Endogenous farmer practices of adaptation to climate variability in the Town of Banikoara, Benin

Abstract

Background: Agriculture is an activity that provides more than 70% of employment in sub-Saharan African countries. However, climate variability has significant negative impacts on agricultural productivity, particularly in countries such as Benin that are highly dependent on rainfall. The objective of this research is to highlight the different perceptions and endogenous strategies of adaptation to climate variability adopted by farmers. It took place in Benin's largest cotton production area, the commune of Banikoara located in the northern region of the country.

Methodology: The surveys were conducted on a sample of 120 farmers randomly selected in four (4) villages, all of which are large agricultural producers, i.e. 30 farmers per village. In addition to descriptive statistics based on the calculation of proportions and averages, a multivariate probit model was estimated in order to identify the factors that influence the choice of endogenous adaptation strategies to climate variability.

Results: Approximately 50% of the respondents stated that they had practiced early seeding in order to cope with the consequences of climatic variability, 38% stated that they practiced ridge tillage, 28% indicated that they practiced late seeding while 15% declared that they practiced agroforestry. The results show that farmers use different combinations of endogenous strategies to drastically mitigate the adverse consequences of climate variability. Each farmer takes a number of parameters into account when defining the strategy to adopt.

Keywords : Climate change ; adaptation strategies ; endogenous practices ; determinant

1- **Introduction**

In Benin, the agricultural sector remains one of the main sources of foreign exchange for the nation. It has been revealed, for example, that this sector contributes around 33% of the Gross Domestic Product (GDP) and helps to combat unemployment by generating more than 70% of jobs, and provides around 75% of export earnings [1]; [2]. That sector is dominated by small and medium-sized farms, which are mostly of the traditional type. It is often shown that these small and medium-sized farms alone provide more than 95% of national agricultural production. However, these farms face enormous difficulties linked not only to their limited access to production factors but also and above all to strong climatic variability due to their high dependence on rainfall [3] ; [4]. For example, from 1960 to 2008, an increase in temperature of around 1°C and a significant reduction in rainfall of around 5.5 mm/year on average were noted [5] ; [6]. These strong climatic variabilities have significant negative impacts, particularly on agricultural productivity. Simulations of the impact of these variabilities on the country's main crops have shown that by 2025, these climate changes will lead to significant drops in yields for cotton (-29%), rice (-12%), maize (-9%), cowpea (-5%), and yam (-4%). These significant declines in agricultural productivity have immediate repercussions on worsening food and nutritional insecurity [7]; [8], especially for families that derive most of their income from agriculture. Yet, climate variability continues to manifest itself and its adverse effects are increasingly noticeable, not only through the increased frequency of vegetation fires, but also through more frequent floods and droughts.

To overcome these constraints inherent to strong climatic variability and mitigate their effects on agricultural productivity, farmers also apply endogenous adaptation practices as well as several other adaptation strategies developed by research and promoted in their communities [9] ; [10] Adaptation is seen as any kind of introduced or endogenous adjustments (ecological, social and/or economic) implemented by the producer in order to mitigate the impacts of observed or perceived climate variability [11] ; [12]. While the literature on the adoption of adaptation strategies to climate variability developed is abundant, that on endogenous adaptation practices and the determinants of their adoption is still scarce. Thee climate variabilities are perceived and understood in different ways by the populations, especially those in rural areas. Overall, it has been shown that the level of adoption of adaptation strategies to climate variability remains low [13], [14]. It is therefore imperative to explore local knowledge in terms of endogenous adaptation practices to climate variability. It is therefore appropriate to highlight the producers' conception of climatic variations and their manifestation and the techniques used by them to cope with them. This study contributes to the literature on climate change adaptation strategies by examining the practices that farmers themselves have developed to mitigate the adverse effects of climate variability. Thus, this research seeks to answer the following main question: what are the local practices of adaptation to climate variations used by the populations of the Commune of Banikoara and the determinants of their applications? Such investigations will make it possible to propose to political decision-makers and organisations involved in the agricultural sector a list of endogenous practices of adaptation to climatic variations used by the populations for an in-depth study of their effectiveness. The general objective of this study is to understand producers' perceptions of climatic variations and the endogenous adaptation and mitigation practices used in order to make proposals for actions to improve productivity and thus food security for populations in this context of climatic stress.

2- Material and methods

2.1- Theoretical framework

The literature on climate change offers a range of definitions of the concept of adaptation. According to the Intergovernmental Panel on Climate Change (IPCC), adaptation is seen as "the adjustment of natural or human systems in response to current or future climatic stimuli or their effects in order to mitigate harm or explore beneficial opportunities". Adaptation is therefore seen as all the response measures to climate change that producers can adopt in order to mitigate or compensate for the impacts and risks associated with climate change. The literature distinguishes between anticipatory or proactive or "ex-ante" adaptation and reactive or "ex-post" adaptation. For reactive ('ex-post') adaptation is seen as a strategic response deemed appropriate and undertaken, for example, by producers to combat or mitigate the perceived adverse effects of climate change in order to facilitate the improvement of existing livelihoods. It is this adaptation, i.e. reactive or 'ex-post' and particularly endogenous, that was the focus of this research. It was therefore a question of examining all the strategies derived from local knowledge implemented by producers to mitigate climatic uncertainties and reduce their consequences. Indeed, faced with the manifestations of current climate variability obstructing rainfed agriculture in their different agro-ecological zones, the farmers surveyed deliberately adopt practices derived from local knowledge to mitigate the effects of this climate variability. This deliberate adoption of endogenous climate change (CC) adaptation strategies stipulates an individual decision [15] because it varies from one producer to another, and is generally guided by the economic principle of rationality of neoclassical theory [16]. Consequently, the producer adopts the endogenous CC adaptation strategy that will enable him to maximise his utility, i.e. in the current context to drastically reduce the harmful effects of CC and maximise productivity.

Suppose a farmer i seeks to maximise his utility (($U_i U_i$)), his productivity in this case, with a set of endogenous CC adaptation strategies at his disposal (π). The farmer will adopt a given endogenous CC adaptation strategy, such as early sowing, if the expected utility (i.e. the expected productivity gain), represented by $U_1^*(\pi)U_1^*(\pi)$, is higher than if he had not adopted this endogenous strategy, represented by $U_0^*(\pi)U_0^*(\pi)$, i.e. $U_1^*(\pi) > U_0^*(\pi)U_1^*(\pi) > U_0^*(\pi)$. These different expected utilities on which the producer's decision to adopt one endogenous strategy or another is based are not observable, but depend on a set of factors (X_iX_i) which may be socio-economic, demographic or institutional. Therefore, the utility that is unobservable can be represented as follows:

$$U_i^* = X_i\beta + \varepsilon_i, i = 1,2,\dots,NU_i^* = X_i\beta + \varepsilon_i, i = 1,2,\dots,N \quad (1)$$

With $\beta\beta$ the parameter vector to be estimated and $\varepsilon_i\varepsilon_i$ the random error

The literature generally recommends the use of a binary regression for the estimation of equation (1) [17] ; [18] ; [19] ; [20] since the producer's decision to adopt an endogenous strategy (1 = adopted) or not to adopt it (0 = did not adopt) is binary in reality. However, such a method assumes the independence of the different endogenous strategies adopted in the study area. Studies have shown that the adoption of one coping strategy leads to the adoption of another by the same producer [21] ; [22]; [14]. For example, we noted that 37.2% of surveyed producers adopted two endogenous strategies in the 2019-2020 crop year, 28.1% adopted three, and 12.4% adapted four at a time. Producers tend to apply several endogenous CC adaptation strategies at once in order to maximise productivity and, in turn, their income level. As a result, the use of a logit or probit regression model could result in biased estimates of the factors influencing the adoption of these endogenous strategies [23].

A multivariate probit model, which is an extension of the bivariate probit model, and which allows the adoption of one random endogenous CC adaptation strategy to be (totally) independent of others [24] was therefore used. The multivariate probit applies Monte Carlo simulation techniques to simultaneously estimate the multivariate probit regression equation system [25].

Suppose we are dealing with four endogenous CC adaptation strategies that are widely used in the study area. The simultaneous adoptions for the four strategies can be modelled by a system of four binary adoption equations as follows:

$$\begin{cases} Y_1 = 1 \ \ if \ \ U_1^* > U_0^*, Y_1 = 0 \text{ otherwise} \\ Y_2 = 1 \ \ if \ \ U_2^* > U_0^*, Y_2 = 0 \text{ otherwise} \\ Y_3 = 1 \ \ if \ \ U_3^* > U_0^*, Y_3 = 0 \text{ otherwise} \\ Y_4 = 1 \ \ if \ \ U_4^* > U_0^*, Y_4 = 0 \text{ otherwise} \end{cases} \quad (2)$$

In practice, the estimated model with the variables included in the estimates is as follows:

$$\begin{aligned} pratikendo_j = {} & \alpha_1 droutp_i + \alpha_2 distm_i + \alpha_3 sexec_i + \alpha_4 age_i + \alpha_5 ninst_i + \alpha_6 alphabc_i \\ & + \alpha_7 supexp_i + \alpha_8 bienetr_i + \alpha_9 group_i + \alpha_{10} format_i + \alpha_{11} cproduct_i \\ & + \alpha_{12} dvoisin_i + \alpha_{13} vechange_i + \alpha_{14} ccarder_i + \alpha_{15} proj_i + \alpha_{16} imf_i \\ & + \alpha_{17} fop_i + \varepsilon_i \end{aligned} \quad (3)$$

The dependent variable in the above equation is a dichotomous variable that takes the value 1 if farmer i adopts the endogenous CC adaptation strategy j (with j = early sowing, ridge tillage, tree planting, and late sowing) and 0 if he does not.

About half of the respondents reported adopting semi-early tillage as an endogenous CC adaptation strategy, 38% reported adopting ridge tillage, 15% reported planting trees as an adaptation to CC, and about 28% reported adopting late tillage as an endogenous CC adaptation strategy. The descriptive statistics for the independent variables entered in the models are presented in Table 1.

Table 1: Description of the independent variables included in the estimated models

Variables	Description	Modalities	Average
	Study dependent variables		
Semipr	Semi-early	1=Yes 0=No	0.5 (0.51)
Labbil	ridge tillage	1=Yes 0=No	0.38 (0.48)
Plantar	Tree planting	1=Yes 0=No	0.15 (0.36)
Semitar	Late sowing	1=Yes 0=No	0.28 (0.45)
	Independent study variables		
Droutp	Distance of village from main road in kilometer (km)	In kilometer (km)	3 (2.24)
Distm	Distance from village to nearest market where producer sells in kilometer (km)	in kilometer (km)	3.64 (3.63)
Sexec	Sex of producer	1= male, 0=female	0.82 (0.38)
Age	Age of producer	Years	40.73 (12.80)
Ninst	Level of education	0=None, 1=Year 1 pupil, 2= Year 2 pupil, 3= Year 3 pupil, 4= Year 4 pupil, 5= Year pupil, 6= Year 6 pupil, 7= First form class, 8= Second form class, 9= Third form class, 10=	2.27 (3.99)

		Fourth form class, 11=Fifth form class, 12= Lower sixth form class, 13=Upper sixth form class, 14=University	
Alphabc	Literacy	1=Yes 0=No	0.33 (0.47)
Supexp	Total area farmed in 2019-2020 in hectare	Hectares	11.97 (11.68)
Wellbeing	Level of the producer	1 = Very poor; 2= Poor; 3= Average; 4= Rich; 5= Comfortable	2,59 (0,73)
Group	Member of a producer group	1=Yes 0=No	0.72 (0.45)
Format	Received agricultural training	1=Yes 0=No	0.48 (0.50)
Cproduct	Contact with producer(s) who have received agricultural training/experimentation	1=Yes 0=No	0.67 (0.47)
Dvoisin	Discussion with neighbours of agricultural concerns	1=Yes 0=No	0.75 (0.44)
Vechange	Benefited from exchange visits and experiences	1=Yes 0=No	0.3 (0.46)
Ccarder	Contact with CARDER/DDAEP	1=Yes 0=No	0.167 (0.37)

Cproject	Contact with project/programme	1=Yes 0=No	0.32 (0.47)
Imf	Contact with microfinance institutions	1=Yes 0=No	0.43 (0.49)
Fop	Contact with PO umbrella organisations	1=Yes 0=No	0.32 (0.46)

Standard deviation in brackets

2.2- Study area, sampling and data

The present study was conducted in the commune of Banikoara in northern Benin, which has a Sudano-Sahelian climate characterised by an increasingly long dry season from November to April/May and an increasingly short rainy season from May/June to October. The far northern region is characterised by an average annual rainfall of about 700 mm, while in the mountainous regions it is around 1400 mm. Compared to the south, the north of Benin has relatively high climate change risks. The cotton zone is one of the regions most exposed to strong climatic variability [26]. The commune and the survey villages were selected on the basis of the weight of the commune's agricultural production in the area and that of the respective villages in the commune. Based on existing statistics, the commune of Banikoara was selected. This choice was confirmed by officials of the Departmental Directorate of Agriculture, Livestock and Fisheries (DDAEP) (formerly the Regional Action Centre for Rural Development - CARDER). The choice of survey villages was made with the help of these DDAEP officials. Four villages were selected, which are those with high agricultural production.

In each village, an exhaustive list of agricultural producers was drawn up with the help of resource persons. The producers were then numbered from 1 to n, taking into account the order of registration. Thirty producers were selected at random from each village, for a total of 120 agricultural producers surveyed during the data collection. Quantitative data were collected using a structured questionnaire. The questions focused on the perception of climate variability on the one hand and indicators of perceived climate change on the other. The questions relating to the perception of climate variability were inspired by the Expert Team on Climate Change Detection Monitoring and Indices (ETCCDMI) [27]. The questions on indicators of perceived climate change were formulated based on the frameworks for analysing farmers' perceptions of climate change developed by [28], [29] and [30]. The study questionnaire also made it possible to examine the perception of the consequences of climate variability, the endogenous practices implemented and the influence of perceptions of problems induced by climate variability on the decision on the types of adaptation strategies used.

In addition to the quantitative approach, a qualitative approach was adopted and semi-structured interviews were conducted to supplement the quantitative data collected using the structured questionnaire. To this end, eight interviews were undertaken with leaders of producer associations and village chiefs.

3- **Results and discussion**

3.1- Descriptive statistics of socio-economic, demographic and institutional variables

The population of agricultural producers surveyed is predominantly made up of men (81.70% against 18.30% of women) (Table 2). The average age of the farm managers is 41 years. More than 3 out of 5 producers surveyed are illiterate (66.70%). Similarly, about 67.50% of these respondents have not received any formal education. Only 17.6% have primary education, about 8.3% have lower secondary education, and 5.8% of the respondents stated that they had a formal education between the third and final year. Agriculture is the main economic activity for almost all the respondents (95%); the remaining 5% have trade (1.7%) or crafts (0.8%) as their main occupation. On average, producers have 16 years of experience in agricultural production and sow an average of 12 ha annually. Almost half of the respondents do not engage in any secondary activity. Trade, handicrafts and processing are secondary activities practised by 20.90%, 9.20% and 5% of the producers surveyed respectively.

The agricultural producers surveyed are members of many producer networks and are very active in them. For example, about three quarters of the producers (71.70%) are members of a producers' association, about 66.70% of them indicated that they are in contact with one or more producers who have benefited from agricultural training, and almost 74.20% stated that they have discussions with their neighbours about agricultural concerns. In addition, more than 2 out of 5 producers surveyed (i.e. 48.30%) had already benefited from (or participated in) a training course on agricultural technologies, while about 30% had already benefited at least once from visits to exchange experiences on agricultural technologies thanks to the producer organisation umbrella organisations, with which 31.70% said they were in frequent contact. A small number of producers (16.70%) have contact with DDAEP (ex. CARDER) extension agents, 1.70% of them reported having contact with local non-governmental organisations, while almost 43% of producers reported having had at least one contact with a microfinance institution.

Table 2: Socio-economic characteristics of the producers interviewed

		Sample
Sex of producer	Male	81,70%
	Female	18,30%
Age of producer		40,73 (12,01)
Education level	None	67,50%
	Primary	17,60%
	Lower secondary	8,30%

	Upper secondary	5,80%
	Higher education	0,80%
Literate	No	66,70%
	Reading abilities	15,00%
	Writing abilities	1,70%
	Reading and writing abilities	16,60%
Number of years of experience in agricultural production		16,44 (11,15)
Total available area in ha		12,86 (11,83)
Workable area in ha		11,97 (11,68)
Secondary activity of the producer	Farming	3,30%
	Animal husbandry	4,20%
	Processing	5,00%
	Trade	20,90%
	Handicraft	9,20%
	Salary (healer, fetishist, etc.)	5,00%
	Household	3,30%
	Motorbike	3,30%
	Inactive (no activity)	45,80%
Member of a producers' group		71,70%
Contact with producer(s) who have received agricultural training/experimentation		66,70%
Do you discuss agricultural concerns with your neighbours		74,20%
Have benefited from or participated in a training/experimental farm		48,30%
Have you benefited from experience-sharing visits?		30,00%
Contact with	DDAEP (ex CARDER)	16,70%

	Local NGOs	1,70%
	MFIS	42,50%
	PO umbrella organisation	31,70%

3.2- Perception of climate variability

Almost all the farmers surveyed (93.3%) reported that they are currently experiencing high levels of climate variability compared to what has occurred in the past. Three categories of indicators were cited as reasons for this observed climate variability: indicators of rainfall changes, temperatures, and winds and dust mists (Table 2). Referring to what they consider to be normal times in the past when rainfall was regular, more frequent and longer, the farmers interviewed believe that the rainy seasons have undergone serious disruption. Indeed, 90% of the producers interviewed noted a reduction in the number of rainy days and 89.20% a decrease in annual rainfall, and 82.50% noted that the rains are more irregular than ever (Figure 1). For 85.80% of the farmers, the rainy seasons are increasingly delayed and 87.5% of them also note that the early cessation of rains is increasingly frequent. According to the producers surveyed, "*we no longer know when the rains will start so that we can get ready for the season. Sometimes you are already preparing your fields, but if it is not the volume of rain you need to sow that is insufficient, it may be the start of the rains that you are waiting for to sow";* this reflects the late arrival of the rains. To illustrate the earlier end of the rainy season, the same respondents stated that: "*If we used to be able to predict exactly when the rainy season will end, today it is difficult. Sometimes we still wait for a couple of rains before the end of the seasons and to allow our crops to complete their cycle, but they don't come anymore and we are surprised that we are already propelled into the dry season early*". In recent years, producers have generally noted major changes in the seasons, in particular the rainy seasons (63.30% of respondents).

As for indicators of temperature changes, the investigations revealed that the perception of producers is that the days and even the nights of the dry seasons are increasingly hot (99.10% of producers). Such hot spells imply an overall increase in daily temperatures, which is not without negative impacts on agricultural production activities. About 77.50% of the producers surveyed reported the appearance of increasingly violent high winds. For all the producers interviewed, these different climatic variabilities directly affect and hinder the development of Benin's agricultural sector, which, as it is in most developing countries, is highly dependent on rainfall. These producers noted that yields have become more random than ever, with far more yield losses than gains. However, the producers indicated the existence of several strategies, both endogenous and modern, that allow them to reduce their vulnerability to climate variability in one way or another. The present research focused on the endogenous strategies used and the factors determining their adoption.

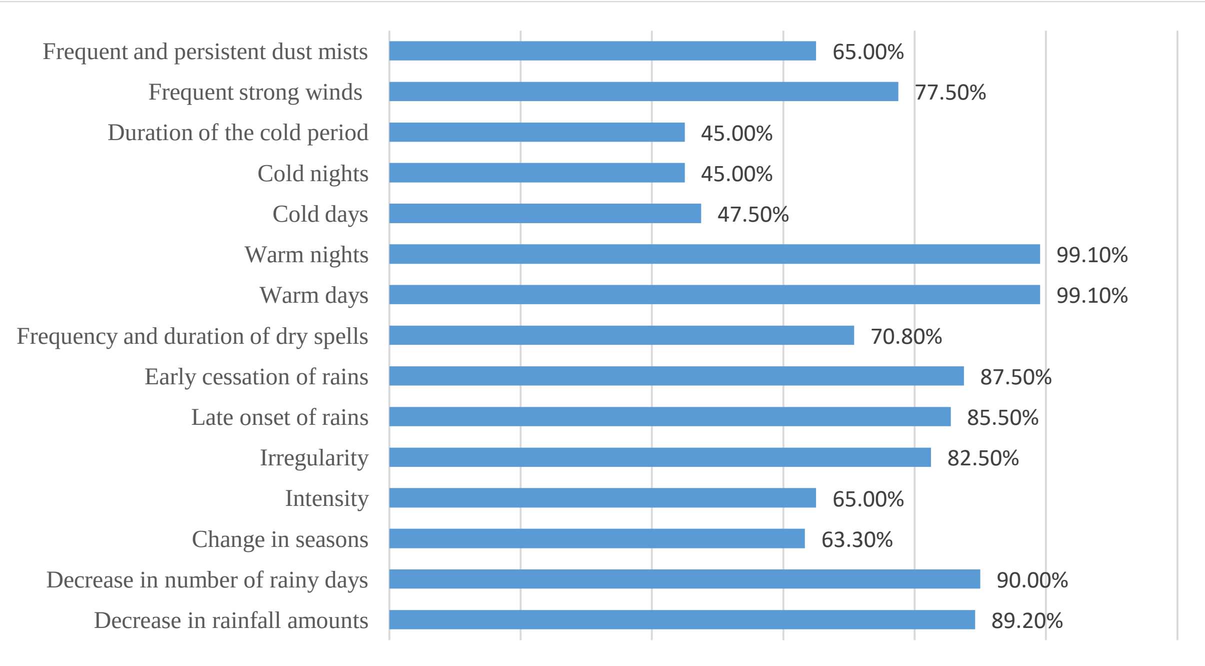

Figure 1: Climate change perception indicators in the North Benin region

3.3- Endogenous practices of adaptation to variability

The agricultural sector, which remains the main source of income for the population of the study area, like the country in general, suffers the adverse effects of climate variability. This justifies the strategies, both endogenous and introduced, developed by producers to mitigate these adverse effects. The main practices, considered endogenous by the producers surveyed, are presented in Table 3. Half of the respondents stated that they had practised early sowing in order to cope with the consequences of the variability of water resources in relation to the climate. About 38.30% of the respondents said that they practiced ridge ploughing, 28.30% late sowing, while 20.80% of the farmers surveyed said that they had used cow bursaries and or stocking of animals on their fields in order to reduce the consequences of climatic variability and thereby improve their agricultural productivity. Some 16.70% of the respondents said that they resorted to crop residue management, while 15% resorted to diversification of income-generating activities and agroforestry by planting trees, respectively, to mitigate the adverse effects of CC.

Table 3 : Endogenous climate change adaptation practices

	Adoption
Early sowing	50,00%
Ridge ploughing	38,30%
Late sowing	28,30%
Cow bursary / animal yarding	20,80%
Crop residue management	16,70%
Diversification of income generating activities	15,00%
Tree planting	15,00%
Increasing the area planted	9,20%
Abandonment of certain crops	8,30%

Crop association	8,30%
Flat ploughing	4,20%
Deep ploughing	2,50%
Use of resistant local varieties	1,70%
Crop rotation	1,70%
Use of organic fertilisers	0,80%

3.4- Correlations between different endogenous climate change adaptation practices

The correlation results between the different endogenous CC adaptation practices from the multivariate probit regression are presented in Table 4. The likelihood ratio test for possible overall correlation of the error terms of the different models, chi2 (6) = 42.75, $p < 0.000$, is significantly different from zero at the 1% level. That makes it possible to reject the null hypothesis that the error terms of the four models of adoption of endogenous CC adaptation practices are not correlated. The decision to adopt an endogenous CC adaptation practice therefore depends significantly on the decision to adopt another practice and vice versa. Our results suggest that the use of a multivariate probit model to estimate the determinants of the adoption of endogenous CC adaptation practices is appropriate.

The correlations between the endogenous CC adaptation practices 'early sowing' and 'ridge ploughing' on the one hand (rho = 0.46, $p < 0.01$), 'early sowing' and 'late sowing' (rho = 0.93, $p < 0.01$), and 'late sowing' and 'ridge ploughing' on the other hand (rho = 0.58, $p < 0.01$) are all positive and significantly different from zero. These results suggest that farmers who adopt 'early seeding' as an endogenous CC adaptation strategy also adopt either 'ridge tillage' or 'late seeding' as a complement, and that those who adopt 'late seeding' as an endogenous CC adaptation strategy necessarily adopt 'ridge tillage' as a complement. These results show that farmers use different combinations of adaptation strategies to CC, even if they are endogenous, in order to drastically mitigate the negative consequences of these climatic variabilities. Our results are consistent with previous empirical research (e.g. [31], [14]).

Table 4 : Correlation matrix from the multivariate probit model between different endogenous CC adaptation practices

	Early sowing	Ridge tillage	Agroforestry	Late sowing
Early sowing		0,46 (0,15)***	0,12 (0,15)	0,93 (0,05)***
Ridge tillage			0,14(0,17)	0,58 (0,16)***
Agroforestry				0,13 (0,17)
Likelihood-ratio test	chi2(6) (rho21 = rho31 = rho41 = rho32 = rho42 = rho43 = 0) : = 42,75***			

Standard error in brackets

*** represent significance at the 1% level

3.5- Determinants of the adoption of endogenous climate change adaptation strategies

The estimation results of the multivariate probit model exploring the determinants of the adoption of endogenous CC adaptation strategies are presented in Table 5. The main factors that explain the adoption of the main endogenous CC coping strategies are the distance of the village from the main road, the distance between the village and the nearest market where the producer sells his products, the gender of the producer, his age, his literacy level, his level of well-being, contact with producers who have being through one training or agricultural experiment at least, exchanges of agricultural concerns with neighbours, and participation in exchange and experience visits. The distance of the producer's village of residence from the main road exclusively influences the practice of ridge ploughing as an endogenous CC adaptation strategy. This influence is positive and significant ($\alpha = 0.38$, $p < 0.05$). Thus, farmers who live in villages (very) far from the main road tend to adopt ridge ploughing as an endogenous CC adaptation strategy. Such results could be explained by the fact that farmers living in areas far from the main road have less contact with extension services (negative, albeit non-significant, correlations between adoption of the ridge ploughing strategy and contact with national extension service agents like CARDER/DDAEP, projects/programmes). Indeed, previous empirical studies have shown that farmers who have access to extension have a high probability of adopting agricultural innovations (improved CC adaptation strategies in our case) compared to their counterparts who do not have access (e.g. [33] ; [22]; [14] as extension serves as a conduit for the transmission and dissemination of useful information about innovations, which is likely to affect producers' decision [14].

The negative influence of the distance of the producer's village of residence from the nearest market where the producer sells his products on the adoption of early sowing ($\alpha = -0.15$, $p < 0.10$) and ridge tillage ($\alpha = -0.34$, $p < 0.01$) as CC adaptation strategies indicates that, all other things being equal, many producers living not far from the market do not adopt the so-called endogenous CC adaptation practices. These results indicate that farmers with access to markets and therefore to market information on their products would certainly prefer to adopt improved strategies that would allow them to respond to market demand, such as improved crop varieties preferred by consumers and that are also resistant to climatic variability.

The gender of the farmer had a positive and significant influence on the adoption of early planting practices ($\alpha = 0.53$, $p < 0.10$) and agroforestry ($\alpha = 0.77$, $p < 0.10$). These results indicate that, in order to cope with the adverse effects of climate change, male farmers practice early seeding and agroforestry compared to their female counterparts. These results are in contradiction with those of [14] who concluded that male maize farmers prefer to adopt improved maize varieties and practice late planting unlike women. The analyses also demonstrated the positive and significant influence of producer age on the probability of adopting late planting as an endogenous CC adaptation strategy (α = 0.02, $p < 0.01$). Such a positive and significant influence indicates that the probability of adopting the strategy 'late seeding' increases along with the age of the producer. In other words, the older the farmer, the greater the probability that he will practice late seeding to protect himself from the consequences of climatic variability. This result could be justified by the fact that older producers would prefer to wait for the rains to set in before starting any sowing, as if to remain in phase with the period before climate change, when rainfall was abundant and regular. Indeed, the influence of the variable "literacy level" of the farmer has a negative and significant influence on the practice of late sowing as a strategy (α = -0.76 $p < 0.05$), thus indicating that farmers who are at least literate might have understood that they could no longer practice the late sowing strategy without a deep knowledge of climatic variability.

Agroforestry appears to be practiced by poor farmers (α = -0.72, $p < 0.01$) while the better-offs prefer to practice late seeding as an adaptation strategy (α = 0.58, $p < 0.01$). The practice of agroforestry by poor farmers could be justified by the benefits that such a practice could bring. Indeed, agroforestry would not only mitigate the consequences of climatic variability, improve agricultural productivity, but also provide marketable wood.

Contact with farmers who have received at least one training course or agricultural experimentation tends to encourage the adoption of ridge tillage (α = 1.16, $p < 0.01$) and late sowing (α = 0.98, p < 0, 05) while exchanges with neighbours of agricultural concerns did not favour early seeding (α = -0.72, $p < 0.10$) as did participation in exchange and experience visits which negatively influenced late seeding practice (α = -0.84, $p < 0.05$). Such results show that producers' actor networks have mixed influences on the adoption of endogenous CC adaptation practices.

Table 5 : Estimation results of the multivariate probit model showing factors influencing the adoption of endogenous climate change adaptation practices

	Early sowing		Ridge tillage		Agroforestry (planting of tree)		Late sowing	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Distance of the village from the main road in km	0.08	0.09	0.38**	0.16	-0.11	0.13		
Distance from the village to the nearest market where the producer sells his products in km	-0.15*	0.08	-0.34***	0.12	-0.06	0.08		
Gender of producer	0.53*	0.28	0.39	0.41	0.67*	0.41		
Age of producer	-0.01	0.01	0.01	0.01	-0.01	0.01	0.02***	0.007
Level of education	0.03	0.03	0.03	0.04	0.01	0.03	0.02	0.03
Literacy	0.01	0.29	0.28	0.29	-0.22	0.32	-0.76**	0.32
Total area farmed in 2019-2020 in ha	-0.02	0.01	-0.01	0.01	0.001	0.02	-0.01	0.009
Producer's level of well-being	0.36	0.22	-0.21	0.21	-0.72***	0.26	0.58***	0.19
Member of a producer group	-0.292	0.39	0.12	0.44	-0.30	0.41	-0.42	0.35
Has received agricultural training	-0.58	0.37	-0.14	0.39	0.29	0.50		
contact with producer(s) who have benefited from	0.49	0.40	1.16***	0.44	-0.44	0.47	0.98**	0.41

agricultural training/experimentation								
Discussed agricultural concerns with neighbours	-0.72*	0.37	-0.35	0.41	-0.041	0.52	-0.74	0.38
Benefited from exchange visits and experiences	-0.18	0.43	-0.04	0.42	0.51	0.46	-0.84**	0.38
Contact with CARDER/DDAEP	-0.13	0.45	-0.63	0.54	-0.62	0.64	-0.28	0.32
Contact with projects/programmes	0.44	0.39	-0.02	0.44	0.49	0.45	0.39	0.42
Contact with microfinance institutions	0.06	0.30	-0.37	0.30	0.13	0.30	-0.57	0.37
Contact with PO umbrella organisations	0.29	0.29	-0.14	0.38	-0.11	0.46		
Constant	-0.12	0.74	-0.63	0.83	1.22	0.96	-2.13***	0.62
Number of observations	120							
Likelihood-ratio test	Wald chi2(63) = 257.59***							

Coef = Coefficients; Err. Std -= Standard error

*, **, *** represent significance at the 10%, 5% and 1% level respectively

4- Conclusion and implications

This study was initiated to contribute to the knowledge of the adaptation strategies developed by the producers and their determinants. It should be noted that the manifestations of climate variability are a reality in the study area and most of the producers surveyed are aware of them. These observed changes are reflected in a general increase in temperature, a decrease in rainfall, the appearance of strong winds, and the early cessation of rainfall events. The consequence of these variabilities is a reduction in crop yields and, as a result, in producers' income. The latter implement several strategies to reduce the impacts of these climatic disturbances on their activity. These include shifting the sowing date (early or late), ridge plowing, organic fertilizer (cow dung, crop residue) and agroforestry. Farmers generally use a combination of strategies to minimize the risks of climatic deterioration and the decision to choose strategies is motivated by a number of factors. Among others, these determinants include the gender of the producer, his age, his literacy level, his welfare level, the distance from the village to the main road, the distance from the village to the nearest market where the producer sells his or her products, contact with producers who have benefited from at least one training or agricultural experiment, the exchanges with neighbors of agricultural concerns and the participation in exchange and experience visits. It will be interesting to analyze each means of adaptation and to look for those that are the most effective and the most adapted to the realities of each category of producers in the study area.

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