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Micro-level social vulnerability assessment towards climate change adaptation in semi-arid Ghana, West Africa

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Abstract This study determined the social vulnerability index (SoVI) of households to climate change impacts for three identified locations (upper, mid and lower) in the Vea catchment, semi-arid Ghana. This study adapted the social, economic and demographic indicator approach. The data used were obtained from a survey of 186 randomly sampled farm households and direct field measurements of 738 farm plots belonging to the same sampled farm households. Information from the literature, expert judgement and principal component analysis were useful for computing and analysing the SoVI. The variables were

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normalized, weighted and subsequently recombined to determine the index of the three locations towards climate change. Although the SoVI to climate change was highest (0.77) for the upper part of the catchment, the mid- and lower parts of the catchment show a high SoVI of 0.72 each. The overall SoVI for the catchment is 0.73. The study re-emphasizes the high vulnerability level of dry areas to climate change. Moreover, it shows there is variability at micro-scale. There is a need to put appropriate measures to address the vulnerability of households to climate change in the semi-arid areas of West Africa. Factors aggravating dry land's vulnerability towards climate change should be prevented with implementable policies. Furthermore, it is important to identify conditions that have made some areas less vulnerable to climate change, and then, we can work out the possibility of adapting such to the vulnerable places.

Keywords Social vulnerability index · Dry lands · Vea catchment · Socio-economic indicators

1 Introduction

1.1 Background

Climate change impact is felt more whenever there is an occurrence of severe weather. These extreme events come in the form of values that are beyond or below acceptable thresholds, i.e. upper or lower ends of ranges of climatic variables (IPCC 2012). It is connected with natural causes acting internally or externally (IPCC 2014). The consequence of the extreme cases could be a disaster that can interfere with the normal performance of the people and public systems, as a result, contributing to extensive socio-economic, material and or environmental losses that exceed the potential of the affected to adjust by means of its own resources (UNISDR 2009). Central to the recent climate change discourse is the preparedness and response activities of the entities at the risk of severe climate (IPCC 2012). Climate change mitigation is an acknowledged response to combating its impacts. For the vulnerable, adaptation plays a key role. UNDP (2008) noted that the recognition of the vulnerable, the circumstances responsible for their vulnerability and their response to climate change are of policy interest.

The experience of climate change impact varies globally, thus impeding the overall development (Atkins et al. 2000). The dry lands (arid and semi-arid), which constitute 41.3% of the globe and 66% of Africa, are expected to be severely affected as the climate becomes harsher (MA 2005). The re-evaluation of adaptation, mitigation strategies and the vulnerability of entities within the various outlooks is vital in living with climate change (Karl et al. 2009). Vulnerability has found its usage in diverse fields, with numerous interpretations and applications (O'Brien et al. 2007; IPCC 2012). According to Cutter et al. (2003) and Turner et al. (2003), exposure, sensitivity and the adaptive capacity of an entity form as a gauge whether an entity or a system is vulnerable. This further explains the

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extent to which the entity or system is anticipated to be affected (Dwyer et al. 2004) or can cope with changes with or without susceptibility (Parry 2007).

Vulnerability from a climate change perspective implies the degree to which a system (social or natural) is predisposed to being adversely affected by the changing climate. It is a function of the enormity of changing climate, how sensitive the system is, to the changing climate and the capability of the system to adjust with its variation. Thus, a modest variation in the climate will severely affect a vulnerable system, especially when the capacity to adapt is extremely constrained (IPCC 2000). Vulnerability is place based because it differs from region to region and even varies within a region and place (Cutter et al. 2003; Turner et al. 2003). The vulnerability of a region links to the resources of the region, and poverty constrains the adaptive capabilities (Watson et al. 1998). In the developing world, the effects of climate change are anticipated to be greater, especially on those that generate their main source of income from primary production (IPCC 2001). In addition, the impacts are compounded by weak ability to adapt, both financially and institutionally (Beg et al. 2002; UNFCCC 2006). As a result of weak adaptive capacity, high rates of poverty and deficiency of safety measures, several nations in Africa are vulnerable to extreme climate (Slingo et al. 2005; Thomas and Twyman 2005) (Fig. 1). Vincent (2004) opined that ranking vulnerability across entities (e.g. populations, countries and regions) is essential in climate change research, particularly for policy implications

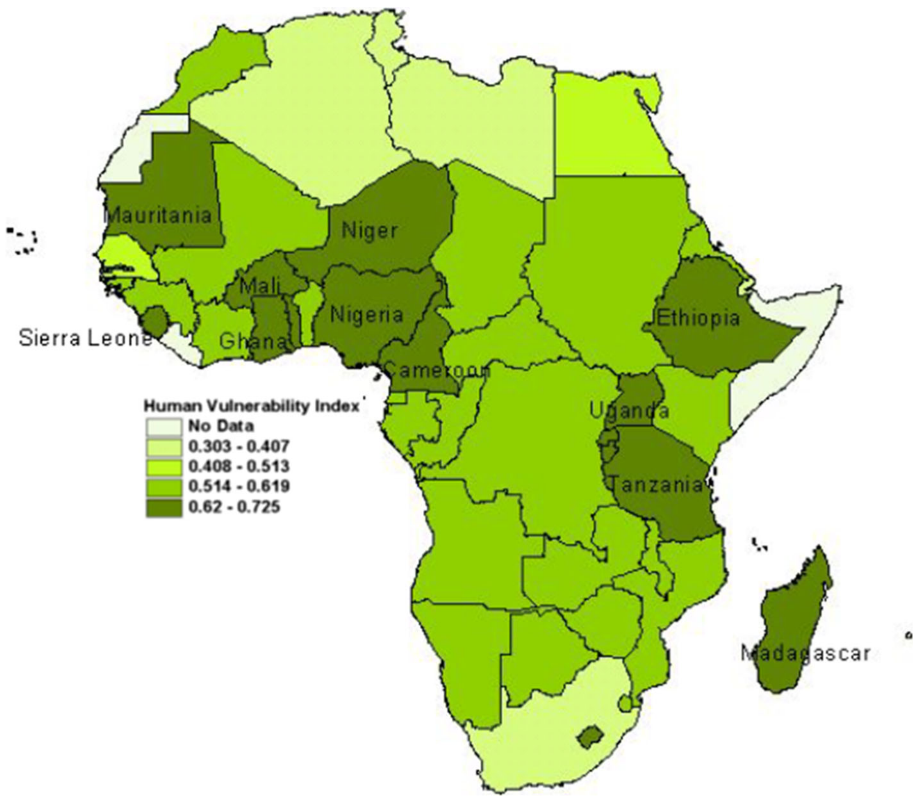


Fig. 1 Social vulnerability index of Africa countries to climate change based on World Development Indicators (Vincent 2004)

and in identifying concerned aspects of aid intervention as well as for the development of adaptive capacity.

The general study of vulnerability is essential to a number of research problems affecting human endeavour. Fussel (2007) concluded that climate change, disaster management, ecology, poverty, natural hazards, sustainability science, public health and land use research areas have vulnerability as a crucial idea that must be understood in making decisions especially human-related decisions. The changing climate is equipped with the capability to degrade and modify the content of the earth systems, particularly cultures, economies and the social system (IPCC 2007). The impact of the changing climate on the social system is opening up the vulnerability of the several social settings. The classification of these systems on how socially vulnerable they are has influenced awareness on climate change impact. Therefore, social issues when linked to climate change kick off the conception of social vulnerability within the boundaries of climate changes dialogue, which deal with finding people in the communities and situations that predispose people to the effects of more frequent extreme and subtle changes, therefore bearing harsh impacts on human basic need (Karl et al. 2009). The three regions in the northern zone of Ghana continue to have the highest poverty depth in the country (Cooke et al. 2016). The semi-arid region of Ghana, which forms part of Northern Ghana, is characterized by increasing exposure to the effect of climate change and variability through increased livelihood vulnerability (EPA 2003). The most vulnerable region in Ghana is the Upper East Region (Antwi-Agyei et al. 2012). Many vulnerability studies have been conducted at the macroscale in this region (Vincent 2004; Madu 2012; Dumenu and Obeng 2016). However, a key challenge of vulnerability study at the macrolevel is the likelihood to amplify or lessen the impact of the contributing factors. To effectively capture the impact of these factors, a micro-level (more detailed) assessment becomes imperative. Thus, in the context of climate change, the following questions were explored: (1) what is the social vulnerability index (SoVI) based on selected indicators? (2) what is the overall social vulnerability in the study area? and (3) does social vulnerability level varies at micro-scale?

1.2 Social vulnerability assessment: an overview

Social vulnerability as a form of vulnerability is a paradigm developed for disaster management in the 1970s, which go beyond both physical and material component quantification for susceptibility to disaster. It requires the identification of the demographic and socio-economic parameters that shapes the resilience of communities (Juntunen 2005). It also amplifies unfavourable exposure and sensitivity to an environmental destructive event as a result of weak, absence or non-performing adaptive capacity (Table 1 shows the frameworks for assessing social vulnerability). The most widely used method for assessing social vulnerability is the social vulnerability index (SoVI). It is based on some demographic and socio-economic factors portraying the vulnerability of people. The original index recognized 32 different factors in its analysis of vulnerability. Social vulnerability assessment is demanding as it depends on the composition of human society and the distinguishing components in the face of pervasive and non-discriminating disaster. As a result, in assessing social vulnerability, defining the ranges of vulnerability attributes and the precise group of people that possess these attributes are central challenges in formulating the response policies and strategies. Another bottleneck is the non-agreements with regard to the exact number of factors and the composition of factors to combine into vulnerability index (Cutter et al. 2003). Hence, analyses of social vulnerability have been

Table 1 Selected summary of indexes/frameworks

Vulnerability indexes/framework	Authors
Composite vulnerability index	Wells (1997)
Commonwealth vulnerability index	Atkins et al. (2000)
Social vulnerability index	Cutter et al. (2003)
Vulnerability assessment	Turvey (2007)
Resilience index	Briguglio et al. (2009)
Socio-economic vulnerability index and Built environment vulnerability index	Holand et al. (2011)
Human development index	UNDP (2013)

based on several adapted ranges of socio-economic factors that can increase proneness to hazard.

For example, Cooley et al. (2012) combined 19 indicators to establish the social vulnerability to climate change in California. Letsie and Grab (2015) identified 27 indicators in the southern part of Lesotho. Dwyer et al. (2004) identified 13 indicators for conceptualizing vulnerability, and Stanturf et al. (2011) combined 11 indicators to determine the vulnerability of the social system in Ghana to climate change. Selecting the proper number of indicators is a challenge in an indicator-based assessment because too many indicators may create noise that can be tricky to explain; at the same time, insufficient indicators may limit the extent of the understanding of vulnerability. Montalbano (2011) noted that if the actual vulnerability is to be assessed, the choice and the combination of variables must be informed by theoretical and the conceptual understanding. In the developing nations, the inadequate or non-availability of secondary data constrains the conduct of an in-depth study on social vulnerability. In some cases, data at the level of community organization, which are crucial in understanding the level of capacity to address and cope with hazards, may not be captured. Studies on social vulnerability may have a twisted result caused by data quality issues, consistency and availability at the required study scale (Cooley et al. 2012). Data on good indicator may be imperfect or limited whereas data on weak indicator may be readily available. The main effect of data inadequacies in social vulnerability appraisal is that the overall vulnerability of the people will be undermined, resulting in under-representation by the selected indexing factors (Cooley et al. 2012). Furthermore, several social vulnerability assessments have relied greatly on a secondary data source (census), which may not be up-to-date. Also, local-scale variation in vulnerabilities may not be effectively captured resulting in a generalization of vulnerability. The social vulnerability stance will constantly re-shape in accordance with the dynamic nature of sampling procedure and the census statistics of the focus population (such as age, employment status, household income, which changes with time). Finally, uncertainty remains on how policy makers, particularly governments, can formulate policies from social vulnerability assessment.

2 Study area

The location of this study is the Ghanaian section of the Vea catchment (Fig. 2). The Vea catchment cuts across Ghana and Burkina Faso. The catchment lies between Bongo and Bolgatanga districts, which belong to the Upper East Region (UER) Ghana, with

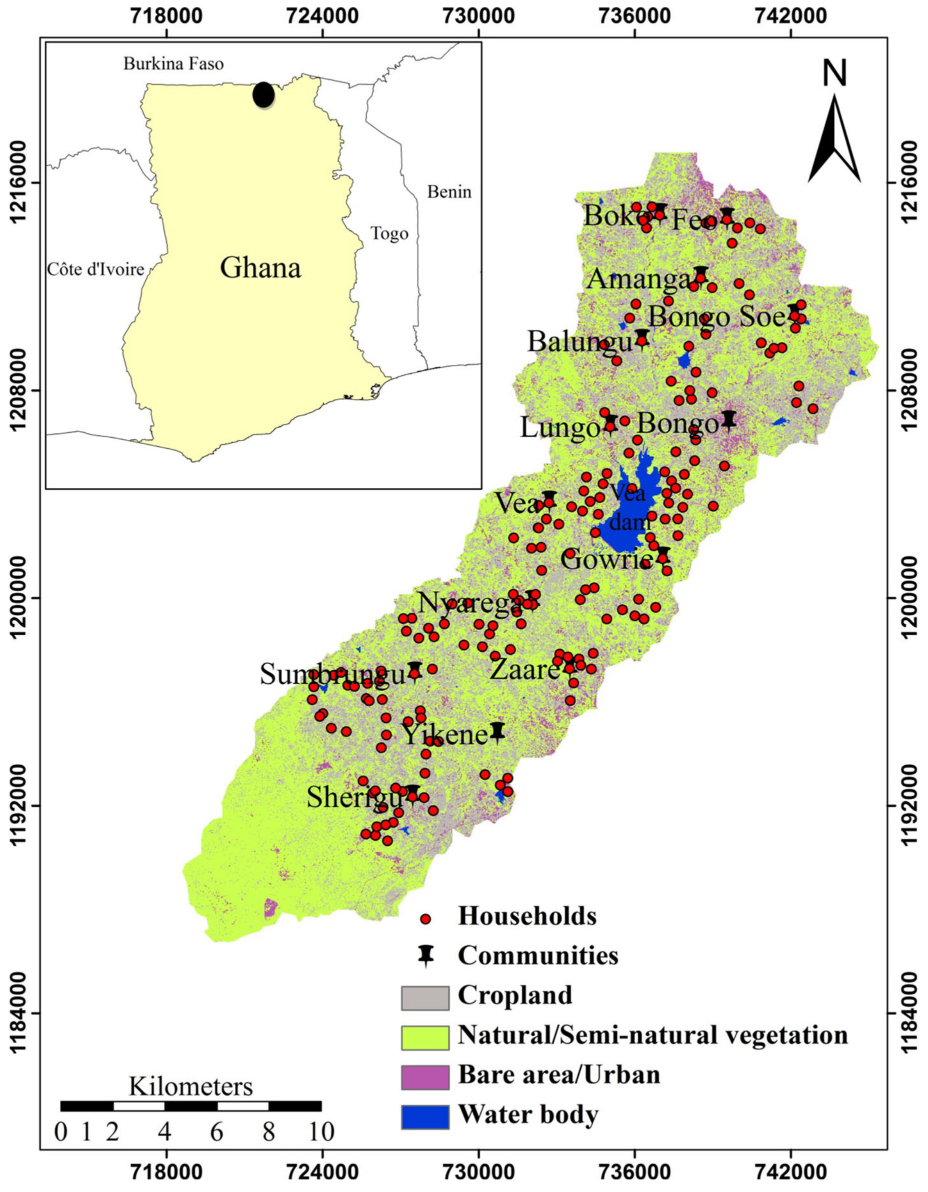


Fig. 2 Land cover map showing some communities within the Vea Catchment, Ghana. (Modified from Forkuor 2014)

Bolgatanga serving as the regional capital. Other than the small portion of land in the extreme north-eastern part, UER is classified to be in the semi-arid Guinea savanna belt of West Africa (Adu 1972). Based on the 2010 census result of Ghana (GSS 2012), a 1.2% increase in population in the UER was recorded between the year 2000 and 2010. The average household size in the region is 5.8 with a population density of 118 persons km^{-2} that exceeded the country's average of 103.4 persons km^{-2} (GSS 2012). The principal source of livelihood for most of the people in the region is agricultural production (Barry et al. 2005; Liebe 2002). People also engage in service and sales works, craft and related trade works (GSS 2012). Rain fed and dry season food crop productions are carried out in the study area. Over the past 30 years, the months of July to September mark the period with most rainfall (Fig. 3). Peculiar to the study area are variations in the commencement of rainfall, the length and the intensity. This in turn brings about variation in the agricultural output potential (IFAD 2007). Compared to the rest of the country, temperatures are by far higher (Martin 2006). The range of the average monthly minimum temperature is from 19.7 to 26.9 °C, and average monthly maximum temperature is from 30.6 to 39.2 °C. The lowest daytime temperatures correspond with the time of the season when the rainy season is at its peak. The months of December and January correspond to the time when the lowest night-time temperatures are experienced (Martin 2006). For more details about the study area, see (Villamor and Badmos 2016; Badmos et al. 2015a, b; Amadou et al. 2015; Badmos et al. 2014).

3 Methodology

3.1 Data collection

General household data were collected by means of survey questionnaire from 186 randomly distributed farm households within the Vea catchment. A household consists of people eating from same pocket or depending on same person (i.e. the household head). The sample size was determined based on random sampling technique (Krejcie and Morgan 1970). Since other studies were at the same time being conducted in the study area and to reduce research fatigue on the respondents, data were collected only from 186 households. The data for this study were mainly focused on socio-economic-, demographic- and climate knowledge-related data. Locations of each farm household were collected using a GPS device. Each household was identified according to the location level (upper, middle and lower) within the catchment (Badmos et al. 2014). The areas of all the farm plots that belong to each household were estimated by walking through the farm boundaries with a GPS device.

3.2 Identification and reclassification of indicators

Different methods have been used for social vulnerability assessment indicator selection. For instance, Dumenu and Obeng (2016) and Kaly and Pratt (2000) used expert judgement for indicator selection, whereas principal component analysis (PCA) was used by Kandeh and Kumar (2015) and Andrew and Keefe (2014). In this study, we adapted the social, economic and demographic indicator approach applied by Dumenu and Obeng (2016) to assess the social vulnerability across four ecological zones in Ghana. We combined information from the literature, expert judgement and PCA for indicator selection. Variables that relate to the social, economic and demographic factors were subjected to PCA to select the final indicators that will be used for measuring the social vulnerability to climate change. PCA helped to identify patterns in data, and the data are conveyed in a manner to show whether they are similar or different (Smith 2002). PCA reduces the complexity of input data and ensure minimal loss of information (Jankovic et al. 2008).

For this study, the e*igenvalue* (e) was set at "$e > 1$", and the PCA was run several times by recombining the variables until we achieved a satisfactory balance between the amount of variance explained and the Kaiser–Meyer–Olkin (KMO) value. KMO is an index (0–1), which measures the sampling adequacy and it checks how appropriate the factor analysis is. A high value for KMO is recommended because it implies that there are other variables that can explain the correlation between the potential factors. The varimax rotation technique was used to identify variables with high loading. Based on the information obtained from the literature and the expert knowledge of the study area, we retained some variables with high loading in the varimax rotation output of the PCA. The selected variables were further tested for multi-collinearity.

To determine the social vulnerability level based on each indicator, the selected variables were standardized between the scale of "0–1" (Eq. 1), with a value "1" signifying highest vulnerability index and value "0" signifying lowest vulnerability index. Standardization is essential so as to give room for comparison (Vincent 2004). Subsequently, weight was assigned to each indicator (based on PCA); thereafter, the social vulnerability index due to climate change was determined by combining all the indicators (Eq. 2).

$$I = \left(\frac{V_i - V_{\min}}{V_{\max} - V_{\min}}\right) \tag{1}$$

where "I" = is the indicator to be used for estimating social vulnerability, "V_i, $V_{\min}$ and $V_{\max}$" are the real value of the chosen variables, the lowest value of the chosen variables and highest value of the chosen variables.

$$\mathrm{SVI} = \sum_{i=1}^{n} (\mathrm{In} * W) \tag{2}$$

where "SVI" represents the social vulnerability index, "In" represents the indicator to be used for estimating social vulnerability and "W" represents the weight assigned to each indicator.

4 Results and discussions

4.1 Social vulnerability indicators

The PCA extracted six components that accounted for 66% of the overall variance of the original independent variables. The Kaiser–Meyer–Olkin (KMO) obtained was 0.64. The rotated component matrix showing variable loading is shown in Table 2, while the justification for retaining a particular variable as an indicator for estimating social vulnerability is presented in Table 2. The indicators were further reclassified into demographic-, land-, income- and climate change-related indicators. Information from the literature and expert knowledge of the study area that supported the choice of high-loading variable that was retained as indicators for determining social vulnerability index are presented in Table 3. The weights assigned to the indicators used to estimate the social vulnerability index are presented in Table 4.

Table 2 Rotated component matrix (i.e. loadings) using varimax with Kaiser Normalization method for the principle components

Variables	Component					
	1	2	3	4	5	6
Income from maize crop farming	*.060*	***.866***	*−.031*	*.136*	*−.054*	*−.049*
Income from dry season rice	***.769***	*.002*	*.010*	*.130*	*−.086*	*−.161*
Total income from dry season farming	*.502*	*.118*	*.058*	*−.010*	*.330*	*−.024*
Labour force of household	*−.052*	*.011*	*−.137*	*−.089*	***.658***	*.085*
Total Land area cultivated in the dry season	**.903**	*.075*	*.043*	*.040*	*−.013*	*.081*
Land area cultivated for rice in dry season	***.864***	*.029*	*−.024*	*.053*	*−.137*	*−.001*
Land area cultivated for traditional cereals	*−.058*	*.000*	*−.194*	*−.157*	*.125*	***.829***
Land area cultivated for maize	*.016*	***.856***	*.046*	*.098*	*.061*	*.053*
Educational level of household head	*−.087*	*.057*	***.830***	*−.045*	*.145*	*−.025*
Member of household involved in off-farm activities	*.082*	*−.019*	*.193*	*.267*	***.708***	*−.092*
Household involvement in maize farming	*.038*	**.906**	*.093*	*.038*	*.017*	*.023*
Household involvement in dry season farming	**.866**	*−.051*	*−.007*	*.022*	*.149*	*−.159*
Household received crop-climate advise	*.044*	*.103*	*.082*	***.708***	*.061*	*.001*
Household received credit	*.104*	*.107*	*−.102*	***.704***	*.016*	*−.015*
Age of household head	*−.148*	*−.037*	**−.792**	*−.020*	*.122*	*.007*
Sex of household head	*−.188*	*.041*	*.343*	*.265*	*−.182*	***.622***

Information from the literature and expert knowledge of the study area that supported the choice of high-loading variable that was retained as indicators for determining social vulnerability index are presented in Table 2

Bold italics High loading and selected an indicator

Bold High loading but dropped as an indicator

Italics Low-loading variables

4.2 Social vulnerability index due to demographic-related indicators

Sex, education and labour force constitute this group (Fig. 3). As regards the sex type of the household head, the SoVI for the three locations in the catchment is 0.15 (upper), 0.20 (mid) and 0.05 (lower). In the case of educational level, the SoVI is 0.84 (upper), 0.78 (mid) and 0.93 (lower). Concerning the household labour force, the SoVI is 0.50 (upper), 0.45 (mid) and 0.48 (lower). With respect to the sex of household heads and their educational levels, there was a statistical difference ($p < 0.05$) in the SoVI among the three locations. However, in terms of labour force, there was no statistical difference in their SoVI.

4.3 Social vulnerability index due to land-related indicators

Land area cultivated for traditional cereals, maize and dry season (irrigated) rice constitute this category (Fig. 4). With regard to the land area cultivated for traditional cereals, the SoVI is 0.71, 0.69 and 0.82 for upper, mid- and lower parts of the catchment, respectively. For land area cultivated for maize, the SoVI is 0.96 in the upper, 0.95 in mid and 0.91

Table 3 Justification for retaining some variables to serve as social vulnerability indicator

	Retained variable	Condition for retaining indicator
1	Land area cultivated for maize	Due to the availability of early maturing varieties, growing maize in the study area was identified as an adaptation strategy to climate change (Abarike et al. 2014). Hence, more land for maize farming could indicate better adaptive capacity
2	Income from maize cultivation	High income from maize farming is a sign of high yield. This could mean having better access to input. Input has been reported as one the adaptation constraint in the study area (Badmos et al. 2015b)
3	Land area cultivated in the dry season	Unlike rainy season, where most households farm for household use. Dry season farming is more of income generation. Therefore, access to land for dry season rice farming could indicate more income
4	Income from dry season rice	Access to more finance could imply that the household is secured in the period of stress, especially at the beginning of growing season where household depends solely on food stored
5	Educational level	Education plays considerable role in gaining access to information, resources and non-climate sensitive occupations which tend to minimize vulnerability (Dumenu and Obeng 2016)
6	Household received crop/climate advise	Majority of people in the study area obtain their livelihood from agriculture, particularly crop farming. The study area being a semi-arid environment implies that farming activities are exposed to climate change/variability. Therefore, households that have access to crop/climate advice are in better position to adapt well
7	Household received farm credit	Households with better access to farm credit are likely to better adapt to climate change because access to farm credit was reported as one of the key barriers for climate change adaptation in the study area (Badmos et al. 2015b)
8	Household labour force	Labour force in this study is represented as the ratio of people in the labour class (GSS 2012), to the total number of people in the household. Higher labour force is expected to translate to more productivity, which is expected to also translate to better adaptation
9	Household into off-farm activities	Households that have member(s) involved in off-farm activities are assumed that cope better in the period of climatic stress
10	Land area cultivated for traditional cereals	Stanturf et al. (2011) described millet (a traditional cereal crop) as the least risky crop with regard to climate-induced fluctuations in yield followed closely by sorghum (a traditional cereal crop). Therefore, households with better access to land for cultivating traditional cereals will cope better in the period climatic stress
11	Sex of household head	Inheritance in the study area is patrilinear. Hence, male are more favoured than female. For this reason, males have more tendencies to cope than females due to better access to land resource

lower part of the catchment. Concerning the land area cultivated for rice in the dry season, the SoVI is 1.00, 0.91 and 0.97 for upper, mid- and lower parts of the catchment, respectively. There was a statistical difference ($p < 0.05$) in the SoVI among the three locations with respect to land area cultivated for traditional cereals and irrigated rice. On the other hand, it was insignificant with respect to land area cultivated for maize.

4.4 Social vulnerability index due to income-related indicators

Income from maize cultivation, income from dry season rice and household involvement in off-farm activities make up this category (Fig. 5). For income from maize cultivation, the

Table 4 Weight of indicators used to estimate the social vulnerability index

#	Indicator name	Weight (%)
1	Land area cultivated for rice in the dry season	0.181
2	Household received credit	0.154
3	Sex of the household head	0.112
4	Land area cultivated for traditional cereals	0.099
5	Household received crop-climate advise	0.092
6	Member of household involved in off-farm activities	0.087
7	Educational level of household head	0.080
8	Labour force of household	0.074
9	Land area cultivated for maize	0.058
10	Income from maize crop farming	0.036
11	Income from dry season rice	0.027

SoVI for three locations in the catchment is 0.96 (upper), 0.93 (mid) and 0.91 (lower). Accordingly, 1.00, 0.90 and 0.98 are the SoVI as regards income from dry season rice cultivation in the upper, mid- and lower parts of the catchment. Concerning the household involvement in off-farm activities, the SoVI for the three identified locations within the catchment is 0.78 (upper), 0.65 (mid) and 0.57 (lower). There was a statistical difference ($p < 0.05$) in the SoVI among the three locations with respect to income from dry season rice and household involved in off farm, but insignificant for the income from maize farming.

4.5 Social vulnerability index due to climate change-related indicators

Access to climate/crop advice and access to credit make up this category (Fig. 6). With regard to the access to climate/crop advice, the SoVI is 0.76, 0.52 and 0.51 for upper, mid- and lower parts of the catchment, respectively. In terms of access to credit, the SoVI for the three locations within the catchment is 0.93 (upper), 0.96 (mid) and 0.91 (lower). There was a statistical difference ($p < 0.05$) in the social vulnerability among the three locations with respect to access to climate/crop advice, but, insignificant as regards access to credit.

4.6 Overall vulnerability

The SoVI to climate change in the three identified locations within the Vea catchment is shown in Fig. 7. The households in the upper part of the catchment show the highest social vulnerability to changing climate with a vulnerability index of 0.77, whereas those in the mid- and the lower part of the catchment show a social vulnerability index of 0.72 each. The overall social vulnerability index for the study area is 0.73.

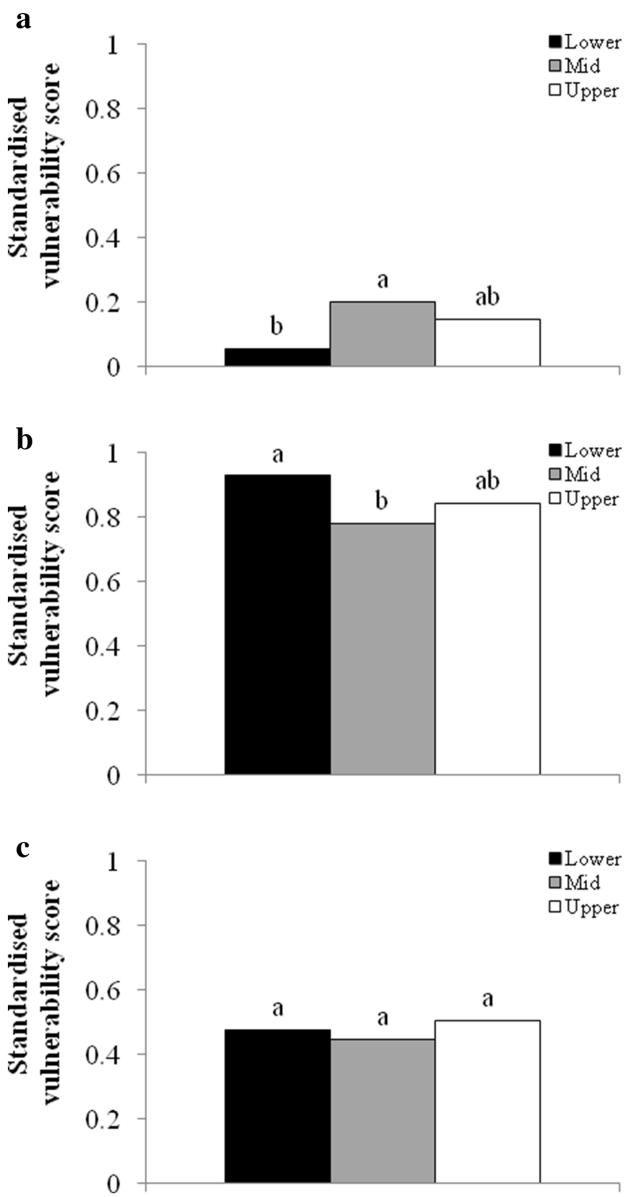


Fig. 3 **a** Social vulnerability score for the sex of household head, **b** social vulnerability score of education level of household head, **c** social vulnerability score for household's labour force. *Note*: *Bars* that do not share a *letter* are significantly different

5 Discussion

Vulnerability assessment is very important in reducing the impacts of climate change on connected human-environmental systems (Adger 2006). It assists in the development of appropriate responses by providing the fundamentals for judging the situation and the risk

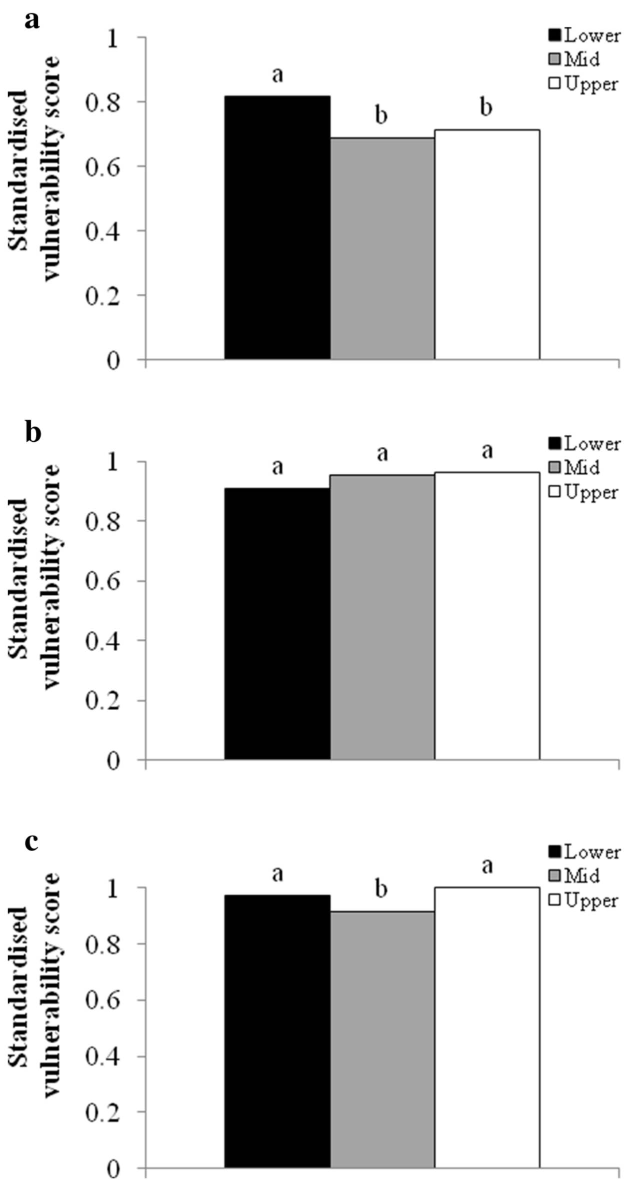


Fig. 4 **a** Social vulnerability score for land area cultivated for traditional cereals, **b** social vulnerability score for land area cultivated for maize, **c** social vulnerability score for land area cultivated for dry season rice. *Note*: *Bars* that do not share a *letter* are significantly different

level (Lyth and Holbrook 2015). The SoVI to climate change is estimated to be high (i.e. >0.70) across the study area. However, there are some significant patterns. With respect to land area cultivated for dry season rice, households in the upper catchment have social vulnerability score of "1" (Very high vulnerability). This could be associated with the fact that none of the surveyed households are into dry season rice farming. In connection to that, households in the upper catchment also have social vulnerability score of "1" for

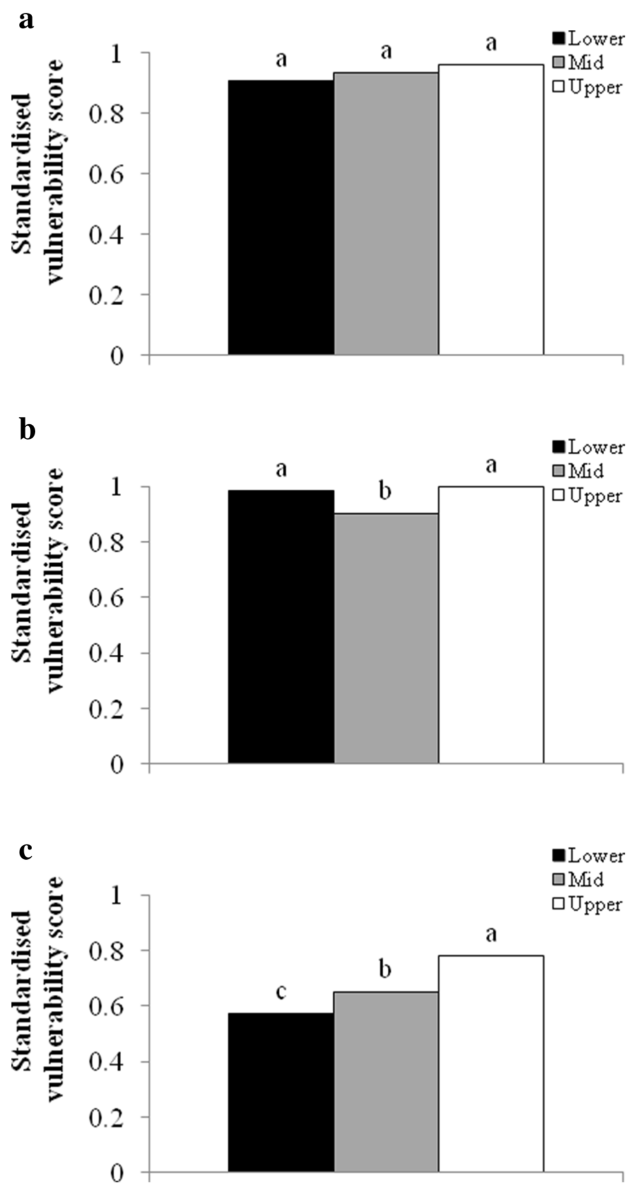


Fig. 5 **a** Social vulnerability score for household income from maize farming, **b** social vulnerability score for household income from dry season rice farming, **c** social vulnerability score for household involvement in off-farm activities. *Note*: *Bars* that do not share a *letter* are significantly different

income generated from dry season rice farming because of similar reason. The vulnerability score for the households in the mid-catchment with respect to dry season rice farming is high, but lower compared to other locations. This observation could be linked to the fact that the Vea irrigation project is at the central part of the Vea catchment. High vulnerability with respect to farm credit across the three locations is an indication that the households do

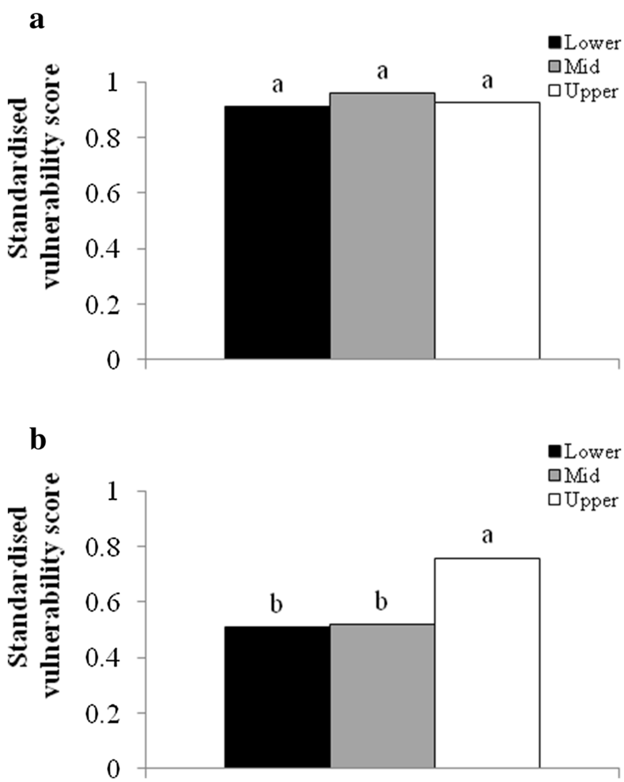
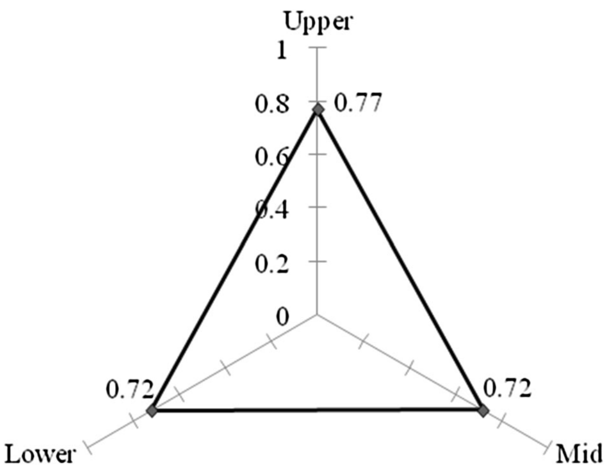


Fig. 6 **a** Social vulnerability score for household receipt of farm credit, **b** social vulnerability score for household receipt of crop-climate advice. *Note*: *Bars* that do not share a *letter* are significantly different

Fig. 7 Overall social vulnerability to climate change



not have adequate access to farm credit. This further affirms the findings of Badmos et al. (2015b), where finance was identified as a key barrier towards adapting to climate change in the study area.

Access to information has significant influence on farmers' ability to adapt well to climate change (Abid et al. 2016). This information could come from mass media, extension officers, researchers, NGO, etc. According to Murage et al. (2012), households that reside in the remote rural areas are usually far away from essential services, e.g. extension services. They are unable to access the precise type of service/information (Abdulai and Huffman 2005; Orikpe and Orikpe 2013) that will enhance their farming activities. Their distance to many services could be associated with the high vulnerability score observed for households in the upper catchment with an average distance of about 18 km from the region's capital almost double to what mid- and lower catchments have (an average of 8 km away from the capital).

Social vulnerability to climate change appears to increase towards north. In this study, all the surveyed households in the upper catchment are in the Bongo district and those in the lower catchment are in Bolgatanga district. Bongo district is higher north than Bolgatanga district, and we observed the social vulnerability index is higher for the upper parts compared to the lower part of the catchment. This finding also agrees with other studies in Ghana. In a countrywide social vulnerability assessment of Ghana to climate change, Stanturf et al. (2011) observed that Bongo district, which is further north, was more vulnerable than Bolgatanga. Similarly, Antwi-Agyei et al. (2012) observed that Ayelbia and Adaboya farming communities in the Upper East Region of Ghana that are slightly north of Vea community show higher social vulnerability to climate change as compared to the rest of the Vea community. Comparing the social vulnerability of four ecological zones in Ghana (semi-deciduous, forest–savanna transition, Guinea savanna and Sudan savanna) to climate change, Dumenu and Obeng (2016) noted that Sudan and Guinea savanna ecological zones that are northern were the most vulnerable.

6 Conclusion

The paper assessed the social vulnerability of three locations (upper, mid and lower) within the Vea catchment in semi-arid Northern Ghana. Based on the data collected from household survey, we identified variables that serve as indicators for the social vulnerability assessment, such as demographic-, land-, income- and climate change-related indicators. These indicators were standardized, and for each indicator, a social vulnerability index was determined. Subsequently, the indicators were weighted and used to estimate the overall social vulnerability towards changing climate in the three identified locations within the Vea catchment. Our findings show that the social vulnerability across the locations was significantly different in some cases and insignificant in others. The overall social vulnerability towards climate change in the three locations is high (>0.70). The upper part of the catchment has the highest social vulnerability score (0.77), whereas the mid- and lower parts have quite similar social vulnerability score of 0.72. The study re-emphasized that the Upper East Region of Ghana is vulnerable to climate change, though the vulnerability varies across location and across farm households. It is obvious that all the locations are in need of support to adapt properly to the impact of climate change. Policies that can help lessen the vulnerability of farm households to climate change should be put in place, such as policies on social protection, common access to fundamental services, and opportunities for alternate source of livelihood. Climate change adaptation policies should be in the forefront of our sustainable development policies. We also need to ensure that adaptation policies are not generalized because the support needed by people and community to adapt may vary. Importantly, we need to ensure that the policies will not increase their vulnerability in the future.

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