradation, since they have a desire to improve their production and have the means to implement these innovations. However, in many cases, West African farmers with non-farm income sources are more likely to adopt such adaptation strategies (Wood *et al*. 2014). Furthermore, the existence of non-farm income could enable farmers to cover capital costs for the implementation of the adaptation technologies. In addition, non-farm income could also reduce the risks associated with experimenting with new technologies.

With regard to social capital, participation in a local agricultural organisation appears to be a key determinant of the effort to conserve environmental resources. Adger (2003) found that social capital facilitates the participation by Kenyan producers in collective action initiatives, which then influence individual soil conservation efforts.

Finally, several studies in economics argue that limited institutional access reduces the likelihood of adopting climate change adaptation strategies (Azhoni *et al*. 2017). In particular, poor access to information and financing has negative effects on the decision to adapt by South African, Ugandan, Ghanaian and Ethiopian farmers (Hisali *et al*. 2011; Boansi *et al*. 2017). Below *et al*. (2012) note that improving farmers' access to markets and infrastructure makes it possible for them to buy inputs needed for farming in a timely manner, to sell outputs at acceptable prices, and to bring farmers who use new technologies closer to local markets. Similarly, farmers' contacts with agricultural extension services are expected to facilitate adaptive adoption practices as they access information on climate, agricultural technologies and advice (Below *et al*. 2012; Yegbemey *et al*. 2014).

This summary of the literature review has shown that a set of demographic, economic, social and institutional factors underlie the adoption of adaptive practices by farmers. The precise identification of the factors influencing the adoption of adaptive practices by the farmers of Bassila could allow the implementation of an effective and sustainable adaptation policy in this area of Benin.

3. Study area and data collection

Following the introduction to the Bassila area, this section discusses the survey procedure used to collect the data.

3.1 Study area

This study was carried out in the Bassila region, which covers an area of 5 661 km^2 and is one of the four communes that make up the Donga department in Northern Benin. It is located approximately 375 km from Cotonou, the economic capital, and 87 km from Djougou, the department's main town (Figure 1). According to the fourth general population and housing census (Institut National de la Statistique et de l'Analyse Économique [INSAE] 2013), Bassila's population increased from 71 511 in 2002 to 130 091 in 2013. This increase corresponds to an intercensal increase of 4.8% over ten years. The Bassila has a Sudano-Guinean climate, and the soils are mainly of the tropical ferruginous types, in addition to raw mineral and hydromorphic soils. These soils are conducive to agriculture. The farmland acreage in the last ten years is estimated at 14 728.25 ha annually. Corn dominates, as it is produced on nearly 27% of the farmland (including 17% for the improved variety and 10% for the local variety). Corn is followed by yams (26%) and cassava (14%). The farmland allotted to millet, rice, sweet potato, taro, cowpea, groundnut, goussi, sesame, tomato, chili, okra, cotton and tobacco represents approximately 17% (Commission Nationale Du Développement Durable [CNDD] 2012).

3.2 Data collection

The data used in this study stem from a survey that was carried out in eight villages in the Bassila area. To choose the surveyed targets, a two-stage sampling method was carried out. The first part covered the villages and the second one was related to the farmers. Villages are the primary units, and the farmers are the secondary units. For the purpose of this study, we selected villages in each of the four districts, giving a total of eight villages. The villages selected for the study are the following: the Partago and Aledjo-Koura villages in the department of Aledjo-Koura; the Bassila and Api villages in the department of Bassila; Ouanou and Manigri villages in the department of Manigri; and the Penessoulou and Chetou villages in the department of Penessoulou.

Farmers are the observation units. Twenty-five farmers were interviewed in each of the eight villages. These farmers were randomly selected from a list of farmers that was established by the village leaders. Each farmer was selected with equal likelihood. In total, 200 farmers were interviewed. Three steps were used in our data collection. An exploratory survey was first conducted with a small number of farmers and some resource persons (representatives of state-owned agencies, representatives of farmer organisations and representatives of NGOs involved in environmental protection). Then, the actual survey was carried out using a questionnaire completed by the farmers selected for the study. Finally, a complementary survey was conducted via interviews with municipal officials and researchers to supplement the information. The questionnaire administered to the farmers had four sections. The first section highlighted the farmers' socio-economic characteristics. The second section was related to the farmers' production systems. The third section focused on the farmers' perceptions of climate change, while the last section emphasised climate change adaptation strategies.

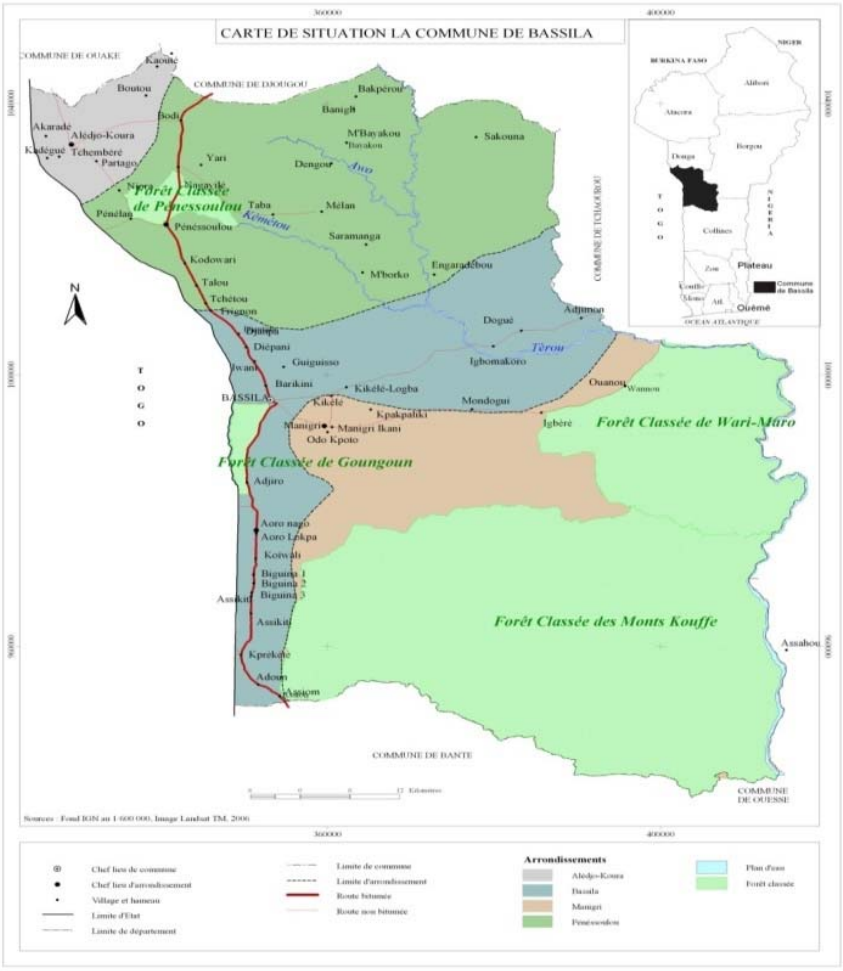

Figure 1: The study area
Source: CNDD (2012)

4. Model estimation

To examine the determinants of farmers' adaptation strategies to climate change, we used the regression model suggested by Cragg (1971). This model is a double hurdle model that uses a binary regression model to determine the effect of the explanatory variables on decisions to adopt an adaptive practice (Yes/No) (first hurdle), and a truncated count distribution model to determine the effect of these same variables on the adaptation intensity (second hurdle). This approach allows a more complete and detailed analysis compared to that used by most studies in the literature. We again take the structure of the model employed by Roco *et al*. (2014) to estimate a logit regression model and a truncated negative binomial regression model. The model used is as follows:

$$\boldsymbol{a_i^* = w_i'\alpha + v_i}\ \text{[Adaptation decision]} \quad (1)$$

$$\boldsymbol{a_i = 1}\ \text{if}\ \boldsymbol{a_i^* > 0}\ \text{and}\ \boldsymbol{0}\ \text{if}\ \boldsymbol{a_i^* < 0} \quad (2)$$

$$\boldsymbol{y_i^* = x_i'\beta + u_i}\ \text{[The intensity of adaptation]} \quad (3)$$

$$\boldsymbol{y_i = x_i'\beta + u_i}\ \text{if}\ \boldsymbol{y_i^* > 0}\ \text{and}\ \boldsymbol{a_i^* > 0} \quad (4)$$

$$\boldsymbol{y_i = 0}\ \text{otherwise} \quad (5)$$

where a_i^* is a latent variable that describes the decision to adapt; a_i is the observed adaptation decision and takes the value of 1 if the farmer adopts at least one practice and 0 if otherwise; y_i^* is a latent variable related to the intensity of adaptation; y_i is the observed intensity of adaptation measured as the number of adopted practices; w and x are vectors of explanatory variables for decision and intensity; α and β are vectors of the parameters to be estimated; and v_i *and* u_i are error terms.

Referring to the theory of utility maximisation, the i*th* farmer adopts a new technology only if the expected utility is greater than the utility associated with the current technology. Since the parameters α and β cannot be interpreted directly, it is common to compare the marginal effects to each variable's average (Greene 2008). To determine if the hurdle model is preferable for the available data compared to the estimation of a one-stage count model (Poisson or negative binomial), a likelihood ratio (LR) test is applied to verify if adoption/intensity is a one- or a two-step decision (Roco *et al*. 2014). The null hypothesis is that the count model is superior to the hurdle model. According to Wooldridge (2002), the test compares the likelihood values of the two models to determine whether they are significantly different from each other using the following formula:

$$\lambda = -2(L_B - L_L - L_{BT}), \quad (6)$$

where L_B, L_L and L_{CT} are the log-likelihood function values for the binomial, logit and truncated binomial regression models respectively. The LR statistic value, LR (λ), has a Chi-square distribution with degrees of freedom equivalent to the number of explanatory variables.

The variables included in the model are presented in Table 1.

Table 1: Variables considered in the climatic change adaptation models

Variables in the model	Description	Mean	Expected effect
Dependent variables			
Adaptation	Dummy variable = 1 if farm has at least one climatic change adaptation practice implemented, and 0 otherwise	0.65	
Intensity	Number of climatic change adaptation practices adopted by farm	2.49	
Independent variables			
▪ *Household and farms characteristics*			
Age	Age of farmer in years	48.55	-
Sex	Dummy variable = 1 if farmer is male and 0 if female	0.80	+
Education	Dummy variable = 1 if farmer has a formal education, and 0 otherwise	0.39	+
Actives	Dummy variable = 1 if the household has more active members than inactive, and 0 otherwise	0.73	+
OffFarm	Dummy variable = 1 if farmer participates in off-farm activities, and 0 otherwise	0.35	+
LandTenure	Dummy variable = 1 if farmer is owner, and 0 otherwise	0.34	+
Intensive	Dummy variable = 1 if farmer produces intensive crop, and 0 otherwise	0.32	+
FarmSize	Dummy variable = 1 if farmer exploits a large area, and 0 otherwise.	0.24	+
▪ *Social capital*			
Membership	Dummy variable = 1 if farmer is member of a local group, and 0 otherwise	0.32	+
▪ *Institutional factors*			
Extension	Dummy variable = 1 if farmer has contact with extension service providers, and 0 otherwise	0.74	+
Market	Dummy variable = 1 if farmer has good access to market, and 0 otherwise	0.94	+
Credit	Dummy variable = 1 if farmer has access to credit, and 0 otherwise	0.76	+

5. Results

This section begins with an analysis of the farmers' perceptions of climate change, followed by a review of their adaptation strategies. The third subsection examines the econometric model, while the fourth presents the results of the econometric estimates of the determinants of decision and intensity of adaptation.

5.1 Farmers' perceptions of climate change

The surveys indicated that all farmers surveyed perceive changes in several climatic factors (Figure 2). An examination of these perceptions shows that rainfall disturbances are recognised the most by farmers. Indeed, all of the farmers interviewed (100%) noted a delay in the initiation of the rainy season, 96% noted a reduction in the duration of this season, and 94.5% considered that there was a decrease in rainfall. In addition, 85% of the interviewed farmers recognised soil and vegetation degradation, while strong temperature variations and the recurrence of droughts were recognised by 83.5% and 65% of the respondents respectively. Finally, 54.5%, 51.5% and 50.5% respectively of the farmers surveyed noted that the high frequency of floods, the strong winds during rainfall and the disappearance of certain animal species were manifestations of climate change.

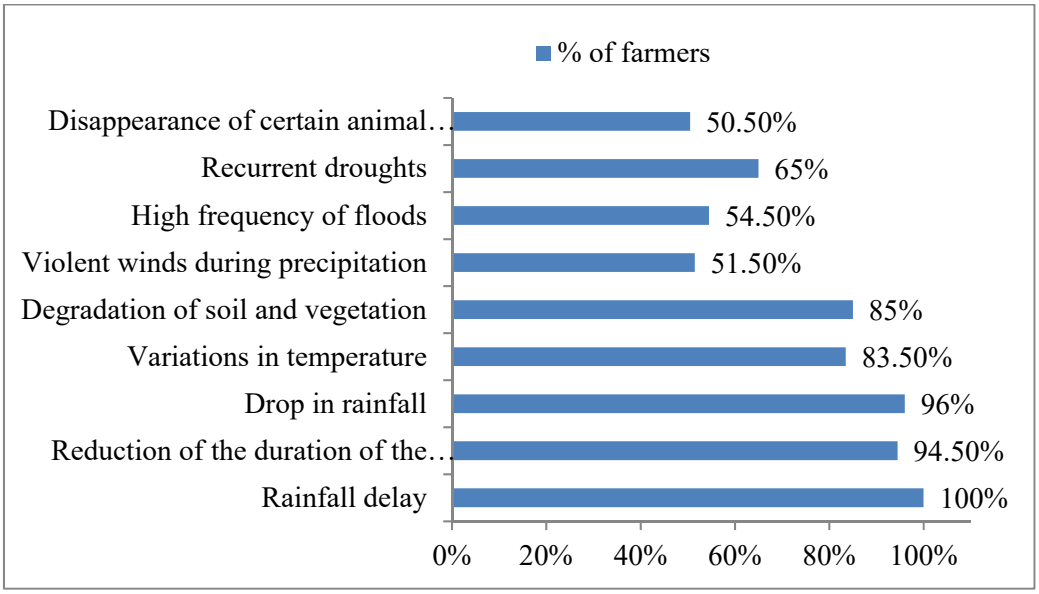

Figure 2: Summary of farmers' perceptions of climate change
Source: Survey data (2014)

These perceptions are consistent with previous studies carried out in Benin (Gnanglé *et al*. 2011; Yabi & Afouda 2011; Vodounou & Doubogan 2016; Padonou *et al*. 2017). Farmers therefore have a good knowledge of the climatic changes that occur in their environment. An in-depth analysis of these perceptions shows that 92% of the interviewed farmers believe that the different climatic disturbances will occur more often in the coming years. In addition, 25% of the farmers perceived severe negative impacts on their activities.

5.2 Adaptations by farmers to climate change in agricultural production

To reduce their vulnerability to climate change, 64% of farmers shifted their planting dates and 64% used mineral fertilisers. It was also found that 60% of the farmers introduced new crops, 60% abandoned some water-intensive crops, 60% changed crop varieties, and 60% diversified their production (Figure 3). There are also four other types of strategies, although these are poorly adopted by farmers. Twenty-five percent of producers increased their farm size, 25% grew a combination of

crops, 15% reduced their planting and 15% prayed or migrated. Finally, a very small percentage of farmers practised crop rotation (4%) or agroforestry (2%).

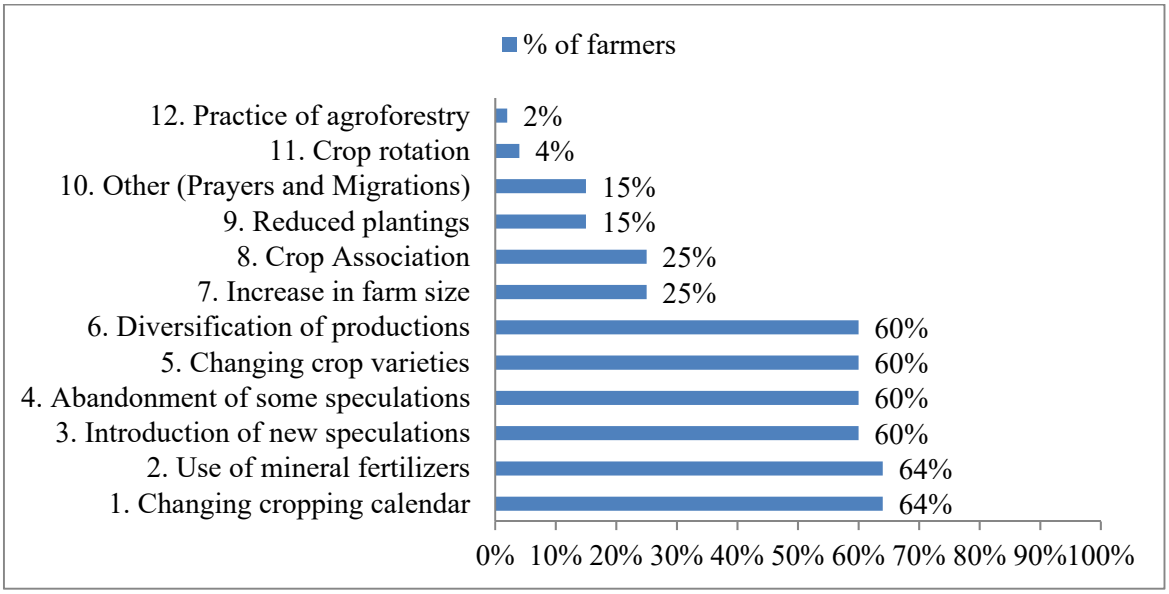

Figure 3: Percentage of farmers who adopted the main adaptation strategies
Source: Survey data (2017)

To eliminate or minimise the damage caused by climate change, farmers apply different adaptation practices simultaneously (Figure 4). An analysis of the adaptation strategies shows that 34% of farmers have not introduced any climate change adaptation practices, while 66% have adopted at least one strategy. More than half of the farmers (54%) have adopted more than one strategy, and 24% of farmers apply five adaptation strategies simultaneously.

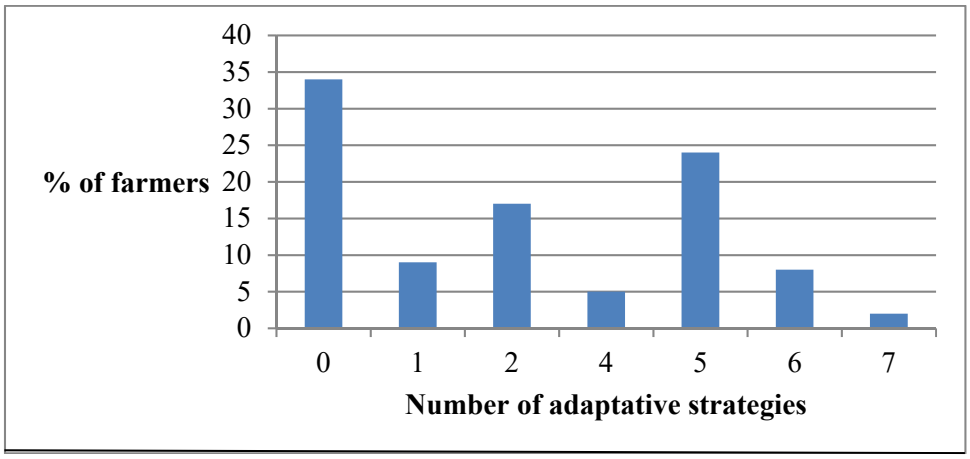

Figure 4: Number of adaptive strategies followed by farmers in reaction to climate change
Source: Survey data (2017)

Unlike several previous studies that have analysed adaptation strategies in isolation, the present study reveals that farmers tend to implement multiple and closely linked strategies. We used a model that analyses the decision to adapt and the intensity of adaptation by farmers in order to better understand the determinants of climate change adaptation. Fourteen explanatory variables were introduced into this model. Table 1 describes these variables and the expected sign for each of the variables.

5.3 Factors influencing farmers' decisions to adapt and the intensity of adaptation to climate change in agricultural production

An estimation and comparison of the two models (the double hurdle model and the negative binomial regression model) made it possible to choose the appropriate model for our study (Table 2). As a first step, it was necessary to determine the distribution of probabilities that describe the adaptation to climate change in the dataset. The estimate of the overdispersion parameter alpha in the negative binomial regression model gives a positive (0.408) and significant coefficient at any threshold. Therefore, negative binomial distribution is deemed preferable to Poisson distribution (Greene 2008; Roco *et al*. 2014). In a second step, it was necessary to compare the negative binomial regression model with the double hurdle model using the LR test, as presented in section 4 (Roco *et al*. 2014). The test resulted in the rejection of the negative binomial regression model at any threshold ,level in favour of the truncated negative binomial regression model included in the double hurdle model. This result validates the hypothesis that the decision to adapt and the intensity of adaptation are considered separately, thereby justifying the use of a two-stage decision process in our study.

Econometric estimates provide the following comparative results. To assess the overall performance of the hurdle model and the negative binomial count, we can compare the pseudo R^2 (Roco *et al*., 2014). For the model hurdle, the pseudo R2 is 58.4%, while the value for the count model without data truncation is only 8.6%. The logit model for adaptation presented five out of 12 statistically significant coefficients – at least at the 10% level, a pseudo R^2 of 43.6%, and 83% of the predictions were correct. The zero-truncated negative binomial regression model presented three out of 12 statistically significant coefficients – at least at the 10% level of significance, and a pseudo R^2 of 14.8%. In both cases, the F statistic for the null hypothesis that the model is not significant is rejected, at a probability of less than 0.1%.

Table 2: Estimation of the determinants of adaptation to climatic change

Variable	Hurdle model						Negative binomial		
	Logit (adaptation)			Zero-truncated negative binomial (intensity)					
	Coef.	Std	ME	Coef.	Std	ME	Coef.	Std	ME
Sex	3.463**	1.597	0.695	-0.106	0.203	-0.354	0.116	0.250	0.221
Age	-0.025	0.017	-0.004	-0.000	0.004	-0.000	-0.009*	0.005	-0.018
Actives	0.453	0.538	0.081	-0.002	0.134	-0.008	0.237	0.193	0.445
Intensive	-1.520**	0.485	-0.293	0.272**	0.114	0.943	-0.159	0.160	-0.306
LandTenure	6.701**	2.442	0.728	-0.519	0.306	-1.640	0.700*	0.431	1.579
OffFarm	0.618	0.778	0.100	0.117	0.158	0.381	0.212	0.242	0.434
Membership	2.850**	1.289	0.371	-0.034	0.158	-0.110	0.250	0.229	0.518
FarmSize	-0.336	0.771	-0.601	-0.082	0.154	-0.261	-0.205	0.208	-0.386
Education	0.117	0.456	0.019	-0.007	0.104	-0.023	-0.002	0.148	-0.003
Extension	6.080***	1.922	0.906	0.480*	0.289	1.304	1.875***	0.276	2.699
Credit	2.627	1.804	0.544	0.453*	0.255	1.352	1.179***	0.333	1.806
Market	-1.041	2.264	-0.134	0.412	0.473	1.113	-0.024	0.497	-0.498
Constant	-9.296	3.167		0.279	0.594		-1.795	0.669	
Obs.	200			132			200		
Alpha							0.443***		
Pseudo R^2	0.436			0.148			0.086		
Prob > Chi^2	0.000			0.000			0.000		
Log likelihood	-72.603			-226.011			-381.747		

* P < 0.10; ** P < 0.05 ; *** P < 0.01

ME = Marginal effects

5.3.1 Factors influencing farmers' decisions to adapt to climate change

Table 2 notes that a male farmer is more likely to adopt adaptive measures than a female farmer. This result is consistent with those of Ngigi *et al*. (2017), who show that differences in natural resource conservation behaviour are correlated with sex because of differences in access to and control of land and labour, which are important factors in determining soil conservation efforts. Women-led farms may therefore suffer more from climate change than those led by men.

In accordance with our theoretical expectations, land security also had a positive and significant effect on the decision to adapt to climate change. The acquisition of land rights increased the probability of adaptation by 72.8%. Landowners are more likely to implement long-term investments than non-owners. This result is similar to the results reported by Yegbemey *et al*. (2013), which indicated that the fear of being dispossessed of valued land limits investment in it. However, this variable has no effect on the number of adaptation practices implemented.

The econometric results also show that belonging to a local agricultural organisation (group, association or committee) positively influences the decision to adapt. Membership in such a social group increases the probability of adaptation by 37.1%. Concurring with several researchers' findings, including those of Adger (2003) and Alam *et al*. (2016), social capital creates an opportunity for the exchange of materials, information and labour among farmers. Farmers' relationships among themselves, which also serve as channels for sharing experiences, can lead to a common adaptation initiative. Participation in a social group also stimulates the adoption of conservation practices for environmental resources because of the possibility of collective learning and access to innovations adapted to local conditions. However, the parameter of this variable is not significant in the intensity of adaptation, suggesting that even if the membership to a group influences the decision to adapt, the membership does not affect the number of adopted adaptive practices.

5.3.2 Factors influencing farmers' intensity of adaptation to climate change

Contrary to our theoretical expectations, access to funding does not influence the decision to adapt to climate change. However, this variable has a significant effect on the adaptation intensity by increasing the probability by 135.2%. This variable makes the greatest marginal contribution to the adaptation intensity, which is understandable, since the implementation of technological adaptation strategies requires the use of certain inputs (improved seeds, fertilisers) or additional agricultural equipment, which is often difficult to access. Access to funding eases farmers' cash-flow constraints, thus facilitating the acquisition of the inputs necessary to adopt adaptive practices (Below *et al*. 2012; Truelove *et al*. 2015). This has a large impact, as rural areas are characterised by extreme poverty and a lack of adequate financing systems for low-income small farmers.

Our results also confirm that contact with agricultural extension services increases the likelihood of adaptation and improves adaptation intensity. Access to farming training/extension increases the likelihood of adaptation by 90.6% and increases the likelihood of adopting a greater number of adaptive practices by 130.4%. This result is consistent with previous studies (Hisali *et al*. 2011; Yegbemey *et al*. 2014; Boansi *et al*. 2017), which conclude that access to agricultural extension provides the producer with information and advice on adaptive strategies. One should know that a farmer needs to be sensitised and use appropriate skills in order to adapt. Awareness is based on access to information, while implementing various strategies requires at least some level of knowledge and skills. Through extension services, farmers do gain information on climate change conditions, the associated risks and improved production techniques, and they are also trained in the effective and efficient implementation of various technologies, which promotes the adoption of various strategies in a changing local climate (Boansi *et al*. 2017).

The nature of agricultural production has a positive and significant effect on the intensity of adaptation. Farmers producing intensive crops are more likely to adopt a higher number of adaptive practices than those producing non-intensive crops. The marginal contribution of this variable is 94.3% to the probability of adopting several adaptive practices. This result is similar to the findings of Roco *et al*. (2014), who found that intensive agricultural production activities often involve relatively modern technologies and have higher economic margins, while non-intensive production tends to be farmed with more traditional technologies. In addition, a good part of the farmers' agricultural income comes from the marketing of this type of crop. According to Alauddin and Sarker (2014), if the farmers' livelihoods are highly dependent on certain marketing speculations, they are more likely to invest in land conservation. Similarly, Amsalu and De Graaff (2007) explain that the conservation function in itself can only induce adoption if the conservation practice also increases the economic margin.

Moreover, contrary to our theoretical expectations, the famer's level of education, the farmer's age and the number of workers did not appear in our estimation as variables influencing the decision to adapt or the intensity of adaptation. Thus, the most educated farmers and young farmers are not more willing to adopt adaptive practices, given their capacity to plan, learn and apply certain technologies. In addition, the number of workers in the household is unlikely to significantly influence the adoption of adaptive practices. The same is true for factors such as proximity to the market, farmland acreage and non-farm income.

6. Conclusions and policy implications

This study first highlights farmers' perceptions of climate change, focusing mainly on rainfall disturbances, changes in wind speed, thermal changes, and soil and vegetation degradation. Then, the study reveals the various strategies used by farmers to cope with climate change, among which the most widespread were changing the cropping calendar, the use of mineral fertilisers, the introduction of new speculations, the abandoning of certain speculations, changing crop varieties and the diversification of production. Unlike previous work, this study takes into account the fact that farmers can use multiple strategies at once, and 54% of the farmers who were surveyed adopted more than one adaptive practice. Finally, a double hurdle model was used, consisting of a logit model to analyse the decision to adapt and a truncated negative binomial regression model to examine the intensity of adaptation.

The findings suggest the formulation and implementation of policy instruments to promote adaptation to climate change. These policies comprise two levels.

First, a large percentage of farmers (36%) in the study area did not adopt adaptation measures to address climate change. The analysis indicated the existence of key factors explaining this behaviour. The most important of these are land ownership and farming social group membership. The results therefore highlight that farmers need institutions that can secure land rights, improve their access to information, and support the creation or strengthening of local agricultural organisations. In particular, the acquisition of land rights could encourage producers to make relevant and sustainable investments. Similarly, by identifying the producers' perceptions and skills that need to be updated, it would be possible to develop targeted training content to strengthen adaptation practices. Finally, institutions need to support the creation and reinforcement of "spaces" in which individuals and groups can experiment, communicate, learn and reflect on new ideas. It should be noted that, since social learning occurs through interaction within social groups, certain characteristics of social groups may hinder or promote the development and diffusion of adaptation options. Therefore, government support for such institutions that aim to enable agricultural producers to adapt to climate change is likely to be effective.

Second, in order to encouraging the simultaneous adoption of several adaptive practices by farmers facing various manifestations of climate change, this study highlights the importance of improving access to finance and strengthening agricultural support. Indeed, these are the two most important factors for increasing the intensity of adaptation. Agricultural financing, training and advice are unavoidable inputs to encourage adaptation. Therefore, support for strengthening financing, training, information and advisory services for agricultural producers should be a priority in policies that promote adaptation to climate change in rural areas. Access to finances will allow producers to purchase improved varieties and other relevant inputs in a timely manner, and to invest in technologies. In addition, we agree with Ngigi (2017) that climate information should be accurate, relevant and accessible. Farmers need to be able to identify, mobilise and use the right knowledge, which is why institutional capacities in terms of information resources are likely to favour preparation for adaptation.

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