Adaptations of market garden producers to climate change in southern Mali

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Abstract This article aims to determine the factors that influence the choice of adaptation measures by market gardeners in the extreme south of Mali in the face of climate change. To this end, interviews with 194 producers were conducted in three cercles of the southern region: Sikasso, Koutiala and Bougouni. The study revealed that access to information on weather forecasts and improved agricultural technologies; easy access to resources and financial services were the main constraints to climate change adaptation for vegetable producers in the study area. The study also used the multinomial logit regression model based on the data collected from the farmers. The results of the multinomial logit model indicate that the mode of access to land, access to information on climate change, agricultural extension, agricultural experience and access to credit constitute the main endogenous strategies developed by the producers to counteract the impacts of climate change. Finally, in order to consolidate these different strategies developed by farmers, increased awareness campaigns among farmers on the importance of adapting to climate change should be encouraged.

Keywords Adaptation · Climate change · Multinomial logit · Southern Mali · Market gardeners

Introduction

The impacts of climate change on ecosystems are unequivocal. In many respects, agriculture is one of the most affected strategic sectors. The reason for this is the natural relationship between harvesting and climatic conditions. Moreover, the relationship between climate change and agriculture is two-way: agriculture contributes to climate change in many ways, and climate change generally has negative impacts on agriculture (IPCC, 2013). According to Seguin (2012), a warming of 2.5–3.5 °C will have potential effects on crop production. These effects will vary greatly depending on the regions and plant cover. Above this threshold, low-latitude regions will experience excessive temperatures and increased frequency of droughts. Bates et al. (2008), Hartmann et al. (2013) concur in stating that, in addition to temperature increase, climate change is associated with changes in the elements of the hydrological cycle on a large scale, such as an increase in atmospheric water vapor leading to changes in rainfall patterns, changes in the intensity of precipitation and extreme events, reduced snow cover and significant ice melt, and changes in freshwater content and soil runoff.

In West Africa, hydro meteorological disasters, particularly droughts and floods, are the most common forms of climate manifestation. The period 1930 to 1960 was considered wet, while the decade 1970–1980 was marked by droughts and the
resumption of rainfall was observed in the years 1990 to 2000 illustrate and show how vulnerable the populations in the Sahelian zone are to climate variability (ECOWAS-SSA/OECD, 2008).

Mali is considered to be one of the most vulnerable countries in the world to climate change due to its geographical location (semi-arid tropical), but also due to its economic dependence on agriculture and the recurrence of natural risks (droughts and floods). Thus, droughts and floods account for 80% of the loss of life and 70% of the economic losses related to natural hazards in sub-Saharan Africa (Bhavnani et al., 2008). Between 1951 and 1970, there was a 20% drop in comparison with the reference period 1971–2000 leading to a displacement of isohyets by 200 km towards the South (MEDD, 2018). According to the same source, the 1200 mm isohyets no longer exist on the map of Mali. This shows how irregular the rainfall regime in Mali is.

Faced with these challenges, in order to increase food and nutrition security, farming communities in Mali’s regions have developed adaptation strategies that improve the productivity, efficiency, profitability and equity of their agricultural production and marketing systems (UNDP, 2014).

At the same time, agriculture plays a prominent role in Mali’s economic and social development. Moreover, agriculture provides employment to more than 70% of the rural population and is the main source of income (Banque Mondiale, 2014). The country’s agricultural population is estimated at 16,838,767, including 8,695,181 men and 8,143,586 women in 2018 (CPS/SDR, 2018). However, the agricultural sector relies mainly on traditional practices subject to geographical and climatic conditions and variable rainfall. To compensate for the loss of crop yields due to the change in the water regime and the galloping urbanisation of Malian cities, which has resulted in a sharp increase in demand for market garden produce, due to changes in consumption habits. In this case, market gardening appears to be a sector in the making. In addition, most vegetable growing systems are not very capital intensive at the outset. Moreover, market gardening is an income-generating activity for farmers. Not only does it help improve their socio-economic living conditions and address the recurring problem of food insecurity, but it also helps to reduce the cost of production. Moreover, market gardening is still dominated by women (60% of market gardening in Mali is done by women). Despite this, women have little access to land and productive resources. In this case, market gardening appears to be a sector in the making. Moreover, most market gardening systems are initially not very capital intensive.

Moreover, market gardening is an income generating activity for the farmers. Not only does it improve their socio-economical living conditions, but it also helps them to cope with the recurrent problem of food insecurity. However, current and future climatic disturbances risk compromising the development of market gardening where agro-climatic conditions are increasingly difficult (Rushigira, 2017).

Numerous studies have been carried out on the adaptation of the agricultural sector to climate change and in various fields. Most of these studies focus on the adaptation behaviour of producers and the factors that influence their adaptation measures. The present study complements previous research by investigating vegetable crops only through multinomial regression analysis. So, this study aims to determine the impact of climate change on market gardening production in the far south of Mali through the adaptation measures actually undertaken by market gardeners. More precisely, it aims to determine the factors that influence the choice of adaptation options for small market gardeners in the communes of Sikasso, Bougouni and Koutiala. This document is structured in three main parts:

- A first part which reviews the literature on adaptation to climate change;
- A second part focused on the methods and materials used;
- A third part which will summarize the results of the analysis and highlight the prospects for improvement.

Literature review

In the literature two models are commonly used to analyse the determinants of producers’ choice or decision to make adjustments or changes, such as adopting strategies or technologies. These are the Logit and the Probit (Maddison, 2007; Hassan & Nhachena, 2008; Gbetibouo, 2009). Depending on the nature of the dependent variable (dichotomous
dummy or with more than two modalities) multinomial models are also used.

In Ethiopia, Deressa et al (2008), applied multinomial logistic regression (MNL) for the analysis of determinants of farmers’ adaptation options and perceptions of climate change in the Nile Basin of Ethiopia. The results of their estimates indicate that the level of education, gender, age and income of the head of household, access to extension services and agricultural credit, climate information, agro-ecological zone and as well as temperature all influence farmers’ choices.

Thus, farmer awareness, research on a new drought-tolerant variety, agricultural insurance, or social awareness and protection programmes can be instruments of a good climate change adaptation policy (Schlenker & Lobell, 2010). Other researchers believe that producers’ perception of climate variability would be the first step in the adaptation process (Deressa et al, 2011). The authors believe that the best response to climate change phenomena would be to understand how farmers perceive climate change in order to adjust.

In Mali, Sanogo et al (2017), collected data on 400 small farmers to elucidate farmers’ perceptions of climate change in southern Mali and the potential consequences for delivery using the multinomial logit model. Their results revealed an increase in the frequency of high winds, dust, drought, high temperatures and the number of hot days as the main indicators related to climate change.

The current level of vulnerability to climate change in developing countries in terms of adaptation is very limited due to ineffective climate policy due to low technical-logistical and financial capacity of the country to adapt to climate change (Makougoum, 2018).

Materials and methods

Choice of study areas

Located in the extreme south of Mali, the Sikasso region is bordered to the north-west by the Koulikoro region, to the north-east by the Ségou region, to the east by Burkina Faso, to the south by Côte d’Ivoire and to the west by Guinea. The region of Sikasso is divided into seven circles which are: Bougouni, Kadiolo, Kolondiéba, Koutiala, Sikasso, Yanfolila and Yorosso.

The relief is made up of hills and mountains in the south, and valleys and plains in the centre and north. The Kénédougou massif peaks at 800 m. In addition, the Sikasso region is a reservoir of the Upper Niger watershed. It is crossed by numerous rivers, tributaries of the Niger River: the Sankarani in the north which collects water and discharges it into the Niger upstream of Bamako and the Bani in the south which joins the Niger at Mopti after collecting the waters of the Baoulé, Bagoé and Banifing.

The climate is of the tropical Sudanian type, subdivided into two climatic zones: the humid Sudanian zone and the Guinean zone. This region remains the most humid in Mali and the wettest (700 to 1,200 mm/year). The average annual temperature is 27 °C. It is also characterized by its predominance in agricultural production. The choice of this zone is based on the criteria of the climatic regime and its high vegetable production. Like the other regions of Mali, the circles surveyed are among the most vulnerable zones, like all the circles in the southern region, to the manifestations of climatic phenomena. In the southern region of Mali, as in other regions of Mali, the effects of climate change are reflected in an increase in temperature, a decrease in rainfall, an increase in extreme weather events, such as droughts, floods and an increase in desertification.

The population of the southern region of Mali was estimated at 2,643,179 in 2009 and exceeded 3,336,752 in 2018, due in particular to the rural exodus, natural growth and the influx of people from the north of Mali because of insecurity and armed conflicts, which led to an explosion in the number of inhabitants, representing an average annual growth of 3.6%. Sikasso is the most populated region in Mali with 18% of the country’s population (INSTAT, 2021). It also has the highest density in the country with 37.1 inhabitants per km². The highest increases were recorded in the cercles of Kadiolo (83%), Koutiala and Yorosso (50%), and Bougouni (49%). It is also a fertile agricultural region with a favorable food security situation, and it plays a major role in the development of the economy. Despite its high agricultural productivity, this area is characterized by its high rate of Severe Acute Malnutrition (SAM): 4.5% (EDS VI, 2018). In addition, the area sown to vegetables in the southern region is 48,550 ha. In
2014, cumulative vegetable production was 1,567,356 tonnes, of which 904,501 tonnes were produced in the cold off-season. The average yield for the 2013/2014 season was 15.24 tonnes. Cumulative market garden production in this region is 634,112 t. Thus, the Sikasso region represents 40% and that of Koulikoro at the national level (INSTAT, 2014) (Fig. 1).

Sampling

The multi-stage random sampling technique was used for this study. First, three agricultural zones (Bougouni, Koutiala and Sikasso) in the far south were selected. In each agricultural zone, two communes were selected at random. In each of the communes, villages were sampled in proportion to the size of the village. Thus, five Communes were sampled in three Circles in the region. Two reasons prevailed in the choice of the communes and villages selected: the high concentration of market garden produce and the accessibility of the area.

Producers were selected from a list of households that are market gardening in the villages and this list was obtained from the World Vegetable Center (WCA) of the < Horticulture Scaling Project 2019 > program.1 A total of 224 producers were randomly selected. However, the study revealed only 194 valid responses and was used for data analysis. On the other hand, 30 people from the Commune of Sokourani in the Koutiala circle could not answer our survey, most of them had been absent at the time of our visit to the Commune (5 men and 10 women), others had moved (2 men and 5 women) and the others were either away for treatment or other reasons. Table 1 shows the distribution of the sample in the surveyed areas.

Collection method

The data collection took place in 2 stages: the pre-collection or concept clarification phase and the actual collection. The questionnaire and the interview guide were used as a guide for the collection of information. The pre-collection phase: this is a transitional phase and allows for the detection of errors in the questionnaire. Then, the choice of producers was made randomly from an exhaustive list of all the beneficiaries of the World Vegetable Center (WCA) < Horticulture Scaling Project 2019 > project.

The focus group discussions were organized to better elucidate the perceptions of producers on the climatic disturbances underway in their locality. The

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1 The project used the participatory approach to select beneficiaries by involving community leaders, lead farmers and the WorldVeg extension officer. In the selected sample there were more women than men, as women are more involved in vegetable production and marketing and their involvement will contribute significantly to household livelihoods. This allowed

Footnote 1 continued

the identification of two groups of beneficiaries: direct/primary beneficiaries and direct/secondary beneficiaries. The direct primary beneficiaries are the men and women who are trained by the project and who are committed to transferring the knowledge gained.
interview guide was used as a basis for collecting information on the aspects of climate change in its manifestations, the consequences on the environment/landscape, and the different strategies developed to cope with it. The focus groups were composed of resource persons and experienced producers with at least 15 years of experience in animal or crop production. On average, two focus groups of 10 men and 10 women were formed separately in each village in order to identify the perceptions and adaptation measures of each group. Individual interviews were then conducted with producers to understand the perceptions of other stakeholders at the local level. Using household questionnaires, data were collected. The questions focused on household and farm characteristics, infrastructure and institutional factors that may influence producers’ perceptions and use of adaptation methods. A total of 194 market gardeners were randomly surveyed.

Analytical framework and empirical specification of multinomial logistic regression model

To analyse the determinants of the choice of adaptation measures to climate variability by smallholder market gardeners, the study used a multinomial logistic regression (NLM) model. This method has been used by several researchers such as (Kurukulasuriya & Mendelsohn, 2006) and (Hassan & Nhachena, 2008), more recently by Magombo et al. (2011) and Shongwe et al. (2014) as methods of adaptation to the adverse effects of climate change. The advantage of the NLM is that when the characteristic is multiple, i.e. when it has several modalities, one can calculate the relative probabilities of encountering any one of these modalities if they are mutually exclusive.

In addition, Koch (2007) emphasises the usefulness of this model by describing the ease of interpretation of the estimates derived from it.

According to, Deressa et al. (2008) and Gbetibouo (2009) opined that the decision regarding whether or not to adopt any adaptation options is considered to be under the general framework of utility and profit maximization. Furthermore, it is assumed that a rational farmer uses adaptation methods only when the net benefit from using such a method is significantly greater than the cost of not doing so (Mendelsohn, 2012). Although the benefit is not directly observed, the action of economic agents is observed through the choices they make (Deressa et al., 2008). Suppose that \( Y_j \) and \( Y_k \) represent a household’s benefit for two choices, which are denoted by \( U_j \) and \( U_k \), respectively.

The linear regression model could then be specified as:

\[
U_j = \beta_j'X_i + \epsilon_j
\]  \( \text{and} \)

\[
U_k = \beta_k'X_i + \epsilon_k
\]

In the case of the adaptation method, if a household decides to use option \( j \), it follows that the perceived benefit from option \( j \) is greater than the benefit from other options.

(i.e., \( k \)) which is depicted as

\[
U_j(\beta_j'X_i + \epsilon_j) > U_k(\beta_k'X_i + \epsilon_k), k \neq j
\]

where \( U_j \) and \( U_k \) are the perceived benefits for adaptation options \( j \) and \( k \), respectively, by farmer \( i \). \( X_i \) is the vector of explanatory variables that influences the choice of the adaptation options, \( \beta_j \) and \( \beta_k \) are the

| Agricultural area | Commune | Town       | Number of housework | Size sample | Response rate (%) |
|-------------------|---------|------------|---------------------|-------------|-------------------|
| Bougouni          | Koumantou | Choubougou | 24                  | 24          | 100               |
|                   |         | Ména       | 24                  | 24          | 100               |
|                   | Sanso   | Finkoua    | 24                  | 24          | 100               |
|                   | Zantiébougou | Koury   | 24                  | 24          | 100               |
| Koutiala          | Zankaso | Sokourani  | 80                  | 50          | 62                |
| Sikasso           | Niéna   | N’golotiorla | 24               | 24          | 100               |
|                   |         | Tiécourala | 24                  | 24          | 100               |
| Total             |         |         | 224                 | 194         | 86.6              |

Table 1 Composition of the study sample. Source: Field survey, August-October 2019
parameters to be estimated, and $e_j$ and $e_k$ are the error terms assumed to be independently and identically distributed (Deressa et al., 2008).

The probability that a household will use method $j$ from the set of climate change adaptation options could then be defined as follows:

$$P(Y = 1/X) = P(U_{ij} > U_{ik}(X)) = P(\beta_j'X_i + e_j - \beta_k'X_i - e_k > 0/X)$$

$$P(\beta_j' - \beta_k')X_i + e_j - e_k > 0/X)$$

$$P(\beta_j'X_i + e^* > 0/X) = F(\beta_j'X_i)$$

where $P$ is the probability function, $U_{ij}$, $U_{ik}$ and $X_i$ are as defined above, is the random disturbance term, $e^* = e_j - e_k$ is the vector of unknown parameters that can be interpreted as the net influence of the vector of explanatory variables that influences adaptation, and $F(\beta_j'X_i)$ is the cumulative distribution function of $e^*$ evaluated at $\beta_j'X_i$. The exact distribution of $F$ depends on the distribution of the random disturbance term, (Deressa et al., 2008; Gbetibouo, 2009).

For this study, the adaptation options or response probabilities are seven:

1. Increase irrigation
2. Drought-resistant crops
3. Use of different crop varieties
4. Agroforestry (Planting trees)
5. Soil conservation
6. Early and late planting
7. No adaptation

Another fundamental characteristic of the multinomial Logit is the property of independence from other events—of the ratio of the two probabilities associated with two possibilities $j$ and $k$:

$$P(Y_i = j) = \frac{\exp(x_i a_j)}{\exp(x_i a_k)} = \exp(x_i (a_j - a_k))$$

This report is independent of possibilities other than $j$ and $k$, this hypothesis is called the Independence of Irrelevant Alternatives (IIA). This property is verified if changing the set of choices (e.g. adding a possibility) does not change the odds ratios.

The estimation of the model parameters is carried out using log-likelihood function maximisation algorithms.

Model specification

**Functional form**

The analytical model used in this study is the multinomial logistic regression model that determines the method chosen by producers to adapt to climate change. It can be written as follows:

$$A_i = \ln \left( \frac{P_j}{P_k} \right) \beta_0 + \beta_1 \times \text{ExpProd}_i + \beta_2 \times \text{SexProd}_i + \beta_3 \times \text{MembOP}_i + \beta_4 \times \text{AgeProd}_i + \beta_5 \times \text{Tailmen}_i + \beta_6 \times \text{Acc_crd}_i + \beta_7 \times \text{Acc_Vulg}_i + \beta_8 \times \text{Acc_Info_climate}_i + \beta_9 \times \text{Mod_Ter}_i$$

where: Age_Prod: Age of producer; Tail_men: Household size; Acc_crd: Access to credit; Acc_Vulg: Access to extension service; Acc_Info_climate: Access to climate information; Mod_Ter: Mode of access to land. Table 2 provides more information on the nature of the variables.

Excel 2010 and STATA 14 software are used in data analysis.

**Results and discussion**

Descriptive and econometric analysis of climate change adaptation measures

**Adaptation measures perceived by producers**

Increasing cultivated land, soil and water conservation and the use of drought-resistant crops remain the main adaptation methods perceived by producers (97.33%; 93.05% and 84.49% respectively). These options could be a better option for coping with the adverse effects of climate change and variability. About 53% of producers said they rely only on their own weather forecasts to discern the right time for the first rainfall so that they sow early or wait for rain and then plant to avoid the associated effects of delayed rainfall. This is the information gathered during the group interviews. Furthermore 31.55% of the farmers felt that another option is to combine trees and crops (agroforestry) in
the same plot for different purposes is also a good alternative to consider. In this way it is possible to reduce the risk of huge production losses due to extreme weather phenomena. In addition, 31.02% of the farmers surveyed stated that they perceived crop rotation as one of the adaptation measures. The adaptation measures least perceived by producers are mulching, working off-farm and use of wetlands and river valleys (7.49% and 2.13% of producers respectively). The results are shown in Table 3 below.

Farmers’ adaptation to climate change and variability

A descriptive analysis of the exogenous variables to be used in the output model was carried out in order to determine the variables that affect farmers’ choice of adaptation measures to climate variability. Table 4 below summarises the explanatory variables assumed to affect farmers’ adaptation strategies to the effects of climate variability experienced in the region over the past 20 years. The results of this analysis have been calculated on the basis of the response of certain market gardeners to the actual adaptation they have adopted.

The distribution of market gardeners by age shows that the age of market gardeners varies from 18 to 80 years, with an average age of 37.83 years. The size of households ranges from 3 to 120 people with an average of 35.71 people. The majority of respondents have access to climate information, extension and credit (86.63%, 73.26% and 66.84% respectively). The vast majority of plots (70.97%) of market gardeners are in VTICS (Garden Champ School) and BPHS. These are fields developed by the World Vegetable Center’s Horticulture Scaling Project and which are accessible to market gardeners without compensation. The interpretation of variables such as farming experience, membership of a farmers’ organization and the gender of the producer are omitted here to avoid redundancy.

Constraints to adaptation

During the individual interviews with producers, one question asked whether they have made any adjustments to mitigate the impacts of climate change and what the obstacles to this adjustment are. Lack of information, lack of money, lack of labor, high cost of labor, unavailability of credit, unavailability of inputs, high cost of inputs and low irrigation potential (Fig. 2) were mentioned. Most of these constraints are associated with poverty: 85.56% of the study sample believe that the first obstacle to adapting to the effects of climate change is related to financial constraints (lack of financial resources). Lack of money prevents producers from obtaining the resources and technologies needed to facilitate adaptation to climate change. Yet research has shown that adjustment to climate change is cumbersome and costly. For example, if farmers do not have enough family labor or financial means to hire employees, they would find it very difficult to adapt. For example, low levels of irrigation are most certainly linked to the inability of producers
to use irrigation water. In addition, 67.38% of producers do not have sufficient knowledge to manage the effects of climate change. In general, farmers in Mali are very poor and do not have the means to invest in irrigation and in research into technologies to adapt to climate change or to maintain their livelihoods in the face of extreme weather conditions, such as floods and drought. In addition, increasing cropland, conserving soil and water, and using drought-resistant crops remain the main adjustment methods used by producers to counteract the adverse effects of climate change in the study area (see Table 3).

Results of the multinomial logit model and discussions

Since the study focuses on the 6 major adaptation options (see methodology section), the regression

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**Table 3** Adaptation option adopted by producers

| Perceived adaptation option by producer | Number of producer | % per producer |
|----------------------------------------|--------------------|----------------|
| Off-farm employment                     | 4                  | 2.13           |
| Increase irrigation                     | 9                  | 4.81           |
| Mulching                               | 14                 | 7.49           |
| Use of wetlands/river valleys           | 4                  | 2.13           |
| Drought-resistant crop                  | 158                | 84.49          |
| Different crop varieties                | 29                 | 15.51          |
| Use of a traditional crop variety       | 29                 | 15.51          |
| Increase in cultivated land             | 182                | 97.33          |
| Crop rotation                           | 59                 | 31.02          |
| Intercropping                           | 26                 | 13.90          |
| Agroforestry use (Tree planting)        | 58                 | 31.55          |
| Water and soil conservation             | 174                | 93.05          |
| Early and late planting                 | 98                 | 52.41          |

Number of observations = 194

**Table 4** Statistical description of variables in the multinomial logistic regression model. Source: Author’s calculation based on Field survey, August-October 2019

| Qualitative variables                      | Absolute frequency | Relative frequency (%) |
|--------------------------------------------|--------------------|------------------------|
| Gender of producer                         | –                  | –                      |
| Woman                                      | 128                | 66                     |
| Man                                        | 66                 | 34                     |
| Access to climate info                     | 168                | 86.63                  |
| OP membership                              | 111                | 57                     |
| Access to agricultural credit              | 64                 | 33                     |
| Access to extension                        | 142                | 73.26                  |
| Mode of access to land                     | –                  | –                      |
| Heritage                                   | 45                 | 23.12                  |
| Purchase                                   | 4                  | 2.15                   |
| Metayage                                   | 4                  | 2.15                   |
| Donation                                   | 138                | 70.97                  |
| Rental                                     | 3                  | 1.61                   |

| Qualitative variables                      | Averages           | Standard Deviations    |
|--------------------------------------------|--------------------|------------------------|
| Age of the producer                        | 37.83              | 11.26                  |
| Household size                             | 10                 | 5.11                   |
| Experience                                 | 12.66              | 7.97                   |
The results of the estimation of the adaptation measures of the multinomial logit model classified into 6 adaptation measures are presented in the table below.

The multinomial logit model is based on the hypothesis of independence of irrelevant alternatives (IIA). Thus, a validation test was carried out and we removed one by one the modalities and performed a Hausman test. The statistic of the \( \chi^2 (12) = 59.40 \) and with Prob = 0.164 > 0.05 so one cannot reject \( H_0 \). Therefore, there is no significant difference when the modalities are removed one after the other. The specification of the multinomial logit is therefore appropriate for modelling climate change adaptation measures of market gardeners in the extreme south of Mali.

**Access to information on climate change**

Access to information on climate change has a positive and significant impact on the choice of producers to adapt to climate change by using irrigation, drought-resistant crops, different crop varieties, soil and water conservation and planting time (sooner or later). Relative to no adaptation options, having access to climate change information increases the likelihood of adaptation to climate change using irrigation, drought-resistant crops, different crop varieties, soil and water conservation and planting time (sooner or later).

**Mode of access to land**

Access to land positively and significantly influences the choice to adapt to climate change by using irrigation and different crop varieties. This means that land-owning producers are able to choose irrigation and use different crop varieties as a means of adapting to climate change than landless producers. Relative to no adaptation options, access to land increases the likelihood of practicing irrigation and using different crop varieties.

**Access to credit**

Access to credit positively and significantly influences the choice to adapt to climate change by using drought-resistant crops and soil and water conservation techniques. This means that producers with access to credit are more likely to choose drought-resistant crops and use soil and water conservation techniques as a means of adapting to climate change than producers without access to credit. In other words, having access to agricultural credit increases the likelihood of purchasing drought-resistant crops and practicing soil and water conservation techniques as adaptation measures.

**Access to the extension service**

The extension of extension services positively and significantly influences the choice to adapt to climate change...
change by using different and timely (sooner or later) planting materials. This means that the more contact a producer has with extension services, the more useful information he or she receives on how to manage the effects of climate change compared to a farmer without access to extension services. Relative to no adaptation options, access to extension services increases the likelihood of practicing irrigation and using different crop varieties.

Agricultural experience

The agricultural experience has a positive and significant impact on the choice to adapt to climate change by combining trees and crops on the same plot. This means that more experienced producers are more likely to use agroforestry as an adaptation option compared to less experienced producers. In other words, the likelihood of practising agroforestry increases with agricultural experience.

### Table 5 Results of the multinomial logit model of climate change adaptation strategies

| Explanatory variables | Increase irrigation | Drought-resistant crops | Different varieties of crops |
|-----------------------|---------------------|-------------------------|-----------------------------|
|                       | Coef                | Exp (β)                 | β-values                    | Coef | Exp (β) | β-values | Coef | Exp (β) | β-values |
| **Constant (β₀)**     | -2.436**             | .087                    | 0.043                       | -3.085***         | .046               | 0.009      | -1.125 | .325 | 0.283 |
| Age of the producer    | -0.009               | .990                    | 0.240                       | 0.029            | 1.029               | 0.344      | -0.025 | .976 | 0.280 |
| Size of household      | 0.010                | 1.010                   | 0.288                       | 0.014            | 1.014               | 0.170      | -0.010 | .990 | 0.280 |
| Experience             | 0.036                | 1.036                   | 0.812                       | 0.030            | 1.030               | 0.459      | 0.026  | 1.026 | 0.359 |
| Gender of producer (1/0) | -0.090              | .914                    | 0.779                       | -0.027           | .973               | 0.953      | 0.640  | 1.896 | 0.106 |
| OP membership (1/0)    | -0.102               | .903                    | 0.954                       | -0.561           | .571               | 0.143      | 0.003  | 1.003 | 0.993 |
| Access to credit (1/0) | 0.022                | 1.022                   | 0.114                       | 0.734*           | 2.083               | 0.060      | 0.227  | 1.255 | 0.542 |
| Access to extension (1/0) | -0.601              | .548                    | 0.947                       | 1.528***         | 4.607               | 0.000      | -0.265 | .767 | 0.497 |
| Mode of access to land | 0.010*               | 1.010                   | 0.055                       | -0.060           | .942               | 0.709      | 0.359** | 1.432 | 0.011 |
| Access to climate info (1/0) | 1.572**          | 4.817                   | 0.043                       | 1.068**          | 2.909               | 0.042      | 1.445*** | 4.242 | 0.004 |

**Explanatory variables**

| Agroforestry | Soil and water conservation | Early and late planting |
|--------------|-----------------------------|-------------------------|
| Coef         | Exp (β)                     | β-values | Coef | Exp (β) | β-values | Coef | Exp (β) | β-values |
| **Constant (β₀)** | -0.2869***                  | .044     | 0.006 | -2.680** | .069     | 0.028 | -2.647** | .071     | 0.031 |
| Age of the producer | -0.004          | .996     | 0.887 | 0.069**  | 1.072     | 0.015 | 0.029  | 1.029     | 0.295 |
| Size of household | 0.002          | 1.002    | 0.846 | -0.014  | .986      | 0.152 | 0.006  | 1.006     | 0.593 |
| Experience | 0.069**               | 1.072    | 0.032 | -0.054  | .947      | 0.114 | 0.004  | 1.004     | 0.908 |
| Gender of producer (1/0) | -1.389***     | 4.009    | 0.000 | -0.270  | .763      | 0.584 | -0.225 | .798      | 0.624 |
| OP membership (1/0) | 0.430           | 1.538    | 0.244 | 0.070   | 1.072     | 0.868 | -0.060 | .942      | 0.879 |
| Access to credit (1/0) | -0.018          | .982     | 0.963 | 0.968** | 2.633     | 0.022 | 0.227  | 1.255     | 0.580 |
| Access to extension (1/0) | 0.524          | 1.689    | 0.195 | 0.397   | 1.488     | 0.378 | 0.729* | 2.074     | 0.093 |
| Mode of access to land | -0.105         | .900     | 0.471 | 0.084   | 1.087     | 0.659 | 0.162  | 1.176     | 0.329 |
| Access to climate info (1/0) | 1.038          | 2.823    | 0.104 | 1.885*** | 6.584     | 0.001 | 1.731*** | 5.648     | 0.001 |

**Observation** 194  

χ²  59.40***  

Pseudo R² 0.452  

Reference category: No adaptation

*p < 0.10, **p < 0.05, ***p < 0.01
**Gender of producer**

The gender variable has an inverse and significant influence on the choice not to adapt to climate change by using agroforestry. This means that female producers are less likely to adopt agroforestry as an adaptation option compared to male producers. The reason for this negative influence is that the practice of agroforestry requires more labor, equipment and access to information, yet women in general have limited access to information and lack equipment and agricultural labor in particular. This discourages women from taking up this activity.

**Conclusion**

This study has identified the socio-economic, infrastructural and institutional factors that influence producers’ adaptation strategies to climate change in the extreme south of Mali. To this end, the multinomial logistic regression model was used, based on data collected from producers in the communes of Koumantou, Sanso and Zantiebougou in the Bougouni circle, Niéna in the Sikasso circle and Zankaso in the Koutiala circle to determine the factors that influence the choice of adaptation measures by producers to climate change.

This study reveals that increasing cropland, soil and water conservation and the use of drought-resistant crops remain the main adaptation methods perceived by producers. These options could be a better option to cope with the adverse effects of climate change and variability. In addition, the main constraints for adaptation to climate change at the farm level are mostly institutional in nature and can be addressed by improving institutional services in terms of access, use. Institutional services are of different types: easy access to information on weather forecasts and improved agricultural technologies; easy access to financial resources and services for improved adaptation at farm level. However, the services currently provided at the farm level are not sufficient to support an effective adaptation process. Based on these findings, there is an urgent need to create synergy of action around this issue. This could involve public–private partnerships and producers. This study also shows that access to land, access to information on climate change, agricultural extension, agricultural experience and access to credit are the main endogenous strategies developed by producers to counteract the adverse effects of climate change.

In the light of the above, governments should make efforts to ensure that producers have access to seasonal credit even before the crop planting period. Interest rates on these credits should be lower to allow producers to increase their capacity and flexibility to change their production patterns in response to expected weather conditions. For example, the credits can be used to buy improved seeds adapted to the different agro-ecological zones of the country, to promote the practice of irrigation, and or to acquire agricultural equipment etc.

However, to promote a better distribution of agricultural land, policy makers need to focus on land reform. This reform should come after a broad awareness-raising campaign among landowners (customary chiefs in rural areas). Secondly, access to climate information increases the resilience of market gardeners, as the more they are informed about the climate situation, the better prepared they are. In addition, training sessions, exchanges and sharing of experiences on adaptation strategies through an efficient extension system are essential to reduce the impacts of climate change. Based on all the above, we recommend investing more in training farmers and improving the institutional framework of the national climate change adaptation policy in order to improve the living conditions of producers.

**Authors’ contributions** The first contribution is, the study that we propose is original insofar as there is no previous work borrowing such a procedure on this theme applied in Mali.

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**Data availability** The datasets used during the current article are available from the corresponding author on request.

**Declarations**

**Conflict of interest** The authors declare no potential conflict of interest.
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