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Local perceptions of climate change and adaptation strategies in the management of *Acacia senegal* parks in Niger

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Abstract

Parklands of *Acacia senegal* play important roles in stabilizing crops production systems and improving the resilience of rural communities in Niger. Population pressure and the effects of climate change strongly impact these parks. It's in this context that the present study is conducted which aims to analyze the local population perceptions of climate change and to identify the adaptations strategies of farmers for *Acacia senegal* parklands management. The study is conducted in the three basins of gum Arabic stands of Niger through a semi-structured individual survey in the western basin, and a focus group discuss in the central and eastern basins. Eleven (11) farmers' perceptions to climate change were identified and 11 adaptations strategies are implemented by producers. These perceptions are mainly summarized as short drought pockets, rising temperature, strong wind velocity, decreasing crops yields, drying up of rivers and loss of biodiversity, etc. dependent on age group and level of vulnerability of producers. Most adults perceive the loss of species in the genus *Acacia* in the studied territories. This could be justified by their experiences in the exploitation of the *Acacia senegal* resource. Control of tree felling or green wood cutting and the practice of human managed natural regeneration are the most promising endogenous management measures. The results of this study could be used to develop sustainable management strategies of *Acacia senegal* parklands with the aim of maximizing the benefits they provide to rural communities.

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Introduction

Climate change is one of the biggest challenges facing humanity in the 21st century. Africa is one of the most vulnerable continents to climate variability and change because of multiple stresses and low adaptive capacity (IPCC, 2007).

The Sub-Saharan Africa, in particular the Sahel, has the particularity of being especially vulnerable to climate change because of geographical conditions that expose them more to climate factors, their low incomes, and greater dependence on activities sensitive to climate such as agriculture (Amoukou, 2009).

Over the past 20 years, the start of the rainy seasons has become erratic in the Sahel, and the total annual precipitations have become more variable. The intra-seasonal variability has increased with longer droughts pockets, a decrease in the stream flows available during the dry season, an increase in the number of extreme rainfall and flooding events (Lacombe *et al,* 2012). All these variabilities are not without consequences on natural resources. In fact, forest cover accounts for only 14% of the area in West Africa, which varies widely from country to country, ranging from 60% for Guinea-Bissau to only 1% for Niger (Zougmoré, 2015; FAO, 2003). Although shrubs and scattered trees are not integrated forest accounting, they occupy an important place, both in terms of area and products and services they offer to the population (Zougmoré, 2015).

Niger has a Sahelian climate which is characterized by a large variability in rainfall resulting in more and more frequent dry years. This situation is related to the nature of the climate and climate changes characterized by extreme adverse events which seriously hamper the development of the country (Amoukou, 2009). Niger ecosystems are fragile and highly vulnerable to climate change phenomena. The difficult socioeconomic environment weakens also the adaptation or coping capacities of the country. Moreover, Niger witnesses the rapid increase of the population with a growth rate of 3.9% per year (INS, 2012).

This population growth is, in most cases, accompanied with the extension of the cultivated lands over the marginal lands, woodlands, and the enclaves and pastoral areas. Numerous forest reserves are transformed into crop fields and natural gum stands to agroforestry parklands in which rain fed crops are grown. These agroforestry parklands provide ecological, agronomic and socio-economic functions. These parklands include those of *Acacia senegal*. Indeed, *Acacia senegal* stabilizes the soil through its highly developed rooting system. It improves the productivity of intercropping (Mansour *et al*., 2014) and constitutes an excellent feed for goats and camels in the Sahel (Ickowicz *et al.,* 2005). Also, as a member of the legume family, *A. senegal* is able to fixe atmospheric nitrogen through it symbiotic association with soil bacteria (rhizobia) through nodules formation (Mansour *et al.,* 2013; Dommergues *et al*., 1999). *Acacia senegal* parks provide other services to the community: the production of the best quality gum, the supply of wood for fuel and service (Amani, 2010; Ichaou, 2008) and traditional medicines (Guinko *et al.,* 1996).

In sub-Saharan Africa, particularly in the Sahel, very little scientific works have been conducted on the farmers' perceptions of climate change in the management of forest resources. The works conducted by theses authors; Brou *et al.* (2005), Aho *et al.* (2008), Gnanglè *et al.* (2009; 2012) and Amoukou (2009) have focused more on adaptation strategies that perceptions.

In Niger, to our knowledge only the work of Wezel et Haigis (2000) focused on farmers' perceptions of vegetation changes. Farmers' perceptions of climate change on the *A. senegal* based agroforestry systems are hardly studied in Niger, despite the multitudes services they provide to rural communities. In this study, we aim to identify farmers' perceptions of climate change in relation to the *A. senegal* parklands and adaptation measures that are implemented by farmers to address climate change effects in these parklands.

Knowledge of farmers' perceptions could be the solid basis for building sustainable management strategies of *A. senegal* parklands in Niger.

Materials and methods

Presentation of the study area

The *Acacia senegal* parklands in the western part of Niger constitutes the western gum production basin. They are in the Sudano-Sahelian zone (Torodi) and cover the far west of the Sahelian zone (Téra) between isohyets 400-600 mm. The other parklands of *A. senegal* are scattered throughout the central part (central basin) and the eastern part of the country (Eastern basin) between 300-400 mm isohyets. These climatic characteristics determine an west-east agro-climatic gradient. The soil types encountered in the study area are the lateritic soils on the plateaus and the hydromorphous or waterlogged soils in the lowlands depressions. The ferruginous leached and depleted soils serve as support for rain fed crops. The study environment is a patchy field of tiger bush, forest galleries, trees and shrub savanna with the presence of Shea parklands, Acacia and *Faihderbia* parklands. It includes steppes with small trees sparsely covering the land. In natural stands and plantations, the commonly encountered species include: *Anogeissus leiocarpa, Tamarindus indica and Diospiros mespilliformis, Parkia biglobosa, Pterocarpus erinaceus, Vitellaria paradoxa, Borassus aethiopim, Adansonia digitata, Acacia senegal, Acacia laeta, Acacia seyal, Vachellia tortilis, Balanites agyptiaca, Combretum micratum, Combretum glutinosum, Pilostigma reticulatum.*

Collected data

The collected data are largely qualitative and concern the socio-economic characteristics, the farmers' perceptions of climate change, and the adaptation strategies developed by the farmers to address climate change in the management of *Acacia senegal* parklands.

Sampling and data collection technics

The choice of survey villages was done using the criteria of Gnangle *et al.* (2012) and Diarassouba *et al.* (2008), related to the importance that farmers give to the exploitation of *A. senegal* parklands, to the socioeconomic diversity, to the socio-cultural features and accessibility of the village. The survey methods used are semi-structured interviews and focus groups discussion. The individually interviewed persons are chosen according to the different age groups (the very young, youth, adults and seniors) and sex. The number of respondents drawn in each village was derived from the number of farm household data derived from the data of the general census of the population and the habitat (INS, 2012). Thus, 38 and 49 farmers were interviewed, that is 10% of the number of farm households at Kokoyé and Kiki villages' respectively. Twelve (12) village assemblies (focus group discussion), that is 3 per locality were held in the localities of Azzeye, Bader Goula and Chétimari (Malam Mainari, N'Guel kolo) gathering 30 farmers (men and women). In fact, this rapid method of data collection was used in these localities because of the insecurity prevailing in the area limiting considerably the time stay of foreigners in the field. The survey was conducted in March and April, 2015.

After the surveys, households are classified according to their level of vulnerability and age class. The level of vulnerability considered are: extremely vulnerability (the annual food production barely exceeding 3 months of consumption), highly vulnerable (annual food production does not exceed 6 months of consumption), moderately vulnerable (annual food production exceeds hardly 9 months of consumption), and low vulnerable (annual food production reaches up to 12 months of consumption). The different age classes used are: Very young (age <25 years), young people (age between 25 and 40 years), adults (age between 40 and 60 years) and seniors (age> 60 years). Occasional meetings were organized for more clarification on some responses that brings new information and need for deep reflections (Gnanglé *et al.*, 2012; Diarassouba *et al.*, 2008).

Data analysis

The frequency of the responses on the perceptions and the adaptive strategies were calculated and histograms performed using the Excel spreadsheet (2007).

The formula for obtaining frequency responses (Fr) is given by $Fr = n_r / N$; with n_r, the number of respondents who mentioned the response r and N, the total number of respondents.

The Chi-Square test of independence was used to check whether there is or no dependency between perceptions and socioeconomic characteristics (vulnerability levels and age groups). The Factorial Correspondence Analysis (FCA) was performed using the R software (*R Core development T. 2010*) to connect the perceptions groups to socio-economic characteristics.

Results

Farmers' perceptions of climate change

Climate change is not only perceived by scientists. It is also noted by rural communities. A total number of 11 perceptions of climate change have been identified by the surveyed producers (Table 1). The identified perceptions, regardless of the level of vulnerability and the age of the producer, are: drought (χ^2= 41, 14; P= 0,000), increase in temperature (χ^2 = 28,56; P= 0,000), high wind velocity (χ^2= 37,75 ; P= 0,000), decrease in the crops yields (χ^2 = 34,57 ; P= 0,000), the drying up of rivers (χ^2 = 37,75 ; P= 0,000), and loss of biodiversity (χ^2 = 41, 14 ; P= 0,000). The most cited perceptions include in this order: wind velovity, drying up of rivers, decrease in the crops yields, loss of biodiversity, low ground cover, and increase in temperature. They account for 72.42% of total perceptions, out of which 91.67% were relevant to natural factors, and 8.33% from socio-cultural factors. Some perceptions, such as short drought (chi-square=41,14; P=0,000), temperature rise (chi-square=28,57; P=0,000), strong wind velocity (chi-square=37,75; P=0,000), declining crop yields (chi-square=34,57; P=0,000), drying up of water sources (chi-square=37,78; P=0,000), and loss of biodiversity (chi-square = 41,14; P=0.000) were dependent on the level of vulnerability and the age of farmers.

Table 1. Farmers perceptions of climate change.

	Relative frequency of responses (%)	Factor origin
Strong wind speed	12,36	Natural
Drying up of rivers	12,36	Natural
Low ground cover	12,07	Natural
Lower yield of crops	12,07	Natural
Loss of biodiversity	12,07	Natural
Temperature rise	11,49	Natural
No social compliance	8,33	Socio-cultural
Late rains	6,32	Natural
Early cessation of rains	6,03	Natural
Rainfall decline	6,03	Natural
Short drought	0,86	Natural
Total of frequency	100	

Typology of perceptions based on vulnerability level

The projection of levels of vulnerability and farmers' perceptions in the axis system from the Correspondence Analysis (CA) is presented in Fig. 3. The first two axes (Dim 1 and 2), the most significant of the CA explain 89.34% of the total variance (Fig. 3). The perceptions most related to the first axis perceptions were drought pockets, disregard of social norms, rain delays and decrease in the rainfall. Early rain stops, decrease in crops yield, and drying up of water points were taken into account by the second axis (Table 2). The vulnerability levels (less vulnerable and very vulnerable) have most contributed to the formation of the first axis, while moderately vulnerable and extremely vulnerable are more related to axis 2 (Table 2). By combining vulnerability levels and farmers' perceptions to climate change which have contributed to the formation of two axes, the less vulnerable and moderately vulnerable variables oppose extremely vulnerable and very vulnerable. Indeed, the less vulnerable group perceive climate change by decreasing rainfall and delayed rains, while the extremely vulnerable group perceive the climate changes through the non-compliance with social norms, the early cessation of rains, decrease in crops' yield, and drying up of rivers (Fig. 3).

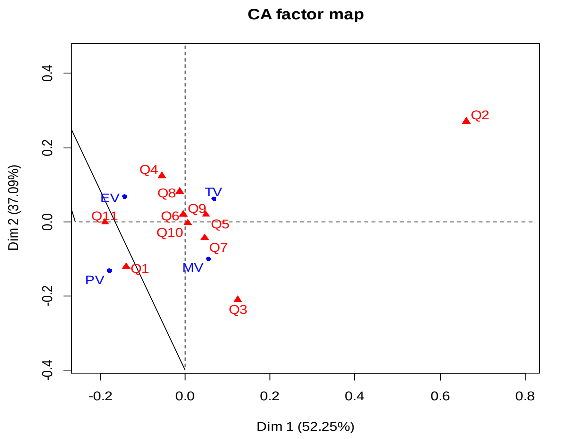

Fig. 3. Map of the Factorial Correspondence Analysis (CA).

PV: Less vulnerable; MV: Moderately vulnerable; TV: Very vulnerable; EV: Extremely vulnerable; Q1: Decrease in rainfall; Q2: Short drought; Q3: rain delay; Q4: Early end to rain; Q5: increase in temperature; Q6: Strong wind velocity; Q7: Low vegetation/ground cover; Q8: Decrease in crops yields; Q9: Drying up of rivers; Q10: Loss of biodiversity; Q11: No respect of social norms.

Table 2. Values of contributions and cosine level of vulnerability and farmers perception type for the first two axes (Dim 1 and 2). The bold values of the variables and factors are those used for interpretation with the canonical axes.

Vulnerability levels	Dim 1		Dim 2	
	Contribution	Cosine	Contribution	Cosine
Less vulnerable	43,95	0,75	14,40	0,18
Moderately vulnerable	9,38	0,22	41,75	0,69
Very vulnerable	26,89	0,53	20,42	0,29
Extremely vulnerable	19,77	0,50	23,43	0,42
Farmers' perceptions				
Decrease in rainfall	10,70	0,516	11,53	0,394
Short drought	42,51	0,751	10,09	0,127
rain delay	11,64	0,257	46,73	0,732
Early end to rain	1,97	0,156	14,76	0,828
Rising temperature	2,87	0,424	0,69	0,073
Strong wind speed	0,02	0,022	0,68	0,684
Low cover of vegetation	2,68	0,473	3,17	0,397
Decrease in yield of crops	0,18	0,019	11,65	0,859
Drying up of rivers	0,02	0,022	0,68	0,684
Loss of biodiversity	0,07	0,063	0,02	0,014
No respect of social norms	27,35	0,868	0,00	0,000

Typology of perceptions according to age groups

The results of Factorial Correspondence Analysis (FCA) have linked age groups and farmers' perceptions to climate change (Fig. 4). The information contained in the variables are controlled to 93.66% by the system of axes 1 and 2 (Fig. 4). Perceptions to climate change such as decreasing rainfall, early cessation of rains, late rains, drought pockets, the drying up of rivers were those that contributed most to the formation of the first axis, while the temperature rise, the early cessation of rains, loss of biodiversity and low vegetation cover are the perceptions related to the second axis (Table 3). Regarding the age groups, the very young and elderly producers group have contributed most to the formation of the first axis, while the younger age groups and adults are more related to axis 2 (Table 3). By combining the farmers' perceptions and age groups variables that contributed most to the formation of the two axes, the seniors group opposed with the very young people group expressing different perceptions to climate change. In fact, the elders perceived climate change through decreasing rainfall and drought pockets, while the very young perceived the changes through the delays and early stops of rains (Fig. 4). Adult's producers, for their own case, express climate change through rising temperatures and the youth through crops yield reduction and loss of biodiversity.

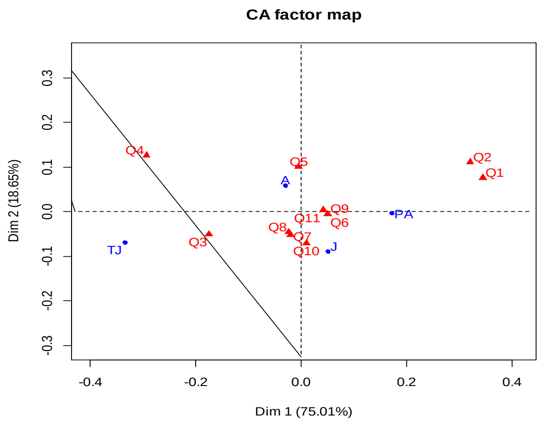

Fig. 4. Map of the Correspondence Analysis (CA).
A: Adults; J: Young; AP: Seniors; TJ: Very young; Q1: Decrease in rainfall; Q2: drought pockets; Q3: rain delay; Q4: Early end to rain; Q5: Rise in temperature; Q6: Strong wind speed; Q7: Low vegetation cover; Q8: Decline in yield of crops; Q9: Drying up of rivers; Q10: Loss of biodiversity; Q11: No respect social norms.

Table 3. Values of contributions and cosinus square of age classes and type of producers' perception for the first two axes (Dim 1 and 2). The variables and factors with bold values are those used for interpretation with the canonical axes.

Age class	Dim 1		Dim 2	
	Contri-bution	Cosine	Contri-bution	Cosine
Adult	2,60	0,19	41,66	0,76
Young	3,94	0,22	48,11	0,67
Senior	32,78	0,89	0,02	0,00
Very young	60,68	0,93	10,22	0,04
Farmers perceptions				
Decrease in rainfall	39,68	0,95	7,84	0,05
Drought pockets	5,97	0,89	2,93	0,11
Rain delay	13,93	0,90	4,54	0,07
Early stop of rain	35,11	0,84	26,54	0,16
Rising temperature	0,02	0,00	28,57	0,91
Strong wind velocity	1,84	0,93	0,09	0,01
Low vegetation cover	0,31	0,13	8,26	0,85
Decrease in yield of crops	0,43	0,20	5,95	0,69
Drying up of rivers	1,84	0,93	0,09	0,01
Loss of biodiversity	0,08	0,02	15,16	0,82
No respect of social norms	0,81	0,12	0,03	0,00

Adaptation strategies to climate change in management of A. Senegal parkland

Eleven (11) adaptation strategies to climate change have been identified in the surveyed village territories, of which 81.81% are of endogenous origin and 18.18% of exogenous origin (Table 4). The most strategies adopted by producers are: the valorization of lowlands; planting valuable species; the practice of farmers' managed natural regeneration (FMNR); the use of improved seeds and the diversification of activities. Depending on the perception, specific coping responses are adopted. Indeed, in order to overcome the decreasing of crops yield, the practices or technology adopted include: the change of cropping system (crops/trees association); the use of organic manure and mineral fertilizer.

Table 4. Farmer's adaptation strategies to climate change.

Farmers adaptive strategies	Relative Frequency of responses (%)	Origin
Valorization of lowland	18,75	Endogenous
Restocking and planting of valuable species	15,63	Endogenous
Protection of *Acacia* seedlings (farmers managed natural regeneration)	14,73	Endogenous
Use of improved seeds	11,16	Exogenous
Diversification of activities	9,38	Endogenous
Changing the type of crops	7,59	Endogenous
Manure use	6,70	Endogenous
Use of mineral fertilizers	5,36	Exogenous
Changing sowing dates	4,02	Endogenous
Development and operation of ponds	4,02	Endogenous
Magical –religious practices	2,68	Endogenous
Total frequency	100	

Perception threatens for loss of Acacia's species complex by farmers' age groups

The investigation found that the disappearance of the Acacias species complex is seen differently according to the age categories. Adult's farmers perceived more (45.64%) the threat of disappearance followed of young farmers (29.53%) and the seniors (20.81%). The very young farmers groups perceived less the disappearance (4.03%) of these species. Indeed, adults perceive that the *A. senegal* is the most endangered species (17.45%) followed by *A. seyal* (14.77%) and *A. laeta* (13.42%).

Measures for management and conservation of A. senegal parklands

Despite the threats to this resource, farmers have adopted several answers. The survey identified five important endogenous measures that are practiced in the context of sustainable management of *A. senegal* parks. These include in order of importance: controlled of tree felling, farmers managed natural regeneration (FMNR); restocking or replanting; deferred grazing and finally the village management committee (Fig. 5).

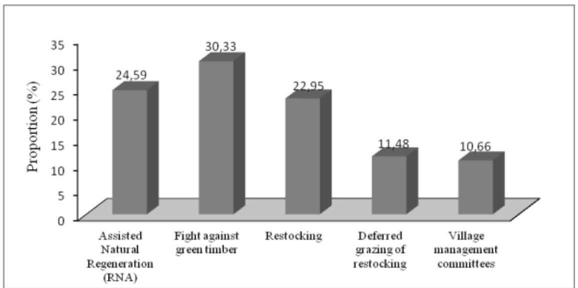

Fig. 5. Management and conservation measures of *A. senegal* parks.

Discussion

Farmers' perceptions of climate change

The study highlighted several farmers' perceptions to climate change. Perceptions such as high winds, drying up of water sources, declining crop yields and loss of biodiversity revealed in the study are consistent with those found by Amoukou (2009) in Niger. According to this author, climatic factors (drought) and anthropic factors (trees felling) are causing the disappearance of vegetation and migration of wildlife to the south.

The works of Gnanglé *et al.* (2012) in northern and central Benin (2009), those of Hassan *et al.* (2008) in sub-Saharan Africa and Traore *et al.* (2002) in Guinea have revealed that more than half of the surveyed farmers perceived climate change through rising temperatures, declining rainfall, changing in the timing of the rains, recurring droughts and the drying up of rivers once perennial in the dry season.

These results diverge to some perceptions such as decreasing crop yields and pronounced loss of biodiversity. These divergence perceptions could be explained by the fact that climate change is perceived in the Sahel by the phenomena of land degradation and desertification. That part of sub-Saharan Africa currently remains one of the areas most exposed to the harmful effects of climate change and that our study area is part of. Brou *et al.* (2005) in Côte d'Ivoire revealed non-compliance with divine rules as perception of climate change through the practice of discrete sexual intercourse in the bush, the desecration of sacred places. This perception is expressed by incestuous practices in Benin (Gnanglé *et al.,* 2012), whereas in our study area, it results in non-compliance with social norms by the new generation.

Farmers' perceptions revealed that the development of agro-climatic and hydrological factors is strongly related to changes in temperature and rainfall. Respondents also highlighted the same observations through excessive heat, strong wind, lower yields of crops and the drying up of rivers.

It is also clear that farmers' perceptions of climate change are function of the level of vulnerability (extremely vulnerable, very vulnerable, moderately susceptible and less vulnerable) and age groups (very young, youth, adults and seniors) of the farmers. These results are similar to those of Gnanglé *et al.* (2012) in northern Benin and also corroborate with those of Teka *et al.* (2010) who indicated that in the coastal areas of Benin, local perceptions to natural risks on people vary according to specific groups (social group and age).

In our own case, the extremely vulnerable and very vulnerable groups are those that express better the perceptions to climate change. This is explained by the fact that these farmers' categories are those whose main activities are based on natural resources exploitation. Their annual food production is highly insufficient (hardly exceed six months of consumption), so they fall back mainly on *A. senegal* parks for the production of gum Arabic and wood, source of substantial incomes for them. In northern Benin, Gnanglé *et al.* (2012) found the same pattern in which the poor and the less prosperous are those that express the perceptions of climate change especially on shea parks, the fact that agriculture and exploitation of shea resource are main activities for meeting their basic needs.

Regarding age groups, adults are better perceiving climate change as opposed to very young. Gnanglé *et al.* (2012) explains that very young don't have good knowledge of the perceptions of climate change because of their age. For some authors such as Sánchez-Cortés *et al.* (2011), adults and seniors, make use of ethno-climatology calendar to compare the detected changes in climate variability, whereas, young people do not have the ethno-meteorological knowledge to predict the weather. Moreover, very young have little experience in the use of agroforestry parks to better discern the climatic variations, unlike adults who can make retrospective analyzes of these parks. The results obtained on the farmers' perceptions of climate change could contribute to the development of highly important tools for the sustainable management and conservation of *A. senegal*.

Adaptation strategies, relations between perceptions and adaptation strategies

Adaptation is a climate risk management processes implementing individual and collective measures for the prevention, response and recovery (Gnanglé *et al.,* 2012; IAVS, 2011). The results of the study highlight coping strategies both collective and individual, which match with the above definition suggested by these authors. This is the case of waters ponds management, magical and religious practices (collective adaptation strategies) as opposes to the individually applied strategies such as the use of improved seeds, the practice of farmer managed natural regeneration. The same observations were made by Gnanglé *et al.,* (2012) and Traoré *et al.* (2002), who also identified individual and collective coping strategies in their areas of study. The valorization of the lowlands, the practice of farmer managed natural regeneration (FMNA), the use of improved seeds and planting of valuable species (*Adansonia digitata, Acacia senegal, Tamarandus indica,* etc.) were the most coping strategies adopted by farmers in the study area. These coping strategies were identified in the Niger basin by Amoukou (2009). Traore *et al.* (2002) found similar results in Guinea-Conakry, where farmer's use varieties resistant to drought and develop irrigated cropping in the lowlands to face the effects of climate change. This reinforces the assertion of Belliveau *et al.* (2006) that the adaptive behavior is relative to time and place.

In our study area, the valorization of lowlands is made through the development of irrigated crops (market gardening) and the diversification of crops (vegetables, fruits, tubers and cereals). In the quest for food security, Brou *et al.* (2005) indicate that local communities in Côte d'Ivoire are engaged in cassava cultivation instead of yams because of the sharply decrease in the yield, and in diversifying income sources to address climate change. In the case of our study, the farmers of western part of Niger have abandoned corn cultivation to sorghum for the same reasons given by Brou *et al.* (2005). Other practices are carried out by the rural communities in the study area like collective prayer meetings to implore "Allah" for fruitful winters. This practice of collective adaptation was observed by the authors such as Teka *et al.* (2010) on the coastal zone of Benin, and Brou *et al.* (2005) in the Ivorian rural communities through ritual and magical-religious practices. The farmers of our study area have adopted coping strategies from their perceptions to climate change in most cases. This assertion corroborate with that of Bryant *et al.* (2000), who said that the adaptation strategies to climate change are the translation of the perceptions of climate change to agricultural decisions.

Conclusion

Climate change is not only perceived by scientists, but also by rural communities. The analysis of perceptions and coping strategies carried out in this study identified that climate change is perceived not only by natural factors but also from the socio-cultural facts. These perceptions vary according to vulnerability levels and age groups of farmers. From these local perceptions, the adaptation strategies are developed to improve the management of *A. senegal* resource in order to reduce the effects of climate change. Therefore, these strategies need to be evaluated scientifically to determine the most relevant and efficient strategies that could help to reduce the vulnerability and enhance resilience of the societies and ecosystems facing climate change.

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