Gender dimension of vulnerability to climate change and variability

Empirical evidence of smallholder farming households in Ghana

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Abstract

Purpose – This paper aims to investigate farmers' vulnerability to climate change and variability in the northern region of Ghana.

Design/methodology/approach – The study assessed the vulnerability of male-headed and female-headed farming households to climate change and variability by using the livelihood vulnerability index (LVI) and tested for significant difference in their vulnerability levels by applying independent two-sample-student's *t*-test based on gender by using a sample of 210 smallholder farming households.

Findings – The results revealed a significant difference in the vulnerability levels of female-headed and male-headed farming households. Female–headed households were more vulnerable to livelihood strategies, socio-demographic profile, social networks, water and food major components of the LVI, whereas male-headed households were more vulnerable to health. The vulnerability indices revealed that female–headed households were more sensitive to the impact of climate change and variability. However, female-headed households have the least adaptive capacities. In all, female-headed farming households are more vulnerable to climate change and variability than male-headed farming households.

Research limitations/implications – The study recommends that female-headed households should be given priority in both on-going and new intervention projects in climate change and agriculture by empowering them through financial resource support to venture into other income-generating activities. This would enable them to diversify their sources of livelihoods to boost their resilience to climate change and variability.

Originality/value – This is the first study that examined the gender dimension of vulnerability of smallholder farmers in Ghana by using the livelihood vulnerability framework. Female subordination in northern region of Ghana has been profound to warrant a study on gender dimension in relation to climate change and

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variability, especially as it is a semi-arid region with unpredictable climatic conditions. This research revealed the comparative vulnerability of male- and female-headed households to climate change and variability.

Keywords Ghana, Gender, Livelihood vulnerability, Smallholder farmers, Climate change and variability

Paper type Research paper

1. Introduction

There is a growing global concern on climate change and variability given its impact on the environment and agriculture. The recent increases in temperatures, erratic rainfall leading to floods, droughts and water scarcity are all evidences of climate change and variability (Adger *et al.*, 2003; Asante and Amuakwa-Mensah, 2015; Intergovernmental Panel on Climate Change [IPCC], 2007; Adu *et al.*, 2017). Odada *et al.* (2008) revealed that climate change and variability is a serious challenge to future development, especially in semi-arid areas. About 85 per cent of the world farmers are smallholders and earn their livelihood through rain-fed agriculture (IPCC, 2014; Morton, 2007; Harvey *et al.*, 2014). Thus, the concern is how climate change and variability is impacting ecosystem, agriculture and livelihoods.

Ghana's economy is basically agrarian, and the agricultural sector is dominated by small-scale farmers who cultivate on two-hectare farm lands or less (Ministry of Food and Agriculture, MoFA, 2010). In Ghana and other parts of the tropical region, climate change and variability is predicted to unduly distress smallholder farmers, making their livelihoods more precarious (IPCC, 2014). Unfortunately, to the best of our knowledge, information on the extent of their vulnerability and adaptation is scanty or non-existent in the literature. Poverty and food insecurity in Northern Ghana continue to be high as a result of climate change and variability (Amikuzuno and Donkoh, 2012).

The Ministry of Environment, Science, Technology and Innovation (2013) noted in the Ghana National Climate Change Policy that the savannah zone is the most vulnerable to climatic stresses in Ghana. Northern region is most vulnerable to climatic stresses because of its high poverty incidence, high rural population, poor agro-climatic systems and predominance of subsistence farmers relative to the southern part of Ghana (GSS, 2014; Nti, 2012). Stanturf *et al.* (2014) stated that northern Ghana is relatively more vulnerable to climate change and variability compared to other parts of Ghana because of its high illiteracy rate and underdeveloped infrastructure. In short, most studies on climate change in Ghana have portrayed the northern region as the most exposed and vulnerable region to climatic stresses with the least adaptive capacities (Etwire *et al.*, 2013; Kuwornu *et al.*, 2013; Al-Hassan *et al.*, 2013; Nti, 2012; START, 2013).

According to Boko *et al.* (2007), the effect of climate change and variability is expected to differ based on agro-ecological regions, spatial features and across socio-economic groups such as gender differentials. Though both male-headed and female-headed farming households within the same geographical location are exposed to the same climatic conditions, the extent of effect of the climatic stresses varies between men and women, because of differences in their levels of adaptive capacities and sensitivity. Thus, vulnerability to climate change is worsened by gender disparity (World Bank, 2010). Women constitute about 50.4 per cent of the northern region's population (GSS, 2012). Yet, female farmers' agricultural activities lack the needed resources relative to male farmers (Asare, 2000; Food and Agricultural Organisation, FAO, 2011). In the northern region, female-headed households have less tenures and access to land and other production resources compared to male-headed households (Blackden and Wodon, 2006; Doss and Morris, 2000; Koru and Holden, 2008).

Numerous studies in the climate change vulnerability literature have examined spatial and sector vulnerability with little emphasis on the gender dimension of vulnerability to climate change. Therefore, the objective of this study is to examine the vulnerability to climate change and variability for female-headed and male-headed farming households in the northern region of Ghana. The authors postulate that there is a significant difference in the vulnerability levels of male-headed and female-headed households. Apart from adding to the climate change literature, the findings of this study will provide specific gender vulnerability levels, sensitivity and adaptive capacities to climate change and variability. This will be instrumental in formulating policies to address the specific needs of gender groups in reducing vulnerability to climate change and variability as a way of achieving Ghana's National Climate Change Policy objective of gender equity.

1.1 Vulnerability to climate change and variability

The term "vulnerability" has been used to portray different interpretations in different disciplines and does not lend itself to a precise and concise definition. Turner *et al.* (2003) defined vulnerability as the extent of injury likely to be caused to a system as a result of its exposure to a hazard. Cutter *et al.* (2008) and Nelson *et al.* (2010) view vulnerability as the predisposition of any group of people, location or system to disorders determined by exposure and sensitivity to distresses, including their adaptive capacity. The Third and Fourth Assessment Reports of the IPCC (2014) defined vulnerability as the level to which a system is susceptible to, or incapable of coping with the adverse effects of climate change, climate variability and extremes. In other words, vulnerability is an embodiment of the character, magnitude and degree of exposure of a system to climate change and variability, its sensitivity and adaptive capacity.

According to IPCC (2007), adaptive capacity of a system is its ability to reduce the possible consequences of climate variability through prevailing opportunities or using measures to deal with these consequences; sensitivity is the extent to which a system is affected by climate-related stimuli either positively or negatively; covertly or overtly; and exposure is the extent to which a system is unshielded from major climate-related events. In the context of this study, vulnerability is the extent to which a farming household is susceptible to, or unable to adapt to, the negative effects of climatic stresses.

2. Methodology

The kind of research designed to be used by a researcher is greatly influenced by research question(s). Qualitative research seeks to understand a phenomenon based on the opinions of the population or people experiencing it (Mack *et al.*, 2005). According to Kothari (2004), quantitative research is a process that involves measurement of phenomenon to obtain numerical data and is often applied to phenomenon that can be measured in terms of quantity. Thus, the quantitative method solicits information from respondents by the use of structured questionnaire, which provides numerical data at the end. Between qualitative and quantitative research methods is the mixed method, which is a process where a researcher uses a qualitative method at one phase of the research and then uses a quantitative method at the other phase to validate the results of the qualitative assessment. In this study, the authors adopted the mixed method. This made it possible to for us to compute vulnerability levels for households from the data gathered from the questionnaire administered to respondents while providing explanations to the vulnerability levels of households through the information gathered from focus group discussions.

2.1 Approaches to measuring vulnerability

There are two main approaches to measuring vulnerability to climate change and variability: the indicator and econometric approaches (Deressa *et al.*, 2009). While the econometric approach uses regression analysis, the indicator approach involves choosing components which a researcher considers as indicators of vulnerability and then computing indices for these components. The econometric approach to measuring vulnerability is limited by the setback of testing several econometric assumptions concerning confidence intervals, standard errors and hypotheses. On the other hand, the major shortfall of the indicator approach is the subjectivity on the part of the researcher in selecting the indicators of vulnerability to be incorporated in computing the vulnerability index. In spite of this criticism, the indicator approach is still preferred over the econometric approach because it is easier to compute and comprehend by readers with low mathematical inclination. In fact, the authors have explored the econometric approach and realized that, in this context, the results of the indicator approach were more appealing and intuitive than those of the econometric approach. Moreover, unlike the econometric approach, the indicator approach (especially the livelihood vulnerability index [LVI]), in addition to determining households' present vulnerability to drought, bushfires and floods, also provides projections of future vulnerability for effective planning (Hahn *et al.*, 2009). Though the indicator approach is subjective, it is possible to compare the vulnerability of a given system to climatic stresses at a particular geographical location within a given time period. In this respect, this study used the indicator approach in measuring vulnerability of female-headed and male-headed farming households to climate change and variability.

In the literature, several indicator methods have been developed by several authors to measure vulnerability. These indicator methods have been dependent on the discipline in which it is used and also the objective of the research. Table I presents a list of indicator methods applicable in measuring vulnerability in the literature. The LVI approach developed by Hahn *et al.* (2009), which is an indicator method, was used in this study to examine farming households' vulnerability to climate change and variability. The selected indicators have to be contextual and relevant to the local communities in which the investigation is being conducted (Asare-Kyei *et al.*, 2014). Therefore, in this study, the authors have chosen indicators that are contextual and relevant to the local communities in which the study was conducted.

2.2 Testing for difference in means of livelihood vulnerability indices

Given that the computed vulnerability indices are averages, there is a need to test for statistical difference in the means of the LVI_s for both gender groups (i.e. female-headed and male-headed households). In the literature, the Student's *t*-test and the Mann–White U test are some of the statistical methods for testing for differences in means of two samples. According to Ruxton (2006a, 2006b), the Mann–White *t*-test is best applicable for smaller sample ($N < 30$) with unequal population variance and non-normal *t* distribution. The Student's *t*-test on the other hand is suitable for larger samples ($N \geq 30$) where equal variance (homogenous population) and normal *t* distribution are assured (Sokal and Rohlf, 1987).

This study used the independent two-sample student's *t*-test (two-tailed) to test for significant differences in the means of the LVI major components, overall LVI, Intergovernmental Panel on Climate Change (IPCC) vulnerability contributory factors and the LVI_{IPCC} indices. The *t*-statistic is calculated using equation (1):

Index	Authors (year)	Assumption	Limitation
Social vulnerability	Lee (2014)	Indicator based (in terms of capital) study Zero-mean normalization was applied to standardize the indicator values	All indicators (variables) showed same (positive) direction to vulnerability Considered only single hazard (flood)
Social vulnerability index (SVI)	Ge *et al.* (2013)	Application of projection pursuit cluster (PPC) model. Hazard-loss assessment by using economic variables (GDP and PCI)	Absence of exposure indicator(s) No algebraic solution of PPC and hence no global optimal solution
Climate vulnerability index (CVI)	Pandey and Jha (2012)	Primary data-based index Useful tool for assessing spatio-temporal scale differences in vulnerability	Suitable only for mountainous areas Weightage of different sub-components were data sensitive
Vulnerability index	Gbetibouo *et al.* (2010)	Large spatial base (nine South African provinces) for data collection Principal component analysis for weighing indicators	Likelihood of paradoxical weight assigning to indicators due to poor data structure
Livelihood effect index (LEI)	Urothody and Larsen (2010)	Primary data were used Comparison between LVI and LEI	Perception on climate change and assigning importance (weights) to contributing factors by the illiterate respondents might not be accurate
LVI	Hahn *et al.* (2009)	Good dataset/primary data Diversified components were considered for vulnerability	Equal weights for all components is not feasible
Vulnerability as expected poverty	Deressa *et al.* (2009)	Measures farmers' vulnerability to drought, floods and other climatic extremes Estimates the probability that a household's consumption will fall below a minimum level due to the occurrence of a climatic shock	Measures only the tendency to be poor (vulnerability) in future due to climatic extremes and not current vulnerability
Social vulnerability index (SVI)	Vincent (2004)	Different weights were used for different sub-indices Multi-country analysis data problem due to us age of secondary data	For multi-country analysis the relative importance(weights) of sub-indices were likely to be different Missing data problem due to usage of secondary data
Social vulnerability index (SVI)	Cutter *et al.* (2008)	County-level socio-economic and demographic data were used Principal component analysis was applied for data reduction	Variables related to exposure to natural hazard were ignored Likelihood of not considering important variable after extraction of principal components due to data structure

Source: Authors' compilation from literature, 2016

Table I.
Different indicator methods of measuring vulnerability to climatic shocks

$$t = \frac{(\mu_F - \mu_M)}{\sqrt{\frac{\sigma_F^2}{N_F} + \frac{\sigma_M^2}{N_M}}} \tag{1}$$

Here, μ_F and μ_M denote the means of computed vulnerability indices for the female-headed and male-headed households, respectively, σ_F^2 and σ_M^2 denote the standard deviations of the vulnerability indices for the female-headed and male-headed households, respectively, and N_F and N_M denote the sample size for female-headed and male-headed households, respectively.

The null hypothesis (*H0*) for the overall LVI is stated as:

H0. There is no significant difference in the means of the livelihood vulnerability index for male- and female-headed households ($\mu_F = \mu_M$).

The alternate hypothesis (*H1*) for the overall LVI is stated as:

H1. There is significant difference in the means of the livelihood vulnerability index for male- and female-headed households ($\mu_F \neq \mu_M$).

The same hypotheses were tested for all the LVI major components, the IPCC contributory factors and the LVI_{IPCC}.

2.3 Measuring vulnerability to climate change and variability

The nature and degree of female-headed and male-headed farming households' vulnerability to climate change and variability were examined by estimating two indices: the LVI based on a balanced weighted average and LVI_{IPCC} based on the IPCC vulnerability framework. These indices are simple to understand and practically reflect the situation of the farming households.

2.3.1 Estimating the livelihood vulnerability index. The livelihood vulnerability framework is commonly used in assessing vulnerability to climate change and variability for the reason that it is a framework that makes it possible to analyze both the essential components constituting livelihood and the contextual factors influencing these components. The LVI assumes equal weights for all major and sub-components (Sullivan, 2002).

Hahn *et al.* (2009) made use of seven major indicators to estimate the LVI. These are socio-demographic profile (SDP), livelihood strategies (LS), social networks (SN), health (H), access to food (F), access to water (W) and natural disasters and climate variability (NDCV). Each major indicator consists of several sub-components known as indicators. The indicators are measured on varied scales. Therefore, each indicator was standardized as an index by using the UNDP's (2007) life expectancy index, given by equation (2):

$$Index_{sc} = \frac{S_s - S_{\min}}{S_{\max} - S_{\min}} \tag{2}$$

Here, S_s is the observed sub-component indicator for a particular gender S and $S_{\min}$ and $S_{\max}$ are the minimum and maximum values, respectively, for each sub-component determined using the combined data.

The sub-component indicators are now averaged using equation (3) to obtain the index of each major component:

$$M_s = \frac{\sum_{i=1}^{n} index_s}{n} \tag{3}$$

Here, M_s is one of the seven major components (SDP, LS, SN, H, F, W or NDCV) for a particular gender S; $index_s$ 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.

After major components indices have been computed, they are also averaged to obtain the gender's LVI by using equation (4):

$$LVI_s = \frac{\sum_{i=1}^{7} w_{Mi} M_s}{\sum_{i=1}^{7} w_{Ms}} \tag{4}$$

Explicitly, equation (4) can be rewritten as:

$$LVI_s = \frac{wSDP_s SDP_s + wLS_s LS_s + wH_s H_s + wSN_s SN_s + wF_s F_s + wW_s W_s + wNDCV_s NDCV_s}{SDP_s + LS_s + H_s + SN_s + F_s + W_s + NDCV_s} \tag{5}$$

Here, w_{Mi}, the weights of each major component, is a function of the number of sub-components that each major component is composed of. These were included to ensure that all sub-components contribute equally to the overall LVI. The LVI is scaled between 0 (least vulnerable) and 1 (most vulnerable). The livelihood vulnerability components used in this study are consistent with locally and nationally evaluated indicator sets for assessing the risk to natural hazards (Asare-Kyei *et al.*, 2014).

2.3.2 Estimating the livelihood vulnerability index based on the Intergovernmental Panel on Climate Change (LVI_{IPCC}). The IPCC defined vulnerability in terms of three contributory factors: adaptive capacity, sensitivity and exposure. Following from the IPCC view on vulnerability, Hahn *et al.* (2009) then computed another variable, LVI_{IPCC_s}, by using equations (2)-(4). The LVI_{IPCC_s} uses the IPCC vulnerability contributory factors in computing the vulnerability index. The LVI_{IPCC_s} differs from the LVI when the major components are combined. Instead of merging the major components into the LVI using equation (2), the major components are first combined into three categories, namely, exposure, adaptive capacity and sensitivity, by using equation (6):

$$CF_s = \frac{\sum_{i=1}^{n} w_{Mi} M_{si}}{\sum_{i=1}^{n} w_{Mi}} \tag{6}$$

Here, CF_s, is an IPCC-defined contributing factor (exposure, sensitivity or adaptive capacity) for a particular gender S, M_{si} are the major components for a particular gender S, indexed by i, w_{Mi} is the weight of each major component and n is the number of major components in each contributing factor. Once exposure, adaptive capacity and sensitivity are estimated, the three contributing factors are combined using equation (7) as follows:

$$LVI_{IPCC_s} = (E_s - A_s) * S_s \tag{7}$$

Here, LVI_{IPCCs} is the vulnerability index for a particular gender S, expressed based on the IPCC vulnerability framework, E_s is the computed exposure index for a particular gender S (equal to the natural disaster and climate variability major component), A_s is the computed adaptive capacity index for a particular gender S (weighted average of socio-demographic, livelihood strategies and social networks major components) and S_s is the computed sensitivity index for gender S (weighted average of the health, food and water major components). The LVI_{IPCC_s} is scaled between −1 (most vulnerable) to 1 (least vulnerable).

2.4 Study area

The study was conducted in the northern region of Ghana, specifically, in the West Mamprusi District, West Gonja District and the Tamale Metropolis. The region is within the guinea savannah agro-ecological zone and is located in a semi-arid climatic region, where rainfall pattern is erratic with high temperatures, especially during the harmatan (dry) season. The region occupies a land area of 70, 384 km^2 (31 per cent of Ghana's total land area), with a population of 2, 479, 461. About 50.4 per cent of the region's population is female. There are 318,119 households in the northern region, with 85.9 per cent of them headed by males (GSS, 2012). About 73.11 per cent of the region's economically active population is employed by the agricultural sector, of which 43.1 per cent are female while the remaining 56.9 is male (GSS, 2012). The region is the food basket of Ghana, producing mainly cereals and tuber crops such as yam. The minimum and maximum temperatures for the region are 14°C at night and 40°C during the day.

2.5 Sources of data and sampling procedure

Data for this study were obtained from primary and secondary sources. Primary data were obtained through household questionnaire administered to male-headed and female-headed farming households. The reference period for the questions on climatic conditions was 2000-2015. Secondary data on rainfall and temperature between 1985 and 2015 were obtained from the Ghana Meteorological Service and were included in computing the exposure components of the LVI.

A multi-stage sampling technique was used. The first stage involved a purposive selection of West Mamprusi District, Tamale metropolis and the West Gonja District of the northern region of Ghana, as these are the top three rice-producing districts in the region. In the second stage, non-proportionate sampling was used to select two rice-producing communities each from West Mamprusi (Arigu and Tinguri) and West Gonja Districts (Busunu and Gurupe), as well as three rice-producing communities in the Tamale Metropolis (Tugu, Kpene and Nyerizie). The number of farming households selected from each community was also based on non-proportional sampling technique. Within each community visited, all households were listed and stratified into male-headed and female-headed, and then, simple random sampling was used to select the required number of male-headed and female-headed households to constitute the sample units to whom questionnaire were later administered. In all, the heads of 210 rice farming households were interviewed, 70 female-headed households and 140 male-headed households, based on the number of male-headed and female-headed farming households listed for the communities.

2.6 Focus group discussion

Focused group discussions were organized separately for men and women in one community each within the three districts of the communities visited by using a checklist of questions of interest. Each focus group session had a membership of 7-12 female and male farmer group leaders and other elderly members of the community who were deemed capable and acquainted with climate issues. Of the three research team members, one asked questions, the other recorded responses while the third took pictures with a camera. The purpose of these focus group discussions was to gather information from both gender groups in relation to their perceived climate change and patterns in the community, access to essential services, livelihood sources and infrastructure (i.e. market and health-care). The findings of the focus group discussion were to complement the quantitative results of the study by providing empirical explanations to the findings revealed by the quantitative results.

Each focus group session lasted for 2-2.5 h. The meetings were held after 16:00 GMT when farmers had returned from their farms. In West Mamprusi and West Gonja Districts, the meetings were held in the Arigu and Busunu communities, respectively, while in the Tamale Metropolis, it was held in Kpene. Both male and female participating groups at the various focus group discussions were asked what their main non-farm activities were as a strategy to overcome the livelihood effects of low crop yields due to unfavorable climatic condition; the general consensus among participants on the accessibility, size and nature of their farm lands; farmers perception on rainfall patterns over the years; the specific roles of men and women in their communities; and the reasons for differences in vulnerability to climate variability by gender.

3. Results and discussion

3.1 Female and male livelihood vulnerability index assessment

Though the ideal value of the LVI ranges between 0 (least vulnerable) and 1 (most vulnerable), the computed indices for the major components in this study ranges from 0.120 (least vulnerable) to 0.597 (most vulnerable). The computed vulnerability indices for the major and sub-components and results of the two-sample *t*-test are presented in Table II. Results of the two-sample *t*-test indicate significant difference in the male-headed and female-headed households in terms of socio-demographic profile, social networks, health, food and livelihood diversity but not climate change and disaster main components. This is presented in Table II.

3.1.1 Socio-demographic profile. The computed vulnerability indices for the socio-demographic profile (SDP) major component of the LVI revealed that female-headed households (LVI_{SDP} = 0.449) were more vulnerable than male-headed households (LVI_{SDP} = 0.423). Although male-headed households (0.149) were more vulnerable with respect to dependency index than female-headed households (0.136), a relatively large percentage of female-headed households (47.33 per cent) have more orphans to cater for than male-headed households (31.0 per cent). The dependency ratios were 1.04 and 0.95 for male-headed and female-headed households, respectively. Though both ratios are relatively higher than the national dependency ratio of 0.67 (GSS, 2012), male-headed households had more dependents than female-headed households, thereby making the former more vulnerable than the later. The reason is that higher dependency ratio implies that many people were dependent on the toils of few others. The computed household head average age indices indicate that male-headed households (0.640) were more vulnerable than female-headed households (0.557). The life expectancy at birth for women and men were 68.19 and 63.38 years, respectively (Central Intelligence Agency, CIA, 2015). More female-headed households (49.33 per cent) have no toilet facilities in their households compared with male-headed households (41.0 per cent). It is worth noting that these statistical values far exceed the 19.3 percentage of Ghanaian households without toilet facility (GSS, 2012). Both female-headed (78.67 per cent) and male-headed households (79.0 per cent) had almost the same

Table II. Computed indices and results of two-sample *t*-test for major and sub-components of LVI

Major component	Sub-component	Index of sub-components (S_{si}) Female	Male	Major component indices (M_{si}) Female	Male	Two-sample *t*-test *t*-value	*p*-value
Socio-Demographic Profile	Dependency ratio	0.136	0.149	0.449	0.423	4.4723	0.000
	Average age of household heads	0.557	0.640				
	% of households without latrines	0.493	0.410				
	% of households with household head never attending school	0.787	0.790				
	% of households with orphans	0.473	0.310				
	Average number of persons per room	0.244	0.241				
Livelihood Strategies	% of households with family member working in another community	0.373	0.360	0.422	0.332	2.6596	0.008
	% of households dependent only on agriculture as a source of income	0.360	0.300				
	% of households who do not own their farm lands	0.380	0.120				
	Average agricultural livelihood diversification index	0.575	0.548				
Social Network	Average receive:give ratio (0-2)	0.333	0.353	0.597	0.587	3.533	0.005
	Average borrow:lend money (0-2)	0.458	0.429				
	% of households that have not gone to their local government for assistance in the past 12 months	1.000	0.980				
Health	Average time to health facility (minutes)	0.125	0.167	0.251	0.279	-13.964	0.000
	% of households with family member with chronic illness	0.333	0.300				
	% of households where a family member had to miss work or school in the past two weeks because of illness	0.400	0.490				
	Average malaria exposure × prevention index (range: 0-12)	0.146	0.160				
Food	% of households dependent on family farm for food	0.360	0.300	0.523	0.512	6.405	0.000
	Average number of months households struggle to find food (range: 0-12)	0.170	0.131				

(*continued*)

Table II.

Major component	Sub-component	Index of sub-components (S_{si})		Major component indices (M_{si})		Two-sample t-test	
		Female	Male	Female	Male	t-value	p-value
	Average crop diversity index (range: 0-1)	0.482	0.417				
	% of households not saving crops	0.753	0.783				
	% of households not saving seeds	0.850	0.931				
Water	% of households reporting water conflicts	0.684	0.310	0.511	0.449	1.064	0.000
	% of households utilizing a natural water source	0.933	0.931				
	Average time to water source (minutes)	0.269	0.313				
	% of households without a consistent water supply	0.600	0.604				
	Inverse of the average number of liters of water stored per household	0.071	0.087				
Natural Disasters and Climate Variability	Average number of flood, bush fires and drought events in the past 10 years	0.509	0.528	0.486	0.483	1.064	0.143
	% of households who lost crops as a result of the floods, drought and bushfires	0.627	0.624				
	% of households that did not receive a warning about the pending natural disasters	0.480	0.436				
	% of households reporting an injury or death due to natural disaster in the past 10 years	0.013	0.020				
	Mean standard deviation of the daily average maximum temperature by month	0.694	0.694				
	Mean standard deviation of the daily average minimum temperature by month	0.341	0.341				
	Mean standard deviation of the daily average maximum temperature by month	0.737	0.737				
Overall LVI				0.463	0.438	25.981	0.000

Note: ***Denotes significance at 1%

percentage of household heads reported who have never attended school. The implication is that in terms of education, both female-headed and male-headed households are equally vulnerable. These observations far exceed the report of the Ghana Statistical Service (2012) that 34.7 per cent of women and 21.6 per cent of men have never attended school. Female-headed and male-headed households recorded a room occupancy rate of 2.49 and 2.47 persons per room, respectively. High room occupancy rate facilitates the spread of air-borne disease during an outbreak. The vulnerability of both male-headed and female-headed households to diseases in a period of pandemic is likely to be the same because they have a similar room occupancy rate.

3.1.2 Livelihood strategies. The second major component of the LVI is the livelihood strategies. The computed vulnerability indices indicate that female-headed households were more vulnerable in terms of livelihood strategies (LVI_{LS} = 0.422) than male-headed households (LVI_{LS} = 0.332). Female-headed households have a relatively higher percentage of members (37.33 per cent) working outside the community than male-headed households (36.0 per cent). About 36 per cent of female-headed households depend solely on agriculture as a source of income compared with 30 per cent for male-headed households. Yet, female-headed households recorded low average agricultural livelihood diversification (2.08) compared to male-headed households (2.16). This makes female-headed households significantly more vulnerable (0.575) than male-headed households (0.548) in terms of agricultural diversification index, as revealed by the results of the two-sample *t*-test. The computed vulnerability indices showed that female-headed households (0.380) were more vulnerable in terms of farmland ownership than male-headed households (0.120), with 38 per cent of female-headed households not owning their farms relative to 12 per cent for male-headed households. The result of the focus group discussion revealed that women were often engaged in non-farm activities such as rice processing, shea business, burning and selling of fire wood and charcoal, petty trading and food vending and men are often engaged in fishing, casual labor at sand loading sites and masonry works.

3.1.3 Social network. The social network major component of the LVI consists of three sub-components. While 98 per cent of male-headed households reported not seeking assistance of any sort from their members of parliament (MPs) or local government, all female-headed households never sought for assistance from their local assemblies and MPs. The computed indices showed that while there were more male-headed households (0.353) who gave assistance than they received relative to female-headed households (0.333), more female-headed households (0.458) reported to have borrowed money from friends and relatives than they lent compared to male-headed households (0.429). Access to credit and assistance increases households' resilience and reduces their vulnerability. The vulnerability index of the social network major component showed that female-headed households (0.597) were more vulnerable than male-headed households (0.587), and this result significant as indicated by the two-sample *t*-test. It is logical to deduce from these indices that female-headed households were more vulnerable in terms of access to credit and assistance than male-headed households. The results of the focused group discussions revealed that women can hardly walk to a traditional or community leader for assistance because of cultural factors. When in need, women can only seek for assistance from such leaders through their husbands or brothers. This limits the social networks of female-headed households, making them more vulnerable than male-headed households.

3.1.4 Health. Male-headed households (LVI_H = 0.279) appeared to be significantly more vulnerable than female-headed households (LVI_H = 0.251) in terms of the health major component of the LVI, as revealed by the computed vulnerability indices and the two-sample *t*-test. Four sub-components constitute the health major component. Averagely, male-headed households spend more time (i.e. 30 min) in reaching health facilities than female-headed households (i.e. 25 min). Male-headed households reported a higher percentage of household members who did not go school or work for the past two weeks because of illness (49 per cent) than female-headed households (40 per cent). However, based on the computed vulnerability indices, female-headed households (0.333) are more vulnerable to chronic illness than male-headed households (0.300). About 33.3 per cent of female-headed households reported at least a chronically ill household member compared to 30.0 per cent of male-headed households. Male-headed households (0.160) were more vulnerable in terms of average malaria exposure × prevention index than female-headed households (0.146). The average number of months of malaria prevalence was 2.12 and 2.09 for female-headed and male-headed households, respectively. The average numbers of mosquito nets owned by female-headed and male-headed households were reported to be 3.27 and 4.54, respectively.

3.1.5 Food. Female-headed households (LVI_F = 0.523) were more vulnerable to food than male-headed households (LVI_F = 0.512). About 78.25 and 93.06 per cent of male-headed households did not save harvested crops (farm produce) and seeds, respectively, compared with 75.33 and 85.0 per cent of female-headed households who reported not to have saved crops and seeds, respectively. Farmers who were able to save their farm produce were able to sell at higher prices for higher incomes and were more food-secure. Also, farmers who were able to save seeds from their farm produce do not struggle much to access seeds for cultivation in the subsequent farming season. Based on the computed indices, male-headed households were more vulnerable than female-headed households in terms of seed availability and income from farm produce. The average crop diversity for female-headed and male-headed households were 2.12 and 2.33, respectively. Yet, a relatively higher percentage of female-headed households depend on family farms for food (36 per cent) than male-headed households (30 per cent). Therefore, male-headed households were less vulnerable than female-headed households in terms of crop diversity, especially in a year where the climatic condition was not suitable for the growth of certain crops. The computed vulnerability indices and the two-sample *t*-test showed that female-headed households were more vulnerable to food (0.170) than male-headed households (0.131). The average number of months of food inadequacy among female-headed and male-headed households was 2.04 and 1.57, respectively. This usually occurs between June and July, when farmers have exhausted their food stock and are just beginning the farming season. The results of the focus group discussion showed that women often cultivate on small scale and very close to the community where the lands are not very fertile and have been abandoned to fallow. The result is often that the farm outputs of women are usually low, which they are unable to depend on for the entire year, making female-headed households more food-insecure than male-headed households.

3.1.6 Water. The sixth major component of the LVI is water, and it consists of five sub-components. Regarding the source of water, almost 93 per cent of both female-headed and male-headed households' sources of water are streams, dams, rain, lakes and rivers. Water from natural sources is sometimes contaminated, leading to the outbreak of waterborne diseases such as bilharzias. The implication is that majority of both male-headed and female-headed households have high risk of contracting water-borne diseases. About 68.4 and 36 per cent of female-headed and male-headed households, respectively, reported water conflict six weeks prior to the data collection. Conflict is a catalyst to social disintegration and retrogresses social cohesion, which are necessary for development. Majority of female-headed households reported water-related conflicts because the culture of northern Ghana charges women with the responsibility of sourcing water for domestic use, hence the likelihood of women engaging in water-related conflicts than their men counterparts. The average times to a source of water by female-headed and male-headed households were 16.1 and 18.8 min, respectively. This suggests that men travel farther for water than women. Almost 60 per cent of both male-headed and female-headed households have no consistent source of water. The average water stored by a male-headed household is 79.78 L compared with 73.67 L for female-headed households. When all the five sub-components indices were averaged, female-headed households were significantly more vulnerable to the water major component (LVI_W = 0.511) than male-headed households (LVI_W = 0.449). It was revealed during the focus group discussions that water fetching for household use is the sole responsibility of women. Men, on the other hand, fetch water for construction, especially building a house, and also for watering and bathing of animals. While women often source water from boreholes, rains, dam and well, men often go to the river, dam, lake and spring for water. The reason from the focused group discussions was that men have bicycles and motor bikes which they can use to go to fetch water at distant places than women. Also, the uses of the water fetched by men do not need to be very clean and pure compared to the water fetched by women, which is used for drinking and cooking.

3.1.7 Natural disasters and climate variability. The results of the two-sample *t*-test revealed that there is no significant difference in the indices of natural disasters and climate change major component of the LVI. This study discussed only components with significant difference in the computed indices for male-headed and female-headed households. However, there was consensus between men and women in all communities visited that the period of rain has changed and spans between May and November, which hitherto began in April and ended in October. The amount of rainfall per annum was, however, stated to be erratic. A female farmer in one of the communities said:

> We used to start clearing our farms in February to March in preparedness for the early rains in April. But now, when you clear your farm within this period, you will wait in vain and even may have to clear it again because the start of the rain now delays and highly unpredictable.

When all the seven major components of the LVI were aggregated, female-headed households with an overall LVI of 0.463 were considered to be more vulnerable to climate change and variability than male-headed households with an overall LVI of 0.438[1]. The results of the independent two-sample student *t*-test revealed a significant difference between the computed LVIs of the female-headed and male-headed households (Table III). The computed vulnerability indices of the major components of the LVI and the overall LVI for female-headed and male-headed households are presented in the gender vulnerability radar diagram in Figure 1.

Table III. Computed indices of the IPCC vulnerability contributory factors by gender and results of two-sample *t*-test

	Computed index		Two-sample *t*-test	
Contributory factor	Female	Male	*t*-value	*p*-value
Adaptive capacity	0.475	0.433	−8.759	0.000
Sensitivity	0.441	0.423	9.823	0.000
Exposure	0.486	0.483	1.064	0.143
LVI_{IPCC}	0.005	0.021	2.668	0.006

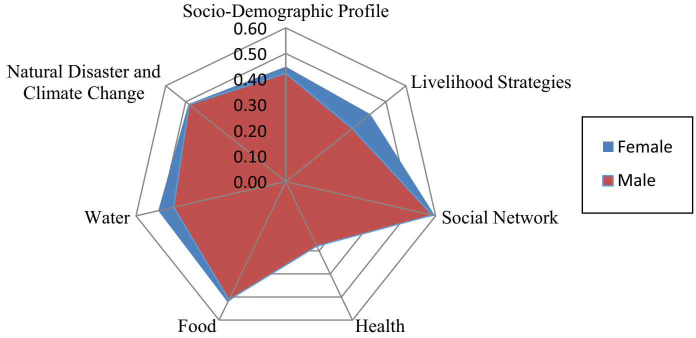

Figure 1.
Gender vulnerability radar diagram

3.2 Assessment of livelihood vulnerability index based on the Intergovernmental Panel on Climate Change for women and men

The definition of vulnerability of a system by IPCC considers its adaptive capacity, sensitivity and exposure to climatic stresses as contributory factors to vulnerability. The major components were first merged into the three contributory factors: adaptive capacity (weighted average of demographic profile, livelihood strategies and social network major components), sensitivity (weighted average of the health, food and water major components) and exposure (equivalent to the natural disaster and climate change major component). The computed indices for the vulnerability contributory factors are presented in Table III.

Based on the computed vulnerability contributory factor indices (CFI), female-headed households were more vulnerable ($CFI_{adaptive\ capacity}$ = 0.475) than male-headed households ($CFI_{adaptive\ capacity}$ = 0.433) in terms of adaptive capacities. Yet, female-headed households were more sensitive to climate change and variability ($CFI_{Sensitivity}$ = 0.441) than male-headed households ($CFI_{Sensitivity}$ = 0.423). Both male-headed households ($CFI_{Exposure}$ = 0.483) and female-headed households ($CFI_{Exposure}$ = 0.486) were almost equally vulnerable in terms of exposure to climate change and variability. This is because they were within the same geographical location and experience similar climatic conditions. The computed LVI_{IPCC} indicates that female-headed households were more vulnerable to climate change and variability (LVI_{IPCC} = 0.005) than male-headed households (LVI_{IPCC} = 0.021). The results of the independent two-sample student *t*-test showed that with the exception of exposure, there are significant differences in the means of the LVI_{IPCC} and the IPCC vulnerability contributory factors for female-headed and male-headed farming households (Table III). *H0* was therefore rejected. The implication is that even though the two sex groups were exposed to the same climatic conditions, female-headed households were more sensitive to climate change and variability and yet had the least adaptive capacities, making them more vulnerable in terms of the contributory factors of vulnerability. This finding is consistent with that of Nabikolo *et al.* (2012), who revealed that female-headed households were more vulnerable to climate change in eastern Uganda because of low adaptive capacity.

4. Conclusions

The results in this study revealed that both male-headed and female-headed rice farming households were vulnerable to the effects of climate change and variability in the northern region of Ghana. The results of this study are consistent with previous research regarding households' vulnerability to social capital, human capital and natural hazards within the context of the various livelihood frameworks (Moser, 1998; Bebbington, 1999; Dorward *et al.*, 2009; Uy *et al.*, 2011; Nakuja *et al.*, 2012; Adu *et al.*, 2017). The results also revealed that the rice farmers are vulnerable to the key dimensions of all the livelihood vulnerability frameworks developed by Carney *et al.* (1999); Drinkwater and Rusinow (1999). These key dimensions of the livelihood frameworks include food, health, social network, water, socio-demographic profile, natural hazard and climate variability, water and livelihood strategies. These dimensions reflect the power relations, access to water resources and health facilities and political, social and economic structures. These results imply that these households would need some temporary assistance to recover when hit by climate change and variability, natural hazard such as floods and any form of shock that adversely affects water and food availability, as well as their livelihood strategies, social network and socio-demographic profiles. This is more especially for female-headed households that were more sensitive to climate change and variability but had the least adaptive capacities, making them more vulnerable in terms of the contributory factors of vulnerability.

Evidence show that women are at the center of sustainable development, and society will benefit enormously through greater gender equalities in all sectors of development (Denson, 2002). Unfortunately, mainstreaming gender issues into the climate change and sustainable development nexus is being done in piecemeal, extremely slow, with varying degrees of success, and often as an afterthought. The situation is aggravated by the lack of women's participation in decision-making at all levels, and the fact that the climate debate so far has made little effort to package the issues in a way that ordinary people can even understand, let alone participate. At the Seventh Conference of Parties under the United Nations Framework Convention on Climate Change (UNFCCC) held in Marrakech, Morocco, from 29 October to 10 November 2001, participants from Samoa argued for increased representation of women within the organizational and decision-making structure of the UNFCCC (UNFCCC 2001) as an avenue for women voice on climate change adaptation to be incorporated into international policy framework on climate change mitigation and adaptation. However, ensuring women's participation is no guarantee that the many issues confronted by women in adapting to climate change will be addressed. According to Denson (2002), power dynamics characterizes the relationship between men and women in poor nations to the extent that women have lesser scope of livelihood diversity to cater for their families, but depend more on agricultural and forestry sectors, which are climate-dependent.

Female-headed households were significantly more vulnerable to socio-demographic profile, livelihood strategies, social network, water and food than male-headed households. This makes female-headed households more sensitive to climate change and variability and also more vulnerable in terms of adaptive capacity than male-headed households. In all, female-headed households were significantly more vulnerable to climate change and variability than male-headed households. Based on these results, the study recommends that women should be given priority in both on-going and new intervention projects in climate change and agriculture by empowering them through financial resource support to venture into other income-generating activities as a way of diversifying their sources of livelihood to boost their resilience to climate change and variability. This will be a pathway to achieving Ghana's National Climate Change Policy objective of gender equity. Nevertheless, men should not be totally excluded in climate change intervention programs. The key point here is that women should be given priority to participate in such programs.

Note

1. This result is supported by the subsequent result of the LVI_{IPCC} that, even though the two sex groups were exposed to the same climatic conditions, female-headed households were more sensitive to climate change and variability and yet had the least adaptive capacities, making them more vulnerable in terms of the contributory factors of vulnerability (Table III).

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