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Assessing social vulnerability to climate-related hazards among Haiyan-affected areas in Leyte, Philippines

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Abstract

Climate-related hazards can lead to disasters in communities with lower socioeconomic conditions, inadequate access to basic social and infrastructure services, and poor institutions. The impacts of Typhoon Haiyan that struck the Philippines in 2013 not only highlighted the exposure of several cities but also indicated the underlying causes of their social vulnerability to climate-related hazards. This study attempted to measure the social vulnerability of Tacloban City (eastern), Ormoc City (eastern), Palo (western) and Kananga (western) in Leyte province using a modified social vulnerability index (SoVI) which was computed from 35 sub-indicators. Results show that Palo obtained the highest overall SoVI, influenced heavily by very high flood susceptibility and high storm surge susceptibility, low level of information and awareness, lack of disaster risk reduction activities, and high level of livelihoods at risk. However, minimal differential vulnerability index among the study areas was observed suggesting that one is almost as vulnerable as the others. Furthermore, a relatively weak association was observed between the SoVI and the number of deaths from Typhoon Haiyan in all the study areas. Nevertheless, an increasing pattern of SoVI and the number of deaths from western to eastern municipalities was observed that could be explained by higher hazard exposure of the eastern municipalities. Adaptive capacity consistently scored the highest among the computed indicators of social vulnerability in all study sites, indicating the importance of prioritizing efforts on increasing adaptive capacity. Overall, the results demonstrate that SoVI allows for better understanding of vulnerability in terms of the study sites' social conditions and situations. The results can facilitate informed vulnerability reduction decisions.

Keywords: vulnerability · social index · Philippines · Haiyan

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Introduction

In the Philippines, the effects of climate change, such as the increase in intensity and frequency of tropical cyclones, drive vulnerability and exposure of many people to climate-related hazards (Intergovernmental Panel on Climate Change [IPCC], 2013; Lasco, Delfino, Rangasa, & Pulhin, 2012). In 2013, Typhoon Haiyan generated one of the biggest and most devastating storm surge events seen in the country in several decades, leaving over 6,300 dead, 1,061 missing, and 28,689 injured and affecting a total of 12,139 barangays, 44 provinces, 591 municipalities, and 57 cities (National Disaster Risk Reduction and Management Council [NDRRMC], 2014b). The typhoon hit the poor hardest, affecting assets, jobs, and incomes, pushing more people into poverty and increasing their vulnerability (Asian Development Bank, 2014). As this event showed, climate change exacerbates the condition of people who are already entrenched in poverty, increasing inequalities (IPCC, 2014) and worsening vulnerability to unevenly distributed climate shocks (United Nations Development Programme [UNDP], 2007).

Vulnerability varies greatly among individuals and groups of people. For instance, vulnerability to climate-related disasters can be more pronounced among people with relatively lower incomes (Stoddart, 2013). This vulnerability is driven by social, economic, and political factors beyond natural processes. The impact of storm surge that devastated Tacloban and Palo illustrates the natural hazard exposure and highlights the social vulnerability of most cities and municipalities in the Philippines. The growing impacts of climate-related disasters pose a great challenge to many cities, especially those with low capacity to mitigate, prepare for, and respond to disasters.

Defining Social Vulnerability

Vulnerability has been defined as the characteristics and circumstances of a community, system, or asset that make it susceptible to the damaging effects of a hazard (United Nations International Strategy for Disaster Reduction, 2009). In the context of climate change, vulnerability is the degree to which a system is susceptible to the negative impact of climate change (IPCC, 2007a). Vulnerability is also a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, further defined in three dimensions: exposure, sensitivity, and adaptive capacity (IPCC, 2007b). While vulnerability has been often understood in terms of natural and physical process, it is now increasingly linked to social, economic, and political conditions that alter natural hazards into social disasters. Cutter (1996) developed the hazards-of-place model showing the "place-based" interrelationship between hazard exposure and social vulnerability in identifying varying degrees of impact caused by hazards and how this interaction has unique temporal and spatial aspects (Ignacio & Henry, 2013).

Furthermore, vulnerability has been defined as a social susceptibility to harm and capacity to respond, while exposure is the physical stress and the assets that are in harm's way. Social vulnerability is associated with social processes, economic systems, and power relations which characterize the conditions to which people become prone or susceptible to damage or injury (Cannon, 1994), emphasizing social inequity along with the lines of class, ethnicity, gender, age, national origin, disability, and health status as being key elements in people's vulnerability (Li & Li, 2011; Wisner, Blaikie, Cannon, & Davis, 2003). Vulnerability is also linked to lack of access to resources, limited access to political power and representation, social capital, beliefs and customs, building stock and age, frail and physically limited individuals, and type and density of infrastructure and lifelines (Cutter, Boruff, & Shirley, 2003). A person's vulnerability depends upon the interaction of a complex set of factors (Lundgren & Jonsson, 2012).

Materials and Methods

The study used a modified social vulnerability index (SoVI) to measure the vulnerability of selected Haiyan-affected areas in Leyte. Social vulnerability was measured using household survey results, census data, and climate-related hazard datasets. It explored the association of the measured SoVI with the actual Haiyan impacts in the study areas by examining the trend of computed vulnerability in relation to the trend of the number of deaths from eastern to western study areas.

Study Area

The study covers four local government units (LGUs) in Leyte: Tacloban City, Ormoc City, and the municipalities of Palo and Kananga. These LGUs were heavily affected by the impacts of Typhoon Haiyan and are located near sources of multiple climate-related hazards. Tacloban, Palo, and Ormoc are coastal areas while Kananga is an upland landlocked municipality. The two cities are severely flood-prone, especially Tacloban which is located in the low-lying, coastal area in the eastern portion of Leyte.

Urbanization and population in the study areas are growing, which translate to increasing sensitivity to natural hazards. With 1,722,036 total population and a population density at 301 persons per square kilometer (National Statistics Office, 2010), the demographic characteristics of Leyte province increase its risk to climate-related hazards. Leyte's poverty incidence was at 39.20% in 2012 (National Statistical Coordination Board, 2012).

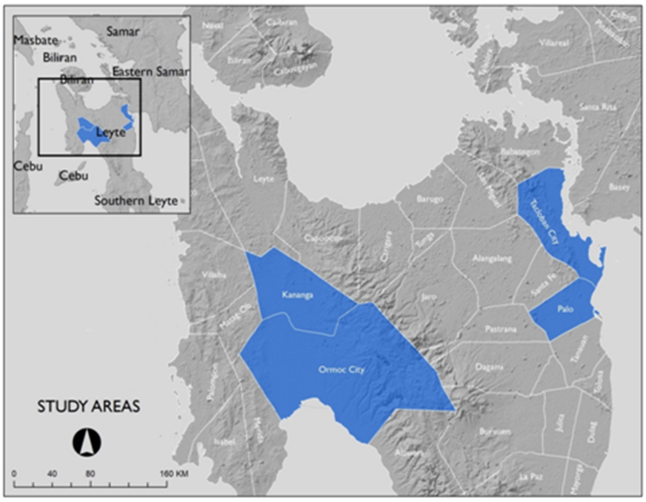

Figure 1. Location map of study sites.

Vulnerability Indicators

Vulnerability indicators were identified based on the general aspects of social vulnerability prescribed by Cutter, Emrich, Webb, and Morath (2009), which are poverty, gender and ethnicity, age, and disabilities. These indicators were modified and proxies were used based on the objectives of the study and data availability (Table 1).

Variables concerning sensitivity include livelihood at risk, unemployment, and population at risk. Measures for adaptive capacity include socioeconomic status, information and awareness, infrastructure guidance and services, and institutions and systems. Exposure indicators are climate-induced hazards, housing materials, and public infrastructure conditions. All dimensions of vulnerability were assessed with respect to the susceptibility of the municipalities to climate-related hazards, such as landslide, storm surge, and flood.

Table 1. Categorization, description and sources of selected indicators (mostly adopted from Cutter et al., 2003).

Major Components/Factors	Determinants	Concept and Description	Sources
Sensitivity	Livelihood at risk	Occupation, etc.	H. John Heinz III Center for Science, Economics, and the Environment, 2000 Hewitt, 1997 Puente, 1999 R. C. Bolin, 1982
	Population at risk	Age, special needs population, population growth/density	Clark et al., 1998 (young and old people) Enarson & Morrow, 1998 (children) Morrow, 1999 (mental or physical disabilities)
Adaptive Capacity	Socioeconomic condition	Socioeconomic status, social dependence (access to social services)	Burton, Kates, and White, 1993 Hewitt, 1997 Puente, 1999 Morrow, 1999 H. John Heinz III Center for Science, Economics, and the Environment, 2000)
	Information and awaeness	Access to knowledge and information, level of awareness	Sietchiping, 2006 Cannon, 1994
	Infrastructure guidelines and services	Infrastructure and lifelines – access	H. John Heinz III Center for Science, Economics, and the Environment, 2000 Morrow & Philipps, 1999 Sietchiping, 2006
	Institutions and systems	Disaster risk reduction and management (DRRM) activities	Sietchiping, 2006 Cannon, 1994 Hammill, Bizikova, Dekens, & McCandless, 2013 Birkmann, 2006
	Climate-induced hazards	Susceptibility to floods, storm surges and landslides	Balica, Wright, & Meulen, 2012 Cannon, 1994 Hammill et al., 2013

Major Components/Factors	Determinants	Concept and Description	Sources
Exposure	Land tenure	Settlement	Balica et al., 2012 Hammill et al., 2013
	Housing materials	Housing and the built environment	R. Bolin & Bolton, 1986 R. Bolin & Stanford, 1991 Godschalk, Brower, & Beatley, 1989 Mitchell, Abdel-Ghaffar, Gentry, Leatherman, & Sparks, 1986 White & Haas, 1975
	Public infrastructure condition	Physical condition of infrastructure	Sietchiping, 2006 Hammill et al., 2013

The composition and size of each determinant varies in this study. While Cutter et al. (2000) used size-absolute numbers, Clark et al. (1998) used percentage values for each proxy to indicate vulnerability. The choice is arbitrary because both approaches are important when measuring vulnerability (Rygel, O'sullivan, & Yarnal, 2006).

Table 2. Ranking, units of measurement, functional relationship to vulnerability, and data sources of indicators.

Major Components/Factor	Determinants	Indicators and classifications/ranking		Unit	Functional relationship to vulnerability	Source
Senisitivity	Livelihood at risk	Proportion of HH engaged in fishing to total number of HH		%	↑	HH Survey
		Proportion of HH engaged in farming to total number of HH		%	↑	HH Survey
		Proportion of HH engaged in livestock raising to total number of HH		%	↑	HH Survey
		Proportion of HH engaged in wholesale/ retail to total number of HH		%	↑	HH Survey
	Population at risk	Population density		population/ha	↑	NSCB/2010 Governance Report
		Proportion of elders (>65 y.o.)		%		HH Survey
		Proportion of children (0-5 y.o.) -0-17		%		HH Survey
		Proportion of persons with disabilities		%		HH Survey
Adaptive capacity	Socioeconomic condition	Average number of assets (physical assets found in a typical house) per HH		#	↓	HH Survey
		Presence of income allocation for DRRM per HH	Yes	%	↓	Survey

Major Components/Factor	Determinants	Indicators and classifications/ ranking		Unit	Functional relationship to vulnerability	Source
Adaptive capacity	Socioeconomic condition	Proportion of household income sufficiency covering basic HH needs	Completely sufficient	Completely sufficient	↓	HH Survey
			Fairly sufficient	Fairly sufficient		HH Survey
			Partially sufficient	Partially sufficient		HH Survey
		Access to basic social services	Completely accessible	%		HH Survey
			Fairly accessible	%		HH Survey
			Limited	%		HH Survey
	Information and awareness	Presence of access to knowledge and info on natural hazards and disasters	Yes; Perception - frequency	%	↓	HH Survey
		Presence of evacuation mao/plan/route (municipal)	Yes; Perception - frequency	%		HH Survey
		Level of HH awareness on natural hazards	High	%		HH Survey
			Moderate	%		HH Survey
			Low	%		HH Survey
		Access to household knowledge on natural hazards in the area	Yes	%		HH Survey
		Presence of early warning system	Yes	%		HH Survey
	Infrastructure guidance and services	Guidance from local government on suggested housing materials	Yes	%	↓	HH Survey
		Accessibility and availability of facilities and utilities during calamities	Completely accessible	%		HH Survey
			Fairly accessible	%		HH Survey
			Limited	%		HH Survey
	Instuitions and systems	Barangay DRRM Committee institutionalizing	Awareness	%	↓	HH Survey

Major components/factor	Determinants	Indicators and classification/ranking		Unit	Functional relationship to vulnerability	Source
Adaptive capacity	Institutions and systems	River, dike embankment strengthening	Awareness	Frequency (#)	↓	HH Survey
		Presence of family preparedness and mitigation activities	Awareness	Frequency (#)	↓	HH Survey
		Presence of emergency medicine	Awareness	Frequency (#)	↓	HH Survey
		Presence of community organizing for preparedness and mitigation	Awareness	Frequency (#)	↓	HH Survey
		Presence of strengthening of bridges, water supply, electricity, etc.	Awareness	Frequency (#)	↓	HH Survey
		Presence of search and rescue	Awareness	Frequency (#)	↓	HH Survey
		Membership in local community DRRM organizations	Households with members participating in DRRM organizations	%	↓	HH Survey
Exposure	Climate-induced hazards	Landslide susceptibility	Very high	Ha	↑	UP DREAM YoRInfo Center
			High	Ha		
			Moderate	Ha		
			Low	Ha		
		Flood susceptibility	Very high	Ha	↑	UP DREAM YoRInfo Center
			High	Ha		
			Moderate	Ha		
			Low	Ha		UP DREAM
		Storm surge susceptibility	High	Ha	↑	
			Moderate	Ha		
			Low	Ha		HH Survey (adopted from Community - based Monitoring System)
	Land tenure	Land tenure stature status	Own house, rent-free lot without consent of owner	%	↑	

Major components/factor	Determinants	Indicators and classification/ranking		Unit	Functional relationship to vulnerability	Source
Exposure	Land tenure	Land tenure status	Rent-free house and lot without consent of owner	%	↑	HH Survey (adopted from Community - based Monitoring System)
			Rent house/ room including lot	%	↑	
			Own house, rent-free lot with consent of owner	%	↑	
			Rent-free house & lot with consent of owner	%	↑	
			Own house, rents lot (or government - owned lot)	%	↑	
			Ancestral domain/ inherited land	%	↑	
			Own house and lot (bought/ granted/ loaned)	%	↑	
	Public infrastucture regarding condition	Poor condition/in-need-of-repair nearest public elementary school	Respon-dents's perception	%	↑	HH Survey
		Poor condition/in-need-of-repair nearest public high school	Respon-dents's perception	%	↑	HH Survey

Abbreviations. DRRM = disaster risk reduction and management; HH = household; UP DREAM YoRInfo Center = University of the Philippines Disaster Risk and Exposure Assessment for Mitigation, Yolanda Rehabilitation Scientific Information Center

Construction of Social Vulnerability Index (SoVI)

The vulnerability index per municipality was derived using determinants representing exposure, adaptive capacity, and sensitivity adapted from the study supported by the Economy and Environment Program for South East Asia (Yusuf & Francisco, 2009), focusing on general aspects of social vulnerability as proposed by Cutter et al. (2009). The indicators under each major component were given equal weights relative to the number of determinants in that component. A balanced weighted approach (Hahn, Riederer, & Foster, 2009; Sullivan, Meigh, & Fediw, 2002) was used due to the arbitrary relationships between determinants. The components of vulnerability were assessed at the scale of 0 to 1 with equal weighting to all associated indicators.

Normalization

Indicators were normalized to a value between 0 and 1, multiplied by the assigned relative weights to generate the normalized indicator scores (Ii). The indicators were standardized using the methodology in calculating Human Development Index (UNDP, 2006) and using functional relationship with respect to vulnerability by judgment of the researchers.

$$Ii = \frac{X_i - MinX_i}{MaxX_i - MinX_i} \quad \text{for + functional relationship (1)}$$

$$Ii = \frac{MaxX_i - X_i}{MaxX_i - MinX_i} \quad \text{for - functional relationship (2)}$$

where X_i is the actual value, $MinX_i$ is the minimum value, and $Max\ X_i$ is the maximum value of the indicator

Ranking and Ordinal Weights

The maximum and minimum values for each municipality were used to convert the indicator to a normalized index so it could be incorporated into the components of the SoVI. For units such as the 'proportion of households who have limited access to basic social services,' the minimum value and the maximum value were set at 0 to 100, respectively, which represent percentage, and were standardized in a scale from 0 to 1. Ranks were assigned to certain indicators such as the 'area of level of hazard susceptibility' with values arranged in ordinal numbers, in which the weights were assigned such that all add up to 1. The value of the unit, in this case the area of susceptibility, is multiplied to the respective ordinal weights, such when combined add up to 1 (see example in Table 3). The area per level of susceptibility of each hazard was calculated using calculate geometry function of ArcGIS 10.2.

Table 3. Ranking and assignment of ordinal weights for storm surge vulnerability.

Level of storm surge susceptibility	Rank relative to vulnerability	Ordinal weight
High	1	0.5
Moderate	2	0.33
Low	3	0.167
	Total	1

The ordinal weight is computed as

$$Wr = \frac{r}{\sum_{k=1}^{n} r} \quad (3)$$

where *r* is the rank, *n* is the number of ranks, and *k* is 1.

The normalized indicator scores (I_i) were combined to generate the values of major components. The scores of the major components were weighted equally (Hahn et al., 2009; Sullivan et al., 2002) and added altogether for the SoVI which ranges from 0 to 1, such that higher values for the index imply higher vulnerability and lower values imply lower vulnerability for each municipality relative to each other.

SoVI was then calculated as follows:

$$SoVI_m = WsS_m + W_{AC}AC_m + W_E E_m \quad (4)$$

where *m* is the municipality, *S* is sensitivity, *AC* is adaptive capacity, and *E* is exposure; such that for municipality *m*, equals the equally weighted values of *S*, *AC*, and *E*. The weight of each indicator (W_i), where *i* is one of the indicators, is measured by 1 over the number (n_c) of the indicators in the component (See Table 5).

$$W_I = 1/\ n_I \quad (5)$$

Table 4. Weights of indicators.

Major Components	No. of indicators (n_I)	Weighr of indicators (W_I)
Sensitivity	8	0.125
Adaptive Capacity	20	0.050
Exposure	7	0.143

$$S = f(LAR,\ U,\ PAR) \quad (6)$$

where *LAR* is livelihood at risk, *U* is unemployment, and *PAR* is population at risk

$$AC = f(SEC,\ IA,\ IGS,\ IS) \quad (7)$$

where *SEC* is socioeconomic condition. *IA* is information and awareness, *I* is infrastructure guidance and services, and *IS* is institutions and systems

$$E = f(CH\ ,\ LT,\ HM,\ PIC) \quad (8)$$

where *CH* is climate-induced hazards (landslide, flood and storm surge), *LT* is land tenure, *HM* is housing materials and *P* is public infrastructure condition

Data Gathering

Sample Selection and Household Survey

The household survey collected data on socioeconomic conditions, household assets and access to social services, exposure and sensitivity, and adaptive capacity at the municipal level. The survey used a semi-structured questionnaire consisting of six sections: Respondent's Profile, Household Socioeconomic Information, Household Assets and Access to Social Services, Exposure, Sensitivity, and Adaptive Capacity.

A simple random sampling was used in selecting respondents across the barangays, which were identified based on their exposure to typhoon-related hazards, accompanying floods, and experiences from previous typhoon-related disasters as observed by the local government units. Twenty-six barangays in Tacloban, 31 in Ormoc, 6 in Palo, and 8 in Kananga were selected. Survey samples were randomly drawn at a 95% confidence level (Krejcie and Morgan, 1970) per municipality and distributed proportionally relative to the populations of the selected barangays (see Table 6). Households were selected through random walk method, adopted from the World Health Organization (WHO)'s Expanded Programme on Immunization (WHO, 2005).

Table 5. Household survey sampling distribution.

Municipality	No. of house-holds (NSO, 2010)	# of selected barangays	# of sample house-holds	Conficdence level (%)	Confidence interval
Tacloban	42,522	26	320	95	5.46
Palo	11,342	6	100	95	9.76
Kananga	9,706	8	100	95	9.75
Ormoc	38,299	31	250	95	6.18

Key Informant Interview

Representatives from national government agencies, regional government agencies, provincial local government officials, municipal departments, and chairpersons from concerned barangays were interviewed to cross-validate certain responses from the household surveys. Questions include functions of the respective agency with respect to disaster risk reduction and management (DRRM), social services, existing natural hazards, and institutional capacity. The questions varied depending on the functions and nature of the institution represented by the key informant. Representation was not comprehensive as some representatives were not available during the scheduled interviews.

Secondary Data

Secondary data included NSCB 2010 population data and geographic information systems (GIS) vector hazard datasets from the Department of Science and Technology-funded project Disaster Risk and Exposure Assessment Mitigation (DREAM) Program through the Yolanda Rehabilitation Scientific Information Center (YoRInfo Center). These data were used to calculate the areas per level of susceptibility of selected climate-related hazards. Available multiple inundation scenarios such as storm surge models and flood hazard maps were also utilized. These data used digital elevation models derived from Shuttle Radar Topography Mission, Global Digital Elevation Map, and Light Detection and Ranging, among others, as the topographic baseline for the various hazard and topographic maps.

Results and Discussion

Palo obtained the highest overall index of 0.3953 (see Table 7), influenced greatly by very high flood susceptibility and high storm surge susceptibility, low level of information and awareness of existing natural hazards, lack of DRR activities, and high level of livelihoods at risk. Tacloban, Ormoc, and Kananga have indices of 0.3796, 0.3272and 0.3249 (see Table 7 and Figure 2), respectively. A mean vulnerability index difference of 0.0443 among the study areas suggests that one area is almost as vulnerable others, particularly in terms of sensitivity and adaptive capacity. Large variations in hazard exposure (see Tables 7-9) were observed among the municipalities. Among three factors considered, adaptive capacity was found the most dominant factor of vulnerability in all municipalities (see Figure 2).

A relatively weak relationship was observed between the SoVI and the number of deaths from Typhoon Haiyan for each study area. Nevertheless, a decreasing pattern of SoVI and number of deaths from eastern to western municipalities was observed. This could be attributed to the distinct disaster response and management (adaptive capacities) and the varying levels of exposure of the study areas.

Table 6. Summary of index values of sensitivity (S), adaptive capacity (AC), exposure (E), and overall vulnerability (V) for Tacloban, Palo, Ormoc, and Kananga.

	S	AC	E	SoVI
Tacloban	0.0857	0.1533	0.1408	0.3797
Palo	0.0505	0.1636	0.1812	0.3953
Ormoc	0.0461	0.1565	0.1246	0.3272
Kananga	0.0472	0.1615	0.1162	0.3249

Sensitivity

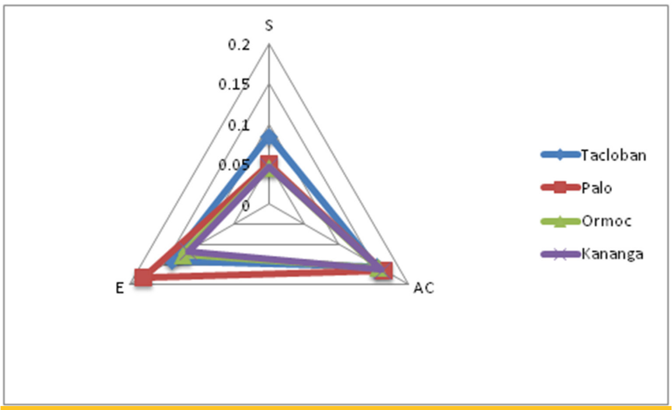

Figure 2. Vulnerability triangle diagram of the factors of social vulnerability index for Tacloban, Palo, Ormoc, and Kananga.

Tacloban scored the highest sensitivity at 0.2596 due to high number of population groups at risk. Palo scored the highest livelihood at risk at 0.0580, compared to Kananga, Tacloban, and Ormoc. Palo's primary livelihood is agriculture-based particularly livestock raising, and rice and coconut production which are highly sensitive to climate-related hazards.

Ormoc, the most sensitive in terms of unemployment, scored 0.0853 due to high unemployment rate. With regard to population at risk, Tacloban is the most densely populated and almost half of Ormoc's population is comprised of children below 15 years old. The highest persons at risk score was 0.1453 gathered by Tacloban.

Adaptive Capacity

Kananga scored the highest in adaptive capacity at 0.4892, followed by Palo at 0.4877. Palo obtained the highest scores in terms of information and awareness and institution and system at 0.11735 and 0.13008, respectively. As for income, Kananga scored 0.0404, with most of the respondents claiming that their household income was only partially sufficient for their families' needs. Concerning information and awareness, Palo got the highest score of 0.1376, due to consistent highest scores in most sub-indicators. On having guidance from LGU regarding housing materials, Kananga has the highest score of 0.0818.

Palo scored the highest on institutions and systems at 0.1300, with 41% of the respondents claiming the institutionalization of DRRM committees, 12% participating in DRRM activities, and 75% being aware of the early warning systems.

Exposure

Palo gathered a standout combined score of 0.5492 and consistently got high scores in almost all the indicators, suggesting that it is the most hazard-prone and physically exposed among the study areas. Kananga acquired the lowest score. As for climate-related hazards, Palo got the highest score of 0.2443 with the highest score in flood susceptibility index (see Figure 3 and Table 8).

Tacloban has the highest landslide and storm surge susceptibility with index values of 0.0875 and 0.0999, respectively. These numbers could be attributed to the topography and location of the study sites, such as the mountain range that stretches from the western part of Tacloban down to Palo. In particular, 9.13% of Tacloban's land area has very highly susceptibility to landslide, while roughly 2.33% has very high flood susceptibility. Palo serves as the catch basin of the water runoff from Tacloban, and has only 2.9% high susceptibility to landslide but 4.8% very high susceptibility to flood. Kananga is also a mountainous municipality having 3.76% very high landslide susceptibility. Even if it is landlocked, eliminating the possibility of a storm surge event, it has 3.3436% very high flood susceptibility due to the Pagsangaan River within its boundary.

In terms of flooding, Tacloban has 8.65% very high susceptibility, Palo has 7.43%, and Ormoc has 3.41%. Among the studied coastal communities, Ormoc experiences frequent flooding due to the occasional overflow of Anilao River.

In terms of land tenure, household survey results showed that Ormoc has the highest score of 0.3821, where 57% do not have their own houses and even 32% could be considered informal settlers. As for housing materials, Tacloban was an outlier with 0.04843 due the significant number of households living in makeshift housing. As for the condition of nearest public schools used as evacuation centers during disasters, 67% of respondents in Palo believed that the nearest public elementary school is in need of repair while 59% of respondents in Tacloban felt the same for the nearest public high school.

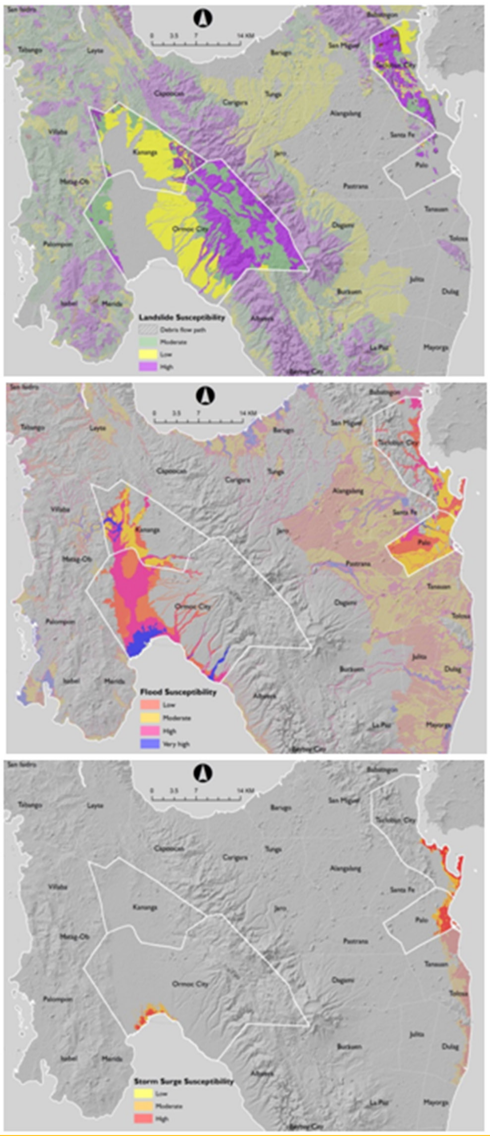

Figure 3. Landslide, flood and storm surge susceptibility maps of study areas (Vector data source: DREAM YoRInfo Center, 2014).

Table 7. GIS computed areas (ha) of landslide susceptibility.

	Very High	High	Moderate	Low
Tacloban	9.1625	4.0835	1.4426	1.6465
Palo	0	2.9022	8.8047	3.778
Ormoc	0	1.6675	1.7526	8.6346
Kananga	3.7632	1.54433	2.7608	5.8692

Table 8. GIS computed areas (ha) of flood susceptibility.

	Very High	High	Moderate	Low
Tacloban	2.3326	1.156	1.2625	1.6375
Palo	4.8077	7.9002	3.3946	1.6469
Ormoc	2.8033	6.6638	5.1567	2.6876
Kananga	3.3436	1.4167	2.6404	8.9146

Table 9. GIS computed areas (ha) of storm surge susceptibility.

	High	Moderate	Low
Tacloban	8.56	3.7727	3.1842
Palo	7.4345	4.4083	2.3075
Ormoc	3.4119	5.1517	9.23
Kananga	0	0	0

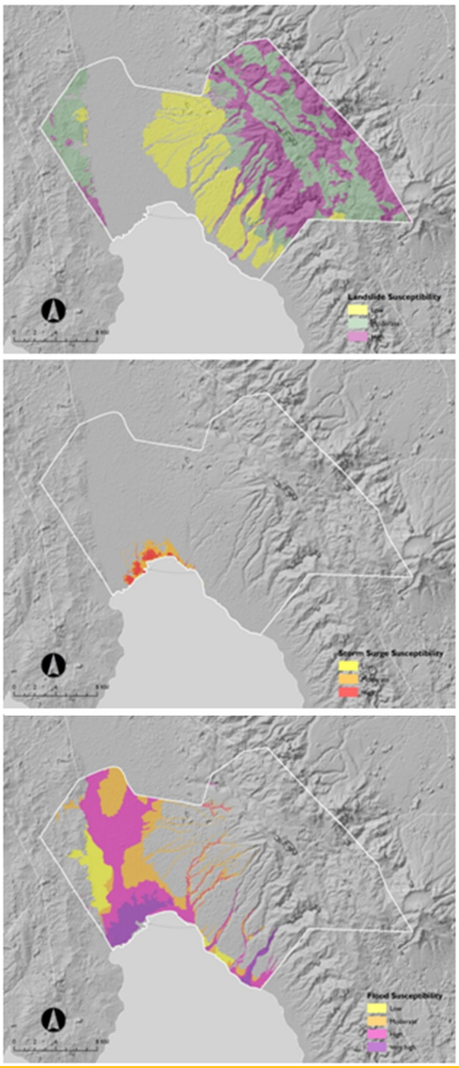

Figure 4. Flood, landslide and storm surge susceptibility maps of Ormoc City (Vector data source: DREAM YoRInfo Center, 2014).

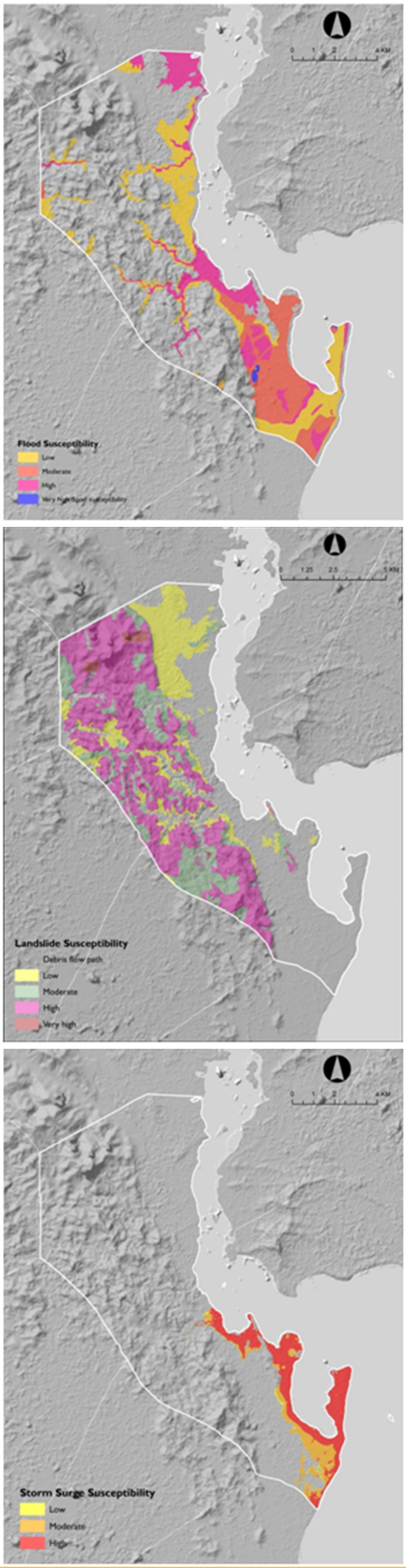

Figure 5. Flood, landslide and storm surge susceptibility maps of Tacloban City (Vector data source: DREAM YoRInfo Center, 2014).

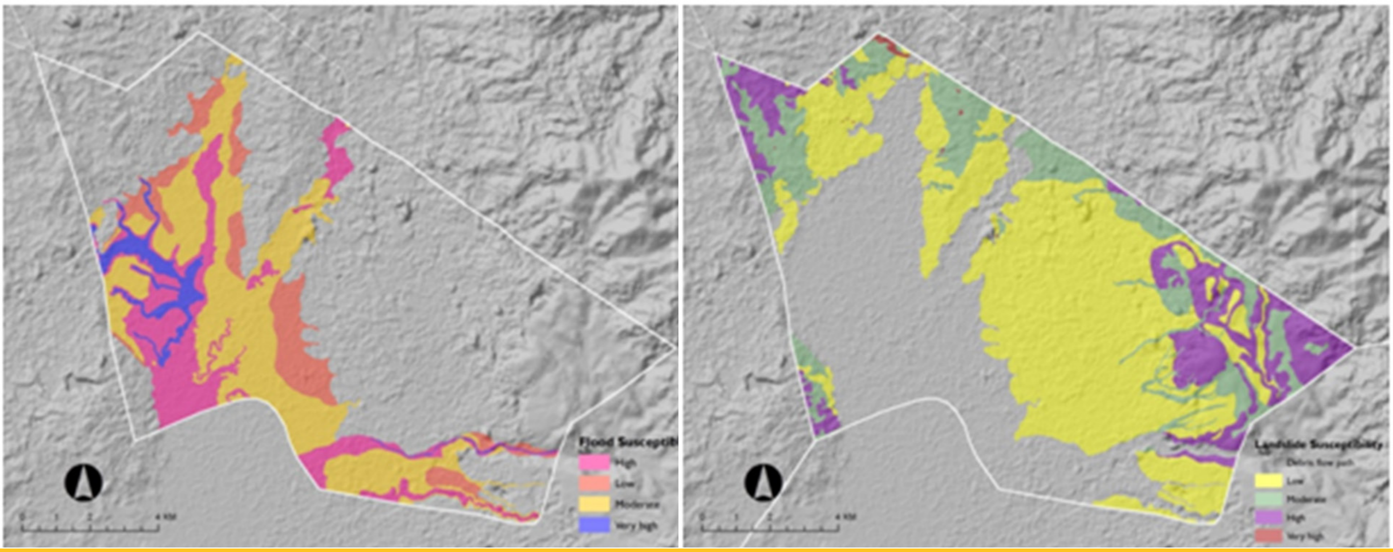

Figure 6. Flood and landslide susceptibility maps Municipality of Kananga (Vector data source: DREAM YoRInfo Center, 2014).

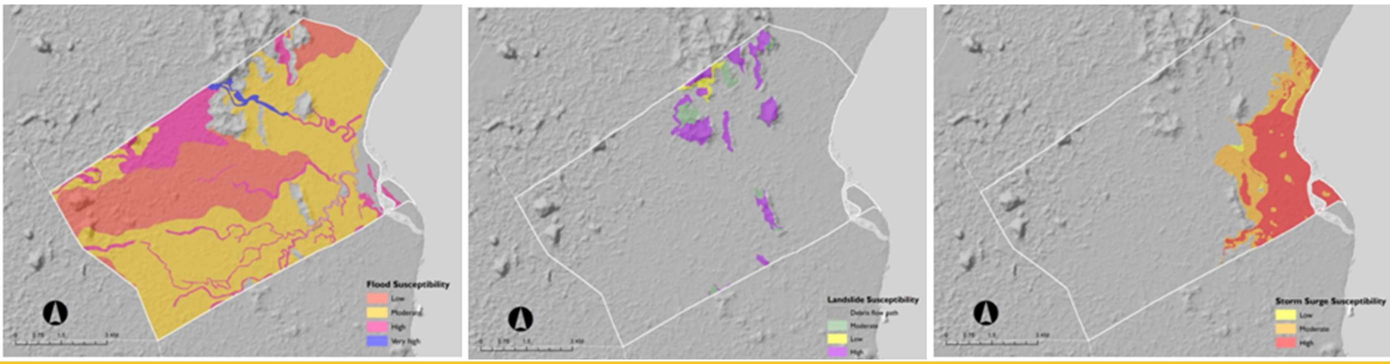

Figure 7. Landslide, flood and storm surge susceptibility maps of Municipality of Palo (Vector data source: DREAM YoRInfo Center, 2014).

Social Vulnerability and Haiyan Deaths

An increasing pattern of SoVI and number of deaths from western to eastern municipalities was observed (see Figure 10), which could be attributed to higher hazard exposure in the eastern municipalities. There are mountain ranges in the eastern portion of Leyte Island, making Tacloban and Palo more prone to landslides and at the same time barring Ormoc and Kananga from intense storms from the east seas. The storm surge brought about by Typhoon Haiyan had a devastating impact in Tacloban and Palo where most of the casualties (see Table 10) and damages were recorded. Although Kananga has slightly higher percentage of deaths than Ormoc, the number of casualties in the western part of Leyte was lower relative to that in the east. Deaths in Ormoc and Kananga were mostly due to strong winds.

Based on the hazard susceptibility maps (see Figures 4 to 7), the eastern plains have larger areas with hazard susceptibility. Haiyan devastated most of the east coast of Samar and Leyte. The death toll at the eastern coast was high because there are no hills providing protection for the residents of densely populated areas (GIZ, 2014). The presence of any topographical barriers such as mountain ridges reduces the intensity of tropical cyclones in coastal areas located on the leeward side, making coastal areas on the windward side of a tropical cyclone more exposed to storm surges (Lee & Wong, 2007). Generally, topographic factors contribute to depth and extent of flooding from storm surge (Lapidez et al., 2014)

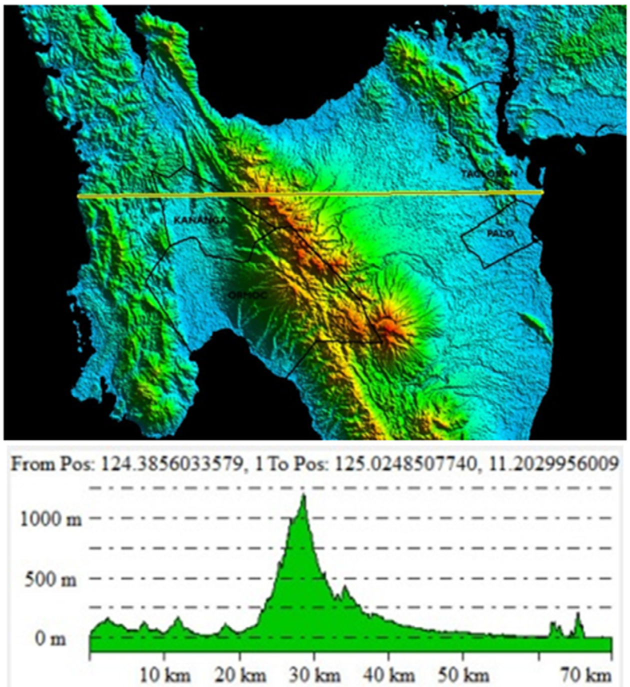

Figure 8. Shuttle Radar Topography Mission (SRTM) digital elevation model (DEM) of northern part of Leyte with west-east elevation profile.

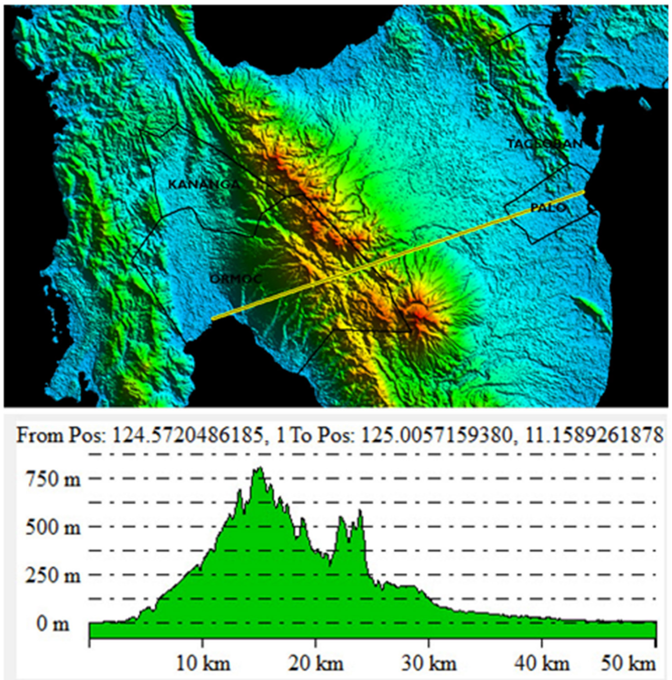

Figure 9. Shuttle Radar Topography Mission (SRTM) digital elevation model (DEM) of northern part of Leyte with southwest-east elevation profile.

Table 10. Estimated percentages of Haiyan casualties and SoVI for Tacloban, Palo, Ormoc and Kananga.

Municipality	Estimated Casualties[a]	Population[b]	Percentage (%) of casualties (over population)	SoVi
Tacloban	2,671	221,174	1.21	0.3797
Ormoc	37	191,200	0.02	0.3272
Palo	1,410	62,727	2.25	0.3953
Kananga	24	48,027	0.05	0.3249

[a]as of April 23, 2014, according to Post Disaster Needs Assessment in TY Yolanda Affected Areas (NDRRMC, 2014a); [b]National Statistics Office, 2010

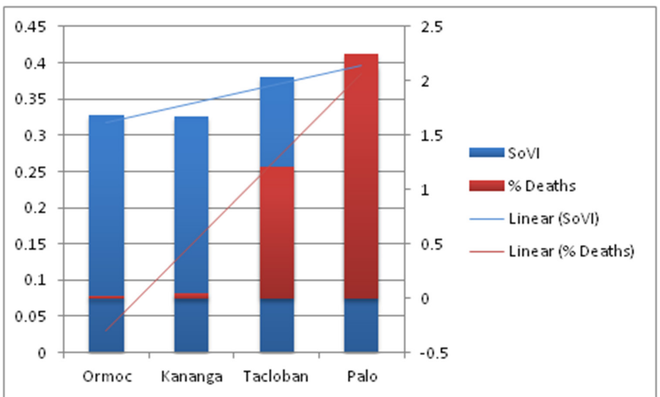

Figure 10. Clustered columns and trend line illustrating the link between and increasing pattern for SoVI and percentages of deaths from Ormoc and Kananga (west) to Tacloban and Palo (east).

Conclusion

While social vulnerability assessment using SoVI encompasses the analysis of intricate socio-demographic, economic, and institutional systems, the results of the assessment should be regarded as a condition rather than as an effect. The study sites are vulnerable to the potential impacts of disasters because of the prevalent living conditions in their area such as rampant makeshift houses, high population, and high poverty incidence. It is not the other way around where the previously-mentioned conditions are the result of their high vulnerability.

There were minimal differences in the SoVI values among the study areas with a mean differential value of 0.04430, which suggests that one is almost as vulnerable as the others. Among three factors considered, adaptive capacity was found to be the most dominant factor of the computed vulnerability, consistently scoring high among all the indicators. This suggests that increasing adaptive capacity should be prioritized. Overall, the vulnerability sub-indicators that scored high were as follows: high flood susceptibility and high storm surge susceptibility, low level of information and awareness, lack of DRR activities and high level of livelihoods at risk. A relatively weak association was observed between the SoVI and the number of deaths from Typhoon Haiyan for each study area. Nevertheless, an increasing pattern of SoVI and number of deaths from western to eastern municipalities was observed, likely due to higher hazard exposure in the eastern municipalities and the topographic barrier in the center of Leyte Island that weakened Typhoon Haiyan as it approached the western portion of the province.

Despite the apparent limitations in how the SoVI was used in this study as a measure of social vulnerability, it is evident that SoVI could be a useful tool for identifying potential interventions for increasing adaptive capacity and reducing vulnerability of a particular area. The assessment of vulnerability to similar extreme events using SoVI could be improved by considering more indicators to complement the data on the perceptions of household individuals, census data, and available climate-related hazard datasets.

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