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ORIGINAL ARTICLE

Smallholder farmers' perceptions of and adaptations to climate change in the Nigerian savanna

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Abstract The savanna region of Africa is a potential breadbasket of the continent but is severely affected by climate change. Understanding farmers' perceptions of climate change and the types of adjustments they have made in their farming practices in response to these changes will offer some insights into necessary interventions to ensure a successful adaptation in the region. This paper explores how smallholder farmers in the Nigerian savanna perceive and adapt to climate change. It is based on a field survey carried out among 200 smallholder farm households selected from two agro-ecological zones. The results show that most of the farmers have noticed changes in climate and have consequently adjusted their farming practices to adapt. There are no large differences in the adaptation practices across the region, but farmers in Sudan savanna agro-ecological zone are more likely to adapt to changes in temperature than those in northern Guinea savanna. The main adaptation methods include varying planting dates, use of drought tolerant and early maturing varieties and tree planting. Some of the farmers are facing limitations in adapting because of lack of information on climate change and the suitable adaptation measures and lack of credit. The study then concludes that to ensure successful adaptation to climate change in the region, concerted efforts are needed to design and promote planned adaptation measures that fit into the local context and also to educate farmers on climate change and appropriate adaptation measures.

Keywords Adaptation · Climate change · Perception · Smallholder farmers · Nigerian savanna

Introduction

There is now a general consensus that the climate is changing and is having significant impacts on agricultural production. The impacts are, however, unevenly distributed with high regional disparities. Some authors argue that agriculture in some countries located in temperate and polar regions is likely to benefit from higher mean temperatures and longer growing seasons, while most countries in tropical and subtropical regions are expected to suffer from decline in agricultural productivity (Dinar et al. 2008; Lybbert and Sumner 2010). Africa is particularly expected to be hard hit by the changing climate because of the geographical disadvantage (already a warm region), high dependence on the most climate-sensitive sector (agriculture) and the limited capacity to adapt due to poverty and low level of technological development (Stern 2007; Collier et al. 2008; World Bank 2009). Smallholder farmers are among those who will suffer most from the impacts of climate change (Easterling et al. 2007).

Nigeria is recognised as one of the African countries very vulnerable to climate change (Huq and Ayers 2007). This is because agriculture is an important sector of its economy, employing about 70 % of the population and contributing significantly to gross domestic product (NBS 2012). Also, agriculture in the country is mainly rain-fed, making it vulnerable to the vagaries of weather. The vulnerability of the country is further exacerbated by the high population (about 150 million), two-thirds of the land cover located in drought prone areas and the long coastal land (about 800 km) which is prone to sea level rise (BNRCC

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2008). Unfortunately, the country has a low adaptive capacity due to low financial, technical and technological capabilities, weak institutions, limited awareness of climate change and the lack of national climate change adaptation policy (ibid).

Adapting agriculture to climate change is recognised as a very important policy option to reduce the vulnerability and the negative impacts; consequently, there is increasing attention on the pressing need for adaptation in African agriculture. Adaptation, as defined by IPCC, refers to 'adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities' (IPCC 2007). Farmers have been experiencing climate change and have continuously adapted to these changes in various ways over time. Understanding these adaptation strategies and the constraints to their implementation could offer options on how to help in mitigating the effects of climate change.

The importance of adapting agriculture to climate change in Africa has resulted in a vast amount of research on farmers' perceptions and adaptations to climate change in the continent (e.g. Tschakert 2007; West et al. 2008; Bryan et al. 2009; Deressa et al. 2009; Gbetibouo 2009; Barbier et al. 2009; Mertz et al. 2009; Speranza et al. 2010; Hisali et al. 2011; Kemausuor et al. 2011; Below et al. 2012; Fosu-Mensah et al. 2012). The overall conclusion of these studies is that most farmers perceive that the climate is changing and are taking up several adaptation measures to reduce the impact. For instance, in a review of climate change adaptation in African agriculture, Below et al. (2010) identified about 104 different adaptation practices used by farmers which are broadly categorised into: farm management and technology; farm financial management; diversification of farm and off-farm activities; government interventions in infrastructure, health and risk reduction; and knowledge management, networks and governance. While major adaptation measures such as new crops or crop varieties and livelihood diversification are adopted by farmers throughout the continent, others are peculiar to certain regions, and the choice of the adaptation options is influenced by different contextual factors (Bryan et al. 2009; Deressa et al. 2009; Gbetibouo et al. 2010; Hisali et al. 2011; Below et al. 2012; Fosu-Mensah et al. 2012). This implies that area-specific studies on climate change adaptation are necessary. This is also noted by Hisali et al. (2011) who argued that responses to impacts of climate change often tend to be localised and context specific, thus requiring that studies on adaptation need to be tailored to specific contexts because a one size fits all solution will not work.

However, most research on farmers' adaptation to climate change in Africa has focused on the Sahel region of West Africa [partly due to the severe droughts and famines in this region in the 1970 and 1980s (West et al. 2008)] and on the rainforest ecological zones. The savanna region, which is a potential breadbasket of Africa but severely affected by climate change (Ker 1995), is under-represented in the literature. Furthermore, with the exception of few studies (Dabi et al. 2008; Onyeneke and Madukwe 2010; Sofoluwe et al. 2011; Ishaya and Abaje 2008), there is limited research on adaptation to climate change by farmers in Nigeria. This study aims to complement existing adaptation studies in Nigeria and Africa by looking at how smallholder farmers in two savanna agro-ecological zones (Sudan savanna and northern Guinea savanna) of Nigeria adapt to climate change.

Before adapting to climate change, farmers must first perceive that changes are taking place, and this implies that farmers' perceptions about climate change are very important in the uptake of adaptation measures (Maddison 2006; Shisanya and Khayesi 2007; Bryan et al. 2009). As argued by Maddison (2006) and Deressa et al. (2011), adaptation to climate change is also a two-step process that involves perceiving that climate is changing and then responding to changes through adaptation. Consequently, this paper also assesses the perceptions of climate by farmers in the Nigerian savanna. Studies have also shown that, to some extent, farmers' perceptions corroborate actual climate trends (Meze-Hausken 2004; Gbetibouo 2008; West et al. 2008; Kemausuor et al. 2011; Fosu-Mensah et al. 2012). In this study, however, contrasting farmers' perceptions with climate trends is not possible due to lack of reliable meteorological data in the study region.

The main objective of this paper is to examine smallholder farmer perceptions of and adaptations to climate change in the Nigerian savanna, a region with very limited research on climate change adaptation but recognised as one of the most vulnerable areas where the livelihood of farmers is under threat due to climate change. Using data from two savanna agro-ecological zones (AEZs) in this region, this paper specifically assesses past climatic events, farmers' awareness and perceptions of climate change, adaptations in response to the perceived changes and barriers to adaptation. The use of two different savanna AEZs also allows analysis of whether farmers' perceptions and adaptations differ within the region.

The rest of the paper will present a brief overview of climate change impacts and adaptation in Nigeria based on existing literature before describing the study region and methods in the third section. Survey results are provided and discussed in Sect. 4 before some summary and implications are presented as conclusions.

Climate change impacts and agricultural adaptation strategies in Nigeria

Various studies have shown that the Nigeria's climate is changing with increased incidence of climatic hazards. In a study on climate change in Nigeria, Odjugo (2010) found an increase in temperature and a decrease in the duration and amount of rainfall over the last century. He asserted that there has been an increase of 1.1 °C in average temperature and a reduction in average rainfall by 81 mm between 1901 and 2005. The coastal region has, however, been experiencing increasing rainfall although rainfall amount is generally decreasing in the country. The study also reported that sea-level rise has inundated 3,400 km^2 of the coastal region, while desert encroachment is reducing arable lands in the northern part of the country by 1–10 km every year. These findings are corroborated by reports of a decline in rainfall in Nigeria since 1960 with a persistent decrease over the last two decades (Uyigue and Agho 2007) and high inter- and intra-annual variability (Odekunle and Adejuwon 2007).

ERM/DFID (2009) examined the potential impacts of climate change on Nigeria's economy and argued that the country is likely to be one of the most negatively affected countries in the world. Using an integrated assessment model, the study projected that climate change could result in 6–30 % loss in GDP by 2050 assuming minimum adaptation and 2–11 % of GDP could be lost if no adaptation is implemented by 2020. It found that all regions in the country will be affected, but particularly the southern coastal regions and the far north. Of all the sectors in the country, agriculture will be mostly affected with key impacts such as decreased agricultural productivity in the north of the country due to increase in drought and 75 % loss of agricultural land in the southern region with a 1-m rise in sea level. Other expected impacts include salinisation of many southern areas and conflicts between farmers and pastoralists over water. The study, however, reported that some aspects of the economy such as production and sale of renewable energy will gain from climate change. Using the erosion productivity impact calculator (EPIC) crop model, Adejuwon (2006) simulated potential effects of changes in climate on yields of maize, sorghum, millet, rice and cassava in the country. The study found that there will be increase in crop yield as the climate changes during the early parts of the 21st century, but this will be followed by decrease in yield towards the end of the century which could be explained in terms of temperatures exceeding range of tolerance for crops.

Very few studies on adaptation have been carried out in Nigeria, but these studies show that farmers use a combination of several adaptation options in different parts of the country. Onyeneke and Madukwe (2010) and Sofoluwe et al. (2011) found that the main adaptation measures used by crop farmers in rainforest zone of southern Nigeria include portfolio diversification, soil conservation techniques, changing dates of planting, planting of trees, changing tillage operations and use of irrigation. Climate change is likely to have more negative effects on returns to agriculture and welfare in northern Nigeria than in the southern part (Oyekale 2009); hence, the former region requires more attention on adaptation. Results from studies in this region show that adaptation measures used by farmers include planting different varieties of crops, cultivating different crops, shortening growing season, changing the extent of land put into crop production, use of drought/early mature resistance varieties, replanting lost crops, relocating of farms and selling of assets (Dabi et al. 2008; Ishaya and Abaje 2008). This paper contributes to the literature by looking at how smallholder farmers located in the savannas of Nigeria perceive and adapt to the changing climate and discusses important policy-driven measures needed for successful adaptations in the region.

Methods

This section presents the study area, methods of data collection and analysis and descriptive summary of the study sample.

Study area

This paper is largely based on primary data collected between April and July 2010 from farm households in the savannas of Borno state of Nigeria. The savanna generally refers to landscape characterised by pure grassland to dense woodland vegetations with a continuous grass layer beneath or between the trees (Ker 1995). It lies between the equatorial rainforest and the deserts of the subtropics and experiences about 2.5–9 months of dry season annually (Harris 1980; Ker 1995). Borno state was chosen for this study because of its vulnerability to climate change and the existence of different AEZs within the state. Gwoza and Biu Local Government Areas (LGAs) were selected as study regions out of the 27 LGAs in Borno state. The Gwoza and Biu LGAs capture two distinct AEZs, Sudan savanna (SS) and northern Guinea savanna (NGS), respectively. NGS and SS are also known as subarid and subhumid savannas, respectively (Ker 1995).

The climatic conditions in the two AEZS vary considerably. The average annual rainfall in NGS is between 900–1,200 mm while that of SS is low, about 600–900 mm with a prolonged dry season of 6–9 months (Ker 1995). Records of rainfall in these AEZs show high interannual variability (Tambo 2010). Rainfall, however, varies from year to year but has tended to decrease over the last two decades. Rainfall has unimodal distribution in both AEZs, and the farming season is normally between June and September in the SS and May and October in the NGS. The average annual temperatures for SS and NGS are 25.3–27.3

and 26.4–29.2, respectively (Sowunmi and Akintola 2010). The inhabitants in both AEZs depend on agriculture (mainly subsistence farming) for their livelihoods. The farming system in the area is mainly the system of permanent cultivation on rain-fed land (Ruthenberg 1971). The cropping pattern is largely cereal-legume based, and the most important crops are millet (*Panicum glaucum*), sorghum (*Sorghum bicolour)*, maize (*Zea mays*) and cowpea (*Vigna unguiculata*) in Gwoza LGA and maize, sorghum, cowpea, peanut (*Arachis hypogaea*), rice (*Oryza sativa*) and soybean (*Glycine max*) in Biu LGA. Many of the farmers also rear cattle, sheep, goats and chicken on a small scale.

Data description

The data for this study were collected mainly through household surveys using questionnaire-based interviews. The surveys were conducted in eight villages that were randomly selected from the two AEZs (Fig. 1). No information was available on the exact number of households in each village so estimates were made based on the sizes of the villages, and the number of sampled households per village was proportionate to the estimated number of households in each village. About 20–30 households were selected from each village, and this represents about 12 % of the estimated number of households per village. One hundred households were selected and interviewed in each of the AEZs, giving a total of 200 surveyed households.

Due to limited time for the fieldwork and the inability of the researcher to speak Hausa, the most widely used language in the study area, an interpreter and one field enumerator were recruited in each LGA so as to assist in the data collection, especially the household survey. They were recruited with assistance from researchers at the University of Maiduguri, based on their experience in conducting household surveys in the study area and their ability to communicate well in the Hausa language. A day was spent to give them thorough training on the questions to be asked during the surveys. In all, 100 questionnaires were administered by the author with the assistance of an interpreter and another 100 by the enumerators. Questionnaires completed each day by the enumerators were carefully checked for accuracy by the author so as to clarify any ambiguities. The questionnaires were administered through face-to-face interviews with respondents who were mainly household heads.

The questionnaire was used to collect information on farmers' knowledge and perception about changes in temperature and rainfall, measures adopted to adapt and the difficulties faced in adapting to the perceived changes. The household survey was followed by two focus group discussions (FGDs) in each AEZ. The FGDs were used to obtain historical climatic events in the area. Eight to ten people comprising of village elders, young and older farmers were involved in each FGD. Data obtained from the questionnaires and FGDs were analysed using descriptive statistics and content analysis, respectively, and the results were presented in the form of tables and charts. The Mann–Whitney *U* test was employed to assess the statistical significance of the adaptation methods between AEZs.

The sampled farmers represent smallholders with limited access to credit facilities (Table 1). The average farm size is 3 hectares (ha), and 90 % of the households cultivate less than 5 ha which is an indication of smallholder farming in Nigeria (Olayide 1980). Illiteracy in the area is high with about 52 % of the household heads having no formal education. The population is almost entirely Muslim with large household size comprising of about 10 people per household. The farming population is relatively young adults. Most of the household heads are male, and only one female-headed household was part of the survey. Despite depending heavily on agriculture for their livelihoods, most of the households have members who are involved in non-farm jobs especially during the long dry season. The non-farm jobs are mainly self-employed activities. There are only a handful of civil servants in the sampled villages. Only about 56 % of the surveyed households have access to agricultural extension services. Very few farmers (13 %) obtain credit for farming. This is attributed to the unavailability of credit providers in the area, high interest rate, lack of collateral and the difficulty in accessing loans due to lack of education. Forty-two per cent of the farmers are members of farmers groups or associations in the area, but only a few of them are active members of these associations.

Results and discussion

Survey results are presented here in 5 categories. We first present results about major climatic events in the survey areas and then farmers' perceptions of climate change and its causes. Later, the adaptation strategies used by farmers and barriers to their implementations are discussed.

Significant climatic events

Past experiences of climate change can provide insights into the possible events that might occur in the future. A timeline of significant climatic events that took place in the two AEZs was, therefore, carried out during FGDs. The historical climatic events were based on memory recall of the farmers. The results for SS and NGS AEZs are presented in Tables 2 and 3, respectively.

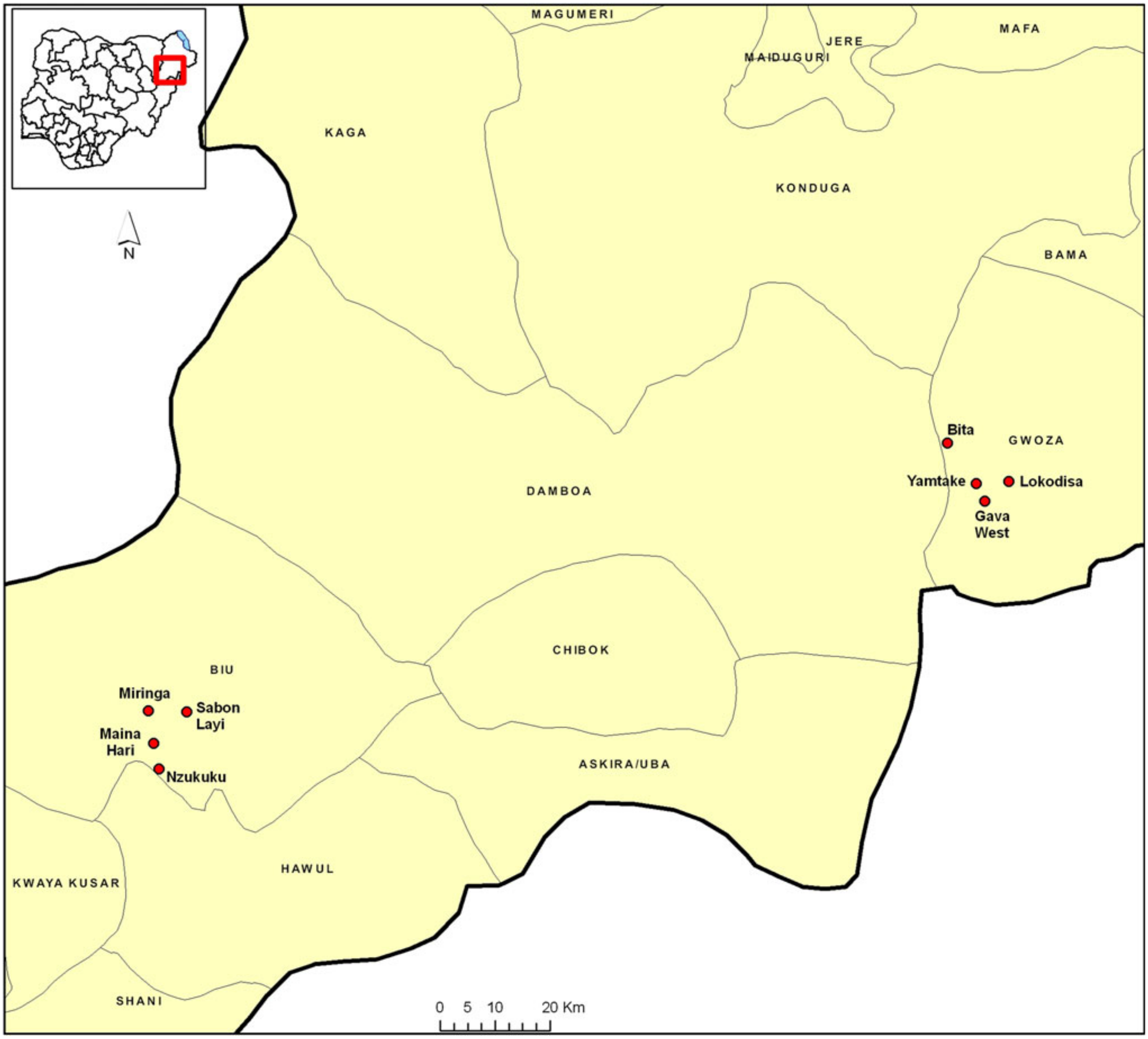

Fig. 1 Map showing the location of the selected villages within the study area. *Source:* IITA GIS-unit, Ibadan, Nigeria

Table 2 shows that drought is a major problem faced by farmers in SS. The region suffered from severe droughts in the 1970 and 1980s which resulted in severe famine and loss of human and animal life. The droughts of 1973, 1983 and 1987 coincided with the general drought in Africa and other parts of the world which was attributed to the result of El Niño's effect (Akeh et al. 2000). The 1973 drought alone is estimated to have caused the death of about 300,000 animals, and farm yields dropped by about 60 per cent resulting in famine in northern Nigeria (Okorie et al. 2010). Other significant events before the past decade were dust storm and flood. Due to proximity to desert, SS AEZ suffered from dust storms which caused damages to crops, thereby reducing yield. Very few incidents of flood occurred in SS, but a heavy one in 1985 led to an outbreak of cholera and lodging of crops. With the cholera outbreak, the farmers spent most of their time tending to the sick or themselves with less time to work on their farms which resulted in low productivity. From the late 1990s onwards, farmers are mainly suffering from the impacts of erratic rainfall. There is uncertainty in the timing, amount and pattern of rainfall. The farmers are no longer able to predict the rain and know precisely when to plant their crops. Also farmers who plant/sow early in the season often lose their seeds and have to replant due to sudden dry spell after the early rains. It was also found that the short period of rainfall was often characterised by torrential downpours, especially in August, leading to heavy flooding.

Table 1 Descriptive statistics of sampled households

Variable	Total (n = 200)		SS (n = 100)		NGS (n = 100)	
	Mean	SD	Mean	SD	Mean	SD[a]
Age of household head (years)	38.18	10.73	38.11	9.48	38.25	11.9
Education of household head (years)	4.77	5.6	4.32	5.39	5.21	5.79
Farming experience of household head (years)	18.9	10.16	20.03	9.31	17.77	10.88
Household size (members)	9.58	5.61	10.2	5.68	8.96	5.51
Distance to closest market (km)	19.12	12.21	26.27	12.25	11.97	6.81
Farm size (hectares)	2.95	7.45	4.21	10.29	1.69	1.54
Extension contacts (times per year)	3.55	5.78	4.36	4.68	2.74	6.63
Non-farm income (% of households)	65.5		61		70	
Ownership of livestock (% of households)	86		84		88	
Access to credit for farming (% of households)	13		12		14	
Group membership (% of households)	42		49		35	

Source: Compiled by authors from survey data

[a] *SD* standard deviation

Table 2 Past significant climatic events in Sudan savanna

Years	Event	Effects on farming
Before 1980		
1966	Severe drought	Unable to cultivate crops. Resulted in famine
1973–1974	Severe drought	Less than 250 mm of annual rainfall led to famine
1978–1979	Severe drought	No farming during the cropping season: food crisis
1980–2000		
1983–1984	Severe drought	It rained only 8 times. No farming which resulted in loss of lives of humans and livestock
1984–1985	Dust storm	Buried young plants
1985	Flood	Cholera outbreak and lodging of crops
1987	Severe heat waves and drought	Scorching of crops
1988	Heavy storm	Broke trees and crops and buried crops with sand
1993–1994	Flood	Lodging of crops and yield loss
1994–1998	Delayed rainfall and intermittent drought	Rain often stopped after planting, resulting in insect invasion and destroying of crops
1998	High temperature accompanied by drought	Wilting of crops which resulted in low yield
2000–2010		
2001	Severe heat	Few rains. Severe heat after the rains led to wilting of crops
2007	Delayed rainfall	Late rainfall but very intensive in August resulting in flood which washed away crops
2008	Rainfall ended early	Abrupt end of rain in September caused crop failures
2009	Erratic rainfall and decreased yield	Late and erratic rainfall led to late planting
2010	Delayed rainfall	Late planting

Source: Compiled by authors from survey data

Table 3 presents the result for NGS. It shows that prior to 2000, there were more incidents of drought in SS than in NGS. The droughts in NGS were mainly the global droughts of 1983 and 1987. These drought incidents resulted in a decrease in crop production and even total crop failure in some cases. Livestock farmers also suffered from inadequate pasture and water for their animals.

One major problem in NGS is flood, which is due to intensive rains during the short rainy season. The previous floods led to relocation of households, damaging of crops and loss of lives. Heavy wind, which often resulted in lodging of cereals, was also a significant phenomenon in the area. A major problem in NGS which was even observed during the period of data collection was armyworm

Table 3 Past significant climatic events in northern Guinea savanna

Years	Climatic event	Effects on farming
Before 1980		
1957	Intense heat and very strong wind	Difficult working on the farm. Wind destroyed sorghum at the stage of pollen formation resulting in empty cobs
1959	Intensive rains and flood	Crops were submerged and destroyed
1979	Wind	Lodging of maize plants
1980–2000		
1982	Flood	Excessive rainfall destroyed crops
1983–1984	Drought	Most cereals could not produce grains leading to food crisis
1986	Heavy flood	Migrated to other part of the village. Farm products stored in homes were destroyed
1987	Drought	Rain stopped at the stage of maize cobbing leading to low yield
1993	Drought late in the season	Wilting of young cereals
1999	Erratic rainfall	Late maturing varieties of cereals produced low yields
2000–2010		
2003	Dry spell	Grasshopper invasion. Caused damages to green leaves and destroyed panicles of sorghum
2004–2005	Erratic rain and heat	Armyworm infestation as a result of lack of rain. The pests destroyed seedlings. Intense heat led to death of animals
2006	Heavy rain at the end of the season	Excessive rainfall during harvesting period destroyed heaped harvested crops. There was aflatoxin infestation
2007	Delay in rainfall, heavy flood and strong wind	Late rainfall and heavy flood in August caused severe damages to crops. Lodging of tall varieties of cereals
2009	Erratic rainfall and storm	Wilting of young plants due to abrupt cessation of rain after germination. Maize started tarselling at a young stage and produced very low yield
2010	Delayed rainfall	Planting was delayed. Armyworm invasion of young plants

Source: Compiled by authors from survey data

invasions. A break or delay in rainfall often led to the emergence of these pests. The feeding habits of the armyworms caused severe damages to plants. Similar to the situation in SS, there were problems of unpredictable and erratic rainfall in NGS over the past decade which affected the time of planting. The farmers complained that because of the rainfall irregularities, seeds sown often failed to germinate, thereby requiring replanting. The erratic nature of rainfall also caused scorching and wilting of plant leaves and consequently resulted in low yields.

Farmers' perception of climate change

The farmers were initially asked whether they have heard or read about climate change in order to ascertain their level of awareness. This was followed by asking them whether they have observed any changes in temperature and rainfall in the area over the past 20 years.

Only about half of the farmers interviewed (51 %) have heard about climate change, mainly through discussions in the media. Other sources include contacts with agricultural extension officers and researchers. Few young farmers learnt about it in schools while studying geography. The farmers' knowledge of climate change through the media was mainly from weather bulletins and two radio programmes: *In kidi ya chanza* and *Noma Tushen Arziki* which were broadcasted in Hausa language. *In kidi ya chanza* is a radio drama series sponsored by International Development Research Center (IDRC) which aims at educating smallholder farmers in northern Nigeria on the impacts of climate change and the needed adaptation measures. Most of the farmers in the surveyed villages were, however, not aware of this programme. *Noma Tushen Arziki* is a weekly agricultural programme which educates farmers on modern farming techniques. Across AEZs, more farmers were aware of climate change in NGS (55 %) than in SS (46 %), and this is partly due to the fact that farmers in NGS were more educated than those in SS.

The result of farmers' perception of changes in temperature is presented in Table 4. It shows that a large share of the farmers' interviewed (92 %) perceived changes in temperature over the past 20 years. Over three quarters of the households surveyed have noticed an increase in temperature. Very few farmers indicated a decrease in temperature (8 %) and no changes in temperature (6.5 %). The farmers opined that they used to experience long periods of

Table 4 Perception of changes in temperature (%)

	Increased	Decreased	No change	Don't know
Total sample (n = 200)	84	8	6.5	1.5
SS (n = 100)	94	1	4	1
NGS (n = 100)	74	15	9	2

Source: Compiled by authors from survey data

harmattan with very low temperature and cold weather, but the length of the harmattan season has been decreasing over the past decade. This means that there is a reduction in the number of cold days and an increase in the number of extreme hot days in the study area. This also implies that farmers' indication of an increase in temperature is mainly due to extreme temperature events and a decrease in the number of cold days. Comparing the results based on AEZs shows the same pattern of increase in temperature. However, more households in SS perceived an increase in temperature than in NGS with almost all sampled households (94 %) in SS arguing that the temperature has increased over the last 20 years. The sampled villages in NGS are on high attitudes and hence experience very low temperatures during certain periods of the year.

The result for the long-term changes in average rainfall shows that the farmers generally agreed on changes in rainfall pattern in the region. About 24 % have noticed a decrease in the volume of rainfall or a shorter rainy season, while 12 % have observed that the timing of rainfall fluctuates from year to year. Majority (60 %) of the respondents have noticed both a decrease in rainfall and changes in the timing of the rains. Only a meagre (3 %) of the farmers reported an increase or no changes in rainfall as shown in Table 5. The result across AEZs also follows the same pattern. The farmers noted that there is more erratic rainfall with seasonal changes in the pattern and unpredictable starts and stops. The farmers asserted that they constantly commenced planting/sowing in May, but in past few years, they are unable to determine when to start their farming season because of the unpredictable rains. They also reported that over the past 5 years, rainfall in the area has not been uniform with the possibility of rains in only one part of a village. Some farmers in NGS argued that length of growing season has decreased, but there is an increase in the volume of rain resulting in floods.

The results from the questionnaires on the changes in climate in the region generally corroborate those of the FGDs. These results are also in line with studies in other parts of Africa (Mertz et al. 2007; Bryan et al. 2009; Deressa et al. 2011; Kemausuor et al. 2011; Fosu-Mensah et al. 2012) which show that most farmers perceive reduced rainfall and increasing temperatures.

Perceived causes of climate change

Nearly all the farmers interviewed (99 %) had noticed at least a change in long-term temperature or rainfall in the area. They were subsequently asked to indicate what they perceive as causes of the changes in temperature and rainfall. Their responses are illustrated in Fig. 2. Thirty-nine per cent believed that God is responsible for the changing climate. Some farmers were very surprised of such a question because they expected everybody to know it is the work of God. They avowed that the climatic changes are punishment from God because of the sins of the world as well as disobedience and unfaithfulness to Him. A 29-year-old Christian farmer in Yamtake village asserted that:

> "The Bible says in Luke 21: 25–28 that when the world is coming to an end there will be signs so the changing rainfall pattern and increased incidence of droughts are all indications that the world is coming to an end".

About 20 % mentioned deforestation as the cause of climate change. They stressed that they previously enjoyed adequate rainfall, but the cutting down of trees for firewood and fodder and the expansion of cultivated areas are contributing to the erratic rainfall in the area. Eleven per cent of the farmers perceived that the changes in climate incidents in the area were natural processes but were not aware that their land degradation activities are also contributing factors. Despite noticing changes in climate variables in the area, as much as 19 % had no knowledge of what was responsible for the changes. Few farmers perceived that desert encroachment as a result of overgrazing and poor soil management, burning of bushes for hunting of animals or clearing of bushes for farming, and pollution from the wide use of motorcycles in the area, was enhancing the changes in climate. Similar observation was reported by Tschakert (2007) who identified bush burning, agricultural overexploitation and deforestation as perceived causes of climate change by farmers in the Sahel of West Africa.

From a strict climate change science point of view[1], desert encroachment, pollution, bush burning, natural phenomenon and deforestation, as listed by the farmers, can be regarded as part of the causes of the changing climate. This implies that about 58 % of the respondents were not aware of the causes of climate change. The high illiteracy level of the farmers is a major contributing factor for the low level of knowledge on the causes of climate change (Tambo 2010). Furthermore, it was discovered that

[1] Climate change may be due to natural processes or external forcing or to persistent anthropogenic changes in the composition of the atmosphere or in land use (IPCC 2001).

Table 5 Perception of changes in rainfall (%)

	Total sample (n = 200)	SS (n = 100)	NGS (n = 100)
Increased	1	1	1
Decreased	23.5	22	25
Changes in the timing of rains (erratic/earlier/later)	12	23	1
Decreased and changes in the timing of rains	60	52	68
Increased and changes in the timing of rains	1	0	2
No change	2	2	2
Don't know	0.5	0	1

Source: Compiled by authors from survey data

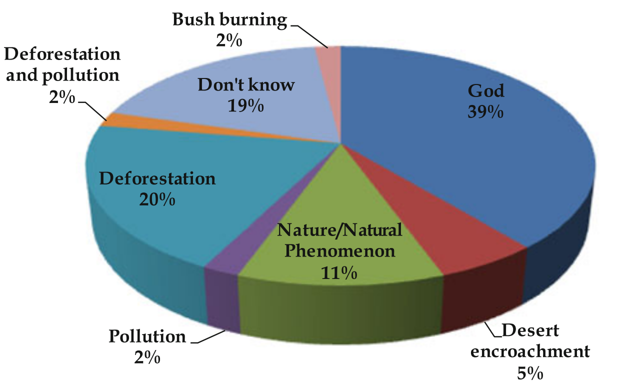

Fig. 2 Perceived causes of climate change (n = 198). *Source:* Compiled by authors from survey data

programmes that educate farmers on climate change in the region focus mainly on adaptation issues without discussing the causal activities and how farmers can contribute to mitigate the impacts.

Farmers' adaptation to climate change

Farmers who responded that they have observed changes in climate over the past 20 years were asked to indicate adjustments they have made in their farming activities in response to the perceived changes in temperature and rainfall.

Table 6 presents the adaptation to changes in temperature. It shows that despite many farmers perceiving changes in temperature, about 46 % did not undertake any adaptation measures. This can be attributed to the small changes in temperature which have little effects on farming activities in the study area compared to changes in rainfall. The adaptation measures to changes in temperature indicated by 54 % of the farmers were mainly adaptation to temperature extremes. The main adaptation option was the planting of trees to provide natural shades for livestock or sheltering of animals. Some farmers also planted trees in and around their farms to shade their crops from harsh temperature conditions. The trees (mainly acacia, eucalyptus and mango) also served as windbreaks. About 11 % of the farmers shifted the dates of planting their crops in order to avoid hot weather, which is detrimental to sensitive growth stage such as flowering. With increase in temperature expected to exacerbate the severity of drought, 6.8 % of the farmers used crop varieties that can tolerate or escape drought. Other adaptation measures include planting different varieties of the same crop, mixed cropping, water conservation practices and changing from farming to non-farming activities when it is difficult to work on the farm due to intense heat. Some of the farmers switched to crops such as cowpea that can tolerate hot weather conditions.

Contrary to the result from adaptation to temperature, most of the respondents took up measures in order to adapt to the decreasing volume or changes in the timing of rainfall as shown in Table 7. Only 15.2 % of the 184 farmers who perceived changes in rainfall did not take up any form of adaptation. Generally, the adaptations methods used by the farmers are directly linked to the perceived changes in rainfall, and this corroborates arguments that the perceptions of farmers influence the type of adaptation methods they adopt (Maddison 2006; Bryan et al. 2009; Deressa et al. 2011).

The main adaptation methods were the use of drought tolerant or early maturing varieties (52 %) and shift in dates of planting (46.7 %). The high use of these two adaptation measures can be attributed to two projects in the study area: Drought Tolerant Maize for Africa (DTMA) and Promoting Sustainable Agriculture in Borno State (PROSAB). These projects identified drought as one of the main problems of farming in the area and assisted farmers with early maturing and drought tolerant varieties of some crops, particularly maize (Tambo and Abdoulaye 2012). Due to the availability of drought tolerant and early maturing varieties, most of the farmers are able to delay the time of planting until there is continuous rainfall. Some of the farmers were also cautious of not losing their entire yield, so engaged in mixed cropping or used combinations of different varieties of the same crop as methods of adaptation. Some farmers reported that they used to cultivate millet, sorghum and cotton a few years back, but due

Table 6 Adaptation to changes in temperature (%)

Adaptation measures	Total[b] ($n = 184$)	SS ($n = 95$)	NGS ($n = 89$)	z
Mixed cropping	2.6	3.1	2.1	−0.452
Drought tolerant/early maturing varieties	6.8	7.4	6.2	−0.286
Different crop varieties	9.9	18.8	1	−4.089[a]
Changing planting dates	10.5	6.4	14.4	−1.881
Planting of trees/shading for animals	21.5	22.3	20.6	−0.175
Water conservation	2	2.1	2	−1.000
Switching of crops	1.8	0	3.6	−1.741
Shift from farming to non-farm work	3.7	6.4	1	−1.919[a]
No adaptation	46.1	37.6	54.6	−2.558[a]

Source: Compiled by authors from survey data

[a] Differs significantly between the two agro-ecological zones (0.05 level of significance)

[b] Multiple responses recorded

Table 7 Adaptation to changes in rainfall (%)

Adaptation measures	Total[a] ($n = 195$)	SS ($n = 98$)	NGS ($n = 97$)	z
Mixed cropping	8.6	6.1	11.1	−1.265
Drought tolerant/early maturing varieties	52	48.5	55.6	−0.988
Different varieties on the same plot	13.6	13.1	14.1	−0.206
Changing planting dates	46.5	46.5	46.5	0.000
Soil conservation techniques	1.5	0	3	−1.741
Water harvesting/irrigation	3.5	5	2	−0.580
Switching of crops	9.6	8.1	11.1	−0.722
Off-farm job	1.5	1	2	−0.580
Other	1.5	2.1	1	−0.580
No adaptation	15.2	14.1	16.2	−0.395

Source: Compiled by authors from survey data

[a] Multiple responses recorded

to the reduction in rainy days, they shifted to crops such as maize, cowpea and vegetables because they have shorter growing periods. Another adaptation option reported was the building of water harvesting systems by digging of wells to get water for irrigation. Few farmers indicated the practicing of soil conservation as an adaptation option. This involved building of terraces with stones across slopes to protect the soil against erosion or by covering the soil with crop residue to conserve moisture and reduce erosion. Few of the farmers were increasing their involvement in off-farm activities due to the risk of climate variability and change. 'Other' in the table refers to adaptation options indicated by only one farmer. It includes changing from crops to livestock, changing from livestock to crops and dry planting which refers to sowing seeds of millet in the dry season for it to germinate with the first rain.

The Mann–Whitney U test results indicate that there is no statistically significant difference between adaptation methods employed by households in response to changes in rainfall in the two savanna AEZs (Table 7: z-scores). Regarding changes in temperature, however, the test results show that households in SS are more likely to adapt than those in NGS (Table 6: no adaptation, $z = -2.558$, $\rho = 0.011$). This is plausible as SS is hotter and more households in this AEZ perceived an increase in temperature than in NGS. The use of different crop varieties and shifting from farming to non-farm work as adaptation measures to temperature are also significantly different between the two AEZs. This also confirms findings that adaptation practices of farmers depend on site-specific socio-economic and biophysical conditions (Deressa et al. 2009; Hisali et al. 2011; Below et al. 2012).

The adaptation measures adopted by households in the Nigerian savanna are considerably similar to those reported by other studies on climate change adaptation in African agriculture (e.g. Deressa et al. 2009; Bryan et al. 2009; Below et al. 2012; Fosu-Mensah et al. 2012) In line with these studies, adaptation to climate change in the Nigerian savanna region can be categorised into six main types. These are

1. *Crop and variety diversification:* It involves switching to varieties better suited to the new climate such as use of drought/heat tolerant and varieties that have shorter growing period. It also includes cultivating crops better suited to the new climate and growing different varieties of crops on the same field to serve as an insurance against complete failure as various crops and varieties respond differently to climatic hazards.
2. *Changing dates of planting:* Given that majority of the farmers perceived changes in the timing of rains: they

have adjusted their cropping sequence to better suit the shifts in growing season by delaying or undertaking early planting/sowing.

3. *Conservation practices:* The farmers have adopted soil and water conservation practices such as terracing and stubble mulching in order to improve soil fertility, prevent erosion, conserve soil moisture and cool the soil.
4. *Irrigation:* With the reduction in rainfall, farmers have built water harvesting schemes such as traditional hand dug or shallow open wells for the abstraction of groundwater for irrigation. Others were involved in wetland (*Fadama*) farming to make use of the available water or use of watering cans to fetch water from streams for irrigation, which is very laborious.
5. *Off-farm income diversification:* It involves changing from farming to non-farm activities or increased involvement in off-farm activities, which are less sensitive to climate change. It also includes exodus of household members to cities in search of alternate means of generating income.
6. *Afforestation:* This involves planting of trees to protect plants from heat and to provide natural shades for livestock. The trees also protect crops and farm houses against severe windstorms.

A look at the adaptation methods used by the farmers suggests that measures that are relatively inexpensive such as changing planting dates and diversifying crops were mostly used, while those that are costly or require more capital such as irrigation were used by very few farmers. This suggests that the choice of adaptation option is influenced by farmers' financial capabilities. Also, most of the farmers' adaptation options to the changing climate in the area were autonomous (which may also be classified as coping strategies) as opposed to planned adaptation.[2] Some of these adaptation options resulted from decisions they were already taken annually even before they noticed significant changes in climate. These autonomous adaptations are not enough to fully adapt to the current and future impacts of climate change. The main planned intervention available was the development and deployment of drought tolerant varieties which were used by about half of the respondents. This planned adaptation is, however, not sufficient because the drought tolerant varieties or early maturing varieties were only available for few of the cultivated crops in the region. Some of the farmers have stopped cultivating traditional and late maturing crops such as millet and sorghum because of insufficient rain. Other planned adaptations are needed to complement the current adaptation methods being used by the farmers.

One of such important planned intervention but remains largely untapped is irrigation. Only about 4 % of the surveyed farmers used some form of irrigation despite the fact that it is one of the most appropriate adaptation methods and the potential exists in the study area. Some of the farmers have lands with underground water reserves and low-lying swamps called *Fadama*. In Borno state where the study was conducted, there are about 489,300 hectares of *Fadama* lands. Also, some of the farmers selected from NGS have access to surface water bodies. These are not being harnessed by the farmers to support farming activities because of their inability to afford irrigation infrastructures. Installation of wells and water pumps such as treadle pumps is considered to be ideal for rural poor communities because it is affordable and manageable, but the cost is beyond the reach of most of the surveyed farmers. With access to irrigation facilities, the farmers could engage in multiple cropping by extending cropping to dry season and also cultivate high-yielding hybrid crops and even long-duration crops. Provision of irrigation assistance to farmers will, therefore, complement their ability to cope with climate change and at the same time increase productivity.

Agricultural insurance, particularly index-based weather insurance, is increasingly recognised as an important measure in assisting farmers to manage risks associated with climate change in developing countries (Hazell et al. 2010). In an effort to help farmers in coping with natural hazards, the Nigerian Agricultural Insurance Corporation (NAIC) has been operating an agricultural insurance scheme since 1987. This insurance is, however, the traditional type which is based on crop and livestock damage assessment. The insurance services are linked to agricultural credits and are mandatory for all beneficiaries of agricultural credit facilities, but self-financed farmers are also covered under the scheme. Surprisingly, none of the surveyed farmers had insured his/her farm against any climatic hazards, and most of them were not even aware of the existence of an agricultural insurance scheme in the country. There is, therefore, the need for awareness creation and exploration of opportunities for design and implementation of pilot index-based weather insurance scheme to support smallholder farmers in the region.

As shown in Tables 2 and 3, one problem facing the farmers is flood, which is intensifying because the short duration of rain is characterised by heavy downpours, and this causes havoc on farms. For instance, some maize seed producers completely lost their farms as a result of floods

[2] Autonomous adaptation refers to "adaptation that does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems", and planned adaptation is considered to be "adaptation that is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain or achieve a desired state" (IPCC 2007).

in 2007. The listed adaptation measures by the farmers, however, suggest that despite experiencing floods, they mainly adapt to decrease and variability in rainfall with little or no adaptation to flood. This is in line with the finding of Tschakert (2007), who reported that farmers lack successful adaptation strategies to high rainfall in the Sahel. Flood management practices and early warning systems will be helpful in reducing the effects of flood after heavy downpours.

Overall, only 15 % of the farmers interviewed reported 'no adaptation' to either changes in rainfall or temperature. Comparing this to other studies on climate change adaptation in Africa indicates that only few farmers were not able to adapt, which is an encouraging result. For instance, Bryan et al. (2009) found 37 and 62 % non-adapters to climate change in Ethiopia and South Africa, respectively. In Nigeria, Apata et al. (2009) obtained 37 % in south-west Nigeria, while Onyeneke and Madukwe (2010) identified 43 % non-adapters in south-eastern part of the country. Fosu-Mensah et al. (2012) also obtained 56 % non-adapters in the sub-humid zone of Ghana. The high number of adapters in this study can be attributed to the work of projects in the study area since most of the farmers were using the technologies promoted by these projects. This implies that there will be an increased adaptation to climate change by farmers if there are planned interventions by government and other institutions.

Perceived barriers to adaptation

The 30 farmers that did not adjust their farming practices in response to the perceived changes in climate were asked about the main constraints/difficulties which hindered their adaptation. It was found that adaptation to climate change in the region is stymied by two main factors: lack of information or knowledge on climate change and appropriate measures of adaptation (56.6 %) and lack of money or credit (40 %). Similar result was obtained in south-west Nigeria by Sofoluwe et al. (2011) and in Ethiopia and in South Africa by Bryan et al. (2009). Although the farmers claimed to have noticed changes in temperature and rainfall, their capacity to adapt was limited by lack of information on changes in climate such as early warnings on possible climate hazards and the appropriate adaptations. They were not aware of the promotion of agricultural technologies such as drought tolerant crops, which can assist them to adapt. Some of the farmers were, however, aware of possible adaptation measures but were not making use of them because of the cost of these technologies. The surveyed farmers were rural small-scale poor farmers with limited access to credit facilities. Only 13 % of the surveyed farmers had access to credit, which was mainly obtained from informal sources such as relatives and friends. Lack or shortage of farm inputs especially seeds was reported by about 13 % as constraint to adaptation. Some of the farmers do not get resources such as drought tolerant or fast maturing seeds they might need to adapt because of the limited supply or non-availability.

Conclusions

This paper analysed smallholder farmers' perceptions and adaptations to climate change in two savanna AEZs in Nigeria. It also examined past climatic events based on farmers' memory of historical events. The results show that the main climatic events in the area are drought in SS and flood, wind and dust storm in NGS, but the past few years have been characterised by unpredictable and erratic rains in both AEZs. Overall, the farmers perceived drier and hotter climate in the two AEZs. Most of the farmers have adapted to the changes noticed, and there are no profound differences in the adaptation measures employed by farmers in the two AEZs. However, farmers located in SS are more likely to adapt to changes in temperature than those in NGS. The farmers' adaptation options can be categorised into: diversification of crops and crop varieties, changing the time of planting/sowing, irrigation, afforestation, soil and water conservation practices and off-farm income diversification. The most common adaptation option across the two AEZs is the use of drought tolerant and early maturing varieties.

This study shows that smallholder farmers continuously adapt to climate change using autonomous adaptation strategies, but planned adaptation measures that fit into their local context are very useful and likely to be adopted. The results of the study imply that in the Nigerian savanna, development and promotion of drought tolerant and early maturing varieties are very promising in helping smallholder farmers to adapt to climate change; hence, more breeding programmes and supports are needed to produce and disseminate more of such varieties. To address the challenges of adaptation, greater efforts to raise awareness on climate change and appropriate adaptation options are necessary. Improvement in access to agricultural inputs could help these farmers in their adaptation strategy of using improved varieties of crops that are drought tolerant and/or escaping. Also, general improvement in farmers' access to financing including credit services could help them to invest more in adaptation technologies. Furthermore, given the reported general trend of decrease in rainfall amounts in the region, concerted efforts by both public and private sectors are also needed to assess and harness the irrigation potential in the area. More research on the prospect of index-based weather insurance in potentially supporting climate change adaptation in smallholder agriculture in the study region is also needed. Finally, further research is needed on adaptation to flood risk as the savanna region is experiencing both droughts and floods.

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