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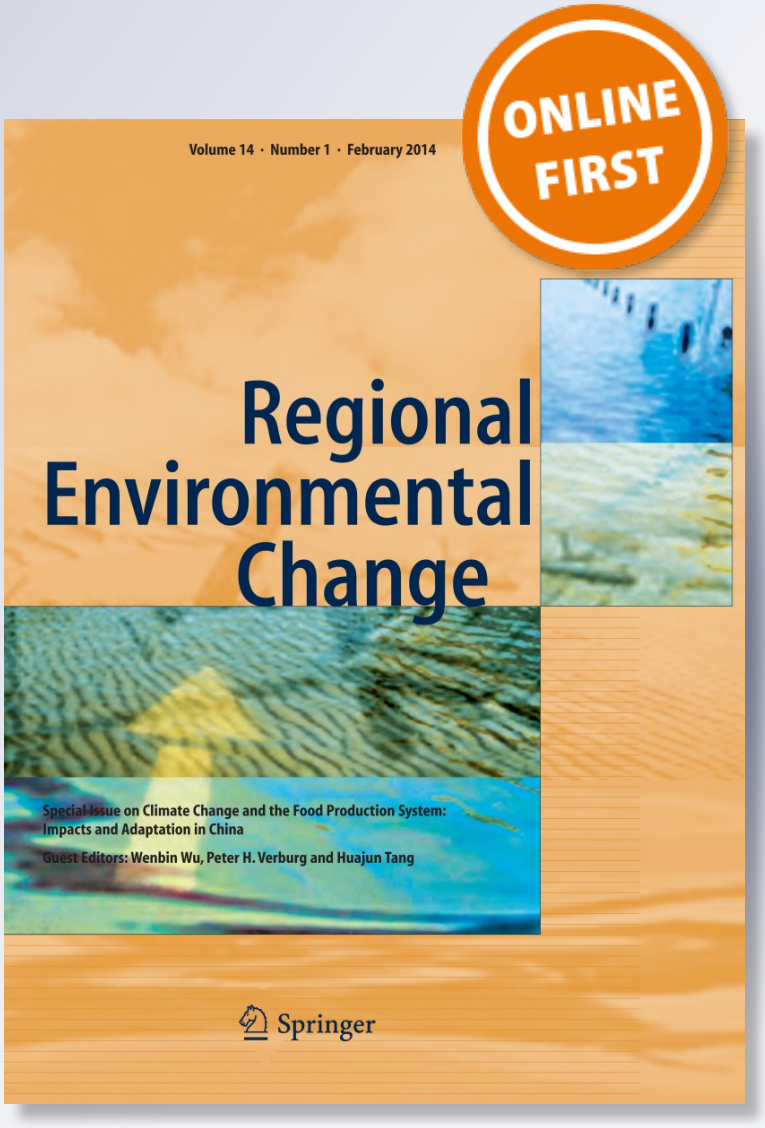

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ORIGINAL ARTICLE

Livelihood adaptations to climate variability: insights from farming households in Ghana

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Abstract Climate variability poses a significant threat to many sectors of Sub-Saharan Africa's economy. Agriculture is one of the most climate sensitive sectors because of its dependence on rain-fed cultivation. This paper identifies the main adaptation strategies used by farming households in the Sudan savannah and forest-savannah transitional agro-ecological zones of Ghana, in order to reduce the adverse impacts of climate variability on their livelihood activities. It combines questionnaire surveys, key informant interviews and a range of participatory methods. Results show that households employ a range of on- and off-farm adaptation strategies including changing the timing of planting, planting early maturing varieties, diversification of crops, support from family and friends, and changing their diets to manage climate variability. Results reveal that most households use adaptation strategies linked to livelihood diversification to adapt to the increased climate variability seen in recent decades. Most households now engage in multiple non-arable farming livelihood activities in an attempt to avoid destitution because of crop failure linked to climate variability (particularly drought). The findings suggest that policy makers need to formulate more targeted climate adaptation policies and programmes that are linked to enhancing livelihood diversification, as well as establishing communication routes for farming communities to better share their knowledge on successful local climate adaptation strategies.

Keywords Drought · Coping · Climate change · Sub-Saharan Africa · Agriculture · Rural livelihoods

Introduction

Although Africa is a minor player in terms of total global greenhouse gas emissions, contributing <3 % of the world's total (IPCC 2007), the continent remains vulnerable to climate change and variability (Lobell et al. 2011). This vulnerability has been attributed to low adaptive capacity and over-dependence on rain-fed cultivation (Boko et al. 2007). Within Africa, Sub-Saharan Africa (henceforth, 'SSA') is the most vulnerable to the adverse impacts of climate change and variability (Boko et al. 2007). Although climate predictions are not clear on future rainfall patterns, studies suggest that there will be increased incidences of extreme events coupled with a shortening of the rainy season in many parts of West Africa (IPCC 2013; Sarr 2012; Van de Giesen et al. 2010). For most of West Africa, Paeth and Hense (2004) observed reduced rainfall in the second half of the twentieth century with some recovery during the 1990s. In terms of future projections, Boko et al. (2007) note that temperature is expected to increase across much of Africa throughout this century, with rises of between +2.0 and +4.5 °C projected for SSA by 2100 (Müller 2009). Such projections will not, however, be uniform across the region. Yields of major staples including maize, groundnut, millet, sorghum and cassava have been projected to decrease by 7–27 % in parts of SSA by 2050 due to climate change and variability (Schlenker

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and Lobell 2010). This causes knock-on implications for household wellbeing in natural resource dependent communities.

Climate variability poses one of the greatest threats to the Ghanaian economy, with agriculture being the most climate sensitive sector because of its dependence on rain-fed cultivation. The Intergovernmental Panel on Climate Change (IPCC) model ensemble has projected that a reduction of 80 mm in monthly rainfall is possible in northern parts of the country, particularly during the June–August farming season (Christensen et al. 2007). This will be exacerbated by high inter-annual rainfall variability, characterised by a reduction in the number of rainy days (Christensen et al. 2007). Ghana experienced severe droughts in 1968–1973, 1982–1984, 1990–1992 with the drought of 1983/1984 being the most significant. It caused huge hydrological imbalances that affected crop productivity throughout the country (EPA 2003) that led to extensive national food insecurity (Ofori-Sarpong 1986).

Intra-annual rainfall variability and increased temperatures that characterise the climate in the region are also situated within a myriad of other political, economic, social and environmental challenges including underdevelopment since colonial times, high rates of poverty, educational gaps, land degradation and agricultural policies that restricted agriculture development. This makes the need to explore the adaptation strategies employed by farming households to cope with the adverse impacts of climate variability even more imperative, in order to identify appropriate policy interventions for reducing livelihood vulnerability.

Adaptation is not new to farming communities in SSA. However, climate variability (particularly drought) and its associated impacts add a new dimension to this challenge (Burton 2009). In the context of climate change research, definitions of adaptation abound. This paper adopts Smith et al. (2000) definition of adaptation to climate variability as the process by which stakeholders make adjustments aimed at reducing the actual and expected adverse effects of climate on their livelihoods. This conceptualisation allows a better understanding of how households and communities use their adaptive capacities and various assets in reducing adverse impacts on food systems and livelihoods. This will help in assessing how such households and communities can be assisted to withstand climatic stresses.

The terms 'coping strategies' and 'adaptation strategies' are widely used in the climate literature and are mostly distinguished with reference to timescale. Adaptation strategies are linked to long-term planning strategies whilst coping strategies refer mainly to short-term actions taken to counteract the immediate negative impacts of climate variability including drought (Yohe and Tol 2002; Eriksen et al. 2005). Coping and adaptation can also be distinguished in terms of the institutional aspects that need to be considered. Coping strategies are taken within the existing institutional structures of the system under consideration, whilst adaptation strategies may demand some transformation in terms of the structures' composition and functioning (Eriksen et al. 2005). Adaptation strategies are therefore more strategic in action and forward-looking, whilst coping strategies may be transformed into adaptive strategies through institutional support (Berman et al. 2012).

Even though agriculture is one of the most widely studied sectors with respect to climate impacts, until recently, research efforts have neglected the possible role of adaptation by farmers (Schipper and Burton 2009). Prior to 1992, the term adaptation was considered a taboo subject and rarely used in relation to global climate policy (Schipper and Burton 2009; Pielke et al. 2007). Despite the recent significance attached to adaptation, studies exploring the adaptation options implemented by farming households in SSA are only gradually growing in number (e.g. Tachie-Obeng et al. 2012; Fasona et al. 2012). To contribute to this growing body of the literature and to guide the direction of new policy options, the purpose of this paper is to identify the main adaptation strategies used by agricultural households in the Sudan savannah and the forest-savannah transitional agro-ecological zones of northern and central Ghana, to reduce the negative impacts of climate variability on their core livelihood activities. Findings from this study will inform policy development on climate change adaptation in Ghana and more widely in SSA.

Research design and methods

Selection and description of study sites

Previous studies by Antwi-Agyei et al. (2012) identified the Ejura Sekyedumase district of Ashanti region and Bongo district of the Upper East region as the most resilient and vulnerable districts in Ghana to changing rainfall in relation to its impacts on crop yields. Resilient districts are locations where major droughts over the past 40 years resulted in insignificant crop losses. Vulnerable districts are defined as situations where there were large losses in crop harvest following relatively minor rainfall perturbations over the past 40 years (Antwi-Agyei et al. 2012). It is hypothesised that compared with the vulnerable districts, resilient districts might possess some underlying high levels of local adaptive capacity, making them less vulnerable to drought factors, which are examined further in this study.

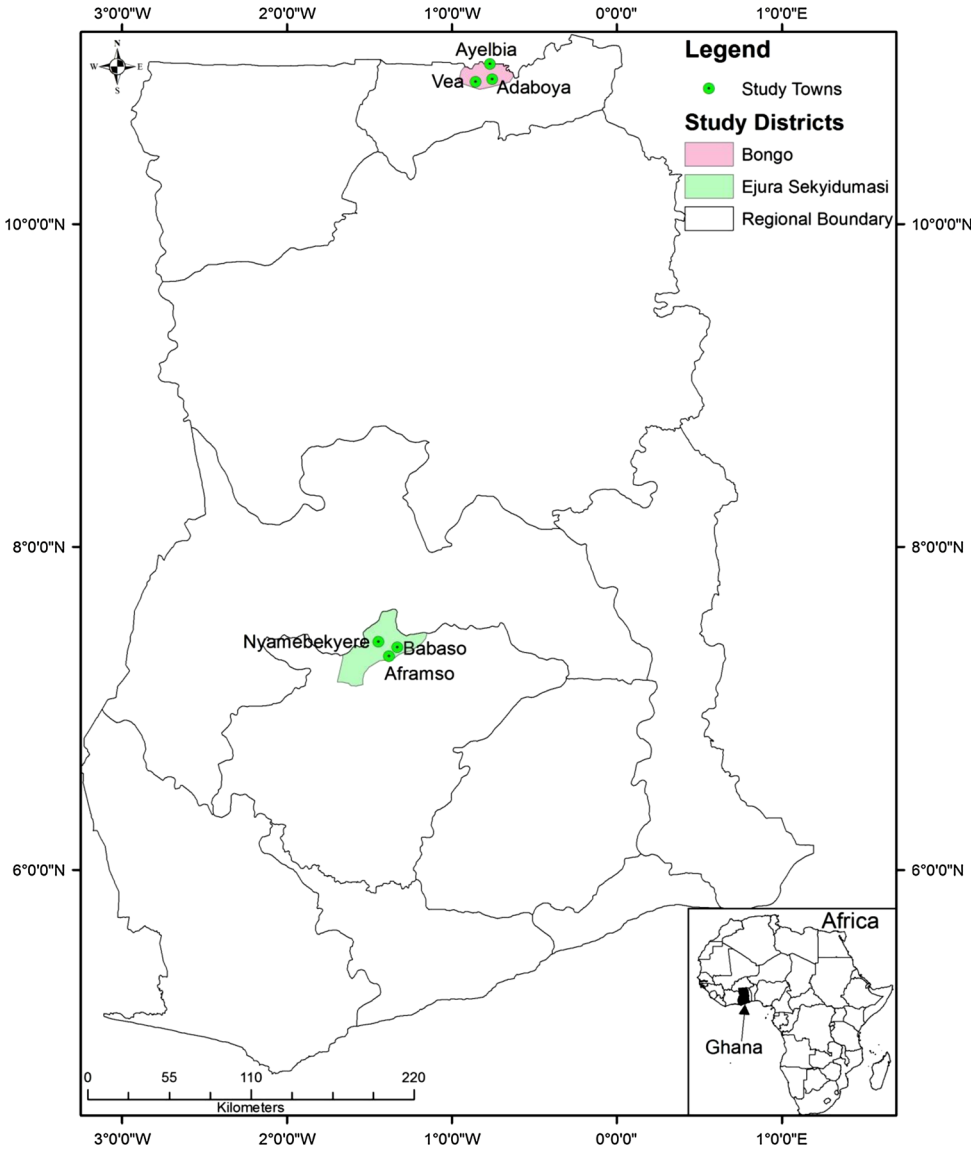

Fig. 1 Ghana showing study communities

Six farming communities were selected from the resilient (Ejura Sekyedumase) and the vulnerable (Bongo) districts (three in each case) for local-level research, based on information gained through interviews with experts and stakeholders and census data. Within the resilient district, Aframso, Babaso and Nyamebekyere were selected as resilient communities, whilst Adaboya, Ayelbia and Vea located in the vulnerable Bongo district were selected as the vulnerable case study communities (Fig. 1). The two districts have different agro-ecological and socioeconomic characteristics. Hence, households in these communities are faced with different climate vulnerability conditions, providing an opportunity to explore a range of household adaptation strategies.

The Ejura Sekyedumase district (Fig. 1), which lies within the forest-savannah transitional agro-ecological zone, experiences average annual rainfall of 1,200–1,500 mm. It is subjected to bi-modal rainfall patterns with the major rainfall season from April to July and the minor rainfall season from September to October (EPA 2003). This constitutes two farming seasons, major and minor, in which minimum and maximum temperatures reach 20 and 32 °C, respectively (EPA 2003). By contrast, the Bongo district lies within the Sudan savannah agro-ecological zone, with average annual rainfall of 800–1,000 mm (EPA 2003). Here, uni-modal rainfall falls from May/June to September/October, with maximum temperatures of 35 °C and mean monthly minimum temperature of 21 °C (EPA 2003). Table 1 summarises the demographic and socioeconomic characteristics of the two study districts.

Research methods

Data presented in this paper were collected during two periods of fieldwork; May–August 2010, and June–August

Table 1 Key demographic and socioeconomic characteristics of the study districts

Characteristics	Ejura Sekyedumase	Bongo
Mean annual rainfall (mm)	1,200–1,500	800–1,100
Rainfall patterns	Bi-modal	Uni-modal
Farming system[a]	Predominantly compound farming	Bush farming
Major crops grown	Maize, yam, rice, groundnuts, cassava and plantain	Millet, sorghum, groundnut and guinea corn
Main livelihood strategies	Crop production and animal production	Entirely crop farming with few livestock farmers
Temperature	Min 20 °C, Max 32 °C	Min 21 °C, Max 35 °C
Population	88,753	77,885
Population in agriculture (%)	60	90
Poverty profile (%)	27.7	88.5
Literacy rates (%)	23.5	65.0
Ethnic composition	Majority *Akans*	Majority *Frafras*

Data compiled from Ghana Meteorological Agency, Accra and Ghana Statistical Services (2010)

[a] Compound farming is the cultivation of land around the close vicinity of the homestead. This is a common practice in the vulnerable communities

2011 using a mixture of participatory methods including focus group discussions (FGDs), household questionnaire surveys and key informant interviews. Data collection started with community gatherings and a transect walk in each of the six communities.

A questionnaire survey was used to collect information on capital assets, endowments and demographic features at the household level. The household was selected as the main unit of analysis because major decisions about adaptation to climate variability and livelihood processes including decisions about agricultural production and consumption are taken at this level (Thomas et al. 2007). A household is defined as 'a group of people who own the same productive resources, live together and feed from the same pot' (Yaro 2006, p. 129). The questionnaire survey assessed adaptation responses used by households. Data were collected on crop varieties, irrigation practices, moisture conservation techniques, timing of farm operations and information systems for weather forecasting. Data were also collected on the availability of, and accessibility to, government subsidies, insurance and general government policies, particularly focusing on land tenure systems and land use. Forty-five questionnaires were administered in each of the six farming communities, giving a total of 270 household questionnaire surveys.

Sampling involved the stratification of households into different groups, based on local perceptions of wealth, and a random sample from each group was then surveyed with consideration given to socioeconomic factors such as age, gender and literacy rates. For example, 79 % of the 270 households in the vulnerable communities had no formal education compared with 47 % in the resilient communities. To ensure representation of the various wealth groups, key informants were used to identify appropriate households where there was under-representation of any group. To triangulate the main issues highlighted during questionnaire surveys, six FGDs were conducted in the farming communities (one in each community) with between 5 and 10 farmers of different socio-cultural backgrounds. During the FGDs and household questionnaire survey, individuals who demonstrated appreciable knowledge on environmental change and food security were selected for subsequent key informant interviews.

Qualitative data analysis involved intensive content analysis. Qualitative data were coded and indexed, and the major themes that emerged were analysed (Krippendorff 2004). Structuring qualitative data into major themes allowed the categorisation of the responses and identification of those that diverged from the common themes. Quantitative data were coded in a way that Microsoft Excel (Version 2010) understands to enable appropriate analysis to be made.

Results

This section presents the findings by exploring the perceptions of climate variability within the study communities and examining the various household adaptation measures used to manage climate variability.

Farmers' awareness of climate variability in the study communities

The evidence from the questionnaire survey shows that households in the study communities are aware that climate change is happening. Table 2 shows that 78 % of the sampled households claimed to have observed increasing temperatures and that the weather has become hotter compared with their childhoods. Furthermore, the majority (90 %) of households indicated that they have observed considerable changes in the onset of the rains during their lifetime (Table 2). Whilst 82 % of the sampled households perceived decreased rains, 18 % reported increased rainfall

Table 2 Proportion of houses that perceived rainfall and temperature changes in the Ejura Sekyedumase and Bongo districts of Ghana over a 40 year period from 1970 to 2010 (%)

Variable	% of respondents who identified climatic changes		
	Resilient communities ($n = 135$)	Vulnerable communities ($n = 135$)	Average
(a) Rainfall			
Changes in onset	93.33	85.93	89.63
Increasing rainfall	21.22	14.07	18.15
Deceasing rainfall	77.77	85.93	81.85
(b) Temperature			
Increasing temperature	74.82	81.49	78.15
Decreasing temperature	5.93	4.44	5.19
Temperature unchanged	19.26	14.07	16.67

during their lifetime (Table 2). There was almost unanimous agreement across the farming households that there is delay in the onset of the rainfall compared with their childhoods.

Farmers' perceptions of climate variability are increasingly used in climate vulnerability and adaptation studies (Maddison 2007; Mertz et al. 2009). This is because farmers' perceptions based on their past experience and future expectations may influence the type of adaptation strategy used as a response to climate problems, with farmers being more likely to adapt if they can perceive the changes in the climate (Maddison 2007; Simelton et al. 2013).

Strategies to deal with changes in rainfall and temperature in the study communities

To manage the changes perceived by farmers in the study communities, various adaptation strategies have been employed. Table 3 summarises these and shows two broad categories. The first encapsulates on-farm adaptation

Table 3 Proportion of households in study communities who reported using a particular adaptation strategy (%)

Adaptation strategies	Resilient communities ($n = 135$)	Vulnerable communities ($n = 135$)	Total ($n = 270$)	Documented examples from elsewhere SSA in the literature
(A) On-farm adaptation strategies				
Changing the timing of planting	127 (94.07)	122 (90.37)	249 (92.22)	Bryan et al. (2009) (Ethiopia and South Africa)
Planting early maturing crops	108 (80.00)	70 (51.85)	178 (65.93)	Cavatassi et al. (2011) (Ethiopia)
Crop diversification	93 (68.88)	121 (89.63)	214 (79.26)	Mary and Majule (2009) (Tanzania)
Using agro-forestry systems	43 (31.85)	0 (0.00)	43 (15.93)	Nyong et al. (2007) (The Sahel)
Planting drought-tolerant crops	100 (74.07)	96 (71.11)	196 (72.59)	Stringer et al. (2009) (Malawi and Swaziland)
Using irrigation	0 (0.00)	18 (13.33)	18 (6.67)	Enfors and Gordon (2008) (Tanzania)
Crop rotation	121 (89.63)	0 (0.00)	121 (44.81)	
(B) Off-farm adaptation strategies				
Livelihood diversification	77 (57.04)	48 (35.56)	125 (46.30)	Barrett et al. (2001) (Burkina Faso) Newsham and Thomas (2011) (Namibia)
Relying on family and friends	37 (27.41)	61 (45.19)	98 (36.30)	Thomas et al. (2007) (South Africa)
Using agro-ecological knowledge	79 (58.52)	97 (71.82)	176 (65.19)	Roncoli et al. (2002)(Burkina Faso); Orlove et al. (2010) (Uganda)
Temporal migration	1 (0.74)	122 (90.37)	123 (45.56)	Wouterse and Taylor (2008) (Burkina Faso)
Governmental and NGOs assistance	49 (36.30)	92 (68.15)	141 (52.22)	
Changing diets	15 (11.11)	98 (72.60)	113 (41.85)	
Reducing food consumption	24 (17.78)	104 (77.04)	128 (47.41)	

Numbers in parenthesis are percentages and those not in parentheses indicate counts of households

strategies and refers to agricultural management practices undertaken by households on the farm aimed at reducing the impacts of climate variability. Second, off-farm adaptation strategies refer to activities that are undertaken outside the farm.

Table 3 presents various on-farm adaptation strategies identified in the study communities, including changing the timing of planting (92 %), planting early maturing crops (66 %), crop diversification (79 %) and using agro-forestry systems (16 %). The majority (73 %) of households reported planting drought-tolerant crops. This comprises 100 (74 %) households in the resilient communities compared with 96 (71 %) households in the vulnerable communities. Whilst irrigation was mentioned by 18 (13 %) households in the vulnerable communities, none of the households in the resilient communities reported this adaptation. A focus group participant provided a characteristic response that illustrates the shift in timing of planting:

> When I started farming in the 1960s, I used to plant in late January or early February and the distribution of the rains was not as erratic as today. Since the late 1990s, I plant in March and sometimes in April to be sure of good rains. Even with that you are not sure the rains will continue for the crops. Hence, the best time to plant in this community now is to wait for the second rain when you will be sure it will be sustained for enough rainfall for the crops [Focus group participant, Babaso, July 2010].

Households in the resilient communities have been planting early maturing varieties of maize that are more drought-tolerant. In the vulnerable communities, households reported planting early maturing varieties of millet and sorghum. According to respondents, by the time seasonal drought sets in, these drought-escaping varieties would have passed the most critical stages of their development that require an appreciable amount of water to produce a good harvest. By maturing earlier, these varieties reduce the risk associated with climate variability. An extract from a household questionnaire response illustrates the importance of planting early maturing varieties:

> Most farmers in this village are able to harvest our early millet in late July and this harvest is crucial for the survival of most households in this village. This harvest after long period of stress is used to prevent hunger and destitution [Qualitative interview, Ayelbia, August 2010].

Although crop diversification has been an important feature of the traditional farming system, some households claimed that erratic rainfall patterns have added an extra dimension to the need for farmers to diversify their crops. A farmer stated:

> When one crop fails, for instance due inadequate rainfall and increasing temperature patterns, I am likely to be compensated by the yield from other crops and avoid total crop failure… [Focus group participant, Aframso, August 2010].

Off-farm adaptation strategies that were reported include relying on support from family and friends (36 %), temporary migration (46 %), using agro-ecological knowledge (65 %) and relying on governmental and non-governmental assistance (52 %) (Table 3). The majority of households that reported migration as an adaptation strategy were from the vulnerable communities (Table 4). In all, 15 (11 %) households in the resilient communities indicated changing their diets to cope with climate variability. By contrast, this strategy was reported by 98 (73 %) households in the vulnerable communities. Further, 128 (47 %) of the 270 households in the study communities reported reducing food consumption to cope with climate variability (particularly drought). Table 3 also shows that most of these adaptation strategies are used widely across SSA. For example, migration has been used as an adaptive measure to drought-induced food insecurity in SSA (Rademacher-Schulz et al. 2013; Mortimore and Adams 2001; Wouterse and Taylor 2008). This indicates that policy recommendations from this paper are likely to be applicable to the wider SSA context.

One of the more significant results that emerged is that most farming households were using coping strategies linked to livelihood diversification (Table 4). A key informant interview illustrates this:

> More households in this village are now engaging in non-farm income jobs than we used to do in the early 1970s. During the 1970s, most of the households were mainly crop farmers with a few farmers keeping livestock in addition to crops. After the droughts of 1983/84, most households began moving into non-farm jobs that are less dependent on rainfall [Key informant, Vea, July 2011].

Petty trading (including the selling of foodstuffs, meat, general wares, provisions, farm inputs etc.) dominated the non-farm jobs with 28 and 15 % of households in the resilient and vulnerable communities, respectively, indicating that they engaged in petty trading (Table 4). About 19 and 10 % of households in the vulnerable and resilient communities, respectively, reported selling livestock (mostly goat, pigs and sheep) and poultry (fowls) to cope with drought (Table 4). Additionally, since the early 2000s,

Table 4 Different wealth groups engaged in non-farm livelihood activities in sampled households in study communities (excluding jobs cited by <1 % of the sampled households)

Livelihood strategies	Resilient communities (%)		Total ($n = 135$)	Vulnerable communities (%)		Total ($n = 135$)	Total for all communities ($n = 270$)
	Rich households	Poor households		Rich households	Poor households		
Petty trading[a]	29	9	38 (28.15)	19	1	20 (14.81)	58 (21.48)
Salaried employment	5	0	5 (3.70)	2	0	2 (1.48)	7 (2.60)
Tailoring	3	0	3 (2.22)	0	0	0 (0.00)	3 (1.11)
Forest assistants[b,c]	13	0	13 (9.63)	0	0	0 (0.00)	13 (4.81)
Bicycle repairer[b]	0	0	0 (0.00)	4	0	4 (2.96)	4 (1.48)
Selling livestock	11	3	14 (10.37)	23	2	25 (18.52)	39 (14.44)
Charcoal production[a,c]	12	2	12 (8.89)	0	0	0 (0.00)	2 (4.44)
Carpenter[b]	3	0	3 (2.22)	0	0	0 (0.00)	3 (1.11)
Food vendor[a]	7	1	8 (5.92)	0	0	0 (0.00)	8 (2.96)
Masonry[b]	3	0	3 (2.22)	0	0	0 (0.00)	3 (1.11)
Grass cutter rearing	3	0	3 (2.22)	0	0	0 (0.00)	3 (1.11)
Fishing[c,d]	0	0	0 (0.00)	9	0	9 (6.67)	9 (3.33)
Casual labour[c,d]	0	0	0 (0.00)	2	1	3 (2.22)	3 (1.11)
Sand mining[c,d]	0	0	0 (0.00)	9	0	8 (5.92)	8 (2.96)
Weaving[d]	0	0	0 (0.00)	12	8	20 (14.82)	20 (7.41
Shea nut gathering[a,d]	0	0	0 (0.00)	2	2	4 (2.96)	4 (1.48)
Pito brewing[a,d]	0	0	0 (0.00)	4	0	4 (2.96)	4 (1.48)
Others	8	1	9 (6.67)	3	2	5 (3.70)	14 (5.19)

Numbers in parenthesis are percentages and those not in parentheses are counts. The percent of male and female-headed households that reported using particular non-farm activity was used to arrive at whether a response was female or male dominated. The 'others' in the table include activities such as firewood harvesting and household asset selling

[a] Female dominated, [b] male dominated, [c] mostly in resilient households, [d] mostly in vulnerable households

households claimed that charcoal production is becoming an important emerging non-farm coping strategy, especially amongst households in the resilient communities, in which about 9 % of households engage in it to raise funds (Table 4). This may be an underestimate because charcoal production involves the illegal felling of trees and households may not want to state that they are involved in such activities.

A critical examination of the results suggests that engagement in a specific non-farm livelihood activity may be determined by gender of the respondent and that livelihood activities may be clustered into three groups: (1) those that are pursued predominantly by females; (2) those pursued predominantly by males; and (3) those that are gender-blind (i.e. those engaged in by both females and males). Non-farm activities such as petty trading, shea nut gathering and pito brewing are specifically undertaken by women. For instance, whilst 72 % of the respondents that indicated petty trading were females, only 28 % were males. On the contrary, selling livestock, sand mining, being a forest assistant, being a bicycle repairer and fishing are predominantly engaged in by males. None of the 39 respondents that reported selling livestock as a non-arable farming livelihood activity were female. Activities such as charcoal production and weaving are gender-blind.

Table 4 reveals that households' engagement in non-arable farming livelihood activities is greatly influenced by location (i.e. whether the household is located in the resilient or vulnerable community). Whilst activities such as charcoal production and working as forest assistants were predominantly undertaken by households in the resilient communities, weaving, sand mining, causal labour and pito brewing were mostly undertaken by households in vulnerable communities.

Amongst the vulnerable communities, Vea households had better opportunities for non-farm livelihood activities as the presence of large-scale irrigation project offered the opportunity to pursue fishing as a non-farm activity. During qualitative FGDs, households described the lack of financial resources, a lack of information on climate change characteristics and a lack of early warning systems as some of the key barriers that impede the effective implementation of the adaptation strategies. The disaggregated results show that different households tend to engage in different adaptation strategies based on their socioeconomic characteristics (i.e. wealth groups) (see Table 4).

Discussion

The findings presented here suggest that smallholder farmers in the Sudan savannah and forest-savannah transitional zones of Ghana are employing various on-farm and off-farm adaptation strategies to cope with and adapt to climate variability. It is significant to stress that the study households, like many other dryland SSA communities, are often confronted by multiple climatic and non-climatic stresses including droughts, lack of markets, poor education and adverse economic development (Mertz et al. 2010).

On-farm adaptation strategies

One of the key adaptation strategies that emerged during FGDs and key informant interviews was changing cropping patterns. Though related to agricultural development more widely, climate variability makes it more important for households in dryland farming systems to change the types of crops grown, as evidenced by the drought events of 1983/84 that led to households in the resilient communities (particularly in Nyamebekyere) to change their cropping patterns. For instance, households claimed that they were growing mainly cash crops such as cocoa when they first settled at Nyamebekyere in the 1960s. However, they changed to growing food crops such as maize in the 1970s, tobacco in the 1980s and have been growing maize, yam and rice since the late 1990s. Qualitative data suggest the change in cropping patterns was in response to bush fires in the late 1960s that destroyed cash crops and the droughts of 1983/84 which destroyed food crops.

Although households claimed to have changed their cropping patterns in response to climate variability, interactions with the farmers during transect walks revealed that such responses might have partly been influenced by non-climatic factors such as economic shocks and opportunities. For instance, the transition to tobacco growing in the Nyamebekyere community was largely influenced by the availability of markets for tobacco during the 1980s. Similarly, the change in cropping practices to growing maize, yam, and rice was partly in response to the closure of the tobacco company in this community as a result of heavy tax levied on tobacco companies by government. Hence, households respond to climate variability within the full myriad of other non-climatic factors that affect rural livelihoods.

Key informant interviews suggest that firewood harvesting and shea nut picking are common adaptation strategies, especially amongst female households in the vulnerable communities. Focus group participants and key informant interviews also noted increasing use of agroforestry systems. Farmers claimed that growing trees was not part of the farming system in the early 1960s. Households in the resilient communities stated that since the 1980s, they had witnessed increased temperatures and started planting trees to improve the microclimate on the farm. Water system technologies including small-scale irrigation facilities are also increasingly used, especially in the vulnerable communities, to practise vegetable farming. In Vea, where there is a large-scale irrigation dam, farmers claimed that households are allocated land around the dam where they can grow vegetables such as tomatoes. Focus group participants claimed that using irrigation as a coping mechanism for drought assumed greater importance especially in the 1980s, when rainfall variability led to a shortened growing season. These claims corroborate other studies (e.g. Enfors and Gordon 2008; Laube et al. 2012) suggesting that small-scale irrigation among smallholders provides additional on-farm income sources during the dry season and thus helps to enhance the resilience of vulnerable households.

Diversification of livelihood activities to reduce the adverse impacts of drought

The results suggest that households in the study communities are pursuing a range of non-farm livelihood activities to spread the risk associated with crop failure due to erratic rainfall patterns. Such livelihood strategies contribute to livelihood resilience at the household level (Paavola 2008; Antwi-Agyei et al. 2013). Interviews suggest that agricultural-based livelihoods remain the predominant source of livelihood for the majority of the households. This challenges the de-agrarianisation thesis that has concerned many assessing the future of African farming systems (e.g. Bryceson 2002; Twyman et al. 2004) and the assumption by development agencies that the non-farm economy holds the prospect and livelihood security for Africa farmers (Haggblade et al. 2010).

Farmers reported that the profits from livestock sales are invested in foodstuffs to keep the household food secure after they have run out of provisions from their own production. Focus group participants reported that part of the income from selling livestock is invested in agricultural production in terms of buying farm inputs. Households claimed that selling livestock is one of the most profitable non-farm activities in the vulnerable communities. In most agriculture-dependent rural African households, livestock represents wealth and serves as an important insurance mechanism because households can sell their animals to buy grain (Hesselberg and Yaro 2006).

By augmenting their livelihood activity portfolio, the smallholder farmer in dryland farming systems reduces the risks of an overall adverse livelihood outcome or production failure (Fraser et al. 2005; Ellis 1998). It is vital to

stress that livelihood diversification may also be used by households to efficiently utilise their factors of production, especially labour. For instance, households in vulnerable communities reported working as causal labourers and undertaking other menial jobs in southern Ghana, especially in the Ashanti and Greater Accra regions, where environmental conditions and job opportunities are better. These farmers depend predominantly on rain-fed agriculture for their livelihoods and the shortening of the growing period linked to increased drought has resulted in a limited period (June–October) during which these farmers could cultivate their land. Hence, one of the more lucrative options is to explore other livelihood opportunities including, selling their labour. It is important to stress the long history of migration that exists, particularly in the vulnerable communities of northern Ghana (van der Geest 2011). Qualitative data suggest that migration is often undertaken by the young who usually engage in on- or off-farm wage labour in southern Ghana.

Despite the significant role played by livelihood diversification in adaptation to climate variability, it can be considered a double-edged sword. For instance, specialising in one livelihood activity could yield higher economic returns than the engagement of the household in a number of livelihood activities (Eriksen et al. 2005). Indeed, many of the rich households in the resilient communities that have resources to engage in large-scale commercial farming are better situated to adapt to the adverse impacts of climate variability. Households may also engage in non-farm livelihood activities for factors other than climate adaptation purposes. Rigg (2006) observed that households sometimes diversify their livelihood activities as a result of decreasing viability of agricultural livelihoods and are confronted with a new and different set of stresses that could reproduce poverty. This could subsequently lead to mal-adaptation. Indeed, Yaro (2006 p. 128) argues that 'adaptation can be positive or negative: positive if it is by choice, reversible, and increases security; negative if it is of necessity, irreversible, and fails to increase security'. Positive adaptation should therefore lead to favourable outcomes.

Similarly, through her de-agrarianisation thesis, Bryceson (2002) challenged the assumed positive relationship between livelihood diversification and poverty reduction, and by extension, climate adaptation. The migration of male labour due to livelihood diversification into distant markets, as noted earlier, could result in depletion of the local productive labour force (Ellis 1999), reducing economic returns. This has the potential to negatively affect food production and food security. Although non-farm livelihood activities could improve the rural economy, when supported with viable markets, Haggblade et al. (2010) argued that the link between non-farm livelihood activities and poverty reduction is complex and requires conscious efforts from policy makers in making sure that such activities benefit rural households.

Social differentiation and climate variability adaptation

Qualitative data indicate that women engage in petty trading to raise extra income to make sure there is food on the dinner table. Despite their important role in ensuring household food security, many married women in the study communities often lack the political capital needed in making decisions regarding potential investments in non-farm livelihood activities without the consent of their husband (Yaro 2006). Although livelihood diversification into non-arable farm activities has been noted to improve the rural economy through poverty reduction (Haggblade et al. 2010), unequal power relations between women and men in the study communities have resulted in differential access to capital assets and opportunities for livelihood diversification. Women in rural Ghana may be constrained by a lack of control over physical assets including irrigation facilities that could increase their resilience to climate variability (Antwi-Agyei et al. 2013).

In terms of wealth groups, results show that compared with their counterparts in poor households, rich households in both the resilient and vulnerable communities are more likely to engage in off-farm livelihood adaptation strategies (Table 4). For example, selling livestock is dependent on the capital outlay that can be invested in livestock production. Rich households with access to credit and other funds are able to invest in livestock production, whereas poor households have limited access to social networks that provide support in times of food insecurity linked to climate variability. The findings suggest that the households in the resilient communities have more diverse opportunities for livelihood adaptations and are implementing diverse adaptation strategies, making them less vulnerable to the negative impacts of climate variability.

Application of agro-ecological knowledge to deal with drought

The findings on the application and sharing of traditional knowledge in reducing the impacts of climate variability, in relation to indigenous knowledge and social networks, are consistent with findings from previous studies (e.g. Nyong et al. 2007; Orlove et al. 2010; Roncoli 2006). Particularly interesting is the reliance of households on their social networks to share indigenous agro-ecological knowledge on early warning signs for weather forecasting—an essential aspect in coping with, and adapting to, climate variability (Boyd et al. 2013). Studies have shown that local farmers in SSA have rich and sophisticated

agro-ecological knowledge that can be useful information for climate adaptation (Nyong et al. 2007; Orlove et al. 2010). According to the farmers in this study, they use their indigenous agro-ecological knowledge to develop complex models which are based on changes and indicators linked to their surroundings. Such traditional models are used to design seasonal calendars that facilitate adaptation by way of planning when to plant their crops. This is crucial in rain-fed dryland farming systems where crop yields can be seriously affected if farmers miss key indicators of change. For instance, households in the vulnerable communities use the flowering and fruiting of certain trees such as the baobab tree (*Adansonia digitate*) and shea tree (*Vitellaria paradoxa*) to indicate the onset of the rains and prepare their farmlands. Also, some households use the direction of the wind to indicate impending rains for agricultural purposes. Still others rely on past rainfall patterns including the start and ending of the rainy season to form expectations and predict the rainfall patterns for the coming season. This knowledge base represents a form of social capital that is shared among the members of the farming communities and can add value to climate change studies when properly integrated.

Are smallholder farmers adapting to climate variability in Sub-Saharan Africa?

It is significant to emphasise that most of the adaptation measures highlighted above including new faster growing crop varieties, migration, planting drought-tolerant varieties, wage labour, etc. and coping strategies such as selling livestock, reducing food intake and changing diets are used by farmers in Ghana and SSA more widely as risk-spreading measures to reduce the negative impacts of climate variability. However, these households have often failed to take advantage of the opportunities presented in relatively good farming seasons (Cooper et al. 2008). Such adaptation strategies reduce present vulnerabilities without necessarily accounting for future climate changes. In this regard, for adaptation strategies to be effective and successful, farmers need to reduce present and future vulnerabilities to climate variability as well as increasing resilience (Huq et al. 2004). Indeed, if adaptation strategies are managed properly, wider environmental benefits can be derived from them (FAO 2008; Mitchell and Maxwell 2010).

Conclusions and policy recommendations

This paper has revealed that farming households in the Sudan savannah and forest-savannah transitional agro-ecological zones of Ghana are actively engaging in various on- and off-farm adaptation activities to reduce the adverse impacts of climate variability (particularly drought) on their livelihoods. These results challenge the oft-painted image of Africa's farmers as passive victims of climate change and variability.

The results show that households employ on-farm adaptation strategies such as changing the timing of planting, diversification of crops, planting early maturing varieties, planting drought-tolerant crops and using irrigation systems. Key off-farm adaptation strategies identified include relying on social networks, temporary migration, changing diets and reducing consumption. The paper has shown that households are using coping strategies that are mostly linked to livelihood diversification. This paper also presents empirical evidence that suggests that farming households are engaged in non-farm activities such as petty trading, selling livestock, sand mining, working as forest assistants, working as food vendors and gathering shea nuts to cope with, and adapt to, climate variability. Within the vulnerable community, migration was reported as a key adaptation strategy. This paper contributes to scientific debates on livelihood resilience by enhancing our understanding of how small-scale farmers are adapting to the challenges posed by climate variability.

The implication of the findings is that policy makers need to formulate more targeted climate adaptation policies and programmes that are linked to enhancing livelihood diversification, building from the positive actions being taken to manage climate variability. For instance, appropriate programmes that foster asset building such as skills training and craftsmanship should be integrated into the national climate change adaptation strategy to enable farming households to venture into non-farm livelihood activities. Livestock rearing is one of the principal alternative livelihood opportunities, especially for households in vulnerable communities. Efforts should be made to develop local expertise aimed at enhancing the production of livestock through regular workshops on livestock production.

Our findings suggest that farming households within the different communities pursued varied adaptation strategies. The households within the resilient communities tend to engage in a wider range of successful adaptations. Therefore, households should be encouraged to establish communication routes to share information and knowledge on successful local climate adaptation strategies. This could be achieved through the formation of community-based associations and farm-based groups. Forming these associations will give households access to social capital and offer them opportunities to access loans from banks and other financial institutions. Information sharing on climate adaptations can also be achieved through regular interactions through farmers' fora and workshops initiated by the

extension officers of the Ministry of Food and Agriculture. Demonstration sites with successful adaptation practices could usefully be demarcated to help in this regard.

Our results further indicate that choice of a particular climate adaptation strategy may be partly influenced by the socioeconomic characteristics of the household. For instance, evidence suggests that rich households, which may have access to capital, are more likely to engage in non-farm livelihood activities that are less vulnerable to the adverse impacts of climate variability. In contrast, women and poor households tend to engage in non-farm livelihood activities that are less capital-intensive and require low skills to implement. It is therefore important that careful considerations are given to socioeconomic factors in the study villages and more widely in the design and implementation of climate adaptations support. This can enhance the effectiveness of adaptation strategies to reduce the vulnerability of farming households to climate variability.

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