Smallholder farmers' perception of climate change and multiple adoption of adaptation strategies in Côte d'Ivoire

ABSTRACT

Climate change is a global concern today due to its impacts on all aspects of life. This study analyzes the perceptions of smallholder cocoa farmers on climate change and their subsequent adaptation strategies in the Zanzan district of northeastern Côte d'Ivoire. Data collected from 322 randomly selected smallholder farmers were analyzed using a multivariate Probit. The results indicate that farmers perceive climate change through changes in climatic parameters such as rainfall, temperature and winds. To adapt to these changes, farmers adopt several strategies that are either complementary or substitutable from their point of view. The most widespread adaptation strategies in the study area are fallow, staking, shifting the sowing period and crop rotation. This multiple adoption is linked to several factors including the gender of the producer, his level of education, the possession of cereal crops, the presence of soil restoration programs in the locality. The study recommends strengthening meteorological and climate information systems and disseminating knowledge in order to increase awareness of climate change and integrate adaptation strategies into local management plans.

Key words :*Adaptation; climate change; perception; small cocoa farmers.*

INTRODUCTION

Climate variation, which is becoming increasingly important, has now become a major global issue. The threats associated with this variation are visible throughout the world, and are most pronounced in vulnerable regions of Africa, which condition the socio-economic and environmental systems in these countries (GIEC, 2014). According to studies by the (FAO, 2024), the effect of climate change has a direct impact on the economies of African countries, given that agriculture contributes 20% to 30% of Gross Domestic Product (GDP) and a total value of around 50% of exports in Africa. To this end, the repercussions of climate variability on agricultural activity could influence household living standards, due to the expected increase in the price of agricultural products, and consequently a rise in household consumption prices. According to the IPCC (2014), 8% of current agricultural land will become climatically unsuitable by 2100, and up to 30% according to the most pessimistic scenario. Yields of major crops such as corn, soy, rice and wheat are already being affected.

Côte d'Ivoire, like all countries in West Africa and around the world, is experiencing climatic variation that is leading to a considerable drop in agricultural yields, changes in agricultural calendars, the abandonment of certain crops and the loss of many seeds (N'da et al., 2016). This climatic variability has a strong impact on the agricultural sector due to increasingly unfavorable weather conditions, likely to damage agriculture (Sohou et al., 2020), which has negative repercussions on the country's socio-economic development. In one of the World Bank's reports (2018), it is stated that in the long term, climate variation will decrease the production of certain key crops in Côte d'Ivoire. This decrease in production linked to climatic hazards could reduce Côte d'Ivoire's GDP by 2 to 4% by 2040 and between 10 and 25% by 2100, which would correspond to an equivalent loss of 380 to 770 billion (IPCC, 2018).

Projections indicate that these phenomena will continue to worsen in the coming years if nothing is done. Côte d'Ivoire is currently feeling the impact of climate change on its economy, environment and society. According to the PNCC (2015), the sectors most vulnerable to climate change in Côte d'Ivoire, in order of importance, are: agriculture, health, fisheries, energy, water resources, livestock, forestry-wildlife, housing, transport, industry and education. The negative effects on production systems, especially agriculture, natural resources and people's quality of life are set to grow. Hence the need for Côte d'Ivoire to put in place tools to measure the vulnerability of its populations, in order to consider measures to adapt and mitigate the effects of climate change. With this in mind, and taking into account the opportunities presented by actions to mitigate and adapt to climate change, the government has decided to adopt a national strategy to combat climate change. The aim of this policy is to identify climate change issues and response strategies.

Understanding of climate change and its impacts has progressed over the years. However, gaps remain in knowledge and know-how. Adaptation interventions must be based on the most reliable and factual knowledge to identify the risks of climate change on different sectors, including agriculture. Today, climate change represents one of the major challenges facing small-scale farmers, particularly in the Zanzan district of Côte d'Ivoire. How do small-scale producers in the Zanzan district perceive climate change in their area? What strategies are they adopting to adapt to climate change? What factors influence the adoption of strategies? Are there any links between the strategies adopted by producers? These are the questions guiding this study.

The objectives of this study are as follows:

General objective: Analyze the determinants of adoption of adaptation strategies in the face of climate change.

The general objective is subdivided into three specific objectives:

Specific objective 1 : Describe small-scale producers' perceptions of climate change.

Specific objective 2: Distinguish relationships between different adaptation strategies.

Specific objective 3: Examine the factors involved in the multiple adoption of adaptation strategies by small-scale farmers in the face of climate change.

In the literature, most authors define climate change perception as the observation of climate change in specific environmental aspects through sensory stimuli and the awareness of climate change effects (Troncarelli et al., 2023). These effects can be increases or reductions in factors such as precipitation, drought, temperature and/or biophysical indicators, as well as others linked to change, such as plant flowering.

Several authors indicate that gender (Falaki et al. (2013), level of education (Poortinga et al (2019) and age (Roco et al., (2015) are among the factors that influence producers' perception of climate change. To adapt to climate change, farmers diversify their crops, modify planting days according to changes in rainfall, plant trees, practice polyculture and generate income from other sources [Juana et al., 2013; Partey et al., 2018).

Dang et al. (2019) have grouped factors in the adoption of adaptation strategies into five categories. The first consists of demographic and socio-economic factors (Pauw, 2013; Sarker, Alam, & Gow, 2013; Shiferaw, 2014). According to Dang et al. (2019), as adaptation to climate change is a complex process involving the characteristics of climatic attributes and agricultural systems, demographic and socioeconomic factors must be included as influencing factors. The second category concerns resources, services and technologies (Antwi-Agyei et al., 2015; Biggs et al., 2013). The third category concerns institutional and political factors (Shiferaw, 2014). Institutional factors have been shown to be important for adaptation. The fourth category consists of social and cultural factors (Jones & Boyd, 2011; Nielsen & Reenberg, 2010). The fifth category consists of cognitive and psychological factors (Grothmann and Patt, 2005; Grothmann and Reusswig, 2006).

2. METHODOLOGY

2.1. Data

The data for this study come from a survey commissioned by the FAO in 2023 in the Zanzan district. The aim of the survey was to gather data on the vulnerability of rural populations to climate change. The target population was small-scale producers in the Bounkani and Gontougo regions. The sampling technique used in this study was purposive sampling. The selection criterion was based on the farmer's knowledge of climate change and the adaptation strategies used on the plots. Villages were selected on the basis of their geographical position, in order to cover all regions and existing agro-ecological zones, the importance of the climate change issue in the country's agricultural production, the representativeness of socio-cultural groups and accessibility during the study period.

This study focused on two types of data: quantitative and qualitative. Overall, 14 villages were visited in the 2 regions of the Zanzan district and 339 small-scale producers were surveyed (see table 1). However, after the questionnaires had been tabulated, 17 forms were removed due to numerous omissions or non-responses. In all, 322 producers were retained. The socio-demographic and economic characteristics of the producers surveyed, the characteristics of the plots farmed, the types of crops and labor used on the plots, indicators of climate change perception, the perceived or experienced effects of climate change on agriculture and producers' adaptation strategies are among the data collected in this study. Producers' perceptions of climate change relate to three (3) main climatic parameters. These are rainfall, temperature and wind. Farmers' strategies for adapting to climate change are numerous and vary from one area to another, depending on their technical capabilities. They involve changes in land use and climate-smart farming practices, which will be detailed in the following sections.

2.2. Analysis method

All the analysis in this document is done at the farmer level. In this study, a multivariate Probit model is used to identify the determinants of the adoption of adaptation strategies in the face of climate change and determine the link between adaptation strategies. Five adaptation strategies were selected: crop rotation, resistant varieties, delayed sowing, staking, shallow ploughing and fallow. The empirical specification of the decision to adopt climate change adaptation strategies will be represented by a multivariate probit regression. The advantage of this model over the multinomial probit is that compliance with one agreement by a producer does not exclude compliance with other agreements. One of the underlying assumptions of multivariate models is the independence of irrelevant alternatives, i.e. that the error terms in the choice equations are mutually exclusive (Greene & Hensher 2003). These models take into account any simultaneous correlation in the choice of simultaneously accessing the 5 coping strategies. In the literature, several studies have already used multivariate probit, notably to assess the factors influencing the adoption of agricultural technologies (Gillespie et al. 2004; Sigue et al., 2019). Gillespie et al. (2004) argue that multivariate probit modeling enables more efficient estimation when choices are simultaneous. The multivariate probit is as follows:

$$\begin{cases} Y_{i1} = \beta_1 X_{ij1} + \varepsilon_{i1} \\ Y_{i2} = \beta_2 X_{ij2} + \varepsilon_{i2} \\ Y_{i3} = \beta_3 X_{ij3} + \varepsilon_{i3} \\ Y_{i4} = \beta_4 X_{ij4} + \varepsilon_{i4} \\ Y_{i5} = \beta_5 X_{ij5} + \varepsilon_{i5} \end{cases} \quad (1)$$

With i representing the grower, X_i =vectors of factors affecting the decision whether or not to adopt an adaptation strategy (socio-demographic variables, plot characteristics, institutional factors), β_j=vector of unknown parameters (j = 1, 2, 3, 4, 5) and ε is the error term. With i representing the producer, X_i= vectors of factors affecting the decision whether or not to adopt an adaptation strategy (socio-demographic variables, plot characteristics, institutional factors), β_j=Vector of unknown parameters (j = 1, 2, 3, 4, 5) and ε is the error term.

To test the hypothesis, we adopt a multivariate model of the following form:

$$Y_{ij} = \beta_j X_{ij} + \varepsilon_{ij} \quad (2)$$

With Y_{ij}(j = 1, 2, 3, 4, 5, 6) representing the 6 climate change adaptation strategies for producer i ranging from 1 to 322 (number of producers). X_{ij}represents a 1 x k vector of observed variables affecting producers' adoption decision and $\beta_j$is a 1 x k vector of unknown parameters to be estimated. $\varepsilon_{ij}$is the unobserved error term.

The unknown parameters in equation (2) are estimated using maximum likelihood under the assumption that the error terms are multivariate and normally distributed with a mean vector equal to zero. The covariance matrix is as follows:

$$\begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \\ \varepsilon_5 \end{pmatrix} \Bigg| X \sim N\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & rho_{12} & rho_{13} & rho_{14} & rho_{15} \\ & 1 & rho_{23} & rho_{24} & rho_{25} \\ & & 1 & rho_{34} & rho_{35} \\ & & & 1 & rho_{45} \\ & & & & 1 \end{pmatrix}\right] \quad (3)$$

Where $rho_{12}, rho_{13}, rho_{14}, rho_{15}$, rho_{23}, rho_{24}, rho_{25}, rho_{34}, rho_{35} et rho_{45} are residue pairs $(\varepsilon_1, \varepsilon_2)$, $(\varepsilon_1, \varepsilon_3)$, $(\varepsilon_1, \varepsilon_4)$, $(\varepsilon_1, \varepsilon_5)$, $(\varepsilon_2, \varepsilon_3)$, $(\varepsilon_2, \varepsilon_4)$ $(\varepsilon_2, \varepsilon_5)$, $(\varepsilon_3, \varepsilon_4)$, $(\varepsilon_3, \varepsilon_5)$ et $(\varepsilon_4, \varepsilon_5)$.

This model controls for unobservable heterogeneity between different coping strategies. In the presence of unobservables that influence decisions to adopt adaptation strategies, the model is able to account for these effects. For example, if we assume that rho_{23} represents the correlation coefficient between the residuals of the strategy of using resistant varieties and the strategy of shifting sowing and that it is significantly positive, then the unobservable characteristics that increase the probability of adopting the strategy of resistant varieties are the same as those that increase the probability of adopting the strategy of shifting sowing. If, on the other hand, this coefficient is negative, then the unobservable factors that increase the probability of adopting resistant varieties reduce the probability of adopting delayed sowing.

We used stata's mvprobit command to run the model.

The explanatory variables used in the adoption model are defined in Table 1 below.

Table 1 : Variables used in the adaptation strategy adoption model

Variables	Definitions
Gender	Binary variable, takes the value 1 if the producer is a woman and 0 otherwise
Educated	Binary variable, takes value 1 if producer is educated and 0 otherwise
Single	Binary variable, takes value 1 if producer is single and 0 otherwise
Household	Continuous variable, representing the number of people in the household
Agriculture	Binary variable, takes the value 1 if the producer is a farmer and 0 otherwise
Agropastoral	Binary variable, takes the value 1 if the producer is an agropastoralist and 0 otherwise
Off-farm	Binary variable, takes the value 1 if the producer has off-farm activities and 0 otherwise
Experience	Continuous variable, representing the number of years of farming experience (in years)
Age	Continuous variable representing the age of the farmer (in years)
Plot size	Continuous variable representing plot size (in ha)
Group	Binary variable, takes value 1 if producer belongs to a group and 0 otherwise
Plateau	Binary variable, takes value 1 if the producer's plot has a plateau relief and 0 otherwise
Program	Binary variable, takes value 1 if there is a land reclamation program in the area and 0 otherwise
Equipment	Continuous variable representing the number of agricultural equipment

Variables	Definitions
	owned by the farmer.
Maize	Binary variable, takes value 1 if producer grows corn and 0 otherwise
Yam	Binary variable, takes value 1 if producer grows yams and 0 otherwise
Vegetables	Binary variable, takes value 1 if grower grows vegetables and 0 otherwise
Cash crops	Binary variable, takes value 1 if producer has cash crops and 0 otherwise
Flooding	Binary variable, takes value 1 if producer has already been flooded on plot and 0 otherwise
Drought	Binary variable, takes value 1 if producer has already suffered drought on plot and 0 otherwise
Strong wind	Binary variable, takes the value 1 if the grower has already suffered wind damage on the plot and 0 otherwise
Gontougo	Binary variable, takes value 1 if producer resides in Gontougo and 0 otherwise

Source : Authors

3. RESULTS AND DISCUSSION

3.1. Descriptive analysis

3.1.1. Perception of climate change parameters

To understand growers' adaptive behavior, it is vital to assess their perception of climate change (Wang et al. 2014). Growers perceive climate change through climatic parameters. In this study, climate change is defined as perceived changes in average temperatures, winds and precipitation over the past 20 years. Consequently, respondents' perception of climate change is based on their farming experience over the past 20 years. Out of a total of 322 growers surveyed across the two regions, 99.38% of growers are aware of changes in climatic conditions, based on perceived changes in temperatures, winds and precipitation. Table 2 shows that the growers surveyed observe climate changes in the form of lower precipitation (78.88%), higher temperatures (93.79%) and higher wind intensity (84.47%). Some growers also observed an increase in precipitation (21.12%) and an increase in drought (97.52%).

These results on the perception of changes in climatic parameters are the same as those found by several authors (Niles et al, 2016; Vani, 2016, Jamshidi et al. 2019) in various socio-economic contexts.

Table 2: Growers' perceptions of climate change

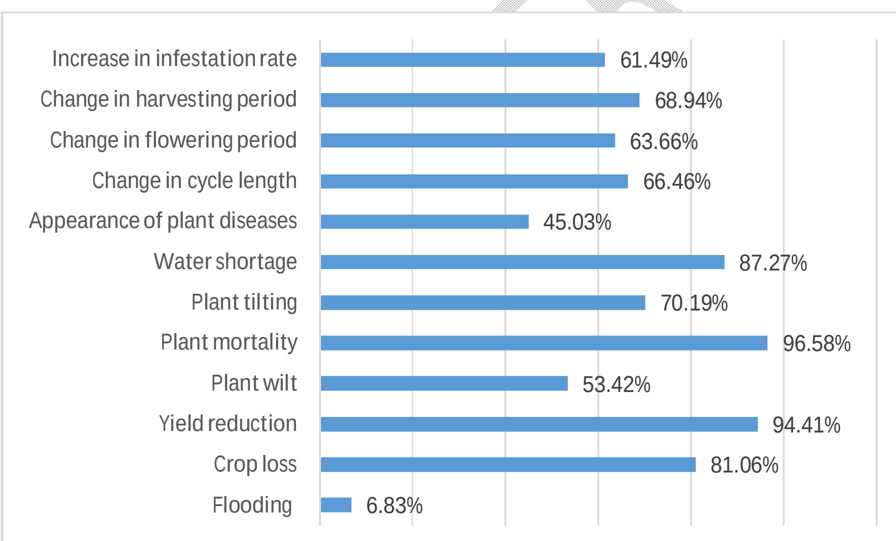
Perceived climate change	Frequency	Percentage
Climate change	320	99.38
Change in rainfall	305	94.72
Rainfall Increasingly lighter	254	78.88
Increasingly heavy rainfall	68	21.12
Temperature rise	302	93.79
Variation in wind	272	84.47
Stronger wind	272	84.47
Change in drought	314	97.52

Source : Author

3.1.2. Indicators justifying producers' perceptions of climate change

Growers' perceptions of climate change in the study area are based on multiple indicators they have observed on their farms. Figure 1 shows that 94.41% of growers observed a drop in crop yields, 96.58% observed plant mortality, 87.27% observed water shortages on farms and 81.06% observed crop losses due to changing climatic conditions. This reduction in the quantity of agricultural produce was attributed to the low rainfall in the regions and the rise in temperatures. These results are consistent with those of Kalungu et al. (2013) and Nyang'au et al. (2021), where respectively 80% and 84.20% of sampled farmers perceived changes in productivity in recent years. As a result of the variation in climatic parameters, some growers noted plant inclinations (70.19%), changes in harvesting period (68.94%), changes in the length of crop cycles (66. 46%), changes in crop flowering period (63.66%), increased plant infestation rate (61.49%), plant wilting (53.42%), outbreak of plant diseases (53.42%) and plot flooding (6.83%), often in lowlands.

Figure 1 : Indicators supporting growers' perceptions of climate change



Source : Autors

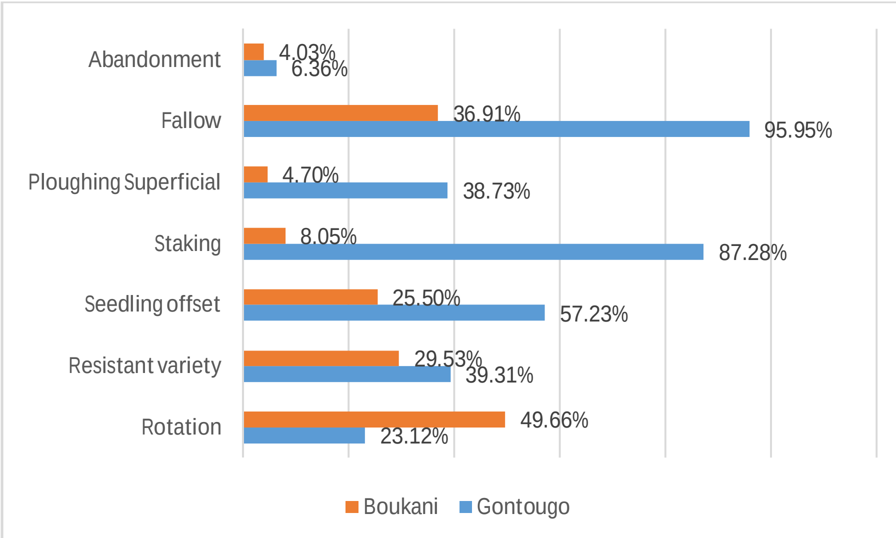
3.1.3. Description of climate change adaptation strategies adopted by producers

The adoption of climate change adaptation strategies by growers varies by region. Figure 2 shows that 7 main adaptation strategies are used by growers to cope with climate change in their different regions:

- Fallowing: this is the dominant strategy in the Gontougo region (95.95%), compared with 36.91% in the Bounkani region. Land use decisions for agricultural production are the main contributors to greenhouse gas emissions in the agricultural sector (MINEDDTE, 2022). Deforestation and soil erosion have been identified as major agricultural practices that contribute to climate change (Nyang'au et al. 2021). This result is consistent with Oladipo's (2010) findings that to improve farmer resilience and mitigate climate change, farmers need to make better land-use decisions ;
- Staking: 87.28% of growers in Gontougo have adopted this strategy, compared with 8.05% in Bounkani;
- Staggered sowing: 57.23% of growers in Gontougo adopted this strategy, compared with 25.50% in Bounkani. Other farmers preferred to change the sowing date, due to the late arrival of the rains, as farmers are obliged to move their sowing date to the period when the first rains are observed, when they were sure there was sufficient moisture in the soil to support growth. This result is in line with that of Olabanji et al. (2021) in the case of South Africa and Nyang'au et al. (2021) in the case of Kenya ;
- Use of resistant varieties: 39.31% of growers in Gontougo adopted this strategy, compared with 29.53% in Bounkani. This result is in line with that of Kalungu et al. (2013) where growers in Kenya stopped growing certain crops due to low yields associated with low rainfall and opted for early-maturing, drought-resistant crop varieties;
- Shallow tillage: 38.73% of farmers in Gontougo have adopted this strategy, compared with 4.70% in Bounkani. This practice is a soil conservation technique, but it is not widely used in the study area, especially in Bounkani, due to the arduous nature of the activities. This result is in line with that of Nyang'au et al (2021), where 56% of farmers use soil conservation techniques.
- Crop rotation: 23.12% of farmers in Gontougo have adopted this strategy, compared with 49.66% in Bounkani. This result is in line with that of Nyang'au et al. (2021) who show that 77.6% of farmers sampled in the Kenyan study area practice crop rotation or polyculture to increase productivity.
- Plot abandonment: 6.36% of growers in Gontougo adopted this strategy versus 4.03% in Bounkani.

These results are the same as those found by Olabanji et al. (2021) and Asrat and Simane (2018), who find that growers in northeastern South Africa and northwestern Ethiopia respectively adopt several adaptation strategies at once in order to strengthen their resilience to climate change.

Figure 2 : Main adaptation strategies adopted by region



Source : Authors

As we can see, the strategies adopted by growers are largely made up of climate-smart farming practices. Perceived climate change may influence the promotion and adoption of these practices. Better adoption of these practices will increase farmers' resilience to climate change, boost productivity and reduce greenhouse gas emissions (Nyang'au et al. 2021). However, the choice of strategy is influenced by the opportunities and constraints available to farmers. These opportunities or constraints are in turn influenced by various factors beyond the farm household scale, at community, landscape and regional levels (Tittonell, 2014).

3.2. Analysis of the determinants of the adoption of climate change adaptation strategies

3.2.1. Links between different adaptation strategies

The (positive) likelihood ratio test justifies estimating the multivariate probit rather than five independent probits (table 3). The null hypothesis (H0) of independence can be rejected (p value < .00001). Moreover, the coefficients are significant overall. Table 3 also shows that all the coefficients of the error terms are significant, with the exception of those between the resistant variety strategy and fallow (rho51), between the staking strategy and delayed sowing (rho32), between the fallow strategy and delayed sowing (rho52) and between the fallow strategy and minimum tillage. The significance of these coefficients justifies the use of a quadrivariate probit.

We find that seeding delay is negatively and significantly correlated with the resistant variety strategy and the minimum tillage strategy. We deduce that there is a substitutability relationship between the delayed seeding, resistant variety and minimum tillage strategies. This means that when a grower uses the staggered sowing strategy, it significantly reduces the probability of using the resistant variety and minimum tillage strategies. This is explained by the fact that by shifting the sowing period, the grower waits for the climate to be favorable for his seed and habit. The resistant variety strategy is positively and significantly correlated with the staking and minimum tillage strategies. Similarly, the staking strategy is positively and significantly correlated with the minimum tillage and fallow strategies. This shows that there is a complementary relationship between these strategies. The use of varieties resistant to climatic shocks increases the adoption of staking and minimum tillage strategies. The adoption of staking also increases the probability of using minimum tillage and fallow. Thus, some strategies are substitutable, while others are complementary from the growers' point of view.

3.2.2. Factors determining the multiple adoption of climate change adaptation strategies

The factors explaining the multiple adoption of climate change adaptation strategies are summarized in Table 3. The results reveal that the gender of the farmer, the level of education, the practice of agro-pastoral farming, off-farm activities, the size of the plot, the relief of the plot, the presence of a land reclamation program in the area, the number of farm equipment, production of maize, yams, vegetables and cash crops, experience of flooding, drought and wind damage in the past and geographical location are the factors that influence the multiple adoption of climate change adaptation strategies.

Categorical variables have a category as a reference for interpretation. The coefficient associated with a category of a given variable therefore represents the impact of change in the category concerned compared with the reference category on the probability of adopting a given strategy. Interpretation of the coefficients is more difficult than for linear regression models, due to the non-linearity of the probability. The coefficients cannot be understood as the result of the marginal effects of changes in the explanatory factors on the variable concerned. All that remains are the changes in sign and the significance of the coefficients.

The results in table 3 show that the factors influencing the adoption of adaptation strategies are not the same. Being female has a negative and significant influence on the probability of adopting staggered sowing and staking strategies. These results are contrary to those of Olabanji et al. (2021) and Asayehegn et al. (2017). These authors find that the gender of the grower has no effect on the adoption of climate change adaptation strategies. In our study area, given the level of knowledge required for staking during high winds, only men engage in it, but women prefer to give up. What's more, because of the numerous occupations within the household, women cannot shift the sowing period.

The farmer's level of education has a negative and significant influence on the probability of adopting resistant varieties and minimum tillage, but has a positive and significant influence on the adoption of the staggered sowing strategy. These results are contrary to those of Chemeda et al. (2023), who find that the level of education of farmers in southern Ethiopia increases the probability of adoption of soil conservation strategies such as minimum tillage and the improved variety strategy. However, our result is in line with that of Nyang'au et al. (2021) who find that education level was negatively corollated with the adoption of climate resilient varieties among growers in southern Kenya. In our study area, the education received by farmers has no connection with agriculture. It cannot therefore be a sufficient lever for the adoption of climate change adaptation strategies.

Agropastoral practice increases the probability of adopting strategies such as staggered sowing and fallowing, but reduces the probability of adopting resistant varieties. This result is in line with that of Asrat and Simane (2018), who find that agropastoral practice increases the probability of adoption of adaptation strategies. The agropastoralists in our study area had the financial means to practice fallowing, aiming for income from their livestock.

Possession of off-farm activities had a negative and significant influence on the probability of adopting the minimum tillage strategy. These results are contrary to those of Asayehegn et al. (2017) and Yegbemey et al. (2020). Asayehegn et al. (2017) show that off-farm activities have a positive influence on the adoption of the mixed strategies of seed diversification, variety change and irrigation. For these authors, income from off-farm activity can be used to increase the level of investment in inputs such as labor, fertilizers and pesticides, and new varieties. In our study area, producers with off-farm activities do not have enough time to invest in climate change adaptation strategies.

Plot size has a negative effect on the probability of adopting the staggered sowing strategy. The larger the plot size, the less likely the farmer is to adopt the staggered planting strategy. This result is contrary to that of Chemeda et al. (2023), who find that plot size increases the probability of adoption of water and soil management strategies, crop management (staggered sowing dates, resistant varieties) and intensive farm management. In our study area, this can be explained by the fact that the larger the plot size, the greater the investment in terms of climate change adaptation strategies. This discourages growers from adopting such strategies.

Plot relief has an influence on the adoption of climate change adaptation strategies. Plateau-type plots positively and significantly influence the adoption of minimum tillage, but negatively and significantly the fallow strategy. This result is in line with that of Asrat and Simane (2018), who find that plot relief type influences the adoption of climate change adaptation strategies. These authors argue that farmers invest in adaptation measures in plots where they expect greater risk from climate hazards.

The existence of soil improvement programs has a significant negative influence on the adoption of delayed sowing strategies. In fact, these programs provide growers with skills and reinforce their ability to anticipate soil degradation using appropriate techniques. As a result, growers are no longer obliged to stagger sowing periods. These results are in line with those of Chemeda et al. (2023), who found that the presence of extension services in farmers' areas had a negative and significant influence on the adoption of strategies such as agroforestry and climate-resistant varieties, but positively affected the probability of fertilizer use.

The number of farming equipment owned by the farmer has a positive and significant influence on the probability of adopting the staggered sowing strategy, but has a negative influence on the probability of adopting the staking strategy. This result is in line with that of Kaboré et al. (2019). These authors indicate that the small tools available to growers enable them to adopt a number of strategies. In our study area, producers with their own farming equipment have the latitude to shift the initial sowing period due to climate change in order to take advantage of the moment they deem favorable. As a result, they do not consider it necessary to adopt staking.

Maize production has a positive and significant influence on the probability of adopting resistant varieties and minimum tillage, while it has a negative and significant influence on the probability of adopting staggered sowing and fallow strategies. This result highlights the complementarity of certain strategies and the substitutability of others from the growers' point of view. This result is in line with that of Yegbemey et al (2020), who showed that the production of cereals such as rice increased the adoption of climate change adaptation strategies, due to the very high sensitivity of these crops to rainfall. The technical itinerary for maize cultivation requires minimum ploughing and the use of resistant varieties to improve crop yields.

Yam production has a positive and significant influence on the probability of staking adoption. This result is logical, as this technique is widely used by growers to maintain yam plants in the event of strong winds. Similarly, legume production has a positive and significant influence on the probability of adopting the staking strategy. This result is contrary to that of Yegbemey et al. (2020), who found that legume production had a negative and significant impact at the 5% threshold on the farmer's decision to adapt to climate change in southern Niger. They explain this by the fact that legumes are hardy and, due to their non-moisture-demanding vegetative cycle, are not very sensitive to climatic variability. However, in our study area, staking is increasingly used to protect short-rooted crops against the effects of climate change.

Cash crop production has a positive and significant influence on the probability of adoption of resistant varieties and fallowing. Several distribution programs for improved or resistant seed exist in the study area to guarantee the grower a good yield. In addition, some growers, due to soil exhaustion, choose to rest the soil in order to improve productivity. These results highlight the fact that growers adapt according to the agricultural crops they produce on their plot. The more sensitive a crop is to the effects of climate change, the more likely the grower is to apply adaptation strategies.

Past experiences of the effects of climate change have an impact on producers' climate change adaptation behaviors. Past experience of farm flooding has a negative and significant influence on the probability of adopting the staggered sowing strategy, but a positive and significant influence on the adoption of minimum tillage. In fact, plots that have been flooded once are easy to plough with small implements, without the need for tractors. What's more, given the high risk of flooding on these plots, growers don't want to run the risk of postponing the sowing period for fear of destroying the crop after planting in the event of heavy rain. In the same way, plots that have experienced drought in the past have a positive and significant influence on the probability of adopting delayed sowing. This is all the more understandable as these plots are highly exposed to water shortages. As a result, growers wait for the right period, corresponding to the onset of the first rains, to start sowing. Past experience of strong winds has a positive and significant influence on the probability of adopting the fallow strategy. Growers prefer to let plots rest after destructive winds, often for fear of further production losses.

Finally, geographical location had a positive and significant influence on the probability of adopting climate change adaptation strategies. This result is contrary to that of Olabandji et al. (2021), who found that the geographical location of farms had no effect on the probability of adopting adaptation strategies. It appears that farmers in the Gontougo region apply several coping strategies compared to those in Bounkani. This could be explained by the fairly developed economic environment in Gontougo, which facilitates the actions of agricultural supervisors and the presence of several development projects.

Table 3 :Multivariate probit results on adaptation strategy adoption factors

Variables	Resistant variety	Sowing time offset	Staking	Minimum tillage	Fallow land
Gender	0.23(0.254)	**-0.37*(0.20)**	**-0.83*(0.47)**	-0.07(0.37)	-0.49(0.38)
Age	-0.01(0.01)	-0.00(0.01)	-0.01(0.01)	0.00(0.01)	0.01(0.01)
Educated	**-0.31*(0.16)**	**0.21*(0.12)**	-0.03(0.22)	**-0.35*(0.20)**	-0.26(0.21)
Single	0.21(0.33)	-0.01(0.20)	-0.46(0.48)	-0.56(0.41)	-0.10(0.39)
Household	-0.00(0.01)	-0.01(0.01)	0.01(0.02)	-0.00(0.02)	-0.01(0.02)
Agriculture	0.44(0.39)	-0.03(0.18)	-0.37(0.41)	0.27(0.53)	0.28(0.34)
Agropastoral	**-1.05***(0.29)**	**0.66***(0.14)**	-0.16(0.34)	-0.20(0.32)	**0.52*(0.27)**
Off-farm	-0.33(0.21)	0.25(0.16)	0.10(0.29)	**-0.77***(0.30)**	0.20(0.28)
Experience	-0.01(0.01)	0.01(0.01)	0.01(0.01)	-0.01(0.01)	-0.01(0.01)
Plot size	0.02(0.02)	**-0.04**(0.01)**	-0.02(0.03)	-0.01(0.02)	-0.01(0.02)
Group	0.06(0.16)	-0.16(0.11)	0.24(0.25)	-0.08(0.21)	-0.13(0.23)
Plateau	0.01(0.17)	-0.13(0.13)	0.22(0.24)	**0.52**(0.23)**	**-0.55**(0.25)**
Program	-0.18(0.32)	**-0.30**(0.14)**	-0.07(0.36)	-0.01(0.36)	0.31(0.32)
Equipment	0.01(0.12)	**0.18*(0.10)**	**-0.79*(0.45)**	0.08(0.20)	0.22(0.19)
Maize	**0.81***(0.17)**	**-0.60***(0.12)**	0.34(0.28)	**0.80***(0.24)**	**-0.57**(0.24)**
Yam	-0.05(0.20)	-0.12(0.14)	**0.50*(0.31)**	-0.18(0.28)	0.22(0.24)
Vegetables	0.07(0.16)	0.14(0.11)	**0.44*(0.27)**	0.13(0.21)	-0.25(0.22)
Cash crops	**0.56*(0.32)**	-0.01(0.14)	0.53(0.42)	0.14(0.36)	**0.79**(0.35)**
Flooding	0.36(0.24)	**-0.56***(0.17)**	0.31(0.37)	**0.61**(0.28)**	-0.54(0.37)
Drought	0.19(0.49)	**0.87***(0.23)**	0.45(0.68)	-0.64(0.58)	0.73(0.51)
Strong wind	0.18(0.20)	-0.21(0.17)	-0.23(0.29)	-0.07(0.22)	**0.75**(0.34)**
Gontougo	**0.56**(0.22)**	**0.51***(0.15)**	**3.17***(0.50)**	**1.75***(0.32)**	**2.22***(0.33)**
_cons	**-2.01**(0.84)**	-0.78(0.52)	-1.21(1.25)	-1.71(1.10)	**-2.43**(0.98)**
Observation	322				
Log likelihood	-589.12				
Significance of the model	Wald chi2(110) = 629.38; Prob > chi2 = 0.0000				
rho21	-0.993***				
rho31	0.240**				
rho41	0.542***				
rho51	-0.083				
rho32	-0.198				

rho42	-0.522***
rho52	0.151
rho43	0.265*
rho53	0.435***
rho54	-0.099
Likelihood ratio test	rho21 = rho31 = rho41 = rho51 = rho32 = rho42 = rho52 = rho43 = rho53 = rho54 = 0: chi2(10) = 174.353 Prob > chi2 = 0.0000

Source : Authors

4. CONCLUSIONS AND RECOMMENDATIONS

Do small-scale farmers in Côte d'Ivoire perceive climate change? Are they adopting strategies to adapt to climate change? This is the main research question to which this study was intended to provide some answers. Perception analysis showed that growers perceive climate change through variations in climatic parameters such as rainfall, temperature and winds. In addition, the estimation of a multivariate probit model enabled us to identify the links between the different strategies adopted by growers to cope with climate change, and the factors that explain the adoption of these strategies by growers. The results revealed complementary links between certain strategies, such as staking, minimum tillage and fallowing, and substitutability links between other strategies, such as the resistant variety, delayed sowing and minimum tillage.

With regard to the factors explaining the multiple adoption of coping strategies, the results reveal that the gender of the producer, the level of education, the practice of agro-pastoral farming, off-farm activities, the size of the plot, the relief of the plot, the presence of a land reclamation program in the area, the amount of agricultural equipment, production of maize, yams, vegetables and cash crops, experience of flooding, drought and wind damage in the past and geographical location are the factors that influence the multiple adoption of climate change adaptation strategies in different directions.

Based on these results, a number of economic policy recommendations can be made.

The first recommendation is to raise awareness of climate change. Farmers' perceptions, when matched with actual changes in weather patterns, can ensure the effectiveness of specific adaptation strategies, such as adjusting agricultural calendars, modifying fallow periods, using native or drought-tolerant varieties, and controlling pests and invasive species. Awareness of climate change can be improved by policies aimed at strengthening weather and climate information systems and disseminating knowledge.

Secondly, the study recommends the integration of climate change issues and adaptation strategies into education programs aimed at rural households, not only to improve the knowledge and skills of local communities, but also to raise awareness of the impact of climate change on agricultural productivity.

To increase the effectiveness and sustainability of adaptation interventions in the study area, the study recommends that knowledge of climate change and farmers' adaptive capacity should be part of the local development program. This can be done by the regional councils, all local stakeholders, led by the prefectoral authorities.

Notwithstanding the results of this study, there are a number of limitations that deserve to be explored in future studies. Firstly, the study did not measure the impact of producers' perceptions of climate change on their farm management decisions, notably on the quantities of seed used, the area to be sown, and the amount of labor to be employed, to name but a few. Secondly, the study did not take into account the impact of adaptation measures on yields and, above all, on the profits of producers who sell part of their harvest. It may happen that the adoption of adaptation measures is linked to high costs that reduce producers' profits. This could discourage any desire to adapt.

Disclaimer (Artificial intelligence)

Option 1:

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

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