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Farmers' perceptions of climate change impacts on ecosystem services delivery of parklands in southern Mali

Kapoury Sanogo · Joachim Binam · Jules Bayala · Grace B. Villamor · Antoine Kalinganire · Soro Dodiomon

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Abstract Agroforestry parklands in the Sahel provide a number of ecosystem services that help farmers cope better with climate change effects and thus reducing their vulnerability. However, parklands are threatened due to the decline in densities of species that are sensitive to drought and that might compromise the delivery of the above mentioned ecosystem services to farmers. Therefore, data were collected by interviewing 400 smallholder farmers to elucidate farmers' perceptions of climate change in southern Mali and potential consequences on the delivery of ecosystem services from the parklands. Descriptive statistics and multinomial logit model were used to analyse the data collected and identify the indictors as well as the determinants of farmers' perception of climate change. The findings revealed increases in the frequency of strong wind, dust, drought, high temperatures and number of hot days as the main climate change-related indicators. Furthermore, an early cessation of the rainy season, frequent drought and wind were found to be the factors impeding a better delivery of the ecosystem services from the parklands. Early cessation of rains and frequent drought might affect the water availability which in turn affects the flowering and fruiting phases of the trees. The occurrence of strong wind causes the shedding of the flowers thus reducing the fruit production. Age, educational level, farm size and gender are key factors influencing farmer's perception of climate change. The strategies adopted by these farmers to cope with climate shocks include use of improved drought-tolerant crop varieties, diversification of crops, off-farm activities and seasonal migration. Based on these findings, we therefore suggest the development of conducive environment that can help create agricultural related off-farm income earning activities that could protect active households from the impacts of climate change and variability.

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Introduction

Climate change continues to be a major threat to rural livelihoods in most developing countries because of the associated recurrent drought and floods (Adger et al. 2003; IPCC 2007a; Mertz et al. 2009; Nhemachena 2009; Pouliotte et al. 2009). In West Africa, this may be due to a number factors including low agro-ecological potential (Traore et al. 2015), high dependency of rural economy on agriculture which employs more than 70 % of the active population (Commission for Africa 2005; FAO 2003) and the unpredictable rainfall pattern (Traoré et al. 2007). Consequently, the agricultural sector is highly vulnerable to the vagaries of climate change (Calzadilla et al. 2013) resulting in poverty and hunger in rural areas (Lobell et al. 2008).

The extent of the impact of such changes on the livelihood of the rural populations has triggered studies on farmers' perceptions, their vulnerability, adaptation and coping strategies to climate change in various countries. From these studies, it seems farmers tend to perceive climate change at local scale (Brockhaus et al. 2013; Gadedjisso-Tossou 2015; Olayemi 2012; Sofoluwe et al. 2011) and the most significant effects perceived by the farmers are increase in the frequency of floods, drought and temperature as well as prolonged dry season (Mengistu 2011). Furthermore, among the above mentioned indicators, farmers identified drought and floods as the most important weather variables which impact most on crop production in different agro-ecological zones (Mertz et al. 2009; Okonya et al. 2013). In general, there is a delay in the start of the rainy season and a shortening in the length of the rainy season (Okonya et al. 2013; Traore et al. 2015). Farmers perceived that the causes of climate change included God's plan to signify the end of the world, deforestation and pollution (Codjoe et al. 2013). The main determinants of farmers perception reported for African countries included educational level of the farmer, household size, livestock ownership, agro-ecological zone, farm size, access to credit and ability to hire farm labour (Deressa et al. 2009, 2011; Nhemachena and Hassan 2007; Olayemi 2012; Okonya et al. 2013).

In Africa, where the production environment is unpredictable, farmers have developed mixed farming systems including parkland systems as adaptation strategies (Mertz et al. 2009, 2011). Indeed, in this continent, mixed crops are usually grown under an over storey component of trees giving what is called agroforestry parklands. Agroforestry parklands generally consist of selected trees and shrubs from the original natural woodland after clearing the bush for crop production and as a result, they are dominated by a few favoured species such as *Adansonia digitata*, *Faidherbia albida*, *Parkia biglobosa*, and *Vitellaria paradoxa* (Boffa 1999). In southern Mali, *V. paradoxa* dominates parklands as they occupy approximately 90 % of the agricultural land (Boffa 2000). They also play an essential role in supplying food to rural dwellers. In these mixed production systems, trees are more tolerant to drought due to their deeper root systems (Verchot et al. 2007). The preserved tree species are in most cases fruit trees, providing a range of products that contribute to the livelihoods of rural poor population, particularly during the periods of food shortage (Faye et al. 2010, 2011). Despite the importance of these mixed cropping systems, other reports indicate that tree densities are declining in the Sahel and this has been attributed to the effects of climate change (Gonzalez et al. 2012; Maranz 2009). Indeed, Idinoba et al. (2010) stated that the density of the common species (*Vitellaria paradoxa*) in parklands declined between 6 and 10 % as well as its ecosystem services delivery due to climate hazards. Besides the decline in density of this important tree species in southern Mali (Kelly et al. 2004), it has been predicted that cereal grain yield will decline by 15–19 % by the year 2030 due to erratic rainfall pattern (Butt et al. 2005). As these mixed cropping systems have been developed for centuries, farmers may have concurrently acquired a well elaborated knowledge on their dynamics including the impacts of the climate (Bayala et al. 2014). Therefore, farmers are certainly able to evaluate the impacts of climate change on parklands and subsequently on their ability to cope with climate change and the reduction in the delivery of tree ecosystem services.

It is therefore critical to understand this local knowledge that can be used as a basis to guide the strategies for adaptation to climate change in the future (Cleveland and Soleri 2007). In order to fill in this gap the present study constitutes an attempt to analyse the case of farmers in southern Mali by trying to provide answers to the following research questions: (1) What are the changes in climate as perceived by farmers and factors explaining such perception? (2) What are the impacts of these changes on the dynamics of the parklands according to farmers? (3) How do these affect the delivery of the ecosystem services: provisioning services (food, fuel wood, fibre, biochemical, and genetic resources); regulating services (climate, diseases, water regulation and purification); supporting services (soil formation, nutrient cycling, primary production and provision of habitat) and cultural services (recreational and ecotourism, aesthetic, inspirational, educational, sense of place and cultural heritage)? and (4) what are the strategies to cope with climate change effects and bottlenecks?

Materials and methods

Study area

The study was carried out in two districts (i.e., Koutiala, and Yanfolila) in southern Mali (Fig. 1). Koutiala is located at 12°38′N and 5°66′W in the Sudano-Sahelian zone with a mono-modal rainfall pattern of about 3–4 months. The remaining months are dry (Fig. 2). The mean annual rainfall and temperature of the last 30 years (1982–2012) are 889 (±173.16) mm and 27.98 (±0.42) °C, respectively. This area is characterized by low soil fertility and consequently low productivity (Voortman et al. 2004). Yanfolila is located at 11°10′N and 8°09′W in the Sudano-Guinea zone with a mono-modal rainfall pattern of about 4–5 months. The other months are dry (Fig. 2). Its mean annual rainfall and temperature for the same last 30 years are 1126 (±173.96) mm and 27.79 (±0.48) °C, respectively. The distance between the two study sites is about 445 km. The two districts (Koutiala and Yanfolila) were selected along a north–south gradient representing two different climatic zones. Other selection criteria included their accessibility, shea tree (*V. paradoxa*) density with 16 trees ha^{-1} in the parklands in Koutiala (Kelly et al. 2004) against 27 trees ha^{-1} in the parklands in Yanfolila (Sanogo et al. unpublished) and the socio-economic importance of *V. paradoxa* particularly for women who are normally the most active in processing and selling tree products.

In the study sites, women's role is housekeeping which includes cooking and sending the food to the men on the field and house cleaning. Generally, women are less engaged in farmland activities but more in collecting and processing of non-timber forest products such as shea nuts which contribute significantly to improve family livelihoods. Despite being less engaged in agricultural activities, a small piece of land can be entrusted to active women by their husbands for vegetable (i.e., okra, onion, sweet potato, and pepper), rice or groundnut production. As a consequence women have more power to make decisions for the provisioning ecosystem services derived from the non-timber forest products, but are not decision makers at any step in the management of the farmland (Brockhaus et al. 2013).

Among the various species comprising the parklands, this study focused on shea tree because of its socio-economic and ecological importance (Bayala et al. 2014). Its importance can be explained by the fact that it accounts for more than 50 % of the population of tree species in parklands of the study sites (Maranz and Wiesman 2003). In both sites the livelihood systems of farmers are based on mixed tree-staple cereals (maize, sorghum, and millet) production in rotation with cash crops (cotton and groundnut). Thus, people in both study sites are mainly farmers and herders and they earn their living through rainfed agriculture, herding (cattle, sheep and goats) and provisioning ecosystem services (fruits, shea butter, firewood) from the trees of the parklands and forests.

The population of Koutiala is estimated to be 622,999 people with a density of 71 inhabitants km^{-2} while that of Yanfolila is estimated to be 228,308 people with a density of 26 inhabitants km^{-2} (DRSI 2013). The main tribes in the study sites are Minianka, Bambara, Malinke, Sarakole, Sonrail, Mossi, Dogon and Fulani. Fulani and Minianka dominate in Yanfolila and Koutiala, respectively.

Sampling of farmers

A sample size of 60 individuals from two agro-ecological zones (study sites) was used in a preliminary investigation to determine the proportion of respondents who have observed both changes in temperature and rainfall. Temperature and rainfall

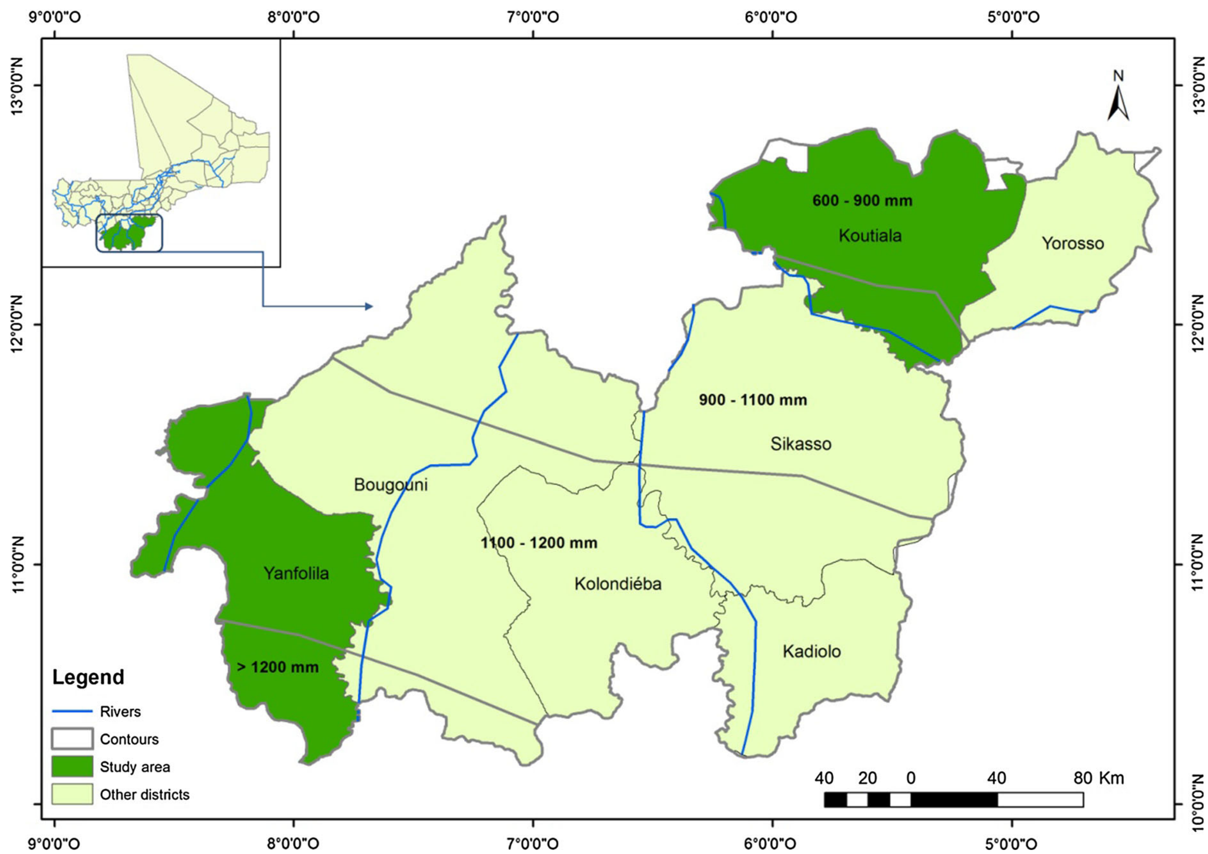

Fig. 1 Location of the sites (Koutiala and Yanfolila) for farmers' perception of climate change study in southern Mali, West Africa

have been selected for the current study because their variation can easily be detected by the farmers. Fifty percent of the respondents who have observed both changes in temperature and rainfall were used to calculate the sample size (*N*) following Dagnelie (1998) formula:

$$N = \frac{U^2_{1-\alpha/2} p(1-p)}{d^2} \quad (1)$$

where *N* is the total number of households to be surveyed, i.e., the sample size; $U_1^2 - \alpha/2$ is the value of the normal random variable for a probability value of $\alpha = 0.05$; $U_1 - \alpha/2 = 1, 96$; *p* is the estimated proportion of people in the villages who have observed changes in both temperature and rainfall ($p = 0.50$); and *d* is the expected error margin of any parameter to be computed from the survey, which was fixed at 0.05.

Then, from this formula the sample size (*N*) was estimated at 384 farmers for the two sites. However, this was adjusted to 400 farmers to cater for gender balance given the heavy involvement of women in the economy activities of shea. Hence, 400 farmers were used in this study and the sample size for each site was prorated to its total number of households giving 240 farmers in Koutiala and 160 farmers in Yanfolila. The sample for each site included 50 % of either sex randomly selected for the interviews.

Data collection

A structured interview was carried out in order to collect information on households' characteristics and their perception of climate change. More precisely, questions were asked to ascertain whether farmers had observed changes in some selected indicators like temperature, rainfall, drought, floods, winds and dust, number of hot days and length of rainy season. The consequences of these changes on shea tree [*Vitellaria paradoxa* C.F. Gaertn. (Sapotaceae)], parkland dynamics were recorded as well as the type of

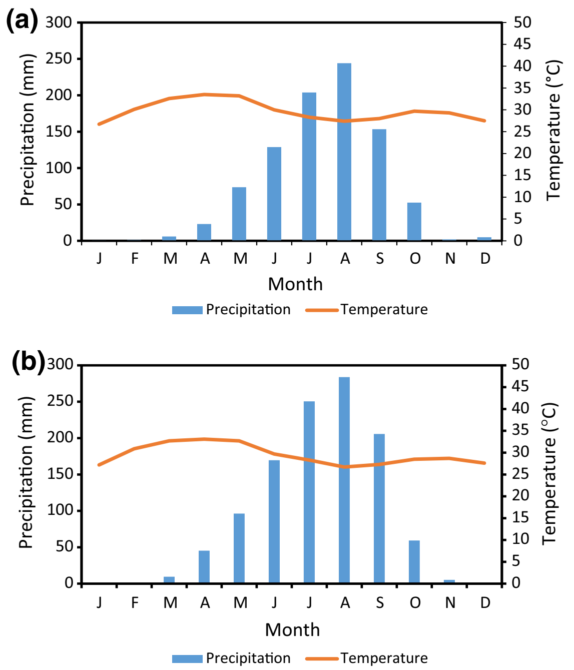

Fig. 2 Mean monthly rainfall and temperature from 1982 to 2012 in Koutiala (**a**) and Yanfolila (**b**) in southern Mali, West Africa

ecosystem services provided (provisioning, supporting, regulating and cultural services) by shea parklands and used by farmers to mitigate climate change effects. Farmer's perception of drivers of climate change as well as adaptation strategies were also recorded.

Statistical data analysis

Descriptive statistics were used to analyse farmers' perception of climate change whereas Chi squared test was used to determine whether there is a significant difference in the perception between the two sites (Koutiala and Yanfolila). A multinomial logit (MNL) regression was used to identify the main determinants of farmers' perception of climate change. The advantage of the multinomial logit is that it permits the analysis of decisions across more than two categories allowing the determination of choice probabilities for different categories of climate attributes. Apart from the well-known drawbacks of the Independence of Irrelevant Alternatives (IIA), this approach is more appropriate than the probit or logit models that have conventionally been used. Instead of having two dichotomous alternatives (0, 1) as in the multivariate logit or probit models, the multinomial logit has J possible states or categories (Cramer 2003; Tse 1987).

To describe the MNL model, let y denote a random variable taking on the values $\{1,2\ldots.J\}$ for choices J, a positive integer, and let x denote a set of conditioning variables. In this case, y representing the category chosen by any farmers in the study sites. Therefore y represents a number of climate attributes (temperature, floods, droughts, rainfall, wind and dust and number of hot days) and x the vector of farmers' characteristics (gender, age, education level, household size, farm size, marital status and farming experience).

The question is how cetirus paribus changes in the elements of x affect the response probabilities:

$$P(y=j/x), \quad j=1,2,\ldots.,J.$$

Since the probabilities must sum to unity, $P(y = j/x)$ is determined once we know the probabilities for $j = 2,\ldots, J$ (Deressa et al. 2009).

Let x be a $1x\ K$ vector with first element unity, the MNL model response probabilities are given by:

$$P(y=j/x) = \frac{\exp(x\beta_j)}{\left[1+\sum_{h=1}^{J}\exp(x\beta_h),\ j=1,\ldots.,J\right]} \tag{2}$$

where β_j is $Kx1$, $j = 1, \ldots, J$.

Unbiased and consistent parameter estimates of the MNL model in Eq. (2), requires the assumption of independence of irrelevant alternatives (IIA) to hold. Specially, the IIA assumption requires that the probability of using a certain perceptions by a given farmer needs to be independent from the probability of choosing another perception (that is, P_j/P_k is independent of the remaining probabilities).

The premise of the IIA assumption is the independent and homoscedastic disturbance terms of the basic model in Eq. (2). The parameter of the MNL model provides only the direction of the effect of the independent variables on the dependent (response) variable, but estimate do not represent either the actual magnitude of the change nor probabilities (Greene 2003). Differentiating Eq. (2) with respect to the explanatory variables (gender, age, education level, household size, farm size, marital status and farming experience) provides marginal effects of the explanatory variables given as:

$$\frac{\partial P_j}{\partial x_k} = P_j\left(\beta_{jk} - \sum_{J=1}^{J-1} P_j\beta_{jk}\right) \quad (3)$$

Thus, the marginal effects or marginal probabilities are functions of the probability itself and measure the expected change in probability of a particular choice being made with respect to a unit change in an independent variable from the mean (Greene 2003). Data were analysed with the STATA (Version 13.1).

Results

Socio-demographic characteristics of the respondents

The results show that farmers in the study areas were largely illiterate with the highest illiteracy rate observed in Yanfolila (Table 1). The average age of the farmers interviewed was 45 (±13) in Koutiala and 42 (±12) in Yanfolila. The average family size was higher in Koutiala compared to Yanfolila and similar trend was observed for farm size. In contrast, the number of years of experience in farming as a head of household was higher in Yanfolila (Table 1). All men were married at both sites whereas 87 and 96 % of women were married in Koutiala and Yanfolila, respectively. Widows were 13 % in Koutiala and 4 % in Yanfolila. Farmers' main activity is rainfed agriculture in both sites, which increases their vulnerability to climate change.

Farmers' perception of climate change

More than 80 % of the respondents in both sites have observed an increase in drought frequency making them more vulnerable as a result of crop failure (Table 2). However, the majority of the respondents indicated that the occurrence of floods has decreased but 30 % of them thought otherwise. Even though, floods can partially damage crops, farmers generally preferred floods to drought because the latter tends to be more detrimental to crop production. A greater proportion of farmers was of the opinion that

Table 1 Socio-demographic characteristics of the respondents of farmers' perceptions of climate change study in southern Mali, West Africa

Variables	Sites			
	Koutiala		Yanfolila	
	Frequency	Percentage	Frequency	Percentage
Gender				
Female	120	50	80	50
Male	120	50	80	50
Education level				
Illiterate	142	59.25	103	64.38
Primary school	77	32.17	32	20.4
Fundamental school	21	9.2	25	16
Age group				
25–40	110	46	86	54
41–60	103	43	59	37
>60	27	11	15	9
Marital status				
Married	227	95	156	97
Widowed	13	5	4	3
	Mean	SD	Mean	SD
Family size	11	±7.38	7	±4
Farm size (ha)	10	±5.1	7	±5
Experience in farming (year)	14	±10.45	15	±11

SD standard deviation

Table 2 Descriptive statistics of farmer's perceptions of climate variables in southern Mali, West Africa

Parameters	Sites			
	Koutiala		Yanfolila	
	Frequency	Percentage	Frequency	Percentage
Drought				
Increase	200	83.33	115	72
Decrease	24	10	18	11.25
No change	16	7	27	17
Precipitation				
Increase	10	4.17	18	11.25
Decrease	213	89	107	67
No change	17	7	35	22
Flood				
Increase	88	37	39	24.37
Decrease	139	58	91	56
No change	13	5.40	30	19
Temperature				
Increase	173	72	114	71.25
Decrease	44	18.33	17	11
No change	23	10	29	18.13
Number of hot days				
Increase	166	69.17	105	66
Decrease	48	20	14	20
No change	26	11	41	26
Frequency of wind and dust				
Increase	169	70.42	77	48.12
Decrease	49	20.42	26	16.25
No change	22	9.17	57	36
Onset of rainy season				
Later	122	51	111	69
No change	60	25	8	7
Not stable	58	24.16	41	25
End of rainy season				
End early	197	82	108	68
No change	20	8.33	11	7
Not stable	23	10	41	26

temperatures and number of hot days have increased across southern Mali (Table 2). About 11 % of the respondents in Koutiala and 26 % in Yanfolila indicated there was no change in the number of hot days. In addition, a greater proportion of farmers perceived an increase in strong wind and dust at both sites. Thus, 36 % of the respondents observed no change in strong wind and dust in Yanfolila, and they argued that formerly strong wind and dust were prevented by a high density of vegetation, which is now sparse. About 90 % of the farmers said annual total rainfall used to be higher when they were young but the total amount had declined over the years. More than 51 % of the respondents at both sites reported that the rains are now unpredictable and the onset tends to delay as the years progress. Most of the respondents observed that the rainy season starts late and rather ends earlier in southern Mali. According to the majority of the respondents, the duration of rainfall has reduced from 6 months occurring between May and October) to

4 months at both sites. A decrease in rainfall amount was mentioned by 89 and 67 % of the respondents in Koutiala and Yanfolila, respectively (Table 2). A few number of farmers from both sites did not perceived any change in rainfall pattern but they argued that the spatial distribution of rainfall is more variable over the last two decades. The Chi square results indicate that farmers' perceptions of climate change do not differ between the two sites (Table 3).

Multinomial logistic (MNL) regression

Table 4 shows the multinomial logit results of how farmers perceive variation in the selected variables as a result of changes in climate in both sites. It appears that four out of seven explanatory variables are significantly associated with farmer's perception of climate change in southern Mali (Table 4). Indeed, the multinomial logit analysis revealed that variables such as age, education level, farm size and gender are the main factors significantly influencing farmers' perception of climate change. In contrast, other variables like household size, experience in farming and marital status had no statistical effect on farmer's perception of climate change in southern Mali.

Aged farmers observed an increase in drought severity, temperature, strong wind and dust, and decrease in rainfall pattern as a result of climate change. Furthermore when considering the ages of the farmers, the results show that the older farmers were able to perceive the changes in climatic variables compared to the young farmers. The probability of observing changes in climatic events increased with educational level of the farmer. Thus farmer with higher education perceived an increase in the following climatic variables: drought, floods, temperature, hot days, wind and dust in Koutiala whereas a change in rainfall pattern was observed in Yanfolila by this category of farmers (Table 4). Our results revealed that farm size was significantly associated with a perceived change in rainfall pattern in Koutiala at 10 % level of probability.

Gender perception of changes in climatic variables (drought, floods, temperature, number of hot days, wind and dust and rainfall) was significantly different between the two sites. Male farmers were more likely to perceive the changes in climatic variables compared to female farmers at both sites.

Farmer's perceptions of drivers of climate change

Even though 23 and 36 % of the respondents in Koutiala and Yanfolila respectively have no idea about the drivers of climate change, some of them listed God's will, deforestation and human behaviour as being the main drivers of climate change in southern Mali. Deforestation was the main driver identified by 63 % of the respondents in Koutiala and 49 % in Yanfolila. Most of the farmers indicated that total amount of rainfall was higher in the past because the vegetation was denser but due to deforestation the vegetation has become sparse and the rainfall is therefore decreasing every year. There are also some spiritual considerations in explaining changes in climate. Indeed, 12 % of those farmers interviewed in Koutiala and 9 % in Yanfolila found human behaviour (i.e., abandoned and disrespectful attitudes of human beings to ancestral spirits) as a cause of climate change.

Perceived impacts of climate change on ecosystem services delivery of parklands

Farmers perceived that drought has been occurring once every 2 years in the last two decades (variability and not change which requires 30-year period of observations) with different intensity and severity at both sites. The erratic rainfall and its variable

Table 3 Chi square test (χ^2) between farmer's perceptions in both sites (Koutiala and Yanfolila) in southern Mali, West Africa

	Value	*df*	Asymp. sig. (2-sided)
Pearson Chi square	288.000[a]	272	0.24
Likelihood ratio	101.281	272	1.000
Linear-by-linear association	14.250	1	0.000
N of valid cases	18		

[a] 306 cells (100.0%) have expected to count less than 5. The minimum expected count is 0.06

Table 4 Results of multinomial regression of farmer's perceptions of climate change according to some explanatory variables in Southern-Mali, West Africa

Covariates	Sites			
	Koutiala		Yanfolila	
	Unchanged	Decreased	Unchanged	Decreased
(A) Perception variable = drought				
Gender (1 if male)	−0.334 (0.601)	−1.498 (0.594)**	−4.046 (1.052)***	−3.576 (1.064)***
HHsize (household size)	0.492 (0.709)	0.300 (0.556)	−0.4055 (0.544)	−0.142 (0.621)
Fsize (farm size in ha)	−0.895 (0.964)	−0.398 (0.767)	0.277 (0.435)	0.034 (0.496)
Age (age category of the respondent: 1 = young active; 2 = adult active; 3 = older)	0.060 (0.385)	−0.952 (0.413)**	−0.356 (0.478)	−0.802 (0.588)
Field_mgt (number of years of experience in farming)	0.063 (0.324)	0.226 (0.271)	0.355 (0.322)	0.490 (0.389)
Status (marital status = 1 if married)	−0.225 (0.871)	0.999 (1.096)	−0.726 (1.247)	−15.033 (1423.48)
Educ (level of education = 0 if illiterate; 1 if primary; 2 if formal)	−1.546 (0.747)**	−1.018 (0.484)**	−0.168 (0.333)	−0.485 (0.408)
Number of observations	240		158	
χ^2	38.5***		69.66***	
Pseudo R^2	0.138		0.279	
(B) Perception variable = flood				
Gender (1 if male)	−0.256 (0.715)	0.398 (0.307)	−2.605 (0.663)***	−0.550 (0.435)
HHsize (household size)	0.490 (0.816)	−0.377 (0.348)	−0.065 (0.551)	0.560 (0.422)
Fsize (farm size in ha)	−0.706 (1.109)	0.168 (0.491)	0.498 (0.453)	0.176 (0.338)
Age (age category of the respondent: 1 = young active; 2 = adult active; 3 = older)	0.077 (0.445)	−0.084 (0.210)	0.004 (0.467)	0.230 (0.323)
Field_mgt (number of years of experience in farming)	−0.120 (0.364)	−0.090 (0.167)	0.042 (0.328)	0.002 (0.247)
Status (marital status = 1 if married)	−0.908 (0.987)	−0.553 (0.639)	−0.542 (1.500)	−0.277 (1.301)
Educ (level of education = 0 if illiterate; 1 if primary; 2 if formal)	−1.411 (0.752)*	−0.538 (0.220)**	0.067 (0.367)	0.215 (0.291)
Number of observations	240		158	
χ^2	16.65**		30.52**	
Pseudo R^2	0.04		0.098	
(C) Perception variable = temperature				
Gender (1 if male)	−1.771 (0.617)**	−1.737 (0.448)***	−3.155 (0.772)***	−2.015 (0.695)***
HHsize (household size)	0.282 (0.602)	−0.034 (0.460)	−0.392 (0.519)	−0.691 (0.608)
Fsize (farm size in ha)	−0.848 (0.840)	0.701 (0.647)	0.593 (0.421)	0.427 (0.496)
Age (age category of the respondent: 1 = young active; 2 = adult active; 3 = older)	0.055 (0.361)	0.534 (0.279)*	−0.649 (0.485)	−0.400 (0.519)
Field_mgt (number of years of experience in farming)	−0.209 (0.273)	−5.055 (0.222)	0.143 (0.303)	0.310 (0.366)
Status (marital status = 1 if married)	−0.522 (0.786)	−0.709 (0.625)	−13.933 (933.987)	0.214 (1.263)
Educ (level of education = 0 if illiterate; 1 if primary; 2 if formal)	−0.934 (0.519)*	−0.093 (0.295)	−0.048 (0.314)	−0.029 (0.380)

Table 4 continued

Covariates	Sites			
	Koutiala		Yanfolila	
	Unchanged	Decreased	Unchanged	Decreased
Number of observations	240		158	
χ^2	50.01***		50.28***	
Pseudo R^2	0.135		0.205	
(D) Perception variable = hot days				
Gender (1 if male)	−0.961 (0.519)*	−1.366 (0.406)***	−2.144 (0.488)***	−0.557 (0.686)
HHsize (household size)	−0.0545 (0.550)	0.105 (0.437)	−0.344 (0.452)	−0.999 (0.645)
Fsize (farm size in ha)	−0.176 (0.766)	0.373 (0.261)	0.583 (0.361)	0.098 (0.549)
Age (age category of the respondent: 1 = young active; 2 = adult active; 3 = older)	−0.344 (0.359)	0.357 (0.261)	−0.160 (0.382)	0.356 (0.494)
Field_mgt (number of years of experience in farming)	0.027 (0.263)	−0.021 (0.209)	0.371 (0.268)	0.022 (0.394)
Status (marital status = 1 if married)	−0.692 (0.789)	−0.674 (0.619)	−14.433 (920)	0.468 (1.329)
Educ (level of education = 0 if illiterate; 1 if primary; 2 if formal)	−0.821 (0.451)*	−0.241 (0.287)	−0.107 (0.275)	−0.359 (0.472)
Number of observations	240		158	
χ^2	35.93***		38.12***	
Pseudo R^2	0.092		0.148	
(E) Perception variable = wind and dust				
Gender (1 if male)	−0.588 (0.505)	−2.431 (0.570)***	−1.482 (0.406)***	−0.396 (0.492)
HHsize (household size)	0.538 (0.599)	−0.164 (0.484)	−0.601 (0.405)	−0.490 (0.504)
Fsize (farm size in ha)	0.244 (1.427)	−0.410 (0.674)	0.126 (0.320)	0.515 (0.407)
Age (age category of the respondent: 1 = young active; 2 = adult active; 3 = older)	−0.469 (0.371)	−0.725 (0.321)**	−0.028 (0.316)	−0.042 (0.393)
Field_mgt (number of years of experience in farming)	0.269 (0.300)	−0.119 (0.227)	0.124 (0.233)	0.027 (0.285)
Status (marital status = 1 if married)	0.051 (1.145)	−0.840 (0.605)	−0.480 (1.064)	−13.542 (950.614)
Educ (level of education = 0 if illiterate; 1 if primary; 2 if formal)	−0.524 (0.411)	−0.898 (0.372)**	−0.111 (0.258)	−0.226 (0.333)
Number of observations	240		158	
χ^2	71.46***		21.57*	
Pseudo R^2	0.192		0.067	
(F) Perception variable = rainfall				
Gender (1 if male)	−0.496 (0.874)	0.163 (0.655)	−2.278 (0.502)***	2.163 (0.693)***
HHsize (household size)	−0.097 (1.006)	−0.722 (0.782)	0.418 (0.631)	0.358 (0.599)
Fsize (farm size in ha)	−1.442 (0.843)*	1.273 (1.128)	−0.472 (0.523)	−0.658 (0.498)
Age (age category of the respondent: 1 = young active; 2 = adult active; 3 = older)	1.094 (0.675)	0.974 (0.576)*	0.984 (0.660)	1.335 (0.640)**

Table 4 continued

Covariates	Sites			
	Koutiala		Yanfolila	
	Unchanged	Decreased	Unchanged	Decreased
Field_mgt (number of years of experience in farming)	0.377 (0.457)	0.427 (1.182)	−0.336 (0.394)	−0.456 (0.374)
Status (marital status = 1 if married)	−0.081 (1.336)	0.768 (1.182)	−0.661 (4068.819)	16.291 (3189.002)
Educ (level of education = 0 if illiterate; 1 if primary; 2 if formal)	−0.880 (0.683)	−0.267 (0.459)	−0.770 (0.332)**	0.300 (0.358)
Number of observations	240		158	
χ^2	14.62*		52.55***	
Pseudo R^2	0.067		0.195	

***, **, * Significant at 1, 5 and 10 % probability level, respectively. Standard errors in parentheses

distribution negatively impact parklands and their provision of ecosystem services. In general, all the respondents are aware that climate change impacts negatively on the delivery of the ecosystem services. According to most of the farmers, shea tree production is directly related to water availability. The respondents enumerated two major climate hazards (drought and wind) which could reduce the ecosystem services provided by shea trees. According to farmers' perceptions in the study areas, drought has more detrimental impacts on trees whereas wind is responsible for the dropping of flowers thus reducing fruiting. More than 82 % of the farmers interviewed asserted that an early cessation of the rainy season and terminal drought results in low fruit set during the next fruiting season which occurs during the following dry season. In addition, more than 50 % of the women have observed a decrease in the delivery of the ecosystem services provided by shea tree due to erratic rainfall in southern Mali.

Perceived ecosystem services delivery of parklands

All the respondents were unanimous about the contribution of parklands for better livelihood especially the shea tree. The butter from this tree has different uses including self-consumption (18 and 13 % of the families in Koutiala and Yanfolila, respectively use it) and income generation. Indeed, the income generated from Shea butter was reported to be about 35,472 ± 21,507 FCFA (USD 74 ± 45) and 28,286 ± 13,376 FCFA (USD 59 ± 28) per woman and per season in Koutiala and Yanfolila, respectively.

Parklands are also providing regulating services that could potentially reduce farmer's vulnerability to climate change impacts. The most frequently mentioned regulating services of parklands are the protection of the soil against wind and water erosion, reduction of temperature through their shade as well as supporting services through improvement of soil fertility. Nearly 93 % of the farmers interviewed in Koutiala and 61 % of farmers in Yanfolila argued that parklands are widely used as windbreak that protect farmlands against soil erosion by reducing wind speed and runoff which are responsible for crop damage. The farmers also argued that farmlands without tree are more vulnerable to soil erosion and runoff. About 64 and 41 % of the respondents in Koutiala and

Yanfolila, respectively, recognized that biomass from parklands improves soil fertility with stable crop yield near the trees compared to the areas away from the trees. About 25 % of the respondents at both sites had different opinions, but they recognized that the trees in the farmlands are very important for their livelihood. More than 90 % of the farmers interviewed at both sites recognized that parklands provide shade and create good microclimate. The shade provided by parklands is a resting place for farmers and also mostly used by livestock during the dry season when the temperature is very high in southern Mali.

Farmer adaptation strategies to mitigate climate change

A total of six strategies were cited as being used to adapt to climate change (Table 5). For instance new varieties and diversification of crops are the main strategies adopted in Yanfolila and Koutiala, respectively to cope with decreasing precipitations. About 11 % of the farmers interviewed in Koutiala mentioned parkland system as a strategy to increase and diversify farmer's production, while 16 % of the respondents in Koutiala reported that they have adopted afforestation (planting food trees) as a way to reduce their exposure to climate change hazards and improve their livelihoods. Erosion control was adopted by 16 % of the farmers in Koutiala against 4 % of farmers in Yanfolila (Table 5). This strategy helps farmer to sustain soil fertility in the farmlands and to conserve soil water. Reduced farm size was also mentioned by 10 and 7 % of the respondents, respectively in Yanfolila and Koutiala and this strategy is related to the availability of labour and equipment.

Table 5 Farmer's adaptation strategies to deal with climate change in Koutiala and Yanfolila in southern Mali, West Africa (in %)

Strategies	Sites	
	Koutiala	Yanfolila
Afforestation	8	16
Diversification of crops	42	15
Erosion control	16	4
New varieties adoption	16	41
Parkland systems	11	14
Reduce farm size	7	10

Drought also often leads to migration of farmers to other sites and this was mentioned by 8 % of the respondents in Koutiala against 11 % in Yanfolila. Most farmers, 63 % at both sites were obliged to carry out off-farm activities (e.g., mason, mechanic, carpenter, trader, and tailor) at the end of the rainy season to cope with food shortages.

Apart from technical responses that were cited as coping strategies, other coping strategies are spiritual (ritual ceremonies and organization of prayers in the mosques). According to most farmers, ritual ceremonies were performed to ask for God's mercy when confronted with drought. Thus, 22 and 25 % of respondents in Koutiala and Yanfolila, respectively thought these practices were relevant and continue to apply them. In the past, ritual ceremonies were the only strategies applied by farmers. However, most of the farmers in the study sites have converted to Islam and have become Muslims and therefore abandoned the ritual ceremonies in favour of prayers. The study showed that 72 and 74 % of the respondents in Koutiala and Yanfolila, respectively thought that organizing prayer in the mosques when farmers are facing drought is an efficient measure.

Discussion

According to our findings farmers are well aware of climate change and its effects such as frequent drought and floods, increase in temperature and number of hot days, stronger winds as well as the rainfall patterns (late start and early cessation of the rainy season). Similar results were reported in West Africa (Ayanwuyi et al. 2010; Mertz et al. 2009; Odewumi et al. 2013; Sofoluwe et al. 2011) and East Africa (Mengistu 2011). The observed increase in temperature in our sites was attributed by the interviewees to a decrease in the vegetation cover. Indeed, these farmers have observed that when they were young the vegetation cover was denser and the temperature was lower than what they currently experience. Together with the increase in temperature, farmers have also observed an increase in the number of hot days corroborating the findings of previous workers in West Africa (Akponikpè et al. 2010; Jenkins et al. 2002) including southern Mali (Butt et al. 2006). According to Rashman (2006) high temperatures are often associated with drought while increase in temperature is expected to reduce crop yields and increase levels of food insecurity (IPCC 2007b; Ogalleh et al. 2012). A Chi square analysis revealed no significant difference in farmers' perceptions about climate change between the study sites indicating that their knowledge might be similar. This agrees with Odewumi et al. (2013), who observed no significant difference in farmers' perceptions of climate change between two sites in Nigeria.

The results of multinomial logit regressions revealed that age, education level, farm size and gender are the main factors significantly influencing farmers' perception of climate change in our sites. This finding is consistent with the fact that the socio-demographic characteristics influence farmers' perception of climate change as reported by previous authors (Ayanwuyi et al. 2010; Legesse et al. 2010; Olayemi 2012; Sahu and Mishra 2013). In contrast, our results are not in agreement with Odewumi et al. (2013), who found no influence of any of the explanatory variables (age, education level and gender) on farmers' perception of climate change. This disagreement with our findings may be attributed to the small sample size (145 against 400 farmers for the current study), which may affect the results. From these logit regression results (Table 4), the age of farmers is also a good predictor associated with the perception of the occurrence of drought, increase in temperature, wind and dust in Koutiala and change in rainfall patterns in Koutiala and Yanfolila. Indeed, older farmers have been exposed more to changes in the climate than the younger farmers (Nhemachena and Hassan 2007; Varadan and Kumar 2014) but the findings of Sahu and Mishra (2013) seem to contradict any relationship between the above mentioned factors. Table 4 shows that men are more likely to perceive the climate hazards such as drought, flood, temperature, hot days, wind and dust and rainfall induced by changes in climate compared to women, and this agrees with the results of Villamor et al. (2015). This is related to the fact that men are the main actors in rainfed agriculture, hence they are more active in taking adaptation strategies to cope with climate change and variability than women in the agricultural sector. However, vulnerability is high among women due to their reliance on non-wood forest products including those of shea trees as source of food and income. The third determinant that influences farmers' perception of climate change is the level of their education. Better educated farmers perceived climate changes more because they have several ways to document and remember past events (Habiba et al. 2012). Farm size showed significant negative influence on farmer's perceptions in Koutiala. This might be due to the fact that this variable affects the timely completion of some field operations in case of late onset of the rainy season thus shortening the duration of the sowing period. This often leads to reduced farm size for the majority of the farmers who do not have the necessary financial resources to hire additional labour (Graft Acquah 2011; Olayemi 2012).

Most observed changes in rainfall patterns (drought, late start and early cessation of rains) frequently lead to decrease water availability and tree density (Gonzalez et al. 2012; Maranz 2009). This will ultimately affect negatively the delivery of ecosystem services (provisioning services, supporting services and regulating services) to rural farmers and communities (Dawson et al. 2011; Okullo et al. 2004). Okullo et al. (2004) found that *V. paradoxa* production was strongly correlated with both relative humidity and wind speed which affects shedding of flowers. Therefore these climate change induced reduction in water and increase in wind speed which often lead to poor fruit formation and reduced yield of trees are unique as previous work in the part of Africa has been more on tree mortality alone (Gonzalez et al. 2012; Maranz 2009). Low yield of non-timber forest products as a consequence of reduced water availability will negatively impact rural people in general and women in particular because these products are the mainstay of rural women who commonly use them to generate income to meet their expenditures. Besides the provisioning services, parklands provide a microclimate through tree shade. More than 60 % of the farmers interviewed in both sites argued that parklands are widely used as wind breaks to protect farmlands against soil erosion. Similarly, Bayala et al. (2014) reported that trees contribute to reducing wind speed and increasing soil fertility. However, 25 % of the respondents did not agree with the opinion that soil fertility may be improved through tree biomass. This must be due to the fact that such soil fertility improvement is more important on poor soils (Bayala et al. 2012, 2014).

Deforestation has been perceived as the main cause of climate change by 63 % of the respondents in Koutiala against 49 % in Yanfolila. In other studies, deforestation was associated with the loss of tree-climate related indigenous knowledge in Nigeria and in Senegal (Codjoe et al. 2013; Ofuoku 2011; Ugwouke 2013). Deforestation in southern Mali is due to a range of factors, including but not limited to agricultural mechanization, fuel wood harvest and charcoal production.

The results also revealed that farmers in the study sites are concerned about crop failure due to climate variability and therefore adopt different responses to tackle this issue. The main adaptation strategies were the diversification of crops and adoption of new crop varieties in Yanfolila and Koutiala, respectively. These two strategies seem to be common practices to cope with the vagaries of climate across the Sub-Saharan Africa (Graft Acquah 2011; Halsnæs and Verhagen 2007; Juana et al. 2013; Kalungu et al. 2013; Lacy et al. 2006; Okonya et al. 2013; Olayemi 2012; Thornton et al. 2007).

More than 11 % of the farmers in both sites indicated that mixed tree-crop systems constitute a strategy to adapt to climate change due to their delivery of some ecosystem services (Table 5). According to the farmers parkland increases crop yield and/or sustains it through its buffering effects on the ecological conditions and soil fertility improvement. Despite this buffering effect, only a small proportion of farmers in Koutiala (8 %) and Yanfolila (16 %) have adopted afforestation to adapt to climate change by planting species like *Eucalyptus camaldulensis*, *Mangifera indica* and *Anacardium occidentale*. Such small percentages are slightly higher than the 5 % of Ayanwuyi et al. (2010) for northern Nigeria. Even if farmers plant less trees due to a range of reasons (cost, survival, etc.), they are more active in preserving naturally occurring trees through what is known as farmers' managed natural regeneration or FMNR. The mixed systems go beyond tree and crops to include livestock as a coping option to the erratic climate and ecological conditions of drylands (Hassan and Nhemachena 2008). Such diversification approach makes the production as well as the livelihood systems more robust to climate hazards (Boffa 2000; Bayala et al. 2014).

In this study, applying soil and water conservation techniques to mitigate climate change induced crop yield decrease was adopted by 16 % of the farmers interviewed in Koutiala and 4 % in Yanfolila (Table 5). Similarly, farm size reduction was also limited to small number of farmers with 7 % of the farmers interviewed in Koutiala and 10 % in Yanfolila (Table 5). Our values are far below the 55 % of farmers in northern Ghana applying farm size reduction as reported by Codjoe et al. (2013).

About 63 % of the respondents in both sites carried out off-farm activities in order to reduce their vulnerability to climate change. Our findings concur with Ayanwuyi et al. (2010) who stated that off-farm activities stabilize income in low crop production year as results of climate change. Furthermore 8 % of farmers in Koutiala as against 11 % of farmers in Yanfolila often migrate after the rainy season in search of alternative income generating activities elsewhere.

Conclusion and recommendations

The main objectives of this study were to elucidate farmers' perceptions of climate change in southern Mali, the consequences of these changes on ecosystem services delivery of the parklands and the adaptive capacity of farmers. The results revealed that farmers have observed an increase in drought frequency, temperature, the number of hot days and frequency of strong wind and dust. Similar findings have already been reported together with their effects on annual crops by previous workers. However, the present study is the first to reveal the impact of limited water availability due to drought and early cessation of the rainy season and wind/dust on the shedding of the flowers and poor fruit yield of Shea tree in the parklands. This ultimately affects the most important provisioning service which is the shea butter for self-consumption and income generation of farmers in general and women in particular. To overcome these adverse effects of climate change, farmers have adopted some adaptation measures like the diversification of crops as well as the adoption of new crop varieties, seasonal migration, etc. Without adaptation strategies, food insecurity and poverty will increase because of the erratic rainfall. The results also show that four out of seven variables studied were the most influential in explaining farmers' perceptions of climate change: age, educational level, farm size and gender. The most common causes of climate change were deforestation and human behaviour according to farmers' perceptions. Almost all respondents perceived drought as the main recurrent phenomenon of climate change which affects crop production and the delivery of ecosystem services of the parklands with dire consequences on the wellbeing of rural communities.

As gender was found to be significant in the way climate change is perceived, we recommend that, within the frame of the National Adaptation Programmes of Action (NAPAs), the government supports farmer's local gender sensitive adaptation strategies to climate vagaries (afforestation, diversification of crops, erosion control, new varieties, etc.). Thus, diversification of vegetables, use of drought tolerant crop varieties and support in adding value to non-timber forest products should be more women focused. Moreover, off-farm income earning activities should be created for rural farmers to protect the active household population from seasonal migration and reduce their vulnerability to climate change. For off-farm activities, women are more active in processing and commercialization of crop and tree products and therefore should be the key targets. Farmers should be encouraged to plant more shea trees on their farms, as a guaranty of future stable shea tree density in order to offset the deforestation and enhance the provision of the ecosystem services for their livelihood.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest to report regarding this submission.

Human and animal rights This research involved human participants.

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