

Application of Livelihood Vulnerability Index in Assessing Vulnerability to Climate Change and Variability in Northern Ghana

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Abstract

Climate change is impacting on climate dependent activities such as agriculture in Africa and Ghana. The extent of the impact of climate change in agriculture depends on the level of vulnerability or exposure of farmers to these impacts. This study estimates the level of vulnerability of smallholder farmers to climate change and variability in northern Ghana using the Livelihood Vulnerability Index highlighting access to, and utilization of water resources. The approach estimates vulnerabilities in terms of exposure, sensitivity and adaptive capacity. The data is based on a survey of 320 farm households, complemented with secondary data on rainfall and temperature. Results of the study shows that Northern Region is the most exposed region to climate change and variability. Upper West Region is the most sensitive to climate change and variability especially with regards to water stress; and the Upper East Region has the least adaptive capacity. Northern Region is the most vulnerable in terms of the overall livelihood vulnerability index, followed by the Upper East and Upper West regions.

Key Words: Livelihood, Vulnerability, Climate change, Climate variability, Northern Ghana

1. Introduction

Climate change impacts are widely observed in Africa where it has directly affected climate-dependent activities and indirectly impacted on social aspects such as poverty, conflict, education and health (Orindi and Murray, 2005). According to the Intergovernmental Panel on Climate Change, IPCC, (2007), Africa is one of the most vulnerable continents to climate change and variability because of multiple stresses and its low adaptation capacity. Boko *et al.*, (2007) report that agricultural production and food security in many African countries are likely to be severely compromised by climate change and climate variability. The implications of climate change and variability on agriculture cannot therefore be overemphasized especially for agrarian economies.

Ghana just like many other tropical countries is very much vulnerable to climate change and variability. An estimated 35 percent of the total land mass is desert. Desertification in Ghana is currently estimated to be proceeding at a rate of 20,000 hectares per annum thereby compromising water resources (EPA, 2009). Morton (2004) notes that some of the most important impacts of climate change in developing countries will be felt by the category of people, mostly referred to as smallholder farmers. Agriculture in Ghana is predominantly on a smallholder basis with about 90 percent of farm holdings being less than 2 hectares in size and producing under rain-fed conditions. According to the Ghana Statistical Service, GSS (2008), 92 percent of households in rural savannah own or operate a farm or rear livestock. In northern Ghana, these farmers are usually involved in the cultivation of staple grains including maize, rice, millet, sorghum, soybean, cowpea and groundnut, and also engage in the rearing of small ruminants such as sheep and goats (MoFA, 2010).

1.1 Vulnerability to Climate Change

The extensive usage of the term vulnerability can be traced to the disciplines of geography, natural hazards research, and poverty and food security analysis. It is conceptualized differently in different disciplines (Gbetibouo and Ringler, 2009). This study situates vulnerability in the context of natural hazards.

Vulnerability to climate change and variability has been defined by various authors as the extent to which a system or society is prone, or at risk to, and unable to deal with the negative effects of climate change and variability (see for example, FAO, 2006; IPCC, 2007; Schneider *et al.*, 2007; FAO, 2008; UNEP, 2009). According to the FAO (2006), vulnerability is not a static concept; it varies in time and space. Vulnerability to climate change depends on the rate of change of the climate and the extent to which a system is exposed, its sensitivity, and adaptation capacity (IPCC, 2007; FAO, 2009; UNEP, 2009). Sensitivity is the extent to which a system is either negatively or positively, directly or indirectly affected by climate change and variability (IPCC, 2007); and adaptation capacity is the ability of a system to reduce to moderate levels, the potential effects of climate change and variability by either taking advantage of existing opportunities or undertaking measures to deal with its consequences (IPCC, 2007; FAO, 2009).

The present study seeks to estimate the level of vulnerability of agricultural communities in northern Ghana to climate change and variability. Past vulnerability studies in northern Ghana have mostly been geared toward poverty (see for example, Norton *et al.*, 1995; Quaye, 2008; Novignon *et al.*, 2012). Nicholls (1995) assessed vulnerability to extreme climatic events in Ghana using national aggregates and not household data. The study also focused specifically on vulnerability to sea level rises. This present study adds to the vulnerability literature in northern Ghana by assessing vulnerability to extreme climatic events such as floods and droughts. There appears to be little efforts on building the resilience of smallholder farmers in northern Ghana in terms of water resource management. Water is a key component of any crop based production system since extreme water stress can result in total crop failure depending on the stage of growth of field crops. This study therefore assesses the level of vulnerability of agricultural communities to water stress. The present study also assesses vulnerability to climate change and variability in all the three regions of northern Ghana unlike Van Der Geest (2004) who focused on only one region in northern Ghana and also used relatively few variables to capture vulnerability. The three northern regions are compared in terms of level of vulnerability to climate change and variability. This result is necessary in ensuring better targeting of future developmental interventions in northern Ghana based on evidence.

2. Methods

2.1 Approaches to Measuring Vulnerability

Econometric and indicator approaches are two techniques commonly employed to measure vulnerability to climate change and variability (Deressa *et al.*, 2009). The econometric technique employs the use of econometric methods such as regression analysis. The challenge of this approach is the problem of testing various econometric assumptions regarding standard errors, hypotheses and confidence intervals as well as imputing causality without making stringent assumptions. This study therefore adopts the indicator approach in measuring the vulnerability of agricultural communities to climate change and variability. According to Deressa *et al.*, (2009), the indicator approach involves selection of indicators that a researcher considers to largely account for vulnerability. Therefore the weakness of the approach is that there is some level of subjectivity in choosing the various indicators.

Different indices have been developed by different authors in measuring vulnerability to climate change and variability. Using the indexing and vulnerability profile method, a composite index was constructed by Swain and Swain (2011). This index is however limited to measuring vulnerability to drought only.

Deressa *et al.*, (2009) developed an index to measure farmers' vulnerability to droughts and floods as well as other climatic extremes such as hailstorms, by employing the "vulnerability as expected poverty" approach. This approach is based on estimating the probability that a given shock or set of shocks will move a household's consumption below a given minimum level (for example, the consumption poverty line) or force the consumption level to stay below the given minimum if the household's consumption is already below this level (Deressa *et al.*, 2009). The drawback of this approach is that, vulnerability, being captured as expected poverty, measures future and not current vulnerability. The technique measures the tendency to be poor in future as a result of climatic extremes.

An aggregate vulnerability index for determining the level of vulnerability of the farming sector to climate change and variability was developed by Gbetibouo and Ringler (2009). It involves selecting and aggregating a number of variables that together, serve as a proxy for vulnerability. The selected variables are normalized and averages are computed to give an idea of the level of vulnerability. The shortfall of this index is that it combines both macroeconomic indicators, for example, share of agricultural GDP, and household level indicators, for example, farm income. The use of the aggregate vulnerability index therefore requires secondary data that may not be current and readily available. Macroeconomic data because of its aggregate nature may not adequately reflect a particular farming community.

Eriyagama *et al.*, (2010), also developed an index of vulnerability to climate change. In addition to combining both

macro and micro indicators, their approach only considered twelve variables in computing the index, with only one variable, frequency of occurrence to climatic stress, measuring the level of exposure to climate change.

This study uses the livelihood vulnerability index (LVI) developed by Hahn *et al.*, (2009). The LVI takes into consideration other earlier methods in estimating the differential impacts of climate change. Several variables are used to capture the level of exposure to natural disasters and climate variability, adaptation capacity of households and their sensitivity to climate change impacts (Hahn *et al.*, 2009). This index is easier to compute because with the exception of precipitation and temperature data, it uses primary data from households. The LVI does not only capture the susceptibility to droughts and floods, but also takes into account the current vulnerability which is useful for current planning (Hahn *et al.*, 2009).

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

A number of factors combine to make smallholder farmers vulnerable to climate change and variability. These factors could be internal or external to the smallholder farmer. According to Ribot (2009), vulnerability analysis is often discussed either in the light of risk-hazard or social constructivist frameworks. The risk-hazard model tends to assess several possible impacts of a single climatic event whereas the social constructivist model tends to emphasize the several possible causes of a single climatic event (ibid). Quantitative applications of the risk-hazard model in assessing climatic impacts generally emphasize exposure and sensitivity to environmental stressors, and works from the hazard to the impacts (Turner *et al.*, 2003). The risk-hazard model is the framework adopted in this study.

Several methods have been developed for aggregating indicators in computing an index; key among them are the gap method and the weighting method. In the present context, the gap method assesses vulnerability based on the deviation of smallholder farmers' current living conditions from predetermined standard living conditions in the absence of climate change and variability. The weighting method on the other hand, is based on correctly valuing each indicator in terms of its importance in contributing to making smallholder farmers vulnerable to climate change and variability (Hahn *et al.*, 2009). A balanced weighted approach is used in computing the LVI.

The livelihood vulnerability index is derived for all the three regions of northern Ghana, taking into consideration, the Intergovernmental Panel on Climate Change, IPCC, definition of vulnerability to climatic impacts developed by Hahn *et al.*, (2009). It makes use of seven major components namely socio-demographic profile, livelihood strategies, social networks, health, access to food, access to water, and finally, natural disasters and climate variability. Each component is made up of several indicators or sub-components, each of which is measured on a different scale; it is therefore necessary to standardize each as an index using equation (1).

$$index_{s_r} = \frac{s_r - s_{\min}}{s_{\max} - s_{\min}} \quad (1)$$

Where s_r is the observed sub-component indicator for region r , and s_{\min} and s_{\max} are the minimum and maximum values, respectively.

After each is standardized, the sub-component indicators are averaged using equation (2) to obtain the index of each major component:

$$M_r = \frac{\sum_{i=1}^n index_{s_{ri}}}{n} \quad (2)$$

where M_r is one of the seven major components [Socio-Demographic Profile (SDP), Livelihood Strategies (LS), Social Networks (SN), Health (H), Food (F), Water (W), or Natural Disasters and Climate Variability (NDCV)] for region r ; $index_{s_{ri}}$ 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.

Once values for each of the seven major components for a region are calculated, they are averaged using Equation (3) to obtain the region-level LVI:

$$LVI_r = \frac{\sum_{i=1}^7 w_{Mi} M_{ri}}{\sum_{i=1}^7 w_{Mi}} \quad (3)$$

This can also be expressed as

$$LVI_r = \frac{w_{SDP}SDP_r + w_{LS}LS_r + w_HH_r + w_{SN}SN_r + w_FF_r + w_WW_r + w_{NDC}NDCV_r}{w_{SDP} + w_{LS} + w_H + w_{SN} + w_F + w_W + w_{NDC}} \quad (4)$$

The weights of each major component, w_{Mi} , are determined by the number of sub-components that make up each major component and are included to ensure that all sub-components contribute equally to the overall LVI.

Following from equations (1)–(3), Hahn *et al.*, (2009) calculated a new variable, LVI–IPCC; this takes into consideration IPCC definition of vulnerability. The LVI–IPCC diverges from the LVI when the major components are combined. Rather than merge the major components into the LVI in equation (3), the major components are first combined according to three categories namely exposure, adaptation capacity and sensitivity using the following equation:

$$CF_r = \frac{\sum_{i=1}^n w_{Mi}M_{ri}}{\sum_{i=1}^n w_{Mi}} \quad (5)$$

where CF_r is an IPCC-defined contributing factor (exposure, sensitivity, or adaptation capacity) for region r , M_{ri} are the major components for region r 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, sensitivity, and adaptation capacity are calculated, the three contributing factors are combined using equation 6:

$$LVI - IPCC_r = (e_r - a_r) * s_r \quad (6)$$

Where $LVI - IPCC_r$ is the LVI for region r expressed using the IPCC vulnerability framework, e_r is the calculated exposure score for region r (equivalent to the natural disaster and climate variability major component), a_r is the calculated adaptation capacity score for region r (weighted average of the socio-demographic, livelihood strategies, and social networks major components), and s_r is the calculated sensitivity score for region r (weighted average of the health, food, and water major components). The LVI-IPCC is scaled from -1 (least vulnerable) to 1 (most vulnerable). Microsoft Office Excel 2010 was the software employed in estimating the livelihood vulnerability index. Details of specific data required as well as procedure for computation are fully described by Hahn *et al.*, (2009) and included as Appendices 1 and 2 of this paper.

2.3 Data Sources and Sampling Procedure

The study employed mainly primary data sourced from smallholder farmers in northern Ghana. A questionnaire was designed, tested and administered at the household level. The questionnaire covered 31 key variables used in computing the LVI. Secondary data on temperature and precipitation were also sourced from the Ghana Meteorological Service. The reference period for most of the survey questions is between 2000 and 2011, and that of the meteorological data is between 2002 and 2011.

The three regions of northern Ghana namely, Northern, Upper East and Upper West were purposively selected for the study. Through simple random method and based on ecology, population and land size, 4 districts were selected from the Northern Region and 2 districts were selected in both the Upper East and Upper West regions. Simple random method was also used to select 4 communities in each district except the Kassena-Nankana East District in the Upper East Region where only 3 communities were selected. Approximately 10 households were enumerated in each community based on a random walk. A total of 320 households were interviewed in November 2011. The reference period for the climate events data was from 2002 to 2011.

3. Results and Discussions

Empirically, the vulnerability indices of the major components ranged from 0.17-0.58 as shown in Table 1. The Indices being relative values are compared across three regions in Ghana within the study sample only. The Vulnerability Index for the water component of the LVI shows Upper West Region to be the most (0.489) vulnerable, and the Northern Region to be the least (0.371) vulnerable. The Upper West Region recorded the highest percentage of households reporting conflicts over water resources in the past. Conflicts negatively affect social integration and neighborliness. Almost all (98.8%) the households interviewed in the region reported utilizing a natural water source such as dam, lake, among others, as compared to households in the Upper East (69.1%) and Northern (34.6%) regions. Utilization of a natural water source is likely to lead to an increase in a household's vulnerability to water borne diseases and water scarcity due to inadequate rainfall. According to the GSS (2008), the percentage of households in rural savannah that source their water from wells and natural sources are 57.7% and 36.5% respectively.

The average time taken to reach a water source is found to be highest in the Northern Region. Water is usually sourced by women and young girls hence distant water sources increases the time burden of household chores and affects time for care in the case of women, and school attendance in the case of the girl child. Northern Region reported the highest percentage (56.6%) of households that do not have a consistent water supply. These households become even more vulnerable during the dry season when most natural water sources tend to dry up. More households in the Upper West Region reported storing water as compared to those in the Upper East and Northern regions.

The second major component is the socio-demographic profile which consists of five sub components. In terms of socio-demographic profile, Northern Region (0.326) was found to be the most vulnerable followed by the Upper East Region (0.307). Majority of the household heads in Northern Region (77.4%) reported not having any formal education. 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. Less than a third of adults in rural areas of the three northern regions have some formal education (GSS, 2008). Illiteracy limits smallholder farmer's access to information especially from written sources, thereby increasingly their susceptibility to climatic stresses. According to Stanturf *et al.*, (2011) northern Ghana is relatively vulnerable to climate change as compared to the rest of Ghana mainly because of the high rates of illiteracy and relatively underdeveloped infrastructure. About thirty (29.6%) percent of households in Northern Region also reported taking care of at least one orphan. This places an additional strain on household resources thereby reducing their resilience to climate change and variability.

Livelihood strategies are the third major component which is made up of three sub components. When results of all the sub components are aggregated, the Upper East Region is found to be the most vulnerable (0.582) in terms of socio-demographic profile. The region reported the highest percentage (46.9%) of households with family members working in a different community. Most of these family members were reported to have migrated to southern Ghana for employment. This phenomenon increases the vulnerability of these households to external stress since household members may return with certain social vices or health challenges. Some family members do however remit to their households.

The major component of social networks is also made up of three sub components. Even though the indices for the three regions are similar, Upper East Region is found to be the most vulnerable (0.54) in terms of social networking. Households in the Upper East Region reported receiving more help than giving help to others when compared to households in the other regions. Help is usually in the form of money, care during indisposition, and marketing among others. The percentage of households that reported not going to their local government for assistance in the past twelve months is generally high (at least 95%) across the three regions. Most households are more comfortable soliciting assistance from friends and relatives than from local authorities. Good social networking mostly lessens the impact of climatic stresses on individual households. The findings of this study is consistent with that of Stanturf *et al.*, (2011) who also reported that the Upper East, Upper West, and Northern regions have the highest overall social vulnerability to climate change in Ghana.

Four sub components are combined to make up the health major component. When the four sub components are aggregated, Northern Region is found to be the most (0.259) vulnerable to health. The average time taken to reach a health facility is highest for the Northern Region. Inadequate access to health services tends to decrease the health status of smallholder farmers, thereby increasing their vulnerability to extreme climatic events. More households (41.5%) in Northern Region reported that a family member had to miss either work or school in the past six months due to illness. Sickness increases the vulnerability of smallholder farmers to other external stresses. According to the GSS (2008) 64.2% of people in rural savannah had to stop their usual activities due to illness or injury two weeks

prior to the fifth round of the Ghana living standards survey.

The Food major component is made up of five sub components. The Upper West is the most vulnerable to food inaccessibility with an index of 0.348. The average number of months households struggle to find food was found to be highest in the Upper West Region (about 3). Food security enhances household's resilience to external stresses including extreme climatic events. The finding of this study differs from Quaye (2008) who opined that the Upper East is the most vulnerable region in northern Ghana with respect to food accessibility.

The seventh major component is the natural disasters and climate variability component which is comprised of six sub components as shown in Table 1. Northern Region was found to be the most vulnerable, in terms of natural disasters and climate variability. Majority of farmers in all three regions did not receive any warning about impending natural disaster such as floods or droughts however the problem is most prevalent in the Northern Region where about 91 percent of the sample reported lack of information about impending disasters and are therefore unable to adequately prepare for them. Annual spillage of the Bagre Dam in Burkina Faso as well as intermittent drought is typical natural disaster that increases the vulnerability of farming communities in northern region to climatic stresses. Northern region by virtue of its land size is more likely to suffer from climatic variability as compared to either the Upper West or Upper East regions. The meteorological data shows that Northern Region recorded more precipitations and also witnessed more variations in both maximum and minimum daily temperature even though the differences are not marked. Due to the relatively small geographical sizes, the appears to be little or no differences in both the Upper East and Upper West regions in terms of intra-regional ecological variability unlike the Northern Region which is not only the largest region in Ghana in terms of land size, but also has parts of the region falling under the Transition, Guinea and Sudan Savannah. Antwi-Agyei *et al.*, (2011) reported that the Northern Region is the most vulnerable region in northern Ghana in terms of drought, followed by the Upper West and Upper East regions.

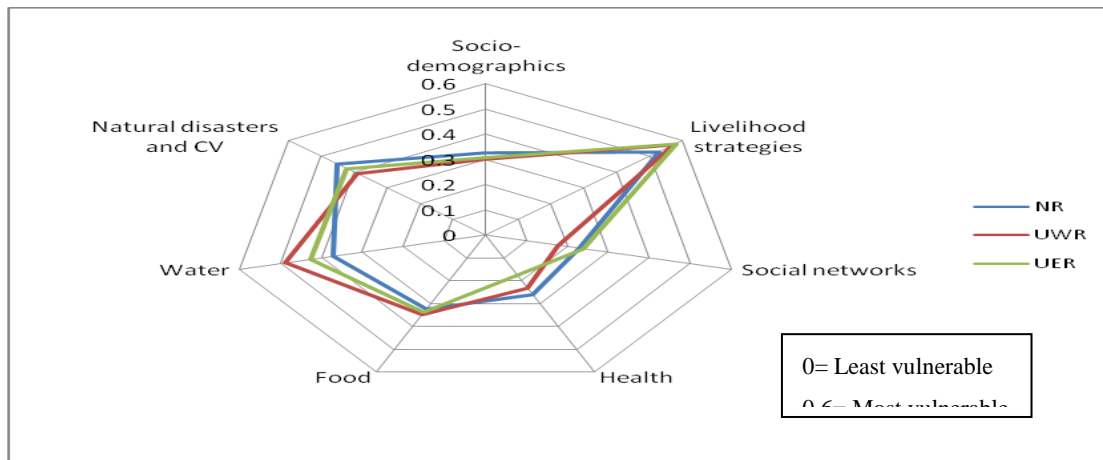
Table 1: Indexed Sub Components, Major Component for Natural Disasters and Climate Variability and Overall LVI for Northern Ghana

Sub-component	Region			Major component	Region		
	Northern	Upper West	Upper East		Northern	Upper West	Upper East
Percent of households reporting water conflicts	0.340	0.412	0.383	Water	0.371	0.489	0.427
Percent of households that utilize a natural water source	0.346	0.988	0.691				
Average time to water source	0.173	0.096	0.109				
Percent of households that do not have a consistent water supply	0.566	0.550	0.531				
Inverse of the average number of litres of water stored per household	0.432	0.400	0.421				
Dependency ratio	0.166	0.179	0.142	Socio-demographic profile	0.326	0.301	0.307
Percent of female-headed households	0.062	0.075	0.185				
Average age of female-head of household	0.333	0.323	0.333				
Percent of households where head of household has not attended school	0.774	0.700	0.593				
Percent of households with orphans	0.296	0.225	0.284				
Percent of households with family member working in a different community	0.277	0.325	0.469	Livelihood strategies	0.528	0.576	0.582
Percent of households dependent solely on agriculture as a source of income	0.987	0.962	0.877				
average agricultural livelihood diversification index	0.320	0.440	0.400				
Average receive: give ratio	0.220	0.210	0.294	Social networks	0.538	0.505	0.540
Average borrow: lend money ratio	0.433	0.317	0.375				
Percent of households that have not gone to their local government for assistance in the past 12 months	0.962	0.988	0.951				
Average time to health facility	0.206	0.159	0.079	Health	0.259	0.232	0.174
Percent of households with family member with chronic illness	0.208	0.250	0.160				
Percent of households where a family member had to miss work or school in the past 6 months due to illness	0.415	0.238	0.235				
Average malaria exposure*prevention index	0.208	0.282	0.221				
Percent of households dependent solely on the family farm for food	0.918	0.938	0.975	Food	0.324	0.348	0.336
Average number of months households struggle to find food	0.127	0.268	0.223				
Average crop diversity index	0.410	0.410	0.433				
Percent of households that do not save crops	0.082	0.062	0.025				
Percent of households that do not save seeds	0.082	0.062	0.025				
Average number of flood and drought events since 2000	0.268	0.259	0.432	Natural Disasters and Climate Variability	0.452	0.391	0.424
Percent of households that did not receive a warning about the pending natural disasters	0.906	0.788	0.617				
Percent of households with an injury or death as a result of flood or drought since 2000	0.019	0.062	0.025				
Mean standard deviation of monthly average of average maximum daily temperature since 2002	0.447	0.317	0.441				
Mean standard deviation of monthly average of average minimum daily temperature since 2002	0.729	0.631	0.704				
Mean standard deviation of monthly average precipitation since 2002	0.339	0.287	0.327				
LVI IPCC							

Source: Computations from field survey, 2011

The results of all the seven major components are summarized in Figure 1. The vulnerability spider diagram ranges between 0 (least vulnerable) and 0.6 (Most vulnerable). Northern Region is most vulnerable in terms of socio-demographic profile, health and natural disasters and climate variability. Upper West Region is most vulnerable to food and water, while the Upper East Region is most vulnerable in terms of social networks and livelihood strategies.

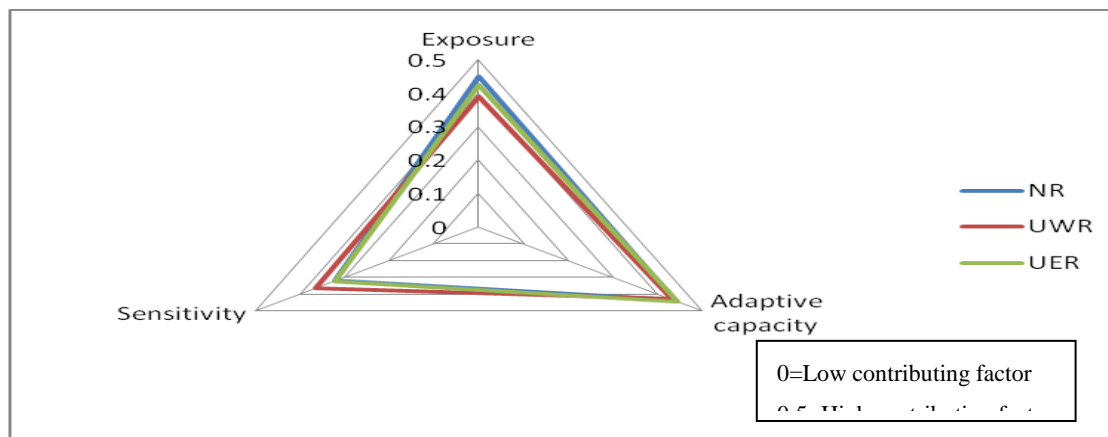
Figure 1: Vulnerability Spider Diagram of the Major Components of the Livelihood Vulnerability Index (LVI) for Northern Ghana



Source: Computations from field survey, 2011

The LVI IPCC is computed by grouping the seven major components into three categories namely exposure, sensitivity and adaptation capacity. Whereas exposure is made up of the score for only one major component, sensitivity and adaptation capacity are made up of aggregated scores of three major components each. IPCC definition of vulnerability, which takes into consideration exposure, sensitivity and adaptation capacity, is represented in the vulnerability triangle as shown in Figure 2.

Figure 2: Vulnerability Triangle Diagram of the Contributing Factors of the Livelihood Vulnerability Index-IPCC (LVI-IPCC) for Northern Ghana



Source: Computations from field survey, 2011

The vulnerability triangle indicates that Northern Region is the most exposed region to climate change and variability. Upper West Region is the most sensitive region to climate change and variability taking into consideration the water, health and food status of the region and Upper East is the most vulnerable region in terms of adaptation capacity of households, taking in account the socio-demographic profile, social networks and livelihoods of households in the region.

The LVI IPCC estimates for the Upper West, Upper East and Northern regions are -0.015, -0.007 and 0.004 respectively. This implies that overall, in terms of climate change and variability, Northern Region is the most vulnerable followed by the Upper East Region and then Upper West Region.

4. Conclusion and Recommendations

Northern Region was found to be the most vulnerable and exposed region in northern Ghana in terms of climate change and variability. Lack of information about pending natural disasters, fluctuations in precipitation and temperature, illiteracy, large family sizes and inadequate access to medical care were found to be important in increasing the vulnerabilities of farming communities in the region to extreme climatic events. Upper West was found to be most sensitive region to extreme climatic events probably because of the region's inadequate access to food and water resources. The most vulnerable region in terms of adaptation capacity of households was found to be the Upper East Region and this could be attributable to the high rate of out-migration in the region.

The findings of the study have important policy relevance that could enable smallholder farmers in northern Ghana to better adapt to the effects of climate change and variability.

The Upper West Region should be given priority by both government and donors in terms of distribution of income generating and food security projects in order to reduce food vulnerability. There is the need to improve water supply in the region by undertaking measures such as construction of boreholes in order to reduce the time taken to get to water sources and to reduce conflicts over water.

It is also imperative to introduce sustainable livelihood options (for example, making of handicrafts and food processing) and social protection programs in order to reduce out-migration in the Upper East Region.

Further, there is the need to build more community health centres in Northern Region in order to reduce the time taken to reach a health facility. In addition, an early warning mechanism to detect natural disasters and climate variability should be put in place. In this regard, Metropolitan, Municipal and District Assemblies (MMDAs) through the National Disaster Management Organisation (NADMO) as well other NGOs should sensitize smallholder farmers in the region about impending natural disasters such as floods, droughts, pests among others. Finally, there is the need to improve the literacy levels of farmers by implementing informal educational programs in the region.

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Appendix 1: Calculating the Socio-Demographic Profile Major Component for the LVI for Northern Region

Sub-components for socio-demographic profile	Sub-component values for Northern Region	Max in combined data	Min in combined data	Index value for Northern Region	Socio-demographic major component for Northern Region
Dependency ratio	1.122	6.75	0	0.166	1.632
Percent of female-headed households	6.200	100	0	0.062	
Average age of female head of household	0.020	0.04	0.01	0.333	
Percent of households where head of household has not attended school	77.40	100	0	0.774	
Percent of households with orphans	29.60	100	0	0.296	

$$\text{Step 1 (repeat for all sub-component indicator): } \text{index}_{\text{SDP1NR}} = \frac{1.122 - 0}{6.75 - 0} = 0.166$$

$$\text{Step 2 (repeat for all major components): } \text{SDP}_{\text{NR}} =$$

$$\frac{\sum_{i=1}^n index_{s_{di}}}{n} = \frac{SDP_{1NR} + SDP_{2NR} + \dots + SDP_{5NR}}{5} = \frac{0.166 + 0.062 + 0.333 + 0.774 + 0.296}{5} = 1.632$$

Step 3 (repeat for all study areas): $LVI_{NR} = \frac{\sum_{i=1}^7 W_{M_i} M_{d_i}}{\sum_{i=1}^7 W_{M_i}} =$

$$\frac{(6)(2.709) + (5)(1.632) + (3)(1.584) + (3)(1.615) + (4)(1.036) + (5)(1.619) + (5)(1.856)}{6 + 5 + 3 + 3 + 4 + 5 + 5} = 0.389$$

Appendix 2: Computation of LVI-IPCC for Northern Region

Contributing factors	Major components for Northern Region (NR)	Major component values for NR	Number of sub components per major component	Contributing factor values	LVI-IPCC value for NR
Adaptation capacity	Socio-demographic profile	0.326	5	0.439	0.004
	Livelihood strategies	0.528	3		
	Social networks	0.538	3		
Sensitivity	Health	0.259	4	0.322	
	Food	0.324	5		
	Water	0.371	5		
Exposure	Natural disasters and climate variability	0.452	6	0.452	

Step 1 (Calculate indexed sub component indicators and major components as shown in Appendix A, taking the inverse of the adaptation capacity sub component indicators: Socio-demographic Profile, Livelihood Strategies, and Social Networks).

Step 2 (repeat for all contributing factors: exposure, sensitivity, and adaptation capacity):

$$Adaptation\ Capacity_{NR} = \frac{\sum_{i=1}^n W_{M_i} M_{d_i}}{\sum_{i=1}^n W_{M_i}} = \frac{5(0.326) + 3(0.528) + 3(0.538)}{5 + 3 + 3} = 0.439$$

Step 3 (repeat for all study areas): $LVI-IPCC_{NR} = (e_{NR} - a_{NR}) * S_{NR} = (0.452 - 0.439)(0.322) = 0.004$ **References**

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