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Revealing the social vulnerability of communities to disasters using a composite index based on village-level poverty data

Michael Arieh P. Medina*, Joseph C. Paquit

College of Forestry and Environmental Science, Central Mindanao University, University Town, Musuan, Bukidnon, Philippines

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Abstract

This study was done to develop a barangay social vulnerability index (BSVI) for the purpose of prioritizing disaster resilience programs in local communities. Six (6) of the Community Based Monitoring System 13+1 Core Local Poverty Indicators were used in computing for the BSVI. Factor Analysis using Principal Component Analysis was able to identify 4 components of the index namely: Water Sanitation and Hygiene Inaccessibility (WASHI), Health and Nutrition Inadequacy (HNI), Financial Vulnerability (FV), and Vulnerability of Housing (VH). The factor loadings were used in the weighting process while normalization was done using Min-Max method. BSVI is computed using the linear additive aggregation. The BSVI was able to identify 5 moderately vulnerable barangays in Valencia City, Bukidnon, Philippines out of the 31 barangays in the city. Furthermore, index evaluation using a series of correlation analyses confirms the soundness of the mathematical architecture of the index.

***Corresponding Author:** Michael Arieh P. Medina ✉ mapmedina@cmu.edu.ph

Introduction

The Sendai Framework for Disaster Risk Reduction 2015-2030 (United Nations Office for Disaster Risk Reduction 2015) has recognized the vulnerability of poor communities to climate change consequences such as natural disasters. In this case, poverty has been understood to cause vulnerability in the sense that the lack of economic means of coping up with environmental crisis leads to life changing impacts to poor households (Murdoch, 1994; Fothergill and Peek, 2004; Cutter *et al.,* 2003; Brouwer *et al.,* 2007).

The concept of "vulnerability" has been appearing more frequently in disasters literature since the 1980s (Wisner and Luce 1993). However, the philosophical and methodological bases of disaster vulnerability analyses are seen in the previous decade as underdeveloped. Few of those analyses involve social data; one of the reasons is because disaster managers and other such user groups fail to appreciate the value of this information, another reason is because techniques for incorporating it in existing vulnerability analyses have not yet been developed during that time (Wisner 1998).

However, the conventional understanding now is that vulnerability to disasters is socially constructed, i.e., it arises out of the social and economic circumstances of everyday living (Morrow 2002). According to Van Zandt *et al* (2012), social factors influence the ability of communities and individuals to foresee, respond, resist, and recover from disasters. For instance, it has been proven that poor families are more vulnerable to natural disasters due to such factors as place and type of residence, building construction, and social exclusion (Fothergill and Peek 2004).

On the other hand, these changes at the global level are found to be a source of new opportunities as well as constraints on building local resilience to natural disaster (Pelling and Uitto 2001). Thus, the current conditions brought about by climate change and natural disasters should be seen as an avenue for improving local communities' social and economic aspects thereby reducing their vulnerability to disasters. In connection to this, households and communities are considered as active agents in vulnerability management. Such groups are seen to have the potential for reducing vulnerability based upon economic poverty (Pelling 1997).

However, in this context, the main question is to whom should disaster resilience programs be directed? According to Boyce (2000) disaster vulnerability reduction is an impure public good: when provided to one it is provided to others, but not equally provided to all. This means that in addition to the question of how much disaster vulnerability reduction to provide, policymakers face the question of to whom it should be provided. Hence, the need for identifying target communities or individuals worthy of such intervention.

It is for this purpose that this study was done. This is an attempt to develop a tool for identifying priority areas for disaster vulnerability reduction programs. Given the limited budget of local government units for disaster risk reduction and management, it is beneficial that decision makers at the local level are able to determine which communities are vulnerable or not. The resulting index of social vulnerability developed in this study answers the above question.

Materials and methods

The construction of the social vulnerability index is based on mainstream methods of developing composite indicators (Cutter *et al* 2003; Organization for Economic Cooperation and Development 2008; Medina, 2015). For this study, the Community Based Monitoring System (CBMS) data of 3,123 barangays (barangay is the smallest geographical unit in the Philippines, equivalent to a village on most Asian countries) from 12 provinces in the Philippines namely: Agusan del Norte, Agusan del Sur, Batanes, Biliran, Camarines Norte, Dinagat Islands, Eastern Samar, Marinduque, Northern Samar, Occidental Mindoro, Oriental Mindoro, and Siquijor were used in selecting social vulnerability indicators in this study.

The dataset was downloaded online from pids.gov.ph. The dataset is composed of the 14 Core Local Poverty Indicators for each barangay.

However, not all of the 14 indicators could qualify as vulnerability factors most especially in relation to disaster vulnerability. Using past literature, the researchers filtered the 14 variables and came up with 6 variables related to disaster vulnerability: 1) Proportion of households without access to sanitary toilet facilities, 2) Proportion of households without access to safe water supply, 3) Proportion of women who died due to pregnancy-related causes, 4) Proportion of children aged 0-5 years old who are malnourished, 5) Proportion of persons who are unemployed, 6) Proportion of households living in makeshift housing.

Furthermore, to determine the underlying structure of the 6 indicators, Factor Analysis was employed using Principal Component Analysis (PCA) technique. Table 1 shows the results of the PCA. The dataset passed preliminary tests of sampling adequacy and sphericity. Moreover, the analysis revealed 4 components for the 6 indicators of vulnerability namely: Water Sanitation and Hygiene Inaccessibility, Health and Nutrition Inadequacy, Financial Vulnerability, and Vulnerability of Housing. The Water Sanitation and Hygiene Inaccessibility (WASHI) component is composed of 2 indicators: Proportion of households without access to sanitary toilet facilities (*NTSTF)*, and Proportion of households without access to safe water supply (*NTSWS)*. The Health and Nutrition Inadequacy (HNI) component is composed of also 2 indicators: Proportion of women who died due to pregnancy-related causes (*DPREG)*, and Proportion of children aged 0-5 years old who are malnourished (*MALN05)*. Financial Vulnerability (FV) is composed of Proportion of persons who are unemployed (*UNEMPL*) as lone indicator. Vulnerability of Housing (VH) is also composed of 1 indicator which is Proportion of households living in makeshift housing (*MSH)*. PCA was done using was done using the Statistical Package for the Social Sciences (SPSS) Version 16 (Demo Version).

Using the Factor Loading from the PCA technique above, the weights of each component were then determined using a procedure from the "Handbook on constructing composite indicators: methodology and user guide" by the Organization for Organization for Economic Cooperation and Development (OECD) (2008). Hence, the resulting equation for the computation is shown below. For the purpose of this study we call the results of the equation below as the Barangay Social Vulnerability Index (BSVI):

$$BSVI = 0.32(WASHI) + 0.24(HNI) + 0.22(FV) + 0.22(VH)$$

Where:

Water Sanitation and Hygiene Inaccessibility (WASHI) = (NTSTF + NTSWS)/2

Health and Nutrition Inadequacy (HNI) = 0.54(DPREG) + 0.46(MALN05)

Financial Vulnerability (FV) = UNEMPL

Vulnerability of Housing (VH) = MSH

Furthermore, before doing the final computation, the raw values for the 6 indicators is first normalized. In this particular index, the Min-Max procedure was suggested due to its simplicity and applicability to the existing dataset. The Min-Max procedure is also considered to be the most popular normalization procedure (OECD 2008). Using the Min-Max method, the raw values of the indicators are converted into a range of 0-1. The Min-Max formula is as follows:

$$X = \frac{V - Min}{Max}$$

Where;

X = normalized value of the indicator (0, 1)

V = value of the indicator

Min = the minimum (lowest) value of the indicator

Max = the maximum (highest) value of the indicator.

The resulting BSVI value is a dimensionless unit. However, interpretation deals with comparative vulnerability among the different barangays measured.

Ideally, a BSVI value of 1.00 means that the barangay is considered the most vulnerable in all indicators, likewise a BSVI value of 0.00 means the barangay has the lowest vulnerability among all the indicators. The value of the index lies in its ability to determine which barangay is better (or worse) in terms of social vulnerability compared to other barangays. Consequently, to provide a qualitative description of the BSVI, the possible values were categorized into 5 descriptive ratings using 20% percentile rank (Table 2).

Testing of the BSVI involves two steps. First, the index will be pilot tested on an actual location. In this particular case the BSVI is pilot tested in Valencia City in Bukidnon, Philippines. Valencia City has been considered as a flood prone area in the province (Medina and Arche 2015, Medina and Moraca 2016). In this particular part of the study, data from the 31 barangays of the city based on the 6 indicators above were gathered from the City Planning and Development Office (CPDO) in Valencia City. From this, the BSVI of each of the 31 barangays in Valencia City were computed. In the second step, evaluation of the index was done through a series of correlation analysis using Pearson (r) Product Moment Coefficient of Correlation between BSVI and its sub-indices and indicators as well as correlation among each of the indicators or sub indices using results from the Valencia City data. This is based on the evaluation framework for composite indices previously employed in past studies (Saisana and Saltelli, 2008).

Results and discussion

Results of the Pilot testing of BSVI

Table 3 shows the BSVI values of barangays in Valencia City. As revealed it is found out that most of the barangays have very low to low vulnerability ratings. Barangay Poblacion is considered to be the barangay with the lowest social vulnerability.

This is understandable since Poblacion is located in the city center, thus it is assumed that it is the most developed barangay compared to the others. The main reason for this is Poblacion's accessibility to the city's social services as well as the economic opportunities in the urban core. Areas with easier access to social services are less likely to be considered as a poor community (Fillone *et al.,* 2011).

Table 1. Results of Principal Component Analysis of CBMS dataset.

Indicators	Components			
	Water Sanitation and Hygiene Inaccessibility (WASHI)	Health and Nutrition Inadequacy (HNI)	Financial Vulnerability (FV)	Vulnerability of Housing (VH)
Proportion of households without access to sanitary toilet facilities	0.818	0.035	0.153	-0.008
Proportion of households without access to safe water supply	0.800	-0.063	-0.139	-0.011
Proportion of women who died due to pregnancy-related causes	0.215	0.761	0.078	0.120
Proportion of children aged 0-5 years old who are malnourished	0.263	-0.712	0.050	0.103
Proportion of persons who are unemployed	0.004	0.021	0.983	-0.018
Proportion of households living in makeshift housing	-0.022	0.015	-0.019	0.989
(Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.501)				
(Bartlett's Test of Sphericity, $X^2 = 641.198$, $p<0.001$)				

Only 5 of the 31 barangays in the city have a moderate vulnerability rating (Maapag, Tongantongan, Barobo, Lourdes, Lumbayao) with Barangay Lumbayao with the highest social vulnerability among the 31 barangays. It should be noted that these areas are far from the city administrative center which means lesser accessibility to social services compared to other barangays. None however, is considered to have high to very high vulnerability rating based on the BSVI.

Results of the Index Evaluation

In the case of the BSVI, its correlation coefficients with the 6 indicators all reveal high significance (99% confidence level) with unemployment having the highest correlation coefficient while malnutrition having the lowest correlation coefficient with BSVI (Table 4). This means that BSVI can be considered as a good index since it is significantly correlated with its underlying factors/indicators (Booysen 2002). Furthermore, each of the indicators when correlated with each other mostly revealed non-significant relationships. There are however few significant relationships among the combinations of indicators however, these are of low correlation. This means that in general, the indicators show aspects of social vulnerability which are different from each other which is an advantage in this particular case (Saisana and Saltelli, 2008).

Table 2. Descriptive Rating of BSVI Based on 20% Percentile Rank.

BSVI Value	Vulnerability Rating
0.00 - 0.20	Very Low
0.21 - 0.40	Low
0.41 - 0.60	Moderate
0.61 - 0.80	High
0.81 - 1.00	Very High

Table 3. Normalized Sub-indices values and BSVI values of Barangays in Valencia City with Vulnerability Scale Ratings.

Barangay	WASHI	HNI	FV	VH	BSVI
Poblacion	0.02	0.14	0.06	0.07	0.07
Lumbo	0.11	0.00	0.30	0.06	0.12
Lurogan	0.18	0.09	0.26	0.05	0.15
Mount Nebo	0.00	0.22	0.48	0.04	0.17
Catumbalon	0.14	0.12	0.48	0.00	0.18
Laligan	0.19	0.13	0.11	0.28	0.18
Vintar	0.09	0.23	0.13	0.31	0.18
Concepcion	0.14	0.05	0.56	0.05	0.19
Guinoyuran	0.31	0.10	0.30	0.01	0.19
Mailag	0.12	0.25	0.39	0.03	0.19
Bagontaas	0.09	0.13	0.50	0.13	0.20
Banlag	0.33	0.23	0.18	0.06	0.21
San Carlos	0.36	0.22	0.17	0.00	0.21
Sugod	0.33	0.15	0.34	0.00	0.22
Batangan	0.42	0.12	0.34	0.02	0.24
Dagat-Kidavao	0.57	0.24	0.00	0.00	0.24
Pinatilan	0.33	0.09	0.34	0.17	0.24
Nabag-o	0.02	0.19	0.45	0.44	0.25
Mabuhay	0.36	0.17	0.50	0.05	0.28
Tugaya	0.48	0.22	0.38	0.00	0.29
Colonia	0.23	0.21	0.55	0.26	0.30
Lilingayon	0.12	0.58	0.14	0.41	0.30
Sinayawan	0.60	0.25	0.15	0.07	0.30
San Isidro	0.48	0.20	0.61	0.00	0.34
Kahaponan	0.26	0.44	0.52	0.20	0.35
Sinabuagan	0.46	0.27	0.73	0.00	0.37
Maapag	0.53	0.46	0.53	0.04	0.41
Tongantongan	0.63	0.24	0.54	0.18	0.42

Barobo	0.77	0.05	1.00	0.00	0.48
Lourdes	0.25	0.33	0.62	1.00	0.52
Lumbayao	0.39	0.55	0.70	0.55	0.53
Legend:					
Very Low		Low	Moderate	High	Very High

When BSVI is correlated with the four sub-indices (Table 5), the results showed significant correlation coefficients same as above. On the other hand, the sub indices show either non-significant correlation coefficients or low relationships with each other. On the overall, this suggests that BSVI is a good index based on these criteria.

Table 4. Pearson r Coefficients for the BSVI and the six indicators.

	Barangay Social Vulnerability Indicators					
	NTSTF	NTSWS	DPREG	MALNO5	MSH	UNEMPL
BSVI	0.73**	0.73**	0.28**	0.27**	0.32**	0.58**
NTSTF		0.53**	0.26**	0.31^{ns}	-0.14^{ns}	0.32**
NTSWS			0.03^{ns}	0.05^{ns}	0.01^{ns}	0.17^{ns}
DPREG				-0.11^{ns}	0.03^{ns}	0.17^{ns}
MALNO5					0.06^{ns}	0.07^{ns}
MSH						-0.05^{ns}

Legend: NTSTF - Proportion of households without access to sanitary toilet facilities; NTSWS - Proportion of households without access to safe water supply; DPREG - Proportion of women who died due to pregnancy-related causes; MALN05 - Proportion of children aged 0-5 years old who are malnourished; UNEMPL - Proportion of persons who are unemployed; MSH - Proportion of households living in makeshift housing; *Coefficient significant at 95% confidence level;
**Coefficient significant at 99% confidence level;^{ns}Coefficient not significant.

Table 5. Pearson r Coefficients for the BSVI and the four sub-indices (Components).

	BSVI Sub-indices (Components)			
	WASHI	HNI	FV	VH
BSVI	0.83**	0.40**	0.58**	0.32**
WASHI		0.12^{ns}	0.26**	-0.01^{ns}
HNI			0.15^{ns}	0.07^{ns}
FV				-0.05^{ns}

Legend: WASHI - Water Sanitation and Hygiene Inaccessibility; HNI - Health and Nutrition Inadequacy; FV - Financial Vulnerability; VH - Vulnerability of Housing;
*Coefficient significant at 95% confidence level;
**Coefficient significant at 99% confidence level;^{ns}Coefficient not significant.

Conclusion

The study is an attempt to develop a barangay social vulnerability index (BSVI). Consequently, the possibility and viability of such tool was demonstrated in Valencia City Bukidnon. Evaluation of the index proves its usefulness to local government units. The pilot testing of the BSVI identified priority communities for vulnerability reduction programs.

Results showed that of the 31 barangays in the city 5 are considered to be of moderate social vulnerability. These provides insights on where to prioritize social development initiatives or programs to enhance disaster resilience in the city.

Moreover, The BSVI through its sub indices (WASHI, HNI, FV, and VH) can be used for comparative studies among the different communities.

It can be able to identify in which sub-indices a community becomes vulnerable compared to other communities. Consequently, this can provide information for local decision makers specifically in what aspect of vulnerability needs more attention and what doesn't in their community. Decisions based on such information leads to the efficiency as well as effectiveness of future programs/projects of the community. Furthermore, because BSVI is based on common and locally available data, annual datasets can be obtained easily to generate BSVI progress charts detailing how communities have built their resilience throughout the years.

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