



Farmers' perceptions and adaptation strategies to climate risks and their determinants: insights from a farming community of Aguié district in Niger

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Abstract Globally climate risks are rising, and agriculture remains one of the most affected sectors. Niger is one of the most affected countries, where, there is little knowledge of farmers' perceptions of climate risks and adaptation strategies. This research aimed to address these knowledge gaps. In total 160 farm households were randomly selected from two villages and respondents were interviewed using a semi-structured questionnaire. Descriptive statistics and a regression model were used for data analysis. Based on the survey results, the perceived risks include temperature increases, short rain season, recurrent droughts, stronger winds, increased pests, and diseases and reduced crop yields. Agronomic practices including crop association and

diversification, changing planting dates, use of improved seed varieties, use of mineral fertilizers were implemented as adaptation strategies. Strategy adoption was significantly influenced by farming experience, education, farm and household size, soil fertility, livestock ratio. 80% of farmers adjusted their farming system, and the level of adaptation was significantly determined by soil fertility, climate change information, food production, and number of strategies adopted. This study highlights that policy-makers should incorporate communities' knowledge of environmental change and locally adapted solutions to streamline their transition to sustainability.

Keywords Climate change · Coping strategies · Drylands · Farm livelihood · Farmer-managed natural regeneration

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Introduction

Climate change refers to short-, medium-, and long-term changes in weather patterns that are anticipated to occur or are already occurring, as a consequence of anthropogenic emissions of greenhouse gases such as carbon dioxide (Parry et al. 2007). Like other parts of the world, Africa has begun to experience the impacts of human-induced climate change (Creech et al. 2014). Although observed changes in climate parameters have not occurred uniformly across the continent,

West Africa has seen substantial increases in rainfall variability during the latter half of the twentieth century, leading to prolonged droughts in the 1970s and 1980s, and greater flood (Creech et al. 2014). Between 1900 and 2005, the Sahel region experienced considerable drying. However, since the 1980s, it appears that rainfall has increased over time. The high rainfall variation over space and time make the weather predictions less robust (Keller 2009). Overlying this increased variability are expected longer-term changes, such as temperature and lower (or in some cases higher) rainfall (Balk et al. 2009). Tubiello and Rosenzweig (2008) argued that moderate warming (up to 2 °C) in the first part of this century may reduce crop yields in the semi-arid and tropical regions.

The agriculture sector is expected to be the most affected by climate change impacts and households whose livelihoods are largely dependent on rainfall and are the most vulnerable to the climate change risks (Pearce et al. 1996). Agriculture, primarily small-scale farming, is the backbone of Niger's economy. It contributes approximately to 45.2% of Niger's GDP and employs about 85% of the population (INS-Niger 2010). Despite its high contribution to the overall economy, this sector is challenged by many factors, particularly climate-related disasters like drought and floods. In recent years, adaptation to climate risk has become in Niger a major concern for farmers, researchers, and policy makers alike. Livelihood vulnerability and climate change adaptation strategies are seen to be linked to poverty reduction measures (Mertz et al. 2009a). It is noteworthy that whether or not farmers in Niger are aware of climate change and associated risks, they have long been attempting to adapt to the effects of a changing climate by using their traditional knowledge and practices. According to Deressa et al. (2011), perceiving climate risks is the first step in the process of adapting agriculture to climate change. How farmers perceive climate risks strongly affects how they deal with climate-induced risks and opportunities, and the precise nature of their behavioral responses to this perception will shape adaptation options, the process involved, and adaptation outcomes (Adager et al. 2009). Therefore, knowing farmers' perception of climate risks and their specific adaptation measures and drivers are very important to understanding the local exposure to climate risks, the farmers' adaptive capacity to cope

with climate change, as well as to enhance policy towards tackling the challenges that climate change poses for farmers. According to Juana et al. (2013), the design and implementation of any climate change policy required an understanding of the target population's existing knowledge of the risks they are exposed to, the preferred and adopted adaptation practices and the barriers to adoption of these practices.

Many studies have examined farmers' perceptions of climate risks and adaptation, but most have failed to balance farmers' perception with a scientific referential for better understanding its extent (Sofoluwe et al. 2011; Mandleni and Anim. 2011). However, Sjöberg (2000) and Smit and Wandel (2006) have argued that individual perception limits better understanding and explanation of the extent to which the community is at risk of climate change impacts because in general, people cannot correctly judge themselves less or more subjected to risk than other people. These studies recommended references to which individual perception should be judged. These references are usually observations, experiences, and traditional knowledge. In our case study, meteorological data are used to test out farmers' perception of weather variability.

Experience from many different fields, including those relevant to climate change adaptation, such as natural resource management and soil and water conservation practice identified households' adaptation measures to deal with specific climate risks as well as factors determining the adoption of strategies (Adebayo et al. 2012; Apata et al. 2009; Jalloh et al. 2013; Yesuf et al. 2008). According to Jinxia et al. (2008) to adapt to climate change, Chinese farmers are more likely to increase irrigation and grow oil crops, wheat, and especially cotton. In general, regarding temperature change farmers are more likely to plant different varieties, practice water conservation, use shading or sheltering technique, while for precipitation change, changing planting dates is the most important strategy (Maddison 2007; Ado et al. 2018). Deressa et al. (2009) found that level of education, farming experience, access to extension and credit, information on climate, and social capital all influence farmers' choices of measures. Analyzing farm households' adaptation to climate change and determinants is necessary to resolve the constraints to climate change adaptation, and to anticipate climate change adaptation on a large scale. This will lead to better

management of climate-induced risks and vulnerability reduction, particularly by creating a continuous emergency-rehabilitation-development for the most vulnerable communities. However, Sub-Saharan Africa is a region where climate change impacts are expected to be more severe yet in terms of research this region has received limited attention. Therefore, this study aimed at contributing to the existing literature by assessing farmers' climate risk perception and adaptation to climate change with specific regard to rising temperature and rainfall variability. Specifically, the study attempts at assessing: (i) farmers' perception of climate risks (ii) adaptation measures and determinants. This will help in understanding how farmers from Sub-Saharan Africa, particularly in Niger, are attempting to cope with new climate demands while also contributing to the academic debate on climate change adaptation. Specifically, the study contributes to the existing literature by utilizing empirical data from local farmers that aids more in explaining the significance of adaptation strategies to changing climate risks.

Methodology

Study area description

The study was undertaken in the Aguié Department of the Maradi Region in south-central Niger. The Department of Aguié covers an area of approximately 1794 km² and has a population of 245,996 people (INS 2014). The population density is approximately 137 inhabitants per km² (Aissétou 2010; INS 2014). The ethnic distribution of the population is predominantly Hausa (83%), while Fulani and Touareg represent 10% and 6%, respectively. Two villages were purposely selected from Aguié district, namely Guidan Dan May Gari accounted 1334 people (52.60% females) while Guidan Kodaou had 1293 people (50.2% females) in 2104. The main economic activities in the study area are herd grazing (sheep, goats, beef cattle and camels), crop production (*Penisetum glaucum*, *Sorghum bicolor*, *Arachis hypogaea*, *Sesamum indicum*, *Cyperus esculentus*) and agro-forestry (*Faidherbia albida*, *Piliostigma reticulatum*, *Combretum nigricans*, *Adansonia digitata*, *Balanites aegyptiaca* and *Guiera senegalensis*).

The climate of Aguié Department is Sahelian, characterized by distinct dry and rainy seasons. The rainy season usually starts during May or June and ends around August–September. According to Niger meteorological data, Aguié Department receives an average of 522 mm/year and has an average minimum temperature of 21.6 °C and an average maximum temperature of 35.8 °C (INS 2014). However, there is a wide spatial, and temporal variation in the annual rainfall received throughout the Aguié Department, and this creates substantial challenges for farming productivity and results in inconsistency of supply of food to families and markets.

Indeed, the Maradi Region has been facing an acute food shortage mainly due to adverse climatic conditions that are making agriculture more difficult. The region is one of several (Agadez, Diffa, Dosso, Niamey, Tahoua, Tilabéri and Zinder) in Niger that was severely impacted by the local food crises of 2005 and 2006 (Haglund et al. 2011). The region is also facing issues of land tenure and related conflicts, and consequently environmental degradation of common-use resources (Aissétou 2010). As a result, there is often a limited availability of pasture, especially in the dry season due to increased competition for grazing and water resources (Andres and Lebailly 2013). All of these factors are increasing the livelihood vulnerability of the people in the region (Kanta 2007). This situation has motivated several Non-Government Institutions (IFAD, CARE, and Save the Children) and Regional Development Institutions (FAO) to intervene in the area through activities including farmer awareness-raising, training, and capacity strengthening for climate risks mitigation (Fig. 1).

Sampling technique and data collection

This work used a mixed-method approach, combining qualitative and quantitative data. The approach focused on understanding the farmers' knowledge and perceptions of climate risks and their management options for climate change adaptation. Sample participants were selected using a multi-stage sampling approach. The first stage was the identification of unit of analysis and sample size determination. The farm household was identified as the unit of analysis, and 160 household heads were identified for the survey. The second stage was study area selection. The two villages namely *Guidan Dan May Gari* and *Guidan*

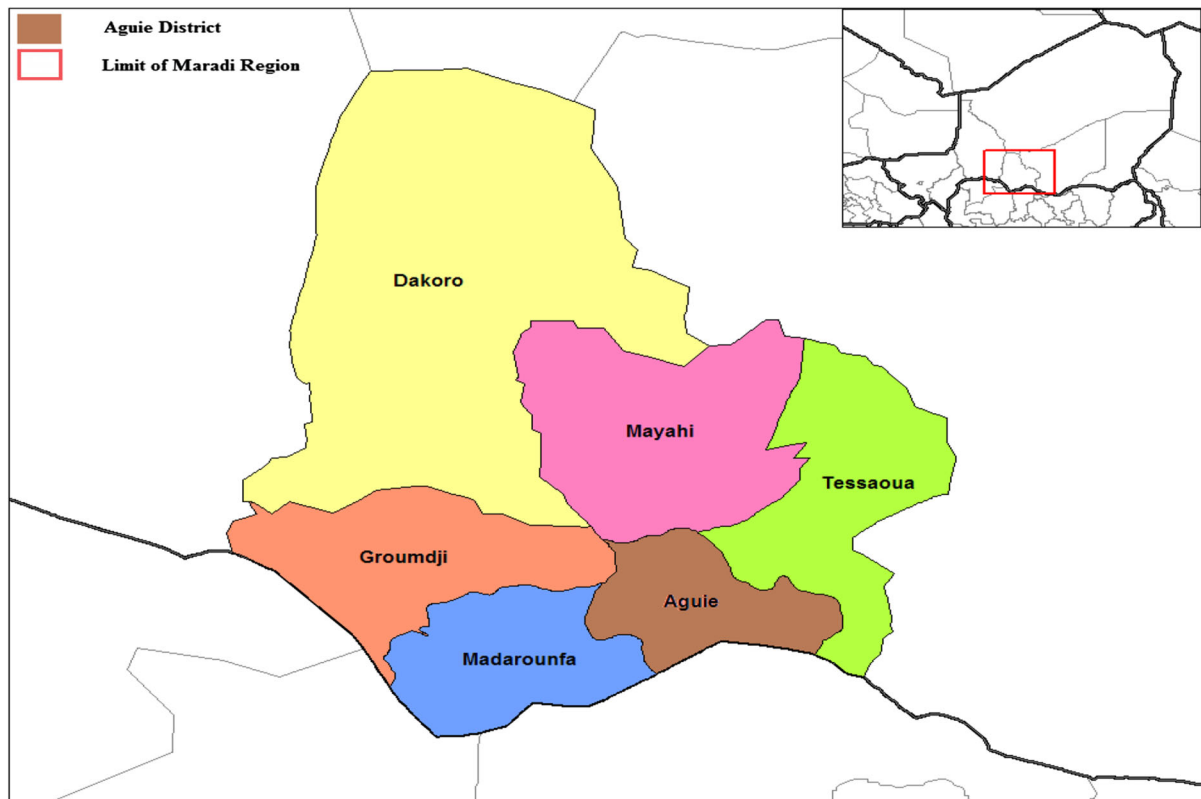


Fig. 1 Map of Niger Republic (top right side) showing the study area of Aguié District. *Source:* DIVA-GIS, Ado ©2018

Kodaou were purposely selected with the help of local government agriculture service and local extension service. The purposeful selection of the two villages was based on their degree of vulnerability to climate change impacts. The researchers' familiarity with the villages and the ease of access to the villages also influenced the selection. *Guidan Dan May Gari* village where no project intervention was made before was considered as neutral and accounted for 226 households and *Guidan Kodaou* village characterized by frequent drought and parasite attacks, and diverse ethnicity (with different agriculture practice) had 220 households.

The third stage was reconnaissance visit and group interview. A reconnaissance visit was made to each of the villages to verify the accuracy of the random selection criteria. During these visits, group interviews were held with the household heads to obtain information about the community climate risks perception and the strategies for dealing with the perceived climate change risks. The collected information served as a basis for the construction of the subsequent survey

(questionnaire and interview) schedule. The fourth stage was focused on questionnaire test. This survey was pre-tested on ten key informant farmers chosen randomly, and the information collected served to amend the questionnaire accordingly. At the fifth and final step, 160 household heads (35% of the total households) were randomly selected for surveying from March to June 2017 depending on household head availability and willingness to take part in the process.

The data collection tools included semi-structured questionnaires and interviews, and resource mapping complemented by background information obtained from local administrations and Non-Government Organizations (NGOs) including documentation of their development projects. The questionnaire covered topics including household socio-demographic and economic characteristics (i.e. ethnic group; household size, gender and schooling levels of household members; the age, household livelihood strategy; household head years of farming experience; membership of a farmers association; their receipt of aid from an

institution; and the household's annual income from different sources [agriculture, livestock, forestry, trader, wage labor, aid, credit or other sources]), farm characteristics (i.e. farm size, type and number of animals, soil fertility appreciation, type and production volume for each crop), and farmers' perception of climate change and associated risks over the past 10 years (i.e. changes in rainfall amounts, rainy season duration, temperature variations, parasite attack, crop yields, wind speeds, droughts, floods and dry season sunshine). The farmers were also asked about the management strategies they currently employ to mitigate each of the perceived climate risks. Finally, the farmers were invited to indicate the extent to which they were adapted to climate risks. All interviews were conducted in the local language (Hausa). The data from group interview and the from the individual interview were recorded using field notes.

Measurement scale

Respondents' perception and level of adaptation are qualitative assessment based on household head appreciation using a Likert scale. Respondents were asked to indicate their perception of climate risk based on a five-point Likert scale where 1 = don't know, 2 = not at all, 3 = low, 4 = medium and 5 = high. Their (respondents) use of indigenous and emerging management strategies to deal with climate risks was binary variable where 0 = "Not adopted", and 1 = "Adopted". The respondents also were requested to indicate their level of adaptation to climate risk using a four-point Likert scale where 0 = not adapted, 1 = low adaptation, 2 = medium adaptation and 3 = high adaptation. However, before applying regression analysis, level of adaptation as the dependent variable was redefined as a binary variable where 0 = Not adapted and 1 = adapted (adapted to include a low, medium and high level).

Data analysis

The qualitative and quantitative data were managed in Microsoft Excel and analyzed using the Statistical Package for Social Scientists (SPSS version 21.0). Descriptive statistics were used to summarize the data distribution into means, averages, frequencies, and percentage (%), and these results were reported as charts, graphs, and tables. Statistical (inferential)

analyses were undertaken using cross-tabulations, Chi square, and Non-linear logistic regression to identify linkages, associations and the influence of farmer characteristics and different land-use activities on the coping strategies and adaptation to climate change.

Empirical method

Worldwide awareness about climate risks is rising and agriculture remains one of the most affected production sectors, especially in developing economies. Niger as a case study is experiencing drought once in every 3 years (Niger-Government 2012), which has led to chronic food insecurity and has consequently increased the vulnerability of farm households. To ensure sufficient food production, farmers have attempted to adjust their farming system and cope with exogenous or endogenous stimuli. Adaptation is viewed as an adjustment in ecological, social, or economic systems in response to actual or expected climatic risks and their effects or impacts. It's referred to changes in processes, practices, and structures to moderate potential changes or to benefit from opportunities associated with climate risks (Smit and Pilifosova 2001). Adaptive behavior studies provide an insight into the processes by which individual households or communities adapt to changes in conditions over time (Bryant et al. 2000; Yohe and Dowlatabadi 1999). Figure 2 conceptualizes our research framework for climate change adaptation.

Following previous studies (Debela et al. 2015; Deressa et al. 2011; Juana et al. 2013) we admit that the implementation of adaptation strategies mainly depends on how farmers perceive the risks and their capacity to respond to shocks or anticipate the risk. From a perception perspective, there is evidence that how farmers perceive climate risks strongly affects how they deal with new climate demand and opportunities and the nature of their behavioral responses to this perception will shape adaptation options, the implicated process, and thus the outcome of adaptation (Adger et al. 2009). In Niger, the most frequent climate risks identified are drought, flood, higher temperature, frequent pest, and soil degradation. Farmers' ability is also an important component influencing adaptation. The farmers' ability depends primarily on the options available to farmers to deal with shocks and anticipate the risks, such as its assets,

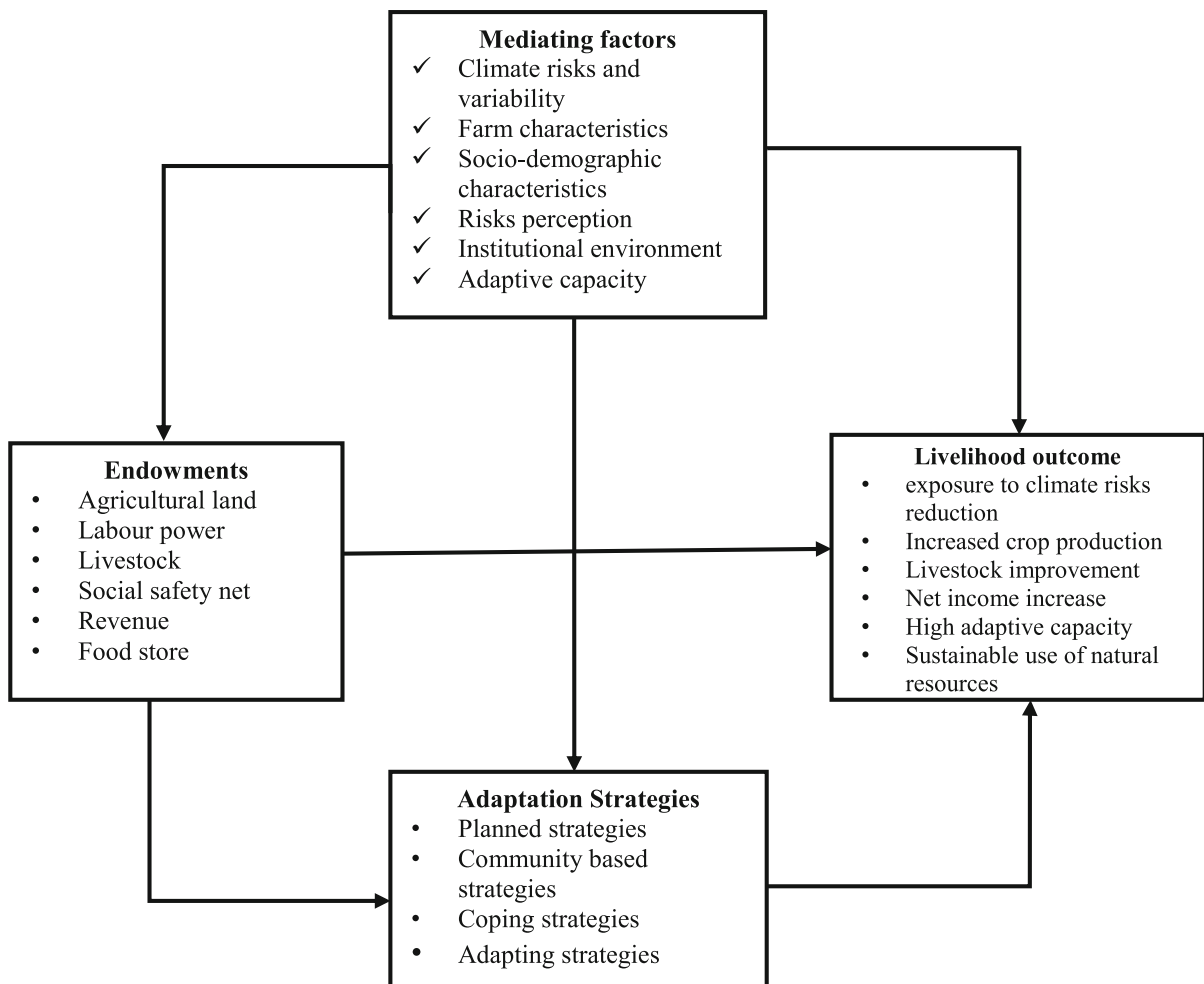


Fig. 2 Framework for assessing farmers' climate change adaptation

education, social safety net, public services, food, and revenue. These options represent a precondition for the mechanisms of household response to a specified risk. The responses usually include coping and adapting strategies from indigenous knowledge or development institutions. Coping strategies include the use of improved seeds, crop combination, changing planting date, use of fertilizers and activities diversification whereas for adapting strategies its comprised farmer-managed natural regeneration, soil and water conservation practices (Zai techniques, half-moon, mulching) and integrated crop-livestock. The different options employed are at differing levels of success. However, knowing the farmers' perception of risks to which they are exposed, the strategies employed and factors demining the adoption these strategies are very

important to understanding the local exposure to climate risks, the farmers' adaptive capacity to cope with climate change impacts as well as for policy makers support and strategies implementation concerning climate change adaptation.

Following previous studies (e.g., Bryan et al. 2013; Smit and Wandel 2006), and based on the conceptual framework outlined in Fig. 2, we assumed that dependent variables are influenced by mediating factors and farmers' endowments. The study firstly assessed the farmers' perceptions of climate change and associated risks and explored their adaptation options. The factors determining the farmers' adoption of adaptation strategies and their self-described adaptation level were then assessed.

A logistic regression (enter method) was performed to identify the most determinant variables affecting farmers’ choice of adaptation strategy. Consistent with previous studies (e.g., Abid et al. 2015; Kato et al. 2011), we assumed that farmers adopt certain strategies if they expect it to deliver a positive farm benefit (i.e., production increase, risk reduction, increased net income). This benefit is also called the utility and is usually noted by U . U_1 is the utility for adoption, U_0 for non-adoption and Y^* is the difference of these utilities ($Y^* = U_1 - U_0$). The farmer will adopt a strategy if the difference of a utility (Y^*) is greater than zero ($Y^* > 0$). Y is a binary indicator that equals one if the farmer adopts a specific strategy and zero otherwise.

Thus, to model the decision to adopt a strategy for climate change adaptation, we consider the latent variable Y^*_{ij} which is equal to the expected benefit from the adoption of specific strategies. i is depicting a farm household that has adopted a specific adaptation measure, and j is depicting the number of different adaptation measures ($j = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12$).

The considered endogenous variables are the different strategies adopted by farmers. We denoted X_k as the vector of exogenous factors influencing the farmers’ decision to adopt specific measures which are the farmers’ characteristics (i.e. household’s size, age, education level, ethnic group, social status, member of associations, education rates, production system, and income) and their farms’ physical characteristics (soil fertility, food production and livestock ratio). We denote β_k as the vector of binary regression coefficient and $\varepsilon_{Y^*_{ij}}$ as the error term. Thus, the equation for strategy adoption is:

$$Y^*_{ij} = \beta_0 + \sum \beta_k X_k + \varepsilon_{Y^*_{ij}} \tag{1}$$

$$Y_{ij} = \begin{cases} 1 & \text{if } Y^*_{ij} > 0 \\ 0 & \text{if } Y^*_{ij} \leq 0 \end{cases} \tag{2}$$

Y^*_{ij} is directly an unobserved latent variable. All we observe is Y_{ij} , a binary variable that equals one if a specific measure is adopted and zero otherwise. A farm household (i) will adopt measure j ($Y_{ij} = 1$) if the expected benefit is greater than zero ($Y^*_{ij} > 0$). If the expected benefit is equal to or less than zero ($Y^*_{ij} \leq 0$), the measure will not be adopted ($Y_{ij} = 0$).

Hence, the conditions from Eq. 2 can be interpreted in terms of observed binary variables (Y_{ij}) as:

$$P_r(y_{ij} = 1) = G(X_k \beta_k) = Y_{ij} \tag{3}$$

$G(X_k \beta_k)$ is the mean function which takes the specific binomial distribution (Alkire et al. 2015).

The parameter estimates of the binary model (β_k) give the direction of the effect of independent variables on the dependent variable and statistical significance associated with the effect of increasing an independent variable just like ordinary least square (OLS) coefficients (Peng et al. 2002). In other words, the coefficient β_k provides the change in the dependent variable due to a one unit increase of independent variables X_k , and e^{β_k} is the multiplicative effect on the odds associated with one unit increase in X_k . To perceive a percentage of odds change, the sign of the estimated parameter must be considered. Thus, a positive coefficient implies that an independent variable X_k increases the likelihood of the adoption of the specific adaptation strategy. Likewise, a negative coefficient denotes a decrease in the likelihood of the adoption of a specific strategy. But the estimated parameter fails to estimate the magnitude of the effect of a change in the explanatory variables. Thus, to interpret and quantify the results, we need to determine the marginal effects. The marginal effects describe the effect of a unit change of the independent variable on the probability of the dependent variable. Following Abid et al. (2015), the results of the partial derivation of (3) will be as follows:

$$\frac{dY_{ij}}{dX_k} = \frac{dG(X_k \beta_k)}{dX_k} = \frac{dG(X_k \beta_k)}{dX_k \beta_k} \cdot \frac{dX_k \beta_k}{dX_k}$$

$$\frac{dG(X_k \beta_k)}{dX_k \beta_k} = G'(X_k \beta_k) \text{ and } \frac{dX_k \beta_k}{dX_k} = \beta_k$$

Thus,

$$\frac{dY_{ij}}{dX_k} = G'(X_k \beta_k) \cdot \beta_k \tag{4}$$

As we know: $G(X_k \beta_k) = \frac{e^{X_k \beta_k}}{1 + e^{X_k \beta_k}} \Rightarrow G'(X_k \beta_k) = \frac{(1 + e^{X_k \beta_k}) \cdot e^{X_k \beta_k} - e^{X_k \beta_k} \cdot e^{X_k \beta_k}}{(1 + e^{X_k \beta_k})^2}$

$$G'(X_k \beta_k) = \frac{e^{X_k \beta_k}}{(1 + e^{X_k \beta_k})^2} \tag{5}$$

We can therefore replace (5) into (4), $\frac{dY_{ij}}{dX_k} =$

$$\frac{e^{X_k \beta_k}}{(1 + e^{X_k \beta_k})^2} \cdot \beta_k = \frac{e^{X_k \beta_k}}{1 + e^{X_k \beta_k}} \cdot \frac{1}{1 + e^{X_k \beta_k}} \cdot \beta_k$$

$$\frac{dY_{ij}}{dX_k} = \frac{e^{X_k \beta_k}}{1 + e^{X_k \beta_k}} \cdot \left(1 - \frac{e^{X_k \beta_k}}{1 + e^{X_k \beta_k}}\right) \cdot \beta_k, \quad (6)$$

The natural logarithm of the odds ratio is equivalent to the linear function of the independent variables. Thus, the antilog of the logit function allows us to find the estimated regression equation:

$$P_r = \frac{e^{X_k \beta_k}}{1 + e^{X_k \beta_k}} \quad (7)$$

We can, therefore, replace P_r in the Eq. (6):

$$\frac{dY_{ij}}{dX_k} = P_r \cdot (1 - P_r) \beta_k$$

$$Y'_{ij} = P_r \cdot (1 - P_r) \beta_k \quad (8)$$

For hypothesis testing, we assume that the null hypothesis (H_0) is accepted if the regression coefficient is zero ($\beta_k = 0$). Otherwise, H_0 is rejected, and the alternative hypothesis (H_1) is accepted. The fit of the final model was assessed by the model Chi square (Model X^2) and the goodness of fit test of Hosmer and Lemeshow. Well-fitting models show significance ($p \leq 0.05$) on the Model X^2 and non-significance ($p > 0.05$) on the goodness-of-fit test.

Based on the review of the literature, the multinomial (MNL) modeling approach is proposed as many studies regarding farmers' adaptation to climate change (e.g., Deressa et al. 2009) where respondents are restricted to select one of the adaptation strategies. However, in the context of the current study, farmers employed many adaptation strategies. Moreover, the dependent variables are binary, and the set of explanatory variables influencing the farmers' decision was expected to be different for different adaptation strategies (Abid et al. 2015). This situation makes the use of MNL approach inappropriate. Therefore, binary logistic regression was employed to assess the effect of explanatory variables on the farmers' decision to adopt adaptation strategies for climate risk mitigation.

The choice of explanatory variables used in this study is based on data availability and literature review (Abid et al. 2015; Deressa et al. 2009; Hassan and Nhemachena 2008; Uddin et al. 2014). The explanatory variables included farms physical characteristics such as farm size (X_1), soil fertility (X_2), and livestock

ratio (X_3), and the farmers' socio-demographic and economic characteristics such as their household size (X_4), ethnic group (X_5), livelihood strategies (X_6), food production (X_7), education rate (percentage of household members who attended formal education in the household) (X_8), education level (X_9), project intervention (X_{10}), age (X_{11}), member of associations (X_{12}), farming experience (X_{13}), information (X_{14}), social status (X_{15}), income (X_{16}), strategy score X_{17} . The dependent variable was farmers' adaptation strategies to climate change such as activities diversification, using mineral fertilizer, use of improved seeds, adopting farmer-managed natural regeneration (FMNR) and raised animals on the farm.

Results and discussion

Farmers' socio-demographic characteristics and adoption of climate change adaptation strategies

The results presented in Table 1 show that the majority of respondents are on average 38-year old and males (89%). Moreover, 93% of them are from the Hausa ethnic group, with only 7% from the Fulani ethnic group. About 48% of the respondents are illiterate, while 31% completed at least primary school and 21% had benefited from mentoring and extension services on crop production technics. Additionally, few of respondents benefited from support of development institutions with only 33% of them being members of farming associations. The most common livelihood strategy of the household is agro-pastoralism (89%), and the average farm size is 3.84 hectares with an average of 1164 kg of food production per year. Farmers have an average of 31 years farming experience (in general the respondents started farming since the age before school). The average of livestock ratio (UTL) and per capita income are respectively 2.51 and \$1522.

With most of the respondents being middle-aged, they may be able to perceive past changes in climate and also have a propensity to adapt to adverse conditions resulting from these changes. 80% of the respondents reported to adjusting their farming system to the perceived climate change but with different level of success. Also, the high level of farming experience, being a member of the farming

Table 1 The socio-demographic characteristics of respondents and their adoption of climate risk adaptation strategies

Variables	Scale	Mean	SD
Project support (0 = non and 1 = yes)	Yes = 1	0.34	
	No = 0	0.66	
Gender	Male = 1	0.89	
	Female = 0	0.11	
Age	Continuous	37.48	12.72
Marital status	Single = 0	0.14	
	Married = 1	0.96	
Ethnic group	Fulani = 0	0.07	
	Hausa = 1	0.93	
Education	Illiterate = 0	0.48	
	Adult courses = 1	0.21	
	Schooling system = 2	0.31	
Livelihood strategy	Farmer = 1	0.11	
	Agro-pastoralist = 0	0.89	
Family size	Continuous	8.48	4.44
Association member	Yes = 1	0.33	
	No = 0	0.67	
Experience (number of years)	Continuous	31	13.10
Income	US\$	1522	168
UTL	Continuous	2.51	3.48
Farm size	Continuous	3.84	3.34
Soil fertility	Low = 0	0.27	
	Medium = 1	0.42	
	High = 2	0.31	
Food production	Continuous	1164	1132
Access to climate change information	Yes = 1	0.76	
	No = 0	0.24	
Strategy score	Number adopted strategies	7	2.06
Adaptation (0 = no and 1 = yes)	Not at all = 0	0.20	
	Low = 1	0.46	
	Medium = 2	0.25	
	High = 3	0.09	

association, the farm size, and soil fertility are expected to positively influence farmer adoption of strategies that will adjust their farming system to new climate scenarios. However, the high rate of illiteracy may be a major constraint for adopting well-defined long-term adaptation strategies. Belonging to an ethnic group and being a member of a farming support association' are also expected to be key factors influencing adoption of measures such as crop association and integrating crops and livestock. However, the respondents' perceptions of climate change

differed based on their level of climate-related knowledge and experience (Below et al. 2012).

Respondents' perception of climate risks

These risks were firstly reviewed during group interviews, where farmers were asked to indicate and rank the commonly perceived risks related to climate change in their village. The farmers commonly note that climate change risks are related to rainfall variability including the shortening of the rainy season

Table 2 Percentage score of respondents' perception of climate risks

Climate risks	Don't know	Not at all	Low	Medium	High
Sunshine intensity	32.50	23.10	22.50	11.90	10.00
Flood frequency	30.00	50.60	10.00	8.80	0.60
Pest and diseases	14.00	6.90	33.00	35.00	11.10
Rainfall variability	23.00	11.30	40.00	14.40	11.30
Drought frequency	22.80	10.40	35.60	18.70	12.50
Wind speed	18.20	15.60	38.80	20.20	7.20
Yield change	21.30	9.40	25.60	23.70	20.00
Temperature change	21.90	6.90	24.40	30.50	16.30
Rainy season duration	20.60	17.50	28.20	23.10	10.60

and increased frequency of floods, increased frequent drought, higher temperatures and increased wind speeds, increased pests and diseases, and reductions in crop yields. However, perceptions of the importance of these risks differed across the villages and among the farmers. In both villages, all of the farmers unanimously agreed with rainfall variability being the most important climate change risk. However, in Guidan Kodaou village, during the group interview, farmers ranked the risks in the following order of importance; increased pests and diseases, crop yield changes, frequent drought, rainy season duration, and higher temperatures and wind speeds. In contrast, in Guidan Dan May Gari village the risks were ranked in the following order; rainy season duration, frequent drought, higher temperatures and wind speeds, and increased pests and diseases. The farmers' climate change risk perceptions are summarized in Table 2.

Table 2 reveals that most of the respondents perceived that there have been changes in climate over the last 10 years and that this change poses several risks, albeit at differing levels. Most of the respondents perceived a medium risk related to increases in temperature and the frequency of pest and disease outbreaks (i.e., 30.5% and 35%, respectively). However, many perceived that rainfall variability (40.00%), drought frequency (35.60%), wind speed (38.80%), crop yield (25.60%), and rainy season duration (28.20%) posed a low risk in the study area.

Most of the respondents believed that rainfall amount (65.30%) and rainy season duration (62.60%) had decreased in contrast to temperature patterns. Research of Maddison (2007) indicates that farmers believe that the temperatures have increased, and rainfall has decreased. Our results are also consistent with the findings of Debela et al. (2015)

and Kosmowski et al. (2016) who reported that most farmers in Ethiopia and Niger perceived a decreased rainfall amount, a worsening of the rainfall distribution and more frequent droughts. Likewise, in a study conducted by Umar (2016) in Katsina State, Nigeria, most of the respondents perceived climate risks such as intense and severe wind, frequent drought, severe pest incidence, warmer temperature and increased disease incidence. However, other studies in Nigeria reported an increase in strong winds and rainfall amounts which sometimes leads to flooding (e.g., Apata et al. 2009; Mertz et al. 2009b; Sofoluwe et al. 2011; Yesuf et al. 2008). Table 2 shows that the majority of respondents (50.60%) reported no changes in flood frequency and near a third (32.50%) were unaware of sunshine intensity.

Figure 3 shows the variations in some climate parameters for the Maradi Region based on Niger national meteorological data. It appears that the study area has experienced changes in the historical climate pattern, especially for temperature (d) and rainfall amount (a), since the 1970s. These changes led to intense drought, and a heat wave projected in lower livestock and food production. This phenomenon continues to be reproduced periodically in the study area, although at differing levels of intensity.

Results from Fig. 3 show that rainfall amount (3a) and the number of rainy days (3b) both evolve intermittently and not in a linear decreasing trend as most of the farmers described. Since 1988, both average temperatures and annual rainfall amounts have increased slightly (3d). This confirms the National Adaptation Plan of Action's (NAPA) climate change simulations for Niger, which in 2006 projected that by 2025 both average monthly precipitation and average monthly temperatures would increase slightly

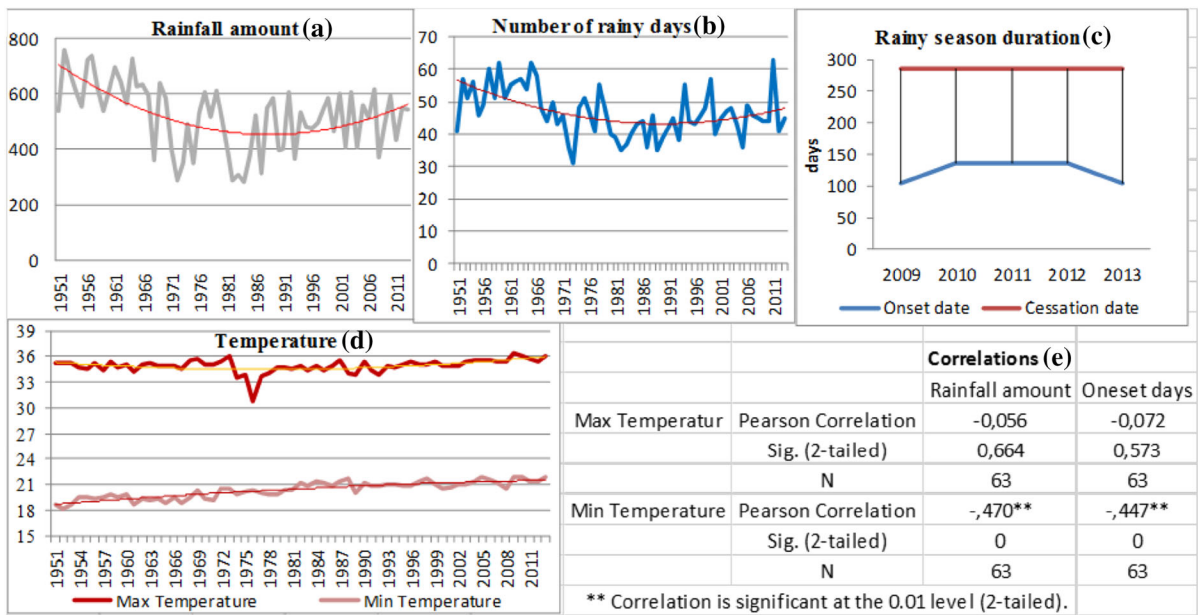


Fig. 3 Climate pattern variation in the Maradi Region of Niger: **a** rainfall amount; **b** number of rainy days; **c** rainy season duration; **d** temperature; **e**: correlation test between temperature,

rainfall, number of rainy days and years. *Source:* Computed from data from the National Meteorological Station

compared to the period 1961–1990 (UNDP 2006). Interestingly, our research revealed a small disparity between regional climate data and farmers’ perceptions of climate risks, particularly for rainfall patterns. Due to the irregular move of the isohyets observed in the Sahel (Wittig et al. 2007), the rainfall regime is very unstable over time; a year of high rainfall amount is followed by some year of drought. Likewise, a single day of heavy rain is followed by a large dry spell. However, the increase humid conditions of heavy rainy day do not compensate the dry spells due to the hotter temperature. This could explain the observed decoupled variations notice in annual rainfall amount. The farmers’ perception of rainfall variability might have been affected by the common uneven distribution of rain over time and space and some particularly poor rainy seasons in recent years (e.g., 2005 and 2010, as evident in Fig. 3a, b), and some might even have had in mind the severe droughts of 1972–1973 and 1984. According to Bryan et al. (2009), farmers’ perceptions of climate patterns are strongly influenced by their observations. Similar results were reported by Zampaligré et al. (2014) who found that farmers’ perception of changes in rainfall patterns was quite different from the meteorological

data on the evolution of rainfall at their study sites of Sokouraba and Tougouri in Burkina Faso.

During the individual interviews, many farmers relayed their perception of changes in climate patterns. These reported changes are reflected in the comments of one tribal leader (i.e., Hardo) from Guidan Kodaou village, who was widely regarded by other farmers as a reliable source of information about climate patterns in the region. Hardo reported that—“the climate is changed compared to previous years and this change started about 30 years ago. Nowadays, the temperature is becoming higher, the wind quite strong and rainy season quite short. The rainy season began late and ended early, but rainfall amount is approximately the same, the only problem is that it’s not well distributed over time and space)”. Hardo’s comments were based on observations that included the behavior of certain plants and animals during specific periods (to determine the start and end of rainfall season and the amount of rainfall, wind speeds, and temperature increases), the movement of the sun from north-to-south (to determine the start and end of different seasons), the movements of stars from east-to-west (to measure the duration of seasons) and lunar length intensity (to measure sunshine intensity).

Ali, old farmer (93 years old) from Guidan Dan May Gari confirmed Hardo's perception of changes in the region's climate patterns regarding temperature (e.g. "nowadays the cold season is less cold and the dry season is warmer") and Hima (representation of extension service at rural area and member of farmers association) explained the link between temperature and rainfall by the decrease in soil moisture (e.g. "the more the rainfall amount during the rainy season, the lesser the temperature is higher during the dry season and vice versa"). The latter belief is confirmed by the correlation analysis, which revealed a negative correlation (-0.47) between rainfall amount and minimum temperature (Fig. 3e). Results displayed in Fig. 3c also show that rainy season duration is now reduced compared to previous years. This is consistent with most of the farmers' perception.

The shortening of the rainy season involves a delayed onset and an earlier ending. Some farmers reported that previously the rainy season started in the seventh month of the lunar calendar (In Hausa the local dialect, "Watan Bakoye") that coincides with the end of April, but now it starts around the end of May and early June. The farmers highlighted this by a local idiom "Watan bakoye manzon ruwa, ko ba ruwan akoy alama" which means that the 7th (lunar) month is a symbol of a rainy season, and even if there is no rain, there are at least its preceding signs. As shown Fig. 3a, the annual rainfall amounts vary each year and are typically irregularly distributed over time and space. Combined with the shortening of the rainy season, repetitive dry periods and stronger winds, this results in a reduction in soil moisture and increases in soil surface temperatures. This situation then results in decreases in crop yields.

In general, households perceived the changes in climate patterns that directly affect their livelihood to include lower rainfall and reduced duration of the rainy season, increased of pests and diseases, and increased temperature. The farmers' perceptions of climate change and especially a reduction in the expected rainfall corroborates with national meteorological observations and the findings from many studies in the semi-arid zone of West Africa (Dasgupta et al. 2014; Jalloh et al. 2013; Seo and Mendelsohn 2007).

Figures 3a and b reveal that the number of rainy days was reduced followed by a slight increase in the annual rainfall amount. This implies the rainfall is

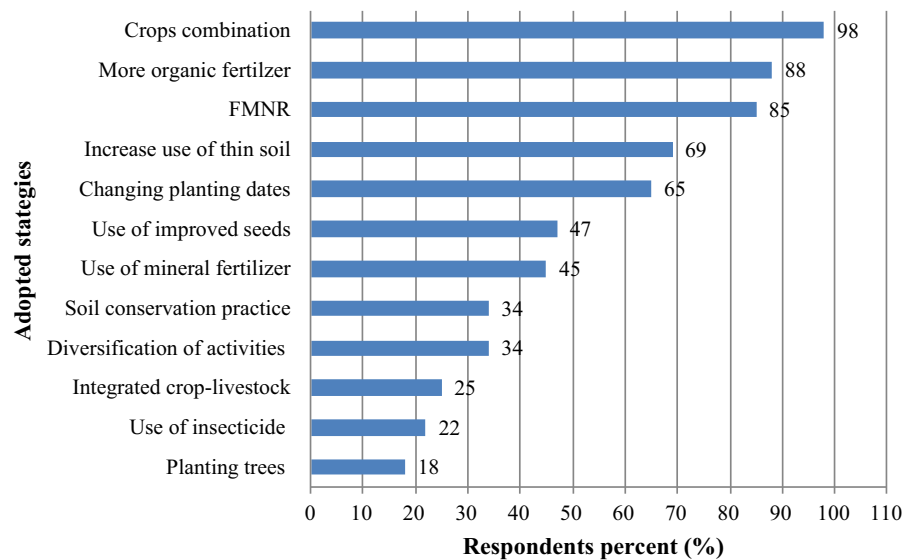
poorly distributed over time and is characterized by very few rainy days, but large daily rainfall amounts followed by repeated long dry spells. Days with the large rainfall amounts are the main cause of flooding and the long dry spells during the rainy season combined with the recent parasite attacks (2014, 2015), and drought may explain the observed disparity in annual rainfall amount. Consistent with, farmers' perception of climate risks may well determine which adaptation measures farmers will implement to confront such risks and misunderstanding of this perception can compromise planned adaptation strategies by policy makers and development agents. Notwithstanding, the disparity between meteorological data and farmers' perception of rainfall amount, did not affect households' adaptation to rainfall variability, because the risk is related to rainfall distribution and not the annual rainfall amount, and most of the farmers' strategies were focused on how to retain soil moisture during extended dry periods.

Farmers' indigenous and emerging strategies for climate risk management

To anticipate climate change adaptation, households must first acknowledge that the climate is changing and perceive that this change poses risks to their well-being that warrant a response, whether it be proactive or reactive (Bryan et al. 2013). In this context, Hardo from Guidan Kadaou reported that – "As the change in climate pattern is nowadays real, we must adjust our agriculture techniques to such change in order to adapt, otherwise it will be a catastrophic situation because our local seed are long duration and rainy season is quite shorter, the rainfall is not well distributed over time, the temperatures keep on increasing and soil fertility is becoming lower and lower, these are big challenges". To mitigate the adverse effects of climate risks, the farmers have adopted various adaptation strategies based on both indigenous knowledge and knowledge diffused through extension services. Figure 4 summarizes the results of the analysis of the most frequently adopted adaptation strategies in the study area.

These strategies have been applied either individually or collectively. Individual strategies have included crop and livestock management, soil fertility management and diversification of income source. More specifically, the practices developed and applied

Fig. 4 Farmers' adaptation strategies for managing climate risks



include crop combinations (i.e., mainly a combination of *Pennisetum glaucum*, *Sorghum bicolor* and *Vigna unguiculata*), the use of organic manure (animals waste), and farmer-managed natural regeneration (FMNR). This latter practice involves the systematic regeneration and management of trees and shrubs from tree stumps, roots, and seeds (Francis et al. 2015).

Other specific practices that the farmers have applied include changing planting dates (early- and/or late-season planting), use of improved seed varieties, planting trees (leguminous plants and indigenous fruit trees are more preferred such as *Faidherbia albida*, *Piliostigma reticulatum*, *Combretum nigricans*, *Adansonia digitata*, *Balanites aegyptiaca* and *Guiera senegalensis*), use of insecticides and mineral fertilizers, soil conservation measures (i.e. covering the soil with crop residues), integrating crops and livestock (i.e. rearing animals on farms) and the recuperation of thin soils (the techniques used include Zai, half lune, and soil cover or tractor usage to aerate the soil. Some of these practices (e.g., FMNR and tree-planting, improved seed, mineral fertilizers, soil conservation) were innovations proposed by extension services. Income diversification activities include wage labor, petty trading, or casual work. The descriptive statistic of the strategies adoption is reported in Fig. 4.

Crop combinations and diversification, the use of organic fertilizers, FMNR practice, and changing

planting dates are management strategies adopted by the majority of farmers in the study area. In particular, the mixed-cropping technique was always adopted by nearly all (98%) of the farmers. This technique was considered important to help reduce the risk of harvest losses due to prolonged dry periods or pests and diseases. Research by Zampaligré et al. (2014) support this finding by highlighting that crop diversification was the most important management strategy for climate change adaptation by farmers in the Sahelian and Sudanian zones of Burkina Faso. Additionally, the respondents who changed their planting dates (65%) reported that they applied early and, or, late sowing in anticipation of the rainfall variability risk and to synchronize the planting with rainfall events. Also, most farmers (88%) used organic fertilizers to reduce the risk of yield losses, while FMNR was employed by 85% of the farmers mainly to prevent soil erosion and reduce the risks associated with increased wind speed and increased temperature. Despite this, very few of farmers (18%) planted trees as a means of mitigating climate risks. This might be due to the limited availability of suitable trees for planting and their high cost when they are accessible. Adoption of most of the strategies is heavily dependent on their being low-cost and their perceived effectiveness.

Abid et al. (2015) have reported that increased adoption of farming techniques as climate change adaptation strategies could be associated with their low-cost and ease of access. However, few of the

farmers (25%) were using the crop-livestock integration strategy because of the high risk of animal theft. The integration of crops and livestock is a management strategy that has great potential to benefit the farming system by providing crop residues for feeding animals and animal manure to improve soil fertility. Most of the interviewed farmers claimed that the most important strategies for climate change mitigation are crop combinations, organic fertilizers use, FMNR, changing planting dates, use of improved seeds and the use of mineral fertilizers, while the limited access to agricultural inputs, decreases in soil fertility, limited extension service delivery and poverty are the main constraints to the adoption of preferred strategies.

Factors determining strategy adoption

A logistic regression model was developed to determine the most influential factors affecting farmers' choice of adaptation strategies. Firstly, the model significance and prediction power were tested. The results of these tests are presented in Table 3.

The results (Table 3) of the logistic regression shows that the choice of independent variables correctly predicted respondents' adoption of adaptation measure condition ranged from 73 and 96% of the total observations. The Cox and Snell R Square ranged from 20% to 34%. The $-2 \text{ Log likelihood}$ is 50 to 157 for all the models. These values indicate an acceptable model fit for cross-sectional data. Therefore, we can conclude that all of the selected variables are have a good fit to significantly predict the factors affecting the adoption of the different adaptation strategies. Table 4 summarizes the statistical outcomes of the logistic regression of the factors affecting strategy adoption.

Interpretation of the results is based on the regression coefficient (β) and odds ratio. For continuous

variables (such as household size, farm size, education rate, livestock ratio, food, soil fertility, age and year experience), a positive coefficient implies an increase in the likelihood of strategy adoption for every unit increase in the predictor variable, whereas a negative coefficient depicts the opposite relationship.

Integrated crop-livestock system is an adaptation strategy employed by farmers to improve soil properties and livestock productivity; it is assumed to be influenced positively and significantly by livestock ratio. The regression test showed that livestock ratio, livelihood strategy, farm size, and food production had a significant influence on the adoption of an integrated crop-livestock system. However, the results revealed that livestock ratio is the most determining factor influencing the adoption of this strategy. Farmers with a high livestock ratio are twice likely to adopt this strategy. Zampaligré (2012) has reported that integrated crop-livestock system is among the most important innovations for farmers. Due to the higher risk of animal theft associated with the adoption of integrated crop-livestock systems, this strategy is used only by members of the Fulani ethnic group who permanently reside on their farm.

Diversification is a risk-sharing strategy enabling farm household to expand their existing activity with one or more new activities. This strategy is expected to reduce household exposure to risks related to changing climate. Low food production and livestock size are found to be the most important factors determining the household's decision to diversify their activities. Household who had a lower food production and higher number of animals were more likely to diversify their existing activity. Our results are in line with the findings of Oluwakemi et al. (2014) who found a significant positive relationship between diversification and family size and livestock size.

Table 3 Descriptive statistic of the variables and model significance test

Model	Mean	$-2 \text{ log likelihoods}$	Cox and Snell R^2	Hosmer and Lemeshow X^2	Hosmer and Lemeshow sig.	Percent of correctness
Integrated crop-livestock	0.25	89.065	0.335	6.226	0.622	86
Activity diversification	0.34	50.120	0.201	8.691	0.369	96
Mineral fertilizer	0.45	157.400	0.330	7.991	0.434	73
Improved seeds	0.47	131.135	0.266	9.428	0.307	74
Use of pesticide	0.22	145.774	0.217	9.260	0.321	76

Table 4 Logistic regression model predicting the factors affecting strategy adoption

Model	Variables	B	SE	Sig.	Exp(B)
Integrated crop-livestock	Household size	– 0.065	0.074	0.379	0.937
	Access to extension service	0.595	0.734	0.418	1.813
	Education rate	– 1.979	1.337	0.139	0.138
	Food production	0.001	0.000	0.011	1.001
	UTL	0.800	0.171	0.000	2.225
	Livelihood strategy	– 2.034	0.800	0.011	0.131
	Farm size	– 0.813	0.293	0.006	0.444
	Constant	0.504	0.935	0.590	1.655
Activity diversification	Education	– 0.684	0.623	0.272	0.504
	Household size	0.166	0.099	0.095	1.181
	Food production	– .002	0.001	0.068	0.998
	Access to extension service	1.466	1.012	0.148	4.332
	Climate change Information	1.119	1.197	0.350	3.062
	UTL	– 0.242	0.126	0.056	0.785
	Ethnic	2.817	1.366	0.039	16.727
	Age	– 0.016	0.036	0.655	0.984
Mineral fertilizer	Constant	– 2.992	2.551	0.241	0.050
	Project support	0.485	0.196	0.013	1.625
	Gender	– .0637	0.669	0.341	0.529
	Household size	– 0.108	0.051	0.035	0.898
	Education rate	– 1.774	1.025	0.083	0.170
	Soil fertility	1.269	0.297	0.000	3.556
	Livelihood strategy	– 0.288	0.639	0.652	0.749
	Ethnic	– 3.996	1.241	0.001	0.018
Use of improved seed	UBT	0.278	0.111	0.012	1.321
	Income	.000	0.000	0.081	1.000
	Constant	3.068	1.672	0.066	21.502
	Association membership	0.637	0.423	0.132	1.890
	Soil fertility	0.709	0.283	0.012	2.031
	Food production	0.001	0.000	0.010	1.001
	Climate change Information	0.269	0.588	0.647	1.309
	Access to extension service	0.790	0.406	0.051	2.204
Use of pesticide	Farming experience	– 0.005	0.017	0.782	0.995
	Education rate	– 1.536	0.953	0.107	0.215
	Constant	– 4.293	1.450	0.003	0.014
	Project support	– 0.427	0.202	0.035	0.652
	Farming experience	0.007	0.018	0.689	1.007
	Climate change information	0.024	0.678	0.971	1.025
	Association membership	1.125	0.591	0.057	3.081
	Household size	0.057	0.055	0.295	1.059
Use of pesticide	Education	1.280	0.383	0.001	3.596
	Income	0.000	0.000	0.016	1.000
	Constant	1.563	3.323	0.638	4.774

Interestingly, soil fertility was found to be the most determining factor affecting the adoption of mineral fertilizers, and farmers with higher soil fertility were 4 times more likely to use mineral fertilizers. The farmers were aware that combining organic and mineral fertilizers are beneficial for crop yields leading to the increase of production volume. This is supported by Zhong et al. (2010) who reported that organic manure plus balanced fertilization with N, P and K has a significant positive effect on soil microbial biomass, diversity and activity and thus enhances crop growth and production. However, the accessibility of inorganic fertilizer increases the likelihood of adoption. The higher the household incomes (UBT) the more the household has access to inorganic fertilizer and the greater the likelihood to adopt this measure. Teklewold et al. (2016) found a strong positive relation between income and the adoption of inorganic fertilizer. Additionally, household with extended family is less likely to use mineral fertility as adaptation measure. Findings of the studies of Cropstedt et al. (2003) supports our results of a significant relationship between household size and adoption of a new agricultural practices. Furthermore, the results reveal that household who benefited from food aid or farm support projects are more likely to adopt the use of mineral fertilizer.

In this study, it is hypothesized that subsidy, being a member of farmers' association, soil fertility will influence significantly the adoption of improved seed variety. The results reveal that soil fertility was a significant factor determining the decision to use improved seed. Farmers with high soil fertility are twice likely to adopt the use of improved seeds as a climate change adaptation strategy. These results are in line with the findings of Fosu-Mensah et al. (2012) and Nyuor et al. (2016) who reported that soil fertility is among the most important factors that influence farmers' adoption of adaptation strategies. Wei et al. (2009) reported that external subsidies are necessary to encourage the adoption of new agricultural practices that require a large financial investment. The study results reveal that farmers who received the subsidy of improved seeds are twice more likely to adopt this strategy. This implies that the availability and accessibility of inputs increase the adoption of adaptation strategies (Below et al. 2012; Maddison 2007). However, observations during field visits revealed that farmers received improved seeds for

free from the development institutions and these seeds were first trialed on a small portion of the farm before being adopted on a larger scale. The same statement was reported by Zampaligré (2012) who found that the adoption of improved seeds is restricted to larger households that are more likely to test new management practices given their higher household labor endowment, which also makes them less risk-averse than smaller households. Interestingly, the results revealed that farmers with higher farming experience (a proxy of age) are not likely to use improved seed variety. This is consistent with the findings of Oluwakemi et al. (2014) in which aged farmers are found to be less likely to use improved varieties.

The test reveals that households that benefited from improved seed varieties from development projects are less likely to use pesticide. This might be due to the fact that the improved seed varieties are less affected by different biotic stress hence it is not necessary to conduct pest control. However, the variables such as belonging to farmers' association, income, and education influence significantly and positively influenced the use of the pesticide. Farmers who were a member of the farming association and who had more educated household members are 3 times more likely to implement pest control measures. This might be explained by the frequent contact of association members' with extension service and regular training received from institutions. The training improves farmers' awareness of climate risk management as well as a better implementation of adaptation strategies. Our findings are supported by Schreinemachers et al. (2017) who reported that training in pest management had a positive effect on pesticide use. Abid et al. (2015) found that farmers with more years of schooling are more likely to adopt strategies compared to the farmers with little or no education. However, there is evidence that the household income influences the accessibility to agriculture inputs and determines the adoption of strategies (Gbetibouo and Ringler 2009; Below et al. 2012).

The level of farm household adaptation to climate change

This article examined respondents' perception of their level of adaptation to climate change and the factors influencing their adaptation. The results are presented in Fig. 5.

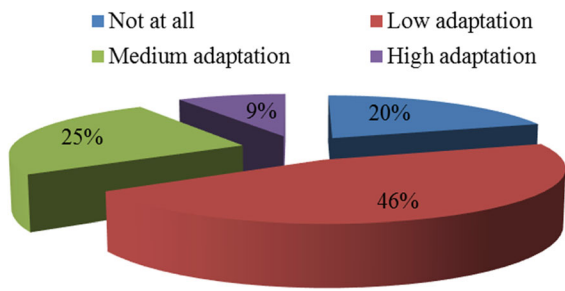


Fig. 5 Farm household adaptation to climate change

Most of the respondents (80%) believed they were adapting to climate change, albeit at differing levels. Very few of these (9%) believed they have a high adaptive capacity, while the majority (46%) believed they have a low adaptation. A compare mean analysis of household adaptation by livelihood strategy reveal that pastoralists had the highest mean ($X = 1.73$) followed by agro-pastoralists ($X = 1.58$) and farmers were the less adapted ($X = 1.34$). This may reflect the effectiveness of the households’ adaptation strategies to cope with climate risks. Bryan et al. (2013) reported that majority (81%) of farmers in Kenya was adapted to perceiving climate change albeit at different levels.

A household’s socio-demographic and farm characteristics, including different land-uses may play an important role in its level of climate change adaptation. Binary regression was performed to identify the most influential factors in the households’ level of adaptation. Results from the test are summarized in Table 5.

Results from model tests show the model performance and the direction of influence of independent

variables. The choice of independent variables correctly predicted households’ adaptation to climate change condition for 94%. The related $-2 \text{ Log likelihood}$ and $\text{Cox and Snell R Square}$ are respectively 43.524 and 23%. The Hosmer and Lemeshow test was not significant ($p = 0.774$). Therefore, we can conclude that the model fitted the data at an acceptable level for cross-sectional data and thus has a good explanatory power to predict the effect of farm households’ socio-demographic and farm characteristics on their adaptation to climate change. Based on the model coefficient, the null hypothesis is rejected. Thus, farmer’s climate adaptation is dependent on the selected farmers’ socio-demographic and farm characteristics.

Linear predictor equation:

$$\begin{aligned} \text{Level of adaptation} = & 4.66 + 0.79X_2 - 0.82X_{13} \\ & + 0.72X_{14} - 0.36X_6 \\ & + 1.04X_{12} - 0.10X_3 \\ & + 0.01X_7 + 0.62X_{10} \\ & + 0.71X_{17} \end{aligned}$$

Households adaptation to climate change is significantly influenced by climate change information, household size, soil fertility, food production and number of strategies adopted. Access to information is expected to increase the household capability of adaptation. The regression results reveal that a household with access to information about climate change is twice likely to adapt. The results are in line with Di Falco et al. (2011) who found that farmers that were informed about the climate are more likely to adapt. Likewise, Bryan et al. (2009) reported positive and

Table 5 The effect of farmers socio-demographic and farm characteristics on households’ adaptation levels

Variables	B	SE	Sig.	Exp(B)
Farming experience	- 0.820	0.440	0.062	0.440
Climate change information	0.717	1.502	0.009	2.048
Household size	- 0.357	0.137	0.009	0.700
Association membership	1.045	1.096	0.340	2.843
UTL	- 0.099	0.086	0.251	0.906
Soil fertility	0.795	0.814	0.029	2.214
Food production	0.004	0.002	0.018	1.004
Project support	0.616	0.568	0.278	1.851
Strategy score	0.714	0.286	0.012	2.042
Education	- 1.134	2.479	0.647	0.322
Constant	4.658	3.056	0.128	105.38

$-2 \text{ Log likelihood} = 43.524$, $\text{Cox and Snell } R^2 = 23\%$, $\text{Hosmer and Lemeshow } X^2 = 4845$ ($p = 0.774$)

significant relationship between access to information and adaptation. Roncoli et al. (2002) indicated that climate information significantly affects farmers' adaptation to climate change.

The respondents' household size is found to be significantly and negatively associated with adaptation to climate change. The larger the household size, the lesser the probability of adapting to climate change. This is because in rural areas of Niger the extended family has a high number of unproductive (less active or unemployed) adults and children, and the higher the number of unproductive people, the higher the burden of productive members in meeting the minimum cost of household needs would be and, hence, the lower the level of adaptation. This is consistent with the finding of Amaza et al. (2006) who found a significant and negative relationship between household size and adaptation.

Farms' soil fertility is an important factor determining crop productivity. The regression results reveal that a farmer with high soil fertility is two times more likely to adapt to climate change. This implies that the higher the soil fertility, the greater the chance to adapt. The soil with a high fertility is expected to be less exposed to climate risks (rainfall variability, high temperature, erosions) and provide better crop production. Zhong et al. (2010) support our results by reporting that soil fertility has a significant positive effect on crop growth and production.

The number of strategies adopted by household is expected to strengthen household adaptive capacity to adapt to climate change. The regression results show that the probability of adaptation increases with the number of the strategy adopted by household. Households that adopt various strategies are twice likely to adapt to climate change compare to who adopted few.

Empirical studies reveal that the majority of rural household livelihood relies on crop production. Food production indicates a significant and positive effect on the probability of adapting. Household with a high annual food production was more likely to adapt to climate change. Bryan et al. (2009) found that food and other aid received increases the probability of household adaptation by 8.8%.

Conclusion

This study assessed farmers' perceptions of climate risks and their adoption of management strategies for adapting to climate change. The findings show that households hold varying levels of perception about climate risks. Most of the respondents' perceived climate risks to involve a medium temperature increase, an increase of rainfall variability, more frequent drought, a shorter rainy season, stronger wind, more frequent pest and disease outbreaks and reduced crop yields. Most of the respondents were unaware of changes in flood frequency and sunshine intensity in the study area.

Households' responses to climate risks are more deliberate and farmers adapted by using a package of management strategies which mainly include crop combinations, the use of organic fertilizers, active management of natural forest regeneration (i.e., FMNR), changing planting dates, using improved seed varieties, the use of mineral fertilizer, soil conservation practices, integrating crops and livestock and the use of insecticides. The adoption of adaptation strategies is influenced by households' socio-demographic and farm characteristics which include the years of farming experience, education, farm and household size, soil fertility, livestock ratio, association membership and project intervention. Other factors may also influence the household decision to adopt specific management strategies. Nevertheless, many farmers expressed the need to adopt several strategies—particularly FMNR, the use of improved seeds, integrated crop-livestock systems, or the use of mineral fertilizers—but could not yet afford to adopt these strategies. A lack of credit facilities and access to agricultural inputs along with declining soil fertility appear to be serious constraints to household adoption of preferred management strategies. Addressing these constraints along with increasing farmer access to extension services, improved seeds, mineral fertilizers, and better market opportunities will be necessary to support farmers' adaptation to climate risks in the study area.

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does not contain any studies with human participants or animals performed by any of the authors.

Authors' contributions AMA and PS conceived of the study, formulated its design, coordinated the conduct of the study including data collection, performed the statistical analysis and interpreted the data, and drafted the manuscript; KP participated in the design of the study, assisted in interpreting the data, and helped to draft the manuscript; GTM participated in the design of the study, assisted in interpreting the data, and helped to draft the manuscript.

Compliance with ethical standards

Conflict of interest The authors declared that they have no conflict of interest

Informed consent Informed consent was obtained from all individual participants included in the study.

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