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Keywords

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The purpose of this quantitative study was to examine agricultural livelihood vulnerability to climate change in Bluefields, Westmoreland, Jamaica based on the Livelihoods Vulnerability Index (LVI). Random sampling was used to select participants. Personal interviews were conducted with farmers using an instrument consisting of LVI components representing livelihood strategies, natural and physical assets, socio-demographic profile, social networks, water issues, food issues, natural disasters, and climate variability. LVI data were aggregated using an indexing approach to create scores for comparison across vulnerability components. The results showed farmers in Bluefields had the most amount of vulnerability in social networks and water issues. Low numbers of farmers owned their land, had contact with extension services, or used irrigation. Most farmers reported having problems with access to seeds and planting material, depended on their farms for food, and experienced frequent crop failure. Development organizations and local change agents should target the areas of greatest vulnerability illuminated by this study. Vulnerability and its contributing factors of exposure, sensitivity, and adaptive capacity, should be reassessed with the LVI and other methods to monitor changes in Bluefields over time. Implications for extension educators to assist subsistence farmers in understanding better the effects of climate change are noted.

Keywords: Agricultural livelihood vulnerabilities; climate change; Jamaica

Introduction

Adaptation is a response meant to reduce vulnerability (Smit & Wandel, 2006). Vulnerability is defined as “the degree to which a system or unit (such as a human group or place) is likely to experience harm due to exposure to perturbations or stresses” (Kasperson, Kasperson, Turner, Hsieh, & Schiller, 2005, p. 249). This definition encompasses the internal and external components of vulnerability expressed by the Intergovernmental Panel on Climate Change (IPCC) and represented elsewhere in the literature (Brooks, 2003; Chambers, 1989; Turner et al., 2003). The IPCC definition of vulnerability includes the internal component *adaptive capacity* as well as external components *exposure* and *sensitivity* (McCarthy, Canziani, Leary, Dokken, & White, 2001). Climate change vulnerability assessments recently incorporated these IPCC vulnerability components (Hahn, Riederer, & Foster, 2009; Shah, Dulal, Johnson, & Baptiste, 2013).

The ability of persons, regions, or systems to adjust to potential disturbances, capitalize on opportunities, or respond to effects of climate change defines *adaptive capacity* (Ebi, Kovats, & Menne, 2006). *Exposure* and *sensitivity* are viewed as interrelated factors of vulnerability (Reid, Smit, Caldwell, & Belliveau, 2007; Smit & Wandel, 2006). Smit and Wandel posed exposure and sensitivity as the “conditions or risks a community may be facing” (p. 289). Kasperson et al. (2005) defined exposure as “the contact between a system and a perturbation or stress” (p. 253). Sensitivity is explained as “the extent to which a system or its components is likely to experience harm, and the magnitude of that harm, due to exposure to perturbations or stresses” (Kasperson et al., 2005, p. 253).

Studies by Campbell et al. (2011) and Gamble et al. (2010) explained adaptive capacity components of vulnerability such as coping and adaptation strategies of farmers in St. Elizabeth, Jamaica. Campbell et al. (2011) paraphrased the coping strategies identified as planting methods, moisture-loss reduction, during-drought mitigation, and recovery. Farmers who employed these coping strategies were considered more resilient. However, coping strategies serve a specific population’s response to their problems, whereas adaptive capacity creates strategies and policies with the potential to address future climate changes (Ebi et al., 2006).

Several studies assessed the vulnerability of systems to climate change (Füssel & Klein, 2006; McCarthy et al., 2001). These studies are important because vulnerability must be understood before planned adaptation is undertaken (Smit & Wandel, 2006). Turner et al. (2003) offered a comprehensive framework that presented vulnerability as a function of many human and environmental factors in a complex system of different processes and scales. Given this complexity, Smit and Wandel developed a participatory assessment approach as a mode for identifying functional adaptation strategies at the community level. With this approach, researchers used qualitative techniques to identify risks, how they were managed, and what limited participants’ abilities to choose. Furthermore, effective solutions for adapting to climate change must be community-based (Beckford, Barker, & Bailey, 2007). Another approach, implemented by Hahn et al. (2009), quantified components of exposure, sensitivity, and adaptive capacity using a Livelihoods Vulnerability Index (LVI). Hahn et al. posited that generating more primary vulnerability data at the community-level was beneficial for policymakers and climate change adaptation research. Community level data helps monitor vulnerability in data-scarce regions by introducing scenarios into the LVI model for baseline comparison. It can be used to assess program resources for assistance and/or evaluate potential program/policy effectiveness (Hahn et al., 2009).

This study employed the quantitative LVI approach, as adapted by Hahn et al. (2009). Many authors (Campbell, 2014; Can, Tu, & Hoanh, 2013; Etwire, Al-Hassan, Kuwornu, & Osei-Owusu, 2013; Panthi et al., 2016; Shah et al., 2013) have adapted the LVI approach to assess vulnerability in limited resource settings. The LVI is a pragmatic approach to monitor vulnerability in data-scarce regions and provide baselines for comparison between communities and changes over time (Hahn et al., 2009). The LVI approach "uses multiple indicators to assess exposure to natural disasters and climate variability, social and economic characteristics of households that affect their adaptive capacity, and current health, food, and water resource characteristics that determine their sensitivity to climate change impacts" (Hahn et al., 2009, p. 75). The primary components in the original LVI were (a) socio-demographic profile, (b) livelihood strategies, (c) health, (d) social networks, (e) food, (f) water, and (g) natural disasters and climate variability (Hahn et al., 2009). Hahn et al. (2009) improved the LVI by determining which secondary components contributed to IPCC's identified components of climate change vulnerability: *exposure*, *sensitivity*, and *adaptive capacity*.

In Campbell's (2014) LVI study, food imports and natural and physical assets were added as additional components while health factors were not assessed. The current study was modeled after Campbell's LVI framework with the exception of food imports. According to Campbell (personal communication, June 3, 2014), food imports were a vulnerability factor in St. Elizabeth, Jamaica because farmers were largely engaged in commercial farming. Primarily engaged in subsistence agriculture, farmers in Bluefields had minimal market participation where competition with imported food existed.

In the LVI-IPCC framework, the primary components *natural disasters* and *climate variability* contributed to exposure, *food issues* and *water issues* contributed to sensitivity, and *socio-demographic profile*, *livelihood strategies*, *natural and physical assets*, and *social networks* contributed to adaptive capacity (Campbell, 2014). The theoretical framework applied by the LVI approach in this study is shown in Figure 1.

In a collaborative effort between researchers at CARE-Mozambique and Emory University, the LVI framework was used to compare impacts of climate change on two districts in Mozambique (Hahn et al., 2009). The Campbell (2014) study also employed the LVI framework in four communities in St. Elizabeth, Jamaica. St. Elizabeth is adjacent to Westmoreland parish, where the current study was conducted.

Hahn et al. (2009) conceded difficulty in establishing validity with an indexing approach and varied indicators. Conversely, Vincent (2007) argued that regardless of uncertainty in measuring vulnerability, empirical assessment is a necessity for informed policymaking. The LVI framework approach is one such form of empirical assessment (Vincent, 2007).

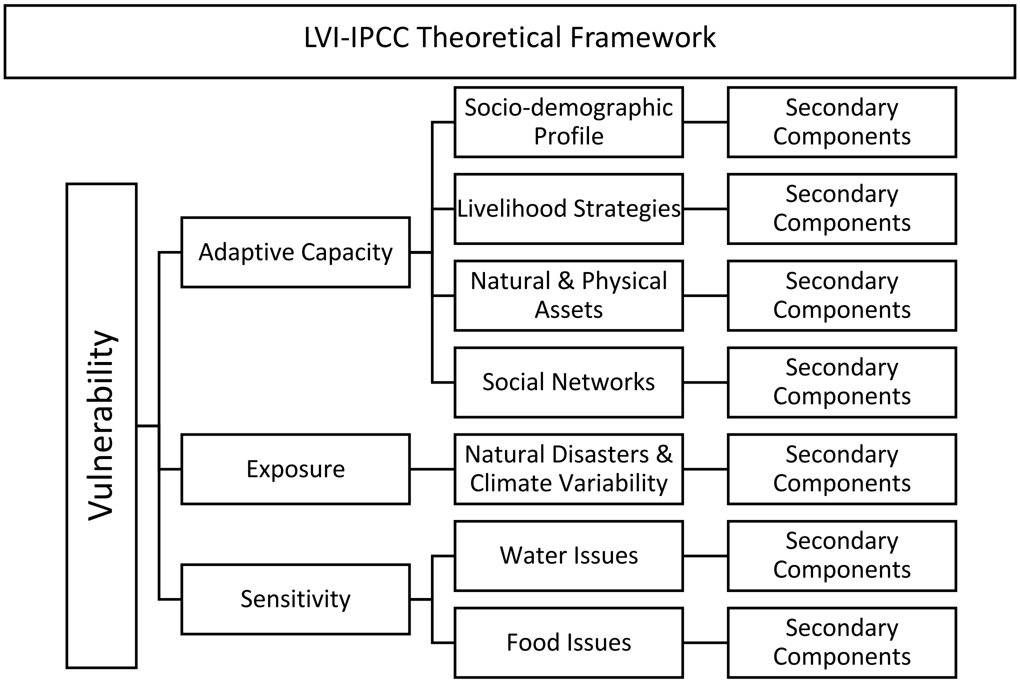

Figure 1. The *LVI-IPCC Theoretical Framework* depicts how LVI secondary components (far right) relate to primary components (second from right) that determine scores for LVI-IPCC contributing factors (second from left), which make up the overall LVI-IPCC Vulnerability (left) for the study area.

Purpose

The study's purpose was to examine farmer vulnerability to climate change in Bluefields, Westmoreland, Jamaica based on the LVI (Hahn et al., 2009). The research objectives were to

1. Assess factors affecting livelihood vulnerability to climate; and,
2. Determine farmers' levels of adaptive capacity, exposure, and sensitivity to climate change.

Methods

This study used a quantitative design with a questionnaire administered through personal interview (Ary, Jacobs, Sorensen, & Razavieh, 2010). Personal administration of the questionnaire was an important design feature because it allowed the researcher to observe respondents and surroundings, control the order in which questions were asked, and increase the response rate (Ary et al., 2010). Quantitative data were needed to calculate the LVI and statistically measure relationships between variables.

A random sample of 52 farmers was drawn from the population (*N* = 112; farmers in the sub-districts of Belmont, Bluefields, Mount Airy, Mount Edgecombe, Robins River, and Shafston from Bluefields communities) to achieve a 95% confidence interval at 10% margin of error (Dillman, 2007). Twelve persons were either unreachable or declined to participate, producing a response rate of 77%. The sample (*n* = 52) was identified using a list of registered producers from the Ministry of Agriculture (Rural Agricultural Development Authority [RADA], 2013), and with input from local farmers (i.e., snowball sampling method). Random sampling techniques (Ary et al., 2010) of the master list were used to derive the sample.

Indicators used in the LVI questionnaire were predominantly theory-driven (Vincent, 2007), with the exception of data-driven meteorological information, such as historical rainfall and temperature. Most questions were worded to elicit categorical responses, including Male/Female, Yes/No, or indicating a range of responses (e.g., 1…4). Open-ended questions (i.e., types of crops grown) allowed participants to list one or multiple items. The LVI for this study employed a balanced weighted average method (Sullivan, Meigh, & Fediw, 2002). The LVI consisted of seven primary components and 34 secondary components (Table 2). Primary and secondary components were adopted from the Hahn et al. (2009) and Campbell (2014) studies. According to the Organisation for Economic Co-operation and Development (OECD, 2015) nearly 900 thousand Jamaicans live abroad, and remittances consist of about 15% of GDP (OECD, 2015). Therefore, an additional secondary component (i.e., remittances) was added to the social network portion of this study.

All secondary components contributed to the overall LVI equally (Hahn et al., 2009). Each secondary component was assessed on a different scale; therefore, it was necessary to standardize each as an index (Hahn et al., 2009). The study adapted the standardized formula from Hahn et al. (2009) without any modification. For this study, district (*d*) should be considered as representing Bluefields as a whole. Variables represented as percentages had a minimum value of zero and maximum value of 100. For indicators such as the *average crop diversity index*, a higher crude score indicated less vulnerability. In these cases, an inverse value was calculated.

After all secondary components were standardized, each were averaged with the following equation to determine the value of each primary component:

$$M_d = \frac{\sum_{i=1}^{n} index_{s_d i}}{n}$$

In this equation, M_d represented one of seven primary components for the district *d* (Socio-demographic profile [SDP], Livelihood strategies [LS], Social networks [SN], Water issues [W], Food issues [F], Natural disasters and climate variability [NDCV], or Natural and physical assets [NPA]). Secondary components were represented by the variable $index_{s_d i}$, indexed by *i*, which made up each of the listed primary components, and *n* was the number of secondary components in each primary component (Hahn et al., 2009).

After values for each of the seven primary components for a district were computed, they were averaged with the following equation to determine the district-level (Bluefields) LVI:

$$LVI_d = \frac{[w_{SDP}(SDP_d)] + [w_{LS}(LS_d)] + [w_{SN}(SN_d)] + [w_W(W_d)] + [w_F(F_d)] + [w_{NDCV}(NDCV_d)] + [w_{NPA}(NPA_d)]}{w_{SDP} + w_{LS} + w_{SN} + w_W + w_F + w_{NDCV} + w_{NPA}}$$

The LVI_d, equals the weighted average of the seven primary components for Bluefields. The weights of primary components, w_{M_i}, were determined by the number of secondary components that made up each primary component (Hahn et al., 2009). The weights were included to ensure that all secondary components contributed equally to the overall LVI (Sullivan et al., 2002). To compute the LVI-IPCC score, the primary components were categorized into the vulnerability contributing factors (exposure, sensitivity, or adaptive capacity) in accordance with the LVI-IPCC framework (Figure 1). The final composite LVI-IPCC score for each contributing factor was calculated using the formula (Hahn et al., 2009):

$$CF_d = \frac{\sum_{i=1}^{n} w_{M_i} M_{di}}{\sum_{i=1}^{n} w_{M_i}}$$

where CF_d represents one of the IPCC-defined contributing factors to vulnerability for district *d* (Bluefields). M_{di} represented the primary components for the district *d* indexed by *i*, the weight of each major component was w_{M_i}, and *n* was the number of primary components that constituted each contributing factor. After each contributing factor (*exposure*, *sensitivity*, and *adaptive capacity*) score was calculated, it was combined using this equation:

$$LVI\text{-}IPCC_d = (e_d - a_d) * s_d$$

in which $LVI\text{-}IPCC_d$ was the LVI for Bluefields, and within the IPCC framework, *e* represented the score for exposure, *α* was the score for adaptive capacity, and *s* was the score for sensitivity. Before calculating a_d, the standardized scores for adaptive capacity were inversed using (1 – n). The scale for the LVI-IPCC is -1.0 to 1.0 (Hahn et al., 2009).

Sijtsma (2009) found the Greatest Lower Bound (GLB) method was one of the most powerful estimators of reliability, as deduced by Woodhouse and Jackson (1977), when considering the total score on a test comprising non-homogeneous items (i.e., dichotomous choices such as yes/no). GLB was used to derive reliability scores for scales measuring *adaptive capacity* (0.83), *exposure* (0.88), and *sensitivity* (0.81).

It is important to note the average receive:give ratio (i.e., financial assistance to family or friends), as used by Hahn et al. (2009), was modified in the current study. For cultural reasons, the researcher did not ask respondents about receiving or giving financial assistance to friends or family. The researcher only asked if the respondent thought that he or she could receive or give financial assistance, rather than if they had done so in the past month. The average receive:give assistance was determined with scores of 0.00 to those who thought they could both give and receive financial assistance to friends or family in emergencies. A score of 0.33 was attributed to those who thought they could receive financial assistance, but not give. Those who thought they could not receive, but could give financial assistance were scored 0.67. Those who thought they could neither give nor receive financial assistance in emergencies received a vulnerability score of 1.00.

Unlike the Campbell (2014) study, the scope of this study precluded the researcher from conducting focus groups to assess the relevance of LVI factors because Bluefields' farmers were preoccupied with subsistence farming tasks during the spring of 2014. However, the researcher lived in Bluefields for an extended time (~20 months) before collecting data. This extended time allowed the researcher to gain insights necessary to observe and understand conditions affecting the population of interest (Mack, Woodsong, MacQueen, Guest, & Namey, 2005).

The instrument was administered during May of 2014 by the researcher, who was familiar to many Bluefields' farmers before the data collection period. This familiarity encouraged farmers to be comfortable and provide more forthright answers (Rogers, 2003). The LVI survey questionnaire was administered via personal interview. Prior to interviews, an information sheet detailing research participants' rights was read to respondents, signed by interviewees, and given to participants to keep. After receiving a participant's verbal consent, a structured questionnaire was used to collect data. Interviews lasted 30 to 45 minutes. Languages used during interviews included English, Jamaican Patois, or a mixture of these languages. No personally identifiable information was collected to ensure privacy and confidentiality for participants. Descriptive statistics including frequencies, means, percentages, and standard deviations were used to analyze and report data.

Results

Respondents were predominantly male (80%) and averaged 52 years of age. Most (67.5%) lived in households of four or less and had an average of 28.8 years of farming experience (Table 1). Most (47.5%) viewed their income as below the community average, while 31.5% considered their income to be average and 21% above average. Seventy percent farmed less than 2.5 acres. Fifty percent reported having access to farm credit while 35% said they had no access and 15% were unsure. It is unknown how many respondents have used credit in the past or would take out a loan if available. One-half of the respondents reported zero contacts with extension services, while others had contacts less than annually (30%), annually (10%), and multiple times annually (10%). The average distance to a permanent market was 4.99 miles.

Table 1
Demographic Profile (n = 40) of Study Participants in Bluefields, Jamaica

Variable	Category	f^a	%
Head of Household Gender	Male	32	80.0
	Female	8	20.0
Farmer Age	≤ 34	2	5.0
	35-44	8	20.0
	45-54	13	32.5
	55+	17	42.5
Household Size	4 or less	27	67.5
	5 or more	13	32.5
Education Level	None	2	5.0
	All-age (1-9)	21	52.5
	Secondary (10-12)	12	30.0
	Tertiary (13+)	5	12.5

The first objective was to assess factors affecting farmers' vulnerability to climate change in Bluefields, Jamaica. The indexed results for primary and secondary LVI components provided insights into Bluefields' vulnerability context. Quartiles were determined for secondary component index scores (excluding temperature and rainfall data): $Q_1 = 0.32$; $Q_2 = 0.48$; and $Q_3 = 0.66$. Table 2 shows indexed scores for contributing secondary components.

Table 2
LVI Scores for Agricultural Livelihoods in Bluefields, Jamaica

Primary Component	Secondary Component	Index Score[a]
Socio-demographic Profile	% household heads with less than 10 years of education	.58
	Dependency ratio	.54
	% households with more than four members	.33
	% households in which no member has off-farm employment	.31
	% female-headed households	.20
Livelihood Strategies	% households lacking access to assistance from outside community	.68
	Average agricultural livelihood diversification index (range: 0.13-1.0)	.54
	% farmers who operate independently	.40
	Income diversification index (range: 0-1) (Inverse of number of alternative income sources)	.32
	% households dependent solely on agriculture as a source of income	.28
Social Networks	% households who do not receive remittances	.70
	% farmers not owning farmland	.70
	Average receive:give ratio	.64
	Number of farm plots (inverse)	.62
	% households without any member in any community group or organization	.53
Natural & Physical Assets	% households reporting problems with getting adequate water for farming	.70
	Farm technology usage (inverse)	.50
	% households that do not practice water harvesting	.35
	% farmers not having access to enough farmland	.05
Water Issues	% households dependent on farm for food	.88
	% farmers primarily dependent on rainfall	.87
	% farmers having trouble obtaining planting material	.73
	% households that buy water for farming	.23
Food Issues	% farmers with four or more production failures in the last 10 years	.62
	Average crop diversity index (diversity index = 1/(n+1)	.47
	% farmers who do not practice drought mitigation	.40
	% households experiencing one month or more annual food insecurity	.28
	% farmers who do not save seeds	.13

Table 2 (continued)
LVI Scores for Agricultural Livelihoods in Bluefields, Jamaica

Primary Component	Secondary Component	Index Score[a]
Natural Disasters & Climate Variability	% farmers who never received assistance from RADA[b] following a weather-related crop failure	.88
	Mean standard deviation of the daily average maximum temperature by month	.52
	Mean standard deviation of average precipitation by month	.47
	% farmers taking more than six months to restore production levels	.38
	Mean standard deviation of the daily average minimum temperature by month	.36
	% farmers not receiving early warning information about drought	.28

Note: [a]Index Scores were on a 0.0 to 1.0 scale. A higher index score indicates a higher level of vulnerability. [b]Rural Agricultural Development Authority (RADA), Ministry of Agriculture, Kingston, Jamaica.

Table 3 displays indexed scores for each of the three IPCC-designated components of vulnerability and the index score for each primary component. The primary components showing the greatest amount of vulnerability were Social Networks (0.59) and Water Issues (0.54). The primary components showing the least vulnerability were Livelihood Strategies (0.36) and Socio-demographic Profile (0.41). The overall LVI score generated from the weighted averages of each primary component yielded 0.48, a number against which future LVI studies in Bluefields can be compared.

Table 3
LVI Composite Scores by Primary Component for Farmers in Bluefields, Jamaica

IPCC components	Index Score[a]	LVI Primary Components	Primary Component Index Score[a]
Exposure	.46	Natural disaster and climate variability	.49
Adaptive capacity	.51	Social networks	.59
		Natural and physical assets	.47
		Socio-demographic profile	.41
		Livelihood strategies	.36
Sensitivity	.49	Water issues	.54
		Food issues	.50
		Bluefields LVI score	.48

Note: [a]Index Scores were on a 0.0-1.0 scale. A higher index score indicates a higher level of vulnerability.

The second objective was to determine farmers' level of adaptive capacity, exposure, and sensitivity to climate change through the LVI-IPCC method. The IPCC identified three contributing factors to climate change vulnerability: (a) exposure, (b) adaptive capacity, and (c) sensitivity (McCarthy et al., 2001). Secondary components of the LVI contributing to each of these factors were illustrated in Table 2. The weighted averages of LVI secondary components were calculated to create LVI-IPCC scores, as listed in Table 4.

Table 4
LVI-IPCC Scores for Agricultural Livelihoods in Bluefields, Jamaica

LVI-IPCC components	LVI-IPCC Score[a]
Exposure	.49
Adaptive Capacity	.54[b]
Sensitivity	.51
LVI-IPCC: [(Exposure – Adaptive Capacity) x Sensitivity]	-.03[c]

Note:. [a]Scores were on a scale of 0.0-1.0. [b]An inverse of adaptive capacity is used in the calculation of overall LVI-IPCC. [c]LVI-IPCC Score is on a scale of -1.0 to 1.0. The closer to 1.0, the greater the vulnerability; the closer to -1.0, the greater the resiliency.

Discussion and Implications

The LVI measured vulnerability based on seven primary components. Social Networks (i = 0.59) and Water Issues (i = 0.58) were primary components with highest scores for vulnerability; Livelihood Strategies (i = 0.36) was the primary component with the lowest vulnerability score. Results provided insight into factors affecting vulnerability of agricultural livelihoods in Bluefields and uncovered opportunities to improve the LVI for future research.

The eight secondary components in the upper quartile for vulnerability provide focus for policies or programs to improve resiliency of agriculturists' livelihoods in Bluefields. Most farmers in this study were dependent on their farms for food, which increased their risk from natural disasters and climate variability (Selvaraju, Trapido, Santos, Del Mar Polo Lacasa, & Hayman, 2013). Additional risk was demonstrated by the finding most Bluefields farmers have never received recovery assistance following a weather-related crop failure. Efforts to increase farm incomes and provide crop insurance could reduce this risk and improve food security (Lotze-Campen & Schellnhuber, 2009).

Water is a key component of productive tropical agriculture (Rockström, Barron, & Fox, 2003). However, most Bluefields producers reported they depended on rainfall and did not have adequate water for farming. When rainfall creates conditions suitable to plant crops, farmers reported they had trouble finding or affording planting material. Agriculture-specific financial services could allow farmers to invest in water harvesting infrastructure, drip irrigation, and planting material. However, most farmers in Bluefields did not own their land, which could be a constraint to the use of some financial services such as credit (Graham & AgDarroch, 2001). Farmers are more likely to invest in agriculture when they have secure tenure (Lim, Spanger-Siegfried, Burton, Malone, & Huq, 2005).

LVI studies used different primary and secondary components depending on what is appropriate for the local vulnerability context (Campbell, 2014; Hahn et al., 2009; Shah et al., 2013). The varied use of components and the standardization of scores limit the ability to compare results across studies, unless said studies employ the same methods (Hahn et al., 2009). This study used several of the same components and methods as Campbell's (2014) investigation with a similar population in Jamaica, which consequently provided an opportunity for comparison. Bluefields exhibited greater vulnerability in nine of the 14 secondary components that lend themselves to direct comparison with Campbell's (2014) results.

Secondary components differing—based on non-statistical comparisons—in LVI scores between Bluefields and the St. Elizabeth communities studied by Campbell (2014), were in (a) land ownership, (b) dependence on rainfall, (c) dependence on farm for food, and (d) receiving assistance from RADA after a weather-related crop failure. Bluefields' farmers had the higher vulnerability score for each of these secondary components. St. Elizabeth parish had high soil fertility, commercial farming, and was referred to as Jamaica's breadbasket ("St Elizabeth still the bread basket parish," 2004) because of high agricultural productivity. These characteristics may have contributed to lesser dependence on farms for food, more assistance from agricultural extension, the ability to invest in irrigation, and higher rates of land ownership among St. Elizabeth's farmers.

Many of the untenured farmers in Bluefields were growing crops on a large tract of land belonging to the Urban Development Commission (UDC), a government-owned corporation that planned and developed urban and rural areas in Jamaica. Many Bluefields farmers had been on UDC land for decades. Though farmers grew crops rent-free, their plots offered no collateral to invest in improved technology, and they were subject to displacement if the UDC developed the land for other purposes. The displaced farmers would have to move to more marginal lands or seek alternative livelihoods. Threat of displacement caused by man or nature was not investigated in this or previous LVI studies, but may be an important factor for untenured farmers in communities such as Bluefields.

Hahn et al. (2009) developed the LVI approach primarily for development planners to study vulnerability at the community level and design targeted programs. Areas of elevated vulnerability warranting intervention in Bluefields have been discussed in this study. This study should be conducted in the future to measure longitudinal changes in Bluefields' vulnerability. Governmental and non-governmental organizations (NGOs) in Jamaica could also employ the LVI approach before and after a developmental program to measure program impact. The LVI is frequently applied to compare vulnerability between communities (Campbell, 2014; Hahn et al., 2009; Shah et al., 2013), but because Jamaica often organizes its communities by sub-districts, the LVI could be used to measure differences within communities (Hahn et al., 2009).

The lack of extension service contacts noted by Bluefields' farmers was a clear indication that extension education in Jamaica may need more resources or improved methods to help subsistence farmers prepare for and manage their vulnerability to climate change. Oladele (2012) noted, "climate change would have high impact in terms of extension services … [as educators] change from [a] generalist approach to [more] specialist" (p. 48). The strategies proposed by George, Clewett, Wright, Birch, and Allen (2007) might be applicable in the Bluefields situation.

Factors affecting low-income households in the developing world are local, complex, diverse, dynamic, and unpredictable (Chambers, 1997) and compound the challenges of using this type of index approach for comparisons of vulnerability across communities, regions, or countries. In Jamaica, Campbell (2014) determined 86.5% of farmers owned the land they farm, whereas this study concluded only 30% of Bluefields farmers owned theirs. A difference likely exists in how tenured farmers and untenured farmers view availability of additional land. A tenured St. Elizabeth farmer may make his or her determination based on if additional farmland is available for lease or purchase, whereas the untenured farmer in Bluefields may see available land for cultivation without considering leasing or purchasing it. This difference in perception could explain differences in scores for access to additional farmland between farmers in this study and those in Campbell's (2014) study. Campbell (2014) reported 33% of St. Elizabeth's farmers lacked access to enough farmland, compared to only 5% of Bluefields' farmers. Using qualitative methods such as focus groups to understand farmers' perceived vulnerability factors, as used in other studies (Campbell, 2014; Masere & Worth, 2015), may be an improved research design.

Studies that use index scores derived from the aggregation of equally weighted factors are limited by the assumption each factor is of equal importance (Eakin & Bojórquez-Tapia, 2008; Hahn et al., 2009; Shah et al., 2013; Vincent, 2007). This oversimplification of reality has led some to apply methods of research aimed at determining a weight for each factor based on local conditions. For example, Eakin and Borjorquez-Tapia (2008) used a methodology involving multi-criteria decision analysis (MCDA) and fuzzy logic to determine weights for vulnerability factors. Participatory rural appraisal (PRA) techniques (Chambers, 1994) such as matrix ranking and scoring (Narayanasamy, 2009) also could be used to derive empirical weights with community input. The use of PRA may be more appropriate than MCDA in areas where minimal or no baseline data exists.

A limitation of this study was a relatively small sample (*n* = 52). A larger sample size may provide the ability to compare results between categories such as gender. The LVI instrument is limited in its ability to generate data that can be used by other researchers for vulnerability research. Future LVI studies should incorporate interval, rather than dichotomous variables to improve measurement of low-income farmers' vulnerabilities to climate change. For example, increased use of interval scale variables could measure important differences between those who harvest sufficient water to sustain full production, versus those who harvest inadequate or no water.

The LVI approach is an effective method to measure vulnerability in a community, but it does not assess farmers' attitudes, beliefs, and/or values regarding how they interpret vulnerability to climate change. It will be important for future research to identify levels of vulnerability, but also to study how farmers perceive their ability to respond through adaptation. Through the combination of the LVI and qualitative assessments of vulnerability, change agents will be better informed about how to assist farmers with decisions to adopt technologies for climate adaptation (Campbell, 2014). One possible way to combine the LVI with a qualitative approach is to incorporate Smit's and Wandel's (2006) *participatory vulnerability assessment* (PVA) framework. The LVI and PVA were designed to identify areas where interventions are needed to reduce vulnerability (Hahn et al., 2009; Smit & Wandel, 2006). Researchers could investigate effective ways to integrate PVA and LVI to generate data that provides rich descriptions (Creswell & Miller, 2000), which are quantifiably measurable over time. This mixed-method research approach could be useful to policymakers needing to measure the impact of programs and policies.

Conclusions

The study's results provided information to support the work of agricultural development and extension personnel in Jamaica, specifically focusing on the factors affecting vulnerability of agricultural livelihoods in Bluefields. George et al. (2007) noted that Australian farmers improved their understanding of climate change/risk after participating in agricultural extension agents' workshops on strategic approaches to managing climate risk. Disseminating knowledge and supporting farms with necessary skills and new technologies on land preparation methods and irrigation (Baloch & Thapa, 2016) helped reduce weather-related crop failure in Balochistan, Pakistan. Davis and Spielman (2017) concluded that agricultural extension services should improve, strengthen, and change to accommodate locals' needs. As such, we believe future extension-led efforts should include development and enactment of localized strategic plans and locally-tailored extension solutions (Davis & Spielman, 2017) pursuant to farmers' needs in Bluefields.

Most farmers in Bluefields did not own their land and depend on rainfall for farming. The primary sources of food come from their farms; however, farmers reported they have trouble finding or affording planting material. Overall, these factors increased their risk for natural disasters and climate variability. In comparisons of LVI scores between Bluefields and St. Elizabeth communities, it was confirmed that Bluefields' farmers had higher vulnerability scores. We assert potential solutions lie in creating opportunities for farmers to secure land ownership or in developing financial services for untenured farmers. Similar to St. Elizabeth communities, we believe Bluefields' farmers also need capacity-building activities on adaptation options (Campbell, 2014) to reduce vulnerability. Improving out-of-community social and financial connections for farmers may be difficult to target through policies or programs, but are important components of vulnerability to consider in Bluefields. The increased use of improved agricultural technology and rainwater harvesting would reduce the overall LVI-IPCC score accordingly. Development planners would then be able to predict the potential impact of their intervention on vulnerability in Bluefields based on the change in the LVI-IPCC score. However, the validity of using these data for sensitivity analysis would degrade over time as changes occur in the vulnerability of farmers in Bluefields.

In addition to agricultural extension officers, other agricultural advisory service providers assist farmers. Recognizing private sector, nongovernmental, and civil society actors involved in agricultural extension and advisory services (Davis & Spielman, 2017) could be a helpful resource for farmers and extension offices. A collaborative effort with agricultural extension service and advisory organizations could be a cost-effective strategy to address the livelihood vulnerability of Bluefields' farmers.

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