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ORIGINAL ARTICLE

Climate change and variability: perception and adaptation strategies of pastoralists and agro-pastoralists across different zones of Burkina Faso

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Abstract Due to the dependence of its economy on rainfed agriculture and livestock husbandry, Burkina Faso, like other Sahelian countries, is particularly vulnerable to climate change. Adaptation is needed to counteract anticipated drawbacks of climate change on crop and livestock productivity; therefore, we examined climate change perceptions of pastoralists and agro-pastoralists and analysed their adaptation strategies. To this end, focus group discussions were held in six villages distributed across three agro-ecological zones. In three of these sites, 162 farmers were also individually interviewed. Perceptions of farmers were compared to actual trends of different climatic parameters extracted from official long-term meteorological records (1988–2008). Results showed that farmers in Burkina Faso were partly aware of climate change, particularly of changes in temperature and rainfall patterns, but their perception did not match well with the recorded annual rainfall data in the southern Sahelian and Sudanian zones. The most important adaptation strategies mentioned by agro-pastoralists were crop diversification, combination of cropping and livestock operations, use of water harvesting technologies and anti-erosive measures such as half-moons or stone dikes. Strategies of pastoralists included seasonal, annual and permanent migration and taking up of cereal cropping. Logistic regression analysis indicated that agro-ecological zone, cultivated surface, ruminant herd size, household size and education were the most important variables affecting farmers' choice of adaptation strategies. These factors should be taken into account in the development and implementation of any programme of adaptation to climate change in Burkina Faso.

Keywords Climate variability · Coping strategies · Local knowledge · Mixed farming systems · Sahelian zone · Sudanian zone

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Introduction

Consensus exists within the scientific community that climate change is reality, expected to worsen through recurrent extreme events such as floods or droughts in the next decades (IPCC 2001; Solomon et al. 2007). Global mean temperature increased by 0.6 °C in the last century, with the hottest temperatures ever recorded in the last two decades. Climate change is also expected to have serious environmental, economic and social impacts particularly on rural farmers in Africa, whose livelihoods depend on the use of natural resources (Thornton et al. 2006; Gbetibouo 2009). In most of the Sahelian countries in Africa, agriculture is of critical importance given its multiple roles for food security, employment and contribution to the gross domestic product (Kandji et al. 2006).

Several empirical studies showed that negative economic effects of climate change on African agriculture can be significantly reduced through adaptation (Benhin 2006; Maddison 2006; Mano and Nhemachena 2006; Seo and Mendelsohn 2006), but only few of them analysed the factors affecting farmers' choice of adaptation strategies (Hassan and Nhemachena 2008; Deressa et al. 2009). These studies used the Ricardian approach which captures farm-level adaptation measures only on the strict condition that farm input and output prices are constant (Mendelsohn et al. 1994), a condition that is unlikely to hold under

global climate change (Darwin 1999). Furthermore, the mentioned studies focussed on the continental, regional and/or national levels and only partially captured local adaptation strategies that are largely site-specific (Mary and Majule 2009). Although farmers are especially concerned with and respond more to short-term climate variability than long-term climate change, Gbetibouo (2009) hypothesised that their ability to cope with current climate variability is an important indicator of their capacity to adapt to future climate change. Brooks (2006) argued that African crop farmers and pastoralists, and particularly those living in the Sahelian zone, developed indigenous mechanisms and strategies to cope with the recurrent very severe droughts in the early 1970s and 1980s, and with the continuous decline in rainfall observed during the last century. Understanding their perception of climate change and their location-specific adaptive responses is supposed to be crucial for the design of supportive mitigating strategies, because mitigation and adaptation yield better results if both strategies are seen as complementary (Nyong et al. 2007). In Burkina Faso, agriculture, forestry and fisheries occupy more than 86 % of the active population and generate 40 % of the country's GDP, to which the crop and livestock sub-sectors contribute 25 and 12 % (MAHRH, 2004). The country is particularly vulnerable to the impact of climate change because its crop and livestock production are heavily dependent on rainfall (Thornton et al. 2006; MECV 2007), and because droughts and high climate variability coincide with an uneven distribution of arable land and other natural resources between agro-ecological zones in the Sahelian countries (Brooks 2006). A national programme of adaptation to climate change was adopted in Burkina Faso in 2007. It identified the decrease in staple crop yields, forage and water resources, diminution of grazing areas and livestock productivity as major threats of climate change to the agricultural sector and called for rapid implementation of effective mitigation strategies.

Previous studies have investigated farmers' perception of climate change and variability, and their adaptation practices in the Sudanian and Sahelian zone of West Africa (West et al. 2008; Mertz et al. 2009 and 2012; Barbier et al. 2009), but most of these studies focused the regional or national level (Ouedraogo et al. 2010; Mertz et al. 2011). Furthermore, they generally used the term "farmers" to describe rural producers including pastoralists, and information on perceptions and coping strategies were hardly disentangled for different livelihood groups such as crop farmers, agro-pastoralists and pastoralists. These three groups of rural producers face different socio-economic circumstances, are differently vulnerable to and probably perceive and react differently to variations in climate and weather conditions. However, there is hardly information available on how climate change perceptions and coping strategies differ between these categories of rural producers in West Africa. Therefore, we sought to address this knowledge gap by assessing the understanding of climate change and variability at local scale, along with their implications for crop farmers' and pastoralists' livelihoods and for farming and herding strategies in three major agro-ecological zones of Burkina Faso.

Materials and methods

Study sites

The study was carried out in six villages located in the three major agro-ecological zones of Burkina Faso: Taffogo and Zogoré in the southern Sahelian zone, Safané and Noberé in the northern Sudanian zone and Sokouraba and Karangasso Vigué in the southern Sudanian zone (Table 1). The southern Sahelian zone, approximately located between latitudes 15° and 14°N, is characterised by an annual precipitation of 300–600 mm occurring during June to September. Moving southwards, rainfall increases to 600–900 mm in the northern Sudanian zone (14°00–11°30′N) and to more than 1,000 mm in the southern Sudanian zone (11°30–9°00′N), while the length of the rainy season increases to 5–6 months (May/June to October/November). Farmers in the southern Sahelian zone cultivate millet (*Pennisetum glaucum* (L.) R. Br.), cowpea (*Vigna unguiculata* (L.) Walp.), bambara groundnut (*Voandzeia subterranea* (L.) Thouars ex DC.) and groundnut (*Arachis hypogaea* L.), whereas those in the northern and southern Sudanian zone grow sorghum (*Sorghum bicolor* (L.) Moench), maize (*Zea mays* L.), rice (*Oryza sativa* L.) and cotton (*Gossypium hirsutum* L.). Cattle, sheep and goats are the most important livestock species, kept by the

Table 1 Climate characteristics at six study sites distributed across three agro-ecological zones of Burkina Faso

Study sites	Agro-ecological zone	Annual rainfall (mm)	Rainy days per season	Rainy season length (days)	Mean annual temperature (°C)
Taffogo, Zogoré	Southern Sahelian	300–600	<45	110	29
Noberé, Safané	Northern Sudanian	600–900	50–70	150	28
Sokouraba, Karangasso Vigué	Southern Sudanian	900–1200	85–100	180–200	27

Source: adapted from PANA (2007)

majority of farmers at the study sites. Pastoralists and crop-livestock farmers (agro-pastoralists) were differentiated according to the area of their crop land and size of their livestock herd. Pastoralist households were considered as those keeping livestock as main source of income and owning at least 30 heads of cattle, a herd of sheep and/or goats. They were also involved in off-farm activities such as mining and trading during dry seasons. Agro-pastoralist households were those which considered crop farming as their main source of income and owned at least 5 heads of cattle and a herd of sheep and/or goats. Their farm size was greater than 3 ha in all sites. The focus groups were mixed groups including male and female household members. Households were randomly selected based on their willingness to participate in the study. At all sites, a full meteorological station was installed in November 2008 or earlier for detailed and continuous recording of weather data.

Assessment of perceptions and adaptation strategies

Methods used to assess farmers' perception of natural environmental degradation (Dolisca et al. 2007; Regessa 2008) and of climate change and adaptation (Nyong et al. 2007; Cooper et al. 2008; Deressa et al. 2009) were adopted for the present study. These methods included different participatory rural appraisal (PRA) techniques such as semi-structured and open interviews, resource mapping and transect walks with farmers, complemented by the collection of relevant background information from local administrations, development projects and non-governmental organisations (NGOs) during February–May 2009.

After an introductory village meeting with up to 60 farmers, a focus group discussion with 15–20 participants per village, composed of pastoralists, agro-pastoralists and crop farmers, was held. The focus groups were mixed groups including male and female household members. Households were randomly selected based on their willingness to participate. The discussion focused on the most important bio-physical and socio-economic characteristics pertaining to crop production and livestock husbandry in the respective village, the perception of climate change (mainly changes in temperature and rainfall patterns) and its effects on crop and animal production over the last two decades, as well as the local responses to perceived changes. The information gathered served as the basis for the elaboration of the semi-structured questionnaire used in the individual interviews of farm household heads. A total of 162 households (HH) were interviewed from January to May 2010 in Noberé, Sokouraba and Taffogo. The questionnaire encompassed detailed information on each household's socio-economic status (HH size, head of HH age, education, cropland surface, animal herd size) and farmers' perception of climate change and variability (CCV) over the past 20 years (increase, decrease or unaltered quantity of rainfall per year, number of rainy days and duration of rainy season, and maximum and minimum temperatures, as well as length of dry season) and of its impacts on their crop and livestock farming activities. Subsequently, the respondents were asked to list for each perceived impact their current coping strategies, and the practices they would adopt if CCV effects worsened.

Before being applied to the 162 households, the questionnaire was pre-tested on fifteen key informant farmers; all interviews were conducted in the respondent's native language to ensure that questions were well understood. Temperature and rainfall data covering the period 1988–2008 were collected from three sites of the National Meteorological Station (Tougouri in the southern Sahelian zone, Manga in the northern Sudanian zone, Orodara in the southern Sudanian zone).

Data analysis

The qualitative and quantitative information gathered was edited, coded and analysed using Excel® spread sheets and PASW Statistical Package software version 18.1 (PASW, IBM Inc. 2010). Frequencies of responses were reported; cross tabulations, chi-square test and the nonparametric Kruskal–Wallis test were used to explore the factors influencing farmers′ choices of specific adaptation strategies. Subsequently, a binary logistic regression with a stepwise backward elimination of predictors was performed to identify the most determinant variables affecting farmers′ choice of future adaptation strategies. The fit of the final model was assessed by the chi-square model (Model χ^2) and the goodness-of-fit test of Hosmer and Lemeshow (Archer and Lemeshow 2006). Well-fitting models show significance ($P \leq 0.05$) on the Model χ^2 and non-significance ($P > 0.05$) on the goodness-of-fit test. Trends of annual rainfall and maximum temperature over the past 20 years (1988–2008) were calculated using simple linear regression. The time series analyses were performed for a 20-year period instead of the at least 30-year period required for meteorological data because of lack of long-term meteorological data records from the stations close to the research locations.

Results

Recorded and perceived changes in temperature and rainfall

Irrespective of the agro-ecological zone, there was a noticeable increase in the average annual maximum

temperature from 1988 to 2008 (Fig. 1). In contrast, rainfall trends differed between the zones. In the southern Sahelian and southern Sudanian zone, the amount of annual rainfall was slightly increasing, whereas it decreased in the northern Sudanian zone; a remarkably high variation in precipitation from one year to the next showed for all zones. In all three agro-ecological zones, the majority of interviewed farmers perceived changes in temperature patterns, namely increasing dry season temperatures and a longer duration of the dry season (Fig. 2). Similarly, across the three zones, more than 70 % of the respondents perceived changes in rainfall variables, but while 50 % of the respondents in Noberé perceived an increase in the amount of rain received in the rainy season, this perception was not shared in Sokouraba (affirmative: 0 %) and Taffogo (affirmative: 2 %). Irrespective of the site, participants of the focus group discussions agreed that today inter-annual rainfall variability is high and that the beginning and duration of the rainy season has become less predictable, rendering planning of cropping and pastoral activities difficult. Differences in the perceived number of rainy days and the duration of the rainy season were significant ($P < 0.05$) between Noberé and the two other sites, while there was no significant difference between the three sites in the perceived prolongation of the dry season.

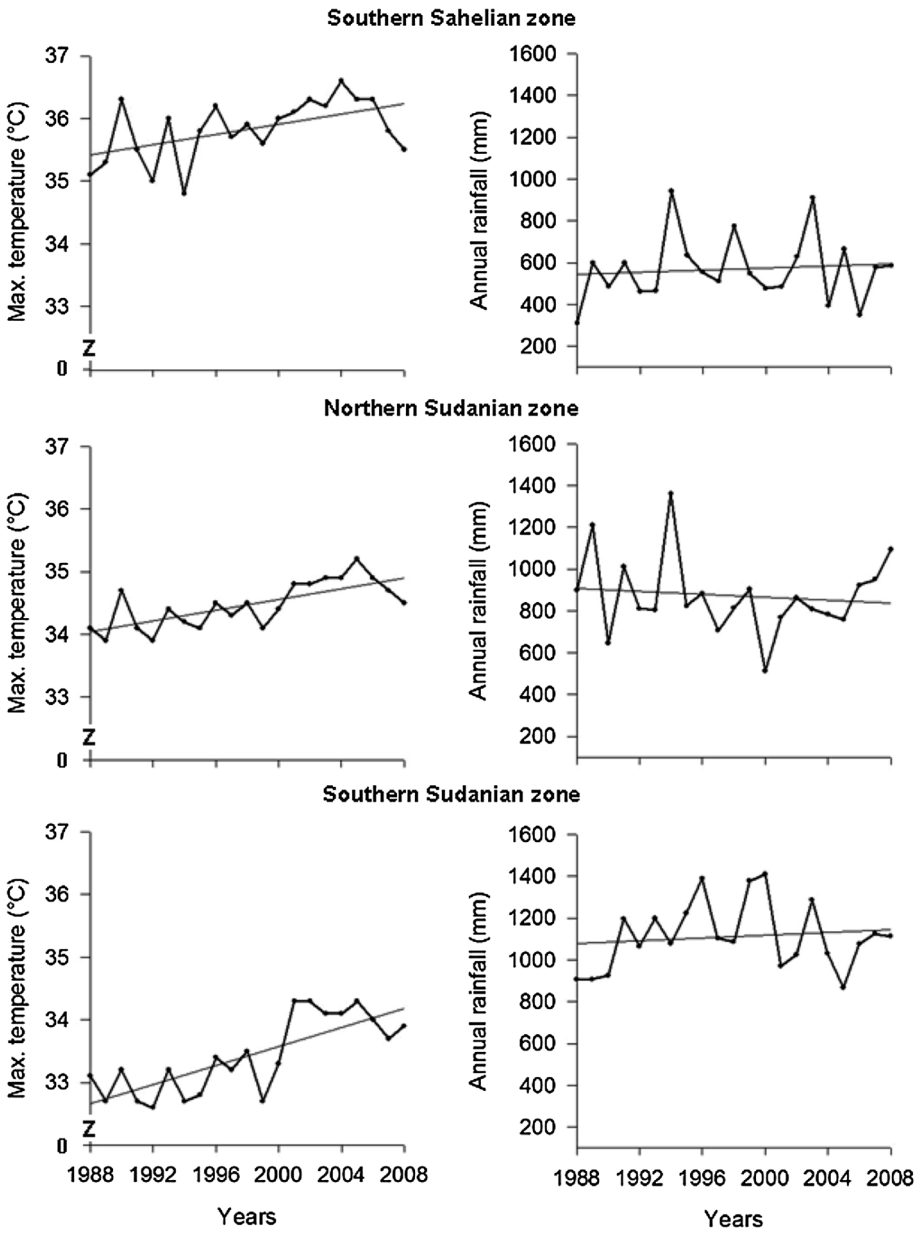

Fig. 1 Annual variability and trend (*line*) of the development of average daily temperatures (*left hand graphs*) and rainfall (*right hand graphs*) during the past 20 years in three agro-ecological zones of Burkina Faso

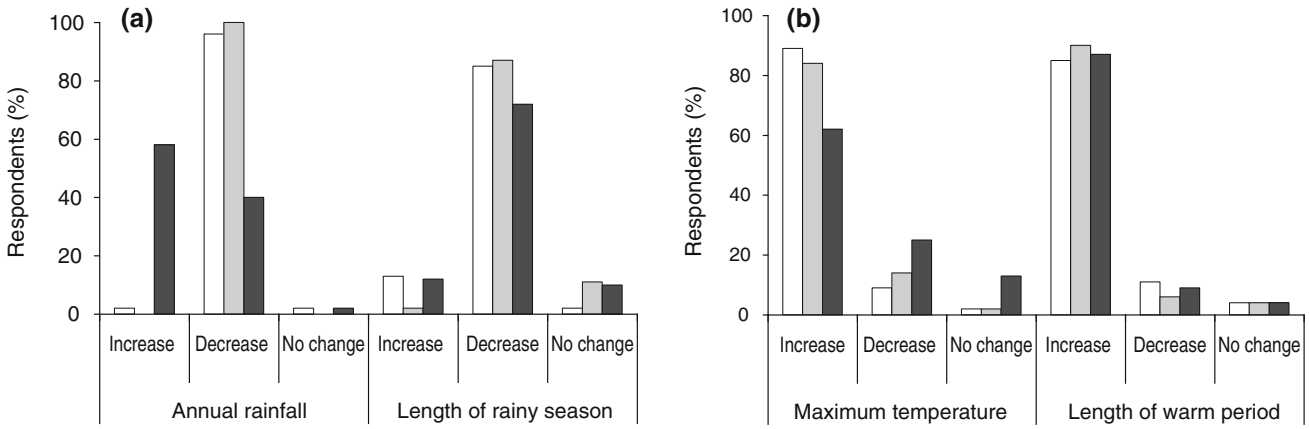

Fig. 2 Farmers' ($n = 162$) perception of changes in precipitation (**a**) and temperature (**b**) variables over the past 20 years across the southern Sahelian (*white*), southern Sudanian (*grey*) and northern Sudanian (*black*) zone of Burkina Faso

Perceived impacts of temperature and rainfall change on crop and livestock production

Farmers in all agro-ecological zones reported that their traditional land management systems and related livelihoods have been affected by the observed changes in rainfall and temperature (Table 2). Decline in crop yields, decreased soil fertility and increased erosion and land degradation were the major impacts of climate change as perceived by the crop farmers. For pastoralists and agro-pastoralists, major impacts of climate change on their livestock husbandry systems were the shrinkage of grazing areas and the decline of forage resources with consequently lowered animal productivity (offspring numbers, milk and meat yields). Since pasture areas and livestock corridors are increasingly cut-off by crop fields that cannot be trespassed during the rainy season until crop harvest, livestock mobility is restricted. Further problems named were limited access to watering places and increased conflicts over natural resource use with crop farmers. All participants mentioned increased vulnerability and poverty as important consequences of CCV.

The results obtained from individual interviews were similar to those of the group discussions (Table 3). Almost all respondents perceived negative impacts of CCV on their production systems and livelihoods. As far as forage availability for livestock was concerned, 86, 98 and 100 % of farmers from Noberé, Sokouraba and Taffogo, respectively, reported its decrease over the past 20 years. In the same villages, between 63–89 % and 50–100 % of the interviewed livestock keepers reported that livestock fertility and meat and milk yields, respectively, had also decreased over the past 20 years. All crop farmers (100 %) reported decreasing soil fertility and hence lowered crop yields per area across the three zones during the past 20 years (Table 3).

Current and anticipated adaptations to climate change

In all focus group discussions, the participants reported to have taken measures that reduce the negative impacts of CCV on their farming systems and livelihoods. These included strategies to increase cereal yields, reduce food insecurity, support household income and mobility of livestock herds (Table 2). Water and soil conservation measures, such as "zaï" and "half-moon" techniques, construction of anti-erosive stone dikes and selective land clearing techniques were claimed to be used to improve soil fertility, water retention and efficiency of use of organic and mineral fertilisers ("Appendix"). Farmers also reported the use of improved seeds of locally adapted varieties of sorghum and millet (further referred to as "improved seeds") provided by the national agricultural research institute through extension activities.

Strategies developed to address food insecurity and sustain household income included diversification of farm activities (combination of crop, livestock and gardening activities) and seasonal migration of young household members to cities where they sought temporary jobs. In addition to resorting to seasonal transhumance and splitting livestock herds into small groups kept at different sites across the country, pastoralists were diversifying their activities by cultivating cereals. They also mentioned a change in livestock species from cattle to goats and sheep, especially in the southern Sahelian zone where a strong decline of water and forage resources over the past two decades was experienced.

As far as individual farmers' initiatives were concerned, 20 % of the respondents in Sokouraba mentioned that they did not have any adaptation strategy (Fig. 3), whereas this was true for only 5 % of farmers in Noberé and Taffogo ($P < 0.05$). However, between 88 and 96 % of the livestock keepers intended to resort to transhumance and

Table 2 Results of focus group discussions on perceived impacts of climate change and local adaptation strategies in six villages distributed across three agro-ecological zones of Burkina Faso

Community	Negative impacts of climate change on production system	Local solutions
Agro-pastoralists ($n = 3$ groups, 180 participants)	Crop yields and production decreasing	Use of manure and compost
	Soil fertility decreasing, soil erosion increasing	Use of water and soil conservation techniques
	Desertification and recurrent droughts	Change of cropping practices
	Increased incidence of crop pests and weeds	Tree planting, abandonment of bush fires
	Conflicts between communities about resources use	Migration and off-farm activities
	Recurrent food insecurity due to early cessation of rainy season	Integration of livestock and crop husbandry
	Pauperisation of farmers due to income reduction	Vegetable gardening during dry season
Pastoralists ($n = 3$ groups, 78 participants)	Animal mortality increasing due to forage lack and diseases	More prophylaxis and veterinary treatments
	Lack of drinking water for animals in dry season	Migration to humid zones
	Decreased animal productivity (milk and meat yield, fertility)	Intensified transhumance practices
	More difficulties for animal keeping due to crop field encroachment of pastures	Adoption of cropping
	Migration of pastoralists to southern zones	Sedentarisation of some pastoralists
	Persistence and apparition of (new) animal diseases	Increased shift to small ruminants
	Conflicts between communities about resources use	Shift to poultry keeping
	Food insecurity and pastoralists' pauperisation	Herd destocking to buy food
	Reduction and degradation of grazing areas and tracking corridors	Use of crop by-products and crop residues as animal feeds
	Decreased forage availability and quality	Concentrate feeding

Note that solutions are to be seen general, mostly responding to several problems mentioned in the second column

permanent migration if CCV effects worsened (Table 4). This was particularly true for the respondents from Taffogo, who stated that they would migrate to the sub-humid zone of Burkina Faso and/or to the neighbouring countries of Ghana and Ivory Coast, where availability and accessibility of feed and water resources seemed to be better. Regardless of the agro-ecological zone, most crop farmers stated that in case of worsening conditions they would change cropping practices and production systems to deal with increased soil degradation and decreased soil fertility (Table 5). Additionally, more than 70 % mentioned that they would introduce improved seeds and new crop varieties to their cropping systems.

Factors affecting anticipated adaptations

From the binary logistic regression analysis (Table 6) it appeared that agro-ecological zone was the most determinant factor for pastoralists to anticipate herd destocking, permanent migration from the present location and change of herd composition as future adaptation strategies. Pastoralists from the northern Sudanian zone were 10 times (odds ratio = 9.8) more likely than those from the other agro-ecological zones to adopt destocking and 15 times (odds ratio = 15.3) more likely to change their herd composition, but were less likely to embrace far-distance migration. Furthermore, the larger their cattle herd size and smaller their goat herd size, the more likely pastoralists were to resort on transhumance. Shifting to other livestock species was most likely to occur when the pastoralist household had a high education ratio.

In contrast to the pastoralists, agro-pastoralists from the northern Sudanian zone were three times more likely to migrate than those from the other agro-ecological zones (Table 7). Size of cropland was significant ($P < 0.01$) in determining the adoption of fertilisation of sorghum, millet and maize with mineral and/or organic fertilisers such as compost, household wastes and crop residues. The likelihood of farmers to adopt new crop varieties was significantly ($P < 0.01$) affected by the age of the household head, the agro-ecological zone and the household size, whereas the use of improved seeds was significantly ($P < 0.01$) affected by the education ratio of the farm household and the agro-ecological zone. The higher the education ratio in a household from the southern Sahelian zone, the less likely the farmer was to adopt improved seeds.

Discussion

Perception of changes in temperature and rainfall and of their impacts

Across the three investigated agro-ecological zones of Burkina Faso, farmers were aware of climate change and

Table 3 Impacts of climate change and variability on crop and livestock production as perceived by individual farmers from three villages located in three agro-ecological zones of Burkina Faso

Agro-ecological zone (study location)	Farming (sub-)system	Variable	Increasing (%)	Decreasing (%)
Southern Sahelian (Taffogo)	Agriculture ($n = 27$)	Crop yields	0	100
		Crop production	0	100
		Crop pests	76.9	23.1
		Soil fertility	0	100
	Livestock ($n = 25$)	Herd size	14.8	85.2
		Livestock fertility	11.1	88.9
		Meat and milk yield	13.0	87.0
		Forage availability	0	100
Northern Sudanian (Noberé)	Agriculture ($n = 32$)	Crop yields	5.3	94.7
		Crop production	5.3	94.7
		Crop pests	31.6	68.4
		Soil fertility	0.0	100.0
	Livestock ($n = 26$)	Herd size	33.3	66.7
		Livestock fertility	49.1	50.9
		Meat and milk yield	28.1	71.9
		Forage availability	14.0	86.0
Southern Sudanian (Sokouraba)	Agriculture ($n = 25$)	Crop yields	0.0	100.0
		Crop production	0.0	100.0
		Crop pests	46.9	53.1
		Soil fertility	0.0	100.0
	Livestock ($n = 25$)	Herd size	81.6	18.4
		Livestock fertility	36.7	63.3
		Meat and milk yield	0.0	100.0
		Forage availability	2.0	98.0

perceived changes in temperature and rainfall. Similar perceptions were reported from farmers in the Eastern Saloum region of Senegal, which is located between the Sudano-Sahelian and Sudanian climatic zones (Mertz et al. 2009) and from the Nile Basin of Ethiopia (Deressa et al. 2011). Interestingly, the perception of changes in rainfall patterns by crop-livestock farmers and pastoralist from our southern Sahelian and southern Sudanian sites (Sokouraba and Tougouri) did not match well the meteorological data on evolution of rainfall in these regions during the past 20 years. Due to the southwards move of the isohyets observed in the Sahel (Wittig et al. 2007), the rainfall regime of the northern Sudanian zone tends to behave like the one of the southern Sahelian zone. This could explain the observed decoupled variations observed in annual rainfall for the northern Sudanian zone (Fig. 1). Farmers' perceptions might probably have been affected by the poor rainy seasons of 2000/2001 and 2004/2005 (Fig. 1), and some might even have had in mind the severe droughts of 1972–1973 and 1984 (CILSS 2009). A similar discrepancy between farmers' perception and recorded weather data was reported by Meze-Hausken (2004) from the Sudanian savannah zone of Central Senegal. Yet, pastoralist and agro-pastoralists in the study region were able to discern trends in climate parameters and their impacts on farming systems (West et al. 2008; Rao et al. 2011). In line with Mertz et al. (2012), our farmers perceived rainfall evolution during the past 20 years more negative than testified by meteorological data. In Burkina Faso, like in any other Sahelian country,

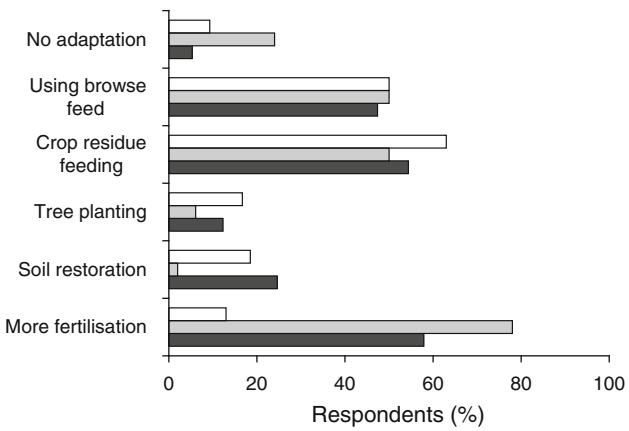

Fig. 3 Current measures adopted by pastoralist and agro-pastoralist farmers ($n = 162$) in response to climate change and variability in the southern Sahelian (*white*), southern Sudanian (*grey*) and northern Sudanian (*black*) zone of Burkina Faso

Table 4 Descriptive statistics of factors affecting the adaptation strategies for livestock husbandry to perceived climate change and variability by pastoralist households (HH) from three villages located in three agro-ecological zones of Burkina Faso

Adaptation measures	Change in herd composition		Change of animal species		Transhumance		Permanent migration		Herd destocking	
Adoption	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Number of respondents	23	53	18	58	69	6	43	33	25	50
Percentage of respondents										
Agro-ecological zone										
Southern Sahelian ($n = 25$)	8	92	24	76	88	12	85	15	84	16
Northern Sudanian ($n = 27$)	28	72	20	80	92	8	32	68	80	20
Southern Sudanian ($n = 25$)	56	44	44	56	96	4	52	48	36	64
P value (chi-square test)	**		**		ns		**		**	
Mean (SD)										
HH characteristics										
Age of head of HH (years)	49.2 (11.10)	48.4 (11.14)	49.2 (10.48)	48.5 (11.32)	49.5 (11.12)	40.2 (6.43)	48.4 (11.72)	49.0 (10.30)	48.0 (10.89)	49.2 (11.28)
Education ratio†	0.4[a] (0.35)	0.2[b] (0.29)	0.5[a] (0.39)	0.1[b] (0.26)	0.2 (0.33)	0.3 (0.24)	0.2 (0.33)	0.2 (0.32)	0.5[a] (0.37)	0.2[b] (0.25)
Goat herd size (number of animals)	6.5[a] (5.11)	11.1[b] (9.51)	7.4 (5.54)	10.4 (9.34)	9.9 (8.94)	8.2 (5.31)	9.4 (8.12)	10.1 (9.43)	6.4[a] (5.36)	11.4[b] (9.58)
Cattle herd size (number of animals)	47.0 (42.88)	34.3 (27.55)	51.6 (45.66)	34.0 (27.40)	40.9[a] (33.48)	12.3[b] (10.61)	34.1[a] (36.45)	43.5[b] (27.96)	42.4 (40.57)	36.7 (29.02)

† Number of household members who went at least to primary school, divided by total number of household members

** $P \leq 0.01$; *ns = differences not significant*. [a,b] Within a single adaptation practice, row means with different superscripts differ significantly (Mann–Whitney U test, $P \leq 0.05$)

temperature and rainfall in general, and more specifically the length of the rainy season, the spatio-temporal distribution of rainfall and the frequency of dry spells or wet periods are the most important climatic factors influencing availability of natural resources and livelihood strategies (MECV 2007). Hence, any significant changes in temperature and rainfall patterns will affect both feed resources for livestock and success of cropping activities (Seo and Mendelsohn 2006; Hassan and Nhemachena 2008). Ringler et al. (2010) showed that climate change and variability associated with other drivers of environmental and anthropogenic changes such as increased demography, vegetation changes, droughts, increased food demand and market opportunities as well as changes in farming systems affect the area cropped, yields and total grain production in sub-Saharan Africa. Case studies predicted that yields of millet and sorghum, the two major staples in the Sahelian zone, will decrease by 15–25 % until 2080 in Niger and Burkina Faso (Sarr et al. 2007). Climate change is expected to increase problems for animal keeping, especially the availability of water and feed resources, with distinct negative impacts on livestock productivity and livelihoods of livestock keepers (CILSS 2009); this is mirrored by the views of pastoralists interviewed in our study. Seo and Mendelssohn (2006), when assessing the economic impact of climate change on animal husbandry in eleven African countries, found that net revenues from livestock keeping are highly sensitive to climate variables, with larger herd size increasing the sensitivity to rising temperatures.

Novelty of farmers' adaptation strategies

The high frequency and severity of extreme climate events (floods, droughts) and the high climate variability in the Sahelian and Sudanian region are threatening farmers' adaptive capacity, which is already weakened by negative effects of past droughts and poverty (Kandji et al. 2006). As climate models predict worsening climatic conditions for the study region, ensuring food security will be a major challenge for the majority of people living there (GIEC 2007). Our respondents used several coping strategies to reduce the adverse impacts of climate change. Innovative cropping strategies were the systematic use of improved seeds (millet and sorghum) and the introduction of new crop varieties of rice and maize. Secondly, the adoption of better fertilisation practices with mineral and organic amendments such as compost and animal dung pointed to farmers' willingness to intensify cropping practices. All mentioned strategies

Table 5 Descriptive statistics of factors affecting the adaptation strategies for crop husbandry practices to perceived climate change and variability by agro-pastoralist households (HH) from three villages located in three agro-ecological zones of Burkina Faso

Adaptation measures	Use of new crop varieties		Use of improved seeds		More fertilisation		Change in cropping practices		Permanent migration	
Adoption	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Number of respondents	42	41	69	16	47	38	60	25	37	47
Percentage of respondents										
Agro-ecological zone										
Southern Sahelian ($n = 28$)	59.4	40.6	96.9	3.1	34.0	65.6	71.9	28.1	67.7	32.3
Northern Sudanian ($n = 32$)	60.9	39.1	68.0	32.0	100.0	0.0	72.0	28.0	88.0	12.0
Southern Sudanian ($n = 25$)	32.1	67.9	75.0	25.0	55.3	60.7	67.9	32.0	14.3	85.7
P value (chi-square test)	*		**		**		ns		**	
Mean (SD)										
HH characteristics										
Farm size (hectares)	6.1	4.3	5.6	6.0	7.8[a]	3.1[b]	6.0[a]	5.1[b]	3.4[a]	7.5[b]
	(6.35)	(3.17)	(6.38)	(4.43)	(7.34)	(1.88)	(6.40)	(4.94)	(2.06)	(7.46)
Age of head of HH (years)	50.2	55.3	53.6	48.8	52.3	52.5	53.8	50.0	50.3	54.2
	(10.62)	(14.08)	(12.28)	(13.30)	(12.49)	(12.78)	(11.66)	(14.36)	(12.03)	(12.70)
HH size (number of persons)	17.3	13.7	16.1	13.6	16.1	15.1	16.8	12.8	15.6	15.7
	(9.53)	(6.59)	(7.91)	(9.81)	(8.48)	(8.13)	(7.75)	(9.02)	(7.87)	(8.77)
Education ratio[†]	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.3	0.2	0.3
	(0.14)	(0.19)	(0.14)	(0.22)	(0.18)	(0.13)	(0.15)	(0.19)	(0.15)	(0.17)

[†] Number of household members who went at least to primary school, divided by total number of household members

** $P \leq 0.01$; * $P \leq 0.05$; *ns = differences not significant*. [a,b] Within a single adaptation practice, row means with different superscripts differ significantly (Mann–Whitney U test, $P \leq 0.05$)

aimed at improving the yields of major cereals; the adoption of these strategies is supported by the government of Burkina Faso through policies of food insecurity reduction and the national programme of adaptation to climate change.

The strategies that pastoralists claimed to have adopted are very traditional practices but are apparently viewed as still valid to respond to CCV. If practiced consequently, the ruminant herd splitting as well the shift from cattle (vulnerable to warming) to sheep and goats (both heat tolerant and, on an individual basis, requiring less water and feed than cattle) in the southern Sahelian zone can be judged quite effective for a risk-spread use of natural resources and reduced risk of livestock losses during extreme climate events across the region (Fratkin and Smith 1994; Seo et al. 2010). Ajibade (2007) and Salick and Byg (2007) hypothesised that local adaptation strategies are based on coping experience acquired over time which is transmitted from generation to generation. The practice of transhumance provides an illustrative example of this. Transhumance is the regular movement of herds between fixed points to exploit seasonal availability of fodder, and herd splitting is one of its characteristic features (Blench 2001). It is a culturally revered way of life and a central social institution around which West African Fulani households and their cultural practices have historically been organised (Crane et al. 2011). It creates ethnic identity across the Sahelian region (De Bruijn and Van Dijk 2001) and has since centuries been a way of adapting to the regionally unbalanced and changeable agro-ecological conditions, making use of ecological complementarities between the Sahelian and Sudanian region (Blench 2001). Consequently, the question arises whether transhumance is a long-term adaptive strategy to climate change, especially when considering the "Sahelisation" of the Sudanian zone (Wittig et al. 2007) and the shrinkage of its pastoral resources. In our study, cattle herd size was found to be a determinant factor for the practice of transhumance, whereby pastoralists owning a large number of cattle were more likely to rely on this practice. This is probably due to the fact that cattle require more of the scarce feed and water resources than small ruminants. Pastoralists from the northern Sudanian zone of Burkina Faso were much more likely to reduce herd sizes through animal sales, probably because they are close to large urban livestock markets (Ouagadougou

Table 6 Results of the logistic regression analysis on factors affecting future adaptation strategies of pastoralist households to climate change and variability across three agro-ecological zones of Burkina Faso

Predictors	β	SE β	Wald's χ^2	*df*	$P\leq$	Odds ratio (exp β)
Herd destocking						
Constant	−1.312	0.589	4.959	1	0.001	0.269
Agro-ecological zone			13.009	2	0.001	
Southern Sahelian (1)	0.535	0.773	0.479	2	0.489	1.708
Northern Sudanian (2)	2.284	0.701	10.628	1	0.001	9.819
Test						
Overall model evaluation			17.950	1	0.001	
Goodness-of-fit[a]			8.470	7	0.293	
Transhumance						
Constant	−6.972	4.795	2.114	1	0.146	0.001
Goat herd size	−0.354	0.175	4.084	1	0.043	0.702
Cattle herd size	0.258	0.111	5.441	1	0.020	1.294
Test						
Overall model evaluation			19.298	5	0.002	
Goodness-of-fit[a]			1.329	7	0.988	
Migration						
Constant	1.913	0.760	6.341	1	0.012	6.775
Agro-ecological zone			11.869	2	0.003	
Southern Sahelian (1)	−2.388	0.698	11.699	1	0.001	0.092
Northern Sudanian (2)	−1.671	0.684	5.972	1	0.015	0.188
Test						
Overall model evaluation			16.434	3	0.001	
Goodness-of-fit[a]			10.440	7	0.165	
Changing livestock species						
Constant	−1.898	0.395	23.037	1	0.000	0.150
Education ratio[b]	2.527	0.820	9.504	1	0.002	12.515
Test						
Overall model evaluation			10.125	1	0.001	
Goodness-of-fit[a]			3.285	6	0.772	
Changing herd composition						
Constant	−2.485	0.736	11.400	1	0.001	0.083
Agro-ecological zone			11.516	2	0.003	
Southern Sahelian (1)	1.540	0.860	3.206	1	0.073	4.667
Northern Sudanian (2)	2.726	0.839	10.556	1	0.001	15.273
Test						
Overall model evaluation			15.142	2	0.001	
Goodness-of-fit[a]			0.000	1	1.000	

[a] Hosmer and Lemeshow goodness-of-fit test (Archer and Lemeshow 2006); [b] Number of household members who went at least to primary school, divided by total number of household members

and Pô for Noberé, and Niangologo for Sokouraba) where animals fetch better prices than in the other two zones where larger cities are only sparsely distributed.

For all farmers, the most important innovation was the diversification of farming activities including the cultivation of different types of crops and the adoption of an integrated crop-livestock farming system which is more risk adverse than a specialised system and well adapted to the conditions of the Sahelian and Sudanian zone (Seo 2010).

While some of the above strategies can be considered pertinent towards addressing negative impacts of climate variability on land-based activities, most are neither recent nor developed specifically to address climate change. From Northern Burkina Faso, Barbier et al. (2009) reported that farmers adopted most of innovative agricultural technologies not because of CCV alone but also because of growing land scarcity and new market opportunities. Nevertheless, crop and livestock farmers in the study region possess valuable local knowledge and adaptive capacity that must

Table 7 Results of the logistic regression analysis on factors affecting future adaptation strategies of agro-pastoralist households to climate change and variability across three agro-ecological zones of Burkina Faso

Predictors	β	SE β	Wald's χ^2	*df*	$P\leq$	Odds ratio (exp β)
Migration						
Constant	−0.314	0.301	1.086	1	0.297	0.730
Agro-ecological zone			23.880	2	0.001	
Southern Sahelian (1)	−1.250	0.726	2.9710	1	0.085	0.286
Northern Sudanian (2)	3.159	0.651	23.576	1	0.000	3.546
Test						
Overall model evaluation			34.957	2	0.001	
Goodness-of-fit[a]			0.000	1	1.000	
Changing cropping practices						
Constant	0.607	0.690	0.774	1	0.379	
Household size (members)	0.064	0.036	3.188	1	0.074	1.067
Education ratio[b]	−2.929	1.514	3.740	1	0.053	0.053
Test						
Overall model evaluation			8.691	2	0.013	
Goodness-of-fit			6.809	7	0.449	
Fertilisation						
Constant	−1.384	1.201	1.328	1	0.249	0.251
Farm size (hectares)	0.343	0.108	10.096	1	0.001	1.409
Test						
Overall model evaluation			21.578	4	0.001	
Goodness-of-fit[a]			5.108	7	0.647	
Use of new crops						
Constant	1.943	1.137	2.921	1	0.087	6.982
Agro-ecological zone			8.411	2	0.015	
Southern Sahelian (1)	1.064	0.835	0.919	1	0.338	0.231
Northern Sudanian (2)	−0.805	0.840	5.646	1	0.017	0.447
Age of household head (years)	−0.065	0.023	7.604	1	0.006	0.937
Household size (members)	0.082	0.038	4.726	1	0.030	1.086
Test						
Overall model evaluation			20.815	6	0.002	
Goodness-of-fit[a]			3.459	8	0.902	
Use of improved seeds						
Constant	2.683	0.623	18.558	1	0.001	14.622
Agro-ecological zone			7.701	2	0.021	
Southern Sahelian (1)	3.752	1.359	7.619	1	0.006	0.023
Northern Sudanian (2)	−0.765	0.794	0.927	1	0.336	0.465
Education ratio[b]	−3.896	1.868	4.347	1	0.037	0.020
Test						
Overall model evaluation			19.191	6	0.004	
Goodness-of-fit[a]			5.016	7	0.658	

[a] Hosmer and Lemeshow goodness-of-fit test (Archer and Lemeshow 2006); [b] Number of household members who went at least to primary school, divided by total number of household members

be harnessed and used as a platform for developing appropriate adaptation strategies and policies (Mortimore and Adams 2001; Nyong et al. 2007; Parry et al. 2007).

Effectiveness of farmers' adaptation strategies

As discussed above, several strategies are adopted by farmers. New strategies such as the use of improved seeds and new crop varieties, and efficient crop fertilisation, are promoted by the government of Burkina Faso. Such measures might play an important role in increasing the country's production of maize, millet, rice, and sorghum, and therefore help farmers to cope with food insecurity and negative impacts of CCV in the crop but also the livestock sector—the latter benefiting indirectly from increased amounts of crop residue feedstuff. Despite

government support, timely access to improved seeds and fertilisers is difficult, and for the adoption of composting practices lack of organic material and lack of knowledge are obstacles. The adoption of improved seeds in Burkina Faso is still low, ranging from 2.6 to 6 % for all crops (Bikienga 2002) and being less than 5 % for sorghum (Trouche et al. 2001). As stated by Maddison (2006), the availability of improved seeds and their accessibility are probably the most significant determinants of their adoption, and the same holds true for the use of mineral fertiliser. In our study, the adoption of better fertilisation strategies was positively related to cropland size. This suggests that the evident decline in farm sizes in West African arid and semi-arid countries over time, brought about by land degradation and restriction of cultivation area (Jayne et al. 2003), may constitute an obstacle to the adoption of some technologies.

According to OECD/SWAC (2008), some of the adaptation strategies reported by our respondents, such as uptake of cropping (pastoralists) and crop field expansion (agro-pastoralists) as well as migration, transhumance and herd splitting (pastoralists) have not proven effective in mitigating negative impacts of CCV. Although transhumance is a strategy adapted to drylands such as the Sahel that are characterised by scarce resources and high climate variability (Brooks 2006), especially cropland expansion provokes social conflicts between farmers and pastoralists over natural resources exploitation and, to a certain extent, challenges transhumance practices (Bonnet and Hérault 2011; Turner et al. 2011; Benjaminsen et al. 2012).

In our study, farmers from different agro-ecological zones opted for different adaptation strategies, which is in agreement with the observations of Deressa et al. (2009). The "zaï" technique, for example, has proven successful in improving soil physical properties (Somé et al. 2004; Zougmoré et al. 2004) and ensuring high crop yields in the dry Sahelian zone (Sawadogo et al. 2008), but digging the pits requires considerable labour (Barro et al. 2005) that can prevent the full adoption of this technique by small households; this seems to be reflected by an adoption rate of only 41 % among farmers in northern Burkina Faso (Barbier et al. 2009). The positive effect of household size on choices of new agricultural practices that showed in the logistic regression may be linked to the higher labour endowment of larger rural families (Croppenstedt et al. 2003; Deressa et al. 2009). The use of improved seeds can enhance crop productivity, but according to our insights the adoption of the strategy might be restricted to larger households that are more likely to test new management practices given their higher family labour endowment, which also makes them less risk averse than smaller households. Surprisingly, the age of the farm household head was negatively related to the probability of adoption of a new crop variety. This result sharply contrasts with the argument that, because of their accumulated knowledge, capital and experience, older farmers are more likely than younger ones to adopt a new technology (Abdulai and Huffman 2005), but might be explained by the fact that risk aversion increases with age (Forsfält 1999).

Conclusions

Our study showed that pastoralists and agro-pastoralists in Burkina Faso have already adopted some coping strategies to secure their livelihoods in view of perceived and actually occurring climate change and variability. Some of these strategies are well established and well known and initially targeted climate variability rather than climate change. The already partial adoption and the strong willingness to further use improved seeds and new crop varieties and to improve fertilisation of crop fields should be used as the basis for national strategies to stabilise and secure the country's cereal production. A consequent and systematic application of herd splitting strategies and the shift from cattle to sheep and goat rearing by pastoralists would be a valid risk aversion strategy ensuring optimised use of pastoral resources across the country. However, farmers' adaptation practices are in general more of spontaneous and short-term nature. Consequently, the implementation of medium- and long-term adaptation measures needs to be based on national and regional policies that provide efficient technical and financial assistance to vulnerable groups when extreme events such as floods and droughts occur. Due to the high spatio-temporal variability of natural resources as well as infrastructure, development and implementation of adaptation strategies aiming at counteracting climate change effects must be site-specific.

Appendix

See Table 8.

Table 8 Definition of several adaptation practices in cropping and livestock keeping encountered across three agro-ecological zones of Burkina Faso

Farming system	Adaptation strategy	Meaning
Cropping	More fertilisation	Increased use of organic fertiliser (manure and/or compost) and mineral fertiliser by farmers for millet, sorghum and maize
	Use of improved seeds (of local cereals)	Local sorghum, millet and maize seeds selected and improved by the national agricultural research institute (INERA), which obtain higher grain yields and are adapted to different climatic zones of Burkina Faso
	New crop varieties	New varieties of sorghum, millet, rice and maize, as well as of cowpea selected and introduced by agricultural extension services
	Zaï technique	Traditional land restoration technology of farmers in Burkina Faso to rehabilitate degraded drylands and to restore soil fertility. Small pits of 20-30 cm diameter and 10-20 cm depth are dug into degraded soils, often hardpans. At the bottom of the pits farmers place about two handfuls of organic material (animal dung or crop residues). Pearl millet or sorghum seeds are planted in these pits as soon as rainfall starts
	Half-moon technique	Variant of the zaï technique, larger diameter of the planting hole
	Anti-erosive stone dikes	Technique in which larger stones are buried in rows to a depth of about one-third of their height, following contour lines. These small dams reduce the speed of surface water runoff and the loss of topsoil and organic matter
Livestock keeping	Permanent migration	Movement of farmers across a specified boundary (village, region, or even the country) for the purpose of establishing a new and permanent residence where pastoral resources are available for livestock
	Transhumance	Seasonal movement of herd and part of the household in search of qualitatively and quantitatively adequate grazing resources
	Herd splitting	Separation of the herd in two or three groups (often of defined physiological stage), each one kept in a different location across the country
	Herd destocking	Sale of some animals to buy food or to reduce the number of animals per herd, primarily targeting young male cattle and small ruminants, and old and sick animals

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