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Smallholder farmers' perception of climate change and drivers of adaptation in agriculture: A case study in Guinea

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Abstract

In developing countries, the adoption of effective climate change adaptation strategies can safeguard rural communities' livelihoods. Using survey data collected in Guinea in 2012, the paper investigates the factors affecting households' strategies to face adverse climate change impacts. A three-step methodology is applied: (1) assessment of the magnitude of real climatic trends in the study area together with farmers' perception of climate change; (2) identification of physical and socioeconomic variables influencing farmers' adaptation propensity; and (3) analysis of factors affecting adaptation choices, including climate change perception. The climatic data analysis confirms increase in minimum and maximum temperature trends, increase in annual average millimeters of rain, and decrease in average number of storms per year. Farmers' perception of climate change turned out to be aligned with historical climatic trends and represents an important determinant for the adoption of adaptation strategies. The regression model results suggest that the propensity to adapt is positively influenced by the level of education and a limited access to water resources and agricultural inputs, forcing households to adopt new

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cropping calendars. Effective policy action should consider different areas, including climate change awareness, education, access to natural and physical assets, and availability of economic resources to local communities.

KEYWORDS

adaptation, climate change, Guinea, multiple correspondence analysis, perception

JEL CLASSIFICATION

Q18; Q54; Q56; O13

1 | INTRODUCTION

Sub-Saharan Africa is particularly vulnerable to climate change effects due to its specific ecological and environmental conditions. This vulnerability is intensified by its dependence on agriculture, the economic sector that is the most exposed to changes in climatic and environmental conditions. Moreover, this area does not benefit from a favorable enabling environment; vulnerable social and institutional networks may hinder the adaptive capacity of local communities (Thomas et al., 2007). Adaptation strategies represent the possible and viable responses that communities may implement to manage and mitigate adverse climate impacts as they seek to moderate or avoid harm or exploit beneficial opportunities (Intergovernmental Panel on Climate Change [IPCC], 2014).

Within this framework, this work aims at studying the main factors influencing the adoption of adaptation strategies by rural households to minimize the adverse climate change impacts on agriculture in vulnerable areas. The paper attempts to answer the following research questions: (1) Is farmers' perception of climate variability and change aligned with the historical climatic trends observed in the area? (2) How does this perception influence households' adaptation propensity? (3) Do other factors promote or prevent households' adaptation strategies?

The study is based on data collected through a household survey conducted in 2012 in the Fouta Djallon Highlands (FDH) in Guinea. The opportunity was given by the project "Fouta Djallon Highlands Integrated Natural Resources Management" (FDH-INRM) (EP/INT/503/GEF), which is implemented by the United Nations Environment Programme and executed by the Food and Agriculture Organization (FAO) of the United Nations. The intervention is cofunded by the Global Environment Facility (GEF) with US$11 million in two tranches between 2009 and 2021. The aim of the project is to mitigate the causes and negative impacts of land degradation on the structural and functional integrity of the ecosystems of the FDH and to improve the rural livelihoods of the inhabitants who are directly or indirectly dependent on them (FAO, 2008).

The paper is structured as follows. First, we analyze the climate data (temperature and rainfall) recorded by two different weather stations to verify whether actual climate change can be observed over a period of 42 years (1971–2012) for temperature and a period of 32 years (1981–2012) for precipitation. Second, we assess how the households living in the area perceive the climate variability and change and to what extent they have implemented adaptation strategies to mitigate the effects. Third, we identify the factors influencing households' adaptation choices by means of a logistic regression model and discuss the results obtained.

2 | BACKGROUND

Climate change is one of the most immediate and complex challenges for society and economies (Hameso, 2018), and the evidence has become unequivocal. The atmosphere and oceans have warmed, the amounts of snow and ice have decreased, the sea level has increased, and the concentrations of greenhouse gases have increased significantly, driven by global population growth (IPCC, 2014). These changes have caused several irreversible impacts on biodiversity and entire ecosystems; they have hindered the development of human systems; and they are expected to exacerbate current social vulnerabilities and inequalities (Otto et al., 2017).

These risks are unevenly distributed and are usually greater for people living in developing countries. Sub-Saharan Africa is considered to be particularly vulnerable to climate change as it is exposed to several global climatic drivers that are likely to increase the incidence and severity of droughts, floods, and other extreme weather events (Collier et al., 2008; Serdeczny et al., 2017). Furthermore, sub-Saharan Africa is highly reliant on the agricultural sector, which accounts for around 60% of employment and, in some countries, more than 50% of the gross domestic product (Collier et al., 2008). Agriculture in sub-Saharan Africa is particularly influenced by climate fluctuations as it is mostly rainfed and modern cultivation techniques are seldom used (Dingkuhn et al., 2006; Thurlow et al., 2012). In West Africa, most households rely on subsistence agriculture and face numerous constraints, such as droughts, soil acidity, and nutrient-depleted and degraded soils (Roudier et al., 2011). In such a context, crop yields can be directly affected by climate variability, mostly due to the decrease in farming areas, the changing length of the cropping seasons, and the decrease in potential yields (Collier et al., 2008).

Adaptation strategies can effectively help rural households to prevent or minimize the adverse impacts of climate change as well as enable them to take advantage of the opportunities that they generate (Barrucand et al., 2017; Deressa et al., 2011; Swe et al., 2015; Thomas et al., 2007). Farm adaptation strategies can include crop diversification, adjustment of cropping calendars, farmers' adoption of more drought-resilient crops (Arndt et al., 2012), increased use of irrigation, implementation of water and soil conservation techniques, and diversification of livelihood sources (e.g., keeping cereal stocks or creating off-farm employment networks) (Mation & Kristjanson, 1988). Cooper et al. (2008) distinguished these adaptation strategies into the following: (1) ex ante management options adopted to prevent negative impacts of climate change, (2) in-season adjustments implemented in response to climatic shocks, and (3) ex post risk management options that are able to minimize the impact of adverse climatic conditions.

Households' choice of adaptation strategy is influenced by many elements. With respect to the rural African context, Deressa et al. (2011) classified the factors shaping the adaptive capacity of households into (1) household socioeconomic characteristics, such as age, gender, education, and farm and nonfarm income; (2) institutional factors, such as extension services and access to information and credit; and (3) social capital, such as farmer-to-farmer training and the number of relatives living in the surroundings. In other studies, the availability of physical assets, such as an electricity connection and ownership of machinery, has also been considered as it increases the chances of farmers undertaking adaptation measures (Hassan & Nhemachena, 2008). Furthermore, adaptation responses are substantially shaped and mediated by their relationships with markets, research and extension, and other institutions, all of which together represent the so-called innovation interface spanning multiple levels (Bhatta et al., 2017).

The literature on climate change adaptation has also highlighted that climate change perception plays a crucial role (Maddison, 2006) in farmers' decision-making on this issue. However, the perception of climate change may be biased. For instance, farmers may overestimate the frequency of negative impacts of climate change and underestimate the positive opportunities (Cooper et al., 2008). Poor access to information reflecting current climate change and future projections can also alter farmers' awareness and thus their adaptation propensity. Indeed, the role of information on climate and production has proved to be crucial in enhancing farmers' awareness of climate change, thus driving their adaptation choices and, in general, improving their planning capacity (Hassan & Nhemachena, 2008). Therefore, it is fundamental to identify the main drivers influencing the adoption of adaptation strategies and highlight the role played by climate change perception in farmers' decision-making process.

3 | STUDY AREA

The analysis focuses on the FDH, a series of high plateaus ranging from 900 to 1,500 m above sea level, concentrated in the central part of Guinea and extending into Guinea-Bissau, Mali, Senegal, and Sierra Leone (Ceci et al., 2014). The FDH is one of the most ecologically important zones of West Africa, hosting wide biological diversity (Wood & Mendelsohn, 2015) and providing the headwaters for some of West Africa's most economically important rivers: the Gambia, Niger, Senegal, and Konkouré rivers (Ceci et al., 2014; Wood & Mendelsohn, 2015). This region is characterized by a tropical climate, with a dry season in winter and a rainy season in summer, due to the southwest monsoon. The higher part of the region receives significantly more rainfall than the lowlands, resulting from interactions among the topography; oceanic proximity; and prevailing warm, wet, southwesterly winds. The rainy season lasts from May to October, and the annual rainfall is mostly below 2,000 mm, with less precipitation in the northern part (Wood & Mendelsohn, 2015).

Due to their geographic and climatic diversity, the highlands and the surrounding foothills support a rich variety of ecosystems (FAO, 2008). The FDH area is predominantly inhabited by the Fula ethnic group, and extensive subsistence agriculture is still the main source of livelihood for most households (Ceci et al., 2018). Farming occurs in home gardens, delimited by fenced perimeters surrounding the houses, as well as in external fields in the valley bottoms and on the plains and slopes (Ceci et al., 2014). Home gardens, which are usually small plots, are dedicated to the cultivation of vegetables and other crops mixed with fruits, medicinal plants, staple crops, and shade trees (Rubaihayo, 2002). They are considered to be an important supplemental source contributing to food and nutrition security and livelihoods (Galhena et al., 2013).

4 | DATA

For the purpose of this study, we used two data sources: (1) historical data on rainfall (related to the period 1971–2012) and temperature (related to the period 1981–2012) from the Labé and Mamou weather stations, located near the case study sites; and (2) socioeconomic data collected during a household survey conducted in January–August 2012 at three specific sites located in the central part of the FDH (Figure 1).

The case study sites considered are as follows:

1. The source of the Senegal River, Bafing in the local language, in the prefecture of Mamou, subprefecture of Tolo: this area covers 151 km^2, and the population density is 50 persons per square kilometer, with a total population of 7,533 people distributed among 748 households (Service Préfectoral du Plan et de la Statistique de Mamou, 2010).

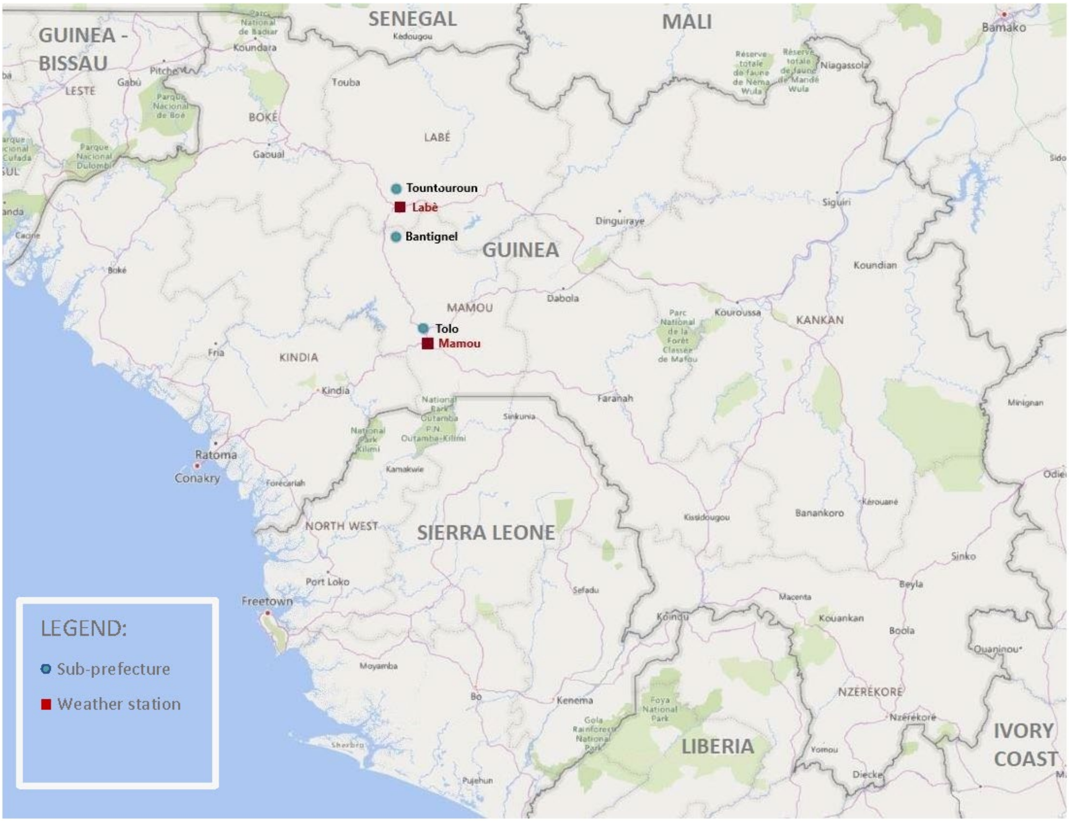

FIGURE 1 Map of the study area. Source: Own elaboration

2. The source of Guétoya, the Konkouré Watershed, in the prefecture of Pita, subprefecture of Bantignel (the reference weather station is Labé): this area covers 273 km^2 and is inhabited by 15,026 people belonging to 1,835 households, with a population density of 55 people per square kilometer (Service Préfectoral du Plan et de la Statistique de Pita, 2010).
3. The source of the Gambia River, Dimma in the local language, in the prefecture of Labé, subprefecture of Tountouroun: this area has a surface of 172 km^2 and a total population of 15,331 people divided into 2,433 households, with a population density of 89 persons per square kilometer (Service Préfectoral du Plan et de la Statistique de Labé, 2010).

These sites were inherited by the FAO-led project FDH-INRM from past development projects implemented in the context of the African Union Commission's Regional Programme for the Integrated Management of the FDH (Organisation de l'Unité Africaine, Bureau de Coordination Internationale [OUA-BCI], 1998), which in 2018 was handed over to the Economic Commission of West Africa States.

Four villages were surveyed at each site, making a total of 12. The villages covered by the survey were those involved in both the present FAO project and the past projects related to the management of natural resources in the FDH. The exact number and a list of the families living in the selected villages were not available from the local administrations and village headmen, so it was not possible to design probabilistic sampling. With the aim of increasing the representativeness of the sample, all the accessible and available households that were willing to be interviewed were surveyed in each of the 12 villages. In sum, 296 households were surveyed (86 households in Tolo, 93 households in Bantignel, and 117 households in Tountouroun), corresponding to 5.9% of the total population of the subprefectures covered by the study and at least almost half of the population of the selected villages, considering that a maximum of 50 families lived in each village.

The questionnaire was administered to local household heads, men or women, or to one of the wives of the male household heads if they were absent for work. The questionnaire consisted of 362 closed-ended questions and was conceptually structured following the Sustainable Livelihoods Framework of the Department for International Development (DfID, 1999), focusing on people's perception and experience of the resources available at the household level. The questionnaire was divided into nine sections, seven of which were considered for this study. Among the questions included in these sections, we selected 54 variables related to households' perception of climate variability and change and to their sociodemographic characteristics and livelihood assets.

It should be noted that, following the military coup d'état in 2008, Guinea faced years of political tension, instability, civil unrest, and violence and that, from 2013 to 2016, it was severely affected by the Ebola virus outbreak. During such difficult socioeconomic and political conditions, the survey data used for this article are particularly valuable.

5 | DATA ANALYSIS

The methodology presented in this paper consists of three steps: (1) climate pattern analysis, (2) selection of survey variables and synthesis through multiple correspondence analysis (MCA), and (3) regression analysis.

5.1 | Climate pattern analysis

Farmers were asked about their perception of climate variability and change in the 10 years preceding the survey. It is commonly believed that farmers' memory is unlikely to keep track of climate alteration events reliably over a long time frame. In addition, many interviewed smallholders might have been too young to be asked about events occurred 10 years ago. To determine whether actual climate change occurred in the area, climate data from meteorological stations over a period of 42 years (1971–2012) were analyzed in the case of temperature, whereas a time span of 32 years (1981–2012) was available for the analysis of precipitation. This allowed the identification of longer-term trends than mere occasional or short-term climate variability.

The analysis was conducted assuming a multiplicative relationship among the time series components:

$$Y = T \times S \times C \times I$$

where Y is the observed series (temperature or precipitation) generated by trend (T), seasonality (S), cycle (C), and irregularity (I). The seasonal component (S) represents monthly fluctuations that occur each year with almost the same timing and intensity. These movements are due to cyclic events that occur each year (Spiegel, 1973). To measure and remove the influence of these predictable seasonal patterns, we used an index of seasonality obtained through the method of simple averages. The seasonal adjusted values (Y') were obtained by dividing the observed data by the monthly indices. Element C is related to the long-term fluctuations, which may or may not follow the same recurrent model with constant timing. In this study, C

was assumed to be absent, given that, during the period of analysis, no cyclic phenomena can be observed in the data. Thus, the time series model can be written as

$$Y' = Y/S = T \times I$$

showing that the seasonal adjusted observed data can be divided into two factors: a long-term trend and a monthly irregular component. The *I* component is related to stochastic elements that influence the short-term variability of climatic phenomena.

Considering the aim of the study, we assessed the long-term climate change, that is, the *T* component, through a linear regression model:

$$T = b_0 + b_1 t$$

where *t* is the time (expressed in the progressive number of months starting at the beginning of the available data). *t* was expressed in months in the analysis of temperature; for the analysis of precipitation, given its high concentration in some months of the year, the time span considered for each observation was instead the full year.

5.2 | Selection of survey variables and data description

5.2.1 | Dependent variable: Adoption of adaptation strategies

This study focuses on households' adaptation strategies in response to both climatic and nonclimatic stimuli. Such adaptation practices serve multiple purposes and are often interconnected (Bhatta et al., 2016). Here, we use the term "adaptation" to refer to all the actions of adjusting agricultural practices to the changing circumstances as well as to the ongoing climate change.

In developing contexts, there is an immense diversity of agricultural practices because of the range of climate and other environmental variables, such as cultural, institutional, and economic factors (Howden et al., 2007). This means that there is a correspondingly large array of possible adaptation options.

With the aim of identifying all the coping mechanisms adopted by farmers in response to external stimuli and assessing their relationship with climate drivers, we considered the following changes in farming practices realized during the previous 12 months: (1) agricultural calendar adjustments, (2) replacement of crop types, (3) utilization of native varieties, (4) longer fallow periods, (5) soil fertilization, (6) pest control, and (7) invasive species control.

As shown in Figure 2, of the 296 respondents, about 57% changed their agricultural practices and adopted at least one of the selected adaptation strategies. Agricultural calendar adjustments were implemented by 45% of the farmers. In a context characterized by rainfed agricultural activities, cropping calendar adjustments are considered to be one of the most effective actions to cope with climate shocks, implemented by tailoring the growth cycle of plants to the changing rainy season (Yegbemey et al., 2014). In the study area, such calendar shifts were mainly related to land preparation and sowing dates, the changes of which determined movements in all the remaining agricultural activities (e.g., harvesting) either forward or backward with respect to the previous calendar.

The replacement of crop types was the second most frequent practice, implemented by 5% of the farmers (Figure 2). In a context characterized by climate variability, altering inputs such as crop species in favor of those with increased resistance to heat shocks and drought is considered to be

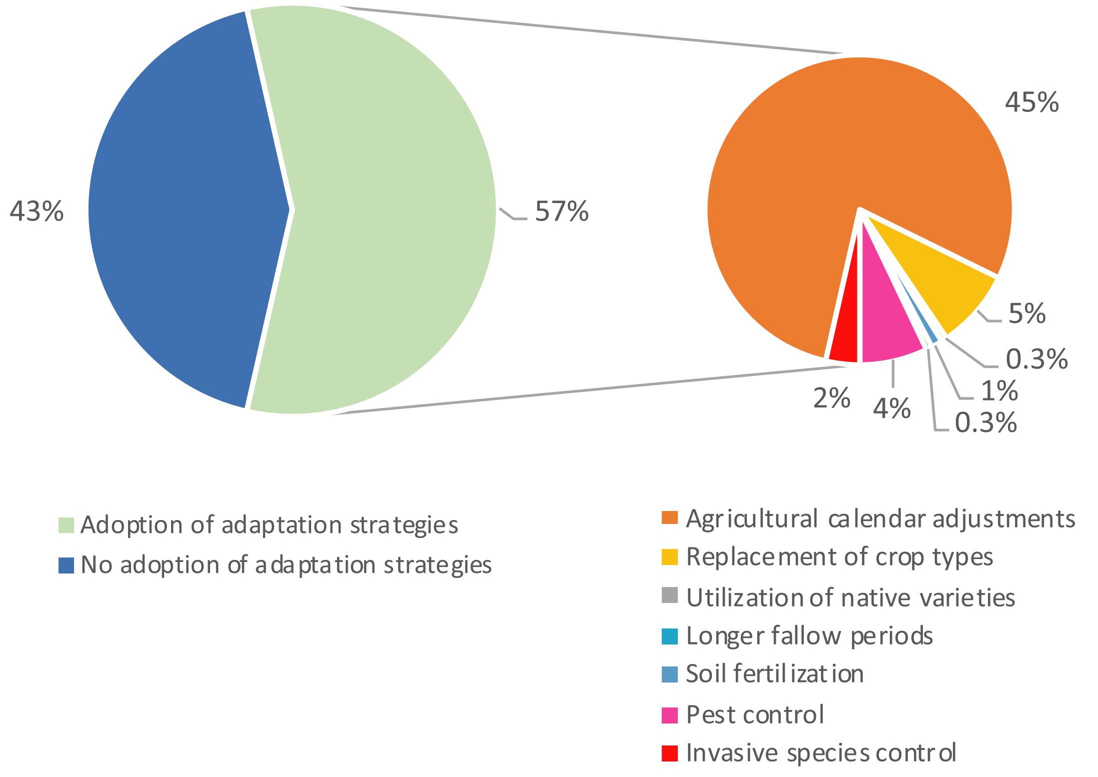

FIGURE 2 Changes in the agricultural practices adopted by farmers during the previous 12 months ($N = 296$). Source: Own elaboration

an effective action to cope with projected climatic and atmospheric changes (Howden et al., 2007). Because climate change has important implications for insect conservation (Palikhe, 2007) and weed proliferation, the control of pests and invasive species represents two other interventions, adopted, respectively, by 4% and 2% of the surveyed households. Indeed, the use of such agricultural practices not only determines an increase in crop yields but also allows households to cope with the negative effects of environmental and climatic changes.

Longer fallow periods were adopted by about 1% of the farmers interviewed. This practice allows moisture to accumulate as a means of adapting to dry conditions (Zhang et al., 2017). Finally, the use of native varieties and the combination of organic and mineral fertilizers were both adopted by about 0.3% of the sampled farmers. While the first strategy mainly focuses on the adoption of native plants that are able to grow in conditions similar to those found in the habitats in which they evolved, the combination of organic and mineral fertilizers as a climate-smart integrated soil fertility management practice might allow greater responses in productivity and agronomic efficiency (Gram et al., 2020).

Considering the adoption rate of the aforementioned adaptation strategies and the predominance of strategies related to agricultural calendar adjustments, a dummy variable was created to synthesize the farmers' adaptation propensity. It takes the value 1 if the household adopted at least one of the adaptation strategies considered earlier and 0 if the household did not implement any of them. This variable was used as a dependent variable in the econometric analysis.

As the second step in the selection of variables, 51 variables were identified to report the following six characteristics of the respondent households:

- demographic characteristics
- natural and physical assets
- economic assets
- human and social assets
- food insecurity
- climate change perception

5.2.2 | Independent variables and descriptive statistics

The independent variables used in the econometric model are presented in Table 1. Households' demographics provide information related to the gender, age, and education level of the farmers interviewed. The descriptive statistics indicate that the sampled household heads are mostly male (69%), middle aged (55 years on average), and do not have a primary education level (only 31% of them attended at least primary school).

The second group of variables concerns the households' natural and physical assets. The descriptive statistics show that nearly all the households (97%) have a home garden. Furthermore, the majority of the farmers interviewed have fields on slopes (67%), do not have access to more than four water sources (87%), do not have access to more than three streams (66%), have access to modern water wells (76%), and use organic fertilizers (73%).

The third group of variables pertains to the households' economic assets. Given the unavailability of quantitative data (e.g., the amount of the annual income) due to a lack of record keeping by households, we used proxy measures of the households' economic conditions. We considered variables such as the main source of income, access to cash and food remittances from migrant relatives, the availability of modern sanitation facilities (e.g., a toilet), access to microcredit, and the possession of livestock (cattle, sheep, and goats). In this regard, the descriptive statistics show that agriculture is the main source of income for 79% of the sample. Furthermore, livestock rearing is quite common among the households interviewed. In particular, 20% of the households own cattle, probably the wealthier ones (Covarrubias et al., 2012), while about 13% and 34% own sheep and goats, respectively.

We also evaluated the level of households' food insecurity by using the Household Food Insecurity Access Scale (HFIAS) score, defined under the United States Agency for International Development's Food and Nutrition Technical Assistance project. It measures the prevalence of food insecurity (access) in a household in the previous 4 weeks under the assumption that the experience of food insecurity causes predictable reactions that can be quantified and summarized on a scale (Coates et al., 2007). Considering that the HFIAS score ranges between 0 (secure access to food) and 27 (insecure access to food), the sample analyzed in the present study is characterized by an overall moderate level of food insecurity because the average HFIAS score is equal to 9.

5.3 | Econometric analysis

We applied an MCA to the most numerous variable groups presented earlier (i.e., natural and physical assets, economic assets, and human and social assets) to synthesize our data set with a minimum loss of information and to create sets of new variables able to summarize the main environmental and socioeconomic characteristics of the households. Then, we built a logistic regression model to assess the probability of adopting adaptation strategies as well as to identify the relevant drivers of adoption. As mentioned in the previous sections, the dependent variable considered in the model is dichotomous;

TABLE 1 Sample description

Variables	Mean	Std Dev.	Min.	Max.
Demographic characteristics				
Gender (male)	0.69	0.46	0	1
Age	55	16	15	94
Education level (at least primary school)	0.31	0.46	0	1
Natural and physical assets				
Fields on the slopes	0.67	0.47	0	1
Fields in the valley bottoms	0.49	0.50	0	1
Fields on the plains	0.21	0.41	0	1
Home gardens	0.97	0.17	0	1
Access to more than four sources of water	0.13	0.34	0	1
Access to more than three streams	0.34	0.40	0	1
Availability of boreholes	0.49	0.50	0	1
Availability of traditional wells	0.21	0.41	0	1
Availability of modern wells	0.76	0.43	0	1
Use of organic fertilizers	0.73	0.44	0	1
Use of chemical fertilizers	0.27	0.44	0	1
Economic assets				
Agricultural income	0.79	0.41	0	1
Food remittances	0.20	0.40	0	1
Cash remittances	0.41	0.49	0	1
Access to microcredit	0.12	0.32	0	1
Ownership of more than four houses	0.27	0.44	0	1
Availability of modern toilet	0.77	0.42	0	1
Use of modern medicine	0.36	0.48	0	1
Possession of three or more cattle	0.20	0.40	0	1
Possession of five or more sheep	0.13	0.34	0	1
Possession of three or more goats	0.34	0.47	0	1
Human and social assets				
More than six household members	0.48	0.50	0	1
Literate household members	0.80	0.40	0	1
Educated children	0.76	0.43	0	1
Household members work in neighbors' fields	0.86	0.34	0	1
Neighbors are employed in household's fields	0.90	0.30	0	1
Participation in decision-making meetings	0.43	0.50	0	1
Participation in socioeconomic interest groups	0.55	0.50	0	1
Food insecurity				
Household Food Insecurity Access Scale score	9	6	0	23
Climate change perception				

(Continues)

TABLE 1 (Continued)

Variables	Mean	Std Dev.	Min.	Max.
No change in temperature	0.11	0.32	0	1
Increase in temperature	0.63	0.48	0	1
Decrease in temperature	0.25	0.44	0	1
No change in precipitation	0.29	0.45	0	1
Increase in precipitation	0.21	0.41	0	1
Decrease in precipitation	0.50	0.50	0	1

Source: Authors' own elaboration.

it takes the value 1 when the household adopted at least one of the considered adaptation strategies and 0 otherwise.

As explanatory variables, we considered all the dimensions extracted from each variable group treated with the MCA in addition to a set of variables identifying key household demographic characteristics and a set of variables describing the perception of changes in temperature and precipitation.

6 | RESULTS

6.1 | Climate change: Actual and perceived

The results of climate trend estimation are shown in Figures 3 and 4. Figure 3a,b shows the trend of minimum and maximum temperatures from 1971 to 2012 (42 years); the minimum temperature increased by 0.66℃, while the maximum temperature increased by 1.11℃.

The regression model on the minimum temperature data showed an R^2 close to zero (0.036); instead, when the same model was applied to the maximum temperature data, R^2 was 0.254. This means that the model related to the maximum temperature fits the climatic data better than the model related to the minimum temperature.

Figure 4a,b report the changes in precipitation patterns that occurred from 1981 to 2012: the annual average rain increased by 19 mm, and the average number of storms decreased by 4.7.

The R^2 value in Figure 4a, which refers to the annual amount of rain in millimeters, is not very high (0.270). On the contrary, the regression model developed with data in Figure 4b (number of storms per year) has a high goodness of fit, with an R^2 value equal to 0.797.

The results show that, in the decades preceding the survey, the study area was affected by climate change, namely increases in temperatures (in particular the maximum temperature) and alterations in the precipitation patterns. The evidence appears to be consistent with the climate change perception of the household heads interviewed in Tolo, Bantignel, and Tountouroun. In fact, as shown in Table 1, only 11% of the surveyed households did not perceive any temperature change, while 29% of them reported no change in precipitation. Increased temperature in the 10 years before the survey was reported by 63% of the households interviewed and decreased precipitation during the same time span by 50% of the sample. With reference to precipitation, we assumed that the people interviewed considered the number of storms happening each year as an element to assess changes in precipitation. We expect that the farmers whose perception of climate change was aligned with historical climatic trends may have implemented adaptation strategies that were able to reduce the losses or capitalize on the opportunities associated with the changes observed.

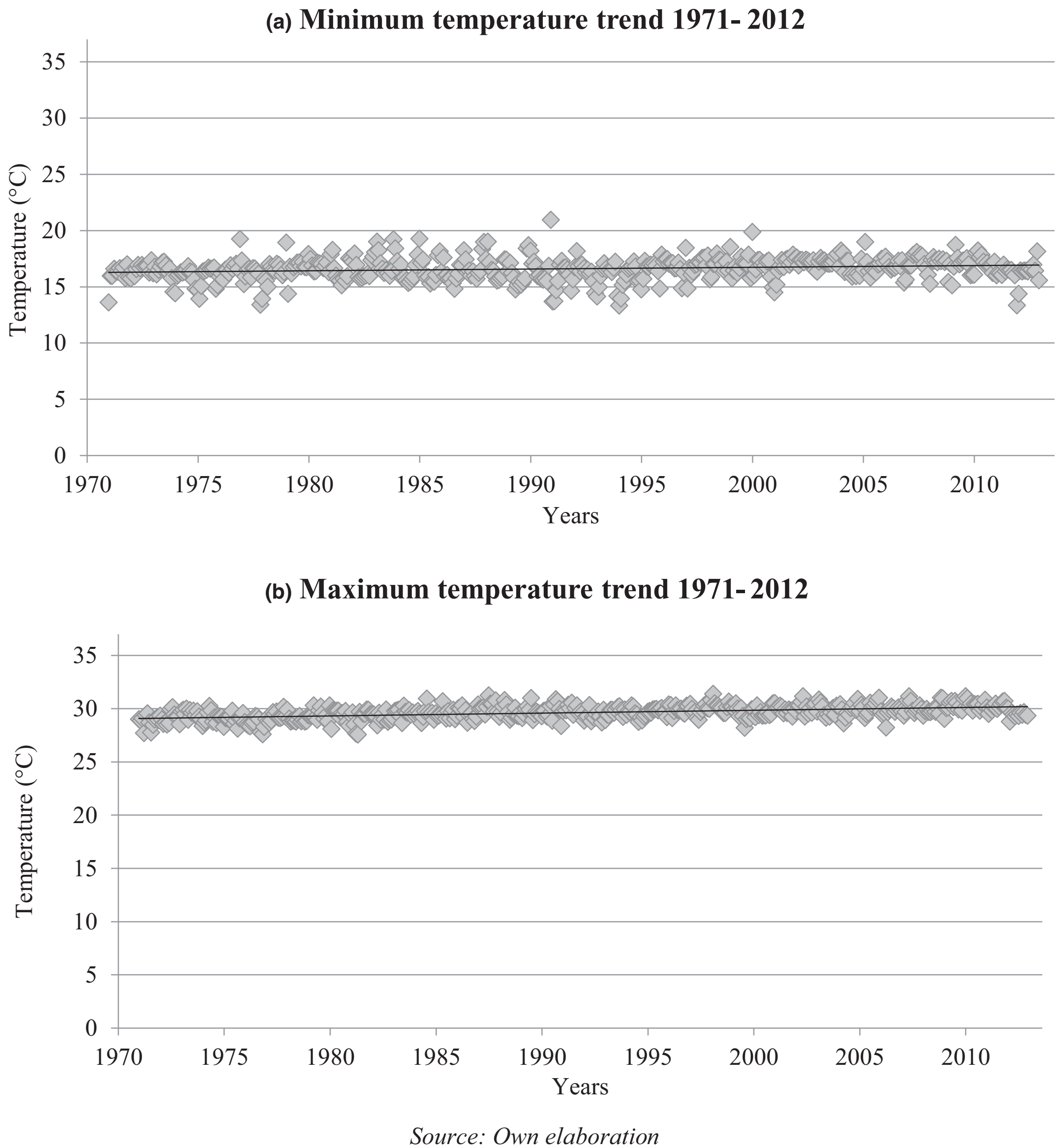

FIGURE 3 Temperature trends from 1971 to 2012. Source: Own elaboration

6.2 | Multiple correspondence analysis

The implementation of the MCA on the three largest groups of variables (natural and physical assets, economic assets, and human and social assets) allowed the definition of a set of new variables representing the main socioeconomic characteristics of the sample. The results of this analysis are presented in Table 2.

As shown in Table 2, in the first group of variables (natural and physical assets), the first dimension alone was able to explain about 72% of the inertia. This means that the relative frequency reconstructed from one dimension could reproduce 72% of the total χ^2 value. Therefore, for this group of variables, we extracted only this dimension, which was then interpreted through the analysis of the

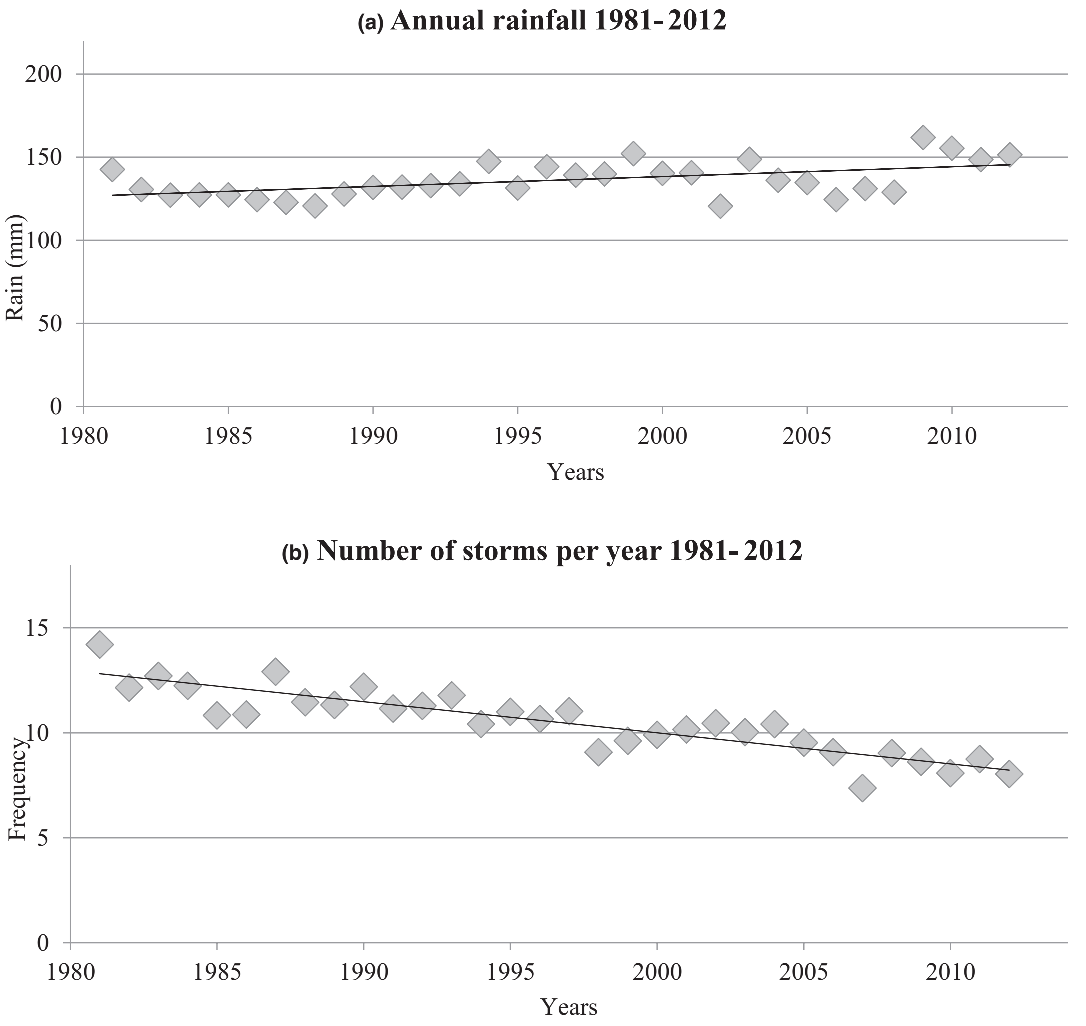

FIGURE 4 Precipitation trends from 1981 to 2012. Source: Own elaboration

MCA plot[1] (presented in the appendix) and considering other parameters, such as the mass, quality, and contribution of each variable level. The results of the analysis showed that the dimension extracted was related to the availability of water resources and agricultural inputs. Households with limited availability of water resources (water sources, water courses, boreholes, and wells) and with limited access to both chemical and organic fertilizers are opposed to households characterized by good access to such agricultural assets.

With respect to the group of variables related to the economic assets, the first two dimensions were extracted, as together they explained about 64% of the total inertia. Examining the MCA plot and interpreting the corresponding parameters, it was possible to observe that the first dimension is mostly related to households' economic stability (livelihoods do not rely solely on unpredictable agricultural yields). It depicted households characterized by a diversified income (which mainly originated from the secondary and tertiary sectors) and receiving cash and food remittances from migrant relatives, as opposed to households that are mainly reliant on the agricultural sector and do not receive support from migrant relatives. On the contrary, the second dimension is related to little savings in small-scale

TABLE 2 MCA outputs by categories of variables

Variable group	Variables considered	Dimensions extracted	Percentage of inertia explained	Dimension interpretation
Natural and physical assets	11	Dimension 1	71.83	Poor availability of water resources and agricultural inputs
Economic assets	10	Dimension 1	43.16	Little savings in small-scale livestock keeping
		Dimension 2	20.74	Economic stability
Human and social assets	7	Dimension 1	71.12	Limited social capital

Abbreviation: MCA, multiple correspondence analysis.

Source: Authors' own elaboration.

livestock keeping. Households characterized by the possession of a few livestock heads and limited access to microcredit are opposed to households with an adequate number of livestock heads (cattle, sheep, and goats) and with access to microcredit.

Finally, with reference to the results obtained by applying the MCA to the group of variables representing human and social assets, only one dimension was extracted, explaining about 71% of the inertia. The dimension is related to limited social relationships and networking of household members. On the corresponding axis, households that do not hire neighbors in their agricultural fields, do not provide labor for neighbors' farming activities, and do not participate in community socioeconomic interest groups are opposed to those that have labor relationships with their neighbors and are involved in community interest groups.

These four dimensions extracted through the MCA were used as explanatory variables in the regression model in addition to the other variables representing households' demographic characteristics and farmers' climate change perception (Table 3).

6.3 | Regression model

The results of the logistic regression model are presented in Table 4. Of the 12 variables fitted in the binary logistic regression model, 7 influenced the choice of adaptation strategies, namely the perception of an increase in temperature, the perception of an increase in precipitation, the perception of a decrease in precipitation, the education level of the household head, the availability of water resources and agricultural inputs, economic stability, and savings in small-scale livestock keeping.

As Table 4 indicates, the variable representing the perception of increased temperature was significant at the 10% probability level and positively related to the adaptation propensity. In particular, the odds of adapting (versus. not adapting) for households that perceived an increase in temperature were 2.60 times greater than those for households that did not perceive a change (holding the other variables constant). Simultaneously, the perception of change in precipitation was found to influence households' adaptation propensity positively and significantly (at the 1% probability level). As a result, the perception of changes in temperature and precipitation can be considered a key driver of the adoption of relevant adaptation strategies.

The household heads' educational level was important in explaining farmers' attitude toward adaptation to climate variability and change. The odds of adapting for households with an educated

TABLE 3 Independent variables: Name, description, and measurement units

Variable category and name	Variable description and measurement unit
Perception of increase in temperature	1 if the household perceived increase in temperature; 0 otherwise
Perception of decrease in temperature	1 if the household perceived decrease in temperature; 0 otherwise
Perception of increase in precipitation	1 if the household perceived increase in precipitation; 0 otherwise
Perception of decrease in precipitation	1 if the household perceived decrease in precipitation; 0 otherwise
Household head gender	1 if male; 0 if female
Household head age	Age of the household head (years)
Household head education level	1 if the household head attended at least primary school; 0 otherwise
Poor availability of water resources and agricultural inputs	Score representing the dimension extracted through MCA
Economic stability	Score representing the dimension extracted through MCA
Little savings in small-scale livestock keeping	Score representing the dimension extracted through MCA
Limited social capital	Score representing the dimension extracted through MCA
Household Food Insecurity Access Scale score	Score ranging between 0 (food secure) and 27 (food insecure)

Abbreviation: MCA, multiple correspondence analysis.

Source: Authors' own elaboration.

head were 2.78 times greater than for households led by an uneducated farmer. Regarding the access to natural and physical assets, the variable representing poor availability of water resources and agricultural inputs was found to be significant at the 10% probability level, with a positive influence on the household adaptation propensity. Finally, considering the economic condition of the households, economic stability was found to influence households' predisposition to adopt adaptation strategies negatively and significantly (at the 10% probability level). On the contrary, little savings in small-scale livestock keeping were negatively related to a household's adaptation propensity.

7 | DISCUSSION

While previous literature has argued that perceived changes may not always reflect the actual context (Cooper et al., 2008; Niles & Mueller, 2016), the results obtained in the present study suggest the opposite. In the presence of an increase in minimum and maximum temperature trends, increase in annual average millimeters of rain, and decrease in the average number of storms per year, the farmers' perception of climate variability and change appears to be aligned with the historical climatic trends. Such awareness suggests that their adaptation choices are not biased by a subjective assessment of seasonality in productivity rates. Furthermore, despite several researchers having questioned the importance of the adoption of adaptation strategies of climatic drivers relative to nonclimatic

TABLE 4 Results of the logistic regression model analysis

Explanatory variables	Coeff.	Std err.	Odds ratio
Perception of increase in temperature	0.957*	0.525	2.60
Perception of decrease in temperature	0.594	0.570	1.81
Perception of increase in precipitation	3.685***	0.662	39.83
Perception of decrease in precipitation	3.739***	0.627	42.07
Male household head	0.549	0.356	1.73
Household head age	0.001	0.010	1.00
Educated household head	1.022***	0.351	2.78
Poor availability of water resources and agricultural inputs	0.337*	0.188	1.40
Economic stability	−0.321*	0.178	0.73
Little savings in small-scale livestock keeping	−0.303*	0.156	0.74
Limited social capital	−0.010	0.173	0.99
Household Food Insecurity Access Scale score	0.028	0.026	1.03
Constant	−5.073	0.995	0.01
Number of observations	296		
Likelihood Ratio (LR) χ^2 (14)	122.31		
Prob. > χ^2	0.0000		
Pseudo-R^2	0.301		
Hosmer–Lemeshow χ^2	6.17		

Note: *Significant at 10%, **Significant at 5%, ***Significant at 1%.

Source: Authors' own elaboration.

forces (Bhatta et al., 2016), the present study shows that a perception of variations in climate, aligned with historical climatic trends, plays an important role in determining the adaptation strategies and their positive impact on households' livelihoods. This finding appears to be in line with some existing literature, which has highlighted that climate change awareness is an important element of the decision-making process related to adaptation (Deressa et al., 2011; Hassan & Nhemachena, 2008; Maddison, 2006; Swe et al., 2015). Maddison (2006) considered the adaptation to climate change as a two-step process: the perception of a change in climate is followed by the identification and the implementation of potentially useful adaptation measures. This means that climate change awareness represents a key component of climate change adaptation and requires an understanding of climate change's causes and impacts (Niles & Mueller, 2016). Interestingly, this study found that no overestimation of the negative impacts of climate change or underestimation of the positive effects of weather modifications altered the households' decision-making process in the selection and implementation of adaptation strategies.

Considering the variables affecting the adaptation propensity, the results of this study show that households' education level has a positive effect on the probability of adapting properly to climate change. Farmers who have attended at least primary school appear to be more inclined to implement adaptation strategies. This is consistent with the studies showing that a higher level of education can stimulate households' awareness of climate change, their propensity to implement adaptation strategies, and their participation in different development and natural resource management initiatives (Anley et al., 2007; Deressa et al., 2011; Dolisca et al., 2006; Kibue et al., 2015). Furthermore, it has been proven that a higher level of education improves farmers' ability to receive, decode, and understand information on climate change (Maddison, 2006).

Among all the sociodemographic drivers of climate change adaptation, previous studies have shown that gender is an important variable affecting the predisposition to adapt at the farm level. In some cases, female farmers have been found to be more likely to adopt sustainable natural resource management and conservation practices (Bayard et al., 2007; Dolisca et al., 2006; Kibue et al., 2015), while, in other cases, it seems that male-headed households tend to adapt to climate change in a more timely manner (Deressa et al., 2011; Zamasiya et al., 2017). However, in this study, the household head's gender was not a significant factor influencing farmers' strategies. This result is surprising in a context like the FDH, where most rural women suffer from social and cultural marginalization and have a lower level of education. This status affects their ability to access information, agricultural extension services, inputs, and improved technologies (Ceci et al., 2014). A possible explanation for such a scarce gender influence on the adoption of adaptation strategies could be related to the crucial role that women play in the household economy. They take on many responsibilities in agricultural production, processing, and small-scale commerce as men and young people leave the household searching for job opportunities elsewhere (Ceci et al., 2014). Being directly involved in agricultural activities, women possess good knowledge of weather patterns, which results in their having the same ability as male farmers to detect climate variability and change and adopt effective adaptation practices.

Previous literature has conveyed mixed standpoints on the influence of age on climate change adaptation. While some studies have found that age is significantly and negatively related to the adaptation attitude (Anley et al., 2007; Bayard et al., 2007; Deressa et al., 2011; Zamasiya et al., 2017), other studies have highlighted the inexistence of an actual influence of age on farmers' decisions to adopt adaptation measures (Anim, 1999; Bekele & Drake, 2003; Hassan & Nhemachena, 2008; Thacher et al., 1997; Zhang & Flick, 2001). The findings of this study are in line with the latter and suggest a slight influence of age on adaptation propensity.

As far as households' access to natural and physical assets is concerned, the results of the study highlight that limited availability of water resources and agricultural inputs, such as organic and chemical fertilizers, promotes the adoption of adaptation strategies. In particular, a lack of access to water resources for irrigated agriculture makes farmers entirely dependent on rainfed agriculture. The perception of changes in the precipitation patterns of the area must have urged the majority of households (69%) to modify their cropping calendar in line with the climate variability and change experienced. Ex ante management of risk represents the only solution in a context characterized by limited economic resources, which prevent the adoption of more expensive adaptation strategies (e.g., water supply improvement, the use of water harvesting tanks, irrigation systems, the use of drought-tolerant or short-cycle varieties).

With respect to the households' economic situation, this study suggests that families for which off-farm activities are the main source of income bear a lower climate risk and have less need to adapt their agricultural practices to climate change. Indeed, their livelihoods do not depend solely on agriculture, and they are therefore more capable of coping with climate variability and change. On the contrary, little savings in small-scale livestock keeping limit the adoption of adaptation strategies. This could be due to the role played by livestock in the African context, in which households keep cattle, goats, and sheep as a buffer stock to insulate their consumption from fluctuations in income (Fafchamps et al., 1998). A buffer stock of livestock is critical to enable risk-averse households facing liquidity constraints to cope with unexpected shocks. In practice, many households with very little livestock do survive but at the cost of adopting an extremely risk-averse production strategy (Aryeetey & Udry, 2000). As shown in the present study, this strategy might be reflected in the inaction of farmers who continue to choose traditional farming practices that are not adapted to address climate change, thus perpetuating the cycle of hampering the household's economic growth.

In the interpretation of the results, some limitations should be considered. First, the procedure for sample selection could not follow a full random design due to contextual factors that prevented the casual selection of the households. Second, in this study, we affirmed that the choice of implementing adaptation strategies in crop management depends on the perception of the climatic changes by the households. However, several other factors could have influenced such choices, for example, borrowing new practices from neighboring villages. Unfortunately, we could not consider these issues in this study.

8 | CONCLUSIONS

The perception of climate variability and change aligned with historical climatic trends had a significant influence on the adaptation propensity in the sample of farmers analyzed. However, household heads' education level, availability of water resources and agricultural inputs, and households' overall economic situation were shown to affect the farmers' decision-making process considerably, leading to the adoption of diversified adaptation strategies. Consistent with these findings, effective policy actions should embrace different areas of interest: (1) climate change awareness, (2) education, (3) access to natural and physical assets, and (4) availability of economic resources to local communities.

Farmers' perception, when in line with the actual changes in climate patterns, may guarantee the effectiveness of specific adaptation strategies, such as agricultural calendar adjustments, changes in the timing of fallow periods, the use of drought-tolerant or native varieties, and pest and invasive species control. Climate change awareness can be enhanced by policies aimed at strengthening weather and climate information systems as well as knowledge dissemination.

Mainstreaming climate change issues and adaptation strategies can be included in education programs targeting rural households not only to improve the knowledge and skills of local communities but also to increase their awareness of the impact of climate change in terms of agricultural productivity. Policies focusing on improving infrastructure and irrigation systems could determine a reduction in climate risks and a safer reliance on the agriculture sector by local communities.

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ENDNOTE

[1] It is possible to represent the relationships between variables graphically using the MCA plot. This graph shows a global pattern within the data. The categories of variables are represented by points; the distance between any points provides a measure of their similarity (or dissimilarity).

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APPENDIX

MCA PLOTS BY CATEGORY OF VARIABLES