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Application of livelihood vulnerability index in assessing smallholder maize farming households' vulnerability to climate change in Brong-Ahafo region of Ghana

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ABSTRACT

Climate change is adversely affecting smallholder farming households in Africa and in particular in Ghana because their activity depends on climate-regulated water resources. This study examined the vulnerability of smallholder maize farming households to climate change in the Brong-Ahafo region of Ghana by employing the Livelihood Vulnerability Index with particular emphasis on access to and utilization of water resources. The primary data were based on 150 maize farming households, complemented by secondary data on rainfall and temperature over the period 1983–2013. To assess the climate change effects and related vulnerability, a comparative analysis was performed for the Wenchi and Techiman municipalities in the Brong-Ahafo region. The empirical results revealed that farming households in Wenchi municipality were more vulnerable to climate change and weather variability in terms of food, water, and health than those in Techiman municipality. Furthermore, farming households in Wenchi municipality were more vulnerable in terms of adaptive capacity, taking into account the socio-demographic aspects, social networks, and livelihoods of households in the municipality than those in Techiman municipality. These results have implications for the initiation and implementation of climate change adaptation and household resilience projects by the government, donor agencies, and other related organizations in the two municipalities in the region.

Introduction

The adverse effect of climate change and variability has become an environmental and socio-economic problem which is increasingly causing climate-driven hazards to people around the world (Scholze, Knorr, Arnell, & Prentice, 2006). They argued that climate change serves as a serious inhibitor to the attainment of food security and also to the fulfillment of major developmental agenda in the majority of global economies from which Ghana cannot be exempted. Climate change has attracted the attention of the academic community, governmental, and non-governmental organizations. Intergovernmental Panel on Climate Change (IPCC) (2014) mentioned that climate change is any change in climate over a period of time which comes about as a result of both human activity and natural variability. Montle and Teweldemedhin (2014) noted that adverse effects of climate change are likely to affect poor people

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whose daily existence depends on semi-subsistence agriculture. The reason for the adverse effect of climate change on the poor can be found in Food Agriculture and Natural Resources Policy Analysis Network (FANRPAN) (2011), which reported that a higher proportion of rural households are limited by the essential ability to adapt to the adverse effects of climate change. This is due to the fact that policy response is inadequate, institutional arrangements are very feeble, and interventions are introduced without consultation with local households. Minia (2004) predicted that globally, the total annual rainfall will decline by 9–27 percent while the mean daily temperatures will rise by 2.5–3.2 °C by 2100. Boko et al. (2007) revealed that agricultural production as well as food security in many African regions and countries has the highest probability to be severely compromised by climate change and variability.

Agriculture contributes significantly to the Ghanaian economy. For instance, in 2013 according to the Institute of Statistical, Social and Economic Research (2014), agriculture contributed 22 percent to the nation's Gross Domestic Product (GDP). In addition, approximately two-thirds of the manufacturing value-addition is based on agricultural raw materials and provides employment to about 56 percent of the work force (FAO, 2010). To reduce food insecurity, maize (*Zea mays* L.) is Ghana's number one staple food crop followed by rice (*Oryza sativa* L.) and domestic demand for these staples is increasing. The domestic demand for maize is projected to grow at 2.6 percent annually between 2010 and 2015 (Millennium Development Authority, 2009). However, the 21st century has seen a shortage in the per capita global food production by 7 percent; the shortage is believed to be caused by climate change and variability and low soil productivity (Rosenzweig & Parry, 1994). Smallholder farming households dominate the agricultural sector in the Ghanaian economy with about 90 percent being resource poor (Ghana Statistical Service [GSS], 2008). Smallholder farmers primarily depend on family labor and also operate under rain-fed conditions (Chamberlin, 2008). This has contributed to the inability of Ghana to produce more maize to feed its people leading to average shortfalls of 12 percent in domestic supply (Millennium Development Authority, 2009). In the Brong-Ahafo region, farmers are predominantly smallholders and are usually involved in the cultivation of staple crops including yam (*Dioscorea* spp), maize (*Z. mays* L.), cassava (*Manihot esculenta)*, cowpea (*Vigna unguiculata)*, and groundnut (*Arachis villosulicarpa)*. Farmers also engage in the rearing of small ruminants such as sheep and goats (Ministry of Food and Agriculture, 2011). The adverse effects of climate change and variability on crop growing and animal rearing cannot therefore be overstated. Models and information about climate variability and change are only available at global, national, and continental levels. Models are not yet able to forecast the impacts at very small scales; hence extension officers face challenges in providing farmers with knowledge that is location specific and ecologically specific. Without suitable policies or adaptive measures in place, the smallholder farming households will find it difficult to undertake sustainable crop production and rearing of animals in an environment with erratic climatic conditions (Al-Hassan, Kuwornu, Etwire, & Osei-Owusu, 2013; Kuwornu, Al-Hassan, Etwire, & Osei-Owusu, 2013; Nakuja, Sarpong, Kuwornu, & Asante, 2012). Past studies on vulnerability in Ghana have mostly been based on poverty (Novignon, Mussa, & Chiwaula, 2012). These studies measured vulnerability to extreme climatic events in Ghana using national aggregates without household level data. Only a few studies have focused on the household level (for example, Etwire, Al-Hassan, Kuwornu, & Osei-Owusu, 2013). The current study fills the gap in the literature by employing household data to analyze farmers' vulnerability to climate change and variability using the lens of the livelihood vulnerability frameworks.

Literature Review

The Livelihood Vulnerability Index (LVI) was used to assess the vulnerability of farming households to climate change and variability. This index was developed by Hahn, Riederer, and Foster (2009) and is based on the IPCC's definition of vulnerability. The LVI approach involves several variables which capture the level of smallholder maize farming households' exposure to natural hazard and climate change, their adaptation capacities and their sensitivity to climate change impacts (Hahn et al., 2009). The computation of the index is simpler once rainfall and temperature data are available, as it uses primary data from households. Numerous studies have measured vulnerability in the context of natural hazards (for example, Parmesan & Yohe, 2003). The term vulnerability is used in many diverse ways by various intellectual communities such as poverty and food security analysts as well as in natural hazards research and each area conceptualizes it differently (Bryan, Deressa, Gbetibouo, & Ringler, 2009). Several strands of literature have provided similar definitions of vulnerability to climate change and variability (FAO, 2006, 2009; IPCC, 2007). These studies define vulnerability as the extent to which geophysical, biological, and societal systems are prone to, or at risk of, and are unable to deal with the negative effect of climate change and variability. IPCC (2001) defines vulnerability to climate change as the degree to which a system is liable, or incapable of surviving under negative effects of climate change and variability. FAO (2006) has suggested that vulnerability to climate change differs across space and time due to the numerous contributing factors. The vulnerability level of a system to climate change and variability is dependent on the character, degree, and the rate of climate change and variation to which the system is exposed, its sensitivity, and its adaptive capacity (FAO, 2009; IPCC, 2007). Climate change exposure is believed to be location specific. For example, communities in semi-arid areas may be most exposed to drought whereas coastal communities will have a higher exposure to sea level rise and cyclones. Sensitivity is the extent to which a body is either adversely or beneficially, directly or indirectly affected by climate change and variability (IPCC, 2007). For example, a tropical ecosystem will be less sensitive to a decrease in rainfall than a fragile, arid or semi-arid one, due to the successive influence on water flows. Also, a mining community is less sensitive to changing rainfall patterns than one dependent on rain-fed agriculture for its livelihood (IPCC, 2007).

Methods

Assessing Vulnerability to Climate Change: The Livelihood Vulnerability Index (LVI)

Once values for each of the seven major components for a household are calculated, they are averaged using equation (4) to obtain the household-level LVI:

$$LVI_h = \frac{w_{SDP}SDP_h + w_{LS}LS_h + w_H H_h + w_{SN}SN_h + w_F F_h + w_W W_h + w_{NDC}NDC_h}{w_{SDP} + w_{LS} + w_H + w_{SN} + w_F + w_W + w_{NDC}} \quad (4)$$

In modeling the vulnerability to climate change by smallholder maize farming households, the balance weighted approach was employed by computing the LVI as developed by Hahn et al. (2009) and employed by Etwire et al. (2013). The Livelihood Vulnerability framework is particularly relevant to understand vulnerability to climate change because it provides a framework for analyzing both the key components that make up livelihoods and the contextual factors that influence them. The LVI was derived from all the households selected for the study, taking into account the IPCC definition of vulnerability to climatic impacts developed by Hahn et al. (2009). It makes use of seven major components, namely socio-demographic profile, livelihood strategies, social networks, health, access to food, access to water and natural hazards, and climate change. Each component is made up of several indicators or sub-components, each of which is measured on a different scale; it is therefore necessary to standardize each as an index using either equation (1) or (2). Equation (1) was employed where a sub-component had a positive relationship with vulnerability while equation (2) was employed where a sub-component had a negative relationship with vulnerability.

$$Index_{shi} = \frac{S_h - S_{\min}}{S_{\max} - S_{\min}} \quad (1)$$

$$Index_{shi} = \frac{S_{\max} - S_h}{S_{\max} - S_{\min}} \quad (2)$$

where S_h is the observed sub-component of indicator for household and S_{min} and S_{max} are the minimum and maximum values, respectively.

After each is standardized, the sub-component indicators are averaged using equation (3) to obtain the index of each major component:

$$M_h = \frac{\sum_{i=1}^{n} index_{shi}}{n} \quad (3)$$

where M_h is one of the seven major components [Socio-Demographic Profile (SDP), Livelihood Strategies (LS), Social Network (SN), Health (H), Food (F), Water (W), or Natural Hazard, or Climate Variability (NDCV)] for household h, $index_{shi}$ represents the sub-components, indexed by I, that make up each major component, and n is the number of sub-components in each major component.

The weights of each major component, w_{M_i}, are determined by the number of sub-components that make up each major component and are included to ensure that all sub-components contribute equally to the overall LVI. The LVI was scaled from 0 (low vulnerability) to 0.6 (extremely vulnerable).

IPCC Framework for Calculating LVI

The alternative method for calculating LVI incorporated the IPCC vulnerability definition by grouping the seven major components under exposure, adaptive capacity, and sensitivity. Each major component comprised several sub-components or indicators, the same as in the LVI.

Similarly, equations (1)–(4) were used to calculate the LVI–IPCC. Instead of using one weighted average as in the LVI approach, this method calculated three weighted averages of the major sub-components according to the three contributing factors explained using equation (5):

$$CF_h = \sum_{i=1}^{n} wM_i M_{hi} \Big/ \sum_{i=1}^{n} wM_i \quad (5)$$

where CF_h is an IPCC-defined contributing factor (exposure, sensitivity, or adaptation capacity) for household, M_{h_i} are the major components for household indexed by i; w_{M_i} is the weight of each major component, and n is the number of major components in each contributing factor.

Once exposure, adaptation capacity, and sensitivity are calculated, the three contributing factors are combined using equation (6):

$$LVI - IPCC_h = (e_h - a_h)*s_h \quad (6)$$

where, $LVI - IPCC_h$ is the LVI for household h expressed using the IPCC vulnerability framework, e_h is the calculated exposure score for household h (equivalent to the natural hazard and climate variability major component). The climate variability is measured by the average standard deviation in monthly minimum and maximum temperatures and monthly rainfall over a 30-year period (Ashok & Sasikala, 2012; Etwire et al., 2013; Hahn et al., 2009). Also, a_h is the calculated adaptation capacity score for household h (weighted average of socio-demographic, livelihood strategies, and social networks major components), and S_h is the calculated sensitivity score for household h (weighted average of the health, food, and water major components).

The *LVI-IPCC* Index is scaled from −1 (least vulnerable) to 1 (most vulnerable). Microsoft Office Excel 2013 was employed in estimating the LVI as described by Hahn et al. (2009).

Data Source and Sampling Procedure

The study employed both primary and secondary data. The primary data were collected from smallholder maize farming households in the Wenchi and Techiman municipalities in the Brong-Ahafo region of Ghana. This region is generally renowned for agriculture and agribusiness activities. Wenchi municipality is located in the western part of the region northeast of the regional capital (Sunyani). It lies between latitudes 7°3′ and 8°50′ N and longitudes 1°55′ and 2°15′ W. It is covered by moist-deciduous forest and the Guinea Savanna woodland vegetation zone (GSS, 2010). The rainfall pattern is seasonal, which is a limiting factor in agriculture and plant growth. The average annual rainfall is about 1,140–1,270 mm with an average maximum temperature of 30.9 °C and a minimum of 21.2 °C. The temperature in the municipality is generally high, averaging about 24.5 °C. The hottest months are February to April (GSS, 2010). Techiman municipality lies between longitudes 1°49′ E and 2°30′ W and latitudes 70°35′ and 80° S. The municipality shares common boundaries with Wenchi municipality Kintampo South district to the northeast, the north and the west, with Offinso North district (in the Ashanti Region) to the south and with Nkoranza South district to the southeast. The total land area is 669.7 square kilometers (GSS, 2010).

Techiman municipality experiences both semi-equatorial and tropical conventional or savanna climates, characterized by moderate to heavy rainfall annually. The municipality highest rainfall (over 1,650 mm) is in the southwest and declines northwards to about 1,250 mm in the North West Guinea-savanna zone around the Offuman area. It has an annual average temperature of 28 °C and a relative humidity of 75–80% in the rainy season and 70–72% for the rest of the year (GSS, 2010). Techiman municipality has three main vegetation zones, namely, the Guinea-savanna woodland, located in the northwest, the semi-deciduous zone in the south, and the transitional zone, which stretches from the southeast and west up to the north of the municipality. The major land uses are crop production and animal production.

A questionnaire was designed by the authors, pre-tested, and administered at the household level to obtain primary data. An initial questionnaire was designed based on the literature and was pre-tested by interviewing 15 randomly selected maize farmers in the study area and then a final questionnaire was developed to mirror local realities of the maize farmers' vulnerability to climate change. Thus, the ambiguities and limitations of the initial questionnaire were corrected in the final questionnaire prior to the actual data collection. The questionnaire covered 31 key variables which were used in computing the LVI as well as other variables to achieve the other objectives. A multi-stage sampling procedure was employed in this study. First, the Brong-Ahafo region was purposively selected due to the predominance of the smallholder maize farmers compared with the other regions in the country. Second, simple random sampling was conducted. In this respect, ecology, population, and land size were considered to select two municipalities: Techiman and Wenchi (Figure 1). Third, the simple random sampling technique was again employed to select two communities from each of the municipalities—Aworowa and Oforikurom from Techiman municipality and Wurompo and Awisa from Wenchi municipality. Fourth, 75 smallholder maize farming households were randomly selected from each municipality. Thus, a total of 150 maize growing households were enumerated from the two municipalities.

Furthermore, secondary data on temperature and rainfall were also collected from the Ghana Meteorological Agency. The reference period for the meteorological data was between 1983 and 2013. This range was chosen based on the definition of change in climate which is believed to take place every three decades. Information pertaining to climate change and variability in the world, Africa, and Ghana was obtained from sources such as journals, text books, and project reports.

Results and Discussion

Households' Livelihood Vulnerability Index

The results revealed that the vulnerability indices of the major component ranged from 0.183 to 0.577 as shown in Table 1. The indices being relative values were compared across the two municipalities. The vulnerability index of the water component of the LVI showed that Wenchi municipality was more vulnerable (0.295) than Techiman (0.183). Wenchi recorded a higher percentage (41.95%) of households reporting conflicts over water resources in the past than Techiman (9.770%). Wenchi recorded a higher percentage (14.67%) of households that utilized natural water source than Techiman (1.130%). Utilization of a natural water source such as a dam or lake among others, had a higher probability of leading to an increase in a household's vulnerability to waterborne diseases and water scarcity during the dry season (Etwire et al., 2013). The average time taken to reach a water source was higher in Wenchi municipality than in Techiman. Water was mostly sourced by women and children, due to the short distance to water sources for communities in both municipalities; this task reduced time available for the burden of household chores and slightly affected time for care in the case of the women and school attendance in the case of the children. Wenchi municipality reported a higher percentage (47.62%) of households that did not have a consistent water supply than Techiman (19.75%). Due to the availability of pipe and bore holes in both municipalities, the households were not affected much during the dry season when most natural water sources tended to dry up. More households in Techiman municipality reported storing water daily compared with those in the Wenchi municipality.

The second major component was the socio-demographic profile which consisted of five sub-components. Wenchi showed greater vulnerability (0.246) on the socio-demographic profile index than Techiman (0.228). About 37.33 percent of the household heads in the two municipalities had no basic education. Formal

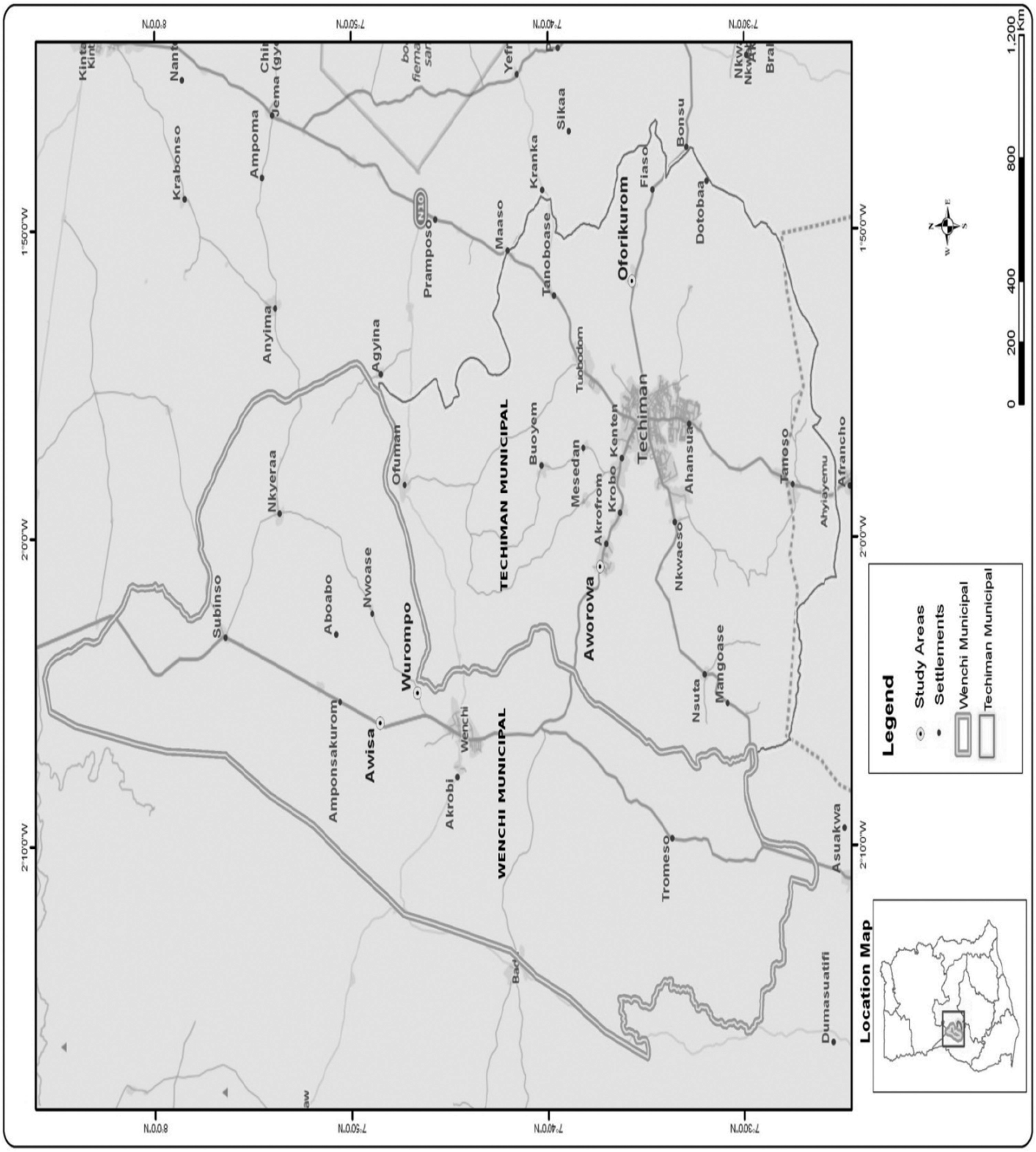

Figure 1 Map of Techiman and Wenchi municipalities and their communities
Source: Geography Department, University of Ghana

Table 1
Indexed sub-components, major component for natural disasters and climate change and overall LVI for both Wenchi and Techiman municipalities

Sub-component	Wenchi	Techiman	Major component	Wenchi	Techiman
Percentage of household reporting water conflict	0.420	0.098	Water	0.295	0.183
Percentage of households that utilize a natural water source	0.147	0.011			
Average time to water source	0.220	0.200			
Percentage of households that do not have a consistent water supply	0.476	0.201			
Inverse of the average number of liters of water stored per household	0.210	0.405			
Dependency ratio	0.140	0.105	Socio-demographic profile	0.246	0.228
Percentage of female-headed households	0.181	0.293			
Average age of female head of household	0.440	0.250			
Percentage of households where the head has not attended school	0.289	0.230			
Percentage of households with orphans	0.173	0.260			
Percentage of households dependent solely on family farm for food	0.640	0.813	Food	0.257	0.252
Average number of months, households struggle to find food	0.149	0.125			
Average crop diversity index	0.364	0.150			
Percentage of households that do not save seeds	0.040	0.040			
Percentage of households that do not save crops	0.093	0.130			
Average Receive: Give ratio	0.292	0.280	Social Networks	0.577	0.516
Average Borrow: Lend money ratio	0.440	0.330			
Percentage of households that have not gone to their local government for assistance in the past 12 months	1.000	0.933			
Percentage of households with family members working in a different community	0.253	0.35	Livelihood strategies	0.384	0.508
Percentage of households dependent solely on agriculture as a source of income	0.587	0.813			
Average agricultural livelihood diversification index	0.311	0.36			
Percentage of households that do not receive a warning about the pending natural hazard	0.773	0.841	Natural hazard and climate variability	0.349	0.324
Percentage of households with injury or death as a result of recent natural hazard	0.013	0.013			
Average number of flood, drought, bushfires events in the past 6 years	0.304	0.355			
Mean, standard deviation of monthly average minimum daily temperature (years: 1983–2013)	0.134	0.134			
Mean, standard deviation of monthly average maximum daily temperature (years: 1983–2013)	0.192	0.192			
Mean, standard deviation of monthly average precipitation (years: 1983–2013)	0.680	0.411			
Average time to health facility (foot)	0.360	0.339	Health	0.410	0.338
Percentage of households with family member with chronic illness	0.280	0.267			
Percentage of households where a family member had to miss work or school in the past 6 months	0.627	0.680			
Average malaria exposure prevention index	0.377	0.068			
Overall LVI				**0.346**	**0.312**

education tends to improve the ability of smallholder maize farming households to better appreciate issues disturbing them and therefore look for possible solutions in the appropriate places (Etwire et al., 2013). Illiteracy limits smallholder maize farming households' access to information, especially from written sources, thereby increasing their susceptibility to climatic stresses. Techiman municipality showed greater vulnerability (0.260) based on the percentage of households with orphans than Wenchi municipality (0.173). Techiman municipality showed less vulnerability (0.105) on the dependency ratio than Wenchi (0.140). This could be explained by the fact that the population proportions under 15 and over 65 years that were dependent were greater in Wenchi than in Techiman municipality.

The third major component was the food which consisted of five sub components. When all the results of the sub-components were aggregated, Wenchi municipality was found to be more vulnerable (0.257) than Techiman (0.252). The average number of months that households struggle to find food was the same for the two municipalities (approximately one month). Food security improves household's resilience to external stresses including extreme climatic events (World Bank, 2010). This is due to the fact that as individuals, communities, and countries get access to quantities of good-quality food, this leads to falling real prices resulting in increase in their real incomes. This could motivate them to adapt a climate change strategy (World Bank, 2010). About 64 percent of the households in Wenchi municipality depended solely on the family farm for food while 81.33 percent of the households in Techiman municipality depended solely on their family farm for food. The average crop diversity index showed that Techiman municipality was more vulnerable (0.321) than Wenchi municipality (0.290), though, based on the index for food as the major component, Wenchi municipality was more vulnerable. However, it was less vulnerable when it came to crop diversity. This could be attributed to the fact that as the households have access to land under different arrangements (leased land, or rented, and family land), this facilitates the production of different crops, and thereby reduces the households' vulnerability to climate change.

The fourth major component was a social network which consisted of three sub-components. When all the sub-components in both municipalities were aggregated, Wenchi was more vulnerable (0.577) in terms of social network than Techiman (0.516). Maize farming households in Wenchi were reported to be receiving more help than giving it to others compared with Techiman. The results also showed that 93.34 percent of farming households in Techiman municipality did not approach their local authority for any help while 100 percent of the households in the Wenchi municipality did not approach their local authority for any assistance. These results imply that even though the farming households in the two municipalities received help, they preferred seeking assistance from their friends and relatives rather than from their local government authorities.

The fifth major component was livelihood strategies which consisted of three sub-components (family members working in a different community, household dependent solely on agriculture as a source of income, and agricultural livelihood diversification index). When all the sub-component were aggregated, Techiman showed greater vulnerability (0.508) than Wenchi (0.384). Techiman municipality showed a greater vulnerability (0.253) based on the percentage of households with family members working in a different community than did Wenchi (0.35). This signifies that more households have some members working in a different community (Wenchi with 35% and Techiman with 25.3%). Techiman municipality had about 81.27 percent of the households dependent solely on agriculture as a source of income whiles Wenchi had 58.66 percent. Techiman showed greater vulnerability (0.360) based on average agriculture livelihood activity than Wenchi (0.311). This implies that the households in Wenchi municipality practiced more diversified agricultural activities compared with Techiman municipality. This finding also suggests that the fewer agricultural activities a household engages in, the more vulnerable it is to climatic stress. This is due to the fact that as diversifying agricultural activities (such as planting different crops or rearing animals with crops) enables the household to move to a higher income level which will further facilitate the adoption of a climate change strategy.

The sixth major component was health, consisting of four sub-components. When all the sub-components were aggregated, Techiman municipality showed less vulnerability (0.338) than Wenchi (0.410). Wenchi municipality had greater vulnerability (0.360) for the average time a household took to reach a health facility than Techiman (0.339). Inadequate access to health services tends to decrease the health status of smallholder farming households, thereby increasing their vulnerability to extreme climatic conditions (World Bank, 2010). Wenchi showed a greater vulnerability (0.377) on average malaria exposure prevention than Techiman (0.068). Techiman also showed less vulnerability (0.267) with respect to a household with family members with chronic illness than Wenchi (0.280). The percentage of households where a family member had to miss school or work in the past 6 months, was greater in Techiman (0.680) than in Wenchi (0.627).

The seventh major component was natural hazard and climate variability. It consisted of six sub-components. When all the components were aggregated, Wenchi municipality showed greater vulnerability (0.349) than Techiman municipality (0.324). About 77.3 percent of the households in Techiman municipality did not receive a warning about a pending natural hazard, while 84.1 percent of the households in Wenchi did not receive a warning about the pending natural hazard with indices of 0.841 and 0.773, respectively. Both municipalities recorded the same index value (0.013) for the percentage of households with injury or death as a result of recent natural hazard. Techiman municipality recorded greater vulnerability to the average number of natural hazard events in the past six years than did Wenchi municipality with indices of 0.355 and 0.304, respectively. Both municipalities recorded the same index for the mean standard deviation of monthly average minimum and maximum daily temperatures in the 30-year period, with 0.134 and 0.192, respectively. Indices recorded for Techiman and Wenchi with respect to the mean standard deviation of monthly average precipitation were 0.411 and 0.680 respectively, over the period 1983–2013. This implies that Wenchi district showed a greater vulnerability in terms of the mean standard deviation of monthly average precipitation than Techiman. The overall aggregated LVI values for all the major components for both Techiman and Wenchi were 0.312 and 0.346, respectively.

The results in this study revealed that both municipalities in the Brong-Ahafo region of Ghana were vulnerable to the effects of climate change and variability, but the vulnerabilities varied with municipality. Such variations are consistent with the previous studies (such as Valdivia et al., 2010) which revealed that northern Alitplano communities are more vulnerable to climate change than central Altiplano ones in the Bolivian Altiplano region. The results of the current study are also consistent with previous research regarding households' vulnerability to social capital, human capital, and natural hazards within the context of the various livelihood frameworks (Bebbington, 1999; Dorward et al., 2009; Uy, Takeuchi, & Shaw, 2011). The results also revealed that the maize farmers were vulnerable to the key dimensions of all the livelihood vulnerability frameworks developed by previous research (such as Carney, 1999). These key dimensions of the livelihood frameworks include food, health, social network, water, socio-demographic profile, natural hazard and climate variability, and water and livelihood strategies. These dimensions reflect the power relations, access to water resources and health facilities, and political, social and economic structures. The overall livelihood indices of the major components for Wenchi and Techiman municipalities were 0.346 and 0.312. However, the empirical results from the major components implied that maize farming households in the Brong-Ahafo region of Ghana are somewhat resilient to shocks resulting from access to water and food and shocks due to changes in their socio-demographic profile such as the dependency ratio, and may require minimal assistance to enable them cope with these shocks.

The results of all the major components are summarized in Figure 2.

The vulnerability spider diagram ranges between 0 (least vulnerable) and 0.6 (extremely vulnerable). Wenchi municipality was more vulnerable in terms of water, food, health, social-networks, and natural disaster and climate change. Techiman municipality was more vulnerable in terms of livelihood strategies.

Table 2 shows the results of the two-sample t-test of the livelihood components. The results indicate that the mean differences in LVI for major components (water, livelihood strategies, health, food, natural hazard, socio-economic and social network) between Wenchi and Techiman are all statistically significant at 1% significant level as indicated by the values of the t-statistics compared with the t-critical value of 1.96. These results are also supported probability values ($p < .001$).

Table 3 presents the results of the two-sample t-test result of the LVI. The null hypothesis was rejected because the t-statistic obtained (2.312) was greater than the value

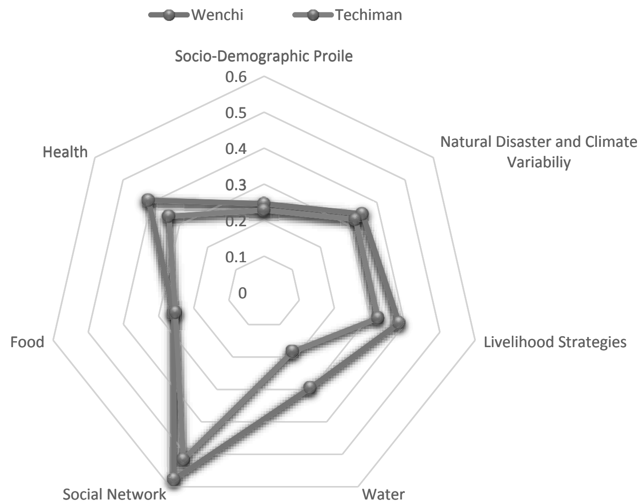

Figure 2 Vulnerability spider diagram of the major components of the LVI for Techiman and Wenchi municipalities
Source: Authors' computations from Field Survey (2015)

Table 2
Results of two-sample *t*-test of the difference in mean LVI for the major components

Variable	Obs.	Mean	Std. Err	Std. Dev.	t	*p*	d.f
Water							
Techiman	75	0.188	0.014	0.124	7.930[a]	.000	148
Wenchi	75	0.388	0.021	0.181			
Livelihood strategies							
Techiman	75	0.478	0.019	0.165	3.686[a]	.000	148
Wenchi	75	0.577	0.018	0.161			
Health							
Techiman	75	0.040	0.001	0.012	45.551[a]	.000	148
Wenchi	75	0.617	0.013	0.109			
Food							
Techiman	75	0.133	0.002	0.016	−41.616[a]	.000	148
Wenchi	75	0.040	0.001	0.012			
Natural Hazard							
Techiman	75	0.327	0.006	0.053	2.499[a]	.006	148
Wenchi	75	0.349	0.007	0.057			
Socio-Economic							
Techiman	75	0.360	0.014	0.125	−3.779[a]	.000	148
Wenchi	75	0.284	0.014	0.123			
Social Network							
Techiman	75	0.617	0.013	0.109	−9.251[a]	.000	148
Wenchi	75	0.247	0.038	0.329			

[a] Indicates significance at 1% significance level

Table 3
Results of two-sample *t*-test of the difference in mean LVI

Variable	Obs.	Mean	Std. Err	Std. Dev.	t	*p*	d.f
Techiman	75	0.358	0.009	0.081	−2.312[a]	.022	148
Wenchi	75	0.329	0.007	0.069			

[a] Indicates significance at 5% significance level

from the statistical table (1.96) with 148 degrees of freedom. This result was also supported by the probability value ($p < .05$). This implies that there is a disparity between the mean LVI computed for Techiman and Wenchi municipalities.

The LVI-IPCC estimates for the Techiman and Wenchi Municipalities were −0.015 and −0.011 respectively (Table 4). This implies that overall, in terms of climate change and variability, Wenchi Municipality was more vulnerable than Techiman Municipality. The LVI-IPCC was computed by grouping the seven major components into three categories, namely, exposure, sensitivity, and adaptive capacity. Exposure was made up of the score of only one major component, while sensitivity and adaptive capacity were made up of the aggregated scores of three major components each (Table 4). The IPCC definition of vulnerability, which takes into account exposure, sensitivity, and adaptive capacity, is presented in the vulnerability triangle as shown in Figure 3, where it ranges from 0 (low contributing factor) and 0.4 (high contributing factor).

The vulnerability triangle indicates that maize farming households in Wenchi municipality were more exposed and sensitive to climate change and variability, taking into consideration the water, health, and food status of the households in the municipality. The maize farming households in Wenchi municipality were also more vulnerable in terms of the household adaptation capacity,

Table 4
LVI-IPCC for Techiman and Wenchi Municipalities

Contributing factors	Major components	Major component values	Number of sub-component per major component	Contributing factor values	LVI-IPCC value
Adaptive capacity	Socio-demographic profile	0.228 (0.246)	5	0.383 (*0.384*)	
	Livelihood strategies	0.508 (0.384)	3		
	Social networks	0.516 (0.577)	3		
Sensitivity					
	Health	0.338 (0.410)	4	0.252 (*0.314*)	
	Food	0.252 (0.257)	5		−0.015 *(-0.011)*
	Water	0.183 (0.295)	5		
Exposure					
	Natural disasters and climate variability	0.324 (0.349)	6	0.324 (*0.349*)	

Note: Values in the parenthesis are for Wenchi Municipality

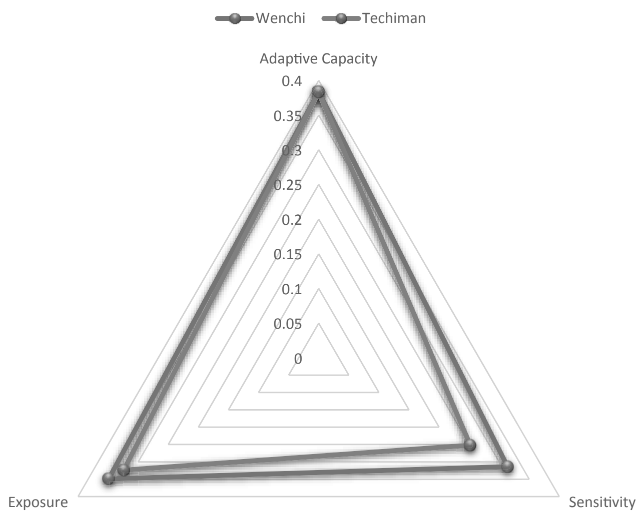

Figure 3 Vulnerability Triangle Diagram of LVI-IPCC for Techiman and Wenchi municipalities
Source: Authors' computations from Field Survey (2015)

Table 5
Results of two-sample *t*-test of the difference in mean LVI-IPCC

Variable	Obs.	Mean	Std. Err.	Std. Dev.	t	p	d.f
Wenchi	75	0.035	0.004	0.037			
Techiman	75	−0.047	0.006	0.050	11.38[a]	.000	148

[a] Indicates significance at 1% significance level

taking into account the socio-demographic, social networks, and livelihoods of households in the municipality.

The result again showed that there was a difference between the LVI-IPCC means computed for the Techiman and Wenchi municipalities (Table 5). This was due to the fact that the t-statistic obtained (11.38) was greater than the value obtain from statistical tables (1.96) with 148 degrees of freedom. This result was also supported by the probability value ($p < .01$).

Conclusion and Recommendation

The current study examined the vulnerability of smallholder maize farming households to climate change in the Brong-Ahafo region of Ghana by employing the Livelihood Vulnerability Index emphasizing access to and utilization of water resources. The study used both primary and secondary data. The primary data was based on 150 maize farming households, complemented by secondary data on rainfall and temperature over the period 1983–2013. A comparative analysis was conducted for Wenchi and Techiman municipalities in the Brong-Ahafo region. The empirical results revealed that farming households in Wenchi municipality were more vulnerable in terms of major components such as water, food, natural disaster and climate variability, social network, and health and socio-demographic profiles than those in Techiman municipality. On the other hand, farming households in Techiman municipality were more vulnerable in terms of livelihood strategies. The overall LVI computed from the major components indicate that farming households in Wenchi municipality were more vulnerable to climate change, with an index of 0.346 compared with that of Techiman municipality with 0.312. The LVI-IPCC index also indicated that farming households in Wenchi municipality were more vulnerable with an index of −0.011 than those in Techiman municipality with an index of −0.015. The results from study indicated that climate change is being experienced in the Brong-Ahafo region of Ghana, and maize farming households are being adversely affected by this phenomenon.

The study provides the following recommendations. First, Wenchi municipality should be given priority by both government and donors in terms of distribution of income generating and food security projects in order to reduce their farming households' vulnerability to food. This is based on the result that Wenchi was more vulnerable in terms of food for the maize farming households. Second, there is a need to improve the water supply in Wenchi municipality using such measures as the construction of more boreholes to reduce the time taken to fetch water from the source and to reduce conflicts over water. This recommendation is based on the result that Wenchi municipality was more vulnerable in terms of water which also had a higher percentage of respondents reporting water conflicts. Third, there is a need to build more community health centers in Wenchi municipality to reduce the time taken to reach a health facility. This recommendation is based on the result that Wenchi municipality was more vulnerable in terms of health aspects. Fourth, the municipal assemblies and meteorological agencies as well as other non-governmental organizations should inform smallholder maize farming households in the Techiman and Wenchi municipalities about impending natural disasters such as floods, droughts, and pests. This is based on the empirical results that the majority of the respondents in both municipalities did not receive warning about impending disasters. Finally, given the moderate levels of vulnerability of maize farming households to climate change and variability, it is important that indicators be developed to monitor how changes in the climate are likely to affect the livelihoods of these farming households.

This study also contributed to the livelihood vulnerability debate by highlighting the vulnerability of maize farming households to climate change and variability in the Brong-Ahafo region of Ghana. This study provided an empirical contribution on the vulnerability of maize farming households in the Brong-Ahafo region of Ghana to climate change and variability as well as other livelihood variables (social networks, livelihood strategies, socio-demographic profile, access to water, and food and health facilities) using the lens of the various livelihood vulnerability frameworks by using household level data. Furthermore, this study analyzed and determined the significant differences in the levels of vulnerabilities across the major components in the two municipalities. Nevertheless, since our study focused only on some selected communities in the Brong-Ahafo region of Ghana, the results should be interpreted as limited to this area until further more extensive data become available. Another limitation of our study was that we analyzed the roles of power relations, access, political, social, and economic structures regarding the maize farmers' vulnerability to climate change. We did not cover the underlying causes of the threat of climate change to people's livelihoods. Thus, examining the underlying causes of the farmers' vulnerability to climate change was beyond the scope of our paper.

Conflict of Interest

The authors declare that no conflict of interest exists.

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