



Assessing vulnerability of horticultural smallholders' to climate variability in Ghana: applying the livelihood vulnerability approach

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Abstract

Changing climate is posing considerable threats to agriculture, the most vulnerable sector, and to smallholder farming systems, the predominant agricultural livelihood activity in Africa. Study of specific systems enables clearer and more effective responses to be directly targeted for enhanced adaptation, but there is limited knowledge guiding specific subsector vulnerability assessments. We applied the Livelihood Vulnerability Index to understand and identify the nature and sources of vulnerability among smallholder horticultural farming households to climate variability in two districts in Ghana. A total of 480 households engaging in fruit and vegetable crop production were surveyed in Keta and Nsawam districts of Ghana. Data were collected on indicators for Livelihood Vulnerability Index components such as socio-demographic profiles, livelihood strategies, social networking, health, food, production, water, natural disasters, and climate variability. The vulnerability-contributing factors were aggregated in a composite index and differences were compared. The results indicate that smallholder horticultural farmers in Keta are more vulnerable in relation to high exposure and high sensitivity to climate variability, while smallholders in Nsawam are more vulnerable in terms of low capacity to adapt to climate variability. As it is the case for smallholder horticultural farming communities, the study suggests that Livelihood Vulnerability Index can be broadly applied to highlight potential areas for intervention and reduce the vulnerability of sector-specific farming communities within local and national levels.

Keywords Climate variability · Vulnerability · Smallholders · Horticultural production · Livelihood Vulnerability Index (LVI) · Ghana

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1 Introduction

The latest Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) indicates widespread impacts from observed changing climate on all continents (IPCC 2014). The report highlights Africa's high exposure to climatic events coupled with low adaptive capacity making the continent as one of the most vulnerable regions. Agriculture is Africa's major economic sector (Challinor et al. 2007; OECD/FAO 2016), and it is also considered as the most vulnerable sector posing considerable threats to farming systems, particularly to smallholder farming systems (Rurinda et al. 2014). Smallholder farming systems support livelihoods and economic growth over most countries as they mainly constitute majority (about 80%) of all the farms in Africa (AGRA 2017) but are characterized by various climatic, demographic, and socioeconomic stresses limiting adaptive capacity (Morton 2007).

Further changes in climate is inevitable for Africa in the coming decades (IPCC 2013), and climate projections suggest likely increase in variability over the coming decade threatening food security in the sub-Saharan Africa (SSA) (OECD/FAO 2016). Impacts from changing climate differ among regions in SSA, subsectors, and from country to country (Adger et al. 2004). Western Africa is of particular concern since instability of total agricultural production since 2007 has been mainly through them (OECD/FAO 2016). For about 24 years, West Africa mainly accounts for the total value of outputs from agriculture (60%) within Africa (OECD/FAO 2016). West African countries including Ghana are also expected to strongly experience temperature increase and rainfall variability (Riede et al. 2016). Projections into the future reported in the AR5 over West Africa show increase in temperature between 3 and 6 °C and rise in rainfall variability (Riede et al. 2016). Ghana also came second after Ethiopia as the most exposed to climate-related hazards and its risks on the African continent (World Bank 2009). Expectedly, impacts from changing climate including floods and droughts will continue in Ghana and that incidence of events such as these would become more intense and frequent (Alley 2014).

A number of studies in Ghana have shown that impacts of climatic changes are already manifesting in response to increased temperatures and rainfall variability (Arndt et al. 2015; Anim-Kwapong and Frimpong 2005) as well as in response to rises in sea level (Stanturf et al. 2011). Consequently, various studies have indicated that change in climatic variability leads to significant negative effects on livelihoods and food resources particularly among subsistence and small-scale agricultural production which activities are mostly land and natural resources dependent (Laube et al. 2012; Fosu-Mensah et al. 2012). This increases vulnerability of people involved in such production systems through threatening lives, property, and livelihoods in the country. Assessing agricultural sector's vulnerability to changing climate is therefore essential as it defines risks posed by climate as well as provides information for identifying measures to adapt to the impacts (Fussel 2007; Preston et al. 2011). It further informs policy planning on climate risk reduction (Fussel and Klein 2006) and assists households to manage current climate variability by assessing their coping capacity (Notenbaert et al. 2013). As a first step toward preparing against increases in extreme events, understanding and assessing current vulnerability are considered a prerequisite (Adger 2003).

According to Chambers and Conway (1992), for sustainable living, vulnerability assessment ought to provide explicit indications required on capabilities, assets, and activities. Vulnerability research has developed in the last four decades and advanced from initial natural hazards discipline to encompass socio-ecological systems (SES) and sustainable

livelihoods framework (SLF) (Barsley et al. 2013). Sustainable livelihoods framework (SLF) is a common conceptual framework dominant in understanding livelihoods of resource-constrained individuals and their environment. It uses multiple indicators to assess households' exposure, sensitivity, and adaptive capacity to impacts from climate change (Chambers and Conway 1992). It has been employed by various scholars under distinctive contexts (Hahn et al. 2009; Gbetibouo et al. 2010; Antwi-Agyei et al. 2013). The Livelihood Vulnerability Index (LVI) by Hahn et al. (2009) provides an insightful way of assessing vulnerability at the community level using household-level data. It draws out critical differences in exposure, sensitivity to climate variability, and households' adaptive capacity to inform policy and strategic community-level planning in Mozambique, Southern Africa. Although it is generally recognized that assessing vulnerability of specific systems enables clearer and more effective responses to be directly targeted (Barsley et al. 2013), there are dearth of studies guiding specific subsector assessments. Understanding vulnerability of specific sector is essential to identify exposure, sensitivity, and adaptive capacity for guidance on "best-fit" adaptation options effective for improved production (Hinkel 2011). More so, given the context specificity from climate variability and change impacts, subsector-specific vulnerability analysis is needed for enhancing resilience of communities particularly smallholder livelihoods. Drawing on the LVI by Hahn et al. (2009), this study exploits applicability of the LVI to understand and identify the sources and nature of vulnerability to climate variability among smallholder horticultural households in two municipalities of Ghana.

Changing climate is reported to have direct implications on different aspects of horticultural production including challenging sustainable production and competitiveness due to the growing demands in the environment with declining land and water resulting in price hike for fruits and vegetable crops and/or reducing livelihood options for rural producers (Malhotra 2017). Williams et al. (2017) also showed consequences of climate variability on pineapple fruit quality and quantity during production in Ghana. High temperature AND limited and excess moisture stresses are the major causes of low yields in vegetables production (Malhotra 2017). Such climatic effects compound with other existing local stressors (economic and social wellbeing), including poor markets and weak institutional support, (Abdulai et al. 2017) to exacerbate the vulnerability of people involved in the production system. Meanwhile, domestic market for vegetable production in Ghana has been growing at more than 10% in recent times, and the potential value for vegetable export is estimated at US\$ 250 million with overall turnover of around US\$ 800 million (NAB Council 2014). Horticulture production provides income for smallholders' and creates household employment opportunities at the farm level (Abdulai et al. 2017). Proceeds from sales of fruits and vegetables also support farmers to access essential staples as food and other goods and services (OECD/FAO 2016).

Most studies done on vulnerability assessments of farming households in Ghana have so far focused on studying production systems of smallholders in general (Dumenu and Obeng 2016; Etwire et al. 2013) and major crops such as cereals (Antwi-Agyei et al. 2013) without adequate attention on horticultural production. More generally, vulnerability studies are not yet addressing fruit and vegetable producers and production areas. With little information on how vulnerable smallholder horticultural production systems' are to climate variability, this paper aims to evaluate and compare climate vulnerability of smallholder horticultural producers in two distinct districts in Ghana applying the LVI. Specifically, it looks at how exposed, sensitive, and the adaptive capacity of smallholder horticultural households are to changing climate; how applicable the LVI is in assessing sector-specific vulnerability assessments; and how the livelihood vulnerability approach provides insights

into future assessments and linkage to adaptation planning. Such contribution provides sector- and context-specific knowledge for improving production and informing local adaptation planning for resilience of horticultural producing communities in a changing environment.

1.1 Concept of Livelihood Vulnerability Index (LVI)

Sustainable livelihood framework (SLF) employed in conceptualizing vulnerability assessment is from IPCC which denotes vulnerability as exposure to natural disasters and climate variability; climate sensitivity to health, food, and water resource characteristics; and households’ socioeconomic characteristics that affect their adaptive capacity (Chambers and Conway 1992). Analyzing SLF is generally using either an econometric approach or an indicator approach (Gbetibouo et al. 2010). According to Gbetibouo et al. (2010), econometric approach is reported to indicate vulnerability of a given place but does not sufficiently capture the dimensionality of vulnerability. Indicator-based approach also captures the three dimensions of vulnerability in a comprehensible form though limited in subjectivity in selection of indicators for assessments (Adger et al. 2004; Bisaro et al. 2010). Most recent approaches combine diverse subcomponents (also referred as indicators) into a single composite index of vulnerability using primary data, to better characterize and quantify the multidimensionality of conditions studied (Shah et al. 2013).

Adapting the SLF, Hahn et al. (2009) developed an indicator-based LVI to provide understanding of the contributions of factors such as social, demographic, and physical as a practical tool to identify areas for possible interventions. The LVI uses household-level data combined with secondary data on climate exposures to capture differences in community-/district-level vulnerability into a single composite index of vulnerability (Hahn et al. 2009). LVI comprises seven major components, namely social networks, livelihood strategies, access to food, water, and health, socio-demographic profile as well as climate variability and natural disaster risks. We added “production” as a major component (Fig. 1). Production is considered due to the high perishability and susceptibility of horticultural crops to post harvest losses as well as pest and disease attacks, and allows to better capture the susceptibility of households’ production to climate variability. Details of indicators considered under the production component are shown in Table 2. We split up natural

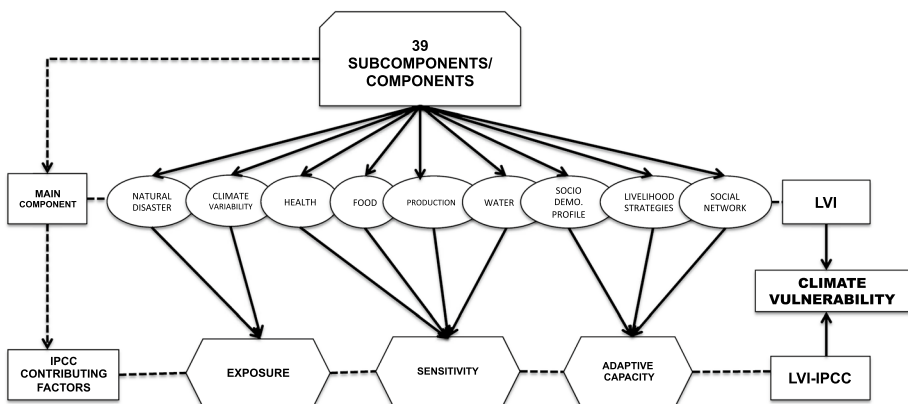


Fig. 1 Grouping of major and subcomponents/indicators into LVI and LVI-IPCC

disaster risks from climate variability components as each factor. We also included climate extreme indicators considered as relevant for the daily activities in the production of fruits and vegetables. A total of nine major components (instead of seven) were therefore used in this LVI evaluation of horticultural producing areas in Ghana (Fig. 1). Further connected to the LVI is the LVI–IPCC method developed by (Hahn et al. 2009) which is also used for calculating climate vulnerability based on categorization of the main components of LVI framework into IPCC vulnerability framework: exposure, sensitivity, and adaptive capacity as illustrated in Fig. 1. Same subcomponents used in the calculation of LVI are employed in the calculation of LVI–IPCC with divergence in the combination of the major components. That is, rather than computing the LVI by combining the major components in the initial step, they were firstly merged according to the three main IPCC categorizations: exposure, sensitivity, and adaptive capacity. Both methods estimate climate vulnerability. Scores from LVI–IPCC has however been noted to be used with caution, as could lead to counterintuitive results with LVI especially when greater value of adaptive capacity compared to the exposure factor and increased sensitivity actually reduces vulnerability (Panthi et al. 2016). Comparison of the IPCC contributing factors rather than the overall score is applied in this study.

2 Materials and methods

2.1 Study areas

The study was conducted with smallholder households primarily engaged in horticultural crop production in two geographical contexts: Nsawam Adoagyiri and Keta Municipalities in the Eastern and Volta regions of Ghana, respectively. The two municipalities are two of the main horticulture-producing areas in Ghana. Nsawam Adoagyiri is an inland area, at the Forest Deciduous agro-ecological zone, while Keta is a coastal area and found at the coastal savannah agro-ecological zone, allowing for some spatial comparative analysis. In addition, rural communities in Nsawam are subjected to considerable climate variability, in terms of both decreasing precipitation and increasing temperature (Williams et al. 2017). Coastal communities on the other hand are prone to droughts and/or coastal inundation and hence could be associated with experiencing climatic impacts (Shah et al. 2013; GSS 2014a).

Smallholders' dominate crop farming in both communities (about 80%). Production of fresh vegetables is strongly sensitive to weather in both areas, and use of irrigation in Ghana is increasing overall for seasonal fruit and vegetable crop production (NAB Council 2014). Summary of physical, climatic, and agricultural related characteristics for both study areas are described in Table 1.

2.2 Research design

Assessing vulnerability of a system should be pragmatically done by comparing different systems and identifying which components contributes more to vulnerability as well as pushes vulnerability levels. (Panthi et al. 2016). A system may be the population, geographic region, or human environment studied. Starting with a selection of climate vulnerability indicators extracted from the literature (indicated as existing in Table 2), we engaged with about 43 local stakeholders (subjectively by engaging smallholder farmers

Table 1 Physical, climatic, and agricultural characteristics of study areas. Source: (GSS 2014a, b)

Physical, climatic and agricultural characteristics	Study areas
	Keta
Location	Lies within longitude 0.30°E and 1.05°E and latitude 5.45°N and 6.005°N. It is about 160 km east from the national capital
Relief	Low-lying coastal plain
Climate	Dry coastal equatorial climate with coastal savannah vegetation
Mean annual rainfall range	800–1000 mm per annum
Mean temperature range	19–29 °C recorded in August and March respectively
Rainfall pattern	Bimodal: Two main peak periods between March–July and September–November
Major agricultural livelihood activities	About 68% of population engaged in crop farming. The second most engaged agricultural activity is livestock rearing followed by fishing
Key horticultural crops grown	Crops cultivated include okro, tomato, pepper, onions, spring onions, carrots, shallots, and watermelon
	Nsawam
Location	Lies within longitude 0.07°W and 0.27°W and latitude 5.45°N and 5.58°N. It is about 23 km south from the national capital
Relief	Undulating plain
Climate	Wet semi-equatorial climate with mainly semi-deciduous forest vegetation (90%) and coastal savanna grassland (10%)
Mean annual rainfall range	1250–2000 mm per annum
Mean temperature range	26–30 °C recorded in August and April respectively
Rainfall pattern	Bimodal: Two main peak periods between May–June and September–October
Major agricultural livelihood activities	About 60% of population engaged in crop farming. The second most engaged agricultural activity is livestock rearing followed by tree planting
Key horticultural crops grown	Crops cultivated include okro, tomatoes, pepper, onion, garden eggs cabbage, pineapple, and pawpaw

Table 2 Established LVI major and subcomponents for Keta and Nsawam Municipalities

Major component and Subcomponent	Status of indicator in LVI	Functional relationship of subcomponent with vulnerability
Socio-demographic profile		
Dependency ratio	Existing	The higher the number of dependents, the less capacity households can adapt. Higher percentages of socio-demographic profile indicators reflect less capacity of households to adapt and the higher the vulnerability
%Female-headed households	Existing	
%Household head who has not attended school	Existing	
Livelihood strategies		
%Households without member working outside community	Existing	Diversification of income sources increases adaptive capacity and decreases risk of losses. Therefore, higher values of indices reflect lower adaptive capacity hence lower vulnerability
Average agricultural Livelihood Diversification Index	Existing	
%Households with agriculture as only source of income	Existing	Access to information through communication devices improves individuals' awareness of impending hazard. The indicator was modified to inquire those with access to 3 basic devices. In Ghana, FBOs and social groups are distinct from each other but play significant roles within communities. Horticultural production in Ghana is capital-intensive therefore access to governments' subsidized input will enhance adaptive capacity of farmers. Social network indicators strengthen adaptive capacity of farmers but higher constraints of this lower vulnerability
%Households not rearing livestock	New	
Social network		
%Households not having communication devices	Modified	The longer the time to a health facility, the more families are ill or miss school/work, the more sensitive and less vulnerable. The indicators show how health impacts family and higher indices imply higher sensitivity
%Households not having access to government subsidy on production inputs	New	
%Households not associated with any farmer-based organization (FBO)	Modified	
Average borrow: lend ratio	Modified	The longer the time to a health facility, the more families are ill or miss school/work, the more sensitive and less vulnerable. The indicators show how health impacts family and higher indices imply higher sensitivity
%Household not associated with any community social group	New	
Health		
Average time to health facility	Existing	The longer the time to a health facility, the more families are ill or miss school/work, the more sensitive and less vulnerable. The indicators show how health impacts family and higher indices imply higher sensitivity
%Households with member having chronic illness	Existing	
%Households where a member missed work/school due to illness	Existing	

Table 2 (continued)

Major component and Subcomponent	Status of indicator in LVI	Functional relationship of subcomponent with vulnerability
Food		
%Households mainly dependent on family farm for food	Existing	Limited ability to save planting materials from preceding harvests reflects sensitivity of the earlier season to unfavorable production conditions including climate. The higher the indicators for food, the more sensitive households are and the higher the vulnerability
%Households that do not save planting materials	Modified	
Average number of months households struggle to get food	Existing	
Average Crop Diversity Index	Existing	
Production		
%Households that do not get information on improved production methods	New	Production components emphasize on some production conditions and outcomes reflecting sensitivity of impacts of climate on horticultural producers/productivity. Horticultural crop production is sensitive to climate, which mostly impact negatively on horticultural crop productivity. In this context, higher indices reflect vulnerability as inadequate information on Good Agricultural Practices. A higher percentage of production losses implies higher sensitivity. The greater demand from more irrigated land, shows potential for water scarcity for crop production purposes hence the higher the vulnerability
%Production output lost to post harvest losses	New	
%Production output lost to pests and diseases	New	
%Households' farm land under irrigation	Modified	
Water		
%Households that reported water conflicts	Existing	Time to water source was changed to measure distance from farmland to the water source for the purpose of this study. This adjustment was to show how distance to available water source determines the number of households that primarily uses irrigation (the longer the distance the more sensitivity). Overall, the higher percentages of indicators for water, the higher the sensitivity and more households are vulnerable
Average distance to water source	Modified	
%Households without consistent water supply	Existing	
%Households utilizing natural water source	Existing	
Natural disasters		
Average number of flood/drought events reported in the past 5 years	Modified	Indicators were modified from initial 6 years memory recall of events to 5 years to improve on potential recall bias noted by Hahn et al. (2009). Mainly, higher index values reflect higher exposure and increased vulnerability
%Households that did not receive warning about expected natural disasters/events	Modified	

Table 2 (continued)

Major component and Subcomponent	Status of indicator in LVI	Functional relationship of subcomponent with vulnerability
Climate variability		
Mean standard deviation of average monthly precipitation from 2007 to 2016	Existing	Higher variability implies higher exposure of all indicators under this component. According to Alexander et al. (2006), number of warm spells duration and very heavy precipitation are indices, which show the extent which most extremes events are changing within a period and have significant impact on livelihoods. For horticultural production, changes in such extreme events challenge sustainable production with detrimental impacts on livelihoods (McCarthy et al. 2001; Williams et al. 2017). Generally, the higher the frequency, the higher the exposure and vulnerability (Hahn et al. 2009; Shah et al. 2013; Panthi et al. 2016). The first three indicators were adapted from Hahn et al. (2009), the following three indicators were also adapted from Panthi et al. (2016) while the last two indicators are new indicators developed for the purposes of this study
Mean standard deviation of monthly average maximum temperature (T_{max}) from 2007 to 2016	Existing	
Mean standard deviation of monthly average minimum temperature (T_{min}) from 2007 to 2016	Existing	
Average number of consecutive dry days (CDD) from 2007 to 2016	Existing	
Average number of consecutive wet days (CWD) from 2007 to 2016	Existing	
Average number of warm days from 2007 to 2016	Existing	
Average number of cold nights from 2007 to 2016	Existing	
Average number of warm spells duration from 2007 to 2016	New	
Average number of very heavy precipitation from 2007 to 2016	New	

With the exception of indicators for climate variability component, data for evaluation of the subcomponents/indicators were obtained from respondents during the field survey. Climate variability indicators were computed from daily climate data from Ghana Meteorological Agency. Detailed description and explanation of the components and subcomponents can be found in online resource 1

and experts at Ministry of Food and Agriculture (MoFA) including agricultural extension agents at both study areas) to select the final set of vulnerability indicators. This inclusive and participatory approach applied during the assessment process is acknowledged to support awareness creation and improvement in the quality and relevance of the assessment data (Raemaekers and Sowman 2015; Tiani et al. 2015) addressing the challenge of indicator-based approach by reducing subjectivity in the selection process as earlier noted. The consultations resulted in the exclusion of some indicators commonly applied in the LVI framework (in literature), yet considered inappropriate in the Ghana smallholder horticulture context. For instance, existing indicators such as percent of households with orphans; average Malaria Exposure and Prevention Index; average receive and give ratio; percent of households that have not gone to their local government for assistance in the past 12 months; percent of households that do not save crops; inverse of the average number of liters of water stored per household and percent of households with an injury or death as a result of the most severe natural disaster in the past 6 years, were considered not relevant in the local context studied and were removed. Other indicators were included (indicated “New” under status of indicator in Table 2) to translate relevant and applicable components and subcomponents. While applying the LVI approach, our study includes substantial modifications (indicated “Modified” under status of indicator in Table 2) toward better operationalization of vulnerability in Ghana. The remaining indicators (indicated “Existing” under status of indicator in Table 2) were adopted directly from the literature.

2.3 Data collection

We conducted data collection for this study in three steps. It started with a reconnaissance visit to each of the municipality's in order to introduce the purpose of the research and seek approval to visit communities within the municipalities. During the visit, local stakeholders were engaged in a workshop for the selection of the final indicators used for the study as explained in Sect. 2.4. Following the reconnaissance survey, we pretested the survey instrument (to improve clarity and applicability of the questions) followed by the main household survey. Data from primary and secondary sources were employed. Primary data were obtained using field survey conducted between October and November 2017 in both study areas in Ghana for original empirical data on all the major components and their indicators except climate variability component. Secondary data on climate from the nearest meteorological station in each municipality (daily precipitation, minimum and maximum temperatures between 2007 and 2016) received from the Ghana Meteorological Agency constituted data for climate variability component of the LVI. Mixed-method approaches using structured questionnaire as well as participatory methods such as stakeholders' workshop, Key Informant Interviews (KIIs), and transect walks through study communities, were employed in the primary data collection process. We first selected four key fruit- and vegetable-cropping areas (named “agricultural operational areas”) affected by climate change and used a multiple stage sampling method to select communities and households. Without exhaustive access to population of smallholder households in identified areas, and in consultation with the Agricultural Extension Agents (AEAs) to ensure thorough representation of communities, we subsequently selected randomly three communities from each agricultural operational area making a total of 12 communities from each municipality. With consideration for availability and willingness of household heads to respond to survey, we randomly selected and interviewed approximately 20 households from each community. We surveyed a total number of 480 smallholder households (60 households in

every four agricultural operational areas, in both municipalities). Culturally, even though males are mostly considered as head of a household in Ghana, women were considered as heads and interviewed when widowed, single, or male partner was absent for six or more months per year (staying outside the community). Interviews were mainly conducted in Ghanaian local languages (Twi and Ewe) with local interpretations where required. Data were coded and analysis was done using SPSS 20.0.

2.4 Data analysis

2.4.1 Climate variability analysis

The climate variability component of the LVI was computed using daily temperature and precipitation. Indices were calculated using RCLimindex software before being collated for standardization in the LVI. Temperature and precipitation indices were measured to reflect aspects of changing climate such as changes in intensity, frequency, and/or duration of climatic events (Alexander et al. 2006). We computed absolute indices (e.g., mean annual rainfall; mean annual minimum and maximum temperatures), duration indices (e.g., warm spell duration; number of consecutive dry and wet days), and extreme percentile-based indices (e.g., number of cold nights and number of warm days and extremely wet days). This analysis allows evaluating the extent to which temperature and precipitation are changing under the climate variability component of the LVI. It was assumed the higher the rate of change of those climate indicators, the higher the households exposure to climate variability and extremes will be. Exposure to climate variability is assumed to be of equal amplitude within a municipality (relatively small spatial spread); hence vulnerability variations within a municipality are mainly as a result of variations in climate sensitivity and adaptive capacity.

2.4.2 Calculating LVI

The evaluation of the LVI relies on the equal weighting of major components (Hahn et al. 2009). Since the subcomponents/indicators were measured on different units, the range of minimum to maximum value standardized them into a single index for comparability. This approach has been similarly applied under different contexts in resource-poor settings and considered accessible, simple, and appropriate in the estimation of standardized indices and was adopted (Shah et al. 2013; Madhuri et al. 2014). Following standardization of all indicators, averaging the standardized scores of related indicators for each main component created the index for each major component. The scores were subsequently averaged using Eq. 1. A combination of the weighted averages for all major components ensures equal contribution of the main components to the overall LVI (Sullivan et al. 2002). The applicable scale was 0 (least vulnerable) to 0.5 (most vulnerable).

$$LVI_r = \frac{w_{SDP}SDP_r + w_{LS}LS_r + w_{SN}SN_r + w_HH_r + w_FF_r + w_PP_r + w_WW_r + w_{ND}ND_r + w_{CV}CV_r}{w_{SDP} + w_{LS} + w_{SN} + w_H + w_F + w_P + w_W + w_{ND} + w_{CV}} \quad (1)$$

where LVI_r is the Livelihood Vulnerability Index for municipal r . This equals the average of the nine major components (socio-demographic profile (SDP), livelihood strategies (LS), social networks (SN), health (H), food (F), production (P), water (W), natural disasters (ND), or climate variability (CV)), each weighted by their number of subcomponents.

2.4.3 Calculating LVI–IPCC

Based on IPCC's definition, climate vulnerability was described as a function of a household's exposure, sensitivity, and adaptive capacity to climate (Fig. 1). Changing events under climate variability and natural disaster occurrences was used in the estimation of exposure in the study areas. Sensitivity was estimated by a municipality's current state of health, food, production, and water status. Adaptive capacity was also estimated by the socio-demographic profile, types of livelihood strategies employed, and the strength of social network of surveyed households in relation to the study districts. Factors corresponding to the previously standardized indicators and weighted LVI main components earlier estimated were applied in populate the LVI–IPCC measures as illustrated in Fig. 1. Finally, climate vulnerability was calculated using estimations of the scores for the three contributing factors (exposure, sensitivity, and adaptive capacity) based on Eq. 2 as applied by other studies (Hahn et al. 2009; Shah et al. 2013). The applicable scale for the LVI–IPCC was from -1 (least vulnerable) to $+1$ (most vulnerable).

$$\text{LVI} - \text{IPCC} = (\text{Exposure} - \text{Adaptive Capacity}) * \text{Sensitivity} \quad (2)$$

3 Results

3.1 Livelihood Vulnerability Index (LVI)

Generally, the results of aggregate scores presented in Table 3 indicate that Keta had a higher LVI (0.395) than Nsawam (0.378). Overall, smallholder horticultural production in both municipalities shows a relatively higher vulnerability to climate variability, but in contrast to smallholder horticultural producers in Nsawam, Keta may be more vulnerable to overall climate variability (Table 3). In distinguishing the different components of vulnerability, the LVI major components show Keta is more vulnerable in terms of health, food, production, and natural disaster, while Nsawam is more vulnerable in socio-demographic profile, social network, livelihood strategies, water accessibility, and climate variability. The highest levels of vulnerability (score > 0.5) were exhibited in 11 indicators/subcomponents for Keta eight indicators/subcomponents for Nsawam (Table 3).

3.2 IPCC-LVI results for Keta and Nsawam Municipalities

Results for the overall LVI–IPCC scores (using groupings of the subcomponents as shown in Fig. 1) suggest that, on a scale of -1 to 1 , horticultural smallholder producers in both Keta and Nsawam shared an almost similar degree of vulnerability though Keta households (-0.010) are marginally more vulnerable than Nsawam households (-0.021). This finding is also consistent with scores from the LVI as Keta was more vulnerable than Nsawam. In comparing the level of contribution from the three vulnerability-contributing factors, as depicted in Fig. 2, Keta is the most exposed (0.391) and most sensitive (0.379) horticulture-producing municipality to climate impacts compared to Nsawam's exposure (0.372) and sensitivity (0.339). This resulted from mostly exposure to natural disasters and high sensitivity to food availability (Fig. 2). In terms of

Table 3 LVI results for Keta and Nsawam municipalities

Subcomponent/unit	Keta		Nsawam		Max. value in study areas	Min. value in study areas
	Actual value	Standardized	Actual value	Standardized		
Socio-demographic profile						
Dependency ratio/ratio	0.911	0.129	0.844	0.154	5	0
%Female-headed households/%	10.4	0.182	11.7	0.169	100	0
%Household head who has not attended school/%	10	0.104	17.5	0.117	100	0
Livelihood Strategies						
%Households without member working outside community/%	58.8	0.485	64.2	0.175	100	0
Average agricultural Livelihood Diversification Index – 1/number of livelihoods	0.505	0.588	0.522	0.493	100	0
%Households with agriculture as only source of income/%	54.2	0.261	63.8	0.638	100	0
%Households not rearing livestock/%	55	0.542	40.4	0.404	100	0
Social network						
%Households not having communication devices/%	49.2	0.538	62.9	0.554	100	0
%Households not having access to government subsidy on production inputs/%	21.3	0.492	46.3	0.629	100	0
%Households not associated with any farmer-based organization (FBO)/%	57.9	0.213	44.2	0.463	100	0
Average borrow/lend ratio	0.975	0.579	0.935	0.442	2	0
%Household not associated with any community social group/%	91.7	0.488	76.7	0.468	100	0
Health						
Average time to health facility/minutes	34.79	0.917	30.87	0.767	140	0.5
%Households with member having chronic illness/%	45.1	0.339	47.6	0.218	100	0
%Households where a member missed work/school due to illness/%	32.1	0.451	22.5	0.476	100	0
Food						
%Households mainly dependent on family farm for food/%	92.5	0.321	89.2	0.225	100	0
%Households that do not save planting materials/%	58.3	0.513	27.9	0.467	100	0
Average number of months households struggle to get food/Months	4.9	0.925	3.73	0.279	12	1
Average Crop Diversity Index – 1/number of crops	0.229	0.583	0.316	0.248	0.5	0.167

Table 3 (continued)

Subcomponent/unit	Keta		Nsawam		Max. value in study areas	Min. value in study areas
	Actual value	Standardized	Actual value	Standardized		
Production		0.478		0.244		
%Households that do not get information on improved production methods/%	51.7	0.517	14.2	0.142	100	0
%Production output lost to post harvest losses/%	10.84	0.155	12.18	0.174	100	0
%Production output lost to pests and diseases/%	27.37	0.304	17.84	0.198	100	0
%Households' farm land under irrigation/Percent	93.59	0.936	46.33	0.463	100	0
Water		0.178		0.329		
%Households that reported water conflicts/%	2.1	0.021	18.8	0.188	100	0
Average distance to water source/Km	0.32	0.040	1.45	0.181	8	0
%Households without consistent water supply/%	35	0.350	81.7	0.817	100	0
%Households utilizing natural water source/%	30	0.300	13	0.130	100	0
Natural disasters		0.604		0.411		
Average number of flood/drought events reported in the past 5 years/Count	4.3	0.478	1.7	0.189	9	0
%Households that did not receive warning about expected natural disasters/events%	72.9	0.729	63.3	0.633	100	0
Climate variability		0.344		0.368		
Mean standard deviation of average monthly precipitation from 2007 to 2016/mm	63.062	0.375	69.579	0.493	97.67	42.27
Mean standard deviation of monthly average maximum temperature (T_{max}) from 2007 to 2016/ $^{\circ}C$	1.953	0.401	2.041	0.496	2.51	1.58
Mean standard deviation of monthly average minimum temperature (T_{min}) from 2007 to 2016/ $^{\circ}C$	0.959	0.366	1.031	0.439	1.58	0.60
Average number of consecutive dry days (CDD) from 2007 to 2016/days	48.60	0.346	40.80	0.244	99	22
Average number of consecutive wet days (CWD) from 2007 to 2016/days	3.90	0.180	4.90	0.380	8	3
Average number of warm days from 2007 to 2016/days	12.832	0.376	6.205	0.166	32.60	0.94
Average number of cold nights from 2007 to 2016/days	7.224	0.556	5.980	0.412	11.20	2.24

Table 3 (continued)

Subcomponent/unit	Keta		Nsawam		Max. value in study areas	Min. value in study areas
	Actual value	Standardized	Actual value	Standardized		
Average number of warm spells duration from 2007 to 2016/days	4.20	0.200	1.20	0.006	21	0
Average number of very heavy precipitation from 2007 to 2016/count	15.50	0.292	19.60	0.633	24	12
LVI		0.395		0.378		

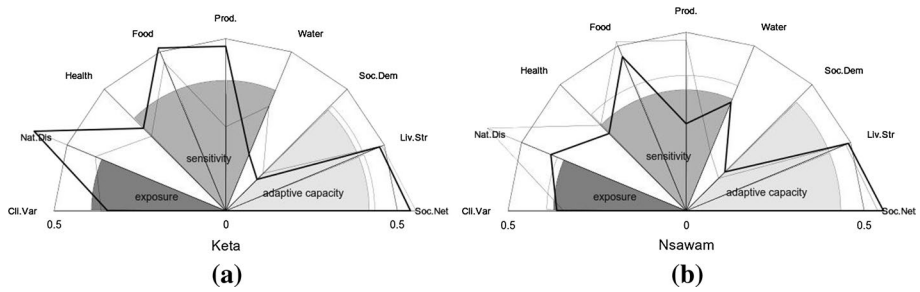


Fig. 2 Diagram showing the LVI major components and the vulnerability-contributing factors of the IPCC (LVI–IPCC). **a** for Keta; **b** for Nsawam. Note: 0=least vulnerable/less contributing factor; 0.5=most vulnerable/highly contributing factor **a** shows Keta is more vulnerable in terms of health, food, production, and natural disaster, while **b** shows Nsawam is more vulnerable in socio-demographic profile, livelihood strategies, social network, water accessibility, and climate variability. The highest levels of vulnerability (score > 0.5) were exhibited for natural disasters (0.604) and food availability (0.512) for Keta and for social networking with scores of 0.554 and 0.5338 in Nsawam and Keta respectively

adaptive capacity, Nsawam has less adaptive capacity (0.434) to climate vulnerability compared to Keta (0.418), which is mainly as a result of weak social network and livelihood strategies (Fig. 2). Detailed results for corresponding indicators for the IPCC-LVI are given in Online Resource 1.

4 Discussion

4.1 Exposure

Findings from the main components and subcomponents (indicators) revealed Keta is more exposed to natural disasters compared to Nsawam. Keta has a higher exposure value as a result of significant extreme climatic events. Coastal areas climatic exposures are often greater and considered hotspots of vulnerability (Wolters and Kuenzer 2015). Our finding concurs with other studies where vulnerability of coastal and inland areas were compared (Shah et al. 2013). Specifically, Keta has been more exposed to occurrence of natural disasters in last 5 years, while over the past decade, number of consecutive dry days (CDD), average number of warm days, warm spells, and cold nights all increased. Such extreme climatic events often relate with occurrences such as droughts in addition to coastal erosion. Most smallholder farmers are particularly exposed to natural disasters due to the lack of prior warning, which is a worrying situation. Frequent drying up of natural water bodies resulting in salt intrusion from seawater with subsequent effect on the quality of fruits obtained from fields and crops that suffer from such occurrences is prevalent in Keta. Although Nsawam is an inland area, it is also exposed to climatic variability, and households mainly do not receive prior information about impending natural events. Increased climate variability, particularly dry spells with increasing temperatures, has negative impact on horticultural crop productivity (McCarthy et al. 2001). Untimely rains results in drought stress and/or high temperatures during crop development stages (flowering and fruit growth), that declines yield and causes physiological disorders in fruit and vegetable crops. Furthermore, increased rainfall variability together with rising temperatures reduces soil moisture availability amid high risk of crop failure (Rurinda et al. 2014). Since smallholder farmers

in both municipalities mainly crop throughout the year with intermittent irrigation support whenever available, the exposure to natural disaster and climatic variation on crops and, consequently on food security, is great and could further increase with projected future increase in climate variability. This is important for horticultural production in both areas as climate extremes coinciding with critical crop growth stages are detrimental and more likely through the production year.

4.2 Sensitivity

Accounting for health, food, production, and water components in both municipalities, smallholder households in Keta are more sensitive to climate than Nsawam. Smallholders' in Keta are more sensitive to current health, food, and largely more sensitive to production conditions, while households in Nsawam are largely more sensitive to prevailing water conditions in the municipality. Higher sensitivity score for health status in the municipalities mainly arises from prevalence of illness. According to farmers, horticultural production is labor-intensive relatively to other crops hence health is particularly important as it relates to labor availability for crop production. Particularly, resource-constrained smallholders depend on family support to complement labor on family farms.

Indicators such as inability of households to save planting materials and low crop diversity impact negatively the food component and consequently affect both municipalities' sensitivity. Availability of planting materials from preceding harvests could save cost of planting for subsequent production seasons. It could also be sold or bartered (as families mostly rely on family farm for food) to economically support other production activities or other family needs. Diversification of crops grown, on the other hand, could reduce risk of production losses during periods of extreme climatic events as different crop types respond differently to different climatic conditions (Malhotra 2017). Dedicated education and promotion of those interventions to farmers could already reduce food vulnerability in Keta and Nsawam.

Nsawam is relatively less sensitive to production conditions. In contrast, production conditions in Keta heighten the vulnerability score. Water use for irrigation during dry spells resulted in reduced quality from increased salinity and increased risk of production losses through higher susceptibility to pest and disease affecting product quality and resulting in low market prices. While production losses is already attributed to pest and disease, their sensitivity to climate variability through limited effect of irrigation in Keta encourages the call for production and dissemination of improved techniques toward better climate variability management. Yet, farmers in Keta have limited access to such information while predominantly relying on irrigation. Active involvement of agricultural extension services in the municipality is therefore required.

Nsawam's sensitivity is affected by irrigation since most households cannot access consistent water supply. Distance of farmland to water sources is three times farther relatively to Keta; meanwhile, that distance largely determines the cost and ability of farmers to irrigate. While farmlands in Keta commonly had traditional (hand-dug) wells on site, farmlands in Nsawam depended on nearest rivers and streams as source of water for irrigation. While irrigation directly minimizes impacts of climatic stresses such as droughts, smallholder horticultural producers in both municipalities are at increased risk of water unavailability due to dependence on natural water sources, which in addition are becoming more unpredictable and unreliable with changing climate. Alternative sourcing of water such as rainwater harvesting or alternative water storage and management practices such as

building ponds or digging wells/borehole (especially in Nsawam), or drip irrigation (especially in Keta) could decrease sensitivity and in some extent vulnerability of cropping systems during dry periods in both municipalities.

4.3 Adaptive capacity

It is critical to enhance the capacity of smallholder horticultural farmers to adapt to changing climate. The findings suggest that, comparatively, Nsawam is less adaptive than Keta. Indicators such as number of female-headed households, dependency ratio, and number of household heads that have not attended school contribute to a relatively low socio-demographic profile in both municipalities. Education increases households' willingness to adopt new agricultural technologies to better cope with negative climate variability and has a positive impact on the farm productivity overall (Lin 1991; Leichenko and O'Brien 2002). With higher literacy rate and lower family dependency, adaptive capacity increases and farmers are more likely to positively cope/adapt to changing climate in both municipalities.

Livelihood strategies and social network had high vulnerability scores, which is critical as they reduce households' capacity in averting climatic risks. Not many farmers engage with livestock rearing, the second most important agricultural livelihood activity after crop farming in both areas. A community is considered more vulnerable if there is too few options in terms of livelihood diversification (Antwi-Agyei et al. 2013). According to the farmers, horticulture production is an intensive production activity demanding relatively more resources and explains a lower capacity to diversify but depend on their horticultural production as major livelihood and income source. This implies farmers hardly can cope with short-term impact on their income. Livelihood stability for households in the study areas is therefore critical especially in the face of changing climate. Additional non-farm livelihoods are suggested to spread the risks from climate threats on farming households.

In both municipalities, the majority of smallholder horticultural producers do not possess basic communication devices (radio, television, and mobile phone) with direct impact on social network scores as they strongly limit access to crop- and weather-related information. It decreases the ability of farmers to plan for any impending climate risk. Additionally, most farmers in both municipalities are not actively associating with farmer-based organizations (FBOs) and other social groups at the local level further limiting access to crop and weather information. Smallholder farmers in Nsawam were better connected with FBOs and other communities showing a higher social capital than Keta. Social capital improves financial support, access to market, information accessibility as well as agricultural technical support and access to formal government structures (Eakin and Bojórquez-Tapia 2008). Furthermore, built trust among such associations is important in positively influencing adoption rate of technologies or adaptation strategies through information dissemination and trials by proximity within the groups (Thomas et al. 2005).

Farmers in Keta have better access to government subsidies on production inputs, especially fertilizer. This may be related to a low-lying coastal plain with poor soil conditions (sandy) characterizing Keta, which is considered less conducive. Nevertheless, Nsawam has undulating land surfaces, and farming equally puts soil conditions at risk of reduced fertility. Subsidized inputs generally enable farmers to reduce production costs, reducing financial burden and in effect increasing adaptive capacity of households. Farmers in both areas acknowledged government support for their production activities through subsidizing inputs, yet this is very limited. Adaptive capacity of farmers would benefit from further

governmental, non-governmental, and other institutional support for a horticultural production, which is relatively capital-intensive.

4.4 Implications of findings

Vulnerability scores for the various components provide direction for recommendation into implementation of both collective and area-specific strategies that could be developed to cope/adapt to climate variability to reduce vulnerability. For instance, Nsawam could benefit from alternative water sources such as ponds, wells, and boreholes to supplement irrigation, while Keta requires water management practices such as drip irrigation to efficiently manage its available water. Overall, both municipalities need district-level project planning to consider providing alternative water sources such as harvesting rainwater at the governance level to effectively manage and supplement irrigation and as solution to water problems. Smallholder horticultural households in Nsawam further require government and other institutional support in relation to further subsidizing production inputs for enhanced productivity. At the farmer level, encouraging interactions and participation of smallholder farmers in FBOs and other community social groups is important in for dealing with emergency situations, adapting to climate variability and handling crises due to changing climate in both municipalities. Farmers may also be introduced to agricultural insurance to reduce and guard against adverse climatic losses. Though this is not practiced among the horticultural producers and also not commonly applied in Ghana, it could be considered as an important means of reducing climate sensitivity related risk and vulnerability during crop production. With fairly good socioeconomic conditions in both municipalities, sensitization and education of smallholder farmers would further build adaptive capacity to cope with and adapt to changing climate in future. At institutional level, micro-finance schemes could be introduced to help farmers through livelihood diversification in terms of both agricultural and supplemental non-agricultural diversification options with the potential to reduce vulnerability in both municipalities. Both areas would benefit from climate disaster early warning systems and education programs to enhance adaptation planning. This includes improved dissemination and accessibility to reliable climate information such as seasonal forecasts to enhance preparedness against extreme weather events. At research level, further investigation into the identification of adaptation options suited to smallholder horticultural producers, particularly in terms of implementation profitability, is recommended. The integration of an economic analysis into the vulnerability framework would provide empirical evidence in direct support of investment and development initiatives responding to a changing climate, in guiding policy recommendations to promote climate adaptation and in providing farmers with critical profitability estimation given their limited resources.

5 Conclusions

This study applied the Livelihood Vulnerability Index (LVI) and IPCC-LVI in the context of smallholder horticultural production in Ghana. Both LVI and IPCC-LVI indicate that smallholder farmers in Keta, a coastal area in Ghana, is more vulnerable to climate variability compared to smallholder farmers in Nsawam, an inland area. Overall, while Keta is more exposed and sensitive to climatic impacts, Nsawam has less adaptive capacity. High exposure was mainly attributed to occurrence of natural disaster and climate variability

with limited prior warning. Inadequate family labor, low crop diversity, insufficient planting material or distance, and limited water sources translate into high vulnerability scores for the health, food, production, and water components in both municipalities. Weak social networking and unstable livelihoods resulted in lower adaptive capacity mainly for Nsawam. Cognizant of a range of options that would reduce sensitivity and/or increase adaptive capacity, identifying the most suitable for smallholder farmers, particularly in the light of limited financial resources, can certainly benefit from the dedicated integration of an economic assessment as part of the vulnerability assessment framework.

Overall, our study builds upon the LVI and IPCC-LVI developed by Hahn et al. (2009) through the revision of some indicators (developing new and modifying indicators incorporated as credible local contextual factors) further reflecting multidimensional realities of vulnerability in Ghana, and critical for uptake at different localities. It presents a range of indicators, which can be used in other settings. The study on horticultural producers also contributes to the understanding of sector-specific vulnerability, relying on a rigorous and replicable approach to studies in other geographical and sectoral settings. The study also contributes to addressing the critique of indicator-based approach studies, which is considered lacking due to subjectivity in the selection of indicators by literature. We employed a literature review together with stakeholder validation in framing and designing indicators representing various components of the LVI to improve robustness of indicator selection. This additionally contributes to a consistently framed vulnerability assessment making it reflective of smallholder producers in Africa. Beside identification of vulnerable people and places, the study further provides adequate understanding, information, and practical guidance to support decision-making on adaptation as expected of vulnerability assessments.

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