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Sunshine, temperature and wind

Community risk assessment of climate change, indigenous knowledge and climate change adaptation planning in Ghana

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Abstract

Purpose – This paper aims to draw on community risk assessment (CRA) for assessing vulnerability to climate change in north-western Ghana, focusing on sunshine, temperature and wind, elements of climate which are seldom explored in vulnerability assessments to climate change.

Design/methodology/approach – The paper draws on data collected from a qualitative research design that used participatory rural appraisal methods, particularly, in-depth interviews, focus group discussions and seasonal calendar analysis in three selected rural communities of the Sissala East District. Furthermore, an inter-generational framework was adopted for comparative assessment of vulnerability and changes in vulnerability to climate change.

Findings – The results show that the current generation of smallholder farmers is more vulnerable to climate change than the past generation, the era of grandparents. Thus, farmers are exposed to higher-intensity sunshine, temperature and wind in contemporary times than was the case in the past. Consequently, their livelihoods are affected the most by the damaging effects of these climatic hazards. The CRA process revealed the relevance of indigenous knowledge systems for vulnerability assessments and at the same time, underpins the need for adaptation of such knowledge if it is to sustain smallholder farmer efforts at climate change adaptation at community levels.

Practical implications – The paper recommends an endogenous development approach to climate change adaptation planning (CCAP), one that will build on indigenous knowledge systems for effective community education, mobilization and participatory response to climate change. Policy interventions should aim at enhancing climate change adaptation through innovations in soil and water conservation, access to water for irrigation and domestic use, climate smart-housing architecture and agro-forestry within the framework of decentralization and district development planning.

Originality/value – This paper will contribute to climate change research in two ways: first, by drawing attention to the usefulness of CRA in vulnerability assessment; and second, by focusing on climate elements which are critical for CCAP but rarely given sufficient attention in vulnerability assessments.

Keywords Climate change, Vulnerability, Indigenous knowledge, Climate change adaptation planning, Community risk assessment

Paper type Research paper

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1. Introduction

The paper draws on indigenous people's knowledge for conducting community risk assessment (CRA) of climate change and climate variability, focusing in particular, on sunshine, temperature and winds in Ghana. Most climate change research focuses on rainfall changes because of its direct effect on farming to the neglect of other equally important factors that affect livelihoods. It is evident that scientific knowledge systems need to be complemented with indigenous knowledge systems for enhancing effective community resilience to climate change.

Climate change, precipitation variability and recurrent droughts have adversely affected the economy of Ghanain urban and rural settlements annually (World Bank, 2010). Rainfall variability, increasing intensity of temperature, sunshine and wind intensities are getting worse and compromising agriculture and food security in Ghana. Temperatures in northern Ghana are the highest in the country and projected to increase by about 2.1-2.4°C by the year 2050 (World Bank, 2010). The forecast is that climate change will have a profound adverse effect on agriculture, leading to a decline in crop and livestock production and consumption in northern Ghana (World Bank, 2010; Gyampoh and Asante, 2011). Thus, CRA is critical for informing climate change adaptation planning (CCAP).

2. Vulnerability to climate change in West Africa

Climate change is distinct from climate variability mainly in relation to time or period of change. Climate change often refers to changes in the mean and/or the variability of its properties for a long period, typically decades or longer. Climate change may be caused by natural internal processes or by external factors as in anthropogenic forces (IPCC, 2012). Climate variability is variations in climate, including the normal highs and lows, wet and dry periods, hot and cool periods and extreme values. It can range from day-to-day variability and to year-to-year variability. It can even refer to decadal scale variability except that such variability over a multi-decadal scale is climate change (USAID, 2014).

Evidence of climate change in West Africa abounds in the literature. In respect of precipitation, the pattern in West Africa demonstrates a high level of year-to-year variability with alternating wet and dry years occurring in series over decades (Hulme *et al.*, 2001). The periods 1950-1970 and 1971-2000 in the climate history of Africa and Sub-Saharan Africa were long, wet and dry periods, respectively. The forecast is that West Africa will witness significant decrease in total rainfall by 2100 because of anthropogenically driven global warming (Lemoalle, 2007; IPCC, 2007). Forecast for Ghana suggests a cyclical pattern for all regions and decrease and increase precipitations toward the northern and southern parts of the country, respectively. Temperatures in Sub-Saharan Africa are projected to increase with mean annual temperatures in the Sahel part of the Volta basin rising by 2°C and further by more than 3°C in April (Kunstmann and Jung, 2005). Forecast for temperature and precipitation trends over a 40-year period (2010-2050) show warming across Ghana with higher temperature projections for northern Ghana (World Bank, 2011). Such increase in temperatures in the basin will have a negative impact on agriculture, food security and health of the inhabitants. For instance, increased temperatures will likely increase the levels of water related diseases such as cholera in tropical waters and reduce agricultural yields (Lemoalle, 2007).

In Sub-Saharan Africa, high levels of poverty, low education, low technology, inequality, limited access to information and low financial status make countries and their populations the most vulnerable to the impacts of climate change (Care International, 2011). These factors coupled with rapid population growth drive extensive exploitation of natural resources and environmental degradation leading to scarcity of water and water resources in the Volta basin (Welling *et al.*, 2012). The incidence of annual floods, droughts and other hydro-meteorological hazards in the Volta basin already breeds tensions between and among the six riparian countries that share the basin (Brown and Crawford, 2008; Oyebande and Odunugu, 2007).

The agriculture sector is climate sensitive and very vulnerable to climate change. Agriculture is the primary occupation for majority of the active youth in West Africa and accounts for about 40 per cent of economic output in the Volta basin. The effects of increasing variations in precipitation and temperatures are negatively threatening agriculture and food security, water and water resources in Sub-Sahara Africa. Changes in precipitation manifest in shorter duration of the rainy season with severe consequences on rain fed agriculture and food security (Lemoalle, 2007; Kunstmann and Jung, 2005; McCartney *et al.*, 2012). A dramatic precipitation decrease of up to 70 per cent over the entire Volta basin is predicted for the beginning of the planting season (Kunstmann and Jung, 2005). This will adversely affect food crop, poultry and livestock production in Sub-Saharan Africa including regions within the Volta basin. Furthermore, increased temperatures will have adverse effects on evapotranspiration, vegetation, animal distribution and productivity. The concentration of carbon dioxide across West Africa reveals an adverse shift in the length of the growing season, with a decrease of about 20 days in the central part of the Volta basin (Lemoalle, 2007). In Benin, it is anticipated that climate change will cause a decrease of about 10-20 per cent in agricultural production by the year 2050. Food crop and livestock production in Togo are also anticipated to be adversely affected by climate change because of decreases in rainfall and increases in temperatures (Lemoalle, 2007). According to Brown and Crawford (2008), a decrease in annual rainfall by 3.4 and 7.3 per cent by 2025 and 2050, respectively, will seriously affect the production of cotton, maize and yam in Burkina Faso. This combined with a rise in temperatures by 1.7°C will reduce water availability for livestock in many Sub-Saharan African countries including Ghana.

In Ghana, as in many Sub-Saharan African countries, rain-fed agriculture is the primary source of livelihood (Antwi-Agyei *et al.*, 2011; McCartney *et al.*, 2012; Republic of Ghana, 2013). This implies that food crop farming and livestock production are vulnerable to climate change and climate variability and thus, undermine efforts at attaining food security, particularly in northern Ghana. Extreme climate conditions result in poor crop yields, crop failures, loss of livestock and loss of agricultural lands in northern Ghana. Overall, climate change evidenced in precipitation and temperature changes and the consequences of droughts and floods adversely affect agriculture production and translate into low agricultural production in Ghana and northern Ghana in particular (File, 2015). Farmers' inability to predict the onset of the rainy season amid decreasing rainfall and increasing duration of dry periods further increases their exposure to climatic risk and hazards such as droughts, floods and extreme temperatures that result in crop failure and loss of livestock (Laube *et al.*, 2008, p. 2; Andreini *et al.*, 2000). The floods that occurred in 2007 in Ghana affected about 332,600 people and caused the death of 56 persons in the Upper East, Upper West and Northern Regions and parts of Western Region (Kankam-Yeboah *et al.*, 2010; Republic of Ghana, 2013). These trends may undermine the socio-economic well-being of the country, particularly, northern Ghana given that the local economy is dominated by agriculture and other climate-sensitive sectors (Kuuzegh, 2007; World Bank, 2011; Republic of Ghana, 2013).

3. Community risk assessment and indigenous knowledge: conceptual framework for assessing climatic risks

In this paper, CRA is adapted as a conceptual framework for drawing on indigenous knowledge of the Sissala people for assessing climate variability. CRA involves the use of participatory approaches for assessment of vulnerabilities (hazards and capacities for disaster risk reduction) at community level (Aalsta *et al.*, 2008, p. 165). The CRA uses participatory approaches that combine local knowledge with scientific information to enable clear understanding of the implications of climate change for the lives and livelihoods of the people. This process builds local people's understanding about climate risks and adaptation strategies. It therefore provides a framework for dialogue within and between communities and other stakeholders for analyzing vulnerability and capacity to adapt to climate change at the community level (Care International., 2011). The recognition of indigenous knowledge in CRA makes it unique.

The CRA process can be complex and detailed depending on the availability of local resources. Rural communities are mostly confronted with inadequate access to weather and climate forecast information, low technology, poor infrastructure and low education among other challenges. In any case, the use of practical participatory tools create room for the use of local knowledge and available local resources in gathering, organizing and analyzing information on the vulnerability and adaptive capacity of communities, households and individuals. This makes CRA a simple process for community members and other users. The participatory process of CRA also provides learning and clear understanding of climate change impacts and adaptation initiatives and as well recognizes the role of indigenous knowledge in in CCAP. Therefore, the extent to which communities conduct risk assessment processes may usually depend much on the capabilities of communities and the resources available to them (Stouffer, 2015).

CRA serves as a guide for taking practical steps in preparedness and mitigation actions on climatic events that reduce both the chance of emergencies and the consequences when they cannot be avoided. It thus facilitates a clear understanding of community vulnerability and exposure to hazards to inform the process of preparing community contingency, emergency response and recovery action plans for addressing climatic events. It provides risk information that informs community residents, business owners and institution managers of the hazards to expect and how to best prepare for them (SRC, 2007). CRA can contribute to vulnerability and risk assessments by helping users to collect, synthesize and organize information about the development context, the climate context, climate impacts and risks and the design of adaptation responses (IISD, 2012).

The International Institute for Sustainable Development (IISD, 2012) outlines three phases and practical steps for conducting CRA in the project context. Phase 1 deals with the context of livelihoods and climate system of communities. The process specifies the impacts of and responses to identified climate hazards in the community. The outcome is a list of livelihood resources for men and women that are most affected by climate hazards and most important for responding to the impacts of these hazards. Phase 2 evaluates the implications for the project and builds on the information collected in Phase 2 to analyze how project activities affect livelihood resources that are either vulnerable to climate hazards or important for responding to the impacts of these hazards. The evaluation process enables actors to revise process activities of CRA toward reducing the level of exposure of livelihood options to climatic risks and hazards and designing new activities to reducing climatic risks. The outcomes include a list of project adjustments and prioritized new activities that support climate adaptation and a list of key opportunities and barriers to successful implementation of activities. Phase 3 is concerned with monitoring and evaluation (M&E) of climate adaptation. It helps identify some key elements that can be integrated into existing or newly developed M&E framework. It assesses the implementation of adaptation activities and the factors that influence or could influence their outcomes. This phase therefore, produces a list of desired adaptation outcomes and important influencing factors to be monitored.

Phase 1 and its steps, processes and outputs are relevant for this paper (Table I). Phase 1 concerns itself with understanding the livelihood and climate context and in particular, providing an opportunity for the local populations to participate in mapping the climate related risks that affect their livelihood systems and totality of life.

Thus, community consultations are very crucial for a successful CRA process. Consultations help identify the real key climatic issues affecting communities and livelihoods and also engage community members to participate fully in the process. This process allows for effective identification of critical issues for effective community risks assessment that informs strong adaptation planning. Community engagements and consultations can be held with key actors, community members, partners and experts throughout the entire CRA process. Consultations are important especially during the initial stages of the CRA process where information is gathered on climate and livelihoods to explore local-level perceptions on climate hazards and their impacts. It also explores the current and potential responses to both present and future climatic risks in communities (IISD, 2012). Community engagements also ensure proper planning, adjustments and management of activities according to local needs, priorities and conditions. The approaches in engagements, however, need to be flexible to ensure maximum participation and accuracy of information.

Indigenous knowledge is critical and crucial for conducting CRA. Indigenous knowledge is the body of knowledge, or bodies of knowledge, of the indigenous people of particular geographical areas that they have survived on for a very long time (Mapara, 2009; Shoko, 2012). Thus, participatory methods of gathering information such as site visits, focus group discussions (FGDs), informal meetings and/or organized workshops using participatory rural appraisal tools such as resource mapping, vulnerability matrix and seasonal calendars are usually used for enabling genuine participation of the local populations in the CRA process and for tapping into their indigenous knowledge. These allow for full participation of all groups/stakeholders and opinion leaders and in particular, drawing on the indigenous and or local knowledge of the local populations participating in the process.

4. The study area and context

The study was conducted in the Sissala East District, located in the north-eastern part of the Upper West Region of Ghana. The district has a total land size of 4,744 sq. km representing

Table I. CRA framework: understanding the livelihoods and climate context

Steps and processes		
Step 1: Understanding the livelihood and climate context	Step 2: Analyses of climatic risks	Outputs
Describe livelihood activities, key actors, gender and diversity aspects, and the ecological context	Document observed and projected climate changes in the area	List of livelihood resources for men and women that are most affected by climate hazards and most important for responding to climate impacts
Assess the implications for analysis	Identify current and potential future climate hazards	
Identify resources that are important to local livelihoods and who has access and control over them	Document the impacts of these hazards	
	Document community responses to climate impacts	

Source: Adapted from IISD (2012, p. 12)

26 per cent of the total landmass of the region (Figure 1). The estimated population of the district is 56,528. Of this number, 48.7 per cent are males and 52.3 per cent females (Ghana Statistical Service, 2012). The district capital, Tumu, has 19.03 per cent of the district population and it is the only settlement with the status of a town population and infrastructure. The settlement pattern is highly dispersed and rural by nature.

The district falls within the Guinea Savannah vegetation belt. The vegetation consists of grasses with scattered fire resistant trees such as the shea nut, the baobab and dawadawa trees. Acacia is also a common tree of this vegetation belt. The heterogeneous collection of these trees meets domestic requirements for firewood and charcoal, construction of houses, cattle kraals and fencing of gardens. The shorter shrubs and grasses provide fodder for livestock. The shea tree is one of the great economic assets of the district.

The climate is tropical continental as experienced in the northern regions of Ghana. Throughout the year, temperatures are high with a minimum of 23°C at night and a maximum of 42°C during the day. The mean monthly temperature ranges between 21°C and 32°C. The highest monthly maximum temperature rises up to 40°C before the rainy season in May with lowest minimum temperature of 12°C in December during the *harmattan* season.

The district has a single rainy season usually from May to September/October during which farmers cultivate crops. This is the main production season as irrigation is very limited. In 2009, the first quarter of the year recorded 6.9 mm rainfall and the second quarter, 447.2 mm. At the beginning of the third quarter, drought occurred threatening food production. Subsequently, rains set in and the quarter registered 937.4 mm of rain. The rains intensified and resulted in floods which adversely affected crops yields, especially, maize and groundnuts. Some fields were totally submerged under water and others were washed away. This affected the entire district but the eastern block was the worst affected. There is an indication that rainfall intensity is decreasing in the district. The total number of days of rain ranged from 70 to 80 days in 1999 compared to 51 days of rain in 2009. The mean annual rainfall in 1999 was 121 mm compared to 104 in 2009 (SEDA, 2013). This has implications for food security in the district.

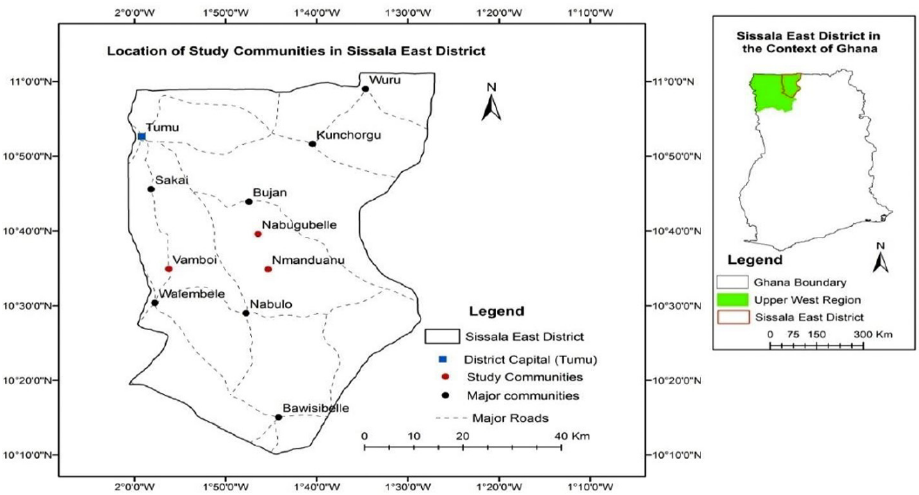

Figure 1.
Map showing Sissala East District in national and regional context

5. Methods of data collection

The paper draws on a qualitative research design, using in-depth interviews, FGDs, seasonal calendar and inter-generational analysis for assessing changes in the selected climatic elements. Three communities namely, *Vamboi*, *Nabugubelle* and *Nmanduanu* in the Sissala East District were randomly sampled from a list of six purposively selected communities prominent in rain-fed crop farming in the district (Figure 1).

In-depth interviews were conducted among 27 purposively sampled key informants, 9 in each community. The distribution was as follows: *Jantina* (earth priest) (3), chiefs (3), traditional chief farmers (3), traditional queens (3), *Magazia* (women leaders) (3) and household heads (12). These interviews enabled an in-depth probe of the issues drawing on the wealth of knowledge and experience of the target respondents.

Data was also collected through 15 FGDs. Five FGDs were conducted in each five community among different groups of discussants, including, elders (usually male), male farmers, female farmers, male youth and female youth. The discussants per session ranged from 8 to 12 and sessions were facilitated with the aid of an FGD guide. Gender segregation was necessary to allow for free expression. Women do not actively participate in discussions in the middle of men because of cultural factors. Seasonal calendar analysis was applied as part of FGDs for understanding indigenous knowledge systems of seasons, activities and changes in seasons. This enabled participatory analysis of changes in climatic elements such as sunshine, temperature and winds.

An inter-generational framework was adopted for data collection and analysis. We analyzed changes between two generations, the era of grandfathers (past generation) and the era of grandsons (present generation). The present generation in this framework refers to the present generation of household heads who were interviewed and the era of their fathers, the transition phase for understanding the changes between the past and present.

6. Results

The results are analyzed around three themes. These include sunshine, temperature and winds and how these have changed over time and between generations.

6.1 Sunshine and changes in sunshine

The indigenous knowledge of the *Sissala* people reveals five local seasons of sunshine that phase into each other in an annual and continuous cycle of occurrence associated with the farming calendar. These include *Wulungyia*, *Kpabilayia*, *Yibiinyia*, *Gbanchanyia* and *Tafaayia*, which were distinct forms of sunshine seasons with varying degrees of intensity in the traditional farming calendar (Table II).

In the traditional farming calendar, *Wulungyia*, meaning the warm or heat season was experienced from February to April in the grandfathers' era. This sunshine was characterized by extreme high intensity, heat and high temperatures both during the day and night. From the analysis, this high intensity sunshine is now experienced over a longer period, from January to May in the present generation. This period is the yam planting season and the extreme conditions cause newly planted tubers to rot and/or wilt especially when tubers are planted after 8.00 a.m. in the morning. Thus, this sunshine is known to cause poor germination in yam farming. It also affects other tubers and root crops such as potatoes.

Kpabilayia is the next season and it was known to occur between June and July and associated with dry spells in the farming season in the grandfathers' era. Sunshine intensity was moderate, with a few intermittent sunny days in the week. It neither affected crops nor farming activities. The season coincided with the second weeding in the farming calendar

Type	Past characteristics – era of grandfathers	Present characteristics – era of grandsons
Wulungyia	Starts from February-April Intense/scorching sunshine Certain and predictable Distinguishable	Starts from January-May Very intense/scorching Difficult to distinguish from others Uncertain and unpredictable Long duration
Kpabilayia	Occurs from June-July	Absent/difficult to distinguish or established period of occurrence
	Alternating sunshine intensity (low and high)	Uncertain and predictable
	Alternating sunny days Distinguishable Certain and predictable Duration was short (2-3 weeks)	High sunshine intensity
Yibiinyia	Starts from July-September Certain and predictable Distinguishable Limited sunny days per week Low sun intensity Limited visibility of sun cloudy conditions	August-September Difficult to distinguish Uncertain and unpredictable Many sunny days High sun intensity Visible sun throughout the week – limited cloudy days
Gbanchanyia	Starts from late September-October Certain and predictable Distinguishable Sunshine with little rains Intense sunshine that warm surface/stagnant waters	Starts from late August-October Difficult to distinguish Almost absent Uncertain and unpredictable
Tafaayia (harmattan sunshine)	Late October-January Occurs during harmattan	Starts from November-December High sunshine intensity because of absence of smoke-like substance to reduce sun rays
	Low sunshine intensity Presence of smoke-like substance that traps sun rays	Uncertain and unpredictable Difficult to distinguish
	Certain and predictable Distinguishable	Short duration Starts from November-December

Table II.
Sunshine types and characteristics

and this helped weeds to dry up after clearing. Farmers report that this season appears to have disappeared in the grandsons' era. The entire raining season is characterized by the alternating occurrence of high sunshine intensity and rains. During dry spells, such high-intensity sunshine has proven harmful to crops and led to crops wilting and or stunning in growth

The next season, *Yibiinyia*, coincided with the peak of the rainy season, from July to September. The intensity of sunshine was low and farmers did not feel the impact in the past. Sunny days were rare. The skies were cloudy and the sun virtually invisible. Heat from the sun rays was not felt. Sunshine was very limited as narrated by a farmer in *Vamboi*:

> In the past we smoked Kuomifian early maturing yellow corn harvested during the peak of the rainy season as a method of drying on our farms. This is because you could not see the sun for many weeks. One could wake up from bed and would not see the sun for the whole day; the sky was always covered with heavy clouds. There was no sunshine for us to dry our yellow corn.

> Smoking corn was virtually done the way meat is smoked to prevent germination due to high moisture and/or to prevent infestation of insects. Have you seen or heard that farmers are smoking maize these days? He asked, rhetorically.

Sunshine intensity is high and the number of sunny days has increased significantly during the peak of the raining season in present times. In fact, sunshine days and rainy days alternate. There is experiencing of sunshine during the entire period because of the absence of heavy cloud cover. Dry spells are common and associated with high-intensity sunshine that destroy crops and or disrupt tussling of cereal crops such as maize, guinea corn and sorghum.

Gbanchanyia is the sunshine experienced at the end of the peak of the rainy season, from September to October. The season was characterized by simultaneous combination of high-intensive sunshine and intermittent drops of rain. Rains did not last more than 5 min and rainfall intensity was low. There were many sunny days than cloudy or rainy days in a week. This sunshine affected late maturing crops. Millet and yams shed leaves within a week. In present times, *Gbanchanyia* has become difficult to distinguish from other seasons, particularly, *Yibiïnyia* and *Tafaayia* . These three types of sunshine appear to have similar characteristics, especially, in intensity and frequency of sunny days. In the past, this sunshine helped farmers to dry their harvest for storage. At present, it is still useful in that respect but when dry spells occur, it dries the land and hampers the harvesting of groundnuts and potatoes which require manual uprooting or digging.

Tafaayia coincided with the harmattan season, from October to January, when the sky was covered with a smoke-like substance and dust particles. There was low intensity of sunshine and farmers did not feel the heat of the sun rays while working on their farms because of the sky cover. The local name *Tafaayia* literally means "a hidden sun" depicting the phenomenon in which the sun was mostly covered by a smoke-like substance, thus, moderating the penetration of sun rays and causing low intensity. In present times, the smoke-like substance is absent in the sky and thus, sunshine intensity is very high and unbearable to many farmers. Such high intensity sunshine was reported to destroy crops such as cotton, beans and vegetable crops.

The analysis revealed indigenous classification of sunshine types. These include *Wulumgyia*, *Kpabilayia*, *Yibiïnyia*, *Gbanchanyia* and *Tafaayia*. The results show that these indigenous classifications of sunshine seasons have become difficult to distinguish by their known and peculiar characteristics in the past. *Wulumgyia*, the warm season appear to be the dominant sunshine type extending its influence over the entire year and overriding other known indigenous seasons of sunshine. The results generally reveal an increasing intensity of sunshine and thus, the dominant influence of *Wulungyia*.

6.2 Temperature and changes in temperature

In the indigenous knowledge of the people, there are two temperature seasons, namely, *Wulumung* and *Tafiala* (Table III).

Wulumung is classified as the warm season. The season was known to occur from February to April, after the *Harmattan*. Thus, it coincided with *Wulungyia*, a high-intensity sunshine season (Table II). Sunshine was very intensive and temperatures were very high, both during day and night. This situation resulted in people sleeping in the open courtyards during nights. Narratives of the people reveal that temperatures have more than doubled during the season in recent times. According to an FGD discussant, sunshine and temperature is "more intense than when we were young" (over 40 years ago) and that "the warm season was no longer distinguishable from other seasons." The *Paari-Nyimma*, chief farmer (CF) of *Nabugbelle* noted during an in-depth interview:

Type of temperature	Characteristics in the past	Present characteristics
Wulumung (warm season)	Starts from February-April High daily temperatures High night temperatures Certain and predictable Distinguishable Short duration	Starts from January-May Very high daily temperatures Very high night temperatures Uncertain and unpredictable Difficult to distinguish Long duration
Tafiala/waaring (cold/ harmattan season)	Starts from October-January Low daily temperatures Low night temperatures Severe cold conditions at mornings and nights Presence of smoke-like substance that traps sun rays during the day Distinguishable Certain and predictable Long duration	Starts from November-December High daily temperatures Mild night temperatures Mild temperatures at mornings and nights Absence of severe cold conditions Absence of smoke-like substance Short duration Difficult to distinguish Uncertain and unpredictable

Table III. Temperature seasons and characteristics

> Wulumung has become more intensified these days than in the past. These days, one still feels abnormal high temperature even if you are sleeping in the courtyard. In the past people packed back into their rooms after 3:00 am because it was extremely cold at that time. Today, temperatures remain warm from night to dawn and so people sleep in the open courtyards till day break. In the future, the world may perish due to extreme high temperatures.

According to the CF, these temperatures do not favor farming. He intimates that farmers would have to adopt a combination of scientific and modern strategies or techniques to secure farm livelihoods. According to him, the changes are becoming more extreme and local strategies adopted by local farmers are becoming overwhelmed. Amid this, available modern scientific solutions do not suit the situation of local farmers; they are by design more suited only to "*Karichising*" meaning, literate/educated people, and thus, may not yield the needed results for the majority of rural farmers who are illiterates.

Tafiala Waaring is the cold season, also known as the *harmattan* season. In the past, temperatures were low with severe cold and dry conditions, especially during nights and early mornings. Because of the severity of *Waaring* (cold), most people, especially children and the aged preferred to be indoors from 7.00 p.m. to 9.00 a.m. the following morning. Men gathered in groups around fires set outside homes to keep warm, during which there was sharing and transmission of information and values among themselves and to the younger generation. The local people assert that one could not take a bath with river water in the morning nor drink it because it was usually as cold as ice block. A discussant corroborates this assertion during an FGD in *Nmanduanu*:

> As children, we used to carry logs from farms to the house for our mothers and the aged to set fires in their rooms. We were usually found in the rooms of our grandparents sitting by the fire every morning till sunrise. These days nobody carries logs to the house for same purpose. The intensity of cold has drastically reduced. One rarely sees old people setting fires in their rooms. The cold season has become warm too.

Overall, farmers observe that the severity of cold and duration of the cold season have reduced significantly in present times. In the past, *Tafiala* started in October and reached its peak in November through to mid-January before it starts to decrease as *Wulumung* sets in. In present times, the season still starts in November but has become difficult for local people to tell when it reaches its peak. Accordingly, there are no significant differences in cold conditions before and during the *harmattan* season. A female discussant noted that:

> The world is really coming to an end [. . .] because we are unable to distinguish the seasons in terms of temperatures. These days we feel heat even during the rainy season and the Tafiala/Waaring (cold/harmattan) season.

Further to this, an old man asked a rhetoric question during an in-depth interview:

> Do you see men gather around fires during Waaring as it happened in the past? He asserts that "the severity of the cold (waaring) had significantly diminished so that nobody feels the severity of the cold that was experienced in the past during the season in present times. He asked again, 'Who baths warm water these days? Even old men like me bath cold water because the warm season has extended and temperatures have increased almost throughout the year.

The analysis reveals significant changes in the characteristics of *Wulumung* (warm season) and *Tafiala/Waaring* (*harmattan* season) between the past (grandfather's generation) and the present (grandson's generation). *Wulumung* (warm season) has become longer in duration, shifting from approximately three months duration to five months duration. Similarly, temperatures are significantly higher and more intense in the present era than the past.

6.3 Wind and changes in wind

In the indigenous knowledge of the people, there are three types of winds, namely, *Duonpeling, Tafaapeling* and *Kukulpapeling* (Table IV). Wind plays an important role in the traditional farming calendar of farmers. In the past, observed wind patterns, direction, speed and intensity informed planning of farming activities. These include planting, staking of yams and harvesting of food crops.

Duonpeling are the rain storms. These winds are usually associated with early rains (rains marking the beginning of rainy season) and late rains (rains marking the end of the

Type of wind	Past characteristics	Present characteristics
Duonpeling (rainstorms)	Came with rains (prevalent at beginning and end of the rainy season)	Mostly come without or with little rains
	Intensive with limited destruction	Very intensive and more destructive
	Mostly came from east-west	Uncertainties in terms of directions
		More predominant only at the beginning of the rainy season
Tafaapeling (harmattan winds)	Starts from October-January	Stars from November-December
	Cold winds both day and night	Mild cold winds at mornings
	Normal/low intensity and no destruction	Becoming absent
	Blow during day time	Normal intensity
	Very cold winds in mornings	Short duration
Kukulpapeling (sweeping winds)	Starts from February-April	Starts from February-April
	Characterized with regular and intensive whirling winds	Absence/irregular whirling winds
	Not destructive	Ineffective winds

Table IV.
Wind types and characteristics

rainy season). In the past, they blew from the east to the west and were associated with heavy rainfall. The direction of the rainstorms determined the direction of rainfall. Rainstorms were highly intensive winds. They caused a lot of damage to houses and food crops. Many houses and other built infrastructure were ripped-off and trees uprooted. They also damaged farms by breaking the stems of cereal crops such as maize, sorghum, guinea corn and millet. They pushed down staked yam plants and sometimes uprooted yam plants from the mounds, especially when they blew from a different direction other than the east to west direction. The locals assert that these winds have been disastrous in nature both in the past and present. However, in recent times, the direction of these winds is not certain. They blow from any direction and commonly associated with low rainfall or no rain at all in the beginning of the rainy season. The results show that these rainstorms are more destructive to property in present times than in the past.

Tafaapeling, are the *harmattan* winds occurring from October to January. These winds are normal winds that indicate the end of the rainy season and are usually felt during the day. They were cold winds and brought severe cold conditions during the *Harmattan* season in the past. They were dry and caused cracked heels, lips and dry skins among people. People frequently applied body cream to their bodies to maintain body moisture. These winds caused general dry weather conditions during and after harvest of crops. The results revealed that the severity of coldness is lower in present times than in the past.

Kukulpapeling, sweeping and or whirl winds, occur from February to April and coincide with *Wulumung*. They swept away rubbish and the top soil in open or bare lands. They were characterized by whirl winds locally known as *vinviling* and causing a dusty environment. This was the period farmers planted yam and did mulching for yams. The results reveal that this wind is still prevalent except that the prevalence and intensities have significantly reduced in recent times if compared with the past.

The results show indigenous classification of three types of winds, namely, *Duonpeling*, *Tafaapeling* and *Kukulpapeling*. All three types of winds have changed in nature over the past few decades. In the case of *Duonpeling*, there is growing uncertainty about the direction of flow and it has become more intensive and destructive in recent times than in the past. *Tafaapeling* are the harmattan winds and are associated with dry and less cold conditions in present times than the past. *Kukulpapeling* are whirl winds and coincide with the warm/heat season. They are less prevalent and intensive but they pollute the environment with dust because of their sweeping nature.

7. Discussion

Comparative analysis of results reveals significant changes in sunshine, temperature and winds with profound implications for development planning in Ghana. The results reveal that increased and prolonged high sunshine intensity in recent times has made it difficult to distinguish between indigenous classifications of sunshine seasons and hence, undermine the relevance of such knowledge systems in their current state. A gradual pattern of convergence and rising dominance of *Wulungyia* is observed. Sunshine intensities have increased significantly and remain high across all seasons in the local calendar year, including the peak of the rainy season. Such high-intensity sunshine is unbearable for farm work during the day, affects crop yields and human health. These findings on sunshine changes corroborate some other research findings. According to Farauta *et al.* (2011), high sun intensity in northern Nigeria resulted in reduced crop yields among farmers. Unlike Ghana, the smoke-like cover in the sky was reported to become more extreme over the years in Northern Nigeria. This study showed that high-intensity sunshine caused damages and or posed challenges in harvesting root and tuber crops such as yam, *yiiria* and potatoes. These food crops easily rot under intense sunshine and lead to high post-harvest losses. High sunshine also causes some crops to wilt and flowering plants to shed off flowers prematurely. These findings corroborate work of Gyampoh *et al.* (2009) who found that intensive sunshine caused crops and vegetables to wilt and ripe prematurely, and thus, affecting yields and sales of crop produce in rural communities in the Offin River basin of Ghana. Thus, while the findings largely corroborate those of other studies in respect of agriculture vulnerability to high sunshine, an additional value is the demonstrated relevance of indigenous knowledge for analyzing and enabling understanding of changes in sunshine in contemporary times.

The results also show increases in temperature and an increase in the duration of the warm season during the year. High temperatures occur during the warm season from January to May. These high temperatures affect farm work and general life in many ways. According to Gyasi *et al.* (2006), high temperatures in northern Ghana compel people to sleep outside their rooms or sleep with their windows and doors opened at night. Even for southern Ghana, in the Ejura-Sekyedumase District, majority of people believed temperatures had become warmer in recent years than in the past (Kemausuor *et al.*, 2011). Similarly, De Pinto *et al.* (2012) note that temperatures were higher in northern Ghana than any other part of Ghana. They project that temperatures could further increase between 1.0 and 3.0°C in 2060 and between 1.5 and 5.2°C in 2090. Similarly, Obeng and Assan (2009) report that temperature trends in northern Ghana in particular suggest gradual increase of 1.9°C, over the period 1962-2002. These findings are consistent with the findings of Bryan *et al.* (2010) and Ogalleh *et al.* (2012) who note that temperatures in Ghana were increasing, worsening drought conditions, impacting negatively on crop farming, water and water resources. Further evidence corroborates temperature increases in Ghana and the negative impact on development. Temperatures across Ghana are increasing and resulting in low crop yields and high prices in foodstuff (Gyampoh and Asante, 2011) and for northwestern Ghana, high temperatures are adversely affecting the production of root and tuber crops (Sagoe, 2006). In general, the coterminous occurrence of high-intensity sunshine and temperature had a doubling adverse effect on people and their livelihoods. The findings reveal increasing warming, intensity and duration of occurrence of both climatic elements and consequently, increasing vulnerability to these observed trends.

The findings also reveal uncertain patterns in wind directions, increased intensity and severer damaging effects of rainstorms in recent times than in the past. These findings corroborate findings from other studies. Gyampoh and Asante (2011) found that strong winds accompanying rainfall in most parts of northern Ghana caused destruction to farms, affecting crops such as maize, millet and yam. In addition, they cause damage to economic trees, including *shea* and *dawadawa* trees and disrupt livelihoods of people who depend on these natural resources. Furthermore, the *Teso* people of Eastern Uganda observed changes in the direction of winds associated with rains and that the intensity of these winds had increased over the years (Egeru, 2012). Several researchers have attributed these changes to climate change as in strengthened westerly winds since the 1960s (Trenberth *et al.*, 2007) and intensification of North East winds since the 1970s (Mörner *et al.*, 2004). Other studies found mixed trends of decreasing and increasing wind speed in Coastal Tanzania since 1972 (Dubi, 2001); complete changes in direction of winds in Tanzania (Mahongo *et al.*, 2011); and the observation among local people in the Laikipiaa District of Kenya that there have been significant changes in winds since the 1960s and that such changes have destroyed farms and crops resulting in poor yields (Ogalleh *et al.* (2012).

8. Conclusion

The paper concludes that the current generation of smallholder farmers is more vulnerable to climate change than the past generation, the era of grandparents. In particular, the current generation is exposed to higher intensity sunshine, temperature and wind and consequently, is affected the most by the damaging effects of these climatic hazards on their livelihoods, especially, smallholder agriculture, housing and health. The CRA process revealed two important lessons. First, it illustrated the relevance of indigenous knowledge systems for vulnerability assessments and second, it underpinned the need for adaptation of such knowledge if it is to sustain farmer efforts at climate change adaptation at community levels within the context of global change.

9. Implications for climate change adaptation planning

This paper advocates an endogenous development (ED) approach to CCAP through implementation of the national policy framework in Ghana and where similar conditions prevail in Sub-Saharan Africa. For most of Sub-Saharan Africa, there is already a decentralized system of local governance and this provides an appropriate institutional framework closer to local populations for implementing an ED approach to CCAP. This process should start with effective community mobilization and education on vulnerability to climate change and for mobilizing and triggering participatory community response to CCAP. Such an approach will enlist community commitment, build on existing knowledge systems and engender sustainability in climate change response. In this context, we put forward specific policy interventions for CCAP.

First, the promotion of pro-poor integrated soil and water conservation measures will be critical for supporting climate change adaptation given that the local populations are mainly smallholder farmers. One of the key vulnerabilities is exposure to high sunshine intensity, temperature and an exacerbating effect on drought with profound adverse effects on farming and life in general. Thus, soil and water conservation for crop production is critical. In the context of poverty, chemical fertilizers are economically out of reach for most smallholder farmers. Thus, the policy orientation should be to promote agronomic and organic practices in soil and water conservation as a more practical, inclusive and sustainable path to adapting smallholder agriculture to climate change.

Second, improving access to water for irrigation and gardening, and for domestic use such as cooking, bathing and laundry will also be critical to adaptation among smallholder farmers. Although Africa has a great irrigation potential, a greater part of that potential has not been developed mainly because of the lack of investments. If Africa is to adapt to climate change, it must develop its irrigation potential to support smallholder production. In addition to investing in community-based irrigation schemes, individual farmer initiatives have pointed to significantly low cost and practical innovations that can be supported. Lessons from research projects (e.g. supporting smallholder farmers' decision-making: Managing trade-offs and synergies for sustainable intensification project) reveal that smallholder farmers are establishing gardens in valley fields and irrigating vegetables with water from manually excavated shallow wells. This has increased agriculture production for such farmers and improved incomes and nutrition for household members. With little extension support, many more smallholder farmers could tap into this potential for production during the dry season. Aside agriculture, improving access to water will facilitate multiple domestic uses and bring relief to the most vulnerable, including the aged, children, women and girls in particular.

Third, promoting appropriate building architecture and technology will also be critical for enhancing adaptation to high sunshine and temperature exposure. Thus, building on and improving local architectural designs and use of local materials with less heat absorption properties will be useful for enhancing adaptation. Some indigenous architectural designs and building materials have proven resilient and enabled smallholder farming households adapt to extreme climate for generations. Thus, improving courtyards and safety of rooftops for sleeping at night, improving ventilation through bigger windows through improved architectural designs is critical for CCA.

Furthermore, planting and protection of trees around homes and farms for the purposes of serving as windbreaks can reduce the damaging effects of storms to housing. In the case of farms, agro-forestry, planting hedge plants around farms and promotion of farmer managed natural regeneration can reduce vulnerability. Economic trees can provide additional benefits such as shades, fruits and income.

Finally, this paper recommends that gender mainstreaming, community advocacy and education be promoted as cross cutting policy issues and mainstreamed into the policy measures put forward. These must be reinforced through gender analysis and gendered approaches for addressing inequalities and promoting inclusive climate change adaptation for development.

References

Antwi-Agyei, P., Fraser, E.D.G., Dougill, A.J., Stringer, L.C. and Simelton, E. (2011), "Mapping the vulnerability of crop production to drought in Ghana using rainfall, yield and socioeconomic data. Centre for climate change economics and policy", Working Paper No. 55. Sustainability Research Institute Paper No. 25.

Brown, O. and Crawford, A. (2008), *Assessing the Security Implication of Climate Change for West Africa, IISD*, Vol. 4 Winnipeg, Manitoba.

Bryan, E., Ringler, C., Okoba, B., Roncoli, C., Silvestri, S. and Herrero, M. (2010), "Coping with climate variability and adapting to climate change in Kenya: household and community strategies and determinants", Report to the World Bank".

Care International Poverty, Environmental and Climate Change Network (PECCN) (2011), "Understanding vulnerability to climate change: insights from application of CARE'S climate variability and capacity analysis (CVCA) methodology".

De Pinto, A. Demirag, U. Haruna, A. Koo, J. and Asamoah, M. (2012), "Climate change, agriculture, and food crop production in Ghana", Ghana Strategy Support Program Policy Note 3.

Dubi, A.M. (2001), "Frequency and long-term distribution of coastal winds of Tanzania", in Richmond, MD. and Francis, J. (Eds) *Marine Science Development in Tanzania and Eastern Africa, Proceedings of the 20th Anniversary Conference in Marine Science in Tanzania*, IMS/WIOMSA, Zanzibar, Tanzania, pp. 131-146.

Egeru, A. (2012), "Role of indigenous knowledge in climate change adaptation: a case study of teso Sub-Region, Eastern Uganda", *Indian Journal of Traditional Knowledge*, Vol. 11 No. 2, pp. 217-224.

Farauta, B.K., Egbule, C.L., Idrisa, Y.L. and Agu, V.C. (2011), "Farmers' perceptions of climate change and adaptation strategies in Northern Nigeria: an empirical assessment", African Technology Policy Studies Network, (ATPS), Research Paper No. 15. Nairobi.

File, D.J.M. (2015), "Local perceptions of climate variability and adaptation strategies in the sissala east district, northwestern Ghana", A Thesis Submitted To The Department of Planning And Management, Faculty of Planning And Land Management, University For Development Studies In Partial Fulfilment of The Requirements For The Award of A Master of Philosophy Degree In Development Management.

Ghana Statistical Service (2012), *2010 Ghana Population and Housing Census Report*, Sakao Press Ltd, Accra.

Gyampoh, B.A., Amisah, S., Idinoba, M. and Nkem, J. (2009), "Using traditional knowledge to cope with climate change in rural Ghana", *Unasylva 231/232*, Vol. 60, pp. 70-74.

Gyampoh, B.A. and Asante, W.A. (2011), *Mapping and Documenting Indigenous Knowledge in Climate Change Adaptation in Ghana*, Africa Adaptation Programme, United Nations Development Programme.

Gyasi, E.A., Karikari, O., Kranjac-Berisavljevic', G. and Vordzogbe, V.V. (2006), "Study of climate change vulnerability and adaptation assessment relative to land management in Ghana", Gyasi, Edwin A, *Land Management Draft Final Report*, Accra, Ghana.

Hulme, M., Doherty, R., Ngara, T., New, M. and Lister, D. (2001), "African climate change", *Climate Research*, Vol. 17, pp. 145-168.

International Institute for Sustainable Development (2012), *Community-Based Risk Screening Tool – Adaptation and Livelihoods (CRiSTAL). CRiSTAL User's Manual Version 5*, Winnipeg, Manitoba.

IPCC (2007), "Summary for policymakers", in Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. and Hanson, C.E. (Eds) *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, 7 22.

IPCC (2012), "Summary for policymakers", in Field, C.B., Barros, V., Stocker, T.F., Qin, D., Dokken, D.J., Ebi, K.L., Mastrandrea, M.D., Mach, K.J., Plattner, G.K., Allen, S.K. and Tignor, M. and Midgley, P.M. (Eds.). *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, and New York, NY, pp. 1-19.

Kankam-Yeboah, K., Amisigo, B. and Obuobi, E. (2010), "Climate change impacts on water resources in Ghana", *Paper for Pan-African Workshop on 'Decision-Making Support for Coastal Zone Management, Water Resourcesand Climate Change in Africa', Held in Cotonou, Benin, from 15-17 February 2010*, pp. 65-69.

Kemausuor, F., Dwamena, E., Bart-Plange, A. and Kyei-Baffour, N. (2011), "Farmers' perception of climate change in the Ejura-Sekyedumase district of Ghana", *ARPN Journal of Agricultural and Biological Science*, Vol. 6NO. No. 10, pp. 26-37.

Kunstmann, H. and Jung, G. (2005), "Impact of regional climate change on water availability in the Volta basin of west Africa", *Regional Hydrological Impacts of Climatic Variability and Change Proceedings of Symposium Held during the Seventh IAHS Scientific Assembly at Foz Do Iguaçu, Brazil, April 2005*, Vol. 295, IAHS Publication.

Kuuzegh, R.S. (2007), *Ghana's Experience at Integrating Climate Change Adaptation into National Planning. Director, Environment Sector*, Ministry of Local Government Rural Development and Environment, Accra, Ghana. UN Hqrs, 12th Nov '07.

Laube, W. Leemhuis, C. and Amisigo, B. (2008), "GLOWA Volta policy brief: impact of climate change on the black volta basin and the bui dam",

Lemoalle, J. (2007), "Global trends in the Volta basin, Volta Basin Focal Project, Report No 3", IRD, Montpellier and CPWF, Colombo, p. 26.

McCartney, M., Forkuor, G., Sood, A., Amisigo, B., Hattermann, F. and Muthuwatta, L. (2012), *The Water Resource Implications of Changing Climate in the Volta River Basin*, 40, International Water Management Institute (IWMI), Colombo (IWMI Research Report 146), doi: 10.5337/2012.219.

Mahongo, S.B., Francis, J. and Osima, S.E. (2011), "Wind patterns of coastal Tanzania: their variability and trends", *Western Indian Ocean Journal of Marine Science*, Vol. 10 No. 2, pp. 107-120.

Mapara, J. (2009), "Indigenous knowledge systems in Zimbabwe: Juxtaposing postcolonial theory", *The Journal of Pan African Studies*, Vol. 3 No. 1, pp. 139-155. available at www.jpanafrican.com/docs/vol3no1/3.1%20Indigenous%20Knowledge%20Systems%20in%20Zimbabwe.pdf.

Mörner, N., Tooley, M. and Possnert, G. (2004), "New perspectives for the future of the Maldives", *Global and Planetary Change*, Vol. 40 Nos 1/2, pp. 177-182.

Obeng, F.K. and Assan, J. (2009), "Environmental variability and vulnerable livelihoods: minimising risks and optimising opportunities for poverty alleviation".

Ogalleh, S.A., Vogl, C.R., Eitzinger, J. and Hauser, M. (2012), "Local perceptions and responses to climate change and variability: the case of Laikipia district, Kenya", *Sustainability*, Vol. 4 No. 12, pp. 3302-3325. doi: 10.3390/su4123302.

Oyebande, L. and Odunuga, S. (2007), "Climate change impact on water resources at the transboundary level in west Africa: the cases of the Senegal, Niger and Volta basins", *The Open Hydrology Journal*, Vol. 4 No. 1, pp. 163-172.

Republic of Ghana (2013), *Ghana National Climate Change Policy*, Ministry of Environment, Science, Technology and Innovation, Accra.

Sagoe, R. (2006), *Climate Change and Root Crop Production in Ghana*, A Report prepared for the Environmental Protection Agency, Accra-Ghana.

Shoko, K. (2012), "Indigenous weather forecasting systems: a case study of the biotic weather forecasting indicators for wards 12 and 13 in Mberengwa district Zimbabwe", *Journal of Sustainable Development in Africa*, Vol. 14No No. 2, pp. 1520-5509.

Sissala East District Assembly (2013), *Composite Budget*, unpublished.

Smart Risk Control (2007), *Community Risk Assessment Hazards, Vulnerabilities and Risks in Town of Sidney. Prepared for: Town of Sidney Emergency Program*, BC, Victoria.

Stouffer, J.A. (2015), "Community risk assessment: a guide for conducting a community risk assessment. Version 1.1 rev. 04/15",

Trenberth, K.E., Jones, P.D., Ambenje, P., Bojariu, R., Easterling, D., Klein Tank, A., Parker, D., Rahimzadeh, F., Renwick, J.A., Rusticucci, M., Soden, B. and Zhai, P. (2007), "Observations: Surface and atmospheric climate change", in Solomon S.Q.D., Manning, M., Chen, Z., Marquis, M., Averyt, KB., Tignor, M., Miller, HL. (Eds) *Climate Change 2007: The Scientific Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, and New York, NY, pp. 235-236.

United States Aid (2014), *Climate-Resilient Development: A Framework for Understanding and Addressing Climate Change*, Washington, DC.

Welling, R. Cartin, M. Baykono, D. and Diallo, O. (2012), "Volta river basin Ghana and Burkina Faso transboundary water management through multi-level participatory governance and community projects",

World Bank (2011), *Vulnerability, Risk Reduction, and Adaptation to Climate Change*, World Bank Group, Washington, DC.

World Bank Group (2010), *The Economics of Adaptation to Climate Change in Ghana*, World Bank Group, Washington, DC.

Further reading

Aalsta, M.K., Cannon, T. and Burton, I. (2008), "Community level adaptation to climate change: the potential role of participatory community risk assessment", *Global Environmental Change*, Vol. 18, pp. 165-179.

Wiid, N. and Ziervogel, G. (2012), "Adapting to climate change in South Africa: commercial farmers' perception of and response to changing climate", *South African Geographical Journal*, Vol. 94 No. 2, pp. 152-173.

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