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Impact of climate change beliefs on farm households' adaptation behaviours: the case of Ivory Coast.

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Abstract

This paper examines how climate beliefs influence the climate change adaptation decisions of Ivorian farmers. Two regions (Bouaké and Bonoua) were selected for data collection and 658 households were surveyed according to the level of exposure to climate shocks and the type of farming practiced. Using a multivariate probit model, we analyze the impact of climate beliefs on decisions to implement an adaptation strategy. Our results indicate that the impact of beliefs on adaptation decisions differs according to the region considered. In Bouaké, religious and traditional beliefs, and subjective predictions about temperature and rainfall trends determine farmers' adaptation decisions. In the Bonoua locality, however, concerns about climate change and confidence in scientific studies on the worsening of CC determine farmers' adaptation decisions. Based on our results, we develop policy guidelines.

Keywords: Climate change, beliefs, multivariate Probit, farm households

Code JEL : Q54, C13, D81

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Introduction

Studies are presenting more and stronger evidence of the effects of climate change on natural systems and human activities. Climate change (CC) is already affecting all regions of the planet and human responsibility is unequivocal. According to the 6th IPCC report (2021), by 2030 the global temperature is expected to reach 1.5 °C. In developing countries, particularly those in sub-Saharan Africa, the IPCC suggests an increase in the warming trend above the global average and variability in precipitation patterns. The most direct effect of global warming is its negative impact on agricultural productivity and farm income.

The agricultural sector on which most of the economies of sub-Saharan countries depend is one of the most affected sectors because it is highly sensitive to climate. Agriculture represents an important source of subsistence for a large majority of the sub-Saharan population and the main source of income for the rural population. The agricultural sector supports between 70 and 80% of employment and contributes between 15% and 50% of gross domestic product (GDP) and at least 40% of exports (OECD/FAO,2016). In Chad, for example, agriculture contributes over 50% of the GDP.

Although sub-Saharan countries are the most vulnerable to CC, the effort to invest in the adaptation by farm households is relatively low compared to other regions of the globe (Serdeczny et al., 2017). While farmers have so far been able to survive under a wide range of climatic conditions, it is undeniable that under constant production technology, climatic factors and climate extremes coupled with limited access to resources can have a strong impact on livelihood conditions and increase food insecurity. To protect livelihoods from the adverse effects of climate change and ensure food security, farmers must adopt adaptation strategies to improve their well-being.

Adaptation is a behavioral response to the immediate challenge posed by climate change. Adaptation is the set of actions that can be implemented to limit the negative effects of climate change on farmers' well-being or potentially exploit its beneficial effects. Specifically, an adaptation strategy aims to reduce the impact of a variation in a climatic parameter on agricultural yields or the productivity of an input such as soil quality (agricultural models) or the value of production (Ricardian studies). In this sense, adaptation strategies are privileged tools to reduce vulnerability.

In the face of climate change, several adaptation strategies are generally identified in the literature to reduce the agricultural sector's vulnerability. These include 1) the use of drought-resistant crop varieties 2) the use of pest and disease-tolerant varieties 3) the rearrangement of the cropping calendar 4) the diversification of crops 5) irrigation and 6) investment in soil and water conservation technologies. Despite the well-documented benefits of these practices in reducing exposure to climate risks, their adoption by farmers remains relatively limited or absent. Certainly, the assumption that implementing one or more of these adaptation strategies requires minimal capital and labor expenditures could be a barrier to adopting a strategy (the adoption of modern technologies such as high-yielding seed varieties or fertilizer for example), as illustrated in the literature. Nonetheless, there are large gaps in the adaptive capacity literature as to why the level of engagement of sub-Saharan farmers to manage climate-related risks remains low, even when financial or institutional resources are not constrained (Onyekuru and Marchant 2017, Bryan et al. 2013).

The motivations that drive farmers to change their farming systems, or conversely to not act under real-world conditions, are more complex and have yet to be revealed. Recent pioneering work increasingly shows that many beliefs (cultural, religious, political, etc.) about climate that prevail in many farming communities in Africa influence their understanding of the causes of climate change and affect their capacity and decision to adapt (Azong,2020, Price et al, 2014). Adaptation decisions are influenced by multiple factors, including how farmers perceive and believe about CC.

In general, in rural Africa, individual perceptions of climate change are shaped by patterns of shared values and traditional beliefs defined as intergenerationally transmitted beliefs, and cultural identities (Davies et al. 2019). In addition, certain value or belief patterns regarding environmental change can lead to "behavioral biases" that legitimize climate change-related risk perceptions and individuals' adaptive responses even when they are mistaken. For example, the symbolic meaning of certain agricultural practices may prevent some farmers from adopting new production techniques. In this regard, Bationo and Mokwunye (1987) reveal that in the Sahelian region of Niger and Burkina Faso, fertilizers are too rarely applied to traditional food crops such as millet and sorghum. Some farmers in northern Namibia rarely use weather information because they consider that rainfall and crop productivity cannot be predicted but depend solely on the will of God (Davies et al,2019). This observation suggests that individual perceptions of climate change are influenced more by individual experiences and traditional values than by scientific considerations (Dessai et al. 2004).

Furthermore, decision-making in favor of climate change adaptation is strongly correlated with the strength of belief in local climate change impacts and the strength of belief in the experience (of impacts) of climate change (Blennow et al,2020).

Beliefs in CCs appear to be a key to understanding the success of adaptation and mitigation policies. Cologna and Siegrist (2020) show that policy effectiveness depends on public trust in experts. In addition, climate skepticism expressed by political elites can affect climate actions at the population level (Hahnel et al., 2020). In particular, the success of agricultural climate policies depends to a large extent on farmers' awareness of climate change, including their knowledge and beliefs about climate change and how it will affect them (Patt and Schröter, 2008; Carlton et al., 2016). Climate beliefs reflect many aspects of what people think about climate change, such as the extent to which people believe that climate change is caused by human actions rather than natural causes and that the impacts of climate change will be primarily negative rather than positive (Ding et al. 2011; Weber 2016).

The question of the role of beliefs in farmers' adaptation decisions at the individual level in Africa remains relatively unaddressed in the empirical literature. To ensure the design of effective policies that minimize unintended consequences, it is important to understand the underlying influences of farmers' desired policy responses at the micro level, in particular, how farmers' beliefs lead to change (Wheeler et al., 2013) in their practice. The first contribution of this article is to understand precisely how beliefs impact farmers' adaptation decisions.

This paper investigates the determinants of farmers' adaptation decisions in two different localities in Ivory Coast, namely Bouaké and Bonoua. The innovative aspect of our study is partly related to the introduction of non-measurable information in the modeling of climate risk management. More precisely, we introduce the determinants of adaptation strategies, variables reflecting the beliefs of farmers on climate change such as the anthropogenic origin of climate change or its manifestations and impacts (increased temperature / decreased rainfall ...), concerns, and their beliefs about scientific studies on the aggravation of CC. We propose to distinguish seven types of beliefs that are relevant. The full description of these variables is given in section 4.2. To our knowledge, this is the first empirical study to investigate the determinants of adaptation options at the farm level in the Ivory Coast by incorporating beliefs.

Using the results of the multivariate probit model, we simulate the impact of a set of variables to measure their magnitude on adaptation decisions. The simulated impacts of these variables on the probability of adoption show that the impact of 'religious beliefs' was about 64% and 47.15 respectively for the introduction of heat-resistant varieties (HRV) and the rearrangement of the cropping calendar (RCC). In the Bonoua model, the impact of 'concerns' was 53.28% and 49.49% for the implementation of RCC and rotation (R) respectively. The study suggests that better knowledge and consideration of farmers' local beliefs offer better ways to build support for farmers' local adaptation measures and lead to more effective use and adoption of adaptation measures in the agricultural sector.

Section 2 provides the country context. Section 3 describes the data collection effort and the survey instrument. Section 4 presents the econometric methodology. Section 5 discusses the results and Section 6 concludes with policy recommendations.

2-Country context

In general, the West African zone is particularly marked by very high intra-annual and inter-annual variability. According to the UNDP report (2013), from 1960 to 2010, Ivory Coast experienced an increase in temperature in most places with an average rate of 1.6°C, i.e. an increase of 3.2°C/century. Rainfall is subject to the high variability and has a downward trend. Crop productivity is therefore very vulnerable to seasonal variations and rainfall patterns. The economic structure of the Ivory Coast is sensitive to CC. Indeed, with more than 20% of the GDP and 66% of the active population, agriculture is a source of income for two-thirds of the 50.3% of the rural population (General population and housing census (GPHC), 2014). Despite the economic performance observed in recent years (an average annual growth rate of 7.5%), the poverty rate is estimated at more than 45%, of which 60.4% is in rural areas (EHCVM 2015). The important role of agriculture in the economy belies the fact that the agricultural sector faces several challenges. The agricultural sector is still dominated by traditional and rudimentary practices. In recent years, there has been a decline in the yields of most food and cash crops (World Bank, 2019). Unlike cash crops, the food sector has not been structured at the initiative of the state. Production and marketing channels remain traditional and face many obstacles such as the high cost of local transport due to deteriorating roads, and the volatility of the selling price on end markets for products such as yam and cassava or plantain (Ducroquet et al, 2017), making the sector increasingly vulnerable.

According to a ranking based on a specific adaptation preparedness index conducted by ND-GAINS, Ivory Coast is ranked 160th out of 192 countries, highlighting its low adaptive capacity, especially in terms of individual adaptation, and suggesting that priority should be given to actions at the farm household level. In the context of rapidly changing weather conditions and the severity of the impact on poor subsistence farmers, there is an urgent need to document and address the microeconomic determinants of adaptation decisions.

3- Data collection

The data used in this study come from a field survey that we conducted in the Ivory Coast in 2019 over three months. The overall objective of this survey was to collect information to analyze and explain the determinants of adaptive behavior of agricultural households in the face of climate risks. More specifically, the study sought to determine the impact of climate beliefs on farmers' adaptation decisions in the face of climate change. The assessment of farmers' beliefs specifically about the existence and causes of climate change was first introduced in an Iowa agricultural survey by Arbuckle et al.,(2013a). Our study was conducted in rural areas of central and eastern Ivory Coast and involved yam and cassava farmers in the departments of Bouaké and Bonoua. These two departments were chosen because they are subject to different climatic regimes. Bouaké is characterized by a humid tropical climate, which is the transition between the subtropical and the subequatorial climate. The rainfall regime is bimodal, with daily temperatures ranging from 27°C to 35°C. The average annual rainfall is between 1000 mm and 1200 mm or even 800 mm and 1000 mm (Koné et al 2009). The climatic extremes common in the Bouaké area are extreme temperatures and regular exposure to droughts. Crop failures are common from one year to the next so many households are chronically food insecure. The Bonoua region, on the other hand, is subject to a transitional equatorial regime, with two rainy seasons and two dry seasons (AKE, 2010). The area is rather temperate, rainfall is abundant, the average annual value is estimated at 1710 mm (AKE, 2010) and the temperature generally varies from 23°C to 32°C throughout the year. Climatic extremes are most often related to flooding. Another difference noted is the type of agriculture practiced. Farming households in Bouaké practice subsistence farming and those in Bonoua practice cash crop farming.

We obtained 658 questionnaires, 403 of which were from the locality of Bouaké and 255 from the locality of Bonoua. In each locality, six villages were selected. The selection of villages was based on an unequal probability sampling method. This method ensures that large villages (in terms of the total number of producers) are selected. In a sample village, a household is a qualified respondent if it resides in the village and is engaged in yam or cassava production activities, and the selection of households was random. To avoid biased responses or resistance from respondents, the village leaders were informed. A meeting was held with each of them in the selected villages before the survey, and the latter informed the villagers. Face-to-face interviews with households were preferred as they provide the maximum degree of communication and interaction between the interviewer and the respondent. In addition, face-to-face interviews are often associated with good data quality and are considered by many researchers to be the preferred mode of data collection for most survey topics (Neumann 2012).

Due to budgetary constraints, we opted for a paper questionnaire rather than an electronic one. The questionnaire was administered in French and lasted less than 20 minutes, but could be longer depending on the respondent's level of understanding. However, interviewers were free to use the local language when necessary to facilitate communication with the respondent. If the interviewer did not know any of the languages spoken by the farmer, he/she was also given the option of seeking the assistance of a third-party translator. Respondents were informed that the study was designed as part of a thesis to better understand their adaptive behavior and to develop public policies better suited to their needs. The question formats were both closed and open-ended, depending on the purpose of the questions. The first part of the questionnaire was devoted to general questions about the farmer's characteristics, activities, size of the farmer's farm, etc. The second part was devoted to information about the farmer's activities and the size of the farm. The second part was devoted to specific information on climate beliefs. Questions were also asked about the perception of climate variability and change, adaptation measures implemented to respond to the risks they face, and many other issues, some of which have not been mentioned and considered in this paper.

4-Analytical framework

4.1 Econometric specification

To analyze the data, we use a variety of analytical methods ranging from simple to advanced econometric tools. To analyze farmers' barriers to adaptation, we will use the multivariate probit model. The analysis of adaptation decisions can be done separately for each decision, one after the other. We wonder if we can use the interdependence that may exist between the various adaptation methods to enrich our analysis. For example, an agricultural household that believes in the phenomenon of climate change and the predictions made by experts could have a high probability of adopting several adaptation measures simultaneously. The multivariate probit (MVP) model simultaneously estimates the influence of the set of independent variables on each of the different adaptation measures while allowing unobserved and unmeasured factors (error terms) to be correlated (Lin et al., 2005; Green, 2003; Golob and Regan, 2002). Moreover, unlike the Logit and Probit multinomial models, it allows us to relax the restrictive hypothesis according to which utility maximization requires a single choice and thus to study in greater detail the competitive dynamics within a category (search for variety, complementarity, substitutability).

Climate risk management aims to control the possible negative consequences of uncertainty that may arise from the unpredictability of the weather. Risk management activities in general do not seek to increase profits per se (Moschini and Hennessy, 2001). Following the example of Mulwa et al. (2017), we consider that the utility of the farmer is not necessarily defined by higher yields. In the context of adaptation, the satisfaction derived from the implementation of an adaptation strategy could be the stability of yields, and the implicit decrease in risk. A risk-averse farmer maximizes utility by choosing an adaptation strategy if the benefits of adaptation (risk reduction) minus the cost of adaptation are higher than the benefits realized without adaptation (Mulwa et al, 2017). The multivariate probit model allows us to simultaneously estimate the five adaptation strategies. We follow Lin et al (2005) in formulating the multivariate model which includes five binary dependent variables $y_1, \ldots, y_5$

$$y_i = 1 \ \ if \ x'\beta_i + \varepsilon_i > 0 \qquad (1)$$
$$and \ y_i = 0 \ \ if \ x'\beta_i + \varepsilon_i \leq 0, i = 1,2, \ldots 5$$

Where x is a matrix of explanatory variables; $\beta_1 \ \beta_2 \ \beta_3 \ \beta_4 \ \beta_5$ are conformal parameter vectors and $\varepsilon_1 \ \varepsilon_2 \ \varepsilon_3 \ \varepsilon_4 \ \ et \ \varepsilon_5$ are random errors distributed as a multivariate normal distribution with zero mean, unit variance and a matrix of $n \times n$ correlations. The variance-covariance matrix

V, such that the variance is normalized to unity[2] . The variance-covariance matrix V is given by :

$$V = \begin{bmatrix} 1 & \rho_{12} & \rho_{13} & \rho_{14} & \rho_{15} \\ \rho_{21} & 1 & \rho_{23} & \rho_{24} & \rho_{25} \\ \rho_{31} & \rho_{32} & 1 & \rho_{34} & \rho_{35} \\ \rho_{41} & \rho_{42} & \rho_{43} & 1 & \rho_{45} \\ \rho_{51} & \rho_{52} & \rho_{53} & \rho_{54} & 1 \end{bmatrix}$$

Of particular interest are the off-diagonal elements of the covariance matrix, ρ_{kj} which represents the unobserved correlation between the stochastic component of the *kth* and *Jth* adaptation strategy. It therefore measures how the unobserved factors influence the decisions to implement each of the 5 adaptation strategies. Moreover, due to the symmetry of the covariances, we necessarily have $\rho_{kj} = \rho_{kj}$

4.2 Description of variables

Belief variables: This study incorporated explanatory variables based on the review of existing literature on climate change adoption and adaptation studies. The novelty of this study is that it introduces variables related to people's beliefs about the climate change phenomenon. These beliefs are subjective variables that express farmers' opinions on CC. We have selected seven variables and they are all dummy variables (see Table 1 in the Appendix). The first one is related to the belief in the existence of climate change. The second is related to human responsibility for the occurrence of CC. According to the literature, the more an individual believes that CC is natural, the less he or she will be concerned and the less he or she will implement strategies. Thus, the belief that human activities do not affect the occurrence of CC reduces the probability of implementing adaptation practices. The expected sign of this variable is therefore positive. The third is related to the subjective estimation of the expected temperature evolution. Believing that rising temperatures will affect agricultural activities increases the probability of implementing a strategy. The expected sign of this variable is therefore positive. The fourth variable is related to the subjective estimation of the expected evolution of precipitation. Believing that a decrease in rainfall will affect the farm increases the probability of implementing an adaptation strategy. The fifth is related to the belief in scientific studies on worsening climate change. Intuitively, belief in scientific studies

[2] In the standard Probit MV model, estimated with cross-sectional data, each of the error variances is normalized to unity - this is necessary for identification. (Cappellari and Jenkins, 2003)

increases the probability that farmers will implement an adaptation strategy. The sixth variable concerns the potential current and future impacts of CC. Intuitively, the more concerned they are, the more likely they are to implement strategies. However, studies in occupational psychology show that high levels of stress lead to mixed performance within a company. The more stressed individuals are, the more likely they are to make changes or maintain the status quo (Mann, 1992). In our study, the expected sign of this variable is therefore positive. Finally, the last variable concerns religious and traditional beliefs[3]. Some studies on adoption indicate that religion is an important cultural factor that can affect farmers' adaptive behavior toward CC. Religion can be seen as capital. As a social resource, households can use it as a network to pursue livelihoods (Kollmair and Gamper, 2002). However, the results remain mixed on adaptation decisions In the context of CC, some farmers perceive CC as a divine event over which they have no control Nassourou et al,2018; Codjia (2009), in this case, it affects negatively the probability of adopting adaptive measures. In our study, the expected sign of this variable is negative.

The other independent variables considered are listed in Table 2. In total, this study has 18 explanatory variables. In the empirical model, each explanatory variable is included in the five (respectively four for the Bonoua locality) equations to help test whether the impacts of the variables differ across adaptation options. The descriptive statistics for all explanatory variables and the expected impacts on the adaptation options are presented in Table 2 below. Variables such as access to credit or land title were not included. This is due to the high number of missing values (only 6.8% in Bouaké and 3.5% in Bonoua), which could lead to incorrect results in the estimation method.

4.3 Descriptive analysis of variables

4.3.1 Descriptive statistics for independent variables

Table 2

Variable	Description	Means	Standard error	Expected sign

[3] Apart from the major religions such as Christianity, Islam, and Fetishism, there is also the cult of ancestors and innumerable local popular beliefs inherited from the many tribes, which give rhythm to the daily life of these new peoples

Independent variables		Bouaké (n=403)	Bonoua (n=255)	Bouaké (n=403)	Bonoua (n=255)	
Education	Level of education measured on a scale where 1= if the individual has an educational level 0= otherwise	0.4665	0.2980	0.3137	0.1973	+/-
Age	Age of head of household in years	49.5880	43.1372	15.1195	12.8075	+/-
Genre	Note 1 = male, 0 = female	0.5757	0.7216	0.4948	0.4491	**+/-**
Belief in the existence of the CC	The CC occurs Note 1 if yes, and 0= otherwise	0.8013	0.5732	0.5893	0.4657	**+**
Religious and traditional beliefs of the CC	(1=if the household associates the CC with divine work,0=otherwise	0.7221	0.4588	0.2445	0.2894	**+/-**
belief in scientific studies	Belief in scientific studies on the aggravation of CC (1 =Yes, 0 = No)	0.5955	0.3184	0.4894	0.4491	+
Belief in the human responsibility of the CC	Belief that human activities also contribute to CC (1 =Yes, 0 = No)	0.4156	0.3308	0.3913	0.2886	+
Opinion temperature	Belief that temperatures will increase (1 =Yes, 0 = No)	0.6179	0.2588	0.4899	0.4388	+
Opinion precipitation	Belief that rainfall will decrease (1 =Yes, 0 = No)	0.6552	0.3098	0.4820	0.4633	+
concerns	concerns about CC and its impacts 1 =Yes, 0 = No)	0.8486	0.4714	0.5539	0.2670	+/-
household size	Number of persons in the household	8.8114	7.0470	6.8730	3.6969	+/-
climate information	Access to information on climate and CC 1 =Yes, 0 = No)	0.6476	0.3019	0.4782	0.4600	+
field size	Field size in hectares	1.4268	1.9647	0.7704	0.9363	+/-
Experience	Agricultural experience in the year	25.6725	18.929	18.1116	12.1873	+/-
orga	Other income-generating activities (1 =Yes, 0 = No)	0.4540	0.2745	0.4985	0.44714	+/-
Atv/radio	Household has a TV/Radio (1 =Yes, 0 = No)	0.6228	0.3372	0.4852	0.4737	+
Telephone	Household has access to a telephone (1 =Yes, 0 = No)	0.8461	0.9176	0.3612	0.2754	+
own cattle	Household owns livestock	0.2953	0.3137	0.4567	0.4649	+

(1 =Yes, 0 = No)

4.3.2 Descriptive statistics for dependent variables

According to the responses on coping practices used at least in the last ten years to deal with the increasingly adverse climatic conditions, we listed five strategies[4] (respectively four strategies in Bonoua) commonly used by farmers in Bouaké, namely: mulching, fallowing, crop diversification, heat and disease resistant varieties, and rearranging calendars. The last three strategies mentioned were also used in Bonoua, with the addition of rotation. Table 3 below presents the descriptive statistics of the dependent variables for the two locations.

Table 3: Proportion of different combinations of climate change adaptation strategies used by farmers

Variables	Description	Means		Standard error	
Coping strategies (dependent variables)		Bouaké	Bonoua	Bouaké	Bonoua
Resistant variety (HRV)	Dummy=1 if households have adapted drought-resistant varieties as an adaptation strategy, 0 otherwise	0.1882	0.5411	0.2094	0.4996
Rearrangement of the crop calendar (RCC)	Dummy=1 if households changed dates as a coping strategy, 0 otherwise	0.2739	0.3922	0.4153	0.4788
Crop diversification(CD)	Dummy=1 if households used diversification as a coping strategy, 0 otherwise	**0.**3451	0.3882	0.4839	0.4763
Fallow land(FL)	Dummy=1 if households used fallow as an adaptation strategy, 0 otherwise	0.4193	----	0.4978	-----
Mulching(M)	Dummy=1 if households used mulching as a coping strategy, 0 otherwise	0.5335	-----	0.4381	----
The rotation	Dummy=1 if households used rotation as a coping strategy, 0 otherwise	----	0.4627	----	0.3228

[4] We find that the strategies used to cope with the increasingly adverse climatic conditions are old practices used to cope with climatic conditions. The increase in the frequency and magnitude of extreme weather events as mentioned by farmers requires deeper transformations of their production systems.

Firstly, we observe a difference in strategy, which can probably be explained by the different geo-climatic configurations of the two regions (see section 2). Secondly, in general, the proportion of adaptation is higher among farmers in Bonoua than in Bouaké. Indeed, 54.11% of farmers in Bonoua use heat-resistant varieties as adaptation strategies compared to only 18.82% in Bouaké. Mulching and fallowing are only used in Bouaké for an adaptation rate of about 53.35% and 42% respectively. The proportion of the strategy of rearranging the cropping calendar is lower in Bouaké than in Bonoua. Indeed, about 27.40% of farmers in Bouaké practice this strategy against 39.22% in Bonoua. Finally, 34.51% of farmers in Bouake practice crop diversification compared to 38.82% of farmers in Bonoua. 46.27% of farmers in Bonoua used rotation[5] as an adaptation strategy.

4.3.3 Socio-demographic characteristics of farmers

In this section, we present some descriptive statistics of the whole sample. In total 658 farmers were interviewed (403 in Bouaké and 255 in Bonoua). The characteristics[6] of the sample are summarised in Table 4 below. The average age of respondents was 49.58 years in Bouaké and 43.14 years in Bonoua. In general, the respondents (generally the 'heads' of households) have no formal education. The proportion of educated people is lower in Bonoua. Indeed, 53.35% of households in Bouaké are illiterate compared to 70% in Bonoua. Nearly 30% of households in Bouaké compared to 24% in Bonoua have a primary level of education and 14% in Bouaké compared to 5.10% in Bonoua have a secondary level of education. Only 3.13% in Bouaké compared to 0.39% in Bonoua had higher education in our sample. Only 10.4% in Bouaké and 4.7% in Bonoua are members of a farmers' organization. In general, few farmers are involved in agricultural associations or organizations and very few participate in agricultural projects, mainly because of the obvious mismanagement and lack of assured benefits. Cumulatively, only 1.76% of farmers have received technological training (2.73% in Bouaké and 1.73% in Bonoua). Experience in agriculture is higher in Bouaké, with an average of 26 years compared to 19 years in Bonoua.

[5] Only 4/403 or 0.009% of farmers mentioned the use of rotation. We consider this very low share as zero.

[6] We would like to compare the results from the main socio-demographic characteristics of our sample with the Ivorian farmer population to see if they were representative. But unfortunately, we do not have recent data, the available data dates from 2008.

Table 4: Socio-demographic characteristics of households

Variables	**Bouaké (n=403)**	**Bonoua (n=255)**
Gender		
Male	57.57	72.13
Female	42.43	27.84
Age (mean)*	49,58	43,14
	1.43	1.96
Education (%)		
none (illiterate)	53.35	70
Primary	30	24.3
Secondary	14	5.10
Higher	3.13	0.39
Type of agriculture practiced (%)		
Subsistence farming	100	-
Cash crop farming	-	100
Livestock	50,37	33,72
Savings	36,47	47,06
Access to credit	6.8	5.52
Member of an agricultural organisation	10.4	4.7
Technology training	2.73	1.57
Expérience (mean)*	26	19
Origin (%)		
Migrants from neighbouring countries	-	49.83
Aboriginal	100	50.17

Notes:* *For these variables, the value reported is the mean.*

4.3.4 Farmers' beliefs about the degree of harmfulness of CC in the near future

To assess beliefs about the degree of severity of CC, we ask farmers how much they think CC will affect their activities in the next five to 10 years.

Table 5: Level of impact of CC on agricultural activity

	Bouake	Bonoua
Very strongly	47.14%	16,86%
Strongly	22.08%	15,68%
Less strongly	19,60%	46,27%
No effect	11.17%	21,17%

The differences are significant for each category of farmers' responses. (Chi-square is significant at the 5% level.

We observe that 47.14% of farmers in Bouaké and 16.86% in Bonoua believe that CC will have a very strong impact on agricultural activity. There is a clear difference between households in the two localities in the way they perceive the harmfulness of CC on agricultural activity. Indeed, only 19.60% of farmers in Bouaké versus 46.27% in Bonoua believe that CC will have a lesser effect on their activity.

5-Results and discussion of the multivariate Probit estimation

5.1 Statistical interpretation of the peer coefficients

This section presents the results of the multivariate probit model. The results for the correlation coefficients of the error terms are significant (according to the t-test statistic) for all pairs of equations indicating that they are correlated (Table 5). All results on the correlation coefficients of the error terms indicate that there are complementarities (positive correlation) between the different adaptation options used by the farmers. Specifically, the positive signs of the correlation coefficients suggest that the decision to adopt a particular adaptation strategy may make the adoption of another strategy more likely. For example, a producer who uses crop diversification to cope with drought risk may also be more likely to use heat-tolerant varieties as a risk management strategy. The results support the hypothesis of interdependence between the different adaptation options, which may be due to the complementarity of the different adaptation options and also to omitted household-specific and other factors that affect the adoption of all adaptation options.

Tableau 6 Correlation coefficients of the climate change adaptation strategies (from the multivariate probit estimation Bouake model).

Climate change adaptation strategy	Correlation coefficient	Standard Error
Use of heat resistant varieties/mulching	. 96148 ***	.02486
Rearrangement of the cropping cale/ Use of resistant varieties	.57132 ***	.06036
Crop diversification / Use of resistant varieties	.65053 ***	.01264
Use of fallow land / Use of resistant varieties	.72047***	.05091
Rearrangement of the crop calendar / mulching	.63174***	.07300
Crop diversification/mulching	.7107***	.04263
Use of fallow / mulching	.76689***	.05205
Crop diversification/ Rearrangement of the cropping calendar	. 3875 ***	.01562
Use of fallow land / Rearrangement of the cropping calendar	.77923***	.04518
Use of fallow land / Crop diversification	.01359***	.01351

Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho32 = rho42 = rho52 = rho43 = rho53 = rho54 = 0: chi2(10) = 459.325 Prob > chi2 = 0.0000 ;***p <0.01

Tableau 7 Correlation coefficients of the climate change adaptation strategies (from the multivariate probit estimation Bonoua model).

Climate change adaptation strategy	Correlation coefficient	Standard Error
Rearrangement of the hold / Use of resistant varieties	.30033 ***	.01890
Crop diversification / Use of resistant varieties	.21972 ***	.02569
Use of rotation/ Use of resistant varieties	.02301***	.01345
Crop diversification/ Rearrangement of the cropping calendar	.32568***	.05396
Use of rotation / Rearrangement of the crop calendar	.59046***	.01400
Use of rotation / Crop diversification	.49430 ***	.01148

Likelihood ratio test of rho21 = rho31 = rho41 = rho32 = rho42 = rho43 =: chi2(6) = 225.062 Prob > chi2 = 0.0000;***p <0.01

5.2 Parameter estimates: a multivariate probit model

This section presents the results of the estimation of factors affecting farmers' climate change adaptation decisions. The results of the parameter estimates for the two samples (Bonoua and Bouaké) are presented in Tables 6 and 7 below. The likelihood ratio test based on the log-likelihood values of the multivariate model for each locality (Bouaké and Bonoua) indicates a significant joint correlation (chi-square () = 0.0000) justifying the estimation of the multivariate probit that considers different adaptation options (see Table 5 above) The parameter estimates of the multivariate probit model give the probability of occurrence of the outcomes (Table 6). The estimated parameter values are not directly interpretable, but rather serve to guide the nature of the relationship between the dependent variable and the explanatory variables. More specifically, we are interested in their signs: a positive (respectively negative) sign means that an increase in the explanatory variable under consideration increases (respectively decreases) the probability of implementing the adaptation strategy.

Tableau 8 Results from the estimation of the multivariate probit model (Bouaké's model)

Variable	Resistant variety (HRV)	Mulching (M)	Rearrangement of the crop calendar (RCC)	Crop Diversification (CD)	Fallo Fallow land(FL)
	Coeff Std. Err.	Coeff Std. Err.	Coef Std. Err.	Coeff Std. Err.	Coeff Std. Err.
Education	.7402*** (.0973)	.0543 (.0890)	-.0296 (.0877)	.1758*** (.0934)	.3466*** (.0928)
Age	-.6248*** (.1006)	-.1491*** (.0933)	-.1555*** (.1056)	.2917 *** (.0953)	-.0674 (.0993)
Genre	-.2864*** (.1638)	-.34201** (.1601)	-.1675 (.1646)	.1455 (.2609)	.4215*** (.1568)
religious beliefs	-2.3753*** (.1102)	-.6429*** (.1154)	-.8983*** (.1179)	-1.5697*** (.1133)	-.7884*** (.1135)
Belief in scientific studies	.24693 (.2572)	.1842** (.1655)	.4104 (.1839)	.0953 (.2581)	-.0937 (.1756)
knowledge of the CC	.7527*** (.1146)	.2965 (.1063)	.2114** (.1135)	.5355*** (.1209)	.0359 (.1293)
Belief in the human responsibility of the CC	7948*** (.1598)	1.8128*** (.1555)	.4373*** (.1602)	-.0784 (.2240)	.9627*** (.1393)
Belief in the impact of rising temperatures	1.5706*** (.1739)	1.6731*** (.1767)	1.8757*** (.1766)	1.4186*** (.2523)	.8694*** (.1716)
Opinion precipitation	.4737 (.1647)	-.0616 (.1729)	-.8304*** (.1838)	2.5079*** (.2566)	-.6986*** (.1811)
Concern	1.3559*** (.3148)	.0915 (.2054)	.2225 (.2329)	-1.7842*** (.3173)	.7869*** (.3108)
Tailmen	-.4385*** (.20696)	-.1187 (.1116)	-.0336 (.1121)	.4847*** (.2018)	.4652*** (.2095)
Tailchamp	.1488*** (.1381)	.0847 (.0844)	-.1463 (.1025)	-.1969*** (.1389)	.09894 (.0893)
Aagr	-.1968*** (.1461)	-.2039 (.1351)	-.6291*** (.1409)	.7863*** (.2213)	-.6209*** (.1494)
Infometeo	.4853*** (.1543)	.4966*** (.1517)	.3146*** (.1687)	-.0654 (.2445)	.5406 *** (.1643)
Experience	.8187*** (.0612)	-.4598*** (.0627)	.6517*** (.0637)	-.1478*** (.0679)	-.0356 (.0465)
Atv/radio	-.0783 (.1527)	-.0777 (.1516)	.0984 (.1644)	.1318*** (.2325)	-.0692 (.1542)
Telephone	.3324*** (.1937)	.4078*** (.1931)	.3289 (.1918)	-1.044*** (.36721)	.2329** (.2028)
Probetail	.3633*** (.1504)	.3373*** (.1492)	-.1586 (.1653)	.3889*** (.1533)	-.1683*** (.1516)
_cons	-.3664*** (.60807)	.2302*** (.6090)	.4531*** (.6582)	-1.697 *** (.6521)	-.7379*** (.6426)

Multivariate probit (SML, # draws = 50)
Log-likelihood value : -757.74716
Wald test chi2 (80) = 241.01
Prob > chi2 = 0.0000
Number of obs: 403

Note: Figures in parenthesis are robust standard errors. *, **, and *** represent statistical significance at 10%, 5%, and 1% levels, respectively.

Tableau 9 Results from the estimation of the multivariate probit model (Bonoua's model)

Variable	**Resistant variety (HRV)**	**Rearrangement of the crop calendar (RCC)**	**Crop Diversification (CD)**	**Rotation (R)**
	Coeff Std. Err.	Coef Std. Err.	Coeff Std. Err.	Coeff Std. Err.
Education	.2047*** (.1507)	.8649*** (.1497)	.4175*** (.1556)	.7049*** (.1523)
Age	-.1629*** (.1768)	-.02865 (.2582)	.3188*** (.1718)	.2281*** (.1678)
Genre	1.0 65*** (.2709)	. 4859*** (.2725)	.5396*** (.2419)	.0026 (.2992)
Religion	.3035 (.2149)	-1.0996*** (.3877)	-.9818*** (.2036)	.5268*** (.2009)
Belief in scientific studies	1.6029*** (.2896)	-1.0329*** (.3383)	.7837*** (.3315)	-1.7209*** (.2875)
knowledge of the CC	.2907*** (.1905)	.0673 (.1932)	4507*** (.1924)	.1617 (.3292)
Belief in the human responsibility of the CC	.3537*** (.1937)	1.5986*** (.1855)	-.0691 (.0413)	1.1751*** (.1875)
Belief in the impact of rising temperatures	-.1469 (.3246)	.0368 (.4579)	-.0726 (.2931)	-.1723 (.2851)
Opinion precipitation	.3522 (.4107)	-.1748 (.4473)	-.5649 (.2903)	-.0959 (.3218)
Concern	.6909*** (.2716)	2.002*** (.2735)	.7985*** (.2728)	1.779*** (.2715)
Tailmen	.60255 ** * (.2721)	-.4839 (.4436)	.7547 *** (.2611)	-.2642** (.2629)
Tailchamp	.4329*** (.1092)	-.0199 (.1449)	.2918*** (.1099)	.2256*** (.1097)
Aagr	-.49134*** (.2391)	1.3849*** (.3664)	.7702*** (.2316)	-.0334 (.2133)
Infometeo	.6199*** (.2465)	1.6396*** (.2375)	.8319*** (.2387)	.3791*** (.2357)
experience	-.0651 (.1449)	.5006 *** (.1416)	-.1758*** (.1017)	-.1179*** (.1498)
Atv/radio	.4568*** (.2282)	.0968 (.3116)	.3259*** (.2213)	.2409*** (.2244)
telephone	.3408 (.398)	3.8921*** (.4174)	.4546*** (.3656)	-.3264 (.4295)
Probetail	.2738*** (.4620)	-1.1469*** (.4849)	.7702*** (.4634)	-.2112 (.2006)
_cons	-.14027*** (.71245)	2.652*** (101.42)	.5836 *** (.9852)	.4700 *** (.3648)

Multivariate probit (SML, # draws = 25)
Log-likelihood value : -486.0816
Wald test chi2 (80) = 146.06
Prob > chi2 = 0.0000
Number of obs: 255

Note: Figures in parenthesis are robust standard errors. *, **, and *** represent statistical significance at 10%, 5%, and 1% levels, respectively.

5.3 Link between adaptation decisions and individual belief variables

In line with the objective of this paper, we attempt to identify the belief variables that determine the adaptation decisions of farm households without placing particular emphasis on certain variables.

Adaptation decisions and religious belief

Although some studies note the beneficial effects of religious belief, particularly in the area of health (Scheier et al.,1989; Howsepian and Merluzzi,2009), religious beliefs can negatively affect individuals' behaviors in other areas. As expected, we find that adoption decisions are influenced by beliefs in both models. However, there are significant differences. In Bonoua's model, the variable has an indeterminate influence on adaptation decisions (Table 9). Indeed, there is a positive and statistically significant association ($p < 0.001$) for the implementation of the R strategy and a negative and statistically significant association ($p < 0.001$) for the RCC and DC strategy (Table 8). In the Bouaké model, on the other hand, religious beliefs play a key role in farmers' decisions regarding strategy implementation. The results reveal that religious beliefs negatively influence (statistically significant, $p < 0.001$) all strategy adoption decisions (Table 8). This result suggests that religious beliefs are likely to decrease farmers' likelihood of adaptation. This result is not surprising, given that the majority of farmers in Bouaké (72% compared to about 46% of the sample in Bonoua) associate CC with the work of God (Table 2). If farmers see climate change as a natural process governed by divine power and over which they have no control, they are less likely to implement adaptation strategies. This result is consistent with the Protection Motivation Theory (PMT) approach, which states that the lower the belief in one's ability to cope with risk, the lower the likelihood of it triggering adaptive behavior. Furthermore, it is worth noting the symbolic nature of yams in the culture of the respondents in Bouaké. Indeed, the farmers of Bouaké belong to the Akan tribe. Historically, yam has mainly contributed to the survival of the Akan people who fled persecution in Ghana to migrate to the Ivory Coast. Thus, every year, commemorative ceremonies are organized to celebrate the yam, mother earth, and the spirits of the ancestors. In case of a bad harvest, sacrifices are offered to the ancestors to appease them so that the next harvest will be good. The Ivorian government has introduced more resistant seed varieties, but many farmers have rejected them because of their slightly different appearance and taste. In addition, it should be noted that on average farmers in Bouaké have more experience than those in Bonoua (26 years versus 19 years) (Table 4). This detail is worth noting because the literature shows that those with more experience and therefore generally older (the average age in Bouaké is about 50 years compared to 43 years in Bonoua) are more attached to traditions and therefore generally more resistant to change than newcomers. Not surprisingly, age is highly significant and its sign indicates a negative effect on most adaptation decisions of farmers in the region.

Adaptation decision and opinion on scientific studies on CC aggravation

Looking at the results, we see that, except mulching, the variable "belief in scientific studies on the worsening of CC" does not significantly influence adaptation decisions in the Bouaké model (Table 8). Thus, our hypothesis that belief in scientific studies has a positive and significant impact on the implementation of adaptation strategies is not verified for this locality. At first sight, this result may seem surprising since 60% of the farmers in our sample (compared to only 32% in Bonoua) agreed with the scientific studies on the worsening of CC (Table 2). However, if we take into account the other statements, we have a better understanding of the farmers' behavior. About 62% (compared to 26% in Bonoua) said that temperatures will increase in the coming years and hurt their production activities, a prediction widely documented in the literature in Sub-Saharan Africa (Table 5). But paradoxically, less than half (41.56% in Bouaké versus 33% in Bonoua) agreed that human activities were also contributing to CC (Table 2). The majority of farmers in Bouaké said they agreed with scientific studies on worsening CC because they were consistent with their already established local climate perceptions of climate disruption. Individuals tend to believe information when it supports their previous beliefs ((Kahan2010).

In the Bonoua model, on the other hand, the variable "belief in scientific studies on CC aggravation" is highly significant ($p < 0.001$) on all adaptation decisions, however, it covers both negative and positive signs (Table 9). In other words, farmers who agree with scientific studies on CC aggravation are significantly and positively more willing to implement adaptation strategies but also significantly less willing to react. First, we justify this mixed result in conjunction with the low level of education: it is less obvious to expect pro-environmental behavior if farmers do not have the minimum knowledge necessary to interpret and understand the warning messages conveyed by scientists. The majority of respondents in our sample have no education (70% vs. 53.35% in Bouaké). Not surprisingly, the positive and significant sign of education indicates that a more educated farmer is likely to adopt coping strategies. Moreover, unlike in Bouaké, most farmers in this region downplayed the magnitude and importance of the threat of climate change on their production activities. Less than half (32.54% of the sample versus 69.22% in Bouaké) felt that CC would have a significant effect on their production activities (Table 5). However, farmers have been exposed to severe drought and flooding over the past 5 years, resulting in the death of two children (Anader, 2017). A rational farmer who considers that CC-related risks will have less impact on his production activity will expect adaptation measures to be of little use. Secondly, according to the information provided by the focus groups, some farmers noted that "it is complicated to decide which crops to grow and when to grow them based on the scientific knowledge broadcast by the meteorological department on radio and television". When forecasts predicted normal or better rainfall, they instead witnessed delayed rains, resulting in bad germination. Frequent exposure to conflicting evidence on potential climate risks can reinforce and legitimize the sense of skepticism about the climate threat among some farmers. For example, although there is now a scientific consensus on the anthropogenic origin of climate change, this has done little to convince society to act on uncontrolled carbon emissions and to adopt behaviors that limit environmental degradation (Bain, Hornsey, Bongiorno, and Jeffries, 2012).

Adaptation decision and subjective estimation of future temperature and precipitation changes

Farmers' estimates of expected climate change and its effects are indicators that provide fairly clear information on adaptation responses. Our results show that no subjective predictions of future temperature and rainfall trends significantly influence farmers' adaptation decisions in Bonoua, which is not consistent with our intuition (Table 9). Conversely, the results concerning temperature change in the Bouaké model converge toward this hypothesis. The variable "Belief in temperature evolution" appears to be a determining factor, and is likely to significantly increase ($p < 0.001$) the probability of adopting all adaptation options (Table 8). We interpret this result by the differences in the degree of exposure to climate change between the two regions. Farmers in Bouaké (unlike those in Bonoua) are heavily dependent on agriculture and are highly exposed to very high temperatures that are extremely damaging to agriculture. Rising temperatures are generally associated with reduced rainfall (Amani Michel et al, 2010) and thus increased water scarcity and shortages for food production and other uses. According to Diggs,(1991), drought plays a crucial role in economic survival and most farmers are likely to have strong opinions about its magnitude, frequency, and timing (Taylor et al. 1982). Higher drought expectations are positively associated with adaptation intentions and planning behavior (Booth et al., 2020). The propensity to engage in adaptation strategies is highly dependent on local conditions (Mogomotsi et al. 2020). For the evolution of rainfall, on the other hand, there is an indeterminate effect of the variable on adaptation decisions for the same locality. This result is hardly surprising, given the variable nature of rainfall. Indeed, unlike temperature, rainfall trends are marked by very high intra-annual and interannual variability in West Africa. Moreover, the current state of climate models on rainfall in sub-Saharan Africa leaves a high degree of uncertainty on the main future evolutions whatever the time horizon is considered. The negative link observed may also be linked to the extremely rare or non-existent irrigation practices in the area. The lack of rainfall combined with a lack of irrigation facilities makes it difficult to implement strategies. In the absence of rain, irrigation techniques are crucial in localities where drought risks are frequent (Arun GC and Jun-Ho Yeo, 2019).

Adaptation decision and concerns about CC and its impacts

The results indicate the existence of a positive and significant relationship ($p < 0.001$) between the variable "CC-related concerns" and the adoption of adaptation strategies in the Bonoua locality. The variable "Concerns" is a determining factor for farmers in Bonoua, affecting all adaptation decisions (Table 9). These results indicate that the more worried farmers are, the more likely they are to implement adaptation strategies. In the Bouaké model, on the other hand, there is an undetermined relationship between coping decisions. The difference in impact between the two regions is because the issues related to each type of farm considered are different. A finer partitioning of the farming world between large farms mainly for domestic and export sales and small subsistence-oriented farms, the relationship becomes less obvious as income is less discriminating within these two modal classes. Furthermore, in the event of a very large climatic shock, income losses for farmers whose farms are geared towards sales (Bonoua) and exports will not be the same for farmers whose farms are geared towards subsistence (Bouaké). The negative result observed in the Bouaké model can be explained by the importance that farmers attach to the risks associated with CC. Adaptation decisions are unlikely to be significant if individuals consider other sources of risk to be more important (Eitzinger et al,2018, Weber, 2010). Farmers may be more concerned about a failure in agricultural production and a lack of access to health services. Farmers make decisions based on what they think is likely to happen, and sometimes on what they fear, or hope will happen (Legesse and Drake, 2005; Patt, 2001).

5.4 Simulation of the marginal probability of success (MPS) on adaptation decisions

We have discussed above the parameter estimates of the multivariate probit model in the two localities. The estimation results for the two regions are quite different concerning the significant variables and the direction of the effect. For each model, we simulated the impacts of a set of selected belief variables to show their impact on the marginal probability of success (MPS). The marginal probability of success (MPS) is defined as the probability of observing the adoption of a strategy conditional on other practices (Tables 10 and 11).To do this, we used the parameter estimates extracted from MVP and the particular values of the covariates to formulate the mvnormal arguments, and then calculated the conditional probability as the ratio of the joint probability to the joint marginal probability (see John Mullahy, 2017).

table 10 Simulated impacts of selected variables on adoption probability (Bouaké)

Bouaké model	**Resistant variety (HRV)**	**Mulching(M)**	**Rearrangement of the crop calendar (RCC)**	**Crop Diversification (CD)**	**Fallow land(FL)**
Variables	% Marginal probability of success	% Marginal probability of success	% Marginal probability of success	% Marginal probability of success	% Marginal probability of success
Religious beliefs	63.8	25,18	-42,04	-47.15	-18,14
Belief in scientific studies	-0,84	11.35	0,58	1.05	0.49
Belief in the human responsibility of	32,94	18,87	27.51	-0,8	25,9

the CC					
Belief in temperature change	36.70	33.08	58.28	-27,41	31.35
Belief in the evolution of rainfall	-11,16	-3.01	-21.23	49	-27.13
Concerns	18,73	0.17	1.55	-.28,73	23,02

Tableau 11 Simulated impacts of selected variables on adoption probability (*Bonoua)*

Bonoua model	**Resistant variety (HRV)**	**Rearrangement of the crop calendar (RCC)**	**Crop Diversification (CD**	**Use of rotation**
Variables	% Marginal probability of success	% Marginal probability of success	% Marginal probability of success	% Marginal probability of success
Religious beliefs	-1.62	-29,04	-22,18	11,41
Belief in scientific studies	35.8	-18,08	13.5	-39.8
Belief in the human responsibility of the CC	16,14	33	-1.2	-30.8
Belief in temperature change	0.70	0.82	1.15	0.35
Belief in the evolution of rainfall	-1,16	-0.73	0.6	-1.13
Concerns	38,72	53.28	35.58	49,49

In comparison, the impact of beliefs is generally greater for farmers in Bouaké. The simulated impacts of beliefs show that the variable with the greatest impact on MPS was "religious beliefs" in Bouaké, followed by the variable "belief in temperature change", while in Bonoua the variable with the greatest impact on MPS was "concern", followed by the variable "belief in scientific studies on the worsening of CC". The impact of 'religious beliefs' was about 64% and 47.15 respectively for the implementation of HRV and CD. In the Bonoua model, the impact of "concerns" was 53.28% and 49.49% respectively for the implementation of HRV and R. The variable "belief in scientific studies on the worsening of CC" was less important when the removal of the variable "concerns" decreased the MPS for the HRV and DC strategy for Bonoua. In the case of Bouaké, the removal of the variable 'religious belief' did not have a significant effect on the variable 'belief in scientific studies on the aggravation of CC'.

Overall, the simulated effects show how beliefs can affect adaptive capacity. It would be interesting to study the extent to which belief systems (religious or cultural) can coexist with scientific knowledge to enhance adaptive capacity.

6. Conclusion and policy implications

Our study focuses on the analysis of the determinants of farmers' adaptation decisions to climate change. We used a quantitative approach based on a discrete choice model, in this case, the multivariate probit model, to assess how beliefs influence farmers' adaptation decisions in two different localities. The rejection of the null hypothesis of the independence of different adaptation strategies justifies the use of multivariate probit for this analysis.

We assess the effect of several beliefs on farmers' adaptive behavior, such as beliefs about the existence of climate change, religious and traditional beliefs, beliefs about scientific studies, subjective estimates of temperature and rainfall trends, concerns about the potential impacts of climate change, and beliefs about anthropogenic responsibility for climate change. For this last variable, given that there is now a scientific consensus on the anthropogenic origin of climate change, we expected it to be a major determinant explaining farmers' motivation to implement adaptation strategies, a controversial aspect in the literature.

The results unambiguously show that the impact of beliefs on adaptation decisions differs according to the region considered. In Bouaké, religious and traditional beliefs and subjective predictions about temperature and rainfall trends significantly affect adaptation decisions among subsistence farmers. We find that most respondents in the locality consider climate change to be the work of God and are likely not to adapt, which is consistent with the literature (Spear et al, 2019). Although there is evidence that climate change beliefs (religious and cultural) are important drivers of adaptation in Africa, the role of farmers' beliefs in the adaptation process may be poorly understood, particularly at the local level. Beliefs influence farmers' understanding of and decisions to adapt and are expressed differently across cultural groups and locations (Azong, 2020; Murphy, 2015).

Our study provides insight into the need to further disentangle the importance of beliefs in determining adaptive capacity. The transmission of scientific information is a pillar of policy to improve adaptation. However, as different belief systems are associated with different types of knowledge (Azong, 2020; Murphy, 2015), the confrontation of scientific knowledge with traditional or religious beliefs can lead to the ineffectiveness of this policy: scientific knowledge presented bluntly can clash with local beliefs. In places where religious and traditional beliefs are strongly held, education campaigns are needed to negotiate the cohabitation and integration of other forms of knowledge. The scientific argument should be presented to accommodate local traditions and beliefs. In addition, the inclusion of religious or traditional spiritual leaders in education and awareness campaigns will help to avoid or limit tensions or outright rejection of the policy. In some communities, for example, farmers must wait for permission from the village chief before starting to plant or harvest (Davies, 2019). The inclusion of traditional religious or spiritual leaders would, for example, allow for better dissemination of information on climate change and possible adaptation strategies to farmers in the rural population. To achieve this, the deployment and training of a significant number of extension workers are required, and the success of such programs depends on the provision of greater resources for information dissemination and farmer monitoring.

Two other results are worth mentioning. Firstly, in Bonoua, concern about climate change determines farmers' willingness to adopt adaptation strategies. Worried farmers are significantly more motivated to respond positively by adopting all adaptation strategies, which is in line with the literature (Woods et al, 2017). In the Bouaké model, however, the results indicate an indeterminate effect. We interpret this difference with the income loss effect: Farmers in Bonoua who are 'aware' of the risk of large income losses in the event of a climate disaster are less reluctant to adopt adaptive practices, whereas farmers in Bouaké with low incomes may consider other sources of risk to be more important (such as production failure). This result is important to highlight to inform policymakers on the need to propose agricultural policies that advocate for differentiated solutions by type of agriculture practiced and by type of farmer. Secondly, our results reveal that the variable "belief in scientific studies on the worsening of CC" has no influence on the adaptation decisions of farmers in Bouaké while it statically and significantly influences all the adaptation decisions of farmers in Bonoua, however, the effect on the adaptation decisions is indeterminate. Most of the farmers interviewed in Bonoua considerably underestimate the magnitude and importance of the threat of climate change on their production activities. With a very low level of education, farmers likely have difficulty understanding scientific messages. Education and communication campaigns on climate change and its impacts on their activities are needed before any advice on adaptation measures can be effective. Furthermore, given the difficulty farmers have in relying on the scientific knowledge disseminated by the meteorological department on radio and television, it is essential that scientific information campaigns take into account local climatic realities, and are sufficiently comprehensive, credible, and well-adapted to the target population.

Our study has several limitations. We were limited in the questions we could ask about culture or religion. In the pre-survey, for example, the cultural aspect, particularly religion, was prominent in the responses, especially in Bouaké, suggesting the possibility of a more in-depth field survey. For a better understanding of beliefs about how climate change is managed in the rural environment, further research is needed. There is a need for an interdisciplinary approach and an analysis that goes beyond theoretical insights. In particular, our study is the first attempt to measure the impact of climate beliefs on farmers' adaptation decisions. It is necessary to accumulate enough small local studies to constitute a considerable database, to help public decision-making (Chevassus-au Louis et al., 2009).

Econometrically, there is a risk of bias due to the omission of confounding variables, which is often the case in cross-sectional studies.

Appendix A

The following table 1 summarises the questions and coding related to the beliefs selected in this paper:

Variables	**Answers**	**Code**
Do you believe that climate change is happening?	Yes/No	1=yes and 0 otherwise
Do you think that human activities also contribute to climate change?	Yes/No	1=yes and 0 otherwise
Based on your personal experiences, do you think that temperatures will tend to rise?	Yes/No	1=yes and 0 otherwise
Based on your personal experiences, do you think that rainfall will tend to decrease?	Yes/No	1=yes and 0 otherwise
Do you agree with scientific studies that predict worsening climate conditions, especially in Africa?	Yes/No	1=yes and 0 otherwise
Do you associate the CC with the work of God?	Yes/No	1=yes and 0 otherwise
Are you concerned about the current and future impacts of CC on your business?	Yes/No	1=yes and 0 otherwise

References

Ake G.E. (2010). *Impacts de la variabilité climatique et des pressions anthropiques sur les ressources hydriques de la région de Bonoua (Sud-Est de la Côte d'Ivoire)*. Revue des sciences de l'eau / Journal of Water Science,, 200 p.

Amani. M. et AL,2010 ; Analysis of climate variability and of its influences on seasonal rainfall regimes in west Africa :Case of the N'zi(Bandama)watershed in Ivory Coast.

ANADER, (2017). Rapport de travail annuel : CR technico-économique de manioc, Direction d'Appui aux filière Agricoles,8p.

Arbuckle, J.G., Prokopy, L.S., Haigh, T. et al. (2013). Climate change beliefs, concerns, and attitudes toward adaptation and mitigation among farmers in the Midwestern United States. *Climatic Change* 117, 943–950 (2013). https://doi.org/10.1007/s10584-013-0707-6

Arun, G.C. and J.H. Yeo(2019). Perception to Adaptation of Climate Change in Nepal : An Emprirical Analysis Using Multivariate Probit Model, Sci, 1, 12, 14 p.

Azong , M.N. (2020): Impact of cultural beliefs on smallholders' response to climate change: the case of Bamenda Highlands, Cameroon, International Journal of Environmental Studies, DOI: 10.1080/00207233.2020.1824866

Bationo A, Mokwunye AU (1987) Soil fertility management of the millet producing sandy soils of Sahelian West Africa: the Niger experience. Paper presented at the workshop on soil and crop management systems for rainfed agriculture in the Sudano– Sahelian zone. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Niamey

Blennow, K., Persson, J., Goncalves, L. M. S., Borys, A., Dutca, I., Hynynen, J., Janeczko, E., Lyubenova, M., Merganič, J.,and al. (2020 online): The role of beliefs, expectations and values in decision-making favoring climate change adaptation – implications for communications with European forest professionals. - Environmental Research Letters.

Booth, Pamela, Patrick J. Walsh, and Pike Stahlmann-Brown. 2020. 'Drought Intensity, Future Expectations, and the Resilience of Climate Beliefs'. *Ecological Economics* 176 (October): 106735. https://doi.org/10.1016/j.ecolecon.2020.106735.

Bryan,E, Ringler,C.,Okoba, B, Roncoli.C,Silvestri, S. Herrero, M., 2013. Adapting agriculture to climate change in Kenya: household strategies and determinants. J. Environ. Manage. 114, 26–35.

Carlton, J.S., Mase, A.S., Knutson, C.L. et al. The effects of extreme drought on climate change beliefs, risk perceptions, and adaptation attitudes. Climatic Change **135,** 211–226 (2016). https://doi.org/10.1007/s10584-015-1561-5

Chevassus-au Louis, B., Salles, J.-M., Pujol, J.-L., Bielsa, S., Martin, G., Richard, D., 2009. Approche économique de la biodiversité et des services liés aux écosystèmes: contribution à la décision publique. vol. 18 Ministère de l'Alimentation, de l'Agriculture et de la Pêche.

Codjia, C.O. (2009). Perceptions, savoirs locaux et stratégies d'adaptations aux changements climatiques des producteurs des communes d'Adjohoun et de Dangbo au Sud- Est Bénin, Université d'Abomey- Calavi (Bénin), 137 p.

Cologna, Viktoria, and Michael Siegrist. "The role of trust for climate change mitigation and adaptation behaviour: A meta-analysis." *Journal of Environmental Psychology* (2020): 101428.

Davies J., Spear D., Chappel A., Joshi N., Togarepi C., Kunamwene I. (2019) Considering Religion and Tradition in Climate Smart Agriculture: Insights from Namibia. In: Rosenstock T., Nowak A., Girvetz E. (eds) The Climate-Smart Agriculture Papers. Springer, Cham. https://doi.org/10.1007/978-3-319-92798-5_16

Dessai , W. N. Adger, M. Hulme , J. Turnpenny, J. Köhler and R. Warren [2004]: Defining and experiencing dangerous climate change. Climatic Change, 64(1-2), 11-25.

Diggs, D.M. (1991). Drought experience and perception of climatic change among Great Plains farmers. Great Plains Research, 1: 114-132.

Ding D, EW, Maibach , X Zhao, C. R-Roser, A Leiserowitz (2011) Support for climate policy and societal action are linked to perceptions about scientific agreement. Nat Clim Chang 1(9):462

Djédjé Antoine, 2013, *Évolution du climat et système cultural dans la région de Bouaké*. Revue des sciences de l'eau / Journal of Water Science, *71* (2), 144–157

Ducroquet H., P.Tillie, K. Louchini , S.G-Y-Paloma. (2017). Les Filières animales et végétales. in L'agriculture de la Côte d'Ivoire à la Loupe: état des lieux des filières de productions végétales et animales et revue des politiques agricoles, Europe 28754 FR, JRC Science for Policy Report European Commission, Luxembourg. Pages 54–71.

Eitzinger. A,C.R.Binder and M.Meyer (2018). Risk perception and decision-making: do farmers consider risks from climate change? Climatic change.Vol 151.n°3, 507-524.

Golob, T.F. and A.C. Regan (2002). Trucking industry adoption of information technology: A structural multivariate probit model. Transportation Research , C - Emerging Technologies, 10:205-228.

Greene, W. (2003) "Econometric Analysis", 5th ed. Upper Saddle River, NJ: Prentice Hall. Hardaker, J., B. Huirne, and J. Anderson (1997), "Coping with Risk in Agriculture", New York: CAB International.

Hahnel, U.J.J., Mumenthaler, C. & Brosch, T. Emotional foundations of the public climate change divide. *Climatic Change* **161,** 9–19 (2020).

Howsepian, B. A., and T. V. Merluzzi, (2009). Religious beliefs, social support, self-efficacy and adjustment to cancer. Psycho-oncology, 18, 1069-1079.

IPCC,(2021), AR6 Synthesis Report: Climate Change 2021: the science.

Kahan, Dan M. and Jenkins-Smith, Hank and Braman, Donald. (2010) Cultural Cognition of Scientific Consensus. Journal of Risk Research, Vol. 14, pp. 147-74, 2011,

Kollmair M. and S.Gamper. (2002). The sustainable livelihoods approach. Input Paper for the Integrated Training Course of NCCR North-South Aeschiried. Development Study Group, University of Zurich, Switzerland.

Legesse B. and L. *Drake* (*2005).* Determinants of smallholder farmer's perceptions of risk in the Eastern Highlands of E thiopia. pages 383-416, July.

Lin, C.-T.J., K.L., Jensen, S.T.Yen (2005). Awareness of foodborne pathogens among US consumers. Food Qual. Prefer. 16 (5), 401–412.

Mann, L. (1992). Stress, affect and risk taking. Dans J.F. Yates (Eds). Risk-taking Behavior. New York : John Wiley and Sons.

Mogomotsi, A. Sekelemani and G.E.J. Mogomotsi [2020]: Climate change adaptation strategies of small-scale farmers in Ngamiland East, Botswana. *Climatic Change* 159, 441–460.

Moschini R.C., R .Pioli, C. MA and O.Sacchi (2001) Empirical predictions of wheat head blight in the northern Argentinean Pampas region. Crop Sci 41:1541–1545.

Mullahy, John."Marginal Effects in Multivariate Probit Models." *Empirical Economics* 52, no. 2 (2017): 447-61. PubMed Central ID in process.

Mulwa, M.,P.Marenya, D.B. Rahut and M.Kassie (2017).Response to climate risks among smallholder farmers in Malawi: A multivariate probit assessment of the role of information, household demographics, and farm characteristics .Climate Risk Management 16.208–221

Murphy, C., Tembo, M., Phiri, A., Yerokun, O., and Grummell, B. (2015). Adapting to climate change in shifting landscapes of belief. *Climatic Change, 134*, 101-114.

Nassourou L. M., B.Sarr., A. Alhassane, S .Traoré and B. Abdourahamane (2018). Perception et observation : les principaux risques agro-climatique de l'agriculture pluviale dans l'ouest du Niger. VertigO, 18(1).

Neuman ,W.L.(2012) Designing the Face to Face Survey Interview,Handbook of survey methodology(pp227-248). Lior Gideon

OECD/FAO (2016), "Agriculture in Sub-Saharan Africa: Prospects and challenges for the next decade", inOECD-FAO Agricultural Outlook 2016-2025, OECD Publishing, Paris.DOI: http://dx.doi.org/10.1787/agr_outlook-2016-5-en

Onyekuru, N. A. and R. Marchant. (2017). Climate change perception, awareness and adaptation decision among forest communities in Nigeria. Agro-Science Journal of Tropical Agriculture, Food, Environment and Extension, 16(3): 51 – 62

Patt AG, D Schröter (2008) Perceptions of climate risk in Mozambique: implications for the success of adaptation strategies glob environ chang.18:458-467.

PNUD. (2013). « Rapport sur le développement humain 2014. Pérenniser le progrès humain: réduire les vulnérabilités et renforcer la résilience », New York.

Price, J.C., Walker, I.A., and Boschetti, F. (2014) Measuring cultural values and beliefs about environment to identify their role in climate change responses. Journal of Environmental Psychology 37, 8–20. doi: 10.1016/j.jenvp.2013.10.001[13]

Scheier, M. F., G. J. S. Magovern., R. A. Abbott, , K. A.Matthews, J. F.Owens, R. C.Lefebvre and al. (1989). Dispositional optimism and recovery from coronary artery bypass surgery: the beneficial effects on physical and psychological well-being. Journal of Personality and Social Psychology, 57, 1024-1040.

Serdeczny, O., S.Adams, F. Baarsch, D. Coumou, A.Robinson, W. Hare, … , J. Reinhardt. (2017). Climate change impacts in Sub-Saharan Africa: From physical changes to their social repercussions. Regional Environmental Change, 17(6), 1585–1600. https://doi.org/10.1007/ s10113-015-0910-2.

Spear. D, J. C. Selato, B. Mosime and A. M. Nyamwanza (2019). Harnessing diverse knowledge and belief systems to adapt to climate change in semi-arid rural Africa. *Climate Services*, Volume 14, Pages 31-36.

Taylor, S. E. (1988). The availability bias in social perception and interaction. In Judgment Under Uncertainty: Heuristics and Biases, ed. D. Kahneman, P. Slovic and k Tversky, 190-200. Cambridge, UK: Cambridge University Press.

Weber Elke U. (2016).What shapes perceptions of climate change? New research since 2010

Weber E.U. (2010) What shapes perceptions of climate change? Wiley Interdiscip Rev Clim Chang 1(3):332–342

Wheeler, T. and von Braun, J. (2013) Climate Change Impacts on Global Food Security. Science, 341, 508-513.

Woods B.A., H. Ø. Nielsen, A.B. Pedersen and D. Kristofersson [2017]: Farmers' perceptions of climate change and their likely responses in Danish agriculture . Land Use Policy 65:109-120.