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ORIGINAL ARTICLE

Impact of prolonged rainy seasons on food crop production in Cameroon

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Abstract This study set out to examine why agricultural production in differing agro-ecological zones of the same country responds differently to a common environmental event (an extension of the rainy season). We find that the heavy reliance of farmers in the drier agro-ecological zones on seasonal cycles make them more vulnerable to an extension of the rainy season than those in regions where rainfall is less relied on. Effects in these vulnerable regions include significant damage to crops as well as a shortage in local markets, which raises prices of basic food commodities. The difference between prices in low and high food producing periods is low for crops that can easily be preserved during rains (such as cassava at 58% from an average of 20% in previous years and yams at 82% from 65%). Crops that depend on sunshine for preservation experience greater differences between low and high periods (maize at 92% from an average of 31% in previous years, sorghum at 180% from 53%, and beans at 68% from 42%). In zones with a history of unreliable dry seasons, farmers are more adapted to coping with an extension of the rainy season and possess technology and skills which can be made available to others in vulnerable zones through inter-regional knowledge transfer of knowledge and skills. This study further reinforces the understanding that isolated climate shocks could be important in understanding and managing vulnerability. Also, vulnerability is quite variable even among

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communities in the same country, in which people practice the same economic activity and are exposed to the same shock.

Keywords Rainfall · Seasons · Effects · Agro-ecological zones · Agriculture · Small-scale farming

1 Introduction

Since 2005, various parts of Cameroon have seen exceptionally long extensions of the rainy season. The rainy season, which corresponds to the summer season in the Northern Hemisphere, is an important period for food crop production in Cameroon because most of the country's food crops are cultivated by small-scale farmers who depend almost entirely on rain-fed agriculture. In Cameroon, the total area equipped for irrigation is 26,000 hectares, constituting just 0.44% of the arable land of 5,960,000 hectares (FAOSTAT 2010), hence the importance of rainfall in food crop production. Given that rainfall is so important, an extension of the rainy season would seem like a relatively welcome phenomenon. However, the relationship between agricultural production among small-scale farmers and rainfall is much more complex. All aspects of agricultural production in rain-fed systems are dependent on many elements of rainfall: its onset, quantity, duration, distribution, frequency and even historical trends. These rainfall characteristics determine the types of crops cultivated, the timing of farm preparation, planting, weeding, harvesting and even post-harvest handling of agricultural produce. All activities are carefully timed to make use of the cycle of seasonal rains, which has for very long been relatively stable or variable at manageable scales. The food crop production culture is therefore heavily dependent on the cycle and character of seasonal rains. As a result, outcomes arising from an extension of the rainy season are complex enough to provide insights into issues of vulnerability, mitigation and adaptation to global environmental change in Cameroon as well as in similar agro-ecosystems in the west and central African sub-region.

The inherent variability of climate conditions from year to year and from decade to decade makes variability an integral part of climate change (Berz 1999; Hulme et al. 1999) and therefore adaptation to climate change is inherently adaptation to variability (Downing et al. 1996; Yohe et al. 1996; Smit et al. 1999). Climatic conditions can, however, vary significantly over short periods of time (from season to season or from year to year) and at relatively smaller spatial scales and may bring with them surprises to an otherwise unsuspecting population. Most socio-economic and ecological systems can cope with changes in mean climatic conditions (SEI 2008; Smit and Pilifosova 2001), however many systems and communities are vulnerable to changes in events of a frequency and magnitude large enough to fall outside their coping range (Schneider 1997; Rayner and Malone 2001). While small-scale farmers living in areas of high environmental stress in the developing world may be highly capable of adapting to short and long-term climatic and environmental variations (Challinor et al. 2007; SEI 2008; Morton 2007), exposure to isolated shocks of natural or man-made origin leads to a degradation of their adaptive capacity and reduces their potential of attaining the goal of sufficiency in food, nutrition and health. Locally specific climate stressors with low predictability are most likely to negatively affect small-holder and subsistence farmers (Morton 2007).

Cameroon is a country with significant agro-climatic diversity, with five main agro-ecological zones ranging from tropical rainforests to Sudan-savanna. The sensitivity of food crops in these areas to an extension of the rainy season varies considerably, and as such, differing outcomes to this condition can be expected (Seo et al. 2009). The occurrence of a common climatic event such as the extension of the rainy season at the same time over five major agro-ecological zones of central and West African offers a valuable opportunity to understand the role of agro-climatic differences in influencing vulnerability, mitigation and adaptation for small-scale farmers.

Rainfall variability in the African Sahel and its surroundings has garnered significant research interest, particularly regarding the implications of such variation on the vulnerability of populations of this region. While some models project a significant drying for the western Sahel (Hulme et al. 2001; Jenkins et al. 2005), others forecast a progressive wetting and greening of the Sahara (Kamga et al. 2005; Hoerling et al. 2006). Notwithstanding these discrepancies, experiments with Global Circulation Models project an increase in rainfall over the African continent, except in southern Africa and parts of the Horn of Africa (IPCC 1997). Rainfall increases of as much as 15% over the 1961–90 average by 2050 in parts of the Sahel and about 5% in Equatorial Africa are predicted (IPCC 1997). Until recently, the majority of the effects of climate change reported for African agriculture were based on an increased intensity of the rainfall in the rainy season, which is related to effects like increased erosion, increased floods and mudslide damage, pressure for food insurance systems and disaster relief (IPCC 1997, 2001). A prolongation of the rainy season in Cameroon is expected to lead to an extension in the length of the growing season. This is predicted for similar agroecological zones in the African continent (Kurukulasuriya and Rosenthal 2003). Changes in the timing and length of growing seasons have been projected as possible outcomes of climate change on African agriculture (Boko et al. 2007; Darwin 2001). Studies have even indicated that in specific areas, such as the Ethiopian highlands and parts of southern Africa (particularly Mozambique), the growing season is expected to lengthen due to an increase in both temperature and the length of rain days (Thornton et al. 2006). In Cameroon, pronounced seasonality (with the dry season becoming drier and the rainy season becoming wetter) is observed from the country's climate data (Molua 2006; Molua and Lambi 2007). An increase in length of the rainy season may also give rise to other impacts, such as pre-harvest damage of mature crops on farms and post-harvest damage of crops in homes, due to limited resources for preservation and lack of preparedness. Such damages can be seen within the context of income shocks likely having a larger impact on the poor (Kurukulasuriya and Rosenthal 2003).

This study set out to attain three objectives: to assess the impact of the rainy season extension on food crop production in Cameroon's agro-ecological zones (using the three main food crops of each zone as indicators); to examine why the same category of farmers (small-holder) in different agro-ecological zones had differing levels of exposure to risk from a common environmental shock; and to identify important management-level adaptation needs for small-scale agriculture in the context of unanticipated events associated with climatic change.

2 Description of the study area (agro-ecological zones and the rainy season extension)

Cameroon is located between west and central Africa and covers an area of 475,442 km^2 lying between latitudes 2° and 13° N (about 1,200 km) and longitudes 8° 30′and 16° 10′ E

(UNEP 2008), (Fig. 1). Its latitudinal extension and topographic diversity enables it to harbor some of the most diverse agro-ecological zones for any single country on the continent. Five major agro-ecological zones can be distinguished (Fig. 2):

- The bi-modal humid forest agro-ecological zone has an annual rainfall range of 1,500–3,000 mm and mean temperature of 23°C. It is situated roughly between 2°N and 4°N and for the most part below an altitude of 800 m (UNEP 2008). It has a four-season climate, with rainfall over 1,500 mm and a maximum of two dry months (Fig. 2). Its vegetation of closed evergreen or semi-deciduous rainforest corresponds to the "humid" and "low- and medium-altitude sub-humid" eco-floristic zones (Lambi and Neba 2010; UNEP 2008). Until recently, the abundance of land in this region enabled its residents to sustain agriculture by shifting cultivation and the use of slash and burn methods.
- The mono-modal humid forest agro-ecological zone is a characteristic equatorial rainforest region with rainfall throughout the year which peaks in the months of July and August. Relative humidity derived from the moisture-laden tropical maritime air mass is usually high and mean temperatures stand at about 28°C with a small range between mean maximum temperature 37°C and a mean minimum of 21°C (Fig. 2). The presence of rich volcanic soils and access to the sea has made this agro-ecological zone ideal for the development of agricultural plantations since colonial times. Its economic opportunities have drawn populations from all over the country and spurred the production of food crops to meet the steep rise in demand following independence in 1960.

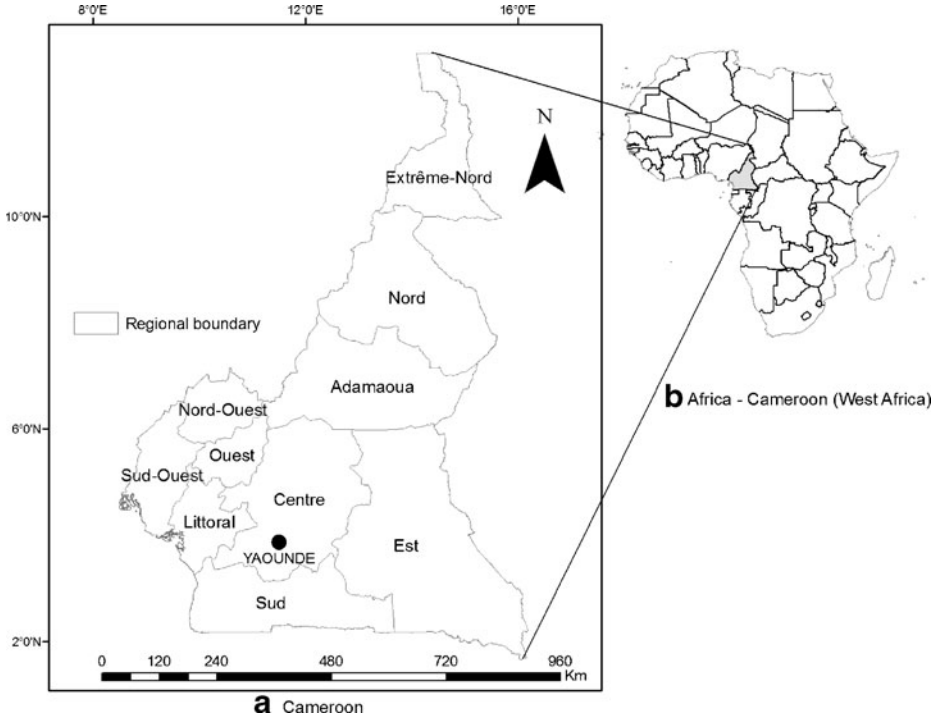

Fig. 1 Location of the study area – Cameroon in Africa

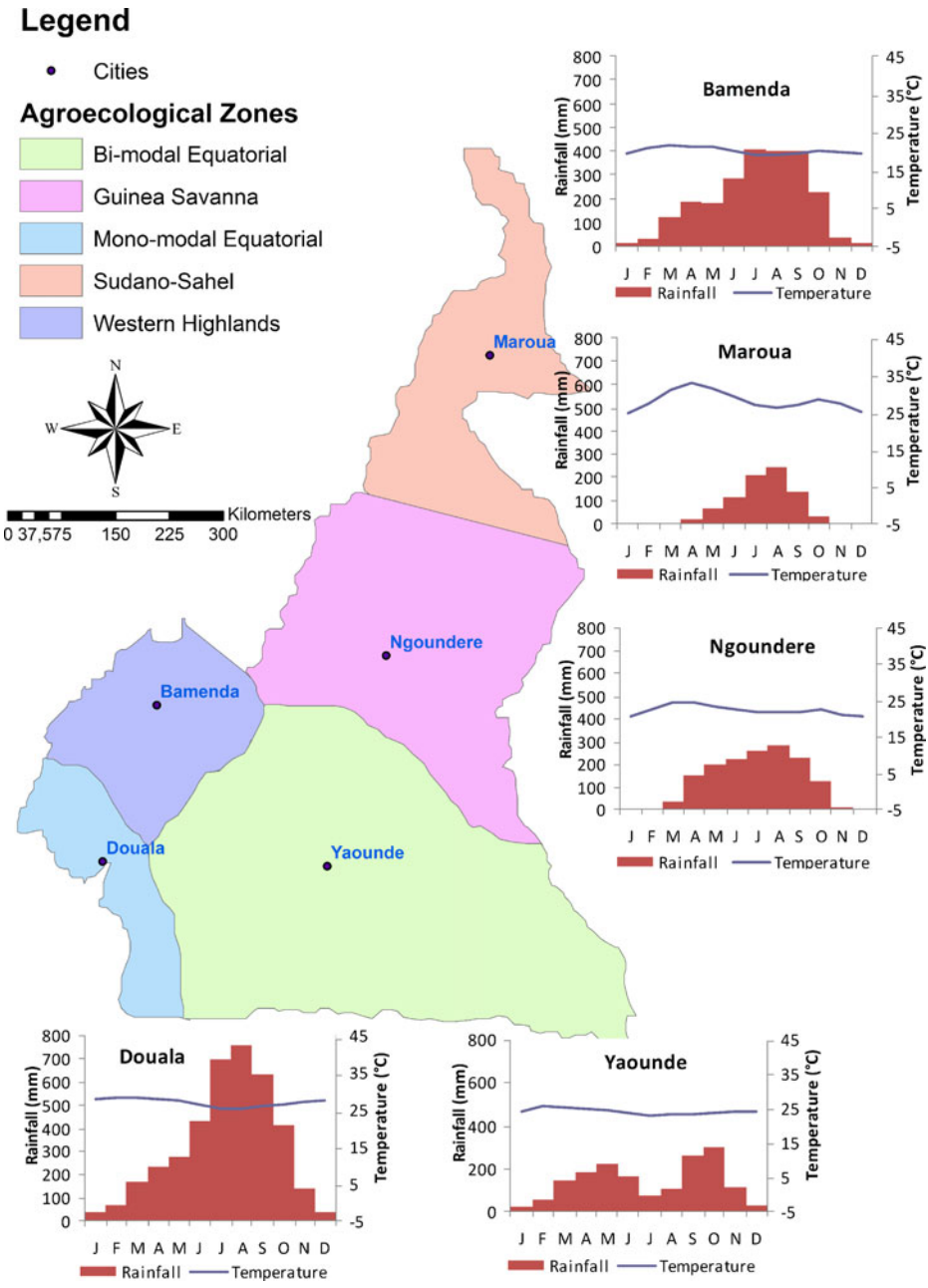

Fig. 2 Major agroecological zones in Cameroon as well as mean monthly rainfall and temperatures for selected cities

- The Guinea-savanna agro-ecological zone is a transition zone between the moist equatorial region in the south and the drier Sahelian north of the country (UNEP 2008). Mean annual rainfall ranges from 700 to 1,500 mm and mean temperature stands at about 22°C (Fig. 2). This region is the main food producing area of the country due to a

number of reasons: The absence of thick forest to serve as an obstacle to farm preparation and management, absence of heavy rains to increase rates of leaching and erosion, and the absence of constant moisture to perpetuate ideal conditions for the growth of many agricultural pests. Its annual production of most grains, pulses and roots is more than that of many other regions in the country.

- The Sudan-savanna is the most northerly agro-ecological zone in Cameroon and has the most distinct division between the rainy and dry seasons. This region also has the greatest diurnal and seasonal ranges of temperatures. In December, mean maximum temperatures may reach 34°C during the day, while mean minimum temperatures may fall to 17°C at night (Fig. 2). Its rainy season lasts for 4 months (May–August), during which time most of the crop cultivation takes place. Annual rainfall inputs range from 400 mm to 1,200 mm and come mainly in the form of strong torrential showers (Fig. 2). Out of this period, crop cultivation is done only in areas where irrigation is possible, such as the banks for the River Chari. In the most northerly parts of this agro-ecological zone (outside the vicinity of Lake Chad), food crop cultivation is practically nonexistent outside the rainy season. The economy here is dependent more on tourism, trade and handicraft.
- The Western Highlands consist of mountains and high plateaus in the west of the country, all of which are over 800 meters tall. Mount Cameroon (4,095 m) is the highest peak, while approximately 20 other peaks stand above 2,000 m. This agro-ecological zone is strongly influenced by its higher elevation. Annual rainfall, which is not only a result of the migration of the ITCZ but also influenced by the orographic effect, ranges from 1,500 mm to 2,000 mm and mean temperatures are about 20°C (Lambi et al. 2010). Like the non-equatorial agro-ecological zones, it has distinct rainy and dry seasons. However, the orographic factor offers it the opportunity of more off-season rains than other northern ecosystems.

3 The prolongation of the rainy season

The rainy season starts and ends at different times in different agro-ecological zones of the country due to its impressive latitudinal extent (Table 1). After taking into consideration the expected end of the rainy season in the regions concerned, for the purposes of this study we defined the end of the rainy season as any day after the 1st of October in which a week's rainfall is equal to or greater than 20 mm and after which rainfall totaled over the next 4 weeks does not exceed 20 mm. We applied this metric for the two agro-ecological zones for which 2007, 2008 and 2009 daily data was available and compared the result with the expected end of the rainy season reported in these agro-ecological zones. While the extension of the rainy season was reported countrywide, data for all agro-ecological zones was not immediately available. For other zones, we relied on accounts from agricultural authorities, who served as key informants, as well as farmers to establish the period of prolongation of rains. In each zone, the expected end of the rainy season is commonly known and largely unambiguous given that annual agricultural activities are planned in reference to it. Agricultural calendars for each agro-ecological zone also clearly indicate the expected dates of start and end of rains.

An increase in the frequency of heavy precipitation over most land areas in recent years has been observed and is consistent with both atmospheric warming and observed increases of atmospheric water vapour (IPCC 2007). Even though episodes of the prolongation of the

Table 1 Expected and actual end of rains for different agro-ecological zones in Cameroon since 2007

Agro-ecological Zone (location of climate station)	Expected End of the Rainy Season	End of the Rainy season	Prolongation	Source
Sudan-savanna (Garoua)	19 October (± 4 days)	13 November (2009)	25 days	Analyzed data
Guinea-savanna (Ngoundere)	21 October (± 6 days)	9 November (2009)	19 days	Analyzed data
Western Highlands (Bamenda)	12 November (± 9 days)	7 December (2008)	25 days	Analyzed data
Bi-modal Equatorial (Lomie)	15 November (± 10 days)	10 December (2009)	25 days	Observed and reported

rainy season have been reported in different parts of the country since 2005, the most significant of these events occurred in 2008. While 2008 was not an El Niño year, it is important to note that studies have established connections between West African rainfall variability and both sea-surface temperature anomalies (Lamb 1978) and remote ocean basins (Folland et al. 1986). The importance of interannual changes in Sahel rainfall and El Niño-Southern Oscillation (ENSO) forcing established by Ward (1992) and Palmer (1986) shows the need for greater investigations into the relationships between the increasing frequency of extended rainy seasons in West and Central Africa and ENSO activities.

4 The dominance of climate control over food production in Cameroon

While progress has been registered in agricultural production in Cameroon over the last two decades (Dewbre and de Battisti 2009), much of the production system remains poorly developed, especially among small scale farmers who form the majority of producers. Nature, particularly climate—remains a dominant control factor in the types of crops produced, yields (Mendelsohn 2009; Seo et al. 2009), the agricultural calendar and all other activities centered on agriculture. The dominant food crops found in different agro-ecological zones are therefore determined by the agro-climatic advantages offered by each zone. For small scale famers whose primary economic activity is farming, climate therefore controls almost all aspects of their economic and social lives.

The mono-modal agro-ecological zone is very similar to its bi-modal counterpart in regards to the food crops grown, agricultural practices, and food culture as a whole. The only difference between them may be the existence of two dry seasons in the bi-modal forest rainfall regime and only one in the mono-modal rainfall regime. It must be noted, however, that the dry seasons experienced in these two agro-ecological zones are in no way comparable to the long and severe dry seasons experienced in the three agro-ecological zones in the northern parts of the country. Dry seasons in the forested agro-ecological zones are mild—more of a brief season of reduced rainfall rather than the prolonged absence of rains experienced in the northern agro-ecological zones. The main food crops of the mono-modal and bi-modal equatorial zones are plantains (*Musa paradisiacal)*, taro cocoyams (*Xanthosoma sagittigolium)*, and cassava (*Manihot esculenta)* (DESA 2009). These crops need significant amounts of rainy days and precipitation input to grow and produce. In the brief "dry seasons" of these regions, farmers produce crops that are less tolerant to abundant precipitation, such as groundnuts

(*Arachis hypogea*), cow pea leaf (*Vigna unguiculata*), green (*Amaranthus spp*), okra (*Abelmoschus spp*) and pumpkin leaves (*Curcubita maxima*).

Many different food crops are produced in large quantities in the Guinea-savanna agro-ecological zone, making it the bread basket of Cameroon's food production. Some of these crops are white guinea yam *(Dioscorea rotundata),* yellow guinea yam *(Dioscorea cayenensis)*, soybeans *(Glycine max.)*, beans *(Phaseolus vulgaris)*, sweet potatoes *(Ipomea batatas)* and sorghum *(Sorghum vulgare)* (DESA 2009). The principal food crops of the region are however maize *(Zea mays)*, cassava (*Manihot esculenta)* and millet *(Eleusine coracana)*. Maize and millet mature at the end of the rainy season, and are allowed to partially dry on the farms, before being harvested during the beginning of the dry season. Farmers allow the maize to dry considerably on the farms to reduce the work of drying at home. This is also done because some farmers have limited resources and space for sun-drying produce at home. This practice utilizes the high intensity of sunshine during the harvesting period to obtain a near-ready maize produce.

The main food crops of the Sudan-savanna agro-ecological zone are sorghum (*Sorghum spp.)*, groundnuts (*Arachis hypogea*), and pearl millet (*Pennisetum glaucum)* (DESA 2009). As with the Guinea-savanna zone, farmers rely on the long, severe dry season in this agro-ecological zone to preserve their grains. Groundnuts mature and are harvested just before the beginning of the dry season. Harvesting at this time is crucial because the sandy soils of this agro-ecological zone easily become dry, crusted and difficult to move with the onset of the dry season. The crop is then left to complete the drying process in the intense sunshine of this region. Alternatively, sorghum and millet is left to attain a considerable degree of dryness on the farms before harvests. During harvests, the produce is dry enough to be stored in barns. The conditions of the dry season make it possible for the rest of the moisture in the crops to dry easily.

The principal food crops of the Western Highlands zone are maize (*Zea mays)*, beans (*Phaseolus vulgaris*) and potatoes (*Solanum tuberosum*) (GP-DERUDEP 2006; DESA 2009). All of these crops are planted at the beginning of the rainy season, which is the middle of March. Beans and potatoes are harvested in June, just before the peak of the rainy season in July and August. Farming households have adapted their homes and surroundings to accommodate the drying and preservation of these food crops even in the middle of the rainy season. Ceilings, veranda roofs and barns are all designed to enable this preservation of food during rains (GP-DERUDEP 2006). Maize is harvested in late August and the month of September when the rains give way to the dry season. The emergence of the dry season means that farmers have the option of allowing the crops attain a reasonable level of dryness on farms before harvesting; otherwise there is drying and preservation space at home to rely upon.

5 Effects of the prolongation of the rainy season and reasons for vulnerability

5.1 Limited effect on high rainfall agro-ecological zones

The main food crops of the mono-modal and bi-modal agro-ecological zones require moist conditions to keep fresh and maintain quality. Plantains (*Musa paradisiaca*) and bananas *(Musa sapientum)* would quickly lose moisture, develop a hard dark skin and a patched outer flesh under dry conditions. Taro cocoyams and cassava would also easily dry out; develop a discolored flesh and loose taste when exposed to dryness (Booth and Coursey 1974; Oke et al. 1998). In times of surplus production, most farmers preserve these food

crops by leaving them on the farms until such time as they would require them for the market or home consumption. Even after harvesting, plantains and bananas are left outside the house, where moist tropical conditions keep them fresh and the relatively cool temperatures outside reduce the rate at which they ripen. Taro cocoyams and cassava are simply left in the ground where they can stay preserved for several weeks (and sometimes months) until they are needed. These main food crops of the East Region therefore suffer little from the prolongation of the rainy season. Farmers contend that a prolongation of the rainy season offers possibilities of undertaking the cultivation of main food crops in virtually any season. Late planters benefit from the prolonged rainy season to obtain a full harvest, a situation that would not otherwise be possible. The lower vulnerability of main food crops to an extension of the rainy season in this area is attributed to the types of crops being cultivated. These types of crops are adapted to regions of high precipitation; several additional weeks of rainfall does not have an effect, especially because no post-rainy season processing requiring drier conditions is needed.

5.2 High vulnerability in drier agro-ecological zones

In the Sudan-savanna agro-ecological zone, farmers have relied heavily on the long, severe dry season to dry and preserve their grains. Groundnuts mature and are harvested just before the beginning of the dry season. Harvesting at this time is crucial because the sandy soils of this agro-ecological zone easily become dry, crusted and difficult to move with the onset of the dry season. The crop is then left to complete the drying process in the intense sunshine of this region. Sorghum on the other hand is left to attain a reasonable degree of dryness on the farms before harvests. During harvests, the produce is dry enough to be stored in barns. The dry conditions of the dry season make it possible for the rest of the moisture in the drops to dry up without much trouble. The prolongation of the rainy season affects groundnuts in that once harvested, they cannot be adequately sun-dried. Poorly dried groundnut seeds easily develop mold which can render the crop poisonous as they may carry aflatoxins (Turner et al. 2005). Fresh groundnuts are also more liable to rot in moist conditions. When not allowed to dry, mature sorghum is also prone to molding and rotting. Vulnerability to a prolongation of the rainy season is therefore seen in the absence of household structures to cope with the challenges posed by such an extension. These structures are absent because the culture of food production has not routinely been challenged by such environmental phenomena.

Given the climatic similarity of the Guinea-savanna agro-ecological zone to the Sudan-savanna, the effects of an extension of the rainy season are seen to be nearly identical for grain crops in the two regions. Farmers of the Guinea-savanna zone have relied heavily on the reliably dry conditions of the dry season for on-farm drying of most of their grains and face the same expression of vulnerability as farmers in the Sudan-savanna zone. However, farmers in the Guinea-savanna zone are more diversified in their practice of intercropping because of more favorable climatic and soil conditions. Damage to grains resulting from an extension of the rainy season constitutes a smaller percentage of the household harvest in farms with a good mix of roots, tubers, cereals and pulses compared to that of the predominantly grain-based production in the Sudan-savanna agro-ecological zone.

The inability to preserve produce affects its availability in the market after the harvest season. Table 2 compares the prices of five crops in three consecutive years, 2006–2008, in the main city of Cameroon's primary food production region. Besides showing an appreciable change between the low and the high periods, the difference between produce that is easily preserved during rains (cassava and yams) and produce that depends on

Table 2 Prices per kilogram of common food commodities in Ngoundere from 2006 to 2008

Crop	2006			2007			2008		
	Low	High	Difference (%)	Low	High	Change (%)	Low	High	Difference (%)
Maize	120	160	33	120	155	29	130	250	92
Beans	305	425	39	310	455	46	300	505	68
Sorghum	225	360	60	245	360	46	305	855	180
Cassava	175	210	20	180	215	19	180	285	58
Yams	175	275	57	170	295	73	145	265	82

[1]Comparing price differences between "Low" periods (periods after crop harvests when a produce is abundant and prices are low) and "High" period (times of scarcity of a produce when supplies are drawn from stores) from 2006 – 2008 in Ngoundere. Blue shades represent the percentage of price differences in the two years prior to 2008 and the red shade represent price differences in 2008. The changes are clearly higher for 2008 when storage and preservation was hampered by a prolonged rainy season. All prices are in Francs CFA

sunshine for good preservation (maize, sorghum and beans) is also evident. The prolongation of the rainy season and associated problems related to heavy rains seriously affected the districts of Bélel and Meiganga in the Adamawa Region (MINADER 2008). In the village of Fada alone, the damage to crops is estimated at FCFA 32,342,500 (approximately USD 60,000) (MINADER 2008).

5.3 High degree of adaptation in the zone with a history of unreliable dry seasons

The topography of the Western Highlands agro-ecological zones enables it to see unpredictable rain showers even in the middle of the dry season. The dry season can be seen in one sense as not being very reliable in this agro-ecological zone when compared to the Guinea-savanna and the Sudan-savanna agro-ecological zones. As a result of this "unreliability" of the dry season, farmers generally depend less on the drying of produce like maize on the farms before harvest. They therefore rely more on improvised facilities for drying and storing their produce at home, which include modifying the ceiling structures of their homes to serve as drying and storage space, using their verandas, drying mats and baskets, barns adapted for the climate of the region, etc (GP-DERUDEP 2006). Coping with unexpected showers of rain is incorporated into the food production and preservation culture of people in this agro-ecological zone. Nevertheless, an extension of the dry season still has a minimal effect on the total harvest of their maize crop. For some maize species with ears that do not wrap firmly on the cob, prolonged rains after maturation may soak into the seeds and damage the produce. These are generally species recently introduced to the agro-ecological zone (Yengoh et al. 2009). Vulnerability in this case is expressed in having a crop that does not fit the environmental challenge posed rather than preparing to meet the challenge through developing household structures and knowledge base. The prolongation of the rainy season also means that the maize crop harvested contains significant moisture, which entails greater care and resources for drying at home. In cases where the resources for drying the maize crop were inadequate, farmers reported some losses from mold. This is

especially true among farmers with the fewest economic resources. In this case, the limited economic resources with which to cope with the environmental challenge is the source of vulnerability.

6 Interim conclusion

Farmers in the Sudan-savanna and Guinea-savanna agro-ecological zones are therefore the most vulnerable to an extension of the rainy season, for a number of reasons. A lack of experience with long delays in the rainy season has made farmers unprepared to anticipate such events. As a result, the farming culture has not developed knowledge of the effects of such events nor tools for mitigating and adapting to them. Hence there are structural and informational gaps about adapting to a prolongation of the rainy season which creates vulnerability in this group of producers. The vulnerability of farmers in the western highlands is attributed to the nature of their planting materials (maize seeds in particular). Many reasons exist why farmers plant these particular seeds. However, if the extension of the rainy season becomes more frequent, farmers may have to select seeds with features more suited to coping with prolonged rains, provided the agricultural cycle remains unchanged. While the main food crops of the rainforest zone remain relatively unaffected, other systems of food production that are by no means less important suffer interruption or damage. For example, marshland crops are flooded for longer periods and some rain-sensitive vegetables are not planted. Though admittedly, they are minor crops in these zones.

7 Discussion

7.1 Outcomes of vulnerability for individual households

Outside of the equatorial agro-ecological zones, an extension of the rainy season entails loss of agricultural produce for farming households at different magnitudes, the loss being larger in regions where the distinction between the rainy and dry season is greater. A majority of farmers in Cameroon are small-scale producers who are largely dependent on agriculture for sustaining their livelihoods. They have smaller production margins to afford significant loss of production at any season. They depend largely on their own food production for both household consumption and the generation of household income from surplus production. With smaller production margins to spare, a loss or significant decrease in food crop production may mean fewer calories available for the household and less income to invest in crop production for the next agricultural season (Fig. 3). These together have the potential of decreasing the production capacity of households and decreasing yields for the next agricultural season. Lower yields for the next season may mean fewer calories available and resources to invest in agriculture for another season. This forms a vicious cycle which farmers find difficult to break, given their low levels of production (Fig. 3).

This vicious cycle makes households more vulnerable because with even fewer or no surpluses resulting from a disruption of production, they have even less means of coping with natural or socio-economic shocks. Therefore farmers' adaptive capacity is reduced and their drive towards attaining food sovereignty or security suffers setbacks. Being caught in this vicious cycle can have far-reaching implications, such as affecting the growth of children, reducing women's economic and social status, driving families to sell valuable

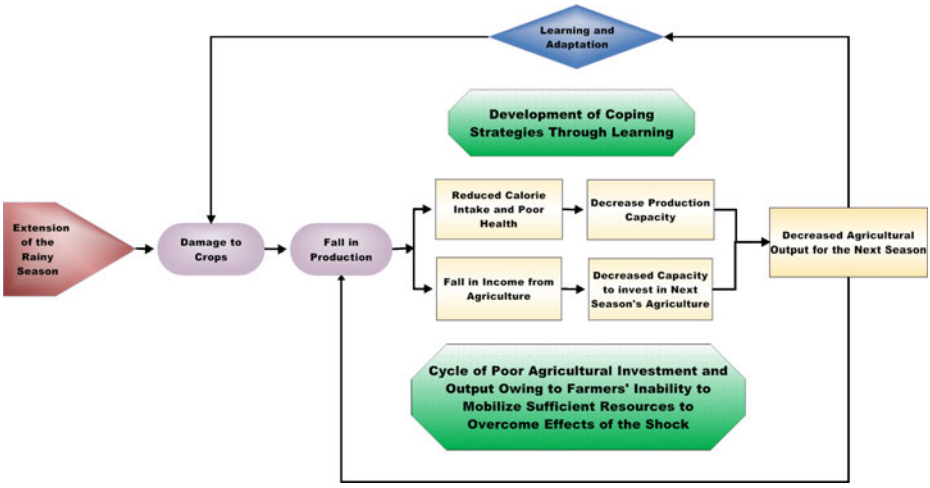

Fig. 3 Short-term and long-term effects of sporadic shocks that damages crops on small-scale farmers in resource-deficient regions

food production assets to make up for short-term food and financial demands, etc. On the other hand, farmers may learn from the situation, especially if it becomes more prevalent, and begin to adapt to it (Fig. 3). Through learning, the development of coping strategies, knowledge, methods, tools, and food production culture in response to the extension of the rainy season can become part of the agricultural tradition of people in Guinea-savanna and Sudan-savanna agro-ecological zones.

7.2 Pressing management level adaptation needs for small-scale agriculture in Cameroon

Many management-level adaptation options have been identified that farmers can employ to minimize climate risk (Howden et al. 2007). For the Sudan-savanna and Guinea-savanna zones of Cameroon, four management-level adaptation options may offer the greatest benefits for coping with surprises, such as an extension of the rainy season. These options cut through spatial boundaries (agro-ecological zones and regional administrative boundaries), disciplinary divides and governance structures (local, national, international, and non-governmental). They also address temporal scales of adaptation needs for small-scale farmers in Cameroon.

- *Inter-regional transfer of adaptation knowledge*. Inter-regional learning between the people of the western highlands (whose food production culture is largely adapted to rainfall surprises outside the traditional rainy season) and the Sudan- and Guinea-savanna agro-ecological zones (whose agriculture depends on a reliable dry season) should be advocated. The technique in the western highlands by which ceilings and verandas of homes are equipped to accommodate the drying of grains is knowledge that should be disseminated in the Guinea and Sudan-savanna agro-ecological zones. This implementation may involve a modification of the system of construction of homes in the savanna zones. Presently, the essentially earthen homes that characterize much of the savanna zones are not very different from those of the western highlands, but are radically different from the mostly wood-based homes of the forest ecosystems. Given the similarity in the nature of raw materials available for home construction in the Western Highlands agro-ecological zone and the Guinea- and Sudan-savana agro-ecological zones, such a transfer of technology may be more attainable. Inter-regional

transfer of knowledge can, however, only be successful if farmers have the resources to convert knowledge of strategies from elsewhere to opportunities for adaptation in their own areas. Small-scale farmers in Cameroon, as in most of sub-Saharan Africa, have limited resources for taking advantage of some of these implementable strategies. Credit schemes at different levels have been proposed as a means through which resource-limited agriculturalists may increase their adaptive capacities to climate change. Limiting national credit schemes available to farmers or removal of subsidies may restrict farmers' ability to adapt to climate change, leaving them more vulnerable (Leichenko and O'Brien 2002). Proposals for funding of climate change adaptation schemes to go beyond pilot projects and one-off interventions illustrate the importance given to helping resource-limited producers access necessary resources (SEI 2008).

- *Expanding the system of agricultural diversification.* Sustaining diversity has been seen as an appropriate adaptation option for protecting food security and livelihoods in the face of climate extremes and uncertainty (IDRC 2009). Crop diversification among farmers in the guinea savanna zone enables them to become less vulnerable to an extension of the rainy season than are farmers in the Sudan-savanna zone. While food crop diversification may offer many benefits, diversification may not be limited only to crops. Even at small scales, integrating livestock production with food production could offer immense benefits in health, income, food production and security for small-scale farmers in the developing world. For diversification to be widespread and succeed in Cameroon and much of sub-Saharan Africa, there is a need to develop and sustain inter-sectoral coordination across the different sectors that form the basis of rural livelihood and support small-scale agriculture. This makes it imperative for sectors like finance, transportation, tourism, health, women's rights and education to collaborate and synergize their efforts.
- *Empowering local initiatives for mitigation and adaptation.* The importance given to local, traditional structures of power and governance both by the government and the populace in Cameroon make them ideal institutions on which adaptation at local level can be based. Such social institutions can be empowered to become key components in the process of adaptation. Empowering local administrative structures by decentralizing decision-making regarding the development and promotion of adaptation measures can be both cost-effective and more responsive to local needs. However, decentralization in the West African sub-region is fraught with a number of challenges, not least limited financial resources, limited number of personnel, incapacity to generate funds internally, political interference from higher level administrations, and institutional conflicts. These challenges call for a local governance system that is mindful of historical antecedents and is more responsive to the aforementioned challenges. Adaptation governance at the local level may also include support and empowerment to local farming common initiative groups and cooperative societies, which should enable them to integrate local and 'imported' knowledge and technologies. It would be naïve to expect that local adaptation governance alone would be sufficient to address the scale of changes expected in small-scale agriculture in sub-Saharan Africa during this century. However, supporting local-level governance structures would make wider policy frameworks more responsive to local needs.

7.3 The important role of a knowledge-sharing framework for environmental change

Information sharing in a multilevel framework can benefit three main stakeholders of global environmental change and global food security. The stakeholders include: farmers affected

by such climatic shocks at local level; researchers who strive to understand, anticipate and educate on the issues; and the governments who strive to protect the social and economic livelihoods of their citizens (Fig. 4). In such a knowledge-sharing framework, greater communication between researchers provides an inter-disciplinary perspective on the issues and challenges. The need for a multi-disciplinary approach in climate mitigation and adaptation research is dictated by the multi-disciplinary nature of problems related to climate change (SEI 2008; Howden et al. 2007). At the center of this communication and collaboration, Vignola et al. (2009) advocate an ecosystem-based framework in which addressing the problems of ecosystem degradation and the conservation of natural capital are the main focus. The 'development first' approach is urged by others, in which the need to achieve the pressing goals of poverty alleviation, food security, social and economic development in different dimensions is emphasized while also meeting urgent environmental goals such as climate change mitigation, sustainable water management, the preservation of biodiversity (Ahmad 2009). Communication and collaboration is also recommended in a more holistic approach of integrating climate change-related issues with all other risk factors, such as climate variability and market risk, and with other policy domains, such as sustainable development as a necessary path towards achieving increased adaptation (Howden et al. 2007).

Access to relevant knowledge and information is identified to be the key to adaptation among farmers in Africa (Challinor et al. 2007). The enabling framework for gaining access to both this knowledge and the resources with which it can be translated into concrete actions that promote adaptation, however, has to be provided by governmental and non-governmental institutions at the local, national and international level (Yengoh et al. 2009; Challinor et al. 2007). Between local communities, knowledge and information sharing can be used to disseminate existing methods and approaches to mitigation and adaptation, such as the

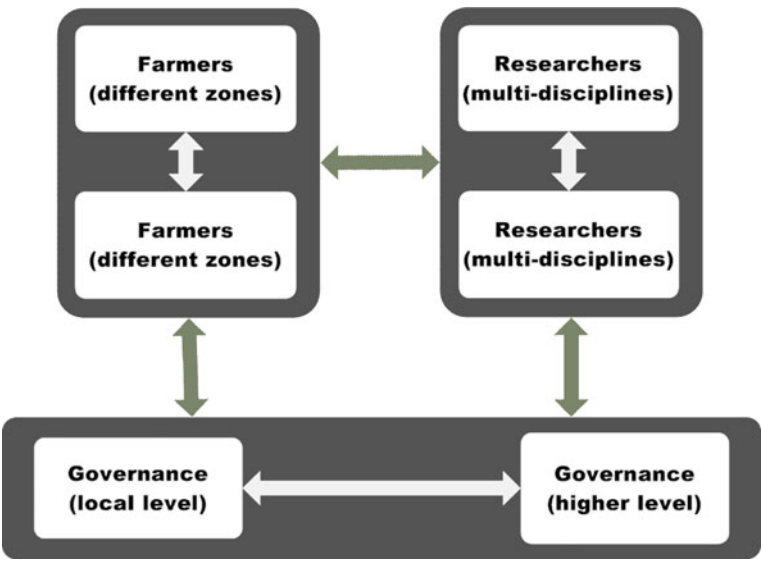

Fig. 4 A multi-level knowledge sharing framework for addressing cross- and inter-sectoral problems like climate risks

transfer of knowledge on coping with sporadic dry season rains in the western highlands to the Sudan- and guinea savanna ecosystems. Between local and higher levels of governance, information sharing can inform different levels of decision-making regarding contingencies and priorities necessary for meeting challenges of mitigation and adaptation. Besides information sharing within sectors, information flow across sectors can also be vital (Fig. 4).

The importance of indigenous people as an indispensable asset of knowledge on environmental issues and problems in their communities is well-known (Johnston and Tauli-Corpuz 2009). In recognition of this importance, the highest levels of climate change research, notably the UN Intergovernmental Panel on Climate Change seeks to include this previously-missing element in its next assessment, due in 2014 (Johnston and Tauli-Corpuz 2009). Research can propose meaningful solutions to challenges of mitigation and adaptation only if it is adequately informed by those who are affected by the events in question and will eventually be beneficiaries of such solutions, hence the importance of information sharing between researchers and farmers at the local level. The need for an early warning system to forecast and report impending events such as a prolongation of the rainy season is expressed by farmers but can only be achieved through such farmer-researcher collaboration. Governance at local and higher levels is important in providing an enabling framework for both developing knowledge on the nature and needs of mitigation and adaptation as well as the favorable implementation of adaptation strategies. Higher-level governance also involves international negotiations that have the potential of positively influencing national policies on adaptation (Vignola et al. 2009).

8 Conclusion

The extension of the rainy season affects farmers in different agro-ecological zones in Cameroon. The effects are more severe in the northern regions of the country, where farmers are accustomed to a clear distinction between the rainy and dry seasons. This distinction has not prepared agriculture for these recent extensions of the rainy season. In the western highlands, where farmers are used to 'surprises' of rainfall in the dry seasons, the agricultural tradition is much more suited to dealing with the extension of the rainy season. In the equatorial region, agricultural production has developed around the abundance of rain almost year-round and the effects of an extension of their rainy season on farmers are very minimal. Inter-regional transfer of knowledge from regions like the Western Highlands, where farming has developed to cope with spasmodic rainfall events during the dry season, can benefit small-scale farmers in the northern regions of the country. Successful mitigation and adaptation for the long-term will also require closer collaboration between stakeholders in climate change research, agriculture and governance.

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References

Ahmad IH (2009) Climate policy integration: towards operationalization, DESA Working Paper No. 73ST/ESA/2009/DWP/73, March 2009

Berz GA (1999) Catastrophes and climate change: concerns and possible countermeasures of the insurance industry. Mitig Adapt Strateg Glob Change 4(3–4):283–293

Boko M, Niang I et al (2007) Africa. Climate change 2007: impacts, adaptation and vulnerability. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE (eds). Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge UK, pp 433–467

Booth RH, Coursey DG (1974) Storage of cassava roots and related post-harvest problems. Proceedings of an international workshop on Cassava processing and storage. Pattaya, Thailand. International Development Research Centre (IDRC) 031:43–49

Challinor AJ, Wheeler TR, Garforth C et al (2007) Assessing the vulnerability of food crop systems in Africa to climate change. Climate Change 83:381–399

Darwin R (2001) Climate change and food security. Agr Inform Bull 765(8):1–2

Dewbre J, de Battisti AB (2009) Agricultural progress in Cameroon, Ghana and Mali: why it happened and how to sustain it. Organisation for Economic Co-Operation and Development OECD

Direction des Enquêtes et Statistiques Agricoles, DESA (2009) Annuaire des statistiques du secteur agricoles campagnes 2006-2007. MINADER/DESA/ AGRISTAT N° 15 Ministere de L'Agriculture et du Developpement Rural MINADER, Yaoundé

Downing TE, Olsthoorn AA, Tol RSJ (1996) Climate change and extreme events: altered risks, socio-economic impacts and policy responses. Vrije Universiteit, Amsterdam

FAOSTAT (2010) Food and Agricultural Organization statistics database. Accessed March, 2010. Available from http://faostat.fao.org/default.aspx

Folland CK, Palmer TN, Parker DE (1986) Sahel rainfall and worldwide sea temperature 1901 1985. Nature 320:602–607

Grassfield Participatory and Decentralised Rural Development Project, GP-DERUDEP (2006) Baseline study of the North West Province 2006, SIRDEP Bamenda

Hoerling M, Hurrell J et al (2006) Detection and attribution of twentieth-century northern and southern African rainfall change. J Climate 19:3989–4008

Howden M, Soussana JF, Tubiello FN, Chhetri N, Dunlop M, Aggarwal PK (2007) Adaptation strategies for climate change. Proc Natl Acad Sci 104:19691–19698

Hulme M, Barrow EM, Arnell NW et al (1999) Relative impacts of human-induced climate change and natural climate variability. Nature 397:688–691

Hulme M, Doherty RM et al (2001) African climate change: 1900–2100. Clim Res 17:145–168

Intergovernmental Panel on Climate Change, IPCC (1997) IPCC special report on the regional impacts of climate change an assessment of vulnerability. In: Watson RT, Zinyowera MC, Moss RH (eds) Cambridge University Press, UK

Intergovernmental Panel on Climate Change, IPCC (2001) Climate change 2001: impacts, adaptation & vulnerability contribution of working Group II to the third assessment report of the Intergovernmental Panel on Climate Change (IPCC). In: McCarthy JJ, Osvaldo F et al (eds). Cambridge University Press, UK

Intergovernmental Panel on Climate Change, IPCC (2007) Summary for Policymakers. In: Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL (eds) Climate change 2007: the physical science basis. Contribution of working Group I to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge

International Development Research Centre—IDRC (2009) Strengthening African adaptation: emerging lessons from the CCAA Programme. CCAA contribution to the 3rd Special Session of AMCEN, Nairobi, 25–29 May 2009

Jenkins GS, Gaye AT et al (2005) Late 20th century attribution of drying trends in the Sahel from the Regional Climate Model (RegCM3). Geophys Res Lett 32:L22705

Johnston S, Tauli-Corpuz V (2009) Traditional knowledge for developing holistic adaptation and mitigation measures. IOP Conf Ser Decis Earth Environ Sci 6:432008

Kamga AF, Jenkins GS et al (2005) Evaluating the National Center for Atmospheric Research climate system model over West Africa: present-day and the 21st century A1 scenario. J Geophys Res Atmos 110: D03106

Kurukulasuriya P, Rosenthal S (2003) Climate change and agriculture a review of impacts and adaptations. World Bank Climate Change Series, Paper No. 91

Lamb PJ (1978) Large-scale tropical surface circulation patterns associated with sub-Saharan weather anomalies. Tellus 30:240251

Lambi CM, Neba EN (2010) Ecology of natural resources development in the Western Highlands of Cameroon. RPCIG Mankon, Bamenda

Leichenko RM, O'Brien KL (2002) The dynamics of rural vulnerability to global change: the case of southern Africa. Mitig Adapt Strateg Glob Change 7(1):1–18

Mendelsohn R (2009) The impact of climate change on agriculture in developing countries. J Nat Resour Policy Res 1(1):5–19

Ministere de l'Agriculture et du Developpement Rural, MINADER (2008) Rapport annuel du service regional des enquetes et des statistiques agricoles de l'Adamaoua: Annee 2008. Service Régional des Enquêtes et Statistiques Agricoles de l'Adamaoua, MINADER—Delegation Regionale de l'Adamaoua

Molua EL (2006) Climate trends in Cameroon: Implications for agricultural management. Clim Res 30:255–62

Molua EL, Lambi CM (2007) Economic impact of climate change on agriculture in Cameroon. Policy Research Paper No. 4364. World Bank, Washington, DC.

Morton JF (2007) The impact of climate change on smallholder and subsistence agriculture. PNAS 104 (50):19680–19685

Oke OL, Redhead J, Hussain MA (1998) Roots, tubers, plantains and bananas in human nutrition. Rome, Italy: Food and Agriculture Organization of the United Nations (FAO) and the Information Network on Post-Harvest Operations - INPhO

Palmer TN (1986) Influence of the Atlantic, Pacific, and Indian oceans on Sahel rainfall. Nature 322:251–253

Rayner S, Malone EL (2001) Climate change, poverty and intra-generational equity: the national level. Int J of Glob Env Iss 1(2):175–202

Schneider SH (1997) Integrated assessment modeling of global climate change: transparent rational tool for policymaking or opaque screen h i ding value-laden assumptions? Environ Model Assess 2(4):229–248

Seo SN, Mendelsohn R, Dinar A et al (2009) A Ricardian Analysis of the Distribution of Climate Change Impacts on Agriculture across Agro-Ecological Zones in Africa. Environ Resource Econ 43:313–332

Smit B, Pilifosova O (2001) Adaptation to climate change in the context of sustainable development and equity. In: McCarthy JJ, Canziani OF, Leary NA, Dokken DJ, White KS (eds) Climate change 2001: impacts, adaptation, and vulnerability—contribution of working group II to the third assessment report of the intergovernmental panel on climate change, vol 18. Cambridge University Press, Cambrige, pp 876–912

Smit B, Burton I, Klein RJT et al (1999) The science of adaptation: a framework for assessment. Mitig Adapt Strateg Glob Change 4:199–213

Stockholm Environment Institute, SEI (2008) Climate change and adaptation in African agriculture, SEI and The Rockefeller Foundation

Thornton PK, Jones PG et al (2006) Mapping Climate Vulnerability and Poverty in Africa. Report to the Department for International Development, ILRI, P.O.Box 30709, Nairobi 00100, Kenya, pp 200

Turner P, Sylla A, Gong Y et al (2005) Reduction in exposure to carcinogenic aflatoxins by postharvest intervention measures in west Africa: a community-based intervention study. Lancet 365(9475):1950–1956

United Nations Environment Programme UNEP (2008) Africa: Atlas of our changing environment. Division of Early Warning and Assessment-North America UNEP, Nairobi, pp 110–115

Vignola R, Locatelli B, Martinez C et al (2009) Ecosystem-based adaptation to climate change: what role for policy-makers, society and scientists? Mitig Adapt Strateg Glob Change 14(8):691–696

Ward MN (1992) Provisionally corrected surface wind data, worldwide ocean-atmosphere surface fields, and Sahelian rainfall variability. J Clim 5:454–475

Yengoh GT, Armah FA, Svensson MGE (2009) Technology adoption in small-scale agriculture: the case of Cameroon and Ghana. Sci Technol Innov Stud 5(2):111–131

Yohe G, Neumann J, Marshall P et al (1996) The economic costs of sea-level rise on developed property in the United States. Climate Change 32:387–410