Environ Dev Sustain (2013) 15:903–926
DOI 10.1007/s10668-012-9418-9

Characterising the nature of household vulnerability to climate variability: empirical evidence from two regions of Ghana

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Received: 3 August 2012 / Accepted: 9 November 2012 / Published online: 21 November 2012

Abstract This paper builds on national- and regional-level vulnerability assessments by developing and applying a livelihood vulnerability index at the community and household scales to explore the nature of climate vulnerability. It provides innovative methodological steps in relation to livelihood assessment to identify the vulnerability of households and communities to drought. This will help to improve drought vulnerability assessments in Ghana and more widely as it shows extra information can be obtained from local-level vulnerability assessment that may be lacking in national- and regional-level analysis. The research employs quantitative and qualitative data collected through participatory methods, key informant interviews and a questionnaire survey with 270 households across 6 communities in two regions in Ghana. Results show that within the same agroecological zone, households and communities experience different degrees of climate vulnerability. These differences can be largely explained by socioeconomic characteristics such as wealth and gender, as well as access to capital assets. Results identify vulnerable households within resilient communities as well as more resilient households within vulnerable communities. These outliers are studied in detail. It is found that outlier households in vulnerable communities have an array of alternative livelihood options and tend to be socially well connected, enabling them to take advantage of opportunities associated with environmental and economic changes. To sustain and enhance the livelihoods of vulnerable households and communities, policymakers need to identify and facilitate appropriate interventions that foster asset building, improve institutional capacity as well as build social capital.

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Keywords Climate variability · Livelihoods · Capital assets · Vulnerability assessment · Resilience · Ghana

1 Introduction

Empirical evidence on the generic characteristics of agriculture-dependent communities that have proven resilient or vulnerable to past climate-related problems is limited at the household and community levels. Addressing this gap will increase our understanding of how communities cope with the impacts of climate-related problems, providing useful insights into the structure and drivers of vulnerability (e.g. Eakin and Bojorquez-Tapia 2008). This will provide valuable lessons for the management of climate variability in agriculture-dependent communities in developing countries in sub-Saharan Africa. Vulnerability assessments have been used to explore the complex set of interactions between humans and their socio-physical environments (Hahn et al. 2009). Though difficult to measure and describe as a concept, several indicator-based vulnerability assessments have been conducted at the global scale (e.g. Action-Aid 2011; Ericksen et al. 2011), regional scale (e.g. Midgeley et al. 2011; Abson et al. 2012), as well as national and district scales (e.g. Hahn et al. 2009). Such assessments allowed comparison of the relative vulnerability of different nations, regions or districts to the impacts of climate change and variability. Hence, these indicator-based assessments may be used to identify vulnerable groups within a particular geographical area to inform policy regarding resource allocation in such areas (Birkmann 2007; Eakin and Bojorquez-Tapia 2008; Hinkel 2011).

Whilst contributing to the understanding of the various factors that may cause vulnerability, many of these studies (e.g. Ericksen et al. 2011; Midgeley et al. 2011; Abson et al. 2012) use national-level data and indicators that have been selected somewhat subjectively from the literature. Vulnerability assessments relying on census data at the national level could mask significant local-level variability in terms of access to assets and entitlements (Eakin and Bojorquez-Tapia 2008) because of the problem of aggregation that makes particular poor regions seem less vulnerable than they really are (see Morse and Fraser 2005). The development of such vulnerability indices (which are based on predefined and theoretically driven indicators) rarely acknowledges the participation of communities regarding what is perceived to influence vulnerability to climate variability at the local level (Thomas et al. 2007). Although such national-level theoretically driven vulnerability assessments provide a strong foundation from which more detailed work can take place, downscaling and contextualising such studies at the local level may be problematic (see Birkmann 2007). The purpose of this paper is to identify and unpack the extra information that can be obtained from community and household levels vulnerability analyses that is lacking in national- and regional-level assessments. This is done by developing and applying a livelihood vulnerability index for households within six communities across two regions in Ghana. We use empirical data based on the factors that local farmers perceive to influence vulnerability to climate variability.

There is no consensus among scholars in the climate change literature on what vulnerability is. Nevertheless, the most commonly accepted approach, which is the approach adopted in this paper, comes from the Intergovernmental Panel on Climate Change (IPCC)'s definition of vulnerability (to climate change) where vulnerability is "the degree to which an environmental or social system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes"

(IPCC 2007, p. 883). This definition allows broad conceptualisation of the extent to which farming households and communities are unable to withstand the adverse impacts of climate variability on their livelihoods. The IPCC expresses vulnerability as a function of exposure, sensitivity and adaptive capacity (IPCC 2007). Nevertheless, the relationship amongst these components of vulnerability is ambiguous and not clearly defined (Hinkel 2011). Exposure relates to the extent to which a particular system may be exposed to climatic stresses or variations (IPCC 2007). On the other hand, sensitivity determines the response of a given system to climate change and may be shaped by socioeconomic and ecological conditions of the system (IPCC 2007). Adaptive capacity in the context of climate change has been defined by the IPCC (2007, p. 869) as "the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences." Adaptive capacity connotes some positive attributes of a system that enable it to reduce the adverse impacts (vulnerability) associated with climate change (Engle 2011). Moser (1998) links vulnerability to asset ownership, as well as the entitlement that the household or community can command in the face of exposure. Hence, the availability of, and accessibility to, assets and resources to households and communities may influence the extent to which they are vulnerable to the impacts of climate change.

Vulnerability is best determined in response to a specific climatic risk (Vincent 2007), which in the case of this paper, is drought. At the household level, Smit and Wandel (2006) argue that the concepts—exposure and sensitivity—as determinants of vulnerability may be inseparable. Hence, the extent of adaptive capacity may be responsible for varying degrees of vulnerability amongst individuals or households within the same community (Eakin and Bojorquez-Tapia 2008). This is also reflected in the livelihood characteristics of the individuals and households within such communities, which directly or indirectly affect the extent of exposure and sensitivity to a particular climate anomaly (Smit and Wandel 2006). In this regard, it is assumed that households within the same agroecological zone may be exposed to the same level of climate anomaly (drought in this case) (Eakin and Bojorquez-Tapia 2008). This paper focuses on drought because it is the major threat to African farming systems (UNDP 2007), with some studies predicting increased incidences of drought in the future across sub-Saharan Africa (Boko et al. 2007). In Ghana, agricultural production is highly sensitive to drought with recent reductions in food production having been linked to drought events (Ministry of Food and Agriculture 2007).

Central to the interpretation and understanding of vulnerability is the idea of resilience of social-ecological systems (Miller et al. 2010). According to Walker et al. (2006), resilience refers to the ability of a system to withstand shocks in order to maintain its structure and identity, though the literature also considers other definitions. In his seminal paper, Holling (1973, p. 14) defines ecological resilience as the "ability to absorb change and disturbance and still maintain the same relationships that control a system's behaviour." Extending this idea, Adger (2000) argues that social resilience involves the capacity of social group or community to withstand socio-political as well as environmental stresses. Consideration of resilience in this paper provides the opportunity to explore livelihood dynamics in order to understand the capacity of a particular system to withstand the adverse impacts of climate variability (Marschke and Berkes 2006).

The household was selected as the main unit of analysis because major decisions about adaptation to climate change and livelihood processes are taken at the household level (Thomas et al. 2007). Nevertheless, households are connected to the wider community, which can greatly influence the decision-making process in relation to the use of productive resources of a particular household; hence, the need to explore vulnerability and

adaptation strategies at the household level in relation to the wider socioeconomic and cultural processes occurring at the community level (Thomas et al. 2007). At the household level, sensitivity is reflected in the type of farming (i.e. monoculture or mixed farming, land tenure security and farm holding) as agricultural production is a key livelihood activity. In this paper, the vulnerability of a household to drought is conceptualised to be a function of the household's access to livelihood capital assets (particularly natural capital) and the extent to which the household has diversified its livelihood activities.

The overall aim of this paper is to explore the characteristics associated with those households and communities that are resilient and vulnerable to climate variability. This will help us to understand the processes and factors that create vulnerability, allows input from the studied communities themselves, as well as providing guidance for the development of effective policies. To achieve this aim, the specific objectives of this paper are to:

1. Develop and apply a household livelihood vulnerability index in relation to climate variability (particularly drought) in order to compare and contrast the components of vulnerability in different case study farming communities;
2. Explore the socioeconomic, environmental and community characteristics associated with resilient and vulnerable households and communities.

2 Research design and methods

This paper follows and applies multi-scale, mixed-methods approach, allowing innovative application of the sustainable livelihood framework to specifically test climate vulnerability at community and household levels. Climate change is a complex problem interacting with different processes, and the use of mixed-method approach permits a holistic understanding of the different dimensions of the problem (Adger et al. 2009).

2.1 Research design

The Ejura Sekyeredumasi district of Ashanti region and Bongo district of the Upper East region of Ghana were selected for this study having been previously identified as the most resilient and vulnerable regions and districts respectively in Ghana (Antwi-Agyei et al. 2012). This was based on a definition of "vulnerable" regions and districts as those where relatively minor perturbations in rainfall over the past 40 years had significant impacts on crop yields (Antwi-Agyei et al. 2012). Conversely, "resilient" regions and districts were defined as those where even large droughts were observed to have had only minor impacts on crop yields (Simelton et al. 2009). Advancing this work further, an assessment of livelihoods offers the opportunity to highlight the various adaptations that might be available to determine how rural communities can cope with declining crop yields due to drought, and also how such declining yields can affect livelihoods (see Ziervogel and Calder 2003).

Within one resilient and one vulnerable district, 6 specific resilient and vulnerable farming communities (3 in each case) were selected for further research, based on information gained through interviews with experts and stakeholders (Antwi-Agyei et al. 2012). Three communities were selected from each district to allow comparisons to be made among communities within the same district without sacrificing the opportunity for in-depth qualitative analysis; hence, three were deemed a suitable sample size. The resilient

communities were Aframso, Babaso and Nyamebekyere located in the Ejura Sekyeredumasi district of Ashanti region, while vulnerable communities were Adaboya, Ayelbia and Vea located in the Bongo district in the Upper East region (Fig. 1; Antwi-Agyei et al. 2012). These two districts (and 6 communities) represent a range of different agroecological and socioeconomic characteristics in Ghana. The Ejura Sekyeredumasi district (the resilient district) lies within the transitional agroecological zone and experiences bi-modal rainfall patterns with the major rainfall season from April to July and the minor rainfall season from September to October (EPA 2003). Average annual rainfall ranges from 1,200 to 1,500 mm with minimum and maximum temperatures of 20 and 32 °C respectively (EPA 2003). Bongo district (the vulnerable district) lies within the Sudan savannah agroecological zone. The Bongo district experiences uni-modal rainfall from May/June—

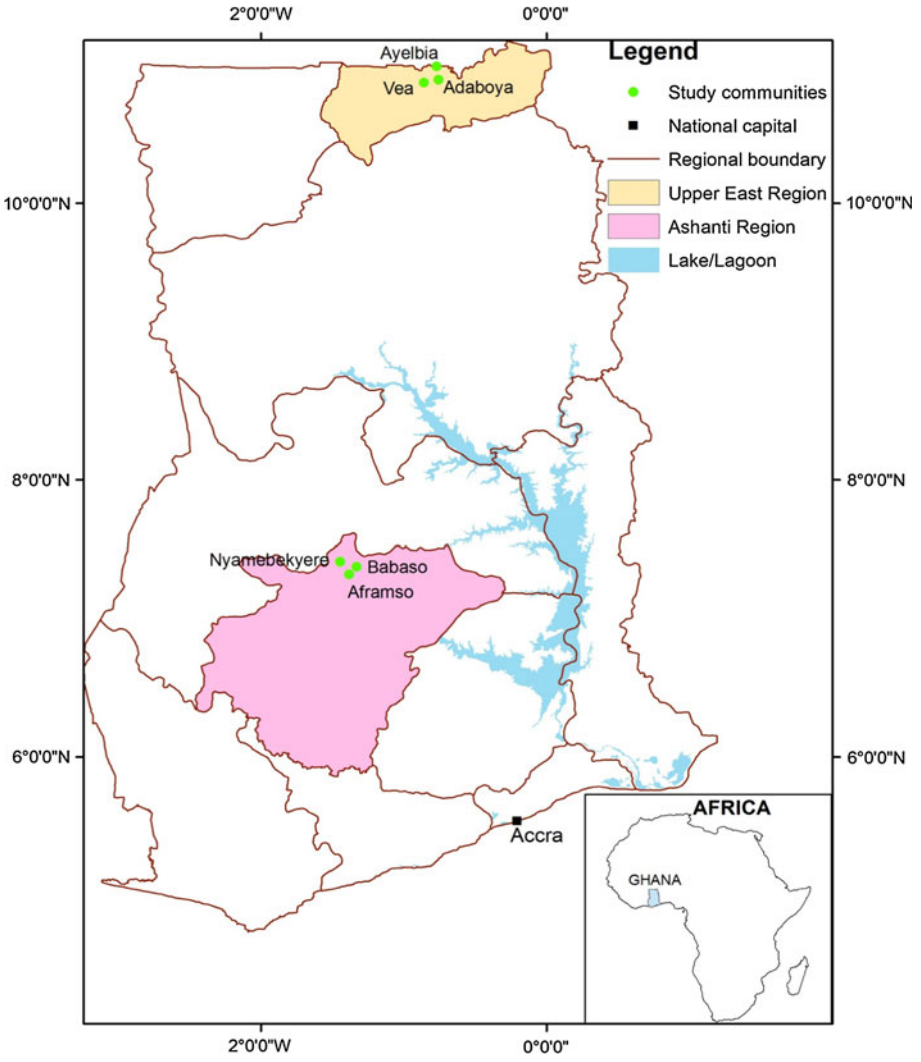

Fig. 1 Ghana showing the study communities

September/October, which constitutes the main farming season (EPA 2003). Average annual rainfall ranges from 800 to 1,000 mm with maximum temperatures of 35 °C (EPA 2003). The uni-modal rainfall pattern experienced by the vulnerable communities could potentially contribute to their vulnerability to climate variability. This is because these are predominately rain-fed agriculture-dependent communities that are constrained by a lack of rainfall for a second growing season. In terms of socioeconomic characteristics, the economy of the resilient district is based on commercial farming including crop production and livestock rearing, whilst that of the vulnerable district is mainly subsistence farming (Ghana Government 2000).

2.2 Research methods

Data presented in this paper were collected using a mixture of participatory methods such as focus group discussions, household questionnaire surveys and key informant interviews. Data collection started with a rapid rural appraisal (Chambers 1994) during which community gatherings and transect walks were conducted with community members including opinion leaders at each of the 6 villages. This provided an overview of the significant social and physical features of the selected communities that influenced their livelihood activities (Sallu et al. 2009). A household questionnaire survey was used to collect both qualitative and quantitative data. The questionnaire survey assessed households' capital assets (financial, human, natural, physical, and social). This information was used to develop a household livelihood vulnerability index (see Sect. 2.3). A total of 270 household questionnaire surveys were conducted in the 6 farming communities (45 Questionnaires in each).

A random sampling approach was used for the selection of communities that participated in the study. Within communities, households were stratified into different wealth groups. A random sample of households was then surveyed. The criterion for wealth ranking was developed based on the perception of wealth and poverty by the communities' opinion leaders and individual households evaluated at the time of the survey. Where there was an under representation of any wealth group, key informants were used to identify appropriate households to supplement the sample. At least one focus group discussion was conducted at each village with between 5 and 10 farmers of different socio-cultural backgrounds to further explore the main themes that emerged in the questionnaire surveys. Oral narratives were used to reconstruct livelihood histories to explore temporal dimensions of vulnerability of outlier households, providing insights into how past events shape livelihood activities (Sallu et al. 2010).

2.3 Choosing specific indicators as determinants of household livelihood vulnerability

The sustainable livelihoods approach (SLA) (Scoones 1998) was originally developed to assess poverty and builds on the entitlement approach (Sen 1981). According to Chambers and Conway (1992, p. 7), "a livelihood comprises the capabilities, assets (stores, resources, claims and access) and activities required for a means of living: a livelihood is sustainable which can cope with and recover from stress and shocks, maintain or enhance its capabilities and assets, and provide sustainable livelihood opportunities for the next generation, and which contributes net benefits to other livelihoods at the local and global levels and in the short and long-term." The SLA is premised on the principle that local communities possess various capabilities that need to be acknowledged by development workers. The SLA can be used to explore how people combine different capital endowments including tangible assets (e.g. material resources such as land) and intangible assets (e.g. educational

levels, claims and access) to achieve livelihoods objectives within the wider socio-politico-economic conditions (Carney 1998). Hence, the SLA may be used to assess communities' capacities to withstand conflicts and other climate and non-climate stresses (e.g. Reid and Vogel 2006). Traditionally, the SLA has been applied by considering the five livelihood capital assets—human, financial, natural, physical and social—as well as their links to an overall vulnerability context, processes, institutions (both formal and informal) and policies that govern people's access to these capital assets (Scoones 1998).

In this paper, the SLA was used to frame the identification of indicators (including capital assets) that determine household livelihood vulnerability. During focus group discussions and questionnaire surveys, households were asked to highlight indicators linked to each form of capital asset (i.e. human, financial, natural, physical and social capitals). The key indicators that emerged from this exercise were cross-checked with those mentioned in the literature (Yohe and Tol 2002; Brooks et al. 2005; Smit and Wandel 2006). Table 1 shows the main indicators that were considered in this paper after the literature review. What follows is a brief description of how the livelihoods assets were characterised in relation to households' ability to adapt to climate variability with a view to using this information to develop a livelihood vulnerability index at the household and community levels.

2.3.1 Social capital

Social capital—including connections to technical support and social resources such as networks, associations and affiliations—was assessed by counting the number of

Table 1 Indicators of household livelihood vulnerability index collected through a household survey across six communities in Ghana

Component	Indicators	Questions posed during data collection to obtain information on this indicator
Social capital	Number of groups or associations households belong to	Do you belong to any social groups? Could you please list them?
	Educational level	Could you please state the highest education attained?
Human capital	Health status	Have any member of this household been ill in the last 12 months?
Natural capital	Farm holding size	Could you please state the size of farm holding in acres?
	Tenure system	By what arrangements do you have access to your farm land for farming activities?
	Access to credit	Do you have access to credit for your agricultural activities?
Financial capital	Ownership of livestock	Do you have livestock or poultry? List the types and numbers of livestock.
	Remittances received	Have you received remittances from family or friends in the last 12 months?
	Irrigation facilities	Do you have access to irrigation facilities for dry season farming?
Physical capital	Ownership of radio, television or mobile phone	Could you please list all communication gadgets that you have? These include TV, mobile phone or radios etc.
Livelihood diversification	Livelihood diversity index	What are your main livelihood activities? Could you rank these in terms of their contribution to household income?

associations or groups to which the members of the household belong (Pretty and Ward 2001; Vincent 2007). It was assumed that households belonging to a high number of social groups and associations are better networked to cope with the impacts of climate change on their livelihoods activities (Adger 2003; Pretty 2003), as these represent the number of social safety nets and a form of informal grassroots insurance available to the household during climate-related crisis (e.g. Fraser 2007; Vincent 2007). Both bonding and bridging social capital were assessed. Bonding social capital is based on characteristics such as family kinship, ethnicity or nationality (Woolcock 2001). Bridging capital refers to ties to external groups and usually transcends different socioeconomic statuses, nationalities, religions, and ethnicities (Woolcock 2001). A scoring procedure for social capital followed the methods of Vincent (2007). A score of 1 was given to households that belonged to no identifiable group, 2 for those who were members of one group, 3 for membership of two groups and 4 for membership of more than three groups. While the level of interaction among the group members and the strength of the ties within such social groups could affect their usefulness, interaction and ties were beyond the scope of the assessment and were not considered.

2.3.2 Human capital

Human capital assets were represented by two indicators: the educational level of the head of the household (or the most educated person in the household) and the health status of the household (Table 1). No formal education was afforded a value of 1; 2 in the case of only primary education; 3 in the case of secondary education; and 4 for households that had tertiary education. As there is a link between health and climate change (Haines et al. 2006), it is assumed that households with significant health problems will have lower human capital as they must allocate a substantial part of their scarce resources to treating illnesses (e.g. Allison et al. 2009), thereby reducing their capacity to withstand the impacts of climate variability. To assess health status, households were asked about the number of times they have been to the hospital (or hospitalised) within the last 12 months. Households with members that had been to the hospital were scored 1 whilst those with members that had not been to hospital as out patients (and those not needing any medical attention) within this period were scored 2. Also, situations where members of a household required hospital treatment but could not arrange transport and other resources needed were taken into consideration when scoring such a household.

2.3.3 Natural capital

Natural capital assets were assessed by two indicators. The first was the size of the farm holding under cultivation (this was estimated as the average area of cultivated land over the past 5 years) (Table 1). It is assumed that the larger the farm holding, the greater the opportunity for the household to have more crops and yield, and hence the lower the vulnerability to climate change, though it is noted that labour availability and financial capital both affect the reality of how much land can be cultivated. Households which cultivated less than 5 acres scored 1; those cultivating between 5 and 10 acres scored 2; those cultivating between 11 and 15 acres scored 3; those cultivating 16-20 acres scored 4, and households cultivating >20 acres scored 5. The type of land tenure and level of security it provides may have serious implications for the management of agricultural soils and could indirectly affect crop productivity and environmental sustainability, consequently influencing household vulnerability (Butt et al. 2006). Three different tenure

arrangements were identified in the study communities. These were "land inherited", "land purchased" and "land rented" by the household. A score of 1 was given to households who rented their farmlands; 2 for households who purchased their farmlands; and 3 for those who inherited their farmlands. Households that inherited their farm lands were given the highest score because it is assumed that they will have the most secure land tenure.

2.3.4 *Financial capital*

Financial capital assets such as savings and remittances play a crucial role in cushioning households against drought-related food shortages. Eliciting information on financial assets was very problematic because of a lack of records on sales and memory lapses. Livestock were considered to offer readily available cash in times of crop failure due to erratic rainfall patterns in the study communities. Indeed, Hesselberg and Yaro (2006) argue that a peasant household's ability to obtain food in northern Ghana, especially in the lean season, largely depends on the availability of disposable livestock and poultry. Households without poultry or livestock scored 1 whilst those with livestock scored 2. In addition, financial assets were assessed by examining the remittances received by the household from family members or friends over the past 12 months. In rural agriculture-dependent communities, remittances from family and friends play a crucial role in helping farmers to cope with the livelihood impacts resulting from climate variability. Households that received remittances in the last 12 months scored 2 and those that did not receive any remittances scored 1. Access to credit may also influence adaptation to climate change including access to inputs such as improved cultivars of crops (e.g. Butt et al. 2006; Fosu-Mensah et al. 2012). Hence, it is assumed that households that have no access to credit will be more vulnerable and scored 1 whilst those with access to credit were given a score of 2.

2.3.5 *Physical capital*

Physical assets that were assessed included the presence of irrigation facilities and ownership of radios, television or mobile phones by a household (Table 1). Irrigation facilities are crucial for rain-fed agriculture-dependent households, as these facilities help farmers to practise dry season farming. It is assumed that households with irrigation facilities will be less vulnerable to changing rainfall patterns. Hence, households without irrigation facilities scored 1, whilst those with these facilities scored 2. The presence of radios, television or mobile phone in a rural household can be an effective tool for communication and accessing information on changing weather patterns (see Naab and Koranteng 2012). Here, households with any of these three assets scored 2, and those without any scored 1. Physical assets such as road networks and the availability of markets and health facilities may enhance the adaptive capacity of a household (see Zhang et al. 2007). These assets were not included in the vulnerability computation because field observations suggested that these physical assets did not significantly differ amongst either the resilient or vulnerable communities.

2.3.6 *Livelihood diversification*

In addition to exploring the five capital assets, this study also examined whether households in resilient and vulnerable communities diversified their livelihood activities. This is

important because diversification has been reported as one of the main strategies for reducing household vulnerability to the impacts of climate change and variability (see Ellis 1998; Barrett et al. 2001). Therefore, the number of livelihood activities that a household was engaged in was also assessed. It is assumed that households with more diversified livelihood sources may be less vulnerable to the impacts of climate change compared to households that depend only on agriculture. The livelihood approach argues that agriculture-dependent households may be able to reduce their overall vulnerability to climate variability by diversifying the strategies pursued within their livelihood portfolios or specialising to take advantage of a niche (see Ellis 1998; Bebbington 1999; Fraser et al. 2005). Hence, the livelihood vulnerability index is estimated to be directly proportional to the number of livelihood activities in which a household engages. A score of 1 was therefore given to households that had only one livelihood activity, 2 for households having two livelihood activities, 3 for those with three livelihood activities, 4 for those with four livelihood activities, and households with >4 livelihood activities scored 5.

2.4 Standardization and weighting of selected indicators

To ensure the comparability of indicators that were used in the construction of the household livelihood vulnerability index, all indicators were standardised following the UNDP (2007) procedure of standardising indicators for life expectancy index (Eq. 1). This ensures that all indicators were normalised to have a relative position between 0 and 1 (see Vincent 2004; Hahn et al. 2009).

$$\text{Index value (standardized value)} = \frac{\text{Actualvalue} - \text{minimumvalue}}{\text{Maximum value} - \text{minimum value}} \quad (1)$$

Having standardised the indicators, it was then necessary to elicit appropriate weights to them. An unequal weighting system, based on relative importance attached to each indicator by local households, extension officers, key informants and experts was used because it was deemed necessary to include the views of both local households and experts in the assessment. Hence, a five-point Likert scale was used where farmers, extension officers, key informants, and experts were asked to rank the five most important indicators that they considered to influence vulnerability at the household level (Table 2). The number of times a particular indicator was cited was used to generate the weighting system (Table 2). The following weights were assigned: 14 % to social capital, 11 % to human capital, 9 % to natural capital, 27 % to financial capital, 10 % to physical capital and 29 % to livelihood diversification (Table 2). The household livelihood vulnerability index for a household was then calculated using the following model (Eq. 2) (Vincent 2004).

$$\begin{aligned}\text{HLVI} = {} & (\text{Ssvi} \times \textit{Wi}) + (\text{Hsvi} \times \textit{Wii}) + (\text{Nsvi} \times \textit{Wiii}) + (\text{Fsvi} \times \textit{Wiv}) + (\text{Psvi} \times \textit{Wv}) \\ & + (\text{Lsvi} \times \textit{Wvi}) \end{aligned} \quad (2)$$

where HLVI = household livelihood vulnerability index, Ssvi = standardised value of social capital asset sub-index, Hsvi = standardised value of human capital asset sub-index, Nsvi = standardised value of natural capital asset sub-index, Fsvi = standardised value of financial capital asset sub-index, Psvi = standardised value of physical capital asset sub-index, and Lsvi = standardised value of livelihood diversification sub-index. The Wi terms refer to the weighting that was applied to each standardised value: $Wi = 0.14$, $Wii = 0.11$, $Wiii = 0.09$, $Wiv = 0.27$, $Wv = 0.10$, and $Wvi = 0.29$ (Table 2). The inverse of the value for the indicators was estimated to ensure that high values always indicated high

Table 2 Weighting system based on local farmers, extension officers, key informants and experts perceived relative importance of various indicators

Component	Indicator	Times cited as most important	Relative importance	Weighting (indicators %)	Rank	Weighting (components %)
Social capital	Access to climate information	11	3.86	4.00	9	14.00
	Membership of social groupings	23	8.07	8.00	6	
	Availability of extension service	6	2.11	2.00	11	
Human capital	Educational level of the household	26	9.12	9.00	4	11.00
	Health of the household	5	1.75	2.00	12	
Natural capital	Type of land tenure system	7	2.46	2.00	10	9.00
	Size of farm holding	19	6.67	7.00	8	
Financial capital	Farmers receiving remittances	24	8.42	8.00	5	27.00
	Ownership of livestock/ poultry	21	7.37	7.00	7	
	Access to credit facility	33	11.93	12.00	2	
Physical capital	Access to irrigation facilities	28	9.82	10.00	3	10.00
	Ownership of radios, television and mobile phones	0	0.00	0.00	13	
Livelihood diversification	Alternative livelihood options	82	28.77	29.00	1	29.00
($N = 270$ households, 9 key informants[a], 3 extension officers, 3 experts[b])		285	100.00	100.00		100.00

[a] Key informants included persons who know something special about such villages including opinion leaders such as chiefs, assemblyman, village teachers and youth leaders who are decision makers in these communities

[b] Experts included academicians and other professionals in NGOs who have specialist knowledge in climate variability and how it affects agricultural productivity in rural agricultural-dependent households

vulnerability. The line of reasoning here is that low vulnerability indices reflect lower vulnerability of a particular household. Indeed, this has important implications in conveying the findings of this study to policy makers as it is easier to communicate that high vulnerability index scores denote high vulnerability.

The limitation of this local-level vulnerability assessment applying indicators is acknowledged. Furthermore, using current proxy indicators based on the existing

vulnerability of households poses a problem when considering vulnerability to climate variability in the future since these indicators are dynamic (Vincent 2007; Eakin and Bojorquez-Tapia 2008). The household livelihood vulnerability index provides a snapshot in time of the vulnerability of a particular household and therefore does not capture its changes over time and space. Nevertheless, it helps in the identification of vulnerable communities and households at the current time, as well as guiding appropriate adaptation pathways (Adger and Kelly 1999; Abson et al. 2012).

2.5 Data analysis

Qualitative data were coded and indexed through content analysis and the major themes that emerged analysed (Krippendorff 2004). This highlighted the major characteristics of households and the main livelihood assets accessible to such households. These major themes were triangulated through more in-depth key informant interviews, and any contradictions between data sources were clarified through focus group discussions. Quantitative data were transcribed and analysed using SPSS and Minitab (Edition 15). Using Minitab, a one-way ANOVA was computed to compare the relative vulnerability among the various households and communities, and all differences resulting in $p < 0.05$ were considered statistically significant. K-means cluster analysis using STATISTICA software was undertaken to group the households according to their vulnerability. K-means cluster analysis, which seeks to group cases into distinct clusters by seeking groups that minimise variability within clusters and maximise variability between clusters (Levia and Page 2000), has been applied to spatial vulnerability assessment in dynamic systems (see Antwi-Agyei et al. 2012).

3 Results

The results of the vulnerability analysis are presented at the community and household levels. First, the paper explores the differences in vulnerability index between the communities studied, using the livelihood vulnerability index that was constructed based on the information collected in Sect. 2.3. Following this, the paper identifies various vulnerability clusters and characterises the households within these clusters. Finally, the paper identifies "outlier households" to explain the nature of vulnerability at household level.

The results of the overall vulnerability of the farming communities are presented in Fig. 2. The vulnerability differs significantly amongst the various communities ($p < 0.05$). Within the resilient region, Aframso showed the greatest vulnerability (0.524) with Babaso demonstrating the lowest vulnerability (0.387) whilst Nyamebekyere recorded a vulnerability of 0.487.

While the standard deviations are quite similar, Fig. 2 shows that amongst the vulnerable communities, Vea recorded the lowest vulnerability of 0.629 with Ayelbia showing the greatest vulnerability of 0.841. Adaboya recorded a vulnerability of 0.749. These results suggest that Babaso and Vea showed the lowest vulnerability in their respective study regions. The results also suggest that Ayelbia was the most vulnerable community amongst the six study communities.

Figure 3 shows the major components contributing to vulnerability for a particular community. Figure 3 suggests that a lack of financial capital is the biggest contributor to overall vulnerability in all the six study communities. Regardless of the context (whether a household is located in a resilient or vulnerable community), low financial capital pulls up

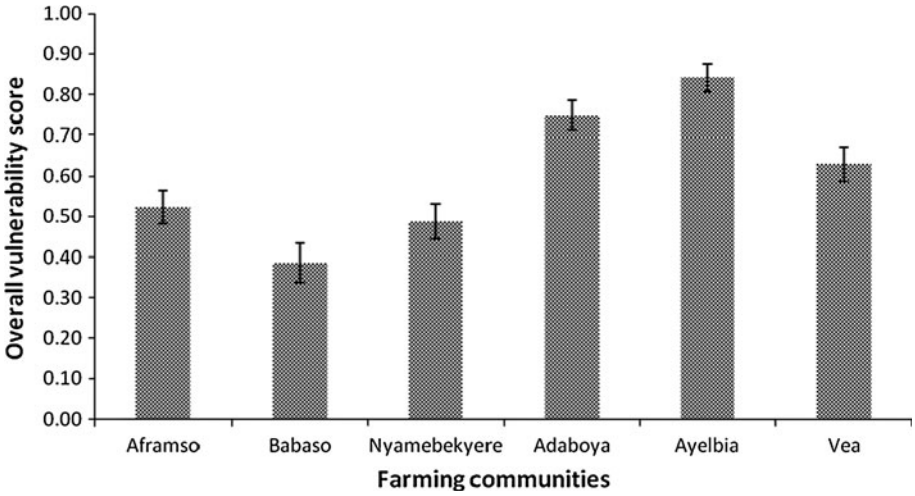

Fig. 2 Vulnerability of the study communities (Aframso, Babaso and Nyamebekyere represent the "resilient" communities whilst Adaboya, Ayelbia and Vea are the "vulnerable" communities)

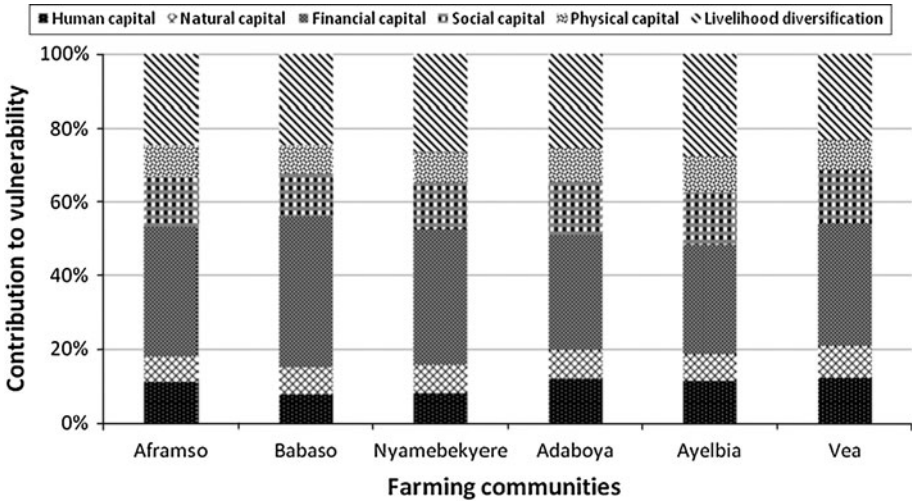

Fig. 3 Components contributing to vulnerability of study communities

the vulnerability index, increasing vulnerability. The impact of financial capital on the overall vulnerability of a particular community was, however, more pronounced in the vulnerable communities.

Despite significant socioeconomic differences across the six study communities, Fig. 4 shows that there are three major clusters of households belonging to *low, medium and high* vulnerability clusters. Households within a particular cluster share similar characteristics in terms of access to livelihood assets and the livelihood activities pursued. The means of the various vulnerability clusters were significantly different ($p < 0.05$). Figure 4 also shows that Babaso (which demonstrated the lowest vulnerability) recorded the highest percentage of households within the low vulnerability cluster (49 %) with only 9 % being within the

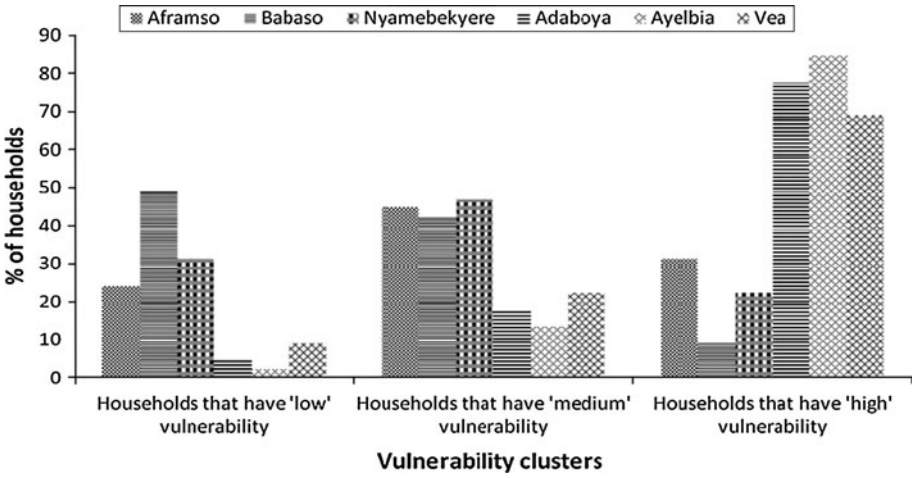

Fig. 4 Proportion of households in different vulnerability clusters in study communities

high vulnerability cluster. Amongst the vulnerable communities, Vea (which showed the lowest vulnerability) recorded 9 and 69 % of households in the low and high clusters respectively (Fig. 4). This compares with Ayelbia (the most vulnerable amongst all the study communities) which recorded 2 and 84 % of households within the low and high vulnerability clusters respectively.

Quantitative analysis shows a small proportion of households (including 35 and 5 % in the resilient and vulnerable communities respectively) that tend to engage in a number of livelihood activities outside of agriculture were found to belong to the 'low vulnerability' cluster (Fig. 4). Households belonging to this cluster had diversified livelihoods including other non-farm jobs such as teaching, petty trading and fishing and also tended to have secure land tenure with relatively large farm holdings. Hence, these could be described as multi-activity households in which the household pursues more than one livelihood activity. Mostly, such households have a principal livelihood activity, with a number of complementary livelihood strategies. Households in this cluster also tend to be highly socially connected with some having political power in terms of decision making, because of a leadership role as for example chief, assemblyman, and other opinion leaders (see Cases 3 and 4).

An estimated 21 and 77 % of households in the resilient and vulnerable communities respectively belonged to the 'high vulnerability' group (Fig. 4). This cluster comprises single-activity households whose livelihoods were defined principally by agriculture-based activities. They tend to depend solely on crop farming as the principal livelihood activity and have limited social capital in the communities. Households in this cluster tend to have insecure land tenure (e.g. Case 1 in Table 3). In between the low and high vulnerability clusters is a group of households that were classified as 'medium vulnerability'. These included 44 and 18 % of the households in the resilient and vulnerable communities respectively. These are households that may have crop farming as a principal livelihood activity but also tend to invest in livestock and poultry production which can be sold when things become hard for such households.

In addition, Fig. 4 revealed that there were outlier households within both the resilient and vulnerable communities. An outlier household is defined as a household that belongs to the resilient community but actually is put into the high vulnerability cluster by the

Table 3 Oral history narratives with example case study of outlier vulnerable and resilient households

Case 1—Vulnerable household in a resilient community: Ms Amina[a]*, age 56 years, living with five children at Nyamebekyere*

This household, which is perceived by the local community as a poor household, is headed by Ms Amina. Born in 1956, Ms Amina, a widow, moved from the Bunkprugu Yooyo district to Nyamebekyere in the 1980s because of the good soil and environmental conditions for farming in this village. During this time, her husband also used to work as a watchman to support the family. They used to cultivate about 8 acres of land and harvested about 50 bags of maize. Ms Amina's husband died in 2007 and she does not have any reliable source of income. This household cultivates an average of 3 acres of land and harvests about 15 bags of maize each year. As a migrant to the area, Ms Amina stressed the difficulties in accessing the most fertile lands for agricultural activities. She indicated that she either rents land and in return gives a bag of maize per acre of land to the land owner after harvesting or she cultivates the land in what is locally termed as '*abanu*' where the land owner gives you land and planting materials and shares the yields equally after harvesting. Without any formal education, Ms. Amina has no alternative source of livelihood apart from farming and she only grows crops. She has no livestock or poultry. To supplement her income, she sometimes works on other people's farms to earn extra income, which means less time on her own farm. She indicated that she has no money to buy fertilizers to improve soil fertility and has to rely solely on animal droppings to enrich the soil. Ms Amina does not belong to any farmers' associations in the village and does not receive remittances. Ms Amina has observed less rainfall recently compared with when she first moved into this village. According to her, the onset of the rains is now delayed and the duration of the rains during the farming season is uncertain. The household uses different climate adaptation options including changing timing of planting and planting different crops to cope with climate variability in the community. Explaining some of the coping strategies, Ms Amina said, "*Sometimes I work on other farmer's farm in exchange for food for my family.*" In terms of barriers to climate adaptation, the household highlighted lack of funds, the high cost of improved varieties of crops and land tenure insecurity. Ms Amina said, *"It is very difficult for farmers to obtain credit facilities for farming operations in this community. I rely on my limited personal resources to plough the land. I provide all the farm labour myself with the assistance from my children."*

Case 2—Vulnerable household in a resilient community: Ms Adwoa Owusuwaa[a]*, aged 58, living with five children at Aframso*

This household is perceived by the local community as poor. Born in Aframso, when Ms Owusuwaa started farming, the rains were quite predictable and farmers could appropriately time this for planting their crops. She used to cultivate maize and did not have to rely so much on fertilisers for higher yields as the soil and the rainfall were reliable. According to her, since the late 1980s, the rainfall pattern has become less reliable. The drought of 1983 destroyed her maize farm and other cash crops including cocoa. She and her husband started growing other crops such as groundnut in the early 1990s. In response to the increasingly erratic rainfall patterns in the community, in the 1990s this household began growing cassava that is drought tolerant. During this period, the household invested part of the money from their crop farming into livestock and poultry. In the late 1990s, the household received support in the form of remittances from their elder son who was working as a driver in Accra. In the mid 1990s, the household sold all their livestock and poultry to cope with drought-related famine. By early 2000, the household had no poultry or livestock. The son who used to send her money has also lost his driving job with the company he used to work with. Currently, the household cultivates only 3 acres of land for maize and rice and sometimes has to rely on friends and family to obtain food. Without formal education, Ms Owusuwaa has no alternative sources of livelihood apart from farming. Ms Owusuwaa put this bluntly as *"I have no alternative sources of livelihood and rely entirely on crop farming to feed my family. This means that any time the rains fail me then my household is in serious trouble in terms of food for the family. This problem is compounded by the fact that I receive no remittance from anywhere."* Currently, this household has no livestock or poultry. The household has no bicycle or spraying machine. Also, they have no radio, mobile phone, or television in the house. Neither Ms Owusuwaa nor any of her children belong to any association in the village. Lack of funds, limited access to and high cost of improved varieties of crops, and lack of farm implements are some of the main barriers confronting the implementation of appropriate climate adaptation by this household.

Table 3 continued

Case 3—Resilient household in a vulnerable community: Mr. Abanah[a]*, age 43, living with wife and four children at Vea*

Born and growing up at this village, the head of this household, Mr. Abanah is a degree holder. Mr. Abanah has been a professional teacher since 1993 and is the head teacher of the local primary school. This household is considered by the local community to be a rich household. Apart from farming, the household also keeps livestock and poultry. Mr. Abanah is also the Assemblyman for the Vea electoral area and one of the opinion leaders upon whom most of the people in this community rely for decision making concerning this community. Mr. Abanah receives a salary from his teaching profession and allowances when he attends meeting at the assembly. As a strategy, this household invests part of their salary in livestock production by buying livestock from other farmers in the village and surrounding communities during the dry seasons when the price of livestock are generally cheap as farmers need to sell to get money to buy foodstuffs to feed their families. Mr. Abanah indicated that his household sells their livestock when the prices are good. The household has two acres of irrigated land around the Vea irrigation dam and this allows them to cultivate tomatoes during the dry season. The household also owns a motor bicycle, radio, and mobile phone that they use to listen to and access information. Mr. Abanah inherited his farm land from his father and therefore has secure land tenure. The household grows late and early millet, guinea corn, beans and sorghum. Mr. Abanah is a member of the Ghana National Association of Teachers (GNAT) as well as The Roman Catholic Church at Vea. Since the mid 1990s, this household has changed their cropping patterns and grows improved varieties of crops in response to climate variability. Additionally, the household has changed its timing of planting since the late 1990s and grows different crops at the same time. Importantly, the household is engaging in more non-farm jobs. Lack of institutional support through extension services, limited access to improved varieties of crops and lack of farm implements are some of the major barriers to climate adaptation highlighted by this household.

Case 4—Resilient household in a resilient community: Mr. Odum[a]*, aged 55 living with wife and five children at Nyamebekyere*

Headed by Mr. Odum, this household lives in a three bedroom aluminium zinc roofed house and is perceived by the local community as rich. Born in 1957 in Mampong, Mr. Odum moved to Nyamebekyere in 1971. Mr Odum claimed that the rainfall patterns have changed. "*When I moved into this village, the rains used to start a bit early in February for planting to be done. But now the rains do not come until late March.*" Apart from farming, Mr Odum keeps livestock and poultry. He has 30 sheep and 25 goats with a number of poultry. Mr. Odum has a Middle School Leaving Certificate. He also works as a farm lands revenue collector which, according to him, brings him extra income. He earns 15 % as commission of the total revenue he collects for the stool land administrator in Kumasi. His wife, Ms Mantey who has primary education is also a petty trader who buys foodstuffs from farmers at the Nyamebekyere village and sells them at the Ejura market. The household is able to cultivate 15 acres of land and harvests, on the average, 100 bags of maize, and 25 bags of beans per annum. Mr. Odum and his wife also have three older children who work in different parts of Ghana (in Kumasi, Dunkwa and Accra). Mr Odum claims his household regularly receives remittances from his sons who are businessmen. Mr Odum said: "*My sons send us money regularly and this is used to help with our farming activities including ploughing, purchasing fertilisers and other farm inputs. This makes us less vulnerable to drought because we are able to plant on time to avoid the drought during the critical period of maize.*" Mr Odum continued: *"Because of this we are always one of the first households to harvest in this village and this gives us premium prices for our cereals including maize."* Mr Odum is a member of the Millennium Development Account, which helps farmers with farm inputs such as fertilisers and seeds. Mr Odum and his wife are members of the local Pentecostal church which serves as informal network for information sharing. In response to climate variability, Mr Odum claimed to have changed his cropping patterns. "*I now grow the improved varieties of maize such as obaatanpa, dobidi* etc. *that are early maturing.*" The major challenges confronting this household in terms of climate adaptation include the lack of and/or high cost of farm inputs, lack of reliable climate adaptation information especially regarding the onset and duration of the rainfall, and lack of institutional support. Elaborating on the barriers to climate adaptation, Mr Odum stated: *"We are not able to receive accurate and reliable information from the weather people in terms of the distribution of the rainfall during the farming season and this makes it very difficult for farmers to plan their farming activities."* The household owns a television, radio, and a mobile phone, which they use to communicate and access information on weather forecast.

[a] Real names have not been used

k-cluster analysis or a household that belongs to the vulnerable community, but k-analysis puts that household into the low vulnerability category.

The qualitative differences between such outlier households and typical households within the same community were explored in greater depth. Identifying such households provides useful insights into the problems that lead to households being vulnerable even in relatively resilient communities. Results revealed that outlier households in the vulnerable communities were more resilient because they have alternative sources of income and have secure land tenure with relatively large farm holdings. They were also characterised by extensive social networks and may have access to both bonding and bridging social capital. Further, the results suggest that some of these outlier households tend to be politically connected because of their positions within the communities (e.g. Cases 3 and 4 in Table 3). By contrast, outlier households in the resilient communities tend to be less socially connected, depend entirely on crop farming and are characterised by limited access to capital assets. Table 3 presents case study oral histories with outlier households in both resilient and vulnerable communities. Table 4 shows the characteristics of outlier and typical households in the study communities and demonstrates how livelihood diversification and access to capital assets can reduce vulnerability to climate variability.

4 Discussion

The results show that rural households with access to capital assets (financial, human, natural, physical, and social) are less vulnerable to the negative impacts of drought (Tables 3, 4). The findings suggest that diversification of livelihood activities into non-farm income jobs is crucial for coping and adapting to drought in rain-fed agricultural systems. These points are expanded on in the following sections, and the implications for drought vulnerability and food security are explored.

4.1 Gender and climate vulnerability

Female-headed households without any reliable sources of income were more vulnerable than male-headed households (Cases 1 and 2). For instance, outlier households Case 1 and Case 2 (within the resilient communities) provide insightful characteristics when compared with a typical household (i.e. Case 4). Outlier Case 1 shows that the household has no reliable source of income and depends solely on crop farming. The head of the household, Ms Amina, claimed that she earned about 10 Ghana cedi (US$6.67) per day by working as a labourer on another farmer's farm. This amount is able to take care of the household for less than 4 days and according to her, she will have to wait for the opportunity to be employed by another farmer. This contrasts sharply with Case 4 in the same community (Nyamebekyere), where the head of the household, Mr Odum, claimed that he has other non-farm income sources and receives regular remittances from his sons working elsewhere. By receiving support from their sons, this household is able to plan their planting and other farming activities that are crucial in these farming communities. With rainfall becoming more erratic in sub-Saharan Africa (Boko et al. 2007), if a household misses the onset of the rains, it can ultimately affect crop productivity. Another possible explanation for higher vulnerability of female-headed households is that women in the study communities and sub-Saharan Africa more widely have limited access and control over physical resources and assets such as radios, irrigation facilities and transportation systems that could enhance their capacity to adapt to climate variability (Naab and Koranteng

Table 4 Key characteristics of the outlier and typical households in study communities

Household cluster	Within resilient communities		Within vulnerable communities	
	Outlier vulnerable households	Typical households	Outlier resilient households	Typical households
Human capital assets	Such households do not have any formal education with relatively large household sizes.	Most households have at least primary education. Can be male- or female-headed households.	Relatively educated households (with at least 6 years of education).	Members of such households have no formal education.
Principal livelihood activities	Crop production on a subsistence basis. May not have livestock or poultry and therefore depend solely on crop farming.	Households have diversified their livelihood sources into non-farm income jobs. Mostly involved in monoculture commercial crop production systems.	Households have at least one member who is in permanent employment or commercial business. These non-farm income jobs are less negatively impacted by climate variability.	Households depend mainly on crop farming. Crops grown include sorghum, late and early millet and beans. No form of non-farm jobs for most households.
Natural capital assets	Majority of households tend to be migrant farmers who are landless and have insecure tenure. Hence, have small farm holding.	Have access to land and tenure security. Have relatively larger farm holding but tend to engage in monoculture commercial cropping patterns because of mechanization.	Households have access to land and secure tenure. Some households have access to irrigation facilities and are able to invest in improved varieties of crops.	Have relatively small farm holdings with poor soil due to continuous cultivation of same land without the addition of suitable soil amendments. Female-headed households have no tenure security.
Poverty levels	Poverty levels are relatively high compared with typical households in such communities. Households have difficulties in accessing credit and do not receive remittances.	Poverty is moderate because of access to non-farm income. May receive regular remittances from families and friends working in the cities.	Received income from non-farm jobs that gives such households some form of financial security.	Extremely poor without access to credit. Unable to sell farm produce as a source of support because of small farm holding. Rely on external support during climate-related crisis such as drought.
Social capital assets	May belong to at most one social grouping. Have no real political power within such community. Social identity includes crop producers.	Highly connected to wide range of social networks. Some households may have access to both bonding and bridging social capital assets.	Have access to bridging social capital in terms of membership of recognised groups. May have political power in the village because of their social status.	Generally, households do not belong to any recognised social grouping. Have no political power in terms of decision making in the village. Mainly crop producers with few livestock keepers.

2012). These findings reaffirm previous research by Eriksen et al. (2005) and contribute additional evidence that suggests that female-headed households without any reliable non-farm income jobs are more vulnerable than male-headed households. This has implications

for policymakers and development partners in enhancing drought preparedness of different households in such communities and implies that a targeted approach is needed to assist female-headed households.

4.2 Vulnerability of different wealth groups

The wealth of particular households could greatly influence their vulnerability. For instance, Table 3 shows that households (such as Cases 1 and 2) that were perceived to be poor by the local community tend to be more vulnerable compared with relatively richer households within the same community that may be experiencing a similar level of climate exposure (e.g. compare outlier Cases 4 and 1). Indeed, several writers have documented the role of wealth in enhancing the adaptive capacity of rural poor households (e.g. Moser 1998; Adger and Kelly 1999; Sen 1999; Brooks et al. 2005; Moser and Satterthwaite 2008). Moser and Satterthwaite (2008) argue that the asset portfolio of the household is crucial in determining its capacity to reduce the impacts of climate variability. This paper advances this debate by highlighting that outlier households such as Cases 3 and 4 that were considered as rich households by the local communities were less vulnerable than poor households (Cases 1 and 2). Results here support Sen's (1999) argument that poverty constrains the capability of poor households to cope with the impacts of climate variability (e.g. Case 1). This is because poor households have limited asset portfolios that can be used to reduce the impacts of climate change and variability on their livelihoods (Adger and Kelly 1999).

4.3 Access to human capital assets and vulnerability

The analysis shows that vulnerable households were characterised by low levels of education. Outlier households in the resilient communities and typical households in the vulnerable communities that demonstrated the greatest vulnerability to drought were defined by low educational levels (e.g. Case 1 and Case 2; Table 4). Increased literacy can increase the capacity of the household to access climate information, which can subsequently enhance the adaptive capacity of the household to buffer against negative impacts induced by climate change and variability (see Leichenko and O'Brien 2002). Education can also have a positive impact on overall farm productivity, and this is especially crucial in the context of dryland farming systems in sub-Saharan Africa. Weir (1999) argues that education may change the belief systems that may be inimical to increased agricultural productivity. Consequently, this may increase the household's willingness to accept agricultural innovations and new technologies to cope with current climate variability that are essential for increased farm productivity (e.g. Lin 1991). Invariably, this helps households to build their adaptive capacity to cope with future climate variability. Low educational standards (such as Cases 1 and 2) limit the capacity of a household to increase their potential for non-farm livelihood activities (Paavola 2008).

4.4 Livelihood diversification

Supporting the studies by Ellis (1998) and Barrett et al. (2001), this paper has shown that vulnerable communities were characterised by households with limited options in terms of livelihood diversification. For instance, comparing outlier case study households in Cases 3 and 4 (i.e. resilient households) with Cases 1 and 2 (i.e. vulnerable households) suggests that those households that have diversified their livelihood activities were less vulnerable

compared with those that depended solely on agro-based farming activities. By diversifying their livelihood sources and having access to or ownership of a range of different capital assets, resilient households (such as outlier households in vulnerable communities) have a broader livelihood portfolio that they can use to reduce their vulnerability to drought (Ellis 1998; Fraser et al. 2005). Case 3 and Table 4 provide further evidence to suggest that the availability of alternative non-farm income is crucial for the survival of rural agriculture-dependent households in the face of climate variability. Building on previous research on livelihood diversification (e.g. Chambers and Conway 1992; Ellis 1998; Barrett et al. 2001; Paavola 2008; Sallu et al. 2010), these results provide additional evidence to show how rural households in vulnerable communities employ a range of non-farm livelihood activities with different risk attributes as complementary strategies to buffer against the negative impacts of drought.

4.5 Institutional support and social capital

Another significant feature of 'outlier' households that can shed some insights into the characteristics of vulnerable households is the kind of institutional support and social capital available. Outlier households in the vulnerable communities such as Case 3 (and Table 4) have greater access to social and political capital compared with typical households within the same communities. In addition, oral history narratives with outlier households in the vulnerable communities revealed that such households have access to bonding social capital through family and ethnic ties, whereas their positions as assemblymen, chiefs, teachers, and other opinion leaders give them access to bridging capital which transcends ethnicity and socioeconomic factors. Also, such households can rely on their informal networks such as the church in times of crisis or drought-related famine in these communities (e.g. Case 3). On the contrary, outlier households within the resilient communities and 'typical' households in the vulnerable communities have limited access to bonding capital. Moreover, their lack of access to external ties does not allow them to access bridging capital. Several writers have documented the role of social capital in coping with the impacts associated with environmental (including climate) change in communities (Adger 2003; Pretty 2003; Osbahr et al. 2010).

4.6 Interaction between natural capital assets and climate vulnerability

In terms of natural capital and vulnerability, the analysis suggests that typical households in the resilient region were characterised by a high natural capital base compared with outlier households within these communities (Table 4). A similar instance was observed within the vulnerable communities, where outlier households were characterised by high levels of natural capital compared with typical households. This high natural capital needs to be explored in terms of its implication for food production in rural agricultural households in sub-Saharan Africa and how this relates to the overall household's vulnerability to climate variability. This is because natural capital assets may provide useful economic opportunities to agriculture-dependent households in rural communities. For instance, picking of wild food such as mushrooms and snails may constitute a significant source of food to reduce vulnerability to drought-induced food insecurity in the study communities and sub-Saharan Africa more widely (Ziervogel et al. 2006; Paavola 2008; Sallu et al. 2010).

5 Conclusions and policy implications

This paper builds on a national- and regional-level vulnerability assessment (Antwi-Agyei et al. 2012) by developing and applying a livelihood vulnerability index at the community and household levels to characterise the nature of climate vulnerability. This targets an important gap in the literature, improving understanding of the processes and factors that create vulnerability, with a view to guiding the development of effective policies. This study has shown that within the same agroecological settings, different communities and households may experience differential vulnerability that may be attributed to differences in livelihood characteristics. The analysis also shows that vulnerable communities tend to have households that are characterised by low levels of human, natural, financial, physical and social capital assets. Further, results identified vulnerable households within the resilient communities as well as more resilient households within vulnerable communities. These novel results suggest that outlier households in vulnerable and resilient communities could offer useful insights into climate vulnerability at the household level. For instance, outlier households in vulnerable communities have an array of alternative livelihood options and tend to be socially connected, enabling them to take advantage of opportunities associated with environmental and economic changes. On the contrary, the results demonstrate that outlier households in the resilient communities tend to be less socially connected, depend entirely on crop farming and are characterised by limited access to livelihood capital assets. Therefore, identifying such outlier households provides valuable insights into the problems that lead to households being vulnerable even in relatively resilient communities.

This study also provides innovative methodological steps in relation to livelihood assessment that can be used to characterise adaptive capacity and hence, the vulnerability to drought of a particular farming community. Although it is acknowledged that such local-level vulnerability assessments are very resource intensive, the innovative methodological approach outlined in this paper is reproducible and will improve drought vulnerability assessments in Ghana and more widely. Use of a mixed-method approach allowed the validation and deepening of understanding of the main issues involved in vulnerability of farming systems to climate variability through triangulation, thus providing a significantly richer understanding of the different dimensions of the problem through its exploration across scales. By using a multi-scale approach (i.e. community and household) as widely called for in the vulnerability literature (Gibson et al. 2000; Wilbanks 2007), this paper avoids the danger of narrowly focusing on one scale of climate variability problems.

This study has provided a more nuanced understanding of how different households could be impacted by climate variability. Building on previous research on livelihood diversification (e.g. Ellis 1998; Barrett et al. 2001; Paavola 2008; Sallu et al. 2010) and livelihood capital assets (e.g. Sen 1981; Moser 1998; Bebbington 1999), a clear need has been identified to support rural households through their participation in non-farm livelihood activities to reduce the adverse impacts of drought. Findings in this paper will help to guide a more general discussion of the sorts of livelihoods that enhance adaptive capacity to future climate changes and thus allow households to maintain food security. The implication of the results is that policy makers need to formulate specific and targeted climate adaptation policies and programmes that foster asset building so as to increase the capacity of vulnerable households to engage in non-farm activities that are less likely to be adversely impacted by climate variability and change. This should be linked to enhancing livelihood diversification as well as institutional capacity and social capital. Vulnerable

households should also be targeted in terms of resource allocations and other interventions aimed at reducing vulnerability to climate variability.

Acknowledgments This study was funded by the Commonwealth Scholarships, UK and the International Foundation for Science (IFS). The authors gratefully acknowledge the constructive comments by Dr Susannah Sallu (University of Leeds) on an earlier draft of this paper. The authors would also like to thank the three anonymous reviewers for their insightful comments and suggestions.

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