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Comparative assessment of vulnerability of smallholder livestock farmers to climate change in North-West Ghana

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ABSTRACT
This study examined the vulnerability of smallholder livestock farmers in North-West Ghana to climate change using data obtained from 200 livestock farmers obtained through the administration of a semi-structured questionnaire. The Livelihood Vulnerability Index (LVI) approach was used to examine the levels of vulnerability. The study compared the vulnerability between the Nandom district and the Lawra district. The empirical results revealed that livestock farmers are more vulnerable to climatic extremes in the Nandom district than the Lawra district. The study highlights the critical role of the government regarding education and construction of water resources, among others.

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Climate change; livelihood vulnerability index; adaptive capacity; exposure; sensitivity; Ghana

1. Introduction

The role of small ruminants in the livelihood of people has not been properly understood (Kosgey et al. 2005). The benefits associated with livestock are societal, economic, and environmental. Livestock contribute 17% to the global food balance, in terms of caloric intake per person per day, and 33% of the protein in human diet (Herrero and Thornton 2013). The livestock sector is crucial in the fight against poverty, especially in rural communities of South Africa where livestock is highly produced (Adem and Oyekale 2015). This is not different from Ghana. Livestock form an integral part of the socio-cultural life of the people. Pastoral farmers rely on livestock as their main source of livelihood, and usually own relatively large numbers of animals under extensive or communal grazing and management (Kosgey et al. 2005). Moreover, livestock products are important sources of protein in urban and rural diets with demand for milk and meat increasing as household income rises above the subsistence level. Livestock manure and traction are also seen as key parts of processes of agricultural intensification in agro-pastoral systems. In these ways, livestock have and will continue to play important socio-economic roles in rural development (Ayantunde et al. 2011).

Climate change is one of the primary developmental challenges facing the African continent (Kuwornu 2019; Alhassan, Kuwornu, and Osei-Asare 2019a, 2019b, 2019c; Amikuzuno, Kuwornu, and Osman 2019; Sadiq, Al-Hassan, and Kuwornu 2019; Adu, Kuwornu, and Datta 2019; Adu et al. 2018; Armah, Al-Hassan, and Kuwornu 2019; Mabe, Sienso, and Donkoh 2014; Etwire et al. 2013a, 2013b; Kuwornu et al. 2013; Al-Hassan et al. 2013; Nakuja et al. 2012). Climatic and agricultural challenges are critical for farmers' decisions and well-being (Amusa, Okoye, and Enete 2015). Smallholder

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farmers are particularly vulnerable to changes in the climate that reduce productivity and negatively affect their weather-dependent livelihood systems (Amusa, Okoye, and Enete 2015). Agriculture in Ghana is predominantly on smallholder basis with approximately 90 percent of farm holdings being less than 2 hectares and producing under rain-fed conditions (Etwire et al. 2013a), and is, therefore, extremely vulnerable to climate variability and change (FAO 2009). Livestock production is the most climate-sensitive economic activity (IPCC 2007).

In Ghana, recorded temperatures rose about 1°C over the last for decades, whereas rainfall and runoff decreased by approximately 20 and 30 percent respectively (Environmental Protection Agency – Ghana, 2000). These indicate changes in the climate system resulting in exposure-sensitivities on different people and at different times (Bawakyillenuo, Yaro, and Teye 2016), thereby making them vulnerable to climatic extremes. This is especially so in the relatively dry areas of northern Ghana. It is therefore not surprising that many of the farmers have noticed a decline in rainfall amounts and an increase in average temperature in their localities in the past 30 years, and that perceptions of temperature changes in the localities (Teye, Yaro, and Bawakyillenuo 2015).

Vulnerability to climate change is a relatively broad area encompassing a variety of concepts and elements including sensitivity or susceptibility to harm, and lack of capacity to cope and adapt (Field et al. 2014). The existence of competing conceptualisations and terminologies of vulnerability has become particularly problematic in climate change research (Fussel 2007). In other words, vulnerability is the susceptibility of a given population, system, or place to harm from exposure to the hazard and directly affects the ability to prepare for, respond to, and recover from hazards and disasters and the potential for loss of property or life from environmental hazards (Cutter, Mitchell, and Scott 2000, 2009). The IPCC has defined vulnerability as the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change including climate variability and extremes (IPCC 2007). Vulnerability does not only depend on the magnitude of climatic stressors but also on the sensitivity and ability of societies that fall victim to the effects, to adopt measures in order to adapt and/or cope with those shocks (Tesso, Emana, and Ketema 2012).

Livestock farmers in northern Ghana are perceived to have been adversely affected by the effects of climate change but the literature on this phenomenon is scanty. Therefore, it is important to measure the levels of vulnerability of these farmers to climate change.

Vulnerability is of two types – physical and social vulnerabilities. Social vulnerability is the extent to which a system or sub-system is likely to be susceptible to the effects of climate change due to interrelationship of social, economic and demographic factors (Dumenu and Obeng 2015). The elements of vulnerability include adaptive capacity, sensitivity and exposure. Exposure refers to the availability of people, species or ecosystems, livelihoods, services, resources, infrastructure, environmental functions, economic, social, or cultural assets in locations and settings that could be adversely affected (Field et al. 2014). Sensitivity on the other hand refers to the degree to which a system is instantly affected by climate change (Fussel 2007). Adaptive capacity is the ability of a system to cope or respond successfully to the impacts of climate change (IPCC 2007; Smit and Pilifosova 2001). In this study, adaptive capacity is defined as the ability of smallholder livestock farmers to use local and scientific techniques to be able to withstand the effects of climate change.

The main drivers of agricultural responses to climate change are biophysical effects and socio-economic factors (Al-Hassan et al. 2013; Etwire et al. 2013b; Parry et al. 2004). The objective of this study is to assess the vulnerability of smallholder livestock farmers to climate change in North-West Ghana.

2. Materials and methods

2.1. Study area

This study was undertaken in two districts in the Upper West region of Ghana, specifically Lawra and Nandom districts (Figure 1). Both districts are located within the Guinea Savannah Zone with tropical

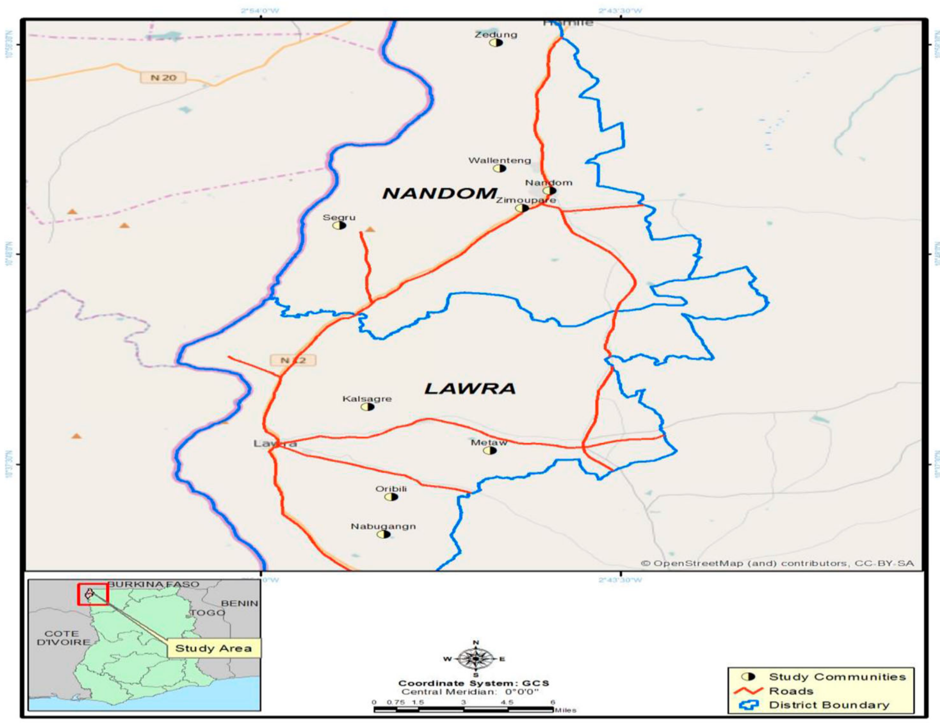

Figure 1. Map of the study area. Source: GIS Laboratory, University of Ghana.

continental climate and have average annual temperature ranging between 27°C and 36°C (Ghana Statistical Service (GSS) 2014a). Also, both districts lie in the north-western part of the Upper West Region of Ghana.

Specifically, the Lawra District is bounded to the north by the Nandom District, to the east by Lambussie-Karni District, to the south-west and west by the Republic of Burkina Faso. It lies between Latitude 10° 35°–10° 40 North and 2°50–2°53 West. The total land mass of the district is 527.37 square kilometres. This represents about 2.8 percent of the Region's total land mass, estimated as 18,476 square kilometres. The district's relief and drainage are gently rolling with a few hills ranging between 180 and 300 metres above sea level. It is drained by the Black Volta River, to the west and that separates the district from Burkina Faso (GSS 2014a). The environment has undergone considerable degradation largely attributed to human activities. Agriculture is the main important economic activity in the district as it employs approximately 78 percent of the economically active people. The dominant crops produced are mainly maize, millet, groundnuts, soya bean and cowpea. Livestock production is a major agricultural activity undertaken by the people to supplement incomes from crop farming (GSS 2014a).

On the other hand, the Nandom district is specifically between Longitude 2°25 W and 2°45W and Latitude 10°20 N and 11°00 S. It is separated by Lawra district to the South, Lambussie-Karni district to the East and Burkina Faso to the North and West. The total land mass of the District is estimated at 404.6 square kilometres, representing approximately 2.1% of the Region's total land mass. The vegetation of the District is good for livestock rearing (GSS 2014b). The minimum and maximum temperatures of the Nandom District fall within 23°C at night and a maximum of 42°C during the day. The relief and drainage of the area could be described as gently undulating with few separated hills which is approximately180 meters above sea level (GSS 2014b).

2.2. Sampling and data

A multi-stage sampling technique was employed to select the respondents for this study. First, the Upper West region was purposively selected. Second, the two (2) districts, Lawra and Nandom were purposively selected because the project titled “Adaptation at Scale in Semi-Arid Regions”, (ASSAR) was being implemented in these two districts at the time of the study. The chosen districts are part of the Wa portion of the Wa-Bobo-Sikasso transect, a name given to a portion of Ghana-Burkina Faso-Mali border which the ASSAR project targets.

Third, each district was then stratified into four strata. The basis of using stratified sampling was to group the Climate Change, Agriculture and Food Security (CCAFS) communities, from which the sample communities were chosen, so that one community was randomly selected from each stratum. Fourth, using the lottery method, simple random sampling technique was then used to select one community from each stratum making a total of eight (8) communities. Finally, simple random sampling technique was used to select 25 smallholder livestock farmers from each community, making a total of two hundred (200) livestock farmers. Table 1 shows the number of farmers selected from each community.

Data used in this study was collected through primary and secondary sources. Primary data was collected from focus group discussions (FGDs) and individual farmer interviews using a structured questionnaire. Prior to this, a reconnaissance survey was conducted in some selected communities. This provided a platform where farmers were engaged to collect information about their farm activities prior to the interviews. The questionnaire designed covered areas such as socio-demographic characteristics of the farmers, income sources, availability and access to services, livestock composition and housing information, climate change among others. Focus group discussion guide was developed and discussions were held in each community. Based on the responses from the FGD and pre-tested questionnaire, further improvements were made on the questionnaire for the data collection. The data collection was done in a period of six (6) weeks. Rainfall and temperature data of thirty years (1984–2014) period for both Lawra and Nandom districts were collected from the Ghana Meteorological Agency. Finally, reference materials used in this study were obtained from working and discussions papers, journal articles, project reports and text books. STATA 13 software was used for analysis. The data was then presented in the form of frequencies, percentages, tables and figures.

2.3. Measuring vulnerability of smallholder livestock farmers

Vulnerability is complex and often not driven by a single factor (FAO 2013). There are a number of proposed methods to measure vulnerability (Galvin et al. 2004). According to FAO (2013), the measurements of vulnerability have been categorised into three main methodologies namely; indicator based, models and GIS-based and stakeholder based methodologies. The indicator based methodologies have four sub-indexes namely; socio-economic, physical process, coastal and livelihood

Table 1. Number of farmers selected in each community.

District	Community	Number of Farmers
Lawra	Metor	25
	Naburnye	25
	Orbilli	25
	Kasalgre	25
Nandom	Zedung	25
	Wallanteng	25
	Zimoupare	25
	Segru	25
Total		200

Source: Field Survey, 2016.

vulnerability indexes. Opiyo, Wasonga, and Nyangito (2014) also identifies these measurements of vulnerability to include; socio-economic, biophysical and an integrated approach. The integrated approach combines the socio economic and biophysical factors. The socio-economic vulnerability assessment approach focuses on the socio-economic and political status of individuals or groups. Thus, it focuses on identifying the adaptive capacity of individuals or communities based on their internal characteristics. The limitation of the socio-economic approach is that it focuses only on variations within society, it does not account for the natural resource bases of society. They further state that the biophysical approach attempts to assess the level of damage that a given environmental stress causes on both social and biological systems. The limitation of this approach is that it neglects both the structural factors and human agency in producing vulnerability and in coping or adapting to it. The third approach is the integrated vulnerability analysis, which combines both the socio-economic and biophysical factors. This approach includes all the internal state of vulnerability and the external situation (Opiyo, Wasonga, and Nyangito 2014).

This study has adopted the latter method to measure the LVI's of smallholder livestock farmers to climate change by considering both the socio-economic and biophysical factors. It expressed the LVI as a composite index comprised of seven major components and then aggregated the seven into IPCC's three contributing factors to vulnerability – exposure, sensitivity, and adaptive capacity (Hahn, Riederer, and Foster 2009; Etwire et al. 2013a; Panthi et al. 2016).

While there is no consensus on the best approach to vulnerability assessment, in general they entail considering one or more of: exposure to climate risks, susceptibility to damage, and capacity to recover. It is difficult to determine the superiority of any given approach to vulnerability. Regardless of the definitions used and the approach taken, for the sake of clarity, comparability, and theoretical and methodological development, each vulnerability study should make clear the definitions it uses and the method of assessment it employs (Barnett, Dessai, and Jones 2007). Vulnerability can be measured by combining poverty indicators with a measurement of the diversity of resources (Adger et al. 2001). Measuring vulnerability is a complex endeavor that requires the ability to analyze the relationships between diverse indicators. A powerful tool for this type of analysis is integrated modelling (Galvin et al. 2004).

The indicator approach computes indices based on selected indicators. Most often, indicators are made up of one or several proxy indicators or variables (Dumenu and Obeng 2015). A vulnerability assessment, by contrast, considers the climate event in the context of other stresses that together produce impacts from compound events. Vulnerability depends upon the assets (labour, human capital, productive assets) that a household has, the entitlements to food that it possesses, and the extent to which people, given the assets at their disposal, can adapt (Kasperson and Kasperson 2001).

2.4. Livelihood vulnerability index (LVI) approach

Vulnerability was measured by the livelihood vulnerability index (LVI) using Microsoft Excel software. The LVI is estimated for each of the two (2) districts under study following the definition by Intergovernmental Panel on Climate Change (IPCC) (IPCC 2007; Hahn, Riederer, and Foster 2009). We considered seven major components which include socio-demographic profile, livelihood strategies, social networks, health, and access to food, access to water, and natural disasters and climate variability. Each component was made up of a few other sub-components known as indicators. Each of these indicators was measured on a different scale. Therefore, we normalised each indicator as an index using equation (1).

$$\text{index}_{sd} = \frac{S_d - S_{\min}}{S\min_{\max}} \quad (1)$$

Where S_d is the observed sub-component indicator for district d and $S_{\min}$ and $S_{\max}$ are the minimum and maximum observed values respectively.

The sub-component indicators are then averaged using equation (2) to obtain the index of each major component:

$$M_d = \frac{\sum_{i=1}^{n} \text{index}_{sdi}}{n} \quad (2)$$

Where M_d 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 Disaster and Climate Variability (NDCV)] for district d; $\text{index}_{s_{di}}$ 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 values for each of the seven major components were averaged using Equation (3) to obtain the district-level LVI:

$$LVI_d = \frac{\sum_{i=1}^{7} W_{Mi} M_{di}}{\sum_{i=1}^{7} W_{Mi}} \quad (3)$$

Alternatively, LVI_d can be rewritten as:

$$LVI_d = \frac{W_{SDP}SDP_d + W_{LS}LS_d + W_H H_d + W_{SN}SN_d + W_F F_d + W_W W_d + W_{NDCV}NDCV_d}{W_{SDP} + W_{LS} + W_H + W_{SN} + W_F + W_W + W_{NDCV}} \quad (4)$$

Where w_{Mi}, the weights of each major component, is a function of 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. Following Hahn, Riederer, and Foster (2009) and Panthi et al. (2016), the vulnerability spider diagram was then used to illustrate the vulnerability index of each major component.

2.5. Measuring vulnerability using the IPCC-LVI approach

Following from the LVI approach to vulnerability measurement, Hahn, Riederer, and Foster (2009) then calculated a new variable and named it LVI-IPCC, using equations (1)–(3). We used the IPCC definition of vulnerability and re-grouped the seven major components into three contributing factors: exposure, adaptation capacity and sensitivity using the following equation:

$$CF_d = \frac{\sum_{i=1}^{n} W_{Mi} M_{di}}{\sum_{i=1}^{n} W_{Mi}} \quad (5)$$

Where CF_d, is an IPCC-defined contributing factor (exposure, sensitivity, or adaptation capacity) for district d, M_{di} are the major components for district 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 the exposure, adaptation capacity and sensitivity are estimated, the three contributing factors are then combined using the following equation:

$$LVI - IPCC_d = (e_d - a_d) * S_d \quad (6)$$

Where $LVI - IPCC_d$ is the LVI for district d, expressed using the IPCC vulnerability framework. The calculated exposure score for district d (equivalent to the natural disaster and climate variability major components) is denoted as e_d, a_d is the calculated adaptation capacity score for district d (weighted mean of socio-demographic, livelihood strategies, and social networks major components), and S_d is the calculated sensitivity score for district d (weighted mean of the health, food, and water major components). The $LVI - IPCC$ is scaled from -1(least vulnerable) to 1 (most vulnerable). Microsoft Office excel was employed to estimate the livelihood vulnerability index (Hahn, Riederer, and Foster 2009). Table 2 presents major and sub-components of the livelihood vulnerability index. Following Hahn, Riederer, and Foster (2009) and Panthi et al. (2016), the vulnerability triangle diagram was used to illustrate the vulnerability index of each contributing factor.

Table 2. Major and sub-components comprising the livelihood vulnerability index.

Major components	Sub-components	Measurement
Water	Household reporting water conflict	Percent
	Household that utilise a natural water source	Percent
	Average time to water source	Minutes
	Household that do not have a consistent water supply	Percent
Socio-demographic Profile	Dependency ratio	Ratio
	Female-headed of household	Percent
	Household where head of household has not attended school	Percent
	Households with orphans	Percent
	Household with rooms made of mud	Percent
	Household with earth floor	Percent
	Household with grass/thatch roof	Percent
	Average number of persons per room	Number
Livelihood strategies	Households with family member working in a different community	Percent
	Households dependent solely on agriculture as a source of income	Percent
	Average agricultural livelihood diversification index (range: 0.20–1)	1/# livelihood
Social network	Average receive: give ratio	Ratio
	Average borrow: lend money ratio	Ratio
	Households that have not gone to their local government for assistance in the past 12 months	Percent
Health	Average time to health facility	Minutes
	Households with family member with chronic illness	Percent
	Households where a family member had to miss work or school in the past 6 months due to illness	Percent
	Average malaria exposure*prevention index (0–12)	Month*Bednet indicators
Food	Households dependent solely on the family livestock farm for food (as source of protein)	Percent
	Average number of months household struggle to find an animal (food) for household consumption (range:0–12)	Number
	Average livestock diversity index (>0 to 1)	1/# livestock
	Household that do not reserve young livestock species for breeding purposes	Percent
Natural disaster and climate variability	Average number of flood and drought events since 2004	Count
	Households that did not receive a warning about the pending natural disaster	Percent
	Households with an injury or death because of flood or drought since 2004	Percent
	Mean standard deviation of monthly average of average maximum daily temperature since 1985	Celsius
	Mean standard deviation of monthly average of average minimum daily temperature since 1985	Celsius
	Mean standard deviation of monthly average precipitation since 1985	Millimeter

Source: Adapted from Hahn, Riederer, and Foster (2009).

Hahn, Riederer, and Foster (2009) approach was slightly modified in this study to include the nature of housing of the farmers. Thus, additional four sub-components were added to the socio-demographic profile major component. The reason is that the type of dwelling of a farmer also indicates how exposed and the probability of being sensitive to climate change. The addition of this variable emanated from a reconnaissance survey and engagement of local stakeholders during the selection of variables for the study.

3. Results and discussions

3.1. Vulnerability of smallholder farmers to climate change

Thirty-two (32) sub-components (indices) of vulnerability were considered among seven (7) major components. Table 3 presents the major and sub-component results of the LVI in the Lawra and Nandom districts.

Following Luers et al. (2003), vulnerability assessments should shift away from attempting to quantify the vulnerability of a place or community; instead, the emphasis should be on the individuals' vulnerability with respect to selected variables and to specific sets of stressors. Consequently, the vulnerability assessment of livestock farmers in the two districts is discussed based on the components that were identified.

Table 3. Indexed sub-components, major components for Lawra and Nandom Districts.

Sub-components	Districts		Major components	Districts	
	Lawra	Nandom		Lawra	Nandom
Dependency ratio	0.16	0.18	Socio-demographic profile	0.385	0.344
% of Female headed households	0.21	0.10			
% of Household head with no education	0.88	0.69			
% of Household with orphans	0.20	0.31			
% of Households with mud walls	0.99	0.93			
% of Households with earth floor	0.14	0.14			
% of Households with thatch roof	0.16	0.04			
Average number of persons per room	0.35	0.37			
% of Household with members working outside the community	0.42	0.65	Livelihood strategies	0.474	0.581
% of Household earning income solely from Agriculture	0.74	0.80			
Average livelihood diversification index	0.26	0.29			
Average receive: give	0.31	0.31	Social network	0.236	0.239
Average borrowed: lend money	0.38	0.38			
% of Households with no assistance from local assembly	0.02	0.02			
% of Household solely family livestock	0.74	0.84	Food	0.245	0.266
Months household struggle to find food	0.11	0.07			
Average livestock diversification index	0.11	0.13			
% of Households not reserving some young animals for breeding purposes	0.01	0.02			
% of Households reporting water conflict	0.41	0.65	Water	0.524	0.623
% of Household that fetch from natural water source	0.84	0.91			
Average time to water source	0.16	0.16			
% of Household with inconsistent water supply	0.69	0.77			
Average time to health facility	0.22	0.29	Health	0.246	0.260
% of Household member/s with chronic illness	0.11	0.04			
% of Household member missing work/school	0.28	0.41			
Average malaria exposure	0.37	0.30			
Total floods and droughts	0.29	0.25	Natural disaster and climate variability	0.505	0.503
% of Household with no warning about any pending disaster	0.68	0.78			
% of Households member with injury/death	0.01	0.02			
Average maximum temperature	0.73	0.73			
Average minimum temperature	0.72	0.72			
Average rainfall	0.60	0.52			

Source: Field Survey (2016).

Firstly, the Socio-Demographic Profile major component was made up of eight (8) sub-components (Table 3). Dependency ratio is the number of economically inactive persons to the number of economically active persons. Economically inactive persons are all persons below the age of fifteen (15) years and those who are at least sixty-five (65) (GSS 2012). The dependency ratio of Nandom district (0.94) was higher than that of Lawra district (0.84). On the average, each economically active person in Ghana had one additional inactive person to support (GSS 2012). For instance, the Nandom ratio of 0.94 showed that for every 100 economically active persons, there are 94 additional economically inactive persons to support.

Female-headed households were also considered as a sub-index under this major component. A female headed household in this study refers to those household heads who were dead and/or whose husbands have migrated for the past six months. The percentages of female-headed households in the Lawra and Nandom districts were 21% and 10% respectively. Also, the percentage of orphans, as a sub-component was higher in the Nandom district (31%) than in the district (20%). Higher percentage of female-headed households and orphans are indicators of higher vulnerability. The findings for the Nandom district is close to that of Hossain and Huda (1995) who reported that, as many as 9% of rural households were managed or headed by women in rural Bangladesh.

Regarding formal education of household head as a sub-component, the results revealed that approximately 73% of the respondents are uneducated. Formal education tends to improve the ability of smallholder farmers to better comprehend issues affecting them and, therefore, look for possible solutions at the appropriate places (Etwire et al. 2013a).

The living standard of farmers can be influenced by the materials used to build their place of residence (house). In this study, the farmer's place of residence is considered vulnerable if the house is built with mud, earth floored and roofed with either thatch or mud. The reason is that, mud houses can easily be affected by severe weather conditions (i.e. excess temperature and flood) than houses build with concrete wall. The results showed that 99% and 93% of the farmers' houses were built with mud in the Lawra and Nandom districts respectively. In both districts, 14% of the respondents had their rooms' earth floored. Also, for each district, the average number of persons sleeping/passing the night in a room are two. In terms of socio-demographic profile, the Lawra district (0.385) was found to be the more vulnerable district than the Nadom district (0.344).

The second major component considered in this study was the livelihood strategies. Three sub-components were used to measure this major component (Table 3). Most of the family members have migrated to the cities to work. Migration is therefore a form of an adaptation strategy. The results indicate that 42% and 65% of the respondents in the Lawra and Nandom districts have at least one family member working outside the community respectively. The implication is that there are better livelihood options in the Lawra than in Nandom district. For this reason, less than 50% of the economically active persons in the Lawra district migrate to other cities in search of unsustainable jobs. Households with higher number of members working outside the community were likely to be more vulnerable. The reason is that those working outside the community are mostly the economically active force, who left their wives, children and possibly the aged back at home (Lawra or Nandom), to fend for themselves. They (migrants) argue with the view of working to feed their family back at home, but usually their (migrants) support is low, making the other family members more vulnerable. Hahn, Riederer, and Foster (2009) also found Mabote district to be more (0.625) vulnerable than Moma district (0.215) in Mozambique.

Also, the percentage of households who had their income solely from Agriculture in Nandom and Lawra districts were 80% and 74% respectively. This suggest that a greater proportion of farmers in Lawra district (26%) are generating additional income from other activities including processing and trading in crop commodities. However, both districts had the same average livelihood diversification index of 0.32. Respondents derived their household income from crops, livestock and other off-farm activities. The average number of farmers' livelihoods in both districts were two, mostly crop and livestock production, and this is consistent with previous research for Mabote and Moma districts in Mozambique for which the average number of livelihoods were 2.4 and 1.9 respectively (Hahn, Riederer, and Foster 2009). Also, unlike socio-demographic profile, respondents tend to be more vulnerable in terms of the livelihood strategies in the Nandom district (0.581) than in Lawra district (0.474). A study of vulnerability index in two districts in Mozambique revealed that Mabote was more vulnerable in terms of Livelihood Strategies component (0.297) than Moma (0.246) (Hahn, Riederer, and Foster 2009).

Social Network is the third major component and consists of three sub-components. Farmers in the Lawra and Nandom districts were reported to be giving help to others slightly more than they receive. Help packages are usually in the form of assisting each other in the farm, purchase of school uniform, books and pens, school bags and sometimes money. This is more likely to improve social cohesion that exist among individuals and thereby prevent future possible quarrels among themselves. Again, in both districts, respondents were reported to be borrowing more than they lend. Some of the farmers were members of farmer-based organisations through which they pay monthly dues to the group, and this makes them qualified to access credit when they are in need. If this system continues into the future, it will improve the living standards of the farmers as credit access from own group savings attracts relatively lower interest rates than formal financial institutions. More importantly, there are few or nearly no bottlenecks and bureaucratic process to be encountered in accessing credit through group savings compared to formal financial institutions. The credit accessed from the farmer-based organisations were used to buy fertilizer to cultivate crops, plough back into businesses (especially the women who were involved in pito brewing), trade, pay school fees of their children and to buy food.[1]

The percentage of households that reported not going to their local government, including chiefs, assembly member and Member of Parliament (MP) for assistance in twelve months prior to the data collection was high as 98% in both districts. This finding is similar to that of Hahn, Riederer, and Foster (2009) who found that 95% and 92% of the sampled households in Mabote and Moma districts respectively in Mozambique had not approached their local government for assistance in the past month. In terms of social network, nearly the two districts have the same scale of vulnerability except that Nandom (0.239) appears to be more vulnerable than Lawra (0.236). Nevertheless, the findings from Mozambique revealed that in terms of social network, Mabote district was more vulnerable (0.480) than Moma district (0.457) (Hahn, Riederer, and Foster 2009).

The fourth major component is food availability, which consists of four sub-components. As high as 79% of the respondents depended on the family farm (crop and livestock) for their food and protein needs. Due to decreasing rainfall amounts, farms performed poorly. This necessitated that the farmers buy food to complete the season before they harvest at the end of the cropping season or livestock for their protein needs, especially during funerals or festive seasons. The average number of months that the households experienced food shortage was about three in both districts, usually occurring in June, July and August. This finding is consistent with Etwire et al. (2013a). Majority of the respondents (98.5%) reserved the young livestock for breeding to increase stockholdings. Farmers in the Lawra district diversified into more livestock types than in the Nandom district. The average numbers of livestock diversification were found to be three and two in the Lawra and Nandom district respectively. Livestock diversification refers to the different types of livestock produce in a geographical location. Livestock types common to both districts were sheep, goats, pigs, cattle and poultry. In the pooled data, the population of poultry (3840) were found to be more than goats (1623) followed by sheep (888), and then pigs (575) and cattle (474). Unlike men livestock farmers who rear all types of the species above, women livestock farmers mostly rear poultry and goats, hence the higher populations of poultry and goats. When all the four sub-components of food major component were aggregated, the Nandom district (0.266) was found to be more vulnerable than Lawra district (0.245).

The fifth major component is water availability. It is composed of four sub-components. The aggregate of the four components revealed that Nandom district (0.623) was more vulnerable to water availability than Lawra district (0.524). Etwire et al. (2013a) found Upper West region to be the most vulnerable region in terms of water with an index of 0.489, and therefore, based on FANRPAN (2011); Muleta and Deressa (2014); Opiyo, Wasonga, and Nyangito (2014) classification, both Lawra and Nandom districts are considered highly vulnerable. The reasons for this could that 65% and 41% of the respondents in the Nandom and Lawra district respectively were found to have reported conflicts over water. Within the study area, as one moves northwards, the semi-aridity of the location decreases, and water availability for agricultural activities decreases. Approximately, 91% of the respondents in the Nandom district utilised natural water sources more than their counterparts in Lawra district (84%). Natural water sources considered for this study include rainfall, rivers/lakes/streams and dams. Every community selected for this study has at least one borehole. The use of boreholes as sources of water depends on the number of months that these boreholes would have water. A high percentage of respondents in the Nandom district (77%) have reported inconsistent water supply than in Lawra district (69%). The average time taken to get to a water source is slightly more for the farmers in the Nandom district (10 minutes) than in the Lawra district (approximately 9.8 minutes) but there is no statistical difference between the average times to water sources.

Health is the sixth major component. It consists of four sub-components. One major cause of vulnerability to farmers is ill-health, especially malaria among adults and children. On the average, malaria cases were up to 48% of Out-Patient attendance for all health facilities in the Lawra District in 2008 (Ganle 2012). On foot, the average time to a health facility was higher (71 minutes) in the

Nandom district than in the Lawra district (54 minutes). This implies that under the same conditions, patients in the Lawra district will get access to medical attendants, and eventually get their health dangers averted earlier than patients in the Nandom district. This findings are markedly different from Hahn, Riederer, and Foster (2009) who found the average travelling time to a health facility to be 189.1 and 593.3 minutes in two districts in Mozambique. Access to a health facility is a good indicator of an adaptive capacity of any community. Of all the eight communities, only one of the communities in the Lawra district has a health post. Having a health post will reduce the travel time to the district capital to access health care.

On chronic illness suffered by members of farmers' household, a greater proportion of the households in the Lawra district (11%) report incidence of chronic illness than in the Nandom (4%) district. Also, a greater proportion of the farmers in the Nandom district (41%) district were reported to have missed school or work due to sickness than in the Lawra district (28%). Students who miss school as a result of sickness would equally miss some lessons taught and this would likely have a negative effect on their understanding of some concepts, and consequently their performance in class and final assessment. Additionally, farmers who were engaged in other non-farm activities and whose earnings depend on daily wages would be adversely affected financially since they would not be able to report to work. Specific to malaria disease, households in the Lawra district were more vulnerable to malaria than households in the Nandom district. The aggregation of the four sub-components revealed that the Nandom district (0.260) is more vulnerable to health major component than Lawra district (0.246). Similarly, the overall health vulnerability index for Moma and Mabote districts in Mozambique were 0.317 and 0.241 respectively (Hahn, Riederer, and Foster 2009).

Natural disaster and climate variability is the seventh and the last major component. The average number of floods that occurred in the Lawra and Nandom districts over the period 2004–2014 were two and one incidence respectively, whereas the average number of droughts for the same districts were seven times each (Table 4).

In the Lawra and Nandom districts, 68% and 78% respectively did not receive warning or information about floods and droughts before they occurred. These results are consistent with Etwire et al. (2013a) who revealed that majority of the farmers did not receive warning about a likely natural disaster such as floods and droughts. Access to information by the respondents is mostly through radio, mobile phone and television. From the results, 60%, 58% and 16% of the respondents own at least a radio set, mobile phone and Television sets respectively in the Lawra district whereas 65%, 59% and 10% own the same equipment respectively in the Nandom district.

Access to information is largely dependent on access to electricity. Out of the eight sampled communities in both Lawra and Nandom districts, only two communities, one in each district is connected to the national grid. In this regard, farmers do not see the reason for owning a television set in the case of those communities that do not have electricity. This is reflected in the ownership of this asset (i.e. television) through which information is received. Radio and mobile phone ownership were above average, on a scale of 100%, because majority of the farmers in the area buy dry cells for their radio sets and those who own mobile phones and do not have electricity in their communities easily carry them to the district capital, especially on market days to re-charge the battery. Table 5 shows the percentage of respondents who own at least a set of communication equipment.

Table 4. Average number of floods and droughts that occurred over the period 2004–2014.

Number of floods and droughts	Lawra District	Nandom District	Total number of floods/droughts across districts
Average number of floods	2	1	3
Average number of droughts	7	7	14
Total number of floods/districts along district	9	8	17

Source: Field Survey, 2016.

Table 5. Ownership of communication equipment.

Equipment type	Lawra (%)	Nandom (%)
Radio	60	65
Mobile phone	58	59
TV	16	10

Source: Field Survey, 2016.

Extreme events of drought and floods lead to poverty as people would be food insecure. If there are droughts, growing crops will wilt and die-off and livestock will also lose weight and eventually die. If there are floods, crop fields would be washed-off and livestock would not be able to graze on flooded pasture, as grazing fields will be collected by water. Approximately 23% and 33% of the pooled set of respondents reported they had lost at least one livestock and recorded lost in the value of the livestock respectively. Meteorological data on minimum and maximum temperatures for the Nandom district was unavailable, therefore, those of Lawra was used for both districts because, until, 2012, the two districts were one, the then Lawra-Nandom district. The Lawra district however recorded more precipitation than the Nandom district. When all the six sub-components of Natural Disaster and Climate Variability major component were aggregated, the Lawra district (0.505) was more vulnerable than the Nandom (0.503).

Nandom district was more vulnerable in five major components compared to two in the Lawra district. This is the reason for the overall result that, the Nandom district was more vulnerable to climate change than the Lawra district. Figure 2 presents a summary of the vulnerability indices of the major components of each district.

By considering IPCC definition of vulnerability, which is the product of the sensitivity score and the difference of the exposure and adaptive capacity scores, Hahn, Riederer, and Foster (2009) calculated a new index for vulnerability, denoted as LVI-IPCC. The exposure, adaptive capacity and sensitivity scores are collectively known as contributing factors. The exposure score is the average score of food, water and health availability major components. The adaptive capacity score is the average score of socio-demographic profile, livelihood strategies and social network major components. The sensitivity score is the score of natural disaster and climate variability major component.

The values of the contribution factors showed that, the Lawra and Nandom districts have equal levels (0.3723) of adaptive capacity, but the Nandom district was more sensitive (0.3827) than the Lawra district (0.3387). Lawra district shows a marginal higher (0.5045) exposure value than Nandom district (0.5035). Overall, the LVI-IPCC values of both districts showed that the Nandom

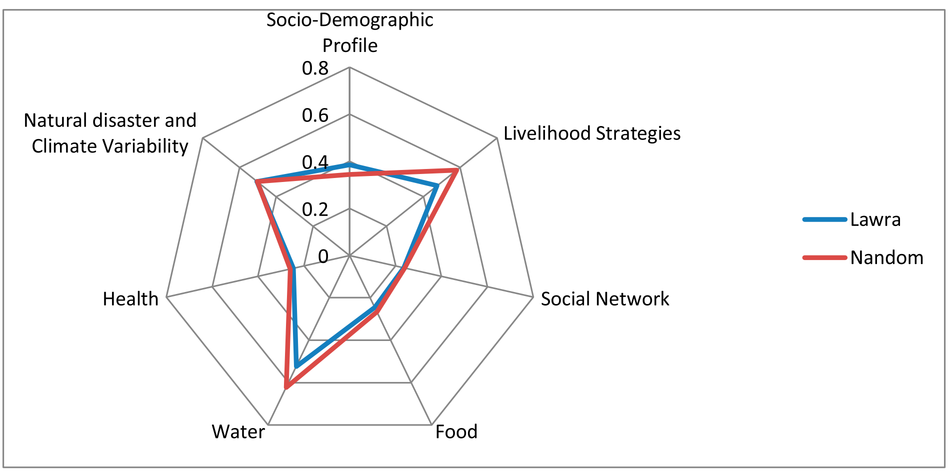

Figure 2. Vulnerability spider diagram of major components of LVI for both districts. Source: Field Survey, 2016.

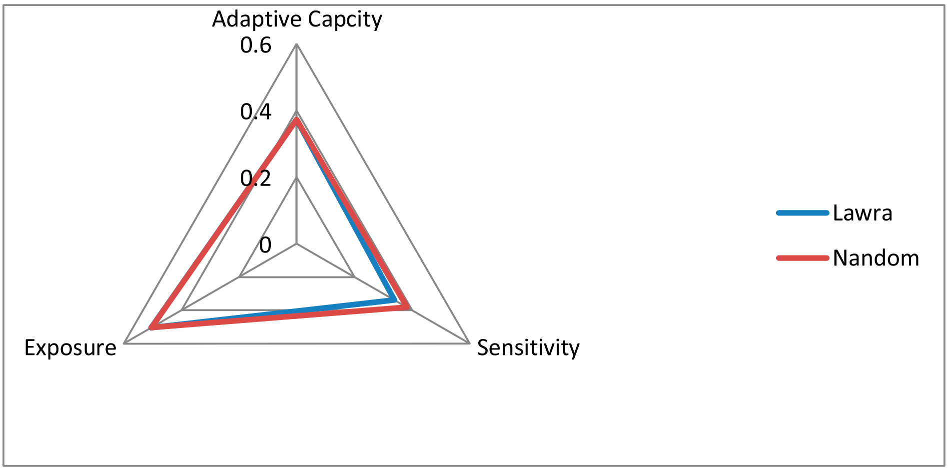

Figure 3. Vulnerability Triangle Diagram of LVI-IPCC for Lawra and Nandom District. Source: Field Survey, 2016.

district was more vulnerable (0.0502) than the Lawra district (0.0448), (Figure 3). The IPCC-LVI index confirmed the earlier findings of LVI when the seven major component values where used.

Further analysis was conducted to determine the significant differences in the LVIs computed for the 7 major components for the two districts. Table 6 shows that the LVI of six out of the seven major

Table 6. Two sample *t*-test results of differences in means of major LVI components between the Lawra and Nandom Districts.

District	Observation	Mean	Standard error	Standard deviation	*t*-test	*p*-value	Degrees of freedom
Socio-demographic profile							
Lawra	100	0.3427	0.0032	0.0324	7.3647 (2.601)	0.0000***	198
Nandom	100	0.2983	0.0051	0.0509			
Pooled data	200	0.3205	0.0034	0.0480			
Livelihood strategies							
Lawra	100	0.7967	0.0088	0.0884	10.2373 (2.601)	0.0000***	198
Nandom	100	0.9144	0.0074	0.0736			
Pooled data	200	0.8556	0.0071	0.1003			
Social network							
Lawra	100	0.4522	0.0097	0.0967	−0.6745	0.2504	198
Nandom	100	0.4611	0.0090	0.0895			
Pooled data	200	0.4567	0.0066	0.0931			
Food access							
Lawra	100	0.2936	0.0077	0.0771	−2.0139 (1.653)	0.0227*	198
Nandom	100	0.3157	0.0078	0.0782			
Pooled data	200	0.3046	0.0055	0.0783			
Water access							
Lawra	100	0.5315	0.0107	0.1069	−4.0373 (2.601)	0.0000***	198
Nandom	100	0.6072	0.0154	0.1539			
Pooled data	200	0.5694	0.0097	0.1375			
Health access							
Lawra	100	0.2473	0.0070	0.0701	−1.5912 (1.653)	0.0566*	198
Nandom	100	0.2618	0.0058	0.0577			
Pooled data	200	0.2546	0.0046	0.0644			
Natural disaster and climate variability							
Lawra	100	0.5638	0.0033	0.0325	−1.7225 (1.653)	0.0433*	198
Nandom	100	0.5711	0.0027	0.0268			
Pooled data	200	0.5675	0.0021	0.0299			

Source: Computation from Field Survey, 2016.
*** and * denote statistical significance at 1% and 10% respectively.
Values in parenthesis are the critical values of the *t* distribution.

Table 7. Two sample *t*-test results of differences between the overall mean LVIs for the Lawra and Nandom Districts.

Variable	Observations	Mean	Standard error	Standard deviation	*t*-statistic	*p*-value	df
Lawra	100	0.4611	0.0030	0.0304	−6.333 (2.601)	0.000***	198
Nandom	100	0.4899	0.0034	0.0339			
Combined	200	0.4755	0.0025	0.0352			

***Denotes significance at 1% level. Value in parenthesis is the critical value of the *t* distribution.
Source: Analysis from field survey, 2016.

Table 8. Categorisation of district level vulnerability index.

		Lawra		Nandom		Combined	
LVI range	Category	Freq	%	Freq	%	Freq	%
0.30–0.39	Low	3	3	0	0	3	1.5
0.40–0.49	Moderate	87	87	58	58	145	72.5
0.50–0.59	High	10	10	42	42	52	26

Source**:** Field Survey, 2016.

components are significantly difference in the two districts. Interestingly, the LVI of social network major component is not significantly different in the two districts.

Indeed, the overall mean LVI computed for Lawra and Nandom districts were significantly different ($p < 0.01$). Thus, the livestock farmers in the Nandom district were more vulnerable than those in the Lawra district (Table 7).

3.2. Categorisation of vulnerability levels of livestock farmers

This study employed the method of classification used by FANRPAN (2011); Muleta and Deressa (2014); Opiyo, Wasonga, and Nyangito (2014) to classify the vulnerability levels into low, moderate and high vulnerabilities. The minimum and maximum vulnerability levels of the smallholder livestock farmers in the pooled data were found to be 0.3287 and 0.5820 respectively. A household is categorised as lowly vulnerable if it can cope with the effects of climatic hazards, whereas moderately vulnerable households are hit hard by a shock and therefore needs urgent but temporary external assistance. Highly vulnerable households were also classified as emergency level households which are described as the equivalent of an intensive care situation but could be brought back to life only with the best possible expertise. In general, the results revealed that majority of the livestock farmers in the two districts (72.5%) were moderately vulnerable (Table 8).

4. Conclusions

This study assessed the vulnerability of livestock farmers in the Nandom and Lawra districts in the Upper West region of Ghana using the Livelihood Vulnerability Index approach. The livestock farmers in both districts were vulnerable, although those in the Nandom district were more vulnerable than those in the Lawra district. The results revealed that majority of the livestock farmers in the two districts (72.5%) were moderately vulnerable. The study made use of 32 sub-components of vulnerability, which can be categorised as household, institutional and environmental sub-components. Improvement in one or more of the sub-components could reduce vulnerability and increase the resilience of the farmers.

The study provides the following recommendations. First, to reduce a society’s vulnerability level, efforts should be made to reduce their exposure and sensitivity to climatic risk. This indirectly increases their adaptive capacity. Secondly, to improve their livelihood strategies, livestock farmers could adopt drought-resistance, short duration, high yielding crop varieties. These varieties are on the market for sale. Drought resistance varieties because, the area is already experiencing up to four weeks of no rainfall during the rainy season. They can take advantage of short duration crop varieties, so that the crops could have matured for harvest before the on-set of the annual drought. On livestock ownership, farmers should learn to diversify into other livestock types rather than relying solely on either goats, sheep, poultry or cattle. To reduce the threat of malaria, farmers should intensify the use of mosquito nets. No household member of a typical farm household (especially children under 5 years) should sleep without mosquito nets. Cleaning the compound and household drains could also reduce the breeding grounds for mosquitos.

Thirdly, the defunct adult education system can be re-introduced and re-enforced at the community/local level so that those who have not had the opportunity can be educated on the recent climatic developments can be trained to enable them to devise strategies to cope with this phenomenon. Education helps to reduce vulnerability because, an educated farmer can easily accept and use an innovation, and that can enhance his/her adaptive capacity. Also, vulnerability can also be reduced when there is reduction in conflict of water usage. This can be improved by constructing more bore-holes. In addition, community water harvesting facilities could be constructed to enable them harvest water during the rainy season to be used in the dry season. When this is in place, competition for water use from other natural sources such as streams, dug-outs by humans and animals would be reduced. With respect to health of the livestock farmers and their households, vulnerability can be reduced by staffing constructed health post with quality health personnel. This can be done by introducing special allowance for health workers who would accept postings to the rural areas such as the communities in the Nandom and Lawra districts. This would reduce the time taken by the rural folks to access health care at the district capitals. Finally, natural disasters can be reduced by establishing early warning systems through mass media such as radio to inform farmers in advance about an impending natural disaster such as drought, floods, disease outbreak among humans and livestock.

Note

1. Pito is a local drink made from millet.

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