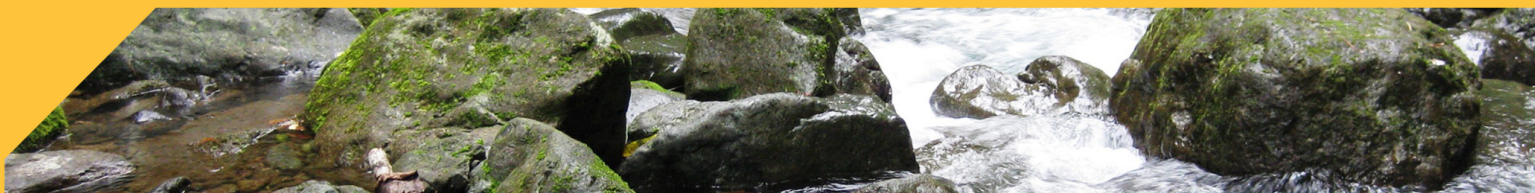


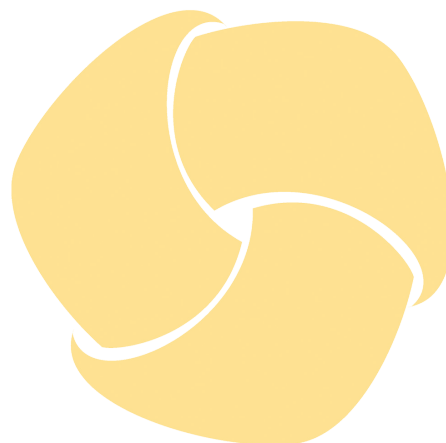


Climate,
Disaster and
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Journal

Open access peer-reviewed papers

Volume 1 Issue 1 January 2016
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Aims and Scope

The Climate, Disaster and Development (CDD) Journal aims to publish peer-reviewed, original research on all aspects and intersections of climate, disasters and development and their interaction. As policy makers, development workers and the general public become more keenly aware of the rising risks posed by climate hazards and disasters and their impacts on national development, the journal provides a forum for the presentation of recent research findings on these topics and their management implications. It is not only for researchers, but for anyone concerned with national development amidst climate risks and disasters.

CDD Journal is a project of the Oscar M. Lopez Center for Climate Change Adaptation and Disaster Risk Management Foundation, Inc., (OML Center) a non-stock, non-profit organization based in the Philippines. The Center is dedicated to promote a resilient society, able to cope and prosper in the midst of climate-related risks and disasters by generating science-based solutions in the area of climate change adaptation and disaster risk management.

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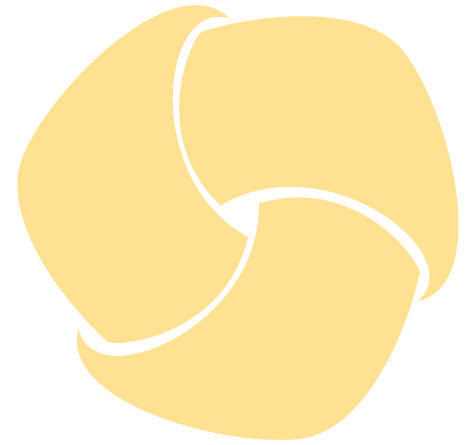


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Note from Editors

Typhoon Haiyan (locally known as Typhoon Yolanda), which devastated portions of Southeast Asia particularly the Philippines, was one of the strongest tropical cyclones ever recorded. In the Philippines alone, it caused more than 6,000 deaths and induced an estimated \$750 million (PhP 36 billion) worth of damages. Even after two years since the tragedy, the survivors are still struggling to recover from one of the deadliest Philippine typhoons on record. The calamity served as an eye-opener for the Filipinos and the world to learn—the hard way—the importance of climate change adaptation and disaster preparedness.

Many organizations stepped up to support the revitalization of typhoon-stricken regions. Different pillars of society, including the scientific community, have been striving to address the need to generate and share knowledge on climate science and disaster risk management. The Oscar M. Lopez Center for Climate Change Adaptation and Disaster Risk Management Foundation Inc. (OML Center), in solidarity with the scientific community, the Filipino people, and all the communities being faced by climate and disaster risks, has been conducting studies to support the development of evidence-based and innovative solutions that could help in post-Haiyan recovery efforts as well as promote sound development planning.

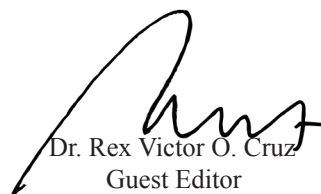
The Climate, Disaster and Development Journal (CDD) Journal is part of the OML Center's efforts to build climate resilient communities. It was conceived to address the insufficient number of open access journals focusing on climate science and disaster risk management in the Asia-Pacific. It also provides a venue to bring the huge number of unpublished studies in the Philippines and other developing countries to a wider audience. The journal aims to:

- Engage researchers in building a body of knowledge on climate, disaster and development by providing and maintaining a system of collecting, reviewing and publishing scientific findings;
- Facilitate a process of producing International Scientific Indexing - standard publication on climate, disaster and development research; and
- Ensure usefulness of the research findings on climate, disaster, development and their interactions and management implications through an open-access platform.

With this, the maiden issue of CDD Journal presents on-the-ground findings of the research work conducted in the Haiyan-affected areas and communities. We dedicate this issue to the survivors of Typhoon Haiyan and to those individuals and groups who engaged and are continually making huge efforts in supporting the recovery efforts. We are truly hoping that our little contribution may help in creating climate resilient communities. May this maiden issue and future papers to be published benefit researchers, scientists, faculty, students, policy-makers and anyone concerned with development amidst climate risks and disasters locally and internationally.



Dr. Rodel D. Lasco
Editor-in-Chief



Dr. Rex Victor O. Cruz
Guest Editor



Ms. Perlyn M. Pulhin
Managing Editor

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Vegetation resistance and regeneration potential of *Rhizophora*, *Sonneratia*, and *Avicennia* in the Typhoon Haiyan-affected mangroves in the Philippines: Implications on rehabilitation practices

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Abstract

Typhoons cause damage to mangrove ecosystems, hampering the delivery of ecosystem goods and services, including coastal protection. We examined the vegetation resistance (VR) and seedling regeneration potential (SRP) of three mangrove genera: *Rhizophora*, *Sonneratia*, and *Avicennia* at the seafront areas. We assessed genus-specific resistance to and recovery from the impacts of Typhoon Haiyan, by far the strongest storm to make landfall in recorded history. VR was estimated using density, tree height, and diameter at breast height (DBH). SRP was measured as the post-disturbance seedling growth rate within a given plot. Thirty-six 3-m radius plots were established in the typhoon-affected mangrove areas of Ormoc City and Tacloban City in Leyte; and Quinapondan and General MacArthur in Eastern Samar. Results showed that *Avicennia* and *Sonneratia* species yielded the higher average VR values compared to *Rhizophora*, which had the lowest VR across all sites. The different genera could also be arranged from highest to lowest SRP: *Avicennia* ($67.27 \pm 2.62 \text{ cm yr}^{-1}$) > *Rhizophora* ($32.46 \pm 4.64 \text{ cm yr}^{-1}$). Overall, our findings on the higher relative VR and SRP values of *Sonneratia* and *Avicennia* call for a shift to these species in mangrove planting at the seafront areas, which currently favor *Rhizophora*.

Keywords: Typhoon Haiyan · seedling recruitment · vegetation resistance · mangrove restoration

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Introduction

Mangrove ecosystems provide numerous ecosystem goods and services to local communities (Polidoro et al., 2010). Coastal protection ranks as the most valuable ecological services that mangrove ecosystems provide (Barbier et al., 2010). During typhoons, storm surges, and tsunamis, mangroves serve as the first line of defense by absorbing the wave energy brought about by these disturbances (McIvor, Spencer, Moller, & Splading, 2012; Tanaka, 2009). Mangrove cover stretching at least one kilometer from the coastline can attenuate wave height by at most 50 cm (Zhang et al., 2012).

However, worldwide mangrove cover continues to decline, and most prominently in Southeast Asia (Polidoro et al., 2010). Mangrove cover in the Philippines, for example, has devolved from huge contiguous blocks into small, scattered patches. Therefore, there is a need to evaluate the protective function and the capacity to recover of existing mangroves in such conditions.

Typhoon Haiyan (local name: Yolanda) hit the Philippines on November 8, 2013, passing through the islands of Samar, Leyte, Cebu, Panay, and Coron. Haiyan was considered the strongest recorded storm in recent years, bearing wind speeds of 315 kph (Lagmay et al., 2014). Consequently, it generated storm surges as high as 5-6 meters (Mori et al., 2014) in Tacloban City. The typhoon disturbed mangrove ecosystems at varying degrees, causing leaf defoliation, stem breakage, uprooting and mortality (Salmo III, Lovelock, & Duke, 2014; Sherman, Fahey, & Martinez, 2001).

The study evaluated the resiliency of mangrove stands dominated by three mangrove genera: *Rhizophora*, *Sonneratia*, and *Avicennia*. The study also identified wave resistant and quick-recovering mangrove species. The identification of these resilient mangrove species guide priorities for mangrove rehabilitation and protection.

Materials and Methods

Study Sites

The study sites are the Typhoon Haiyan-disturbed mangrove forests of Tacloban City and Ormoc City in Leyte; and Quinapondan and General MacArthur in Eastern Samar, where storm surges and strong winds were the primary cause of mangrove damage. The degree of damage varied across all sites and may be attributed to their geographical location and forest cover. The survey was done during the period of May-June 2014, approximately six to seven months after Typhoon Haiyan.

The mangroves in Tacloban City come in small patches and are often situated within an immediate community. In Barangay 83-A, Tacloban City, the mangrove cover is dominated by 25-year old planted *Rhizophora apiculata* stands, and natural growth of *Avicennia marina*. Further inland are *Nypa fruticans* that are being harvested by the communities for shingles.

The mangrove forest in Ormoc City is situated in the western portion of Leyte province. The site covers a vast expanse of mangrove cover but it is being encroached on by fishpond operators. Along the seafront are natural stands of *Rhizophora*, *Sonneratia*, and *Avicennia* species while further inland are covered with nipa and coconut plantations. The said area is co-managed actively by the local government and the local community.

The mangrove study site in Quinapondan and General MacArthur is part of an intact and continuous coastal greenbelt along the coast of Matarinao Bay. Along the seafront are predominantly *Rhizophora*, *Sonneratia*, and *Avicennia* species, with occurrences of *Bruguiera* and *Aegiceras* species. Further inland are the genus *Lumnitzera*, *Bruguiera*, *Xylocarpus*, and *Camptostemon* species, making the said site the most diverse among other study sites. Plots within this study site had sightings of mature trees characterized by large stem diameter, and propagules and fruits larger than their average sizes. Thirty-six circular plots at 3-m radius were established on the selected Typhoon Haiyan-affected natural growth mangroves. The plots were situated in Tacloban City and Ormoc City in Leyte and, General MacArthur and Quinapondan along the Matarinao Bay coastline in Eastern Samar (see Figure 1).

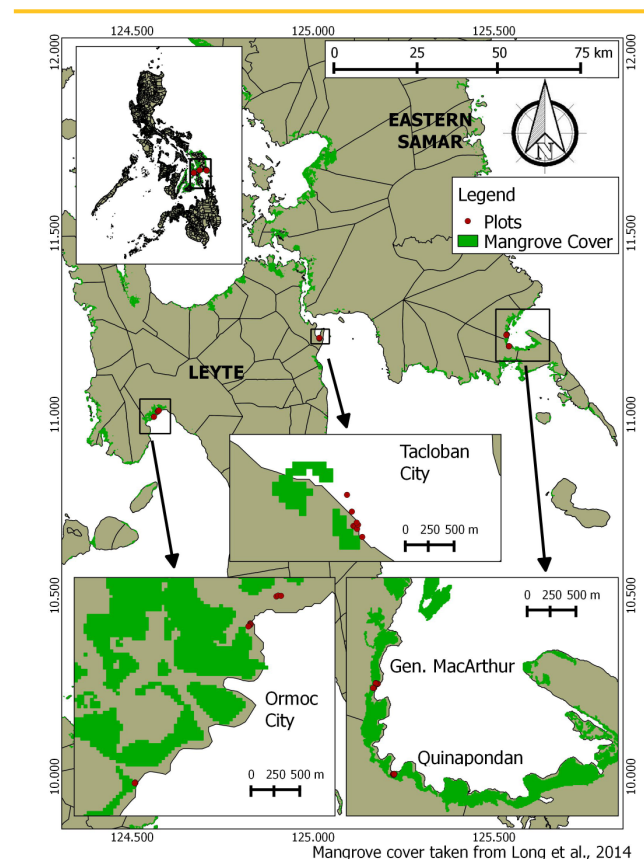


Figure 1. Map of the selected cities and municipalities as sampling sites of the study. Site selection considered the different geographical locations and the extent of mangrove area to cover the different characteristics of the mangrove sites of the region. Zoomed images indicate the location of the plots along the identified study sites (mangrove area taken from Long, Napton, Giri, & Graesser, 2014).

The sites were selected according to their geographical location, mangrove cover extent and how they were affected by the impact of Haiyan. The plots were established haphazardly within the seafront areas. The study did not consider seafront areas near rivers to maintain similarity of sampling plots. At least eight plots were selected per municipality. Variations observed between sites may provide information pertinent for the restoration of mangrove ecosystems. Table 1 summarizes the basic information on the mangroves and on the physico-chemical characteristics of the study sites.

Table 1. Basic information on the mangrove forests of the study sites.

Site	Size (ha) ^a	No. of Plots	Salinity (%)	Typhoon Impact	Inundation (m)	Substrate
Tacloban	125	8	24 ± 1.58	Storm Surge	0.34 ± 0.06	Muddy
Ormoc	1,463	12	25 ± 2.17	Wind	0.51 ± 0.07	Muddy
Quinapondan	1,085	8	32 ± 2.21	Wind	0.42 ± 0.04	Muddy
Gen. MacArthur	425	8	30 ± 3.75	Wind	0.30 ± 0.10	Sandy-Muddy

^a Long et al., 2014

Vegetation Resistance

In trees within the plot, circumference at breast height (CBH) and tree height (H) were measured. The CBH is then translated to its diameter at breast height (DBH) value assuming that the trunk cross-section is circular. The trees were identified through the mangrove identification guide by Primavera et al. (2004). Tree density per plot was also recorded. At least 30 mangrove trees belonging to the same genus across the sampling sites were tagged and used to determine vegetation resistance. Mangroves monitored with less than 30 tags were disregarded. Only mangroves with intact stem and root systems were tagged to capture pre-typhoon information from the said selected mangrove species.

The equation for determining the vegetation resistance (VR) was derived from Bayas et al. (2011), that is:

$$VR = H * DBH^2 * d \quad (1)$$

where *H* refers to the vegetation height (m), *DBH* (m) and, *d* corresponds to the vegetation density (number of individuals per hectare). The root systems were taken in consideration to measure *VR*. Similar to the trees, the prop roots and pneumatophores were counted as though they were individual plants. Thus, their respective diameters at ground level and heights were considered in the estimation of the root contribution to the *VR*.

Generating *VR* can determine the ability of mangroves belonging to a particular genus to resist wave impacts. The *VR* values only reflect the resistance of a collective group of trees belonging to the same genus in a given area. However, the estimation of *VR* values do not consider the drag from the sediments, which also contribute to reducing surge impacts (Zhang et al., 2012). The estimated *VR* values were aggregated

according to genus in order to derive a genus-specific *VR*. Analysis of variance (ANOVA) was used to compare variations between sites and with respect to zonation within a given site. Prior to the ANOVA, normality and heterogeneity tests were done. Tukey's honest significant difference (HSD) was used for post hoc test.

Seedling Recruitment and Growth

Seedling recruitment and growth rates are important in assessing the regeneration of an impacted mangrove ecosystem (Duke, 2001). Seedling density was monitored by counting the seedling recruits on the established 3-m radius plots, then converting the count into a per hectare unit.

Seedling growth was surveyed through counting of plastochron interval and measuring the seedling height. Analysis of seedling growth according to its genus was done by deriving the annual growth rate, further derived by multiplying the total number of internodes per year to the observed intermodal length. The recorded growth shall be the seedling regeneration potential (SRP) of a certain mangrove genus. Since the survey was done post-typhoon, we determined those seedlings that survived the impact of Typhoon Haiyan through the estimated time of internode formation as derived from Duarte et al. (1999) and Samson and Rollon (2008). Multiplying the number of internodes to the estimated number of days for the formation of one internode shall provide an estimate on how old the seedlings were. Seedlings with age estimates of at least 210 days were likely to have survived the impacts of Typhoon Haiyan and those aged less than 210 days were seedling recruits after the typhoon.

Variations of the tagged seedlings were assessed through ANOVA using the statistical software, R (R Core Team, 2014). Prior to ANOVA, heterogeneity and normality tests were done.

Results

Vegetation Resistance

Variations in the species composition were observed among the four mangrove sites. However, species belonging to the genus *Rhizophora* (n=135), *Sonneratia* (n=46), and *Avicennia* (n=177) dominated the mangrove stands of Leyte and Eastern Samar. Particularly, most of the seafront species identified were *Rhizophora apiculata*, *Sonneratia alba*, and *Avicennia marina*. Table 2 summarizes the estimates of the monitored height and DBH, and of the derived *VR* values.

The average density of the mangroves did not have a significant difference in the study sites. However, the average density of the mangroves in Quinapondan and General MacArthur was higher compared to those in Tacloban City and Ormoc City, but the difference is not significant. Mangrove heights were not significantly different across sites except in Quinapondan ($P < 0.01$).

DBH values yielded significant differences in mangrove genus across all sites. *Rhizophora* species had lower DBH

Table 2. The average density, tree height, DBH and VR of selected seafront mangrove genus for every study site. Results show that VR values of *Rhizophora* are lower compared to that of *Sonneratia* and *Avicennia* species, across all sites. Superscript letters indicate significant differences from the Tukey HSD derived from ANOVA. The two variables that do not share the same superscript letter are significantly different statistically.

Mangrove Genus	Density (nha ⁻¹)	Height (m)	DBH (m)	VR (cm ³ ha ⁻¹)
Tacloban City				
<i>Rhizophora</i>	2,986 ± 128	3.88 ± 0.23	0.048 ± 0.004 ^a	34 ± 9 ^a
<i>Avicennia</i>	2,925 ± 219	4.44 ± 0.69	0.098 ± 0.004 ^b	184 ± 48 ^b
Df	1	1	1	1
MS	975,882	0.7962	0.006557	57136
F	0.697	0.885	61.05	16.01
P	ns	ns	***	**
Ormoc City				
<i>Rhizophora</i>	2,713 ± 279	8.43 ± 1.77	0.069 ± 0.014 ^a	129 ± 46 ^a
<i>Avicennia</i>	2,528 ± 425	10.63 ± 0.55	0.152 ± 0.035 ^b	655 ± 258 ^b
Df	1	1	1	1
MS	72,206	10.175	0.0146	580283
F	0.196	1.472	5.998	3.855
P	ns	ns	*	*
Quinapondan				
<i>Rhizophora</i>	3,229 ± 441	4.07 ± 0.52 ^a	0.045 ± 0.006 ^a	32 ± 9 ^a
<i>Sonneratia</i>	3,539 ± 478	7.54 ± 1.16 ^b	0.116 ± 0.006 ^b	342 ± 20 ^b
<i>Avicennia</i>	3,539 ± 518	7.42 ± 1.20 ^{ab}	0.129 ± 0.015 ^b	372 ± 48 ^{ab}
Df	2	2	2	2
MS	191,691	23.685	0.011048	201517
F	0.096	5.828	0.096	8.181
P	ns	*	**	**
General MacArthur				
<i>Rhizophora</i>	3,438 ± 480	4.64 ± 0.31	0.069 ± 0.0008 ^a	70 ± 11 ^a
<i>Sonnerati</i>	3,303 ± 236	5.40 ± 0.59	0.140 ± 0.017 ^b	372 ± 118 ^b
Df	1	1	1	1
MS	3,849	1.2267	0.0106	191649
F	0.03	1.642	18.02	17.3
P	ns	ns	**	**

Abbreviations. DF=degrees of freedom, MS=mean of squares, F=F value; P=P value; ***P < 0.001, **P < 0.01, *P < 0.05

values than *Sonneratia* species in Quinapondan and General MacArthur (DBH= 0.116 ± 0.006 m and 0.140 ± 0.017 m, respectively). The DBH of *Rhizophora* species were likewise smaller than *Avicennia* species in Tacloban City, Ormoc City, and Quinapondan (DBH= 0.098 ± 0.004 m, 0.152 ± 0.035m, and 0.129 ± 0.015m, respectively).

Vegetation resistance values yielded significant differences among mangroves across the study sites. In Quinapondan and General MacArthur, the VR values of *Rhizophora* species (VR = 32 ± 9 cm³ ha⁻¹ and 70 ± 11 cm³ ha⁻¹, respectively) were significantly lower as compared to *Sonneratia* species (VR = 342 ± 20 cm³ ha⁻¹ and 372 ± 118 cm³ ha⁻¹; P < 0.01 and P < 0.05, respectively). In Tacloban City and Ormoc City, VR values of *Rhizophora* species were significantly lower (VR = 34 ± 9 cm³ ha⁻¹ and 129 ± 46 cm³ ha⁻¹, respectively) as compared to *Avicennia* species (VR = 189 ± 49 cm³ ha⁻¹ and 655 ± 258 cm³ ha⁻¹; P < 0.05 and P < 0.01, respectively).

Regeneration Potential

Accounts from key informants from all the municipalities revealed that total defoliation of mangroves occurred

immediately after the impact of Typhoon Haiyan. The rate of refoliation was noted to be faster in denser, more intact mangroves as compared to mangroves with smaller vegetation cover. Figure 2 illustrates the different conditions of mangrove stands across all the study sites.

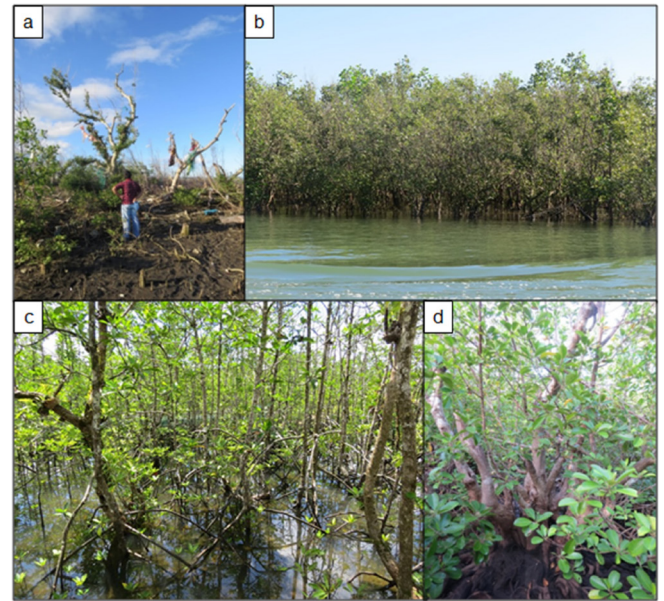


Figure 2. Condition of the mangroves in the study sites six months after Typhoon Haiyan (Yolanda): (a) the mangroves of Tacloban were badly damaged; (b) Ormoc mangroves having intact stand showing refoliation; and (c) Quinapondan and (d) General MacArthur having recovered mangrove stands.

The Tacloban mangroves (Figure 2a) were severely affected by Haiyan. Six months post-typhoon, the planted *Rhizophora* stands remain defoliated, indicating two possibilities: dead vegetation or delayed mortality. However, natural stands behind the *Rhizophora* zone dominated either by *Sonneratia* or *Avicennia* species withstood the typhoon impact. Moreover, these *Sonneratia* or *Avicennia* species exhibited refoliation and coppice on broken stems and trunks, indicating signs of recovery after the typhoon impact. In Ormoc (Figure 2b), Quinapondan (Figure 2c), and General MacArthur (Figure 2d), signs of vegetation regrowth were visible through refoliation. The coppice of existing mangrove stands, particularly on the *Sonneratia* and *Avicennia* species for the dominant mangrove stands, provide further evidence of regrowth. Among the study sites, the mangroves of Quinapondan and General MacArthur along the Matarinao Bay coastline exhibited faster vegetation regrowth.

Regrowth of affected mangroves appeared to be genus-specific as well. The *Rhizophora* species situated at the low elevation or foreshore area had higher mortalities as compared to the other mangrove species (see Figure 3a). Based on the refoliation, we surmised that a majority of the planted *Rhizophora* mangroves in Tacloban have not recovered. *Sonneratia* and *Avicennia* species, on the other hand, have started refoliating and coppicing six months post-Haiyan. Furthermore, we have observed site-dependent seedling recruitment rates among

different Haiyan-affected areas. The dominant seedling recruits were non-*Rhizophora* species. Particularly in Tacloban, we have verified that most of the seedling recruits were from the species *Avicennia marina*.

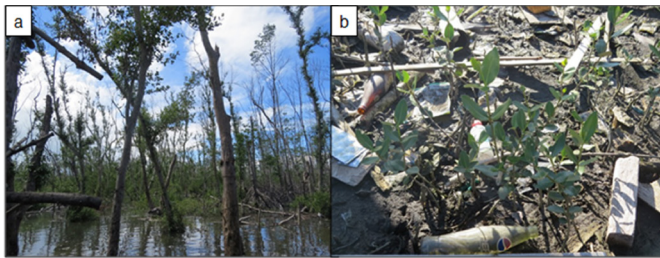


Figure 3. Images of mangrove regrowth indicators within species with (a) *Sonneratia* and *Avicennia* species showing leaf refoleation and coppice in Ormoc City. (b) In Tacloban, the visible seedling recruits were *Avicennia marina*.

Seedling density showed that *Avicennia* species had the most seedling recruits six months after Typhoon Haiyan in Tacloban, Ormoc, and Quinapondan. Seedling recruits in General MacArthur showed diversity as it had seedling recruits of *Bruguiera* and *Aegiceras* species. *Sonneratia* species had one seedling recruit recorded in Quinapondan. Figure 4 summarizes the seedling density six months after Typhoon Haiyan.

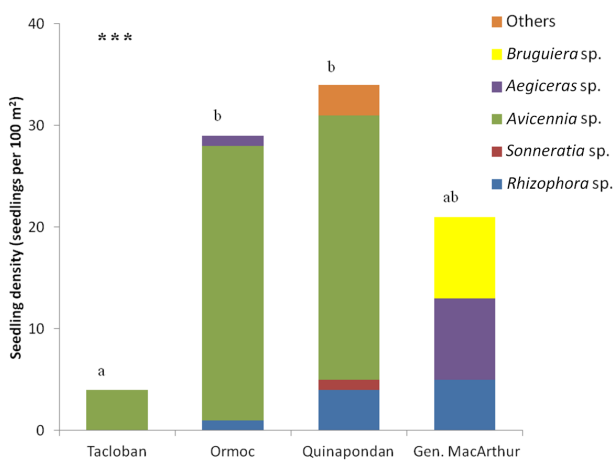


Figure 4. Seedling density of mangroves arranged according to genus type on all study sites. Seedling recruits showed the prevalence of *Avicennia* species across all sites except for Gen. MacArthur, which had a more diverse and even set of recruits. Letters above bars indicate significant differences based from Tukey HSD (***) $P > 0.0001$.

There were 31 and 159 tagged seedlings for *Rhizophora*, and *Avicennia*, respectively. *Sonneratia* seedlings were not included due to the lack of seedlings present in the plots. Of the 190 tagged seedlings, 30 or 18% survived the typhoon impacts. Their survival may be due to the number of their internodes which roughly indicates the age of the seedlings.

The annual vertical growth rate of the seedlings was at $32.46 \pm 4.64 \text{ cm yr}^{-1}$ and $67.27 \pm 2.62 \text{ cm yr}^{-1}$ for *Rhizophora* and

Avicennia, respectively ($P < 0.001$). Figure 5 provides a visual comparison of the said measurements.

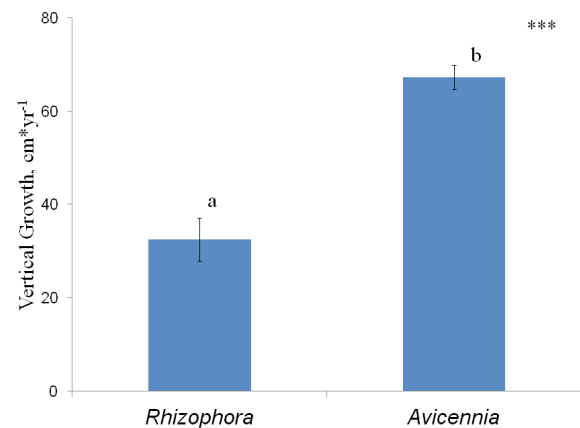


Figure 5. Estimated SRP of *Rhizophora* and *Avicennia* species through annual vertical growth. Letters above the bars indicate Tukey's HSD among *Rhizophora*, and *Avicennia*, with *Avicennia* having a longer annual vertical growth. Error bars represent growth differences among the tagged seedlings. Bars with different letters are significantly different based on Tukey HSD tests (***) $P < 0.001$.

Discussion

Resiliency of Mangroves

This study has shown that *Sonneratia* and *Avicennia* species are able to recuperate and regenerate six months after the typhoon. With *Sonneratia* and *Avicennia* being the natural colonizers on seafront areas (Primavera & Esteban, 2008; Samson & Rollon, 2008), it was expected that the seedling annual growth rate would be higher as compared to that of *Rhizophora* species. Observations on the seedling recruitment of the seafront areas have shown the same result. Comparing the findings of this study to the results from other literature, *Avicennia* species likewise have longer annual vertical growth than *Rhizophora* (see Table 3).

Aside from the seedling observations, the mangrove tree stands also showed larger growth in terms of height and DBH. Based on a mathematical relation between VR (equation 1), an increase in height, DBH or density consequently leads to an increase in VR value. VR increases the fastest with DBH (Bayas et al., 2011). Given the direct relationship of height and DBH to resisting external forces brought about by wind (Peltola, Kellomaki, Hassinen, & Granander, 2000) and water (Bayas et al., 2011), the ability of a tree to resist wave impact is therefore dependent on the size of a tree through its height and/or DBH. Moreover, optimal abiotic conditions for growth are related to the location of the mangrove at the intertidal zone through stressor gradients. The results support the hypothesis that *Sonneratia* and *Avicennia* species are highly suited for the seafront region. Consequently, tree growths of the said species are optimal, leading to their high VR six months post-typhoon.

Table 3. Documented annual growth rate classified according to mangrove genus situated at the seafront. *Avicennia* species have longer vertical growth as compared to *Rhizophora*.

Location	Annual Growth (cm yr ⁻¹)	Remarks	Source
<i>Rhizophora</i> spp.		typhoon-affected	this study
Leyte and Eastern Samar, Philippines	32.46		
Tayabas Bay, Philippines	35.00	low intertidal, planted stands	Samson and Rollon, 2008
Oyster Bay, Palawan, Philippines	7.08	natural growth	Padilla, Fortes, Duarte, Terrados, & Kamp-Nielsen, 2004
Buenavista, Palawan, Philippines	11.97	natural growth	Padilla et al., 2004
Ulugan Bay, Palawan, Philippines	6.16	natural growth	Padilla et al., 2004
Panama	15.65	oil spill	Duke and Pinzón, 1992
Panama	5.67		Duke and Pinzón, 1992
Nakhon Si Thammarat, Thailand	32.76	oil spill, shaded	Duarte et al., 1999
<i>Avicennia</i> spp.			this study
Leyte and Eastern Samar, Philippines	67.27	typhoon-affected	
Nakhon Si Thammarat, Thailand	140.40		Duarte et al., 1999

The VR values further established the relevance of *Sonneratia* and *Avicennia* species as resilient mangroves. The higher VR values of tagged *Sonneratia* and *Avicennia* species along the coastline indicate the ability to withstand stronger wave impacts brought about by storm surges. The implied sturdiness of high VR in turn increases the likelihood of minimizing infrastructural and property damage behind the mangrove zone. Comparatively, in terms of VR, *Rhizophora* stands showed sturdiness within the range between rice plantations and shrubs. On the contrary, *Sonneratia* and *Avicennia* stands are sturdier than coconut plantations (see Table 4).

Table 4. Vegetation resistance coefficient values comparing the mangroves to other land cover types (adapted from Laso Bayas et al., 2011). The *Sonneratia* and *Avicennia* stands had VR values that are higher than coconut plantations, making them ideal greenbelts along coastlines. Estimated planting density is based from field observations, averaged throughout the entire study sites.

Land Cover Type	Est. Planting Density (stems ha ⁻¹)	Veg. Resistance (m ³ ha ⁻¹)
Cleared Land	0	0
River	0	0
Vegetable Plantations	31,250	13
Grassland	2,000,000	15
Rice Field	2,000,000	15
<i>Rhizophora</i> stands	3,103	49
Shrub	4,445	150
Coconut Plantation	156	281
<i>Avicennia</i> stands	2,915	320
<i>Sonneratia</i> stands	2,915	331
Agroforest	625	844
Forest	494	2,099
Settlements	n/a	3,538

The density, DBH and height were derived from values of the said variables from the sampling plots.

It should be noted that the *Rhizophora* stands were situated at the seafront area where it is likely not their optimal living conditions (Kitaya et al., 2002; Smith III, 1987). Low VR implies that the seafront areas may not promote the optimal growth of *Rhizophora* species. Colonies of *Rhizophora* growing on a more suitable site, may be expected to have greater height and DBH (Juanico & Salmo III, 2014; Salmo III & Juanico, 2015), and in turn greater VR values.

Although the VR values were pooled by genera in the present study, it is possible to estimate a multi-species VR for a given site. A multi-species VR may provide a more accurate explanation to why some sites receive better vegetal protection than others. Due to the limitations of our approach, we assume that the VR of the entire mangrove site is best represented by its totality.

Implications on Mangrove Rehabilitation and Management Practices

The capacity of a mangrove forest to deliver its ecosystem function depends on the rate of mangrove regeneration of denuded or typhoon-affected areas. Designed to brace these disturbances, they also have the capability to recuperate. However, there is a tendency for humans to attempt to assist this recuperation. Since typhoon damages are heterogeneous in nature (Sherman et al., 2001), ideally, we should first observe the natural regeneration rather than do immediate human interventions such as replanting (Lewis, 2005). Natural occurrence of seedlings is an excellent indicator of regeneration (Bosire et al., 2008) and its density reflect the extent of mangrove recovery as attributed to its corresponding physico-chemical environment (McKee, 1995).

The findings of this study suggest the need for careful selection of species for rehabilitation purposes. The usual choice, *Rhizophora*, is generally not suitable for seafront areas due to its hampered ability to regrow (Primavera & Esteban, 2008). Optimal growth of these mangroves is not attained, as evidenced by a larger number of recorded mortalities, slow refoliation rate, and slower rate of seedling recruitment. Hence, current planting practices must be reconsidered. Instead, *Sonneratia* and *Avicennia* species are shown here to be more appropriate for seafront areas wherein these species remain to grow at optimal rates.

Conclusions

Sonneratia alba and *Avicennia marina* have high refoliation and coppicing potential. Further, *Avicennia marina* has high SRP thus making it the better contender for planting along seafront areas. The higher rate of natural regeneration of both genera implied that seedlings were successfully recruited because of their suitability to the abiotic conditions prevailing at the seafront areas. Further, the VR reinforces the suitability of these species as tolerant to strong wave impacts thereby making them resilient species, able to withstand typhoons at the seafront area. While this case is true for most mangrove ecosystems in the region, there should be caution

in implementing rehabilitation activities. We would later use the findings presented in this paper to formulate and explore strategies for mangrove rehabilitation toward the development of coastal bio-shields.

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References

- Barbier, E. B., Hacker, S. D., Kennedy, C., Koch, E. W., Stier, A. C., & Silliman, B. R. (2010). The value of estuarine and coastal ecosystem services. *Ecological Monographs*, 81(2), 169–193. <http://doi.org/10.1890/10-1510.1>
- Bayas, J. C. L., Marohn, C., Dercon, G., Dewi, S., Piepho, H. P., Joshi, L., Cadisch, G. (2011). Influence of coastal vegetation on the 2004 tsunami wave impact in west Aceh. *Proceedings of the National Academy of Sciences*, 108(46), 18612–18617. <http://doi.org/10.1073/pnas.1013516108>
- Bosire, J. O., Dahdouh-Guebas, F., Walton, M., Crona, B. I., Lewis, R. R., Field, C., Koedam, N. (2008). Functionality of restored mangroves: A review. *Aquatic Botany*, 89(2), 251–259. <http://doi.org/10.1016/j.aquabot.2008.03.010>
- Duarte, C. M., Thampanya, U., Terrados, J., Geertz Hansen, O., & Fortes, M. D. (1999). The determination of the age and growth of SE Asian mangrove seedlings from internodal counts. *Mangroves and Salt Marshes*, 3(4), 251–257. <http://doi.org/10.1023/A:1009967401337>
- Duke, N. C. (2001). Gap creation and regenerative processes driving diversity and structure of mangrove ecosystems. *Wetlands Ecology and Management*, 9, 257–269.
- Duke, N. C., & Pinzón, Z. S. (1992). Aging *Rhizophora* Seedlings from Leaf Scar Nodes: A Technique for Studying Recruitment and Growth in Mangrove Forests. *Biotropica*, 24(2), 173–186. <http://doi.org/10.2307/2388671>
- Juanico, D. E., & Salmo III, S. (2014). Simulated effects of site salinity and inundation on long-term growth trajectory and carbon sequestration in monospecific *Rhizophora mucronata* plantation in the Philippines. *arXiv:1405.6944*. Retrieved from <http://arxiv.org/abs/1405.6944>
- Kitaya, Y., Jintana, V., Piriyayotha, S., Jaijing, D., Yabuki, K., Izutani, S., Iwasaki, M. (2002). Early growth of seven mangrove species planted at different elevations in a Thai estuary. *Trees*, 16(2-3), 150–154. <http://doi.org/10.1007/s00468-002-0166-6>
- Lagmay, A. M., Agaton, R. P., Bahala, M. A. C., Briones, J. B. L. T., Cabacaba, K. M. C., & Caro, C. V. C. (2014). Devastating storm surges of Typhoon Haiyan. *International Journal of Disaster Risk Reduction*, 11. <http://doi.org/10.1016/j.ijdr.2014.10.006>
- Lewis, R. R. (2005). Ecological engineering for successful management and restoration of mangrove forests. *Ecological Engineering*, 24(4), 403–418. <http://doi.org/10.1016/j.ecoleng.2004.10.003>
- Long, J., Napton, D., Giri, C., & Graesser, J. (2014). A Mapping and Monitoring Assessment of the Philippines' Mangrove Forests from 1990 to 2010. *Journal of Coastal Research*, 260–271. <http://doi.org/10.2112/JCOASTRES-D-13-00057.1>
- McIvor, A., Spencer, T., Möller, I., & Spalding, M. (2012). *Storm surge reduction by mangroves*. The Nature Conservancy and Wetlands International.
- McKee, K. L. (1995). Seedling recruitment patterns in a Belizean mangrove forest: effects of establishment ability and physico-chemical factors. *Oecologia*, 101(4), 448–460. <http://doi.org/10.1007/BF00329423>
- Mori, N., Kato, M., Kim, S., Mase, H., Shibutani, Y., Takemi, T., Yasuda, T. (2014). Local amplification of storm surge by Super Typhoon Haiyan in Leytea Gulf: Storm surge by super-typhoon Haiyan. *Geophysical Research Letters*, 41(14), 5106–5113. <http://doi.org/10.1002/2014GL060689>
- Padilla, C., Fortes, M. D., Duarte, C. M., Terrados, J., & Kamp-Nielsen, L. (2004). Recruitment, mortality and growth of mangrove (*Rhizophora* sp.). *Trees*, 18, 589–595. <http://doi.org/10.1007/s00468-004-0351-x>
- Peltola, H., Kellomäki, S., Hassinen, A., & Granander, M. (2000). Mechanical stability of Scots pine, Norway spruce and birch: an analysis of tree-pulling experiments in Finland. *Forest Ecology and Management*, 135(1–3), 143–153. [http://doi.org/10.1016/S0378-1127\(00\)00306-6](http://doi.org/10.1016/S0378-1127(00)00306-6)
- Polidoro, B. A., Carpenter, K. E., Collins, L., Duke, N. C., Ellison, A. M., Ellison, J. C., Yong, J. W. H. (2010). The Loss of Species: Mangrove Extinction Risk and Geographic Areas of Global Concern. *PLoS ONE*, 5(4), e10095. <http://doi.org/10.1371/journal.pone.0010095>
- Primavera, J. H., & Esteban, J. M. A. (2008). A review of mangrove rehabilitation in the Philippines: successes, failures and future prospects. *Wetlands Ecology and Management*, 16(5), 345–358. <http://doi.org/10.1007/s11273-008-9101-y>
- Primavera, J. H., Sadaba, R. B., Lebata, M. J. H. L., &

- Altamirano, J. P. (2004). Handbook of mangroves in the Philippines: Panay.
- R Development Core Team. (2014). R: *A language and environment for statistical computing*. Vienna, Austria; 2014. R Foundation for Statistical Computing. Retrieved from <http://www.R-project.org>
- Salmo III, S. J., Lovelock, C. E., & Duke, N. C. (2014). Assessment of vegetation and soil conditions in restored mangroves interrupted by severe tropical typhoon “Chan-hom” in the Philippines. *Hydrobiologia*, 733(1), 85–102. <http://doi.org/10.1007/s10750-013-1766-4>
- Salmo III, S. J., & Juanico, D. E. O. (2015). An individual-based model of long-term forest growth and carbon sequestration in planted mangroves under salinity and inundation stresses. *International Journal of Philippine Science and Technology*, 8(2), 31–35.
- Samson, M. S., & Rollon, R. N. (2008). Growth Performance of Planted Mangroves in the Philippines: Revisiting Forest Management Strategies. *AMBIO: A Journal of the Human Environment*, 37(4), 234–240. [http://doi.org/10.1579/0044-7447\(2008\)37\[234:GPOPMI\]2.0.CO;2](http://doi.org/10.1579/0044-7447(2008)37[234:GPOPMI]2.0.CO;2)
- Sherman, R. E., Fahey, T. J., & Martinez, P. (2001). Hurricane Impacts on a Mangrove Forest in the Dominican Republic: Damage Patterns and Early Recovery1. *Biotropica*, 33(3), 393–408. <http://doi.org/10.1111/j.1744-7429.2001.tb00194.x>
- Smith III, T. J. (1987). Effects of light and intertidal position on seedling survival and growth in tropical tidal forests. *Journal of Experimental Marine Biology and Ecology*, 110(2), 133–146. [http://doi.org/10.1016/0022-0981\(87\)90024-4](http://doi.org/10.1016/0022-0981(87)90024-4)
- Tanaka, N. (2009). Vegetation bioshields for tsunami mitigation: Review of effectiveness, limitations, construction, and sustainable management. *Landscape and Ecological Engineering*, 5(1), 71–79. <http://doi.org/10.1007/s11355-008-0058-z>
- Walters, B. B., Rönnbäck, P., Kovacs, J. M., Crona, B., Hussain, S. A., Badola, R., Dahdouh-Guebas, F. (2008). Ethnobiology, socio-economics and management of mangrove forests: A review. *Aquatic Botany*, 89(2), 220–236. <http://doi.org/10.1016/j.aquabot.2008.02.009>
- Zhang, K., Liu, H., Li, Y., Xu, H., Shen, J., Rhome, J., & Smith, T. J. (2012). The role of mangroves in attenuating storm surges. *Estuarine, Coastal and Shelf Science*, 102–103, 11–23. <http://doi.org/10.1016/j.ecss.2012.02.021>



Potential long-term impact of Typhoon Haiyan on the water resources of Tacloban and its vicinity

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Abstract

Tacloban City is one of the hardest hit cities of the 2013 Super Typhoon Haiyan. Aside from the recorded thousands of deaths, Haiyan is predicted to have altered the terrestrial ecology of the affected area. This study investigated the probable impact on water resources as a result of the change in forest cover resulting from Haiyan. An empirical method was adopted to estimate groundwater recharge from surface data of Tacloban City's watersheds. Remote sensing and geographic information system techniques were used to acquire, integrate, and analyze data to come up with recharge estimates. Soil erosion was calculated using the openLISEM (Limburg Soil Erosion Model). A design storm with a total rainfall of 20 mm was used to compare the difference between the soil erosion considering the land cover change between 2013 and 2015. The results of the simulations indicated a 6% decrease in forest cover. This translated to a decrease in groundwater recharge and an initial seven-fold increase in soil loss due to higher erosion rates and larger surface water discharge. While validation of the calculated impacts on groundwater recharge, flooding events, and soil erosion is required, such estimation provides another dimension of long term effects of tropical cyclones in our country.

Keywords: water resources · land cover change · Yolanda · forest cover · Tacloban · soil erosion

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Introduction

Super Typhoon Haiyan hit the Philippines in November of 2013 and was then considered as the most powerful tropical cyclone that made landfall in world history. The strong winds, heavy rains, and resulting hazards such as landslides, floods, and storm surge resulted in 6,300 casualties, as well as massive destruction of livelihood and infrastructure (National Disaster Risk Reduction and Management Council, 2014). The brunt of the super typhoon was most heavily felt in the central region of the country, particularly Tacloban City in Leyte Province.

Aside from the aforementioned impacts, Haiyan is assumed to have altered the terrestrial ecology of the affected areas, as tropical cyclones are known to heavily influence the structure, function, and dynamics of many tropical and temperate forest ecosystems (Lee, Lin, Vadeboncoeur, & Hwong, 2008). Among the forces associated with typhoons, precipitation has the most effect particularly on soil loss, as runoff occurs when the amount of water exceeds the soil's holding capacity and floods follow when the outflow rate is significantly higher than the infiltration rate (Wang, Huang, & Budd, 2012). Hence, the high volume of precipitation brought by Haiyan also resulted in forest cover loss due to erosion as well as the direct uprooting of trees by strong winds.

The forest ecosystem plays an important role in the provision of hydrological services (Calder, 2002). The loss of forest cover heavily impacts water resource availability as forests enhance water infiltration, which in turn, increases soil moisture content and groundwater recharge (Bruijnzeel, 2004). The root system of the trees maintains soil stability, improves water quality in terms of sediment loading (Ilstedt, Malmer, Verbeeten, & Murdiyarso, 2007), and regulates hydrological processes in terms of flood control and low-flow augmentation (Lele, 2009). With the large-scale vegetative destruction brought by Haiyan, a problem in water supply is seen to occur in the hardest hit areas of the country.

Tacloban City, one of the hardest hit cities of Haiyan, has had water shortage problems in the past. Moreover, most barangays in the northern part of the city are still not connected with the Metropolitan Leyte Water District (which mainly sources its water from the Binahaan River) and thus depend on individual shallow groundwater wells for their domestic use. A typhoon-related decrease in groundwater recharge is expected to worsen the pre-existing problem. In addition, potential impacts on water resources may also be realized if the Binahaan River will likewise reflect any impact of forest cover loss.

This study aims to quantify the probable impact on water resources as a result of the change in forest cover using geographic information system (GIS) methods. Specifically, this research looks upon the change in forest cover before and after the occurrence of Typhoon Haiyan. The results of this investigation would provide insights on the relationship between land use and water availability that may be useful for urban planning and development.

Methods and Materials

Study Area

The study was performed on eight watershed basins in northeastern Leyte, shown in Figure 1. These basins cover an area of 660 square kilometers including the headwaters of the Binahaan River that drains towards the municipality of Palo and Lake Danao in Leyte. The Binahaan, Tacloban 1, and Tacloban 2 basins are characterized by moderately steep to very steep slope, which form part of the southwestern side of Mt. Janagdan and Mt. Naganaga near Tacloban City. The rest of the basins that form part of the foothills of Mt. Lobi and Mt. Cancajanag are characterized by flat to gently undulating slope.

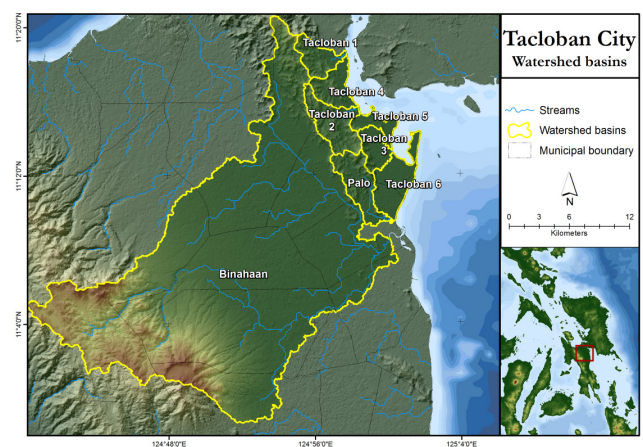


Figure 1. Watershed basins in Tacloban City.

The land cover of these basins was determined using unsupervised classification techniques based on the March 2013 and March 2015 Landsat 8 images of the basins. The digitization, integration, and data analysis were done using ArcGIS while land cover classification was done through the remote sensing software, ENVI.

Hydrological Data

Estimating the amount of groundwater recharge in these basins required the acquisition of various datasets. Soil maps from the National Mapping and Resource Information Authority (NAMRIA) were digitized to provide soil classification for the area. Vertical hydraulic conductivities and water capacity were estimated from the soil type. Physical characteristics of soils from the study of Jahn and Asio (1998) in Leyte were used as reference. Land cover is based on the Landsat images from 2013 and 2015. The depth to water table was estimated to be at around 4.8 meters below ground level based on a single well data. The length of flow from the main channel was computed based on the formula by Cherkauer and Ansari (2005):

$$L_f = \frac{\text{Drainage area (km}^2\text{)}}{2 \times \text{channel length (km)}} \quad (1)$$

Average basin slopes were computed based on a 10-meter resolution satellite radar digital elevation model (DEM). Annual rainfall per watershed is extrapolated from weather station data from the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) and Department of Science and Technology (DOST).

Groundwater Recharge

Adopting the study of Cherkauer and Ansari (2005), a method to estimate the spatial variability and amount of groundwater recharge was utilized for the computation of the effects of Typhoon Haiyan on groundwater recharge for Tacloban City and its surrounding areas. The following formula was adopted:

$$\frac{R}{P} = \frac{0.0085}{K_v} \left(\frac{K_v}{Sx D^{0.3}} \right) - 4.18 \left(\frac{D_w}{L_f} \right) + 0.0025N + 0.0022 \quad (2)$$

R/P represents the annual recharge per unit precipitation (cm/cm); K_v is the vertical soil conductivity estimated from soil type (m/d); S is the average slope of the basin as derived from the topographic model of the area; D_w is the average depth to the water table (m); L_f is the length of flow to the primary stream; D is the proportion of agricultural and built-up areas in the watershed (%); and N is the portion of forested land cover (%).

Note that this equation for groundwater recharge is oversimplified and should only be used as a general estimate (Cherkauer & Ansari, 2005). No discharge areas are considered except for the primary stream and the heterogeneity of the watershed properties are not accounted for.

This regression equation, adopted from Cherkauer and Ansari (2005), was originally developed and used for watersheds in Wisconsin, United States. Although dissimilar hydrologic and climatic conditions describe Wisconsin, USA and Leyte, Philippines, applying this empirical relationship to Leyte would provide the best estimate for groundwater recharge. Without field and laboratory testing of the soil, stream discharge, groundwater levels, or doing geochemical experiments, the regression equation provided a quick way to estimate recharge given readily-available information.

Soil Erosion Calculation

Soil erosion was calculated using the openLISEM (Limburg Soil Erosion Model). OpenLISEM is a physically based numerical model developed in the Netherlands (De Roo & Jetten, 1999). It calculates discharge and soil erosion on a per event basis. Input data include the DEM, soil maps, and land cover maps. The DEM that was used is a satellite radar DEM that was resampled from 10 m to 30 m resolution. These maps were processed using the PCRaster GIS software, an open source GIS platform, to produce the other maps that will be used by the model such as the local drain direction (LDD) map, the gradient map, and the river network maps. A design storm with total rainfall of 20 mm, with a duration of 200 minutes (3.33 hours) and peak rainfall at 6 mm/15 min was used to model soil erosion in the basin. The same design storm (which is typical of a normal thunderstorm event) was used

to compare the difference between the soil erosion based on a land cover change between 2013 and 2015. The simulation was run for 4,000 minutes with a time step of 1 minute. The initial watershed parameters used was for a temperate watershed; however, these have been calibrated to suit tropical conditions, particularly for short thunderstorm events (Clutario & David, 2014).

Results and Discussion

Land Cover Change

Based on the land cover classification performed on the 2013 (Figure 2) and 2015 (Figure 3) Landsat imagery, around 92% of the total land area of the eight basins were forested in 2013. Most of the forest cover was located in the mountainous Binahaan basin. Forested areas decreased in 2015, this time only covering 78% of the total land area covered by the eight basins.

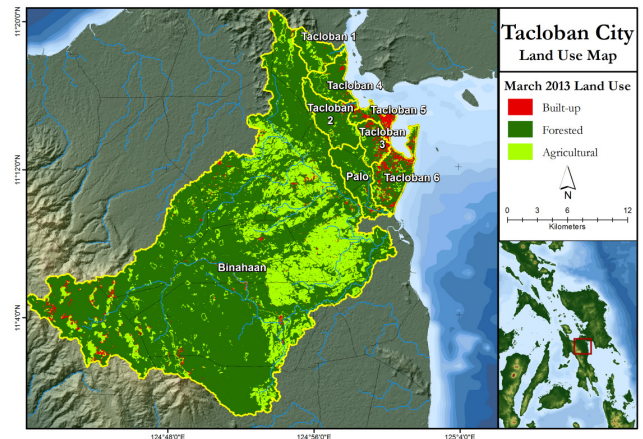


Figure 2. Land use map of Tacloban City in 2013. Note that in the satellite-based land use classification, agricultural areas will include shrubs and grasslands while built-up areas will include barren soil.

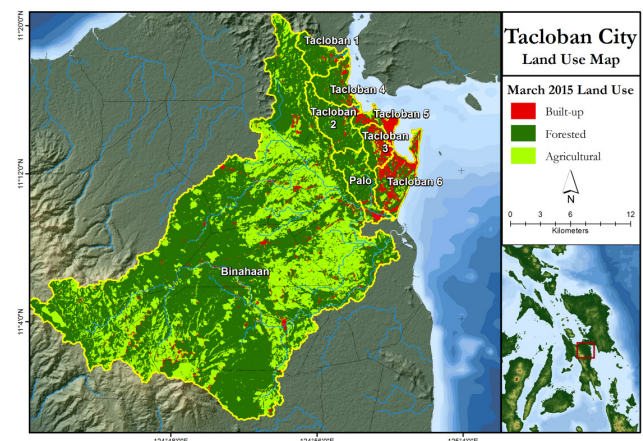


Figure 3. Land use map of Tacloban City in 2015. Note that in the satellite-based land use classification, agricultural areas will include shrubs and grasslands while built up areas will include barren soil.

Land cover moderately changed from the year 2013 to 2015. Most of the basins' forest cover and other naturally vegetated areas decreased by at least 6% while some, like the Tacloban 5 river basin's forest cover, lost more than a third of its land area. The largest basin, the Binahaan watershed area, lost around 66 sq km of its forest cover or around 15% from 2013 to 2015. Most of the lost forest areas were either converted to agricultural areas in the lowlands, bare soil and grasslands in the uplands, and to built-up areas near Tacloban City.

Decrease in Infiltration

Table 1 shows the properties of the study watershed basins derived from the datasets. In the year 2015, there was a marked decrease in the forest cover on all but one basin. This may be partly due to land conversion from forest to agricultural during the intervening years. However, due to the short time span between the imagery analysed, the loss in forest cover can be mostly attributed to Typhoon Haiyan. Additional conversion of forested areas to farmlands and built-up areas may also have happened after Typhoon Haiyan devastated the area.

Table 1. Properties of the study watershed.

Watershed	Hydrogeology			Land Cover (2013)		Land Cover (2015)		Topography	
	Drainage Area	K _v	D _w	Forested	Developed	Forested	Developed	Length	Slope
	(km ²)	(m/d)	(m)	(%)	(%)	(%)	(%)	(km)	(m/m)
Tacloban 1	11.5	0.012	4.8	80.68	19.32	86.61	13.37	2.30	0.278
Tacloban 2	20.1	0.022	4.8	89.65	10.35	83.79	16.21	3.54	0.247
Tacloban 3	10.1	0.665	4.8	71.92	28.08	49.86	50.14	5.05	0.178
Palo	19.0	0.432	4.8	90.69	9.31	77.72	22.28	1.28	0.210
Binahaan	559.8	3.707	4.8	74.62	25.38	62.74	37.25	7.63	0.146
Tacloban 4	12.9	0.012	4.8	88.17	11.83	81.35	18.63	4.30	0.195
Tacloban 5	7.4	1.162	4.8	48.36	51.64	30.37	69.64	2.48	0.118
Tacloban 6	20.0	3.204	4.8	65.83	34.17	43.62	56.37	6.68	0.064

Table 2 shows the effects of land cover change on the amount of groundwater recharge of the eight watershed basins.

Table 2. Precipitation and recharge of the watersheds.

Watershed	Annual Precipitation (cm)	R/P (cm/mm)		Groundwater recharge (MCM)		Change in GW recharge	
		2013	2015	2013	2015	MCM	%
Tacloban 1	3191	0.149	0.165	5.52	6.06	0.54	9.87
Tacloban 2	3177	0.198	0.184	12.63	11.69	-0.94	-7.42
Tacloban 3	3181	0.179	0.123	5.78	3.95	-1.83	-31.72
Tacloban 4	3187	0.203	0.186	8.33	7.63	-0.70	-8.41
Tacloban 5	3188	0.099	0.052	2.36	1.25	-1.11	-47.19
Tacloban 6	3178	0.309	0.232	19.61	14.77	-4.84	-24.66
Total				521.79	346.87	-172.92	-33.52

The reduction of the forested lands by 15.39% from March 2013 to March 2015 equates to about 93.86 km² decrease. The reduction of forested lands translates to an estimated one-third

decrease in infiltration and the potential groundwater recharge for the eight basins.

As check to the computed recharge-precipitation proportion for Leyte using Cherkauer and Ansari's method, a basin-wide simple soil-water balance was computed. Water budget parameters were calculated. An annual average of 3169 mm precipitation for the basin became the basis for the computed evapotranspiration (1694 mm), runoff (722 mm), and infiltration (752 mm). Around 24% of precipitation returns as infiltration to the ground, similar to the computed recharge proportion using regression equation.

Other Impacts

The decrease in infiltration likewise translates to an excess of 173 million cubic meters (MCM) per year of additional potential runoff which can result in the increased height and frequency of ensuing floods. The flood impact cannot yet be quantified because it will largely depend on the characteristics of the rainfall events, particularly in their intensity and duration. In terms of the ensuing soil erosion, Table 3 summarizes the results of the openLISEM calculation for the 2013 and 2015 scenarios.

Table 3. Soil erosion calculation using OpenLISEM.

	Units	2013	2015
LISEM results at time	min	3,998.00	3,998.00
Total rainfall	mm	20.00	20.00
Total discharge	mm	0.37	0.65
Total interception	mm	0.32	0.31
Total infiltration	mm	19.29	19.02
Water in runoff + channel	mm	0.02	0.02
Total discharge	m ³	245,450.00	430,382.00
Peak discharge	l/s	6,523.00	17,435.00
Peak time rainfall	min	101.00	101.00
Peak time discharge	min	489.00	408.00
Discharge/rainfall	%	1.86	3.26
Splash detachment (land)	ton	82,057.00	78,059.00
Flow detachment (land)	ton	2,368.00	3,434.00
Deposition (land)	ton	1,379.00	1,312.00
Suspended sediment (land)	ton	82,416.00	78,829.00
Flow detachment (channels)	ton	98,901.00	99,831.00
Deposition (channels)	ton	99,014.00	97,474.00
Susp. sediment (channels)	ton	29.79	29.80
Total soil loss	ton	487.00	3,680.00
Average soil loss	kg/ha	7.22	54.55

It can be seen that following the increase of runoff in the watershed, soil erosion also increased. The amount of soil exiting the watershed increased from 487 to 3680 tons. This increase is directly linked to the increase in the total discharge (from 254,449 to 430,381 cubic meters).

The excess runoff coming from the rain water that did not

infiltrate the ground due to the change in land cover increased the amount of sediments that it carried, as can be seen from the increase in flow detachment from 2,368 to 3,434 tons. On the other hand, splash detachment, which is the amount of sediments that was dislodged by the impact of rain on the surface of the soil, decreased. This is due to the increase in the built-up areas in the basin, where there are no soil particles to be eroded.

Higher siltation can likewise be expected in the Binahaan River which is the main water supply of Tacloban City.

Conclusions and Recommendations

Super Typhoon Haiyan's impact in the city of Tacloban and its vicinity transcends the immediate destruction it caused in 2013. Due to the loss in forest cover in its watersheds, potential effects include decrease in groundwater recharge, increase in flooding events, and heightened soil erosion. These should be considered in the rehabilitation process of the area. Restoration of the forest cover or at least the installation of groundwater recharge structures and mitigation measures for soil loss should be done to augment infiltration and decrease flooding and soil erosion. Recharge models developed for tropical climate settings will be used in succeeding iterations (Izuka, Oki, & Engott, 2010). Still, reliable estimates can only be obtained if all the physically important processes are represented satisfactorily (De Silva & Rushton, 2007). Therefore, the calculated impacts will need to be ascertained with actual ground measurements and observations. Nevertheless, this research provides another dimension of the effects of tropical cyclones in the country.

Acknowledgement

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References

- Bruijnzeel, L. A. (2004). Hydrological functions of tropical forests: not seeing the soil for the trees? *Agriculture, Ecosystems & Environment*, 104(1), 185–228. <http://doi.org/10.1016/j.agee.2004.01.015>
- Calder, I. R. (2002). Forests and Hydrological Services: Reconciling public and science perceptions. *Land Use and Water Resources Research*, 2.
- Cherkauer, D. S., & Ansari, S. A. (2005). Estimating Ground Water Recharge from Topography, Hydrogeology, and Land Cover. *Ground Water*, 43(1), 102–112. <http://doi.org/10.1111/j.1745-6584.2005.tb02289.x>
- Clutario, M. V. A., & David, C. P. (2014). Event-based Soil Erosion Estimation in a Tropical Watershed. *International Journal of Forest, Soil and Erosion (IJFSE)*, 4(2), 51–57.
- De Roo, A. P. J., & Jetten, V. G. (1999). Calibrating and validating the LISEM model for two data sets from the Netherlands and South Africa. *Catena*, 37(3), 477–493.
- De Silva, C. S., & Rushton, K. R. (2007). Groundwater recharge estimation using improved soil moisture balance methodology for a tropical climate with distinct dry seasons. *Hydrological Sciences Journal*, 52(5), 1051–1067. <http://doi.org/10.1623/hysj.52.5.1051>
- Ilstedt, U., Malmer, A., Verbeeten, E., & Murdiyarso, D. (2007). The effect of afforestation on water infiltration in the tropics: A systematic review and meta-analysis. *Forest Ecology and Management*, 251(1–2), 45–51. <http://doi.org/10.1016/j.foreco.2007.06.014>
- Izuka, S. K., Oki, D. S., & Engott, J. A. (2010). Simple method for estimating groundwater recharge on tropical islands. *Journal of Hydrology*, 387(1–2), 81–89. <http://doi.org/10.1016/j.jhydrol.2010.03.034>
- Jahn, R., & Asio, V. B. (1998). Soils of the tropical forests of Leyte, Philippines I: Weathering, soil characteristics, classification and site qualities. In P. D. A. Schulte & D. D. Ruhayat (Eds.), *Soils of Tropical Forest Ecosystems* (pp. 29–36). Springer Berlin Heidelberg.
- Lee, M.-F., Lin, T.-C., Vadeboncoeur, M. A., & Hwong, J.-L. (2008). Remote sensing assessment of forest damage in relation to the 1996 strong typhoon Herb at Lienhuachi Experimental Forest, Taiwan. *Forest Ecology and Management*, 255(8–9), 3297–3306. <http://doi.org/10.1016/j.foreco.2008.02.010>
- Lele, S. (2009). Watershed services of tropical forests: from hydrology to economic valuation to integrated analysis. *Current Opinion in Environmental Sustainability*, 1(2), 148–155. <http://doi.org/10.1016/j.cosust.2009.10.007>
- National Disaster Risk Reduction and Management Council. (2014). NDRRMC Update, SitRep No. 108, *Effect of Typhoon "Yolanda" (Haiyan)*. Quezon City, Philippines. Retrieved from [http://www.ndrrmc.gov.ph/attachments/article/1329/Effects_of_Typhoon_YOLANDA_\(HAIYAN\)_SitRep_No_108_03APR2014.pdf](http://www.ndrrmc.gov.ph/attachments/article/1329/Effects_of_Typhoon_YOLANDA_(HAIYAN)_SitRep_No_108_03APR2014.pdf)
- Wang, S.-H., Huang, S.-L., & Budd, W. W. (2012). Resilience analysis of the interaction of between typhoons and land use change. *Landscape and Urban Planning*, 106(4), 303–315. <http://doi.org/10.1016/j.landurbplan.2012.04.002>



Perceptions of Typhoon Haiyan-affected communities about the resilience and storm protection function of mangrove ecosystems in Leyte and Eastern Samar, Philippines

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Abstract

The destruction caused by Typhoon Haiyan in the coastal areas of central Philippines drew greater international attention to the vulnerability of coastal communities to extreme weather and climate events. Mangrove ecosystems enhance coastal resilience by acting as barriers against storms and its impacts. However, given the strength of and damage brought by Typhoon Haiyan, the extent to which mangroves and coastal vegetation can reduce the impacts of waves caused by storm surge has emerged as a salient issue. Drawing on the results of a survey of 870 households; focus group discussions with community members; and interviews with representatives from government agencies, non-government organizations, people's organizations, and communities, the study examined local perceptions on whether or not mangroves played a role in reducing the impacts brought by Typhoon Haiyan in five affected municipalities and cities. It explored how peoples' perception of the coastal protection function of mangroves differed according to the state of mangroves—in terms of area, width, and species richness—validated through vegetation surveys. It also identified insights on how community participation may help improve coastal rehabilitation and management strategies. In general, the respondents were aware of and appreciated the functions performed by the mangrove forests in protecting their lives and properties from Typhoon Haiyan. However, the participation involvement of local communities in mangrove rehabilitation and management remains low. Community awareness needs to be improved and residents must be encouraged to participate in mangrove rehabilitation and management. This study complements existing studies that show the ability of mangroves and coastal vegetation in attenuating storm surges, the factors that affect the level of protection, the limitations of this function, and the need for further studies that will look more closely into these crucial factors.

Keywords: social perception · resilience · storm protection · mangrove ecosystems · Typhoon Haiyan · coastal communities

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Introduction

Ecosystems contribute to community resilience through their functions in provisioning of services and regulating the impacts of natural disasters (S. Das & Crépin, 2013; A. L. McIvor, Möller, Spencer, & Spalding, 2013; Saikia, Davis, & Ariyabandu, 2013; Zhang et al., 2012). Mangrove ecosystems provide coastal protection as well as diverse benefits that help enhance community resilience, including livelihood options such as tourism, transport, fishing, and other extractive uses (Alongi, 2008; Spalding et al., 2014; Thiaw & Munang, 2013).

The resilience of coastal communities to hazards is therefore extensively dependent on the health of the coastal ecosystem. Any artificial loss or damage could diminish an ecosystem's capacity to carry out its essential resilience-enhancing functions (Saikia et al., 2013). The decline of protective and regulatory functions reduces the ecosystem's capacity to reduce impacts of hazards. Disasters then consequently lead to further decline of ecosystems. The loss of resilience due to degraded ecosystems could, therefore, undermine local development and national economic growth (UNISDR, 2013). Corollary to this, community resilience may be enhanced by the regenerating and absorptive capacity of coastal ecosystems (Adger, 2000).

In the Philippines and around the world, mangrove ecosystems are threatened by human activities such as mismanaged aquaculture, forest extraction, and urban expansion (Primavera & Esteban, 2008). In addition, mangrove ecosystems are exposed to natural events such as typhoons, storm surges, and tsunamis. Pond culture is the major cause of mangrove losses in the Philippines (ASEAN Centre for Biodiversity, 2010). The country's total mangrove area was estimated to be 500,000 ha in the 1900s (Brown and Fisher, 1920 as cited by Melana, Melana, & Mapalo, 2000). It went down to 210,497 ha by 2008 (Department of Environment and Natural Resources, 2009). The total annual loss rate has been estimated at 0.52% between 1990 and 2010 (J. B. Long & Giri, 2011).

In November 2013, Typhoon Haiyan (locally known as Yolanda) wreaked havoc on the central part of the Philippines. Typhoon Haiyan is considered to be one of the most powerful typhoons to have made landfall in recorded history (David, Racoma, Gonzales, & Clutario, 2013; Lagmay et al., 2014). Storm surges, strong winds, and heavy rainfall resulted in over 6,200 deaths, more than 1,000 missing, and almost PHP89.5 billion worth of damages (National Disaster Risk Reduction and Management Council [NDRRMC], 2014).

In the aftermath of Typhoon Haiyan, plans to establish coastal greenbelts along the country's coasts have been put forward. The government launched a campaign for the rehabilitation of coastal areas. The case for coastal greenbelt establishment as a natural barrier against storm surge is supported by a number of studies (Badola & Hussain, 2005; Barbier et al., 2011; S. C. Das, Iimura, & Tanaka, 2011; S. Das & Vincent, 2009; A. L. McIvor et al., 2013; Zhang et al., 2012). Vegetation serves as an important source of friction to moving water, slowing down and reducing the size of waves brought by storms as they approach coastlines (Barbier et al., 2011; Liu, Hsu, & Wang,

2003). Others also studied the protection function of coastal vegetation against tsunamis (Bayas et al., 2011; Danielsen et al., 2005). The rule of thumb, according to Zhang et al. (2012), is that for every kilometer of dense mangrove, 0.5 meter is reduced in wave height (A. L. McIvor et al., 2013). Das and Crepin (2013) also established that mangroves can provide substantial protection to properties by attenuating impacts of strong cyclonic winds. However, the coastal protection function also depends on many other factors including the location, bathymetry, forest floor slope, and the properties of the storm itself (Engle, 2011; Koch et al., 2009; Tanaka, 2009).

There is growing understanding of the factors that affect the efficacy of the coastal protection function of mangroves. Improved understanding, based on empirical and scientific evidence, of its effectiveness and more importantly its limitations, will form part of a more holistic ecosystem rehabilitation and management (UNEP, 2014). Success of such initiatives will depend on how communities view or appreciate this function as well as the other services coastal ecosystems provide.

This study examines local communities' perception of the role of mangroves in reducing the impacts brought about by Typhoon Haiyan. It explores how the cause of damage, extent of housing damage, and the state of mangrove ecosystems played a role in the extent by which the mangroves were able to reduce the damages. It also identifies insights on community participation and how these may help inform coastal rehabilitation and management strategies.

Materials and Methods

Study Sites

The study was conducted in the cities of Tacloban and Ormoc, the municipality of Palo in Leyte, and the municipalities of General MacArthur and Quinapondan in Eastern Samar (Figure 1).

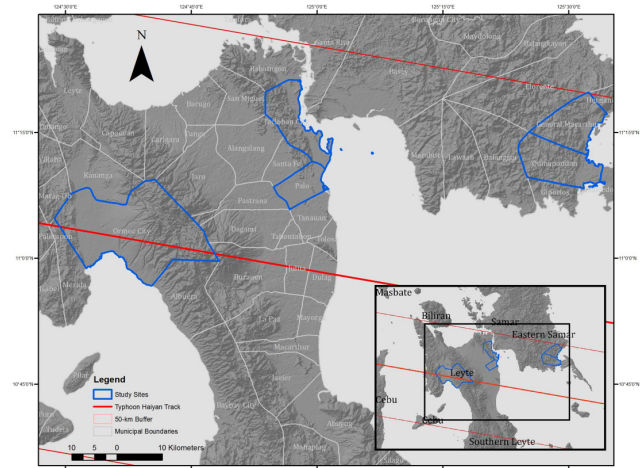


Figure 1. Location map of the selected cities and municipalities as sampling sites of the study.

All of the study sites are within 50-km radius from the storm's track. Leyte and Eastern Samar were among the provinces that suffered major losses and damages due to the impacts of storm surge and intense cyclonic winds.

Of the total area of the Philippines' mangrove forests, Leyte is estimated to have 2.26% and Eastern Samar with 2.18% (based on 256,185 ha total area estimate in 2000 by Long et al., 2014).

Table 1 shows the total land area and estimated mangrove area per municipality. Among all the study sites, Ormoc City and Quinapondan have the highest estimated area of mangroves. Most of the communities of General MacArthur and Quinapondan along the Matarinao Bay have mangroves along the coastlines. In Tacloban and Palo, only small patches of mangrove remain along the coastlines (Carlos, Delfino, Juanico, David, & Lasco, 2015).

Table 1. General characteristics of the study sites.

General Characteristics Location details	Tacloban	Palo	Ormoc	Gen. Mac-Arthur	Quinapondan
Total Land area (ha) ^a	20,172.00	22,127.00	61,360.00	8,324.00	11,729.00
Mangrove area (ha) ^b	170.00	125.00	1,463.00	1,085.00	432.00
Percent mangrove area	0.84	0.56	2.38	13.03	3.68
No. of houses destroyed ^{c,d}	12,270.00	11,607.00	34,228.00	2,403.00	11,185.00
No. of houses partly damaged ^{c,d}	46,553.00	3,741.00	14,983.00	1,857.00	

^aNational Statistics Coordination Board. Accessed last 14 Oct. 2014. ^bEstimated from Long et al., 2011 ^cNational Disaster Risk Reduction and Management Council (2014) ^dQuinapondan and General MacArthur Post-disaster Needs Assessment

Tacloban and Ormoc are both highly populated coastal cities with 221,174 and 191,200 recorded inhabitants, respectively, while Palo has 62,727 (as of 2010). The population in Quinapondan and General Mac Arthur, on the other hand, are 13,841 and 12,214, respectively (Table 2).

Table 2. Population of the study sites and number of affected families by Typhoon Haiyan.

Study Site	Population ^a	No. of Affected Families ^b	No. of Casualties ^c
Tacloban	221,174	58,823	2,678
Palo	62,727	15,481	902
Ormoc	191,200	64,637	37
Quinapondan	13,841	3,723	10
Gen. MacArthur	12,214	3,858	0

^aNational Statistics Office, 2010. ^bNDRRMC, 2014. ^cLagmay et al., 2014

Due to its geography and proximity to the eye of the storm, Tacloban City and Palo suffered the highest fatalities during Typhoon Haiyan, reporting 2,678 and 902 deaths respectively, while Ormoc City reported 37 deaths (Lagmay et al., 2014).

Interviews, Vegetation Survey and Analysis

Key informant interviews (KIIs), focus group discussions (FGDs), and household surveys were conducted to determine the perception of the people living along the coastlines about the presence of mangroves, extent of damage, and sense of security and well-being afforded by mangroves.

Semi-structured interviews with key officials from local government units (LGUs), national government agencies (Department of Environment and Natural Resources [DENR] and the Department of Agriculture's Bureau of Fisheries and Aquatic Resources), and field offices (regional, provincial, and community level) were done to get an overview of the state of ecosystems as well as rehabilitation and management efforts in the study sites. A series of FGDs with local stakeholder groups i.e., LGUs at the municipal and village level (barangay, the smallest administrative unit in the Philippines), people's organizations (farmers and fisher folks associations; women, youth and elderly groups), local basic service providers (coastal and security patrols/volunteers), and non-government organizations in selected villages for each municipality were done to collect community level information and perception on mangroves and coastal ecosystems.

Semi-structured interviews were also done with residents of coastal communities. There were 26 villages selected in Tacloban, 6 in Palo, 31 in Ormoc, 5 in General MacArthur and 4 in Quinapondan with a 95% confidence level and different margins of error (Figure 2).

These villages were chosen based on their coastal location, presence and/or absence of mangroves, the proximity of houses to water bodies and mangrove areas, and population exposed to hazards. Field enumerators selected households through a randomized field walk; assessing one household out of every five in the villages they were assigned. Households were assessed based on the criteria set until the target sample size for the municipality had been reached. The total sample size of 870 individuals from five municipalities and selected villages (Table 3) were interviewed.

The questionnaire's themes revolved around the respondents' awareness and perceptions prior, during, and after the typhoon. The respondents, most of whom are household heads and permanent residents, were asked about their socioeconomic profile, the perceived protection functions of mangroves/coastal vegetation, and the activities and strategies conducted by the community, government and other organizations.

We tried to compare the extent of damage caused by Typhoon Haiyan in areas with and without mangrove forests. Firsthand information was collected by asking the respondents about the cause of damages and the extent of damage to their houses due to Typhoon Haiyan.

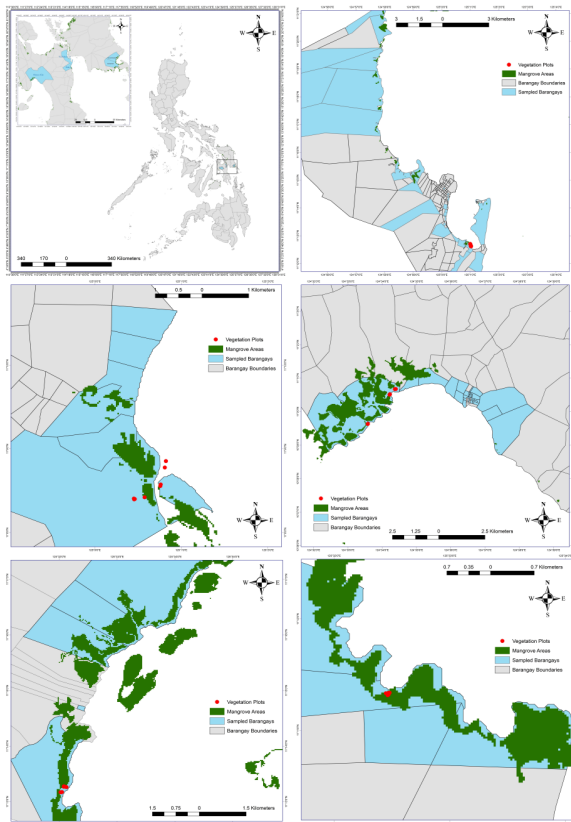


Figure 2. Maps showing location map (top left); and sampled barangays, location of vegetation plots in each of the study sites: Tacloban (top right), Palo (middle left), Ormoc (middle right); General MacArthur (bottom left), and Quinapondan (bottom right).

Table 3. Household samples per municipality.

City/ Municipality	Total # of Households	# of Selected Villages	# of Households in Selected Villages	# of Sample Households	Sampling Rate (%)
Tacloban	45,522	26	12,560	320	2.56
Palo	11,342	6	3,592	100	2.78
Ormoc	38,299	31	17,294	250	1.44
Gen. MacArthur	12,214	5	850	100	11.76
Quinapondan	13,841	4	545	100	18.35

Observations on the characteristics of the mangrove trees and seedlings were also considered. In addition, 36 circular plots at 3-m radius were established on the selected Typhoon Haiyan-affected natural growth mangroves in Tacloban City and Ormoc City in Leyte, mangroves and beach forest in Palo, and General MacArthur and Quinapondan along the Matarinao Bay coastline in Eastern Samar (see Figure 2).

The plots were distributed and selected to consider variations in inundation levels within the mangrove areas as well as its proximity to the settlements. At least eight plots were selected per city/municipality.

Data were analyzed using geographical information system software (ArcGIS) and Microsoft Access for cross-tabulating the results of the interviews with that of the vegetation survey. Awareness of the benefits and protection provided

by mangroves as well as participation in rehabilitation and protection programs were measured categorically (yes/no) by asking respondents whether they think the mangroves can be beneficial, provided them a sense of security, and if they participated in the programs. The results were cross-tabulated with their characteristics: age, gender, resources taken, and level of housing damage due to Typhoon Haiyan. The percentage of surveyed residents that perceived that mangroves provided coastal protection were mapped and compared with the estimated mangrove area in hectares, estimated width of mangroves in meters and species richness in the study sites. The estimated mangrove area per hectare was based from Long et al. (2014). The estimated width and species richness were based from the on-the-ground vegetation surveys.

Results and Discussion

Table 4 shows the characteristics of the respondents of each site: average age, average number of years of residence, sources of income, and type of housing structures. The average age of residents is generally concentrated between 40 to 50 years old. Majority of the respondents are either small business owners or employed. Most lived in houses made of light materials, with only 14% living in permanent type of structures.

Table 4. General characteristics of the respondents

General Characteristics	Tacloban	Palo	Ormoc	Gen. MacArthur	Quinapondan
<i>Demographic characteristics</i>					
Ave age of respondents	45.21	42.77	47.56	46.74	46.1
Ave # of years of residence	25.79	27.73	31.1	24.05	30.51
<i>Source of Income (n)</i>					
Business/employment/others	250	70	193	38	39
Farming/livestock	15	7	9	23	21
Fishing	15	4	26	23	25
Multiple sources	32	18	8	4	10
<i>Type of house (n)</i>					
Light materials	112	39	103	69	61
Mixed materials	164	48	112	23	19
Permanent	44	13	35	8	15

Damage Attributed to Wind and Storm Surge

Majority (85%) of households reported that wind was one of the main causes of housing damage, followed by storm surge (37%) and flooding (18%) (Figure 3).

Ormoc has the highest number of respondents (95%) that reported wind as the major cause of damage. The city was along the track of the eye of the storm. General MacArthur (69%) and Quinapondan (82%), both within the 50-km distance from the storm track, also recorded high rates of damage due to wind. Storm surge and flooding were seen at almost equal rates with wind as the major causes of damage in Palo and Tacloban where waves were recorded to be high. Houses along the typhoon track and within 25-50 km distance are usually exposed to winds at their maximum speed while such speed decreases by moving further from the storm track.

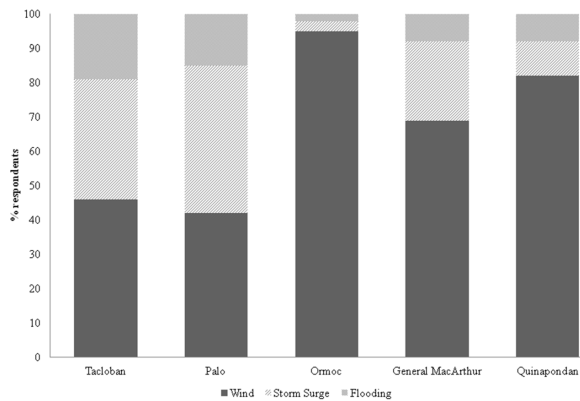


Figure 3. Major causes of housing damage as identified by the respondents.

Other studies performed on the ground were consistent with the impacts and damages reported by the respondents. The high wind speed and storm surge of Typhoon Haiyan brought most of the damage to properties in most of the study sites. At the onset of the storm, the predicted storm tide for Typhoon Haiyan was 4.5 m for Tacloban, Leyte (along San Juanico Strait) and 5.3 m for Matarinao Bay, Eastern Samar. The storm surge inundation levels (flood depths) that were observed in Tacloban reached 4-6 m and 3-5 m in municipalities along the Matarinao Bay, including Quinapondan, General MacArthur, Hernani and Salcedo (Lagmay et al., 2014). In another study by Mori and team (2014), storm surge with estimated heights of 5-6 meters were observed in Tacloban City. Bricker, et al. (2014) also studied the site-specific mechanisms that caused the structural damages between Tacloban and Eastern Samar.

Extent of Housing Damage

The household survey results comparing housing damage between sites with and without mangroves showed that coastal communities with mangroves suffered less damage compared to respondents living in areas without mangroves. This is particularly evident in Tacloban, where the number of respondents in areas without mangroves (n=81) that reported total damage is higher than those with mangroves (n=52) (Figure 4).

In Ormoc, however, where most houses were made of light materials, damage was higher in areas where there are mangroves.

While Das and Crépin (2013) showed that mangroves provide substantial protection from damage caused by cyclonic winds, the wind protection value of mangroves in reducing housing damage based on type of housing materials and exposure to winds was not considered in this study.

State of Mangroves

Leyte and Eastern Samar used to have natural mangrove stands. During the last few decades, mangroves from these areas were destroyed or degraded due to the rising urban population and higher demand for fisheries. Consequently,

coastal communities became more exposed to the relentless power of storms originating from the Pacific. Results of the household survey where respondents said that mangroves were thick and healthy or otherwise (Figure 5) were confirmed by the results of the vegetation surveys.

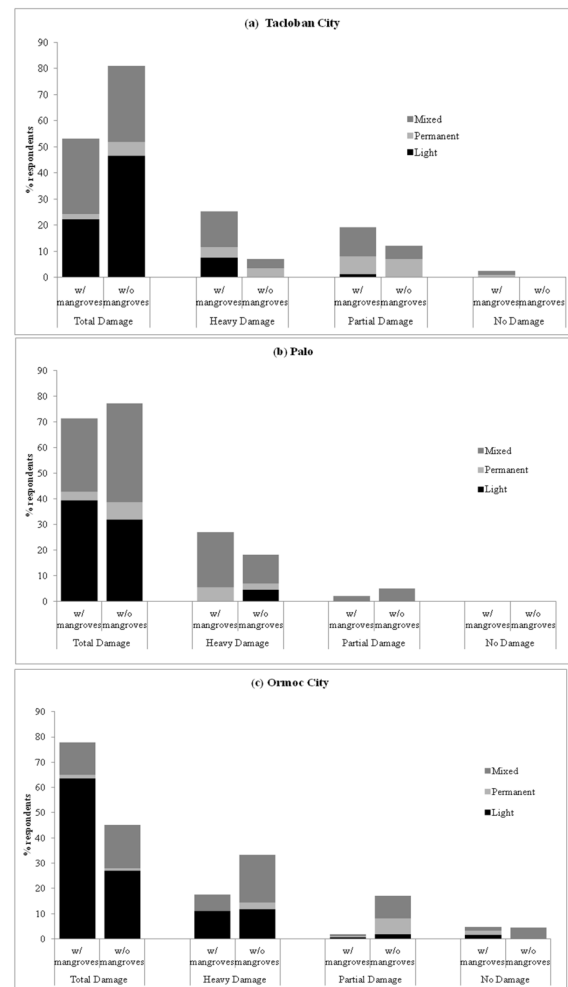


Figure 4. Comparison of the damages in housing to sites with and without mangroves in Leyte.

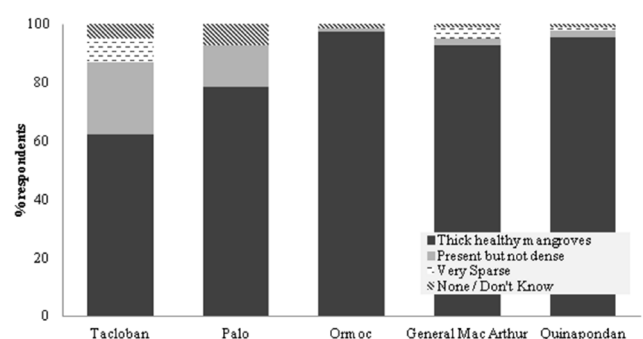


Figure 5. State of mangroves before Typhoon Haiyan according to the respondents per study site.

The mangroves of Tacloban are dominated by planted stands of *Rhizophora* along the seafont and natural stands of *Sonneratia* and *Avicennia* with sightings of *Acanthus sp.*, *Aegiceras sp.*,

Exoecaria agallocha, and nipa plantations. The vegetation of Palo, Leyte is predominantly abundant with beach forest species rather than true mangrove species. Beach forest vegetation included *Cocos nucifera* (coconut), *Thespesia populnea* (banalo/portia tree), *Talipariti tiliaceum* (malubago/beach hibiscus), and *Ipomoea pes-caprae* (bagasua), among others. Mangroves also occur but come in very small patches along the coast. Dead or damaged stands of *Rhizophora* and *Sonneratia* were observed during the survey while *Avicennia* stands showed signs of faster regeneration. Plantations of nipa account to the majority of mangrove species found in Palo, Leyte.

The mangrove forests in Ormoc City cover a large expanse of about 726 ha but many portions of the mangroves had been converted to fish ponds. *Sonneratia* and *Avicennia* species dominate the mangroves with sightings of planted *Rhizophora* sp., *Lumnitzera*, *Exoecaria*, and other beach forest species. On nearby villages, plantations of *Nypa fruticans* are utilized by the local communities for forest products.

The Quinapondan mangroves had 20 mangrove species observed with *Avicennia*, *Bruguiera*, and *Xylocarpus* species being dominant from seaward to landward, respectively. Also sighted is the endangered *Camptosthenom philippinense*. In General MacArthur, there were also 20 sightings of mangrove species with natural stands of *Rhizophora* and *Sonneratia* species dominating the seafront with sandy soil substrate. *Bruguiera* and *Xylocarpus* species dominate the landward portion of the mangrove forest.

The mangroves in Quinapondan and General MacArthur in Eastern Samar had the highest values in terms of species richness, diversity index (H'), and evenness. Tacloban City had the lowest species richness with eight mangrove species observed. However, Palo had 0 values for H' and evenness as the areas sampled were situated mainly in the nipa plantations although nine species were recorded on small mangrove patches. Table 4 summarizes the mangrove biodiversity indices from the study sites.

Table 4. Biodiversity indeces and parameters in the study site.

Site	Area (ha)	Species Richness	Shannon- Weiner (H')	Density (trees/ha)	Height (m)	DBM (m)
Tacloban	125	8	0.944396	3760	4.16	0.0659
Palo	33	9	0	1327	5.70	0.1320
Ormoc	1,463	13	1.2350663	3096	10.32	0.1238
Quinapondan	1,085	20	1.969263	3229	5.07	0.0769
Gen. MacArthur	432	20	1.748424	3539	4.79	0.0860

Given that biodiversity indices are good indicators of ecological integrity, the mangroves of Quinapondan and General MacArthur have a higher standing in terms of mangrove biodiversity followed by Ormoc, Palo and Tacloban. These two municipalities provide a long stretch of intact mangrove cover along the coastline of Matarinao Bay. Ormoc has a wide

stretch of mangroves, although fishpond conversions may have compromised the ecological integrity of these areas. Palo and Tacloban have the least biodiversity as mangroves in these sites come in small patches. Furthermore, human interventions continue to threaten the mangroves.

Mangroves are considered more effective in dissipating the energy of waves brought by storms (S. Das & Vincent, 2009; A. McIvor, Spencer, Möller, & Spalding, 2012; Zhang et al., 2012). The wave energy absorbed by mangroves strongly depends on a few biotic and abiotic factors. The biotic factors include forest density and the diameter of stems and roots. The abiotic consideration encompassed physical characteristics, such as forest floor slope, bathymetry and spectral characteristics of the incident waves, and the tidal stage at which the wave enters the forest (Tanaka, 2009). Carlos et al. (2015) described the vegetation resistance based on forest density of the study sites.

However, previous studies showed that at high tide, there will be a 50% decline in wave energy for *Rhizophora*-dominated forest (Brinkman et al., 1997 as cited by A. L. McIvor, Möller, Spencer, & Spalding, 2012) within 150 m and *Sonneratia* forest within 100 m off the coast, respectively (Mazda, Magi, Ikeda, Kurokawa, & Asano, 2006). It is unclear how other variables such as distance from the coast and topography affect this protective function.

Perception of Local Communities

Findings from the household survey showed that the peoples' perception on the coastal protection function of mangroves differed according to the state of mangroves, as shown in Figure 6 in terms of area, width, and species richness. The least number of respondents that agreed to the protective functions of mangroves were from Palo and Tacloban where area, width, and species richness were the lowest among all the study sites. On the other hand, the areas with the highest mangrove area, width, and species richness were also the sites where most respondents agreed to the protective role that mangroves play (Ormoc City, General MacArthur, and Quinapondan).

Undeniably, mangroves and coastal vegetation were found to be an important resource for the communities (Table 5). Across all study sites in Leyte, the mangroves are found to be very beneficial to the community as they serve as a source of seafood, fuel wood for cooking, housing materials, and livelihood opportunities through mud crab and nipa shingles production. When respondents were asked if it will be beneficial to plant mangroves in the community, an overwhelming majority (90%) acknowledged the benefits of planting mangroves along the coast lines. In particular, residents of Quinapondan and General MacArthur of Eastern Samar perceive great benefits from the mangroves, which they use as sources of food and fuel wood. In some areas, mangroves are still utilized for housing structure such as stilts and fences. A number of respondents also recognized that mangroves play a substantial role in supporting recovery from disasters, because some residents utilized wood and other resources for survival and reconstruction after Typhoon Haiyan. Of those who perceived that mangroves are beneficial, 55% percent were using

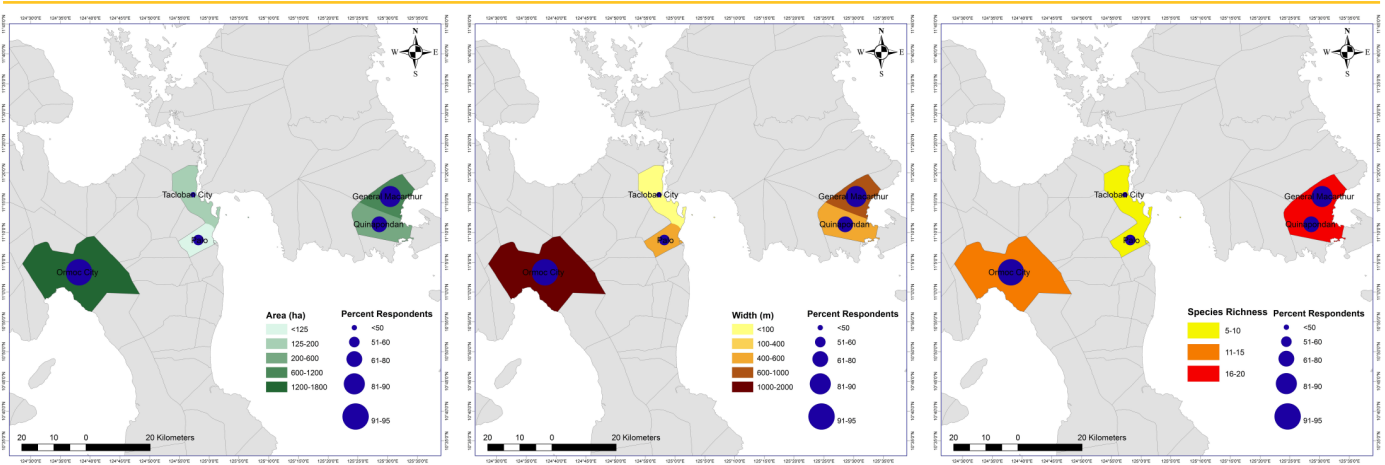


Figure 6. Percentage of surveyed residents that perceived mangroves provided coastal protection compared with the estimated mangrove area in hectares (left), estimated (average) width of mangroves in meters (middle) and species richness (right) in the study sites.

Table 5. Respondents' characteristics and perception on the benefits of, protection of mangroves, and participation on activities to rehabilitate, conserve, and protect mangroves.

Characteristics of respondents	Survey category and response					
	Benefits		Sense of security		Participation	
	Yes	No	Yes	No	Yes	No
<i>Gender</i>						
Female	66	7	62	11	21	53
Male	24	3	22	5	8	17
<i>Age Group</i>						
15-19	3	1	2	0	2	2
20-24	14	2	12	3	5	9
25-29	25	2	18	2	8	13
30-34	26	3	22	4	6	18
35-39	14	2	15	2	3	13
>60	18	3	15	4	7	15
<i>Source of income</i>						
Business/employment/others	58	4	48	12	16	42
Farming/ livestock	8	4	11	1	4	8
Fishing	11	1	14	2	3	11
Multiple source	7	1	7	1	4	5
<i>Taking resources from mangroves</i>						
Yes	55	5	59	7	20	46
No	35	5	26	9	10	24
<i>Level of housing</i>						
Totally destroyed	54	8	49	9	18	43
Heavily damaged	21	1	21	4	8	16
Slightly damaged	11	1	11	3	3	0
Not damaged	1	0	1	0	0	0

resources such as fishes, crabs, shrimp, shells or a combination of many resources. Majority of the respondents with ages 25-34 years old recognized the benefits of the mangroves. Also, the appreciation of the benefits provided by mangroves were apparent across different income groups: business and employment, fishing, and farming. Despite having their houses

totally destroyed by Typhoon Haiyan, 49% of the respondents still perceived that they were protected by the mangroves.

However, in spite of understanding the significance of mangroves, only 29% of the respondents participated in the programs and activities to rehabilitate, conserve and protect the mangroves after Typhoon Haiyan.

The current level of awareness and appreciation by the local people of the functions performed by the mangroves can be used as a good starting point and opportunity for the rehabilitation and management of these ecosystems. In order to ensure the sustainable use of the ecosystem goods and services provided by mangroves, it is important to increase the understanding and appreciation of coastal communities on the functions of mangrove forests. Community awareness in coastal areas on the importance of mangroves in disaster mitigation and risk reduction remains inadequate and needs to be raised further. More importantly, the local community must be motivated enough to be actively involved in the rehabilitation, conservation, and protection programs. The presence and visibility of institutions and organizations (such as DENR, NGOs and people's organization) can also encourage active involvement among the residents. Stakeholders should be easier to motivate if they understand how their efforts would eventually pay off regardless of how far into the future will it happen.

Conclusion and Recommendations

We highlight that the resilience of coastal communities to tropical cyclones are, to some extent, reduced by the removal of mangroves. The study results showed that the appreciation of the protective function of mangroves is lower in areas where mangrove cover is low compared to the study sites with thicker mangrove cover (Table 6). Although only indicative and based on social perception, we show that the housing damage attributed to either wind and storm surge was more extensive in sites where there are no or very little patches of mangroves. While this study attempted to provide evidence on whether

mangroves can attenuate impacts of storm surges and provide protection, continuous collection of empirical data and conduct of more in-depth studies could help enhance understanding on the roles of mangroves in reducing the vulnerability of Philippine coastlines to typhoons and its associated hazards such storm surges.

Table 6. Summary of conclusion and recommendations per study site.

Site	Perception	Recommendations
Tacloban	Protective function of mangroves and community participation were perceived to be low	Mangrove rehabilitation efforts should be supported by extensive communication campaigns
Palo	Protective function of mangroves and community participation were perceived to be low	Residents with claims on mangrove areas should contribute to mangrove protection; extensive communication campaign needed
Ormoc	High awareness on the ecosystem services provided by mangroves; community involvement is higher as compared to other study sites	Sustain community participation and protection activities by supporting the existing people's organization (PO)
Gen. MacArthur	High awareness on the ecosystem services provided by mangroves; high community involvement as compared to other sites	Establishment of PO or a network of POs to enhance mangrove protection in the community
Quinapondan	High awareness on the ecosystem services but involvement of community in mangrove rehabilitation/ protection remains to be low	Interventions should cater to the enforcement of ordinances and non-destructive livelihood options

It is conceivable that this observation would have been different if other factors such as distance, bathymetry, and properties of the typhoon were considered in the study. A more sophisticated analysis on the combined role of storm surge, flooding, and wind on the property damages could shed more light on the effectiveness or limitations of the coastal protection function of mangroves. Understanding the interactions among the hazards associated with the typhoon (e.g., storm surge, wind, duration, depth and extent of inundation) and the state of the mangroves and other physical factors such as those mentioned above may provide additional evidence to show that to be effective against storm surges with magnitude similar to that of Typhoon Haiyan, buffer zones or coastal greenbelts would need to be far wider than the existing mangrove areas and even those currently proposed (40-m buffer).

If implemented properly, the establishment of coastal greenbelts may not only provide protection against damages caused by storms, it may also provide ecosystem services including the provision of food and fuel wood, source of income and housing materials, erosion control, and possibly enhanced biodiversity and tourism that could help build the resilience of coastal communities. The observations in this study highlight

the multi-functionality of mangrove ecosystems that could justify investments in coastal rehabilitation and management. Additionally, this study generated information that could be used in raising the level of awareness and participation of all stakeholders in mangrove ecosystem rehabilitation and management.

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References

- Adger, W. N. (2000). Social and ecological resilience: are they related? *Progress in Human Geography*, 24(3), 347–364. <http://doi.org/10.1191/030913200701540465>
- Alongi, D. M. (2008). Mangrove forests: Resilience, protection from tsunamis, and responses to global climate change. *Estuarine, Coastal and Shelf Science*, 76(1), 1–13. <http://doi.org/10.1016/j.ecss.2007.08.024>
- ASEAN Centre for Biodiversity. (2010). *ASEAN Biodiversity Outlook* (p. 208). Philippines.
- Badola, R., & Hussain, S. a. (2005). Valuing ecosystem functions: an empirical study on the storm protection function of Bhitarkanika mangrove ecosystem, India. *Environmental Conservation*, null (01), 85–92. <http://doi.org/10.1017/S0376892905001967>
- Barbier, E. B., Hacker, S. D., Kennedy, C., Koch, E. W., Stier, A. C., & Silliman, B. R. (2011). The value of estuarine and coastal ecosystem services. *Ecological Monographs*, 81(2), 169–193. <http://doi.org/10.1890/10-1510.1>
- Bayas, J. C. L., Marohn, C., Dercon, G., Dewi, S., Piepho, H. P., Joshi, L., Cadisch, G., Noordwijk, M.V. (2011). Influence of coastal vegetation on the 2004 tsunami wave impact in west Aceh *Proceedings of the National Academy of Sciences*, 108(46), 18612–18617. <http://doi.org/10.1073/pnas.1013516108>
- Bricker, J. D., Takagi, H., Mas, E., Kure, S., Adriano, B., Yi, C., & Roeber, V. (2014). Spatial Variation of Damage due to Storm Surge and Waves during Typhoon Haiyan in the Philippines. *Journal of Japan Society of Civil Engineers*, 70(2), I_231–I_235. http://doi.org/10.2208/kaigan.70.I_231

- Carlos, C., Delfino, R. J. P., Juanico, D. E., David, L., & Lasco, R. (2015). Vegetation resistance and regeneration potential of *Rhizophora*, *Sonneratia*, and *Avicennia* in the Typhoon Haiyan-affected mangroves in the Philippines: Implications on rehabilitation practices. *Climate, Disaster and Development Journal*, 1(1), 1-8. <http://doi.org/10.18783/cddj.v001.i01.a01>
- Danielsen, F., Sørensen, M. K., Olwig, M. F., Selvam, V., Parish, F., Burgess, N. D., Suryadiputra, N., Sorensen, M.K., Karunagaran, V.M., Rasmussen, M.S., Hansen, L.B., Quarto, A. (2005). The Asian Tsunami: A Protective Role for Coastal Vegetation. *Science*, 310(5748), 643–643. <http://doi.org/10.1126/science.1118387>
- Das, S. C., Iimura, K., & Tanaka, N. (2011). Effects of Coastal Vegetation Species and Ground Slope on Storm Surge Disaster Mitigation. *Coastal Engineering Proceedings*, 1(32). <http://doi.org/10.9753/icce.v32.currents.24>
- Das, S., & Crépin, A.-S. (2013). Mangroves can provide protection against wind damage during storms. *Estuarine, Coastal and Shelf Science*, 134, 98–107. <http://doi.org/10.1016/j.ecss.2013.09.021>
- Das, S., & Vincent, J. R. (2009). Mangroves protected villages and reduced death toll during Indian super cyclone. *Proceedings of the National Academy of Sciences*, 106(18), 7357–7360. <http://doi.org/10.1073/pnas.0810440106>
- David, C. P. C., Racoma, B. A. B., Gonzales, J., & Clutario, M. V. (2013). A Manifestation of Climate Change? A Look at Typhoon Yolanda in Relation to the Historical Tropical Cyclone Archive. *Science Diliman*, 25(2). Retrieved from <http://www.journals.upd.edu.ph/index.php/sciencediliman/article/view/4425>
- Department of Environment and Natural Resources. (2009). *The 4th National Report to the Convention on Biological Diversity: Assessing Progress towards the 2010 Biodiversity Target*. Philippines. Retrieved from <https://www.cbd.int/doc/world/ph/ph-nr-04-en.pdf>
- Engle, V. D. (2011). Estimating the Provision of Ecosystem Services by Gulf of Mexico Coastal Wetlands. *Wetlands*, 31(1), 179–193. <http://doi.org/10.1007/s13157-010-0132-9>
- Koch, E. W., Barbier, E. B., Silliman, B. R., Reed, D. J., Perillo, G. M., Hacker, S. D., Wolanski, E., Granek, E.F., Primavera, J.H., Muthiga, N., Polasky, S., Halpern, B.S., Kennedy, C.J., Kappel, C.V., Wolanski, E., (2009). Non-linearity in ecosystem services: temporal and spatial variability in coastal protection. *Frontiers in Ecology and the Environment*, 7(1), 29–37. <http://doi.org/10.1890/080126>
- Lagmay, A. M., Agaton, R. P., Bahala, M. A. C., Briones, J. B. L. T., Cabacaba, K. M. C., & Caro, C. V. C. (2014). Devastating storm surges of Typhoon Haiyan. *International Journal of Disaster Risk Reduction*, 11. <http://doi.org/10.1016/j.ijdr.2014.10.006>
- Liu, W., Hsu, M., & Wang, C. (2003). Modeling of Flow Resistance in Mangrove Swamp at Mouth of Tidal Keelung River, Taiwan. *Journal of Waterway, Port, Coastal, and Ocean Engineering*, 129(2), 86–92. [http://doi.org/10.1061/\(ASCE\)0733-950X\(2003\)129:2\(86\)](http://doi.org/10.1061/(ASCE)0733-950X(2003)129:2(86))
- Long, J. B., & Giri, C. (2011). Mapping the Philippines' Mangrove Forests Using Landsat Imagery. *Sensors*, 11(3), 2972–2981. <http://doi.org/10.3390/s110302972>
- Long, J., Napton, D., Giri, C., & Graesser, J. (2014). A Mapping and Monitoring Assessment of the Philippines' Mangrove Forests from 1990 to 2010. *Journal of Coastal Research*, 260–271. <http://doi.org/10.2112/JCOASTRES-D-13-00057.1>
- Mazda, Y., Magi, M., Ikeda, Y., Kurokawa, T., & Asano, T. (2006). Wave reduction in a mangrove forest dominated by *Sonneratia* sp. *Wetlands Ecology and Management*, 14(4), 365–378. <http://doi.org/10.1007/s11273-005-5388-0>
- McIvor, A., Spencer, T., Möller, I., & Spalding, M. (2012). *Storm surge reduction by mangroves* (Natural Coastal Protection Series: Report 2 Cambridge Coastal Research Unit Working Paper 41). The Nature Conservancy and Wetlands International.
- Melana, D. M., Melana, E. E., & Mapalo, A. M. (2000). *Mangrove Management and Development in the Philippines*. Presented at the Mangrove and Aquaculture Management, Kasetsart Univ. Campus, Bangkok, Thailand. Retrieved from http://www.oneocean.org/download/20000427/mangrove_management_phils.pdf
- Mori, N., Kato, M., Kim, S., Mase, H., Shibutani, Y., Takemi, T., Tsuboki, K., Yasuda, T. (2014). Local amplification of storm surge by Super Typhoon Haiyan in Leyte Gulf: Storm surge by super-typhoon Haiyan. *Geophysical Research Letters*, 41(14), 5106–5113. <http://doi.org/10.1002/2014GL060689>
- National Disaster Risk Reduction and Management Council. (2014). *Post Disaster Needs Assessment in TY Yolanda Affected Areas*. Quezon City, Philippines. Retrieved from [http://www.ndrrmc.gov.ph/attachments/article/1329/Effects_of_Typhoon_YOLANDA_\(HAIYAN\)_SitRep_No_108_03APR2014.pdf](http://www.ndrrmc.gov.ph/attachments/article/1329/Effects_of_Typhoon_YOLANDA_(HAIYAN)_SitRep_No_108_03APR2014.pdf)
- National Statistics Office. (2010). Population Data. Quezon City, Philippines.
- Primavera, J. H., & Esteban, J. M. A. (2008). A review of mangrove rehabilitation in the Philippines: successes, failures and future prospects. *Wetlands Ecology and Management*, 16(5), 345–358. <http://doi.org/10.1007/s11273-008-9101-y>
- Saikia, A., Davis, I., & Ariyabandu, M. M. (Eds.). (2013). *Ecosystem Based Disaster Risk Reduction. Ecosystem Based Disaster Management Planning*, (93), 16.
- Spalding, M. D., Ruffo, S., Lacambra, C., Meliane, I., Hale, L. Z., Shephard, C. C., & Beck, M. W. (2014). The role of ecosystems in coastal protection: Adapting to climate change

and coastal hazards. *Ocean & Coastal Management*, 90, 50–57. <http://doi.org/10.1016/j.ocecoaman.2013.09.007>

Tanaka, N. (2009). Vegetation bioshields for tsunami mitigation: Review of effectiveness, limitations, construction, and sustainable management. *Landscape and Ecological Engineering*, 5(1), 71–79. <http://doi.org/10.1007/s11355-008-0058-z>

Thiaw, I., & Munang, R. (2013). The role of ecosystem services in climate change adaptation and disaster risk reduction. *Current Opinion in Environmental Sustainability*, 5(1), 47–52. <http://doi.org/10.1016/j.cosust.2013.02.002>

UNEP. (2014). *The importance of mangroves to people: a call to action*. (J. Van Bochove, E. Sullivan, & T. Nakamura, Eds.). Cambridge: United Nations Environment Programme World Conservation Monitoring Centre.

UNISDR. (2013). From shared risk to shared value - *The business case for disaster risk reduction. Global Assessment Report on Disaster Risk Reduction 2013*. Geneva, Switzerland: United Nations Office for Disaster Risk Reduction (UNISDR). Retrieved from <http://www.preventionweb.net/english/hyogo/gar/2013/en/home/index.html>

Zhang, K., Liu, H., Li, Y., Xu, H., Shen, J., Rhome, J., & Smith, T. J. (2012). The role of mangroves in attenuating storm surges. *Estuarine, Coastal and Shelf Science*, 102-103, 11–23. <http://doi.org/10.1016/j.ecss.2012.02.021>



Assessing and mapping barangay level social vulnerability of Tacloban City and Ormoc City to climate-related hazards

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Abstract

The destruction left by Typhoon Haiyan in the Philippines highlighted not only the exposure of the country but also the underlying vulnerability of barangays (villages) to climate-related hazards. This study used geographic information system (GIS) tools to characterize social vulnerability to climate-related hazards of barangays of Tacloban City and Ormoc City using a modified social vulnerability index (SoVI). The SoVI used socioeconomic data mainly drawn from census and was computed from 11 indicators influencing sensitivity, adaptive capacity, and exposure. Social vulnerability varies spatially across the study areas, where Barangay 88, said to be the worst-hit barangay in Tacloban, and Barangay Naungan in Ormoc, recorded the highest vulnerability scores. Demographic and socioeconomic shifts are likely in both cities, given the population growth and increasing density of settlements already concentrated in hazard-prone barangays. Measures to reduce vulnerability should be a local priority and would require political will for community-based climate action, disaster risk reduction and management, and risk-sensitive land use development. This study provides an approach for assessing social vulnerability using available census and climate-related hazard data to determine areas for intervention at the barangay level.

Keywords: social vulnerability · climate-related hazards · geographic information systems (GIS) · vulnerability assessment · Haiyan

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Introduction

Hazards that cause vulnerability have unequal distribution of impacts on a population (Zahran, Brody, Peacock, Vedlitz, & Grover, 2008) and across geography (Cutter & Finch, 2008) due to factors other than forces of nature, such as social systems and power (Wisner, Blaikie, Cannon, & Davis, 2003). Considering the characteristics or the conditions of social processes, economic systems, and power relations which render people susceptible to damage or injury (Cannon, 1994; Wisner et al., 2003), the concept of vulnerability has evolved over time, addressing one of the missing links in how to measure social vulnerability (Cutter & Corendea, 2013).

Vulnerability is the characteristic of a system that refers to its susceptibility to the negative impact of a natural hazard (United Nations International Strategy for Disaster Reduction, 2009) or the adverse effects of climate change (Intergovernmental Panel on Climate Change, 2007); or how that system's ability to prepare for, respond to, and recover from such hazards and adverse effects is affected. Accordingly, disaster impacts are more experienced by communities with the most vulnerable populations, rampant poverty, and least political influence (Asuero et al., 2012).

Social vulnerability provides an understanding of the factors that make some communities more susceptible to the impacts of disasters and of their capacity to recover (Cutter, Boruff, & Shirley, 2003). Vulnerability varies because natural environments, social structure, and housing differ spatially (Uitto, 1998). Accordingly, social vulnerability also varies across geography (Cutter & Finch, 2008) and across many levels of interaction (e.g., individual, community, regional, local) (Thomas, Philipps, Lovekamp, & Fothergill, 2013). Changes in an area's socioeconomic and demographic characteristics, such as population increase due to rural-to-urban transition, brings a certain pattern of exposure to hazards on the changing landscape and the built environment, particularly along coastal areas (Cutter, Johnson, Finch, & Berry, 2007). There have been attempts to incorporate vulnerability metrics at different subnational spatial scales and sub-county units (Cutter & Finch, 2008) such as the model developed by Yusuf and Francisco (2009) to measure sub-national vulnerability to climate change in Southeast Asia.

Typhoon Haiyan (local name Yolanda) is considered the most destructive typhoon ever recorded in the Philippines. It hit the country in November 2013, leaving over 6,300 dead, 1,061 missing, and 28,689 injured and affecting 12,139 barangays, 44 provinces, 591 municipalities, and 57 cities (National Disaster Risk Reduction and Management Council, 2014). Such devastation highlighted the underlying vulnerability of the country, particularly those living near natural hazards and those with low socioeconomic status.

Two years after the typhoon struck, recovery and rehabilitation efforts in affected areas are moving at a slow pace. Most of the displaced populations are still living in temporary shelters where exposure to other forms of hazards may still be likely. The disaster did not only challenge local capacity to face

critical pre- and post-disaster issues, but it also put to question the country's social, economic, and even political structures, the very foundation of sustained, if not lessened, vulnerability.

This study attempts to assess the extent to which Tacloban City and Ormoc City are vulnerable to climate-related hazards by measuring the social vulnerabilities of their barangays. The social vulnerability index (SoVI) was built on available and recent barangay-level datasets classified into sensitivity, adaptive capacity, and exposure, then measured using statistical approaches and mapped using geographic information systems (GIS).

Materials and Methods

Scope and Limitations

The geographical scope of the study covers the barangays of Tacloban and Ormoc in Leyte Province, coastal cities which were heavily affected by the impacts of the Typhoon Haiyan (Figure 1).

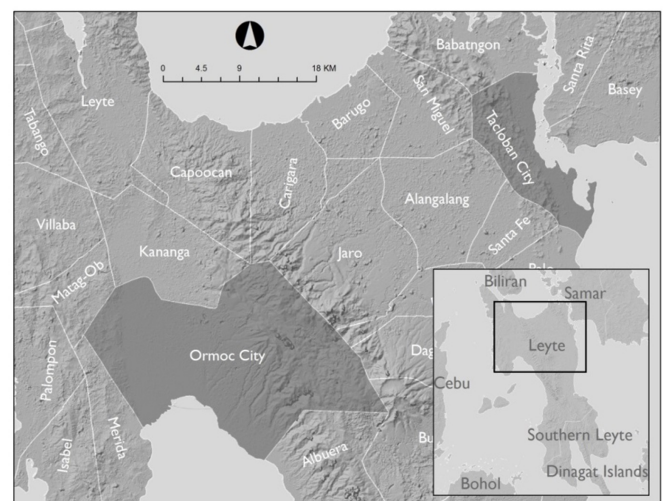


Figure 1. Location map of study sites.

Typhoon Haiyan had a devastating impact on the cities of Tacloban and Ormoc where most of the fatalities and damage occurred due to storm surge and wind. In particular, the effects in Tacloban were aggravated because the coastal area is below sea level and has many key public infrastructures such as schools, hospitals, and private residences. Tacloban has had an average of 2.3 typhoons per year in the last 50 years, and is now considered as among the Philippines cities that are most vulnerable to climate change (WWF & BPI, 2013).

The mapping extent is barangay level, with raw scales of 1:50,000 for flood and landslide hazard maps and 1:25,000 for storm surge maps. However, a careful recognition of the complexity of integrating hazard datasets of varying scales used to calculate areas per level of hazard susceptibility with socioeconomic data is required in the use and interpretation of the vulnerability maps. In addition, the vulnerability maps do not represent the absolute and actual vulnerability

of barangays due to scarcity of other important indicators available at the barangay level. However, the measurement of relative vulnerability among barangays allows for informed interventions aimed at reducing vulnerability.

Moreover, there may be discrepancies on the barangay boundaries between the maps generated by the study and the boundaries Tacloban City currently uses. During the course of data gathering, the available shapefiles were still based on the old city boundaries despite the fact that the city already uses a different boundary configuration on the ground. This study opted to refer to these outdated shapefiles because the census data and other local reports are still based on them.

Construction of Social Vulnerability Index (SoVI)

The first step in measuring the social vulnerability of barangays was to identify relevant indicators from existing knowledge and literature on social vulnerability. All dimensions of vulnerability were assessed using GIS with respect to the susceptibility of the barangays to climate-related hazards, such as landslide, storm surge, and flood (Figure 2), to classify the level of vulnerability of barangays.

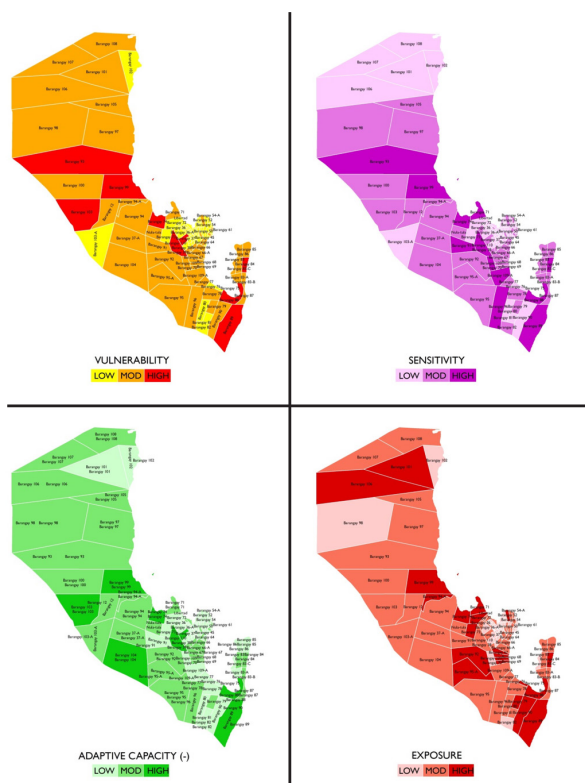


Figure 2. Social vulnerability, sensitivity, adaptive capacity, and exposure maps of Tacloban City, per barangay.

Secondary data used included National Statistical Coordination Board (NSCB) 2010 demographic and employment data, GIS vector climate-related hazard datasets from the Yolanda Rehabilitation Scientific Information Center (YoRInfo Center), and Community Based Monitoring System (CBMS) 2011 data on households living in makeshift houses (CBMS, 2011,

NSCB, 2010, NSCB, 2012, NSO, 2007, NSO, 2010).

The SoVI per barangay (Table 1) was derived using indicators representing exposure, adaptive capacity, and sensitivity adopted from the Economy and Environment Program for South East Asia (Yusuf & Francisco, 2009), focusing on generally accepted aspects of social vulnerability as proposed by Cutter et al. (2009).

Table 1. List of vulnerability components, indicators and sub-indicators used for computing barangay SoVI.

Indica- tors	Major component/ Factor	Sub-indicators and classification/ranking		Unit	Functional relationship to vulner- ability	Source
Unemployment	Sensitivity	Proportion of unemployed persons in the labor force (15 y.o. and above)		%	↑	NSCB
Population at risk	Sensitivity	Population density		pop/ha	↑	NSCB
	Sensitivity	Proportion of elders (>65 y.o.)		%	↑	NSCB
	Sensitivity	Proportion of children (0-5 y.o.) - 0-17		%	↑	NSCB
	Sensitivity	Proportion of persons with disabilities		%	↑	CBMS
	Sensitivity	Proportion of informal settlers house-holds		%	↑	NSCB
Poverty	Adaptive Capacity	Poverty incidence			↑	NSCB
Climate induced hazards	Exposure	Landslide susceptibility	Very high landslide susceptibility	ha	↑	UP DREAM YoRInfo Center
			High landslide susceptibility	ha		
			Moderate landslide susceptibility	ha		
			Low landslide susceptibility	ha		
		Flood susceptibility	Very high flood susceptibility	ha	↑	
			High flood suscep-tibility	ha		
			Moderate flood susceptibility	ha		
			Low flood suscep-tibility	ha		
	Storm surge susceptibility	High storm surge susceptibility	ha	↑		
		Moderate storm surge susceptibility	ha			
Low storm surge susceptibility		ha				
Indicators	Major component/ Factor	Sub-indicators and classification/ ranking		Unit	Functional relationship to vulner- ability	Source
Housing materials	Exposure	Proportion of HH living in makeshift houses		%	↑	CBMS

Abbreviations. NSCB: National Statistical Coordination Board; CBMS: Community Based Monitoring System; UP DREAM YoRInfo Center: University of the Philippines Disaster Risk and Exposure Assessment for Mitigation, Yolanda Rehabilitation Scientific Information Center; HH: household

The sub-indicators under each major component were given equal weights relative to the number of indicators in that component. This balanced weighted approach (Hahn, Riederer, & Foster, 2009; Sullivan, Meigh, & Fediw, 2002) was used due to the arbitrary relationships among different indicators. Thus, the components of vulnerability (Table 2) were assessed at the scale of 0 to 1 with equal weighting given to all associated sub-indicators.

Table 2. Categorization, description, and sources of selected sub-indicators (mostly adopted from [Cutter et al., 2003]).

Indicators (Major Components)	Sub-indicators	Concept and description	Sources
Unemployment (Sensitivity)	Unemployed persons in the labor force	Employment loss	Mileti, 1999
Population at risk (Sensitivity)	Population density	Population growth/density	H. John Heinz III Center for Science, Economics, and the Environment, 2000; Cutter, Mitchell, & Scott, 2000; Morrow, 1999; and Puente, 1999
		Age spectrum extremes Special needs populations	Cutter et al., 2000; O'Brien & Mileti, 1992; Hewitt, 1997; and (Ngo, 2001 Morrow, 1999 and Tobin & Ollenburger, 1992
	Elders children		
	Persons with disability	Special needs populations	H. John Heinz III Center for Science, Economics, and the Environment, 2000 and Platt, 1991
Poverty (Adaptive capacity)	Poverty incidence	Renters/ informal settlers	
		Socioeconomic status	H. John Heinz III Center for Science, Economics, and the Environment, 2000; Burton, Kates, & White, 1993; Wisner et al., 2003; Peacock, Gladwin, & Morrow, 1997; Hewitt, 1997; Puente, 1999; and Platt, 1991
Climate- induced hazards (Exposure)	Flood Storm surge Landslide	Susceptibility to floods, storm surges and landslides	Balica, Wright, & Meulen, 2012; Cannon, 1994; and Hammill, Bizikova, Dekens, & McCandless, 2013
Housing materials (Exposure)	Households living in makeshift houses	Housing and the built environment	Bolin & Bolton, 1986; Bolin & Stanford, 1991; Godschalk, Brower, & Beatley, 1989; Mitchell, Abdel-Ghaffar, Gentry, Leatherman, & Sparks, 1986; and White & Haas, 1975

The indicators used and prescribed by Cutter et al. (2009) in their study were modified in this study based on the context of the study areas and the availability of data. A SoVI was constructed with the same indicators as that of Cutter's but the sub-indicators were redeveloped to fit the situations and conditions in the study areas. These sub-indicators were chosen to ensure that the units and sources of data are consistent for standardization (Table 2).

Indicators were normalized to a value between 0 and 1, multiplied by the assigned relative weights to generate the normalized indicator scores (I_i). These normalized indicator scores (I_i) were combined to generate the normalized scores of sensitivity (S), adaptive capacity, (AC) and exposure (E). The maximum and minimum values of the barangays 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 unemployed persons in the labor force (15 years old and above)', 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.

The scores of the components were then multiplied equally by 0.33 and added altogether for the SoVI which ranges from 0 to 1, and classified into three classes using natural breaks (Jenks) method in GIS. Features are divided into classes whose boundaries are adjusted where there are relatively huge differences in the data values, such that high values for the index imply high vulnerability, moderate values imply moderate vulnerability and low values imply low vulnerability. The indicators were normalized using the methodology employed to calculate the Human Development Index (United Nations Development Programme [UNDP], 2014). Because all indicators have functional relationship with vulnerability, normalization was calculated as follows:

$$I_i = \frac{X_i - \text{Min}X_i}{\text{Max}X_i - \text{Min}X_i} \quad (1)$$

where X_i is the actual value, $\text{Min}X_i$ is the minimum value, and $\text{Max}X_i$ is the maximum value of the indicator.

The ranks of certain indicators and sub-indicators (e.g., 'area of level of hazard susceptibility') were assigned to values arranged in ordinal numbers which correspond to weights that add up to 1 (100%). The area per level of susceptibility of each hazard was calculated using calculate geometry function of ArcGIS 10.2. =Ordinal weight is computed as:

$$W_r = \frac{r}{\sum_{k=1}^n r} \quad (2)$$

where r is the rank, n is the number of ranks, and k is 1. SoVI was then calculated as follows:

$$\text{SoVI}_b = W_b S_b + W_b A C_b + W_b E_b \quad (3)$$

where b is the barangay, S is sensitivity, AC is adaptive capacity, and E is exposure; such that barangay b equals the equally weighted values of S , AC , and E . The weight of each major component (W_{C_i}), where C is one of the major components, indexed by i , is measured by 1 over the number (n^C) of the major components, which is 0.33 (Table 3).

$$W_{C_i} = 1/n^C \quad (4)$$

The same approach was used to calculate the weights (W_{sc}) of the sub-indicators (Table 4).

$$W_{sc} = 1/n_s j \quad (5)$$

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

where U is unemployment and PAR is population at risk

$$AC = f(Pov) \quad (7)$$

where Pov is poverty

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

where CH is climate-induced hazards (landslide, flood and storm surge) and HM is housing materials.

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

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

Table 4. Weights of sub-indicators.

Major Components	Weight of major components (W_{ci})	No. of indicators (n_i)	Weight of sub-indicators (W_{si})
Sensitivity	0.33	6	0.17
Adaptive Capacity	0.33	1	0.33
Exposure	0.33	4	0.25

Results and Discussion

From the identified indicators, the social vulnerabilities of the barangays were evaluated and ranked. These indicators have sub-indicators that could determine the characteristics of a particular barangay that make it more vulnerable to disasters relative to other barangays. For instance, in Tacloban City, the most socially vulnerable barangay has the demographic and socioeconomic characteristics that make it more sensitive to climate-related hazards: it is the most populated, it is highly exposed due to its location, and it has the least adaptive capacity due to its high poverty incidence. Therefore, its social vulnerability score is the highest among all barangays in Tacloban.

In the case of Ormoc City, the barangay that got the highest social vulnerability index is the barangay most exposed to climate-related hazards and also has the highest number of population at risk. However, unlike in Tacloban, the SoVI scores of the barangays in Ormoc do not have significant differences. Ormoc City is geographically more exposed to hazards than Tacloban City. A number of barangays in Ormoc are located along the shore and a number of those are prone to riverine flooding. Furthermore, the remaining parts of Ormoc are the rural areas whose populations are dependent to fishing and planting—livelihoods at risk to disasters. Thus, all barangays are almost equally vulnerable to disasters.

Tacloban City

Based on the computed vulnerability, Barangay 88 is consistently highest in all factors of vulnerability, recording a large differential vulnerability value relative to other barangays. The overall social vulnerability of every barangay is determined by its respective sensitivity, exposure, and adaptive capacity indices. Complete list of vulnerability levels and values for Tacloban City barangays can be found in Annex 2. The values were classified into the clusters of low, moderate, and high (Table 5). Tacloban yielded a value of 6.52%, or nine of its barangays with high vulnerability index.

Table 5. Range of values for sensitivity, adaptive capacity, exposure, and overall social vulnerability for Tacloban City.

	S	AC	E	V
Low	0.00148-0.02870	0.00000-0.03753	0.00328-0.02372	0.00749-0.09772
Moderate	0.02975-0.08384	0.04012-0.10784	0.02542-0.05634	0.09772-0.24304
High	0.08769-0.20234	0.05694-0.33000	0.05833-0.13559	0.24304-0.66792

Among these barangays, Barangay 88 got the highest index of 0.66792 (Table 6), almost twice as high as the second highest, Barangay 99 (Diit), with the next highest vulnerability index of 0.39874. Barangay 88 consistently got the highest index for all the indicators whereas Barangay 99 consistently got high indices.

Table 6. Barangay in Tacloban City with the highest values for sensitivity, adaptive capacity, exposure, and overall social vulnerability.

	Barangay	Score
Sensitivity	Barangay 88	0.20234
Adaptive capacity	Barangay 88	0.33000
Exposure	Barangay 88	0.13558
Social vulnerability	Barangay 88	0.66792

Barangay 88 is located in San Jose area in the peninsula facing San Pedro Bay (Figure 2). It is where Daniel Z. Romualdez (DZR) Airport is located and according to the interviews and other accounts, the most devastated barangay during Typhoon Haiyan. The barangay was practically washed out, the airport included, when the typhoon hit. Barangay 88 is a highly-urbanized, densely populated barangay with a number of commercial establishments within the residential areas. Most of its former residents were fisherfolks dependent on San Pedro Bay for income.

Barangay 99 is located in the central part of the City. It has the highest unemployment rate and the most number of persons with disabilities among all the barangays. It is facing the Samar Island in the east and is thus at lower risk to storm surges relative to Barangay 88, but has Tigbao River connected to San Juanico Strait, making it as flood-prone as Barangay 88.

Among the 51 barangays with moderate vulnerabilities, only

Barangay 71 (Naga-Naga) has high sensitivity and exposure, while the rest merely have high indices on exposure. Barangay 71 is a densely populated coastal community near Anibong District where Barangays 68, 69, and 70 are located. The latter barangays also have moderate vulnerabilities computed from their high exposure indices and moderate sensitivity and adaptive capacity indices. Anibong District has several coastal communities with a high number of houses on stilts over the waters. It was also where the eight cargo vessels were swept inland by the storm surges brought by Typhoon Haiyan.

More than half or 78 of the total barangays have low vulnerability (Figure 3). These are mostly the barangays in the downtown area and a few small communities in the outskirts of the city.

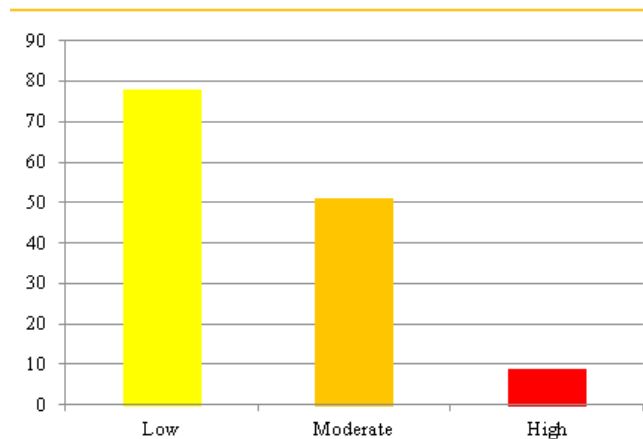


Figure 3. Number of barangays in Tacloban City per degree of social vulnerability.

Sensitivity

The proportions of unemployed persons in the labor force (15 years old and above), informal settlers households, vulnerable sectors, and the population density were considered in measuring sensitivity. These proportions were normalized then ranked to assess the sensitivity among the barangays. Out of the 138 barangays of Tacloban City, 13 fell within the range of 'high sensitivity' (Figure 4). These are among the most populated barangays with a high number of informal settlers, according to the data from the CBMS. Barangay 88 has the highest sensitivity with 0.202469. It consistently has the highest number of population at risk and unemployed. The increasing number of population during daytime and the concentration of settlements in Tacloban can be attributed to the series of migrations from neighboring towns for economic reasons. Furthermore, fish vendors and other informally-employed residents were rampant in the barangay because of the coastal location of the barangay.

About 50 barangays have moderate sensitivity to climate-related hazards (Figure 4). Several of these barangays are along the coast with many informal settlements. The remaining 75 barangays have relatively low sensitivity. These are mainly the upland barangays whose land areas are

mostly occupied by the mountains rather than communities. The barangay with the least sensitivity is Barangay 15, located in the highly commercialized downtown area.

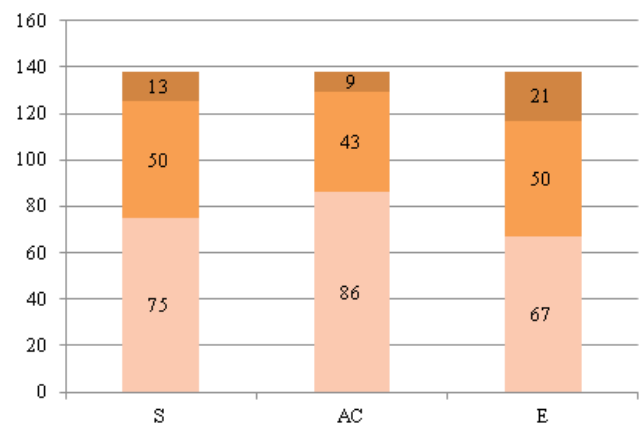


Figure 4. Number of barangays in Tacloban City per degree of sensitivity, adaptive capacity, and exposure. Lightest to darkest color denotes low to high index.

Exposure

Due to their natural and built environments, 21 barangays were highly exposed to climate-related hazards (Figure 4). These barangays scored between 0.05833 to 0.13559, with Barangay 88 scoring the upper limit. This could be attributed to the high susceptibility of these barangays to particular hazards (Figure 5) and to the structure of their houses which could not provide protection during disasters.

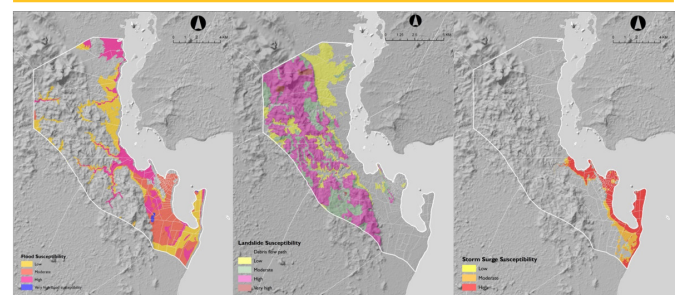


Figure 5. Landslide, flood, and storm surge susceptibility maps of Tacloban City.

Similarly, 50 barangays were moderately exposed. These are the barangays adjacent to those that were identified to have high exposure score. The remaining 67 barangays have low exposure; mostly in the downtown area with Barangay 16 having the lowest exposure score. Tacloban downtown is a highly built-up, commercialized area and most of Barangay 16 is in the heart of it. Prior to Haiyan, building codes across all development zones and building types were not enforced and standard designs for houses and public infrastructure could only withstand winds of 200 kph. Most public infrastructure and critical facilities used as evacuation centers such as the Astrodome are located in hazard-prone areas.

Adaptive Capacity

Barangay 88, having 54.37% of its households earning below the poverty threshold, scored an adaptive capacity index of 0.33, recording a large differential value compared to the nine other barangays with high adaptive capacity index. Barangay 103 got the next highest index with 0.16435, almost half of that of Barangay 88.

These barangays were spatially scattered showing that poverty in the city is not concentrated in certain areas. The index for moderate adaptive capacity is within 0.04012 to 0.10784, with 43 barangays falling within the range. The remaining 86 barangays whose index is low have the lowest proportions of households with income below the poverty threshold. The barangays with the lowest indices are Barangays 109-A, 77, 80, 109, 17, 62-B, and 16. The land uses among these barangays are mostly commercial and institutional, with only a few residential areas.

Ormoc City

Typhoon Haiyan did not directly hit Ormoc but still brought strong winds that caused damage and deaths. Ormoc is generally vulnerable to disasters due to its exposure to natural hazards, not to mention that the livelihoods of many residents are dependent on the environment.

Although Ormoc (Figure 6) has a higher proportion of barangays (8.18%) with high social vulnerability score (Figure 7), its barangays have lower social vulnerability scores compared to those in Tacloban (Table 8).

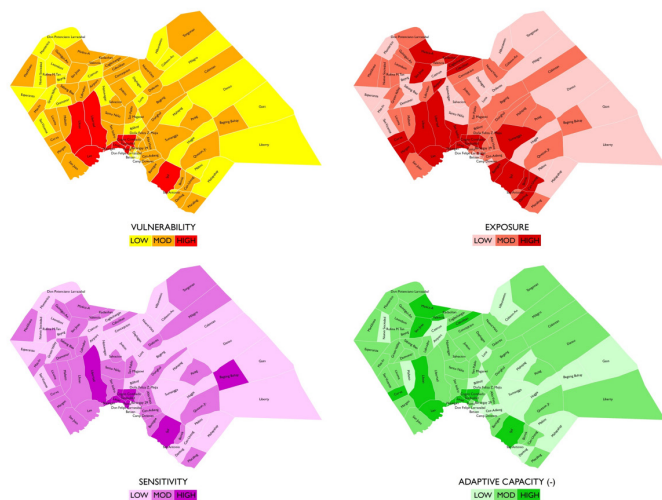


Figure 6. Social vulnerability, sensitivity, adaptive capacity, and exposure maps of Ormoc City, per barangay.

Naungan obtained the highest social vulnerability index of 0.32726 in Ormoc City (Table 8). Those with high overall social vulnerability are those with high sensitivity indices, indicating that population at risk is the main factor contributing to their vulnerability. Bagong Buhay is the only barangay whose sensitivity is high but has moderate overall social vulnerability

index. On the other hand, Lao has moderate sensitivity, but has high adaptive capacity and exposure indices, contributing to a high overall social vulnerability.

Table 7. Range of values for sensitivity, adaptive capacity, exposure, and overall social vulnerability for Ormoc City.

	S	AC	E	V
Low	0.00067- 0.03649	0.00000- 0.00766	0.00237- 0.02432	0.00574- 0.06546
Moderate	0.03650- 0.09972	0.00766- 0.02143	0.02483- 0.05260	0.06608- 0.16831
High	0.10481- 0.19014	0.02265- 0.06437	0.05325- 0.11370	0.17656- 0.34983

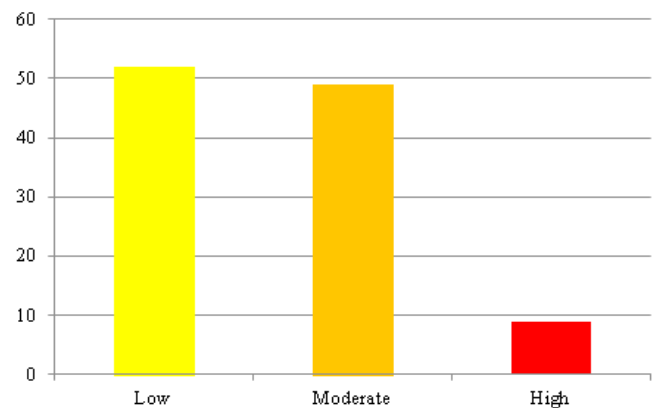


Figure 7. Number of barangays in Ormoc City per degree of vulnerability.

Table 8. Barangays in Ormoc City with the highest values for sensitivity, adaptive capacity, exposure, and overall social vulnerability.

	Barangay	Score
Sensitivity	Cogon Combado	0.19014
Adaptive Capacity (Lack)	Naungan	0.06437
Exposure	Naungan	0.08879
Vulnerability	Naungan	0.32726

The barangays with moderate social vulnerability have indices ranging from 0.06788 to 0.16252. These are 49 barangays whose residents are engaged in small-time commercial fishing and/or subsistence farming, acquiring irrigation from the tributaries of Anilao and Malbasag Rivers. Most of these barangays also have high exposure and high adaptive capacity indices (Figure 8). The 52 barangays that have low social vulnerability indices are mostly the upland barangays that are sparsely occupied and the poblacion (town center) barangays that are commercialized. The least vulnerable among them is Barangay 5, which is a commercial block along Real Street in Ormoc City Proper.

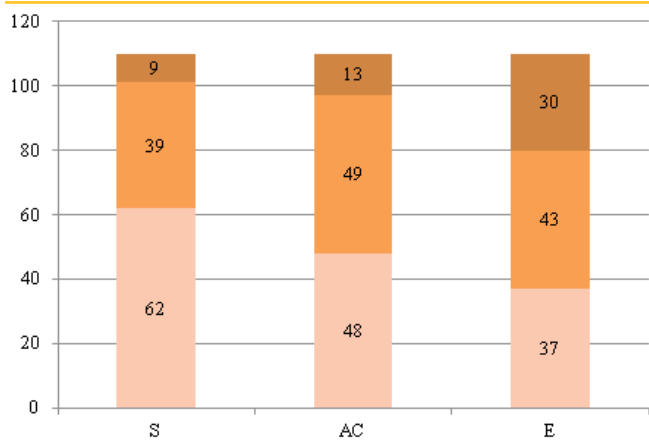


Figure 8. Number of barangays in Ormoc City per degree of sensitivity, adaptive capacity, and exposure. Lightest to darkest color denotes low to high index.

Sensitivity

Out of the nine barangays with high sensitivity, Barangay Cogon Combado is the area most sensitive to disasters because it is the most densely populated barangay in Ormoc City; it scored 0.19014. The other barangays with high sensitivity are Tambuilid, Naungan, Linao, Ipil, Punta, Libertad, Bagong Buhay, and Liloan, which are either coastal communities or barangays with large population.

There were 39 barangays with moderate sensitivity. Barangay 14 registered the lowest sensitivity sub-index among the 62 barangays which have low sensitivity index. This is likely due to the low numbers of population at risk because Barangay 14 is in the poblacion (town center) district and not a residential area. All the poblacion barangays have low sensitivity.

Exposure

Past disasters could validate that Ormoc is at risk to natural hazards such as flooding and landslide (Figure 9). Thirty barangays have high exposure, with Barangay Naungan having the highest with 0.08879. As a coastal community also traversed by Jaoban River, it has very high susceptibility to flooding and is most likely to be affected by storm surges. The other barangays with high exposure index are its neighboring barangays and seven poblacion barangays which are near Anilao River. The remaining 43 barangays have moderate exposure index and the 37 barangays have low.

Adaptive Capacity

Ormoc, though highly urbanized like Tacloban, have more families living below poverty threshold. Therefore, more barangays in Ormoc have high adaptive capacity index. About 13 barangays in Ormoc have high adaptive capacity index (Figure 8). Naungan has the highest adaptive capacity index, perhaps due to the large number of informal settlers in the area. Most of these informal settlers live in stilt houses

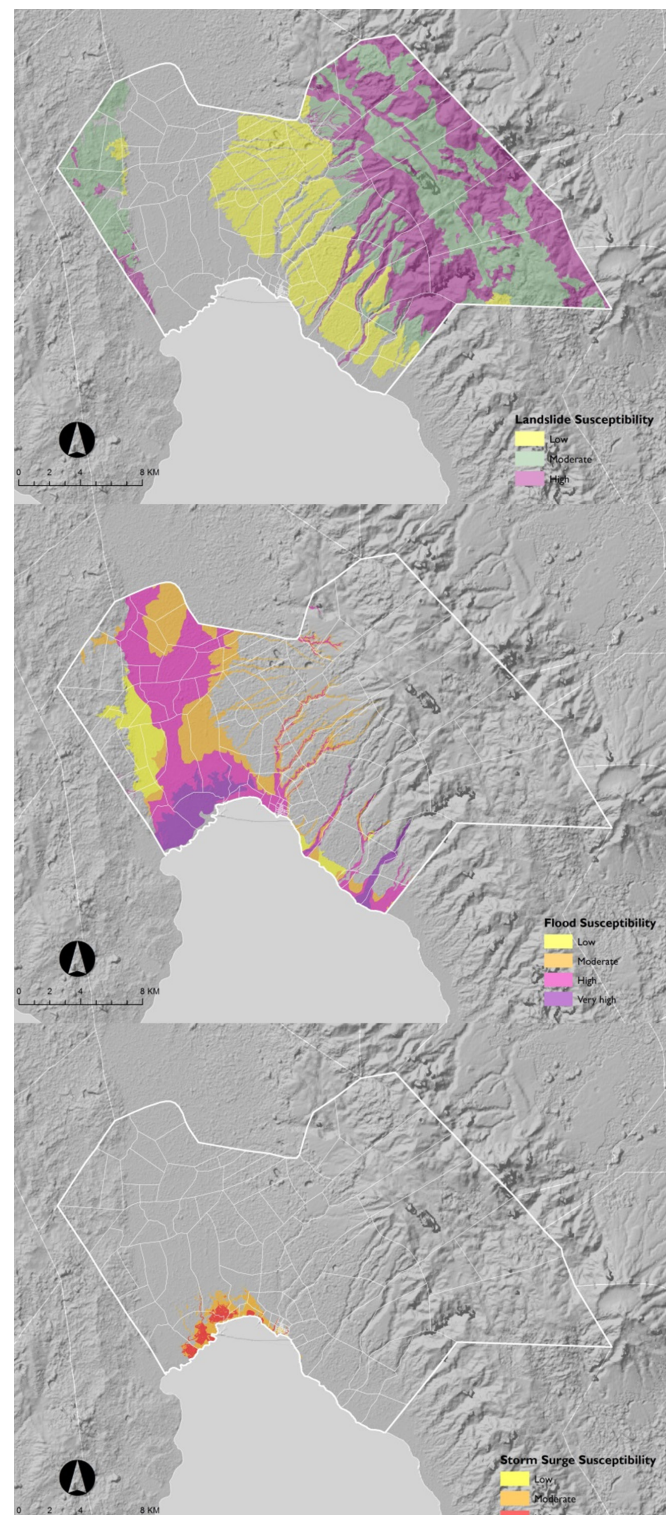


Figure 9. Landslide, flood and storm surge susceptibility maps of Ormoc City.

over the water, while the rest live in houses that are usually submerged during the high tide. The 49 barangays that have moderate adaptive capacities are the rural barangays engaged in fishing and subsistence farming, aside from Barangay 29 which is a poblacion barangay but has residents living under Anilao Bridge. More than half of the remaining 48 barangays that have low adaptive capacity index are located within the

poblacion area. These areas are commercialized with only a few residents. Inadequacy in adaptive capacity due to poverty is observed to be higher in Barangay Naungan with index of 0.06437 as compared to the other barangays.

Conclusion and Recommendation

Typhoon Haiyan highlighted that the combination of exposure to climate-related hazards, underlying socioeconomic conditions, and changing demographic characteristics in Tacloban and Ormoc increases the threats of climate-related hazards to communities. Haiyan's impacts would require the examination of the various causes of vulnerability to facilitate measures to reduce these causes or adapt from the combined factors of disasters.

Barangay 88, said to be the hardest hit barangay in Tacloban City by Typhoon Haiyan, is consistently highest in the city in all factors of vulnerability, recording a large differential vulnerability index relative to other barangays. Tacloban has nine barangays with high vulnerability index. Unfortunately, there is no official data on the number of deaths per barangay due to Typhoon Haiyan in Tacloban City that can be used to validate the computed vulnerability scores.

In Ormoc City, Barangay Naungan, located in the western seaboard of the City, got the highest vulnerability index. Ormoc has nine barangays with high social vulnerability scores, which are lower than those of Tacloban. The barangays with high overall social vulnerability are also those with high sensitivity indices, with population at risk as the main factor contributing to their vulnerability. However, no association can be established between the vulnerability score and the impact of Typhoon Haiyan as represented by the number of deaths per barangay (see Annex 1). This could be attributed to other factors not considered by the study such as the use of pairwise index in evaluating the weights of the sub-indicators. Furthermore, Ormoc City is located in the southwestern portion of the Leyte Island and only experienced strong winds, which this study was not able to evaluate. Typhoon Haiyan hit the hardest in Eastern Leyte and passed through the province in a northeast direction.

While Tacloban City and Ormoc City are examples of a looming and varying social vulnerability across barangays, it is important not only to consider short-term structural mitigation measures but also to adopt sustainable and long-term strategies addressing the underlying factors of vulnerability targeted at the community level. This matter will also require basic social services to be more accessible in barangays who score moderate to high vulnerability. Measures to reduce vulnerability should be a local priority and would require political will for community-based climate action, disaster risk reduction and management, and risk-sensitive land use development.

This study provides an approach for assessing social vulnerability using available census and climate-related hazard data to determine areas for intervention targeted at the barangay level. Future related research should consider other

key indicators available at the barangay level to capture a more precise vulnerability index.

Annexes

Annex 1: Comparisons of vulnerability level, index, exposure and number of deaths per barangay for Ormoc City.

Barangay	Vulnerability Level	Vulnerability Index	Highly Exposed to	No. of Deaths due to Haiyan*
Airport	moderate	0.08785	riverine flooding	2
Alegria	moderate	0.06788	storm surge & riverine flooding	0
Alta Vista	moderate	0.09294	riverine flooding	1
Bagong Buhay	moderate	0.15142	landslide & flash-flood	2
Bagong	moderate	0.07628	landslide & flash-flood	1
Bantigue	moderate	0.15385	storm surge	0
Barangay 1 (Pob.)	low	0.01386	riverine flooding	0
Barangay 10 (Pob.)	low	0.01971	riverine flooding	0
Barangay 11 (Pob.)	moderate	0.07361	riverine flooding	0
Barangay 12 (Pob.)	low	0.02257	riverine flooding	0
Barangay 13 (Pob.)	low	0.04069	riverine flooding	0
Barangay 14 (Pob.)	low	0.02251	riverine flooding	0
Barangay 15 (Pob.)	low	0.05439	riverine flooding	0
Barangay 16 (Pob.)	low	0.03704	riverine flooding	0
Barangay 17 (Pob.)	low	0.02823	riverine flooding	0
Barangay 18 (Pob.)	low	0.01361	riverine flooding	0
Barangay 19 (Pob.)	low	0.01684	riverine flooding	0
Barangay 2 (Pob.)	low	0.02637	riverine flooding	0
Barangay 20 (Pob.)	low	0.03240	riverine flooding	0
Barangay 21 (Pob.)	low	0.04844	riverine flooding	0

Barangay	Vulnerability Level	Vulnerability Index	Highly Exposed to	No. of Deaths due to Haiyan*
Barangay 22 (Pob.)	low	0.05057	riverine flooding	0
Barangay 23 (Pob.)	low	0.05257	riverine flooding	0
Barangay 24 (Pob.)	low	0.04885	riverine flooding	0
Barangay 25 (Pob.)	low	0.05947	riverine flooding	0
Barangay 26 (Pob.)	moderate	0.07102	riverine flooding	1
Barangay 27 (Pob.)	low	0.03519	riverine flooding	0
Barangay 28 (Pob.)	moderate	0.07474	riverine flooding	0
Barangay 29 (Pob.)	moderate	0.13147	riverine flooding	0
Barangay 3 (Pob.)	low	0.00463	riverine flooding	0
Barangay 4 (Pob.)	low	0.02466	riverine flooding	0
Barangay 5 (Pob.)	low	0.00393	riverine flooding	0
Barangay 6 (Pob.)	low	0.00735	riverine flooding	0
Barangay 7 (Pob.)	low	0.00839	riverine flooding	0
Barangay 8 (Pob.)	low	0.00609	riverine flooding	0
Barangay 9 (Pob.)	low	0.00811	riverine flooding	0
Batuan	low	0.02924	riverine flooding	0
Bayog	low	0.05176	riverine flooding	0
Biliboy	low	0.05367	flooding	0
Boroc (Don Carlos Rivilla)	moderate	0.12073	NA	1
Cabao-nan	low	0.04164	landslide & flash-flood	0
Cabintan	moderate	0.08457	landslide	0
Cabulihan	moderate	0.14556	landslide & riverine flooding	0
Cagbuhangin	moderate	0.08533	landslide & riverine flooding	0
Camp Downes	moderate	0.08473	landslide & riverine flooding	0
Can-adieng	moderate	0.10348	riverine flooding	0

Barangay	Vulnerability Level	Vulnerability Index	Highly Exposed to	No. of Deaths due to Haiyan*
Can-untog	moderate	0.09086		
Catmon	low	0.03343	landslide & riverine flooding	0
Cogon Combado	high	0.28843	riverine flooding	0
Concepcion	moderate	0.07210	riverine flooding	0
Curva	moderate	0.13312	riverine flooding	10
Danao	low	0.05618	riverine flooding	0
Danhug	moderate	0.08139	storm surge & riverine flooding	0
Day-hagan	low	0.04754	landslide & riverine flooding	2
Dolores	moderate	0.08383	riverine flooding	1
Domonar	low	0.06482	riverine flooding	0
Don Felipe Larrazabal	moderate	0.08289	landslide	0
Don Potenciano Larrazabal	low	0.03793	landslide & flooding	0
Doña Feliza Z. Meija	moderate	0.11771	riverine flooding	0
Donghol	moderate	0.08141	riverine flooding	0
Esperanza	low	0.01924	landslide	0
Gaas	low	0.02217	landslide & flash-flood	0
Green Valley	low	0.05977	riverine flooding	1
Guinti-gui-an	moderate	0.09171	riverine flooding	0
Hibunawon	low	0.04108	landslide & flash-flood	0
Hugpa	low	0.02699	NA	0
Ipil	high	0.24413	storm surge	0

Barangay	Vulnerability Level	Vulnerability Index	Highly Exposed to	No. of Deaths due to Hai-yan*
Juaton	moderate	0.07426	riverine flooding	0
Kadao-han	moderate	0.09428	landslide & riverine flooding	0
Labrador (Balion)	moderate	0.08146	riverine flooding	0
Lao	high	0.18155	storm surge	0
Leondoni	low	0.04938	riverine flooding	0
Libertad	high	0.18857	storm surge	1
Liberty	low	0.03215	landslide & flash-flood	0
Licama	moderate	0.07499	riverine flooding	0
Liloan	high	0.18401	storm surge	2
Linao	high	0.25736	storm surge	1
Luna	low	0.04415	riverine flooding	0
Mabato	moderate	0.10000	riverine flooding	0
Mabini	low	0.05082	landslide & flash-flood	0
Macabug	moderate	0.10435	storm surge	0
Magaswe	low	0.03606	riverine flooding	0
Mahayag	low	0.04022	riverine flooding	0
Mahaya-hay	low	0.03115	landslide & flash-food	0
Manlili-nao	moderate	0.07316	landslide	0
Margen	moderate	0.12990	landslide & riverine flooding	1
Mas-in	moderate	0.06948	landslide	0
Matica-a	moderate	0.12063	landslide & riverine flooding	1
Milagro	low	0.06632	landslide & flash-flood	0
Mon-terico	low	0.03772	landslide	0
Nasu-nogan	low	0.05052	riverine flooding	1

Barangay	Vulnerability Level	Vulnerability Index	Highly Exposed to	No. of Deaths due to Hai-yan*
Naungan	high	0.32726	strom surge & riverine flooding	1
Nueva Sociedad	low	0.04133	NA	0
Nueva Vista	moderate	0.06979	riverine flooding	2
Patag	moderate	0.10018	NA	1
Punta	high	0.19365	storm surge & riverine flooding	0
Quezon, Jr.	moderate	0.08708	riverine flooding	0
Rufina M. Tan	moderate	0.08743	landslide & riverine flooding	0
Sabang Bao	moderate	0.07681	riverine flooding	0
Salva-cion	moderate	0.09689	riverine flooding	0
San Antonio	low	0.05364	storm surge & riverine flooding	0
San Isidro	moderate	0.13146	riverine flooding	0
San Jose	moderate	0.15853	landslide & riverine flooding	0
San Juan	moderate	0.07650	storm surge & riverine flooding	0
San Pablo (Siman-gan)	moderate	0.13378	riverine flooding	0
San Vicente	low	0.04400	landslide	0
Santo Niño	moderate	0.09484	riverine flooding	0
Suman-gga	moderate	0.08423	riverine flooding	0
Tambu-lilid	high	0.28127	storm surge & riverine flooding	2
Tongo-nan	moderate	0.07163	landslide	0
Valencia	moderate	0.16252	riverine flooding	0

*City Health Office-Health Emergency Management Staff (CHO-HEMS), Ormoc City

Annex 2: Vulnerability level, vulnerability index, and exposure level per barangay for Tacloban City

Barangay	Vulnerability Level	Vulnerability Index	Exposure Level
Barangay 2	low	0.03711	moderate
Barangay 5	low	0.02299	low
Barangay 5-A	low	0.01646	low
Barangay 6	low	0.06986	low
Barangay 6-A	low	0.08478	low
Barangay 7	low	0.01922	low
Barangay 8	low	0.01827	low
Barangay 8-A	low	0.01549	low
Barangay 100	moderate	0.21673	moderate
Barangay 101	moderate	0.10727	high
Barangay 102	low	0.06355	low
Barangay 103	high	0.26579	moderate
Barangay 103-A	low	0.09772	moderate
Barangay 104	moderate	0.18604	moderate
Barangay 105	moderate	0.14059	moderate
Barangay 106	moderate	0.12677	high
Barangay 107	moderate	0.11479	moderate
Barangay 108	moderate	0.1134	moderate
Barangay 109	moderate	0.11885	low
Barangay 109-A	moderate	0.19379	moderate
Barangay 110	high	0.29659	moderate
Barangay 12	moderate	0.14724	moderate
Barangay 13	low	0.04870	moderate
Barangay 14	low	0.02080	low
Barangay 15	low	0.01010	low
Barangay 16	low	0.00749	low
Barangay 17	low	0.01211	low
Barangay 18	low	0.01391	low
Barangay 19	low	0.01750	low
Barangay 20	low	0.02621	low
Barangay 21	low	0.01259	low
Barangay 21- A	low	0.01260	low
Barangay 22	low	0.01500	low
Barangay 23	low	0.02670	low
Barangay 23-A	low	0.03406	low
Barangay 24	low	0.03739	low
Barangay 25	low	0.09707	moderate
Barangay 26	low	0.02575	low
Barangay 27	low	0.01580	low
Barangay 28	low	0.02083	low
Barangay 29	low	0.01325	low
Barangay 30	low	0.00903	low
Barangay 31	low	0.05402	low
Barangay 32	low	0.01648	low
Barangay 33	low	0.01327	low

Barangay	Vulnerability Level	Vulnerability Index	Exposure Level
Barangay 34	low	0.02129	low
Barangay 35	low	0.01706	low
Barangay 35-A	low	0.07173	low
Barangay 36	low	0.06522	moderate
Barangay 36-A	low	0.03831	low
Barangay 37	low	0.28076	moderate
Barangay 37-A	moderate	0.11399	moderate
Barangay 38	low	0.02877	low
Barangay 39	moderate	0.18749	moderate
Baragay 40	low	0.01479	low
Barangay 41	low	0.01716	low
Barangay 42	low	0.06566	low
Barangay 42-A	moderate	0.11472	low
Barangay 43	low	0.03159	low
Barangay 43-A	low	0.06915	low
Barangay 43-B	moderate	0.13364	moderate
Barangay 44	low	0.02740	low
Barangay 44-A	low	0.01278	low
Barangay 45	low	0.04316	moderate
Barangay 46	low	0.03581	low
Barangay 47	low	0.03517	low
Barangay 48	low	0.02361	low
Barangay 48-A	low	0.05200	low
Barangay 48-B	low	0.04867	low
Barangay 49	moderate	0.10501	moderate
Barangay 50	low	0.04541	moderate
Barangay 50-A	low	0.06230	moderate
Barangay 50-B	low	0.06625	moderate
Barangay 51	low	0.03752	low
Barangay 51-A	low	0.03478	low
Barangay 52	moderate	0.13886	high
Barangay 53	low	0.04306	low
Barangay 54	low	0.08507	moderate
Barangay 54-A	low	0.09310	moderate
Barangay 56	low	0.08555	moderate
Barangay 56-A	low	0.06237	moderate
Barangay 57	low	0.7275	low
Barangay 58	low	0.06525	low
Barangay 59	moderate	0.13905	low
Barangay 59-A	moderate	0.17042	low
Barangay 59-B	low	0.04785	low
Barangay 60	low	0.04741	low
Barangay 60-A	moderate	0.11937	low
Barangay 61	low	0.07855	low
Barangay 62	moderate	0.11849	low
Barangay 62-A	moderate	0.21872	low
Barangay 62-B	low	0.06849	low

Barangay	Vulnerability Level	Vulnerability Index	Exposure Level
Barangay 63	moderate	0.16040	moderate
Barangay 64	moderate	0.11326	moderate
Barangay 65	low	0.08539	low
Barangay 66	moderate	0.11216	moderate
Barangay 66	moderate	0.11216	moderate
Barangay 66-A	moderate	0.11326	moderate
Barangay 67	moderate	0.15057	high
Barangay 68	moderate	0.20725	high
Barangay 69	moderate	0.20741	high
Barangay 70	moderate	0.13941	high
Barangay 71	moderate	0.23353	high
Barangay 72	low	0.08595	high
Barangay 73	low	0.08052	high
Barangay 74	high	0.36425	high
Barangay 75	low	0.09240	high
Barangay 76	low	0.05999	moderate
Barangay 77	moderate	0.10745	moderate
Barangay 78	moderate	0.10824	moderate
Barangay 79	moderate	0.16567	high
Barangay 80	low	0.05063	moderate
Barangay 81	low	0.07812	moderate
Barangay 82	low	0.06379	low
Barangay 83	moderate	0.12186	moderate
Barangay 83-A	moderate	0.10225	moderate
Barangay 83-B	moderate	0.18425	moderate
Barangay 83-C	moderate	0.18361	moderate
Barangay 84	high	0.27474	high
Barangay 85	moderate	0.11136	moderate
Barangay 86	moderate	0.10646	moderate
Barangay 87	moderate	0.13132	moderate
Barangay 88	high	0.66792	high
Barangay 89	high	0.34450	high
Barangay 90	moderate	0.13461	high
Barangay 91	moderate	0.18401	moderate
Barangay 92	moderate	0.22149	high
Barangay 93	high	0.26810	moderate
Barangay 94	moderate	0.17355	moderate
Barangay 94-A	moderate	0.16367	high
Barangay 95	moderate	0.18215	moderate
Barangay 95-A	moderate	0.24304	high
Barangay 96	moderate	0.22288	moderate
Barangay 97	moderate	0.19934	moderate
Barangay 98	moderate	0.13117	low
Barangay 99	high	0.39874	high
El Reposo	low	0.03813	low
Libertad	low	0.09325	moderate
Nula-tula	moderate	0.00000	moderate

References

- Asuero, M. P., Nelson, G. L. M., Espaldon, M. V. O., Acosta, L. A., Macandog, D. M., Lalicán, N. M., Talubo, J. P. P. (2012). Social characteristics and vulnerabilities of disaster-prone communities in Infanta, Quezon, Philippines. *Journal of Environmental Science and Management*, 15(2), 19–34.
- Balica, S. F., Wright, N. G., & Meulen, F. van der. (2012). A flood vulnerability index for coastal cities and its use in assessing climate change impacts. *Natural Hazards*, 64(1), 73–105. <http://doi.org/10.1007/s11069-012-0234-1>
- Bolin, R., & Bolton, P. (1986). Race, religion, and ethnicity in disaster recovery (Disaster Recovery, Program on Environment and Behavior Monograph No. 42). Boulder, CO: Institute of Behavioral Science, University of Colorado.
- Bolin, R., & Stanford, L. (1991). Shelter, Housing and Recovery: A Comparison of U.S. *Disasters*. *Disasters*, 15(1), 24–34. <http://doi.org/10.1111/j.1467-7717.1991.tb00424.x>
- Burton, I., Kates, R. W., & White, G. F. (1993). *The Environment As Hazard* (Second Edition). New York: The Guilford Press.
- Cannon, T. (1994). Vulnerability analysis and the explanation of “natural” disasters. In A. Varley (Ed.), *Disasters, Development and Environment* (pp. 13–30). Chichester: Wiley.
- Community-Based Monitoring System Network. (2011a). *Ormoc City CBMS*. Manila, Philippines: De La Salle University - Angelo King Institute for Economic and Business Studies.
- Community-Based Monitoring System Network. (2011b). *Tacloban City CBMS: The Many Faces of Tacloban*. Manila, Philippines: De La Salle University - Angelo King Institute for Economic and Business Studies.
- Cutter, S. L., Boruff, B. J., & Shirley, W. L. (2003). Social vulnerability to environmental hazards. *Social Science Quarterly*, 84(2), 242–261. <http://doi.org/10.1111/1540-6237.8402002>
- Cutter, S. L., & Corendea, C. (2013). *From social vulnerability to resilience: measuring progress toward disaster risk reduction*. UNU- EHS. Retrieved from <http://collections.unu.edu/view/UNU:1885>
- Cutter, S. L., Emrich, C. T., Webb, J. J., & Morath, D. (2009). Social vulnerability to climate variability hazards: A review of the literature. *Final Report to Oxfam America*, 5. Retrieved from http://www.mfpp.org/Climate_Solutions_University/pluginfile.php/171/mod_resource/content/0/Literature_Review.pdf
- Cutter, S. L., & Finch, C. (2008). Temporal and spatial changes in social vulnerability to natural hazards. *Proceedings of*

- the *National Academy of Sciences*, 105(7), 2301–2306. <http://doi.org/10.1073/pnas.0710375105>
- Cutter, S. L., Johnson, L. A., Finch, C., & Berry, M. (2007). The U.S. hurricane coasts: Increasingly vulnerable? *Environment: Science and Policy for Sustainable Development*, 49(7), 8–21. <http://doi.org/10.3200/ENVT.49.7.8-21>
- Cutter, S. L., Mitchell, J. T., & Scott, M. S. (2000). Revealing the Vulnerability of People and Places: A Case Study of Georgetown County, South Carolina. *Annals of the Association of American Geographers*, 90(4), 713–737. <http://doi.org/10.1111/0004-5608.00219>
- Godschalk, D. R., Brower, D. J., & Beatley, T. (1989). *Catastrophic Coastal Storms: Hazard Mitigation and Development Management*. Duke University Press.
- H. John Heinz III Center for Science, Economics, and the Environment. (2000). *The Hidden Costs of Coastal Hazards: Implications For Risk Assessment And Mitigation*. Washington, D.C.: Island Press.
- Hahn, M. B., Riederer, A. M., & Foster, S. O. (2009). The Livelihood Vulnerability Index: A pragmatic approach to assessing risks from climate variability and change—A case study in Mozambique. *Global Environmental Change*, 19(1), 74–88. <http://doi.org/10.1016/j.gloenvcha.2008.11.002>
- Hammill, A., Bizikova, L., Dekens, J., & McCandless, M. (2013). *Comparative analysis of climate change vulnerability assessments: Lessons from Tunisia and Indonesia*. Eschborn, Germany: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. Retrieved from <https://gc21.giz.de/ibt/var/app/wp342deP/1443/wp-content/uploads/filebase/va/vulnerability-guides-manuals-reports/Comperative-analysis-of-climate-change-vulnerability-assessments.pdf>
- Hewitt, K. (1997). *Regions of Risk: A Geographical Introduction to Disasters*. Routledge
- IPCC. (2007). *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. (Core Writing Team, R. K. Pachauri, & A. Reisinger, Eds.). IPCC, Geneva, Switzerland: Intergovernmental Panel on Climate Change.
- Mileti, D. (1999). *Disasters by Design: A Reassessment of Natural Hazards in the United States*. Joseph Henry Press.
- Mitchell, J. K., Abdel-Ghaffar, A. M., Gentry, R. C., Leatherman, S. P., & Sparks, P. (1986). *Hurricane Diana, North Carolina: September 10-14, 1984*. National Research Council. Retrieved from <http://hdl.handle.net/2027/uiug.30112104066565>
- Morrow, B. H. (1999). Identifying and mapping community vulnerability. *Disasters*, 23(1), 1–18. <http://doi.org/10.1111/1467-7717.00102>
- National Disaster Risk Reduction and Management Council. (2014). *NDRRMC Update, SitRep No. 108, Effect of Typhoon “Yolanda” (Haiyan)*. Quezon City, Philippines. Retrieved from [http://www.ndrrmc.gov.ph/attachments/article/1329/Effects_of_Typhoon_YOLANDA_\(HAIYAN\)_SitRep_No_108_03APR2014.pdf](http://www.ndrrmc.gov.ph/attachments/article/1329/Effects_of_Typhoon_YOLANDA_(HAIYAN)_SitRep_No_108_03APR2014.pdf)
- National Statistical Coordination Board. (2010). *Poverty Statistics*. Makati City, Philippines.
- National Statistical Coordination Board. (2012). *Poverty Statistics*. Makati City, Philippines.
- National Statistics Office. (2007). *Population Data*. Quezon City, Philippines.
- National Statistics Office. (2010). *Population Data*. Quezon City, Philippines.
- Ngo, E. B. (2001). When disasters and age collide: reviewing vulnerability of the elderly. *Natural Hazards Review*, 2(2), 80–89. [http://doi.org/10.1061/\(ASCE\)1527-6988\(2001\)2:2\(80\)](http://doi.org/10.1061/(ASCE)1527-6988(2001)2:2(80))
- O’Brien, P., & Mileti, D. (1992). Citizen participation in emergency response following the Loma Prieta earthquake. *International Journal of Mass Emergencies and Disasters*, 10(1), 71–89.
- Peacock, W. G., Gladwin, H., & Morrow, B. H. (1997). *Hurricane Andrew: Ethnicity, Gender and the Sociology of Disasters*. Routledge.
- Platt, R. H. (1991). Lifelines: An emergency management priority for the United States in the 1990s. *Disasters*, 15(2), 172–176. <http://doi.org/10.1111/j.1467-7717.1991.tb00446.x>
- Puente, S. (1999). Social vulnerability to disasters in Mexico City: An assessment method. In J. K. Mitchell (Ed.), *Crucibles of hazard: Mega-cities and disasters in transition* (p. 535). Tokyo: UNU Press. Retrieved from <http://collections.unu.edu/eserv/UNU:2385/nLib9280809873.pdf>
- Sullivan, C. A., Meigh, J. R., & Fediw, T. S. (2002). *Derivation and Testing of the Water Poverty Index Phase I*. Final Report May 2002 (Report to Department for International Development, Centre for Ecology and Hydrology, Wallingford, UK.).
- Thomas, D. S. K., Philipps, B. D., Lovekamp, W. E., & Fothergill, A. (Eds.). (2013). *Social Vulnerability to Disasters, Second Edition* (Second Edition). Boca Raton: CRC Press.
- Tobin, G., & Ollenburger, J. (1992). *Natural hazards and the elderly*. Natural Hazards Research and Applications Information Center, University of Colorado. Retrieved from http://scholarcommons.usf.edu/fmhi_pub/16

- Uitto, J. I. (1998). The geography of disaster vulnerability in megacities: A theoretical framework. *Applied Geography*, (1), 7–16. [http://doi.org/10.1016/S0143-6228\(97\)00041-6](http://doi.org/10.1016/S0143-6228(97)00041-6)
- United Nations Development Programme. (2014). *Sustaining Human Progress: Reducing Vulnerabilities and Building Resilience* (Human Development Report 2014.).
- United Nations International Strategy for Disaster Reduction. (2009). *2009 UNISDR terminology on disaster risk reduction*.
- White, G., & Haas, J. E. (1975). *Assessment of Research on Natural Hazards*. Cambridge, Mass: The MIT Press.
- Wisner, B., Blaikie, P., Cannon, T., & Davis, I. (2003). *At Risk: Natural Hazards, People's Vulnerability, and Disaster* (Second Edition). London: Routledge.
- WWF & BPI. (2013). *Business Risk Assessment and the Management of Climate Change Impacts*. Retrieved from <http://wwf.org.ph/wwf3/downloads/publications/Business%20Risk%20Assessment%20and%20the%20Management%20of%20Climate%20Change%20Impacts%20-%202012%20Cities.pdf>
- Yusuf, A. A., & Francisco, H. (2009). *Climate Change Vulnerability Mapping for Southeast Asia* (EEPSEA Special and Technical Paper No. tp200901s1). Economy and Environment Program for Southeast Asia (EEPSEA). Retrieved from <https://ideas.repec.org/p/eep/tpaper/tp200901s1.html>
- Zahran, S., Brody, S. D., Peacock, W. G., Vedlitz, A., & Grover, H. (2008). Social vulnerability and the natural and built environment: a model of flood casualties in Texas. *Disasters*, 32(4), 537–560. <http://doi.org/10.1111/j.1467-7717.2008.01054.x>



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 (Figure 1). 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.

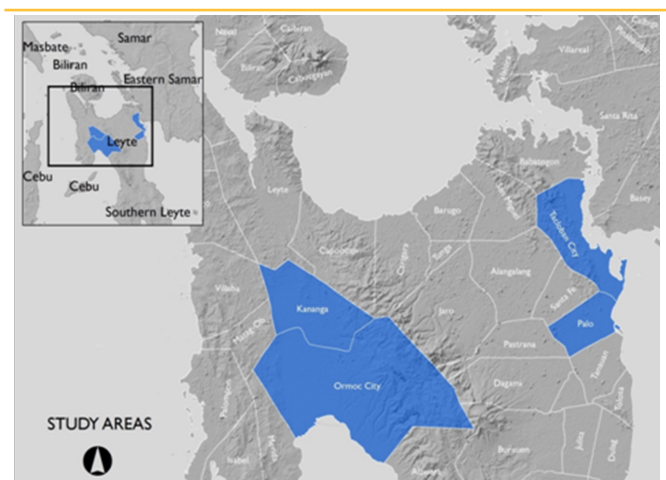


Figure 1. Location map of study sites.

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).

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.

Accordingly, a detailed list of indicators and their corresponding classifications or rankings, units of measurement, functional relationships to vulnerability and sources is shown in Table 2. 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 1. Categorization, description and sources of selected indicators (mostly adopted from Cutter et al., 2003).

Major Components/Factor	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 awareness	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
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

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
Sensitivity	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
		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

Major Components/Factor	Determinants	Indicators and classifications/ranking		Unit	Functional relationship to vulnerability	Source
Adaptive capacity	Information and awareness	Presence of access to knowledge and info on natural hazards and disasters	Yes; Perception - frequency	%	↓	HH Survey
		Presence of evacuation map/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
	Instiutions and systems	Barangay DRRM Committee institutionalizing	Awareness	%		HH Survey
		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

Major Components/Factor	Determinants	Indicators and classifications/ranking		Unit	Functional relationship to vulnerability	Source
Adaptive capacity	Institutions and systems	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		
		Storm surge susceptibility	High	Ha	↑	UP DREAM
			Moderate	Ha		
			Low	Ha		
	Land tenure	Land tenure stature status	Own house, rent-free lot without consent of owner	%	↑	HH Survey (adopted from Community - based Monitoring System)
			Rent-free house and lot without consent of owner	%		
			Rent house/ room including lot	%		
			Own house, rent-free lot with 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 & lot with consent of owner	%	↑	HH Survey (adopted from Community - based Monitoring System)
			Own house, rents lot (or government - owned lot)	%	↑	
			Ancestral domain/ inherited land	%	↑	
			Own house and lot (bought/ granted/ loaned)	%	↑	
			Respon- dents's perception	%	↑	
			Respon- dents's perception	%	↑	
				%	↑	
	Public infrastructure regarding condition	Poor condition/in-need-of-repair nearest public elementary school		%	↑	HH Survey
		Poor condition/in-need-of-repair nearest public high school				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 adopted 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 (I_i). 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.

$$I_i = \frac{X_i - \text{Min}X_i}{\text{Max}X_i - \text{Min}X_i} \text{ for } + \text{ functional relationship (1)}$$

$$I_i = \frac{\text{Max}X_i - X_i}{\text{Max}X_i - \text{Min}X_i} \text{ for } - \text{ functional relationship (2)}$$

where X_i is the actual value, $\text{Min}X_i$ is the minimum value, and $\text{Max}X_i$ 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

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

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:

$$\text{SoVI}_m = W_s S_m + W_{AC} AC_m + W_E E_m \quad (4)$$

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 4).

$$W_i = 1/n_i \quad (5)$$

Table 4. Weights of indicators.

Major Components	No. of indicators (n_i)	Weight 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, thirty-one in Ormoc, six in Palo, and eight 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 5). 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 households (NSO, 2010)	# of selected barangays	# of sample households	Confidence 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 6), 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, 0.3272 and 0.3249 (see Table 6 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.

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	0.3796
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

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	1.5443	2.7608	5.8692

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

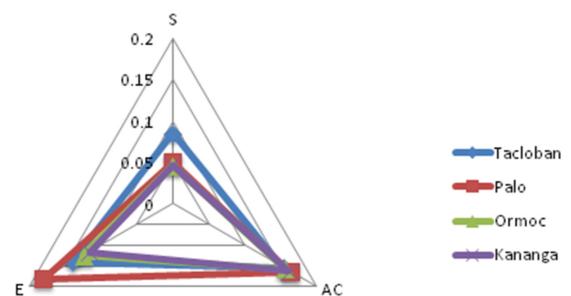
	Very High	High	Moderate	Low
Tacloban	2.3326	1.1560	1.2625	1.6375
Palo	4.8077	7.9002	3.3946	1.6469
Ormoc	2.8033	6.6638	5.1567	2.6876
Kananga	3.3436	1.4167	2.6404	8.9146

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

	High	Moderate	Low
Tacloban	8.5600	3.7727	3.1842
Palo	7.4345	4.4083	2.3075
Ormoc	3.4119	5.1517	9.2300
Kananga	0	0	0

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.

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

Sensitivity

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. Meanwhile for climate-related hazards, Palo got the highest score of 0.2443 due to 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. On landslide and storm surge susceptibility, Tacloban has the highest scores.

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.

Social Vulnerability and Haiyan Deaths

An increasing pattern of SoVI and number of deaths from western to eastern municipalities was observed (see Figure 4), 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

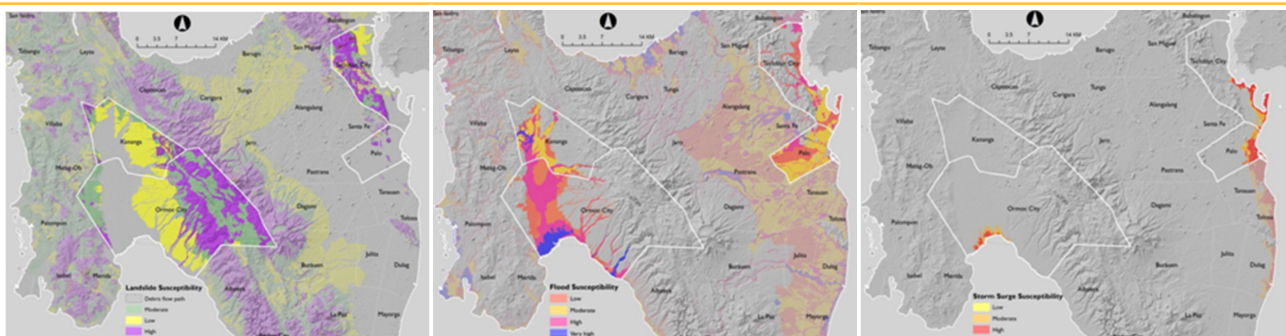


Figure 3. Landslide, flood and storm surge susceptibility maps of study areas (Vector data source: DREAM YoRInfo Center, 2014).

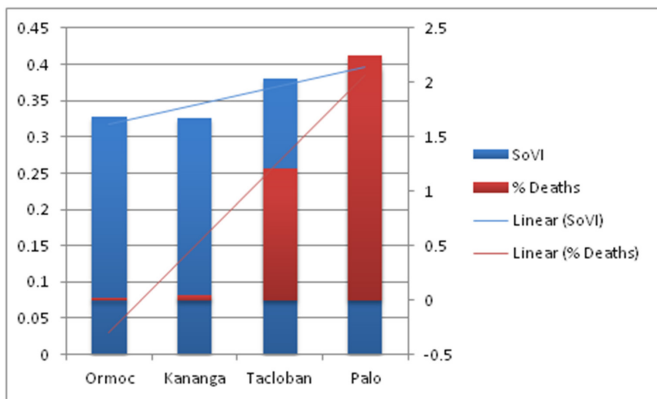


Figure 4. Clustered columns and trend line illustrating the link between and increasing pattern for SoVI and percentages of deaths from Ormoc and Kananga (west) to Tacloban and Palo (east).

to that in the east. Deaths in Ormoc and Kananga were mostly due to strong winds.

Based on the hazard susceptibility maps (see Figures 5 to 8), 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).

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

^aas of April 23, 2014, according to Post Disaster Needs Assessment in TY Yolanda Affected Areas (NDRRC, 2014a); ^bNational Statistics Office, 2010

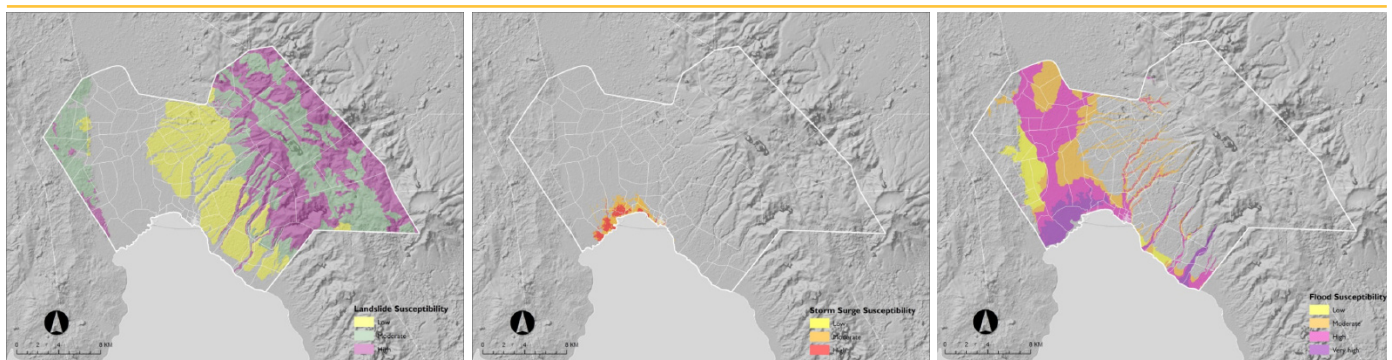


Figure 5. Flood, landslide and storm surge susceptibility maps of Ormoc City (Vector data source: DREAM YoRInfo Center, 2014).

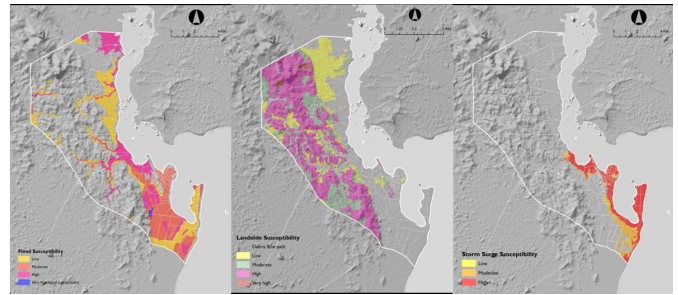


Figure 6. Flood, landslide and storm surge susceptibility maps of Tacloban City (Vector data source: DREAM YoRInfo Center, 2014).

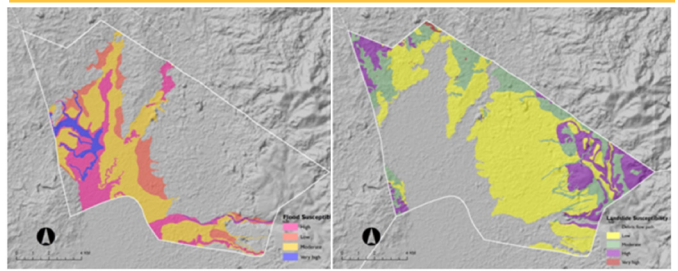


Figure 7. Flood, landslide and storm surge susceptibility maps of Municipality of Kananga (Vector data source: DREAM YoRInfo Center, 2014).

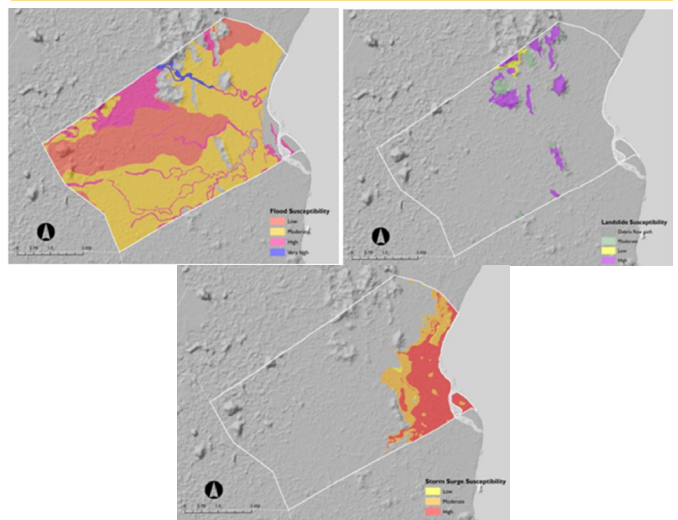


Figure 8. Flood, landslide and storm surge susceptibility maps of Municipality of Palo (Vector data source: DREAM YoRInfo Center, 2014).

Generally, topographic factors contribute to depth and extent of flooding from storm surge (Lapidez et al., 2014). Topographic maps of northern part of Leyte with elevation profiles from west to east and southwest to east are shown in Figures 9 and 10, respectively.

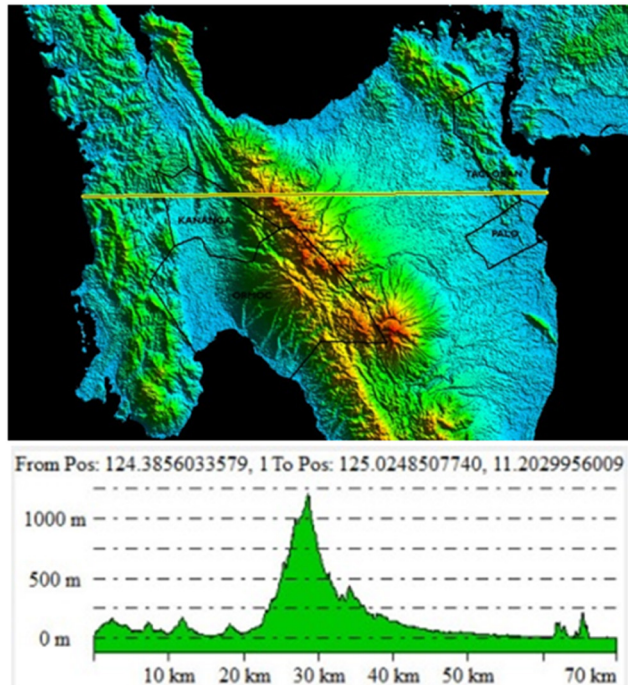


Figure 9. Shuttle Radar Topography Mission (SRTM) digital elevation model (DEM) of northern part of Leyte with west-east elevation profile.

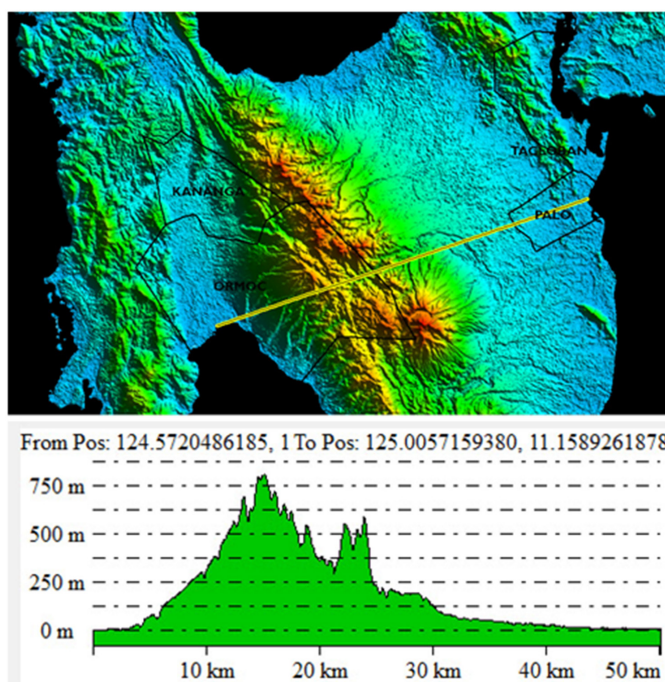


Figure 10. Shuttle Radar Topography Mission (SRTM) digital elevation model (DEM) of northern part of Leyte with southwest-east elevation profile.

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.

References

- Asian Development Bank. (2014). *Key Indicators for Asia and the Pacific 2014*. Asian Development Bank. Retrieved from http://www.adb.org/sites/default/files/publication/43030/ki2014_0.pdf
- Balica, S. F., Wright, N. G., & Meulen, F. van der. (2012). A flood vulnerability index for coastal cities and its use in assessing climate change impacts. *Natural Hazards*, 64(1), 73–105. <http://doi.org/10.1007/s11069-012-0234-1>
- Birkmann, J. (2006). Indicators and criteria for measuring vulnerability: Theoretical bases and requirements. In J. Birkmann (Ed.), *Measuring vulnerability to natural hazards: Towards disaster resilient societies* (pp. 55–77). New York: UNU Press.

- Bolin, R., & Bolton, P. (1986). *Race, religion, and ethnicity in disaster recovery* (Disaster Recovery, Program on Environment and Behavior Monograph No. 42). Boulder, CO: Institute of Behavioral Science, University of Colorado. Retrieved from http://scholarcommons.usf.edu/fmhi_pub/88
- Bolin, R. C. (1982). *Long-term family recovery from disaster*. Boulder, CO: Institute of Behavioral Science, University of Colorado.
- Bolin, R., & Stanford, L. (1991). Shelter, Housing and Recovery: A Comparison of U.S. Disasters. *Disasters*, 15(1), 24–34. <http://doi.org/10.1111/j.1467-7717.1991.tb00424.x>
- Burton, I., Kates, R. W., & White, G. F. (1993). *The Environment As Hazard* (Second Edition). New York: The Guilford Press.
- Cannon, T. (1994). Vulnerability analysis and the explanation of “natural” disasters. In A. Varley (Ed.), *Disasters, Development and Environment* (pp. 13–30). Chichester: Wiley.
- Clark, G. E., Moser, S. C., Ratick, S. J., Dow, K., Meyer, W. B., Emani, S., ... Schwarz, H. E. (1998). Assessing the Vulnerability of Coastal Communities to Extreme Storms: The Case of Revere, MA., USA. *Mitigation and Adaptation Strategies for Global Change*, 3(1), 59–82. <http://doi.org/10.1023/A:1009609710795>
- Cutter, S. L. (1996). Vulnerability to environmental hazards. *Progress in Human Geography*, 20(4), 529–539. <http://doi.org/10.1177/030913259602000407>
- Cutter, S. L., Boruff, B. J., & Shirley, W. L. (2003). Social vulnerability to environmental hazards. *Social Science Quarterly*, 84(2), 242–261. <http://doi.org/10.1111/1540-6237.8402002>
- Cutter, S. L., Emrich, C. T., Webb, J. J., & Morath, D. (2009). Social vulnerability to climate variability hazards: A review of the literature. *Final Report to Oxfam America*, 5. Retrieved from http://www.mfpp.org/Climate_Solutions_University/pluginfile.php/171/mod_resource/content/0/Literature_Review.pdf
- Cutter, S. L., Mitchell, J. T., & Scott, M. S. (2000). Revealing the Vulnerability of People and Places: A Case Study of Georgetown County, South Carolina. *Annals of the Association of American Geographers*, 90(4), 713–737. <http://doi.org/10.1111/0004-5608.00219>
- Enarson, E., & Morrow, B. (1998). *The gendered terrain of disaster*. New York: Praeger.
- GIZ. (2014). Assessment of Early Warning Efforts in Leyte for Typhoon Haiyan/Yolanda. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. Retrieved from http://www.preventionweb.net/files/36860_36860gizassessmentofearlywarningvol.pdf
- Godschalk, D. R., Brower, D. J., & Beatley, T. (1989). *Catastrophic Coastal Storms: Hazard Mitigation and Development Management*. Duke University Press.
- Hahn, M. B., Riederer, A. M., & Foster, S. O. (2009). The Livelihood Vulnerability Index: A pragmatic approach to assessing risks from climate variability and change—A case study in Mozambique. *Global Environmental Change*, 19(1), 74–88. <http://doi.org/10.1016/j.gloenvcha.2008.11.002>
- Hammill, A., Bizikova, L., Dekens, J., & McCandless, M. (2013). *Comparative analysis of climate change vulnerability assessments: Lessons from Tunisia and Indonesia*. Eschborn, Germany: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. Retrieved from <https://gc21.giz.de/ibt/var/app/wp342deP/1443/wp-content/uploads/filebase/va/vulnerability-guides-manuals-reports/Comperative-analysis-of-climate-change-vulnerability-assessments.pdf>
- Hewitt, K. (1997). *Regions of Risk: A Geographical Introduction to Disasters*. Routledge.
- H. John Heinz III Center for Science, Economics, and the Environment. (2000). *The Hidden Costs of Coastal Hazards: Implications For Risk Assessment And Mitigation*. Washington, D.C.: Island Press.
- Ignacio, J. A., & Henry, S. (2013). Assessing changes in village-level social vulnerability based on census data. Presented at the XXVII IUSSP International Population Conference, Busan, Korea.
- IPCC. (2007a). *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. (M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, & C. E. Hanson, Eds.). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press. Retrieved from <http://www.ipcc-wg2.gov/publications/AR4/index.html>
- IPCC. (2007b). *Climate Change 2007: Synthesis Report*. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. (Core Writing Team, R. K. Pachauri, & A. Reisinger, Eds.). Geneva, Switzerland: Intergovernmental Panel on Climate Change.
- IPCC. (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. (C. B. Field, V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, ... L. L. White, Eds.). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.
- Krejcie, R. V., & Morgan, D. W. (1970). Determining

- Sample Size for Research Activities. *Educational and Psychological Measurement*, 30(3), 607–610. <http://doi.org/10.1177/001316447003000308>
- Lapidez, J. P., Suarez, J. K., Tablazon, J., Dasallas, L., Gonzalo, L. A., Santiago, J., ... Malano, V. (2014). Identification of Storm Surge Vulnerable Areas in the Philippines Through Simulations of Typhoon Haiyan-Induced Storm Surge Using Tracks of Historical Tropical Cyclones (Vol. 16, p. 15376). Presented at the EGU General Assembly Conference Abstracts. Retrieved from <http://adsabs.harvard.edu/abs/2014EGUGA..1615376L>
- Lasco, R., Delfino, R. J., Rangasa, M., & Pulhin, F. B. (2012). The role of local government units in mainstreaming climate change adaptation: The case of Albay, Philippines. In *Local Climate Change and Society* (p. 54). Routledge.
- Lee, T. C., & Wong, C. F. (2007). Historical Storm Surges and Storm Surge Forecasting in Hong Kong. Presented at the JCOMM Scientific and Technical Symposium on Storm Surges, Seoul, Republic of Korea.
- Li, K., & Li, G. S. (2011). Vulnerability assessment of storm surges in the coastal area of Guangdong Province. *Natural Hazards and Earth System Sciences*, 11(7), 2003–2010. <http://doi.org/10.5194/nhess-11-2003-2011>
- Lundgren, L., & Jonsson, A. C. (2012). *Assessment of social vulnerability: a literature review of vulnerability related to climate change and natural hazards* (CSPR Briefing No. 9, 2012). Norrköping, Sweden: Centre for Climate Science and Policy Research.
- Mitchell, J. K., Abdel-Ghaffar, A. M., Gentry, R. C., Leatherman, S. P., & Sparks, P. (1986). *Hurricane Diana, North Carolina: September 10-14, 1984*. National Research Council. Retrieved from <http://hdl.handle.net/2027/uiug.30112104066565>
- Morrow, B. H. (1999). Identifying and mapping community vulnerability. *Disasters*, 23(1), 1–18. <http://doi.org/10.1111/1467-7717.00102>
- Morrow, B. H., & Philipps, B. (1999). What's Gender "Got to Do With It"? *International Journal of Mass Emergencies and Disasters*, 17(1), 5–11.
- National Statistical Coordination Board. (2012). *Poverty Statistics*. Makati City, Philippines.
- National Statistics Office. (2010). *Population Data*. Quezon City, Philippines.
- NDRRMC. (2014a). *Post Disaster Needs Assessment in TY Yolanda Affected Areas*. Quezon City, Philippines: National Disaster Risk Reduction and Management Council. Retrieved from [http://www.ndrrmc.gov.ph/attachments/article/1329/Effects_of_Typhoon_YOLANDA_\(HAIYAN\)_SitRep_No_108_03APR2014.pdf](http://www.ndrrmc.gov.ph/attachments/article/1329/Effects_of_Typhoon_YOLANDA_(HAIYAN)_SitRep_No_108_03APR2014.pdf)
- NDRRMC. (2014b). *SitRep No. 108, Effect of Typhoon "Yolanda" (Haiyan)* (NDRRMC Update). Quezon City, Philippines: National Disaster Risk Reduction and Management Council. Retrieved from [http://www.ndrrmc.gov.ph/attachments/article/1329/Effects_of_Typhoon_YOLANDA_\(HAIYAN\)_SitRep_No_108_03APR2014.pdf](http://www.ndrrmc.gov.ph/attachments/article/1329/Effects_of_Typhoon_YOLANDA_(HAIYAN)_SitRep_No_108_03APR2014.pdf)
- Puente, S. (1999). Social vulnerability to disasters in Mexico City: An assessment method. In J. K. Mitchell (Ed.), *Crucibles of hazard: Mega-cities and disasters in transition* (p. 535). Tokyo: UNU Press. Retrieved from <http://collections.unu.edu/eserv/UNU:2385/nLib9280809873.pdf>
- Rygel, L., O'sullivan, D., & Yarnal, B. (2006). A Method for Constructing a Social Vulnerability Index: An Application to Hurricane Storm Surges in a Developed Country. *Mitigation and Adaptation Strategies for Global Change*, 11(3), 741–764. <http://doi.org/10.1007/s11027-006-0265-6>
- Sietchiping, R. (2006). Applying an index of adaptive capacity to climate change in north-western Victoria, Australia. *Applied GIS*, 2(3), 16–1.
- Stoddart, H. (2013). Lift Lives for Good: Actions to tackle inequality and climate change. *Policy & Practice*. Retrieved from <http://policy-practice.oxfam.org.uk/publications/lift-lives-for-good-actions-to-tackle-inequality-and-climate-change-307847>
- Sullivan, C. A., Meigh, J. R., & Fediw, T. S. (2002). *Derivation and testing of the Water Poverty Index Phase I. Final Report May 2002* (Report to Department for International Development, Centre for Ecology and Hydrology, Wallingford, U.K.).
- UNDP. (2006). *Beyond Scarcity: Power, Poverty and the Global Water Crisis* (Human Development Report 2006). New York: United Nations Development Programme.
- UNDP. (2007). *HDR 2007/2008 - Fighting climate change: Human solidarity in a divided world* (Human Development Report (1990 to present)). Human Development Report Office (HDRO), United Nations Development Programme (UNDP). Retrieved from <https://ideas.repec.org/b/hdr/report/hdr2007-2008.html>
- United Nations International Strategy for Disaster Reduction. (2009). *2009 UNISDR terminology on disaster risk reduction*.
- White, G., & Haas, J. E. (1975). *Assessment of Research on Natural Hazards*. Cambridge, Mass: The MIT Press.
- Wisner, B., Blaikie, P., Cannon, T., & Davis, I. (2003). *At Risk: Natural Hazards, People's Vulnerability, and Disaster* (Second Edition). London: Routledge.
- World Health Organization. (2005). *Immunization Coverage Cluster Survey—Reference Manual*. Geneva, Switzerland: World Health Organization.

Yusuf, A. A., & Francisco, H. (2009). *Climate Change Vulnerability Mapping for Southeast Asia* (EEPSEA Special and Technical Paper No. tp200901s1). Economy and Environment Program for Southeast Asia (EEPSEA). Retrieved from <https://ideas.repec.org/p/eep/tpaper/tp200901s1.html>



The impacts of Typhoon Haiyan in the Philippines: Implications to land use planning

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Abstract

Recent extreme weather events have brought devastating impacts on people's lives and infrastructure in many parts of the world. The scale of the impact of Typhoon Haiyan in the Philippines revealed a high degree of vulnerability and exposure of coastal communities to extreme events in a region that is regularly hit by tropical cyclones. This paper is based on initial assessment of the immediate impacts of Typhoon Haiyan. It was conducted in the cities of Tacloban and Ormoc and in the municipality of Palo, which were heavily affected by the impacts of Haiyan. Vulnerability to typhoon-related hazards and impacts of climate change is considered to be one of the major issues affecting land use in these areas. This paper analyzed existing legal framework and how climate change adaptation (CCA) and disaster risk reduction (DRR) can be incorporated in policies and plans such as the Comprehensive Land Use Plan (CLUP). It also examined the roles and responsibilities of both central and local governments in the Philippines in terms of land use planning and disaster mitigation strategies and their implications towards the future development of climate resilient communities, particularly in the context of a contentious resettlement process as a result of the application of a hazard-based zoning process. The vulnerability of the Philippines to climate change and natural disasters calls for risk reduction measures that decrease the vulnerability through land use planning, hazard-based zoning, climate resilient building codes and retrofitting as well as innovative financial incentives. These CCA and DRR measures should be mainstreamed into the local government plans through the CLUP and followed by an effective implementation. However, a key challenge to local decision-makers in these Typhoon Haiyan-affected areas is how to incorporate a range of possible vulnerabilities driven by changing landscape, infrastructure, and socioeconomic conditions in land use planning.

Keywords: Typhoon Haiyan · Philippines · land use planning · climate change · disaster risk reduction

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Introduction

The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) concluded that “impacts from recent climate-related extremes, such as heat waves, droughts, floods, cyclones, and wildfires reveal significant vulnerability and exposure of some ecosystems and many human systems to current climate variability (very high confidence)” (IPCC, 2014a). The same report emphasizes that “in urban areas, climate change is projected to increase risks for people, assets, economies and ecosystems, including risks from heat stress, storms and extreme precipitation, inland and coastal flooding, landslides, air pollution, drought, water scarcity, sea-level rise, and storm surges (very high confidence)” (IPCC, 2014a).

Recent extreme weather events were responsible for some of the most destructive impacts in years such as Hurricane Katrina in 2005, Cyclone Nargis in 2008, Hurricane Sandy in 2012, and Typhoon Haiyan in 2013. In the U.S.A., tropical cyclones pose a significant threat to coastal population, mostly not due to extreme winds but to the associated storm surge most often combined with fresh water flooding due to extreme rainfall (Rappaport, 2000).

Asia and the Pacific is the region more affected by the impact of extreme weather events, coupled with high level of exposure to the impacts by exceedingly vulnerable populations who are extremely poor and marginalized (Asian Development Bank [ADB], 2012). The disaster risk in cities increases through high population density, deficient urban planning, and poor infrastructure (Chughtai, 2013). Due to poverty, people often have no alternatives but to live in the low-lying coastal areas, riverbanks, flood plains, dangerous slopes, and degraded urban environments where the impacts of extreme weather are more severe (ADB, 2012).

In the Philippines, the consequences of extreme weather events have been overwhelming in terms of human lives, ecosystems, and infrastructure destruction, with the national economy and local governments often taking many years to recover.

Planners are being faced with the challenges of growing population, limited appropriate space, and the risks from natural disasters (Sutanta, Rajabifard, & Bishop, 2010). It is important to prepare cities and municipalities to deal with cyclic natural hazards to enable them to address the transformations that result from climate variability and change while developing innovative solutions in spatial planning (Costa, 2011).

This paper analyzed the issues facing central and local governments in the Philippines in terms of the impacts of climate variability and change in the context of the impact of tropical cyclone Haiyan and the implications for long-term land use planning, zoning, and building regulations in the overall climate change adaptation (CCA) and disaster risk reduction and management (DRRM) process.

Typhoon Haiyan, also known as “Yolanda” in the Philippines, made landfall over Guiuan, Eastern Samar in the Visayas

region on the morning of November 8, 2013 (National Disaster Risk Reduction and Management Council [NDRRMC], 2014b). It brought maximum sustained winds of 315 kph with gusts reaching 380 kph with heavy rains (Mullen, 2013) and caused a 5-meter storm surge. This category 5 typhoon is considered as one of the strongest tropical cyclones ever recorded globally (United Nations Office for the Coordination of Humanitarian Affairs [UNOCHA], 2013). Haiyan left 6,300 dead, 1,061 missing, and 28,689 injured and affected 12,139 barangays (villages), 44 provinces, 591 municipalities, and 57 cities (NDRRMC, 2014b, 2014c). According to Delfino, Carlos, David, Lasco, and Juanico (2015), Haiyan also caused damages to the different ecosystems found in the region (e.g. mangroves), affecting the delivery of important ecosystem services such as livelihood and coastal protection.

It was reported that approximately 12.2 million people were affected by this catastrophe, leaving 489,613 houses completely destroyed and 595,149 that are partially damaged (NDRRMC, 2014a; National Economic Development Authority [NEDA], 2013). Typhoon Haiyan caused an overall estimated cost “of damaged physical assets—both public and private—at PhP424 billion (3.7 percent of GDP)” (NEDA, 2014 cited by the World Bank, 2014).

Methodology

This study was based on desk reviews with household surveys and key informant interviews and expert consultations, focusing on land use-related factors of vulnerability. To assess the conditions and the situation on the concerned local government units (LGUs), key informant interviews with their mayors, city or municipal planning and development officers, city and municipal engineer’s office, local social welfare and development officers, local DRRM officers, Department of the Interior and Local Government (DILG) officers, and barangay chairpersons were conducted. Experts on the field of land use planning and policy interpretation (the Commissioner of Housing and Land Use Regulatory Board, and the Dean of Ateneo School of Government) were also consulted.

The household surveys were conducted to assess infrastructure guidance and services, land tenure status, public infrastructure conditions, and housing materials, indicators that influence land use planning. This assessment also considered the risk factors associated with the tropical cyclones.

Documents such as the revised Comprehensive Land Use Plan (CLUP) Guidebooks, the CLUPs of Tacloban, Palo, Ormoc and its Master Plan, the National Building Code, the National Disaster Risk Reduction and Management Plan, the Climate Change Act, and Typhoon Haiyan government reports were reviewed.

Land use planning records in Leyte only date back from 1990s, limiting the study in terms of analysis of past land use planning DRR measures and how coastal communities sought to adapt to the impacts of extreme weather events.

Climate Trends in the Philippines

The Philippines is extremely vulnerable to the impacts of climate change and natural hazards (Lasco et al., 2009). An analysis of the climate trend done by the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA, 2011) revealed that from 1951 to 2010, there has been an increase of 0.65°C in annual mean temperature (Figure 1) in the Philippines.

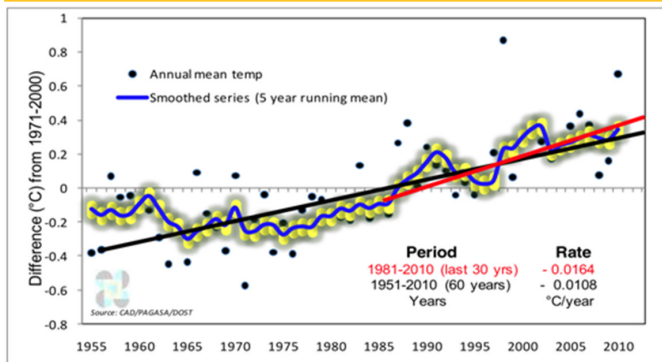


Figure 1. Observed mean temperature anomalies in the Philippines (1951-2010). Departures from 1971-2000 normal values (Cinco, 2014b).

A study by Cinco, de Guzman, Hilario, and Wilson (2014) indicated that “the climate in the Philippines, like much of the rest of the region and the globe, is warming” and potentially contribute to extreme weather events. The same study also reported that weather stations showed an increase in the frequency and intensity of extreme daily rainfall. This fact could be helpful in investigating possible links between global warming and tropical cyclones (Cinco, de Guzman, Hilario, & Wilson, 2014).

A review by Cinco, de Guzman, Hilario, Ortiz, and Lasco (2014) indicated that every year, an average of 19.4 tropical cyclones go through the Philippine Area of Responsibility (PAR). PAGASA (2014) analyzed the tropical cyclones that entered or were formed in the PAR from 1949 to 2013 (Figure 2) and Cinco (2014a) concluded that the tropical cyclone variability in the last 66 years is still constant. Cinco (2014a) said that “there is a trend of increasing number of typhoons hitting Mindanao: the highest frequency of typhoons hitting Mindanao in the past 66 years was recorded in the last five (5) years. Luzon is seeing a decreasing trend in the frequency of typhoons but it still gets the highest number of typhoons in the Philippines.”

Nevertheless, the trend in tropical storms (Figure 3) indicates that over the decades, there has been a high inter-annual variability even though there is no indication that there is an increase in frequency (PAGASA, 2014).

The Commissioner of the Philippines’ Climate Change Commission estimated in 2013 that the impact of each tropical cyclone season cost 2% of the country’s gross domestic product (GDP) and another 2% in reconstruction costs. This represents a loss of approximately 5% of the economy every

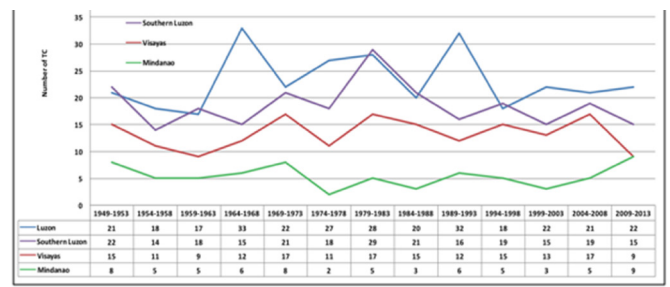


Figure 2. Five-year frequency of tropical cyclone in Luzon, Vizayas and Mindanao period: 1949-2013 (Cinco, 2014b).

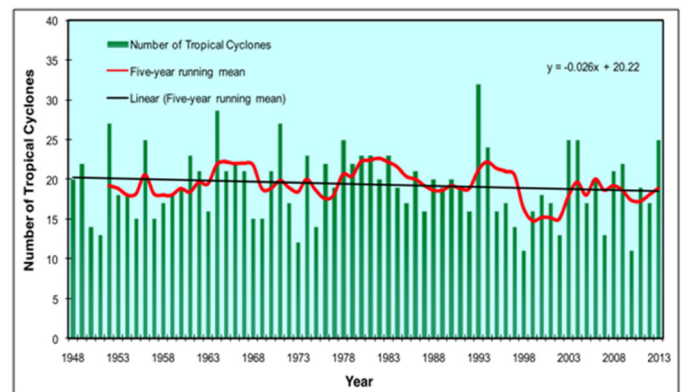


Figure 3. Annual number of tropical cyclones in the PAR period: 1948-2013 (Cinco, 2014b).

year to tropical storms (Vidal, 2013), which could be used instead in development and poverty reduction efforts (Asian Development Bank [ADB], 2012; UNISDR, 2012).

Study Area

The study sites are located along the coasts of Leyte, which over the years have experienced several climate-related disasters. Population in these areas have been increasing, potentially enhancing the degree of exposure to hazards every year. The 2010 census data showed that the population densities of Tacloban, Palo, and Ormoc were higher than the average population density of the Philippines, with Tacloban’s population density reaching as much as five times the national average.

The province of Leyte is considered a hazard prone area and 35.60% of its total population is exposed and vulnerable to weather-related hazards and seismic hazards since the area is “traversed by the Philippine Fault Zone (PFZ) and is within the vicinity of the Philippine Deep,” as well as volcanic hazards (Province of Leyte, 2011).

Government Planning Before Typhoon Haiyan

Legal and institutional framework to address climate change and disaster risk reduction and management. The enactment of the Climate Change Act of 2009 (Republic Act 9729) initiated a process aimed at mainstreaming the planning

for adverse impacts of climate change into government policy formulation, development plans, strategies targeting poverty reduction, as well as other development tools and techniques.

The approval of the National Disaster Risk Reduction and Management Act of 2010 (Republic Act 10121) provided an opportunity to mainstream DRRM into development plans through the institutionalization of the National Disaster Risk Reduction and Management Plan.

The latest CLUP guidelines have been revised to comply to the mandate to mainstream CCA and DRR, with the release of the Supplemental Guidelines on Mainstreaming Climate and Disaster Risk in the CLUP (Housing and Land Use Regulatory Board, 2013, 2015).

The National Building Code. The National Building Code of the Philippines (NBCP) was approved in 1977 through the Presidential Decree 1096 (P.D. 1096). The purpose of this Code was to provide “a framework of minimum standards and requirements to regulate and control their location, site, design quality of materials, construction, use, occupancy, and maintenance” (National Building Code of the Philippines, 1977). Government agencies, including LGUs, have the authority to exceed the NBCP and promulgate stricter and more stringent standards through local laws, like zoning ordinances (National Building Code of the Philippines - NBCP, 2014).

Comprehensive Land Use Plans. In the case of the Tacloban City Government, its CLUP 2013-2022 had integrated the potential impacts of typhoons and storm surges. The CLUP referred to the susceptibility of low areas along the coast to the impact of storm surges, identifying which ones were more at risk (Tacloban City Government, 2013). However, there was probably no time to implement these measures. Given the impact of the Haiyan’s storm surge, this CLUP and its accompanying zoning ordinance need to be reviewed and updated to further mainstream CCA and DRR into the planning process.

The municipality of Palo had a CLUP for the period of 2001-2010, which was due for updating (Municipality of Palo, Province of Leyte, 2001). Like Tacloban, Palo was also strongly affected by the storm surge and strong winds brought by Haiyan. The 2014 Post-Disaster Redevelopment Plan will be used to initiate the update of this CLUP, which will integrate the impacts of Typhoon Haiyan as well as environment and climate change issues (Municipality of Palo, Province of Leyte, 2014).

The City of Ormoc had a CLUP (and zoning ordinance) integrated in the Master Development Plan (MDP) that ended in 2014. The MDP discussed the risks of flash floods and included geohazards, indicating the flood and earthquake-prone areas, as well as a rain-induced landslide hazard map and a tsunami hazard map (Ormoc City Government, 1998). Given that its CLUP would expire in 2014, the city initiated a process after Haiyan to review and mainstream DRR and CCA measures in the new CLUP to ensure that it would be better prepared for future extreme weather events.

Compliance with building codes. An assessment of government buildings (schools, hospitals, municipal and barangay halls as well as different public buildings) by the Department of Public Works and Highways (DPWH) found that the requirements from the building code were not rigorously followed at the local level (Office of the Presidential Assistant for Rehabilitation and Recovery [OPARR], 2014c). The key informant interviews that were conducted in the study areas provided some information about the enforcement of the building codes in these affected zones. In Tacloban, it was recognized that building codes were not enforced before Haiyan. In the municipality of Palo, a local official said that before any building construction, a location clearance must be obtained. In the City of Ormoc, local officials stated that they undertake monitoring of the structural analysis of all buildings two storeys and above.

Due to the nature of the impact of Typhoon Haiyan, the DPWH subsequently issued the Minimum Performance Standards and Specifications for public buildings, which updated “the minimum requirements in the design of structural elements including the increase of the wind load from 220 kph to 250 kph. (OPARR, 2014c).

Government Planning After Typhoon Haiyan

Reconstruction Assistance on (Haiyan) Yolanda. Immediately after Typhoon Haiyan, the Government of the Philippines started the planning process to respond to the impacts of this natural disaster by putting together the Reconstruction Assistance on Yolanda (RAY), which incorporated some of the lessons learned from the 2004 Indian Ocean tsunami.

The government would ensure that under the “Build Back Better” principle, rebuilding of public infrastructure and government buildings would consider hazard maps and would comply with resilient designs and standards. Building plans would also address hydro-meteorological risks, taking into consideration storm surges height and wind force of 250 kph, as well as ground shaking, liquefaction, and other hazards (OPARR, 2014a, 2014b, 2014c).

In the areas that were badly affected, there was a need to completely reformulate the land use plans. The process of recovery and rehabilitation is an opportunity to promote CLUPs as an instrument that “will not only provide a framework for zoning of areas for new housing but also clarify hazard zones, and areas suitable for commercial and industrial use” (NEDA, 2014).

The Post Disaster Needs Assessment. In December 2013, a Post Disaster Needs Assessment (PDNA) was undertaken to determine the costs of the damages, losses, and infrastructure needs in infrastructure across sectors in the Typhoon Haiyan affected areas (OPARR, 2014a). It also discussed the need to consider several important issues in sound DRRM practices, such as the demarcation of safe locations and hazard zones as well as strengthening of engineering standards and designs especially for critical infrastructure. Some policy issues were

identified, like the urgent review of the National Building Code or strict monitoring and regular inspection to ensure compliance with building standards and designs (NDRRMC, 2014a; OPARR, 2014a).

The Comprehensive Rehabilitation and Recovery Plan. Zoning restrictions were imposed after Typhoon Haiyan through the application of a 40-meter “no-build” zone policy which was based in the Presidential Decree 1067 (The Water Code of the Philippines, 1976), whose Article 51 states that “the banks of rivers and streams and the shores of the seas and lakes throughout their entire length and within a zone of three meters in urban areas, twenty meters in agricultural areas and forty meters in forest areas, along their margins are subject to the easement of public use in the interest of recreation, navigation, floatage, fishing and salvage.”

Atty. Linda Malenab-Hornilla, Commissioner of the Housing and Land Use Regulatory Board (HLURB) said in an interview that as a result of the Typhoon Haiyan storm surge, the immediate reaction was to move people away from the hazard-prone areas and prevent them from coming back and rebuilding their homes (L. Malenab-Hornilla, personal communication, September 29, 2014). This also led to an involuntary resettlement process of informal settlers to protect them from the impact of similar future events.

However, the OPARR deemed the application of the 40-meter “no-build zone” policy in the affected areas impractical, because it would not allow for the construction of any infrastructure and it would not address exceptional circumstances such as “fishing industries and tourism-oriented businesses that still need to build structures within 40 meters from the coastline” (Official Gazette of the Republic of the Philippines, 2014).

Consequently, OPARR recommended the adoption of “safe zones,” “unsafe zones,” and the identification of “no dwelling zones,” which would be based on mapping the areas to determine the risk for each of them such as flooding or landslides. according to the OPARR proposal, under the “no dwelling zones,” only structures considered for livelihoods and commercial purposes would be allowed (Official Gazette of the Republic of the Philippines, 2014).

The Comprehensive Rehabilitation and Recovery Plan (CRRP) also recommended the establishment of “safe zones,” “unsafe zones,” and “controlled zones” that would be based on multi-hazard risk assessments undertaken by the Department of Science and Technology (DOST) and Department of Environment and Natural Resources (DENR) together with the LGUs (OPARR, 2014e). However, it did not provide any specification in terms of the hazard zone classification and the recommended actions.

To bring more clarity into the hazard zone classification issue and to the institutional mandates as well as provide better guidance to the LGUs, a joint memorandum circular was agreed among five government agencies (DENR, DOST, DPWH, DILG, and the Department of National Defense). This joint memorandum provides guidelines for hazard zone

classification and recommended activities. These are divided into hazards (floods, landslides and storm surges) and hazard zones (low, moderate and high), which would be identified according to hazards maps (DENR-DILG-DND-DPWH-DOST, 2014).

The Typhoon Haiyan CRRP was articulated into a strategic vision and included short, medium, and long term plans and programs for the 171 cities and municipalities affected by the typhoon (OPARR, 2014e). In terms of the shelter and land use planning sectors, the CRRP identified the following objectives: “address shelter needs including affected indigenous communities with totally damaged houses through disaster-resilient designed housing located in safe areas” as well as “strengthen disaster preparedness and mitigation by assisting local governments develop Comprehensive Land Use Plans (CLUP) with integrated disaster resiliency” (OPARR, 2014b).

The tacloban recovery and rehabilitation plan. The Tacloban Recovery and Rehabilitation Plan was one of the provincial plans of the CRRP and it envisaged risk-sensitive land use planning, urban design, and construction as fundamental in the recovery process that would contribute towards the reduction of the impact of future disasters in this city. In the case of its land use, the update would incorporate CCA and DRR considerations in the distribution of zones of specific land uses, which will encourage development in safer areas of the city (OPARR, 2014d).

Resettlement after Haiyan. Many of the affected LGUs do not own or have available land and they do not have the titles to the land that they had identified as suitable for resettlement, but only have the tax declaration. Many municipalities also have large areas that are considered prone to geohazards, further constraining on the availability of land for resettlement (OPARR, 2014e).

One of the biggest challenges of this process was the identification and acquisition of available and safe land for relocation and resettlement of low-income population located in hazard-prone areas. Another aspect was the willingness of the communities to move to new areas as well as the need to meet their expectations to keep their livelihoods and stay together as a community. In addition, there was always the possibility that people would return and rebuild their homes in the unsafe areas where they used to live.

Discussion

Vulnerability to typhoon-related hazards and impacts of climate change is considered to be one of the major issues affecting land use in Tacloban, Palo and Ormoc. Factors relating to vulnerability (e.g., socio-demographic characteristics, increasing poverty incidence, high population density and growth, uncontrolled development, location of informal settlements and infrastructure) could strongly influence the land use planning in these municipalities as they can drive and affect land use policies, zoning ordinances, and building regulations.

One area of concern in these study areas was the exposure of public infrastructure to the impact of Typhoon Haiyan, specifically schools because they were poorly maintained and in need of repairs. This is particularly important because of the role of public schools as evacuation centers during calamities and one of the issues raised by the respondents was the need for the government to provide safe evacuation centers.

Study respondents considered that it was fundamental to enhance the resiliency of public infrastructures to better cope with disasters especially given the poor enforcement of the building codes, which contributed to the severity of the damages by Typhoon Haiyan.

Given that one way to measure the vulnerability to natural disasters is to assess the type of housing materials and housing conditions, the people from the study areas were asked on the resilience of the building materials. Their perceptions were compared to the local officials' statement on the matter. These local government officials claimed that they provide assistance and guidance on the construction of houses. In Ormoc, structural analysis and monitoring of buildings two storeys and above is conducted to ensure that they are safe to live in. However, the majority of the respondents from Ormoc considered that the structural design of their houses was poor and needed to be improved to cope with disasters. The same was applicable to Tacloban and Palo. In addition, the majority of respondents stated that they did not receive any suggestions on the type of materials that they should use for their houses.

At the time of the survey, the application of the "no-build zone" process was extremely contentious because many of the respondents were not aware that they were living within this zoning restriction and were told that they had to relocate.

Common trends that contribute to make the study areas more vulnerable are increasing population densities and growth rates, uncontrolled development, and increased number of informal settlements due to poverty incidence.

It is also essential to consider the importance of the bio-protection and the ecosystems services provided by the mangroves in the studied areas. These have a role to decrease vulnerability of coastal areas by potentially reducing the impact of the storm surge and protecting communities and infrastructure (Delfino et al., 2015; IPCC, 2012).

Like in the case of the 2004 Indian Ocean tsunami, the impact of Typhoon Haiyan pointed to the need to undertake hazard-based zoning. According to an interview with Atty. Antonio La Viña, Dean of Ateneo School of Government of the Ateneo de Manila University, the application of the Water Code provision of a 40-meter "no-build zone" was an after the fact justification with the intention to protect and prevent communities from being affected by similar future hazard events (A. La Viña, personal communication, Oct. 3, 2014). Nonetheless, the applicability of the 40-meter "no-build zone" should have been restricted to forest areas, in accordance with the Water Code, and yet was enforced outside them. In addition, this

application could have been interpreted as confiscatory with potential intention to expropriate and also as an encroachment into private property rights (L. Malenab-Hornilla, personal communication, September 29, 2014).

This decision should be done based on local risk analysis followed by a vulnerability assessment, which should then lead to policy recommendations (A. La Viña, personal communication, October 3, 2014). It is also important from an institutional point of view to understand who would be responsible for its implementation both at central and local level and to have more guidance on its implementation (e.g., the CLUP). Nevertheless, according to Atty. Malenab-Hornilla, in terms of performance-based zoning, structures and activities should be allowed as long as they follow the safety building standards set by the national government. These standards may be set higher by LGUs but not lower.

However, the OPARR/CRRP recommendation, the subsequent joint memorandum on hazard zone classification, and the recent CLUP guidelines on the zoning policy can potentially be confusing and daunting for the local planners in terms of the correct zoning to plan and apply.

Even though the zoning for hazards classification approach is similar, it would be useful for LGUs to have just one set of zoning for hazards classification (i.e. CLUP guidelines) not only for typhoon affected areas but also nationally. Some of the suggested guidance may require a level of capacity that LGUs may lack, which could potentially delay the designation of hazard prone areas and zoning ordinances. Nevertheless, this issue could be addressed through partnerships to help address any capacity limitations. Despite these issues, land use planning, implementation of building codes, and retrofitting can be very effective to enhance CCA and DRR and therefore should not be ignored.

In 2014, a plan was approved to build a dike that will be four meters high above sea level to protect Tacloban, Palo, and Tanauan from storm surges. Building a 27-kilometer dike right after Haiyan to defend coastal areas from storm surge with flood return periods of 50 years could potentially be seen as a costly defense mechanism if no other options were discussed and experiences from other countries taken into consideration.

Conclusion and Recommendations

In the wake of Typhoon Haiyan, one key learning point is that it is imperative to reduce the potential risks of extreme weather events and ensure long-term resilience of people and infrastructures by seriously investing on and implementing risk-sensitive land use planning and instruments like zoning, building codes, and retrofitting of vulnerable buildings. However, these measures need to be properly implemented and supported by strong political commitment. Additionally, risk reduction actions in the context of land use planning should combine regulatory measures with innovative financial incentives.

Local governments should actively anticipate the impacts of extreme climate events and seek opportunities to enhance the planning process in terms of DRR and CCA. In addition, local decision making should incorporate risk assessment and the identification of hazards, and how it affects land use and physical framework planning.

Another policy for risk reduction that should be taken into consideration by LGUs, particularly when defining the zones in their CLUPs, is designating mangrove conservation, preservation, and rehabilitation areas to protect the coastline. These natural buffer areas should be increased to enhance the resilience of coastal communities to tropical cyclones and storm surges.

One essential lesson to take is the need for LGUs to avoid implementing no build zones as a reactive measure to the impact of tropical cyclones without undertaking vulnerability and risk assessments in support of their hazard zone classification.

It is also important to undertake monitoring and evaluation to assess the impacts of the rehabilitation and recovery process in the resilience of communities in the Typhoon Haiyan affected areas.

The social vulnerability assessment is one way to mainstream CCA and DRR issues into local policies and plans. The CLUP process should take this aspect into consideration in the identification of sensitivities, exposures, and adaptive capacities into development planning.

An issue that should be taken into consideration is ensuring the use of technical knowledge such as the national and regional climate projections and geohazards information in local decision making. Given the adaptation capacity needs of local governments, generating partnerships with the scientific community, non-governmental organizations, and the private sector to address knowledge gaps in land use planning is critical.

To enable the LGUs approaches promoting community resilience, planning processes should encourage public participation and should take place before disasters hit. This has to be followed by making hazard, vulnerability, and risk information readily available to the public (e.g., maps). LGUs should also exceed the standards set by the national government, such as the building code, based on their particular climate and hazard conditions. As such, LGUs should apply, enforce, and monitor realistic risk-compliant building regulations.

To further advance this matter, LGUs should consider improving the information dissemination to the communities on the services that they can provide regarding guidance on the structural design and construction of houses. LGUs should consider approaches such as resilient housing design that follow safety-building standards strictly enforced, and based on geohazard maps. The same is applicable to recommendations on the adequate type of materials that should be used to resist the impacts from typhoon-induced hazards such as storm surges, flooding, and strong winds. To address potential capacity gaps,

LGUs could partner with professional organizations such as the Philippines Institute of Civil Engineering or the Association of Structural Engineers of the Philippines.

Lessons learned from the Haiyan experience should be integrated not only in Haiyan-affected areas but also in CLUPs in other areas of the country, particularly when contextualizing with the updated CLUP guidelines. These can be effective long-term planning instruments to improve climate resilience by mainstreaming DRR and CCA measures in development planning, particularly at local level and duly implemented.

Lastly, future research should be undertaken in these typhoon-affected areas to study the reasons for poor compliance of building standards and designs of both public and private infrastructures in hazard prone areas.

References

- Asian Development Bank. (2012). *Addressing Climate Change and Migration in Asia and the Pacific*. Asian Development Bank. Retrieved from <http://www.adb.org/publications/addressing-climate-change-and-migration-asia-and-pacific>
- Chughtai, S. (2013). *Typhoon Haiyan, The response so far and vital lessons for the Philippines Recovery* (Oxfam Briefing Note). UK: Oxfam International. Retrieved from <https://www.oxfam.org/sites/www.oxfam.org/files/bn-typhoon-haiyan-philippines-response-071213-en.pdf>
- Cinco, T. A. (2014a, April). *Severe Risk Modeling*. Presented at the Technical Workshop on Holistic Response to the Need for Resilient Low-Cost Housing, Oracle Hotel, Quezon City. Retrieved from http://essc.org.ph/content/wp-content/uploads/2014/04/Report_TechnicalWorkshop_2_3April2014.pdf
- Cinco, T. A. (2014b, August). *Understanding Past and Future Climate (Climate Change Scenario for the Philippines). Presented at the OML Center Workshop on Translating Climate and Disaster Information for Effective Decision-Making*, Richmonde Hotel, Ortigas Center, Pasig City. Philippines.
- Cinco, T. A., de Guzman, R. G., Hilario, F. D., Ortiz, A. M. D., & Lasco, R. D. (2014). *Climatology of Tropical Cyclones in the Philippines*.
- Cinco, T. A., de Guzman, R. G., Hilario, F. D., & Wilson, D. M. (2014). Long-term trends and extremes in observed daily precipitation and near surface air temperature in the Philippines for the period 1951–2010. *Atmospheric Research*, 145-146, 12–26. <http://doi.org/doi:10.1016/j.atmosres.2014.03.025>
- Climate Change Act of 2009, Republic Act 9729 (2009). Climáticas. As Frentes de Água. In *Climate Proof Cities* (p. 218). Lisbon, Portugal: Universidade Técnica de Lisboa.
- Costa, J. P. (2011). *Urbanismo ea Adaptação às Alterações*

- & Juanico, D. E. (2015). Perceptions of Typhoon Haiyan affected communities about the resilience and storm protection function of mangrove ecosystems in Leyte and Eastern Samar, Philippines. *Climate, Disaster and Development Journal*, 1(1), 1-8. <http://dx.doi.org/10.18783/cddj.v001.i01.a03>
- Delfino, R. J. P., Carlos, C. M., David, L. T., Lasco, R. D., Land Use Plan Preparation. Volume 1. The Planning Process. Republic of the Philippines.
- Housing and Land Use Regulatory Board. (2013). A Guide to Supplemental Guidelines on Mainstreaming Climate and Disaster Risks in the Comprehensive Land Use Plan. Republic of the Philippines.
- Housing and Land Use Regulatory Board. (2015). *disasters to advance climate change adaptation. A special report of Working Groups I and II to the Intergovernmental Panel on Climate Change*. (C. B. Field, V. Barros, T. F. Stocker, Q. Dahe, D. J. Dokken, K. L. Ebi, ... P. M. Midgley, Eds.). Cambridge, UK and New York, NY, USA: Cambridge University Press.
- IPCC. (2012). *Managing the risks of extreme events and and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. (C. B. Field, V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, ... L. L. White, Eds.). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.
- PCC. (2014a). *Climate Change 2014: Impacts, Adaptation, Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. (Core Writing Team, R. K. Pachauri, & L. A. Meyer, Eds.). Geneva, Switzerland: Intergovernmental Panel on Climate Change.
- IPCC. (2014b). *Climate Change 2014: Synthesis Report*. Circular. Adoption of hazard zone classification in areas affected by Typhoon Yolanda (Haiyan) and providing guidelines for activities therein. (2014).
- Joint DENR-DILG-DND-DPWH-DOST Memorandum strongest storm of 2013, hits Philippines - CNN.com. Retrieved December 18, 2015, from <http://www.cnn.com/2013/11/07/world/asia/philippines-typhoon-haiyan/index.html>
- Lasco, R. D., Pulhin, F. B., Jaranilla-Sanchez, P. A., Delfino, R. J. P., Gerpacio, R., & Garcia, K. (2009). Mainstreaming adaptation in developing countries: The case of the Philippines. *Climate and Development*, 1(2), 130–146. <http://doi.org/10.3763/cdev.2009.0009>
- Mullen, J. (2013, November 8). Super Typhoon Haiyan, strongest storm of 2013, hits Philippines - CNN.com. Retrieved December 18, 2015, from <http://www.cnn.com/2013/11/07/world/asia/philippines-typhoon-haiyan/index.html>
- Municipality of Palo, Province of Leyte. (2001). Comprehensive Land Use Plan 2001-2010.
- Municipality of Palo, Province of Leyte. (2014). Redevelopment Plan. Grandt Planners, Inc.
- National Building Code of the Philippines, Presidential Decree 1096 (1977).
- National Building Code of the Philippines - NBCP. (2014, November 9). The LGU Office of the Building Official (OBO) can actually impose a lower building height limita(BHL) for any LGU zoning classification provided... [Facebook status update]. Retrieved from <https://www.facebook.com/BuildingCode.Ph/posts/943239319020308>
- National Disaster Risk Reduction and Management Act of 2010, Republic Act 10121 (2010).
- NDRRMC. (2014a). *Post Disaster Needs Assessment in TY Yolanda Affected Areas*. Quezon City, Philippines: National Disaster Risk Reduction and Management Council. Retrieved from [http://www.ndrrmc.gov.ph/attachments/article/1329/Effects_of_Typhoon_YOLANDA_\(HAIYAN\)_SitRep_No_108_03APR2014.pdf](http://www.ndrrmc.gov.ph/attachments/article/1329/Effects_of_Typhoon_YOLANDA_(HAIYAN)_SitRep_No_108_03APR2014.pdf)
- NDRRMC. (2014b). *SitRep No. 108, Effect of Typhoon "Yolanda" (Haiyan)* (NDRRMC Update). Quezon City, Philippines: National Disaster Risk Reduction and Management Council. Retrieved from [http://www.ndrrmc.gov.ph/attachments/article/1329/Effects_of_Typhoon_YOLANDA_\(HAIYAN\)_SitRep_No_108_03APR2014.pdf](http://www.ndrrmc.gov.ph/attachments/article/1329/Effects_of_Typhoon_YOLANDA_(HAIYAN)_SitRep_No_108_03APR2014.pdf)
- NDRRMC. (2014c). *Updates, Situation Report, the Effects of Typhoon "Yolanda" (Haiyan)* (NDRRMC Update). Quezon City, Philippines: National Disaster Risk Reduction and Management Council. Retrieved from [http://www.ndrrmc.gov.ph/attachments/article/1329/Update_on_Effects_Typhoon_YOLANDA_\(Haiyan\)_17APR2014.pdf](http://www.ndrrmc.gov.ph/attachments/article/1329/Update_on_Effects_Typhoon_YOLANDA_(Haiyan)_17APR2014.pdf)
- NEDA. (2013). *Reconstruction Assistance on Yolanda: Build-Back-Better* (p. 21). National Economic and Development Authority. Retrieved from <http://yolanda.neda.gov.ph/reconstruction-assistance-on-yolanda-ray-build-back-better/>
- NEDA. (2014). *Reconstruction Assistance on Yolanda: Implementation for Results* (p. 43). National Economic and Development Authority. Retrieved from <http://yolanda.neda.gov.ph/reconstruction-assistance-on-yolanda-ray-implementation-for-results/>
- Office of the Presidential Assistant for Rehabilitation and Recovery. (2014a). Comprehensive Rehabilitation and Recovery Plan.

- Office of the Presidential Assistant for Rehabilitation and Recovery. (2014b). Comprehensive Rehabilitation and Recovery Plan. Annex A: Social Services Plan.
- Office of the Presidential Assistant for Rehabilitation and Recovery. (2014c). Comprehensive Rehabilitation and Recovery Plan. Annex B: Infrastructure Cluster Plan.
- Office of the Presidential Assistant for Rehabilitation and Recovery. (2014d). Comprehensive Rehabilitation and Recovery Plan. Annex E: Provincial Plans.
- Office of the Presidential Assistant for Rehabilitation and Recovery. (2014e). Yolanda Rehabilitation and Recovery Efforts [Brochure].
- Official Gazette of the Republic of the Philippines. (2014, March 14). PARR: "No Build Zone" Policy not recommended in Yolanda-affected areas. Retrieved December 19, 2015, from <http://www.gov.ph/2014/03/14/parr-no-build-zone-policy-not-recommended-in-yolanda-affected-areas/>
- Ormoc City Government. (1998). Ormoc City Master Development Plan/Comprehensive Land Use Plan, Final Report.
- PAGASA. (2011, February). Climate Change in the Philippines. Philippine Atmospheric, Geophysical and Astronomical Services Administration. Retrieved from http://kidlat.pagasa.dost.gov.ph/cab/climate_change/Climate%20change%20in%20the%20Philippines%20-%20August%2025%202011.pdf
- PAGASA. (2014). Current Climate and Observed Trends. Retrieved from <http://www.pagasa.dost.gov.ph/climate-agromet/climate-change-in-the-philippines/116-climate-change-in-the-philippines/594-current-climate-and-observed-trends>
- Province of Leyte. (2011). Disaster Risk Reduction Climate Change Adaptation-Enhanced Provincial Development and Physical Framework Plan 2011-2016. Provincial Planning and Development Office, Province of Leyte.
- Rappaport, E. N. (2000). Loss of Life in the United States Associated with Recent Atlantic Tropical Cyclones. *Bulletin of the American Meteorological Society*, 81 (9), 2065–2073. [http://doi.org/10.1175/1520-0477\(2000\)081<2065:LOLITU>2.3.CO;2](http://doi.org/10.1175/1520-0477(2000)081<2065:LOLITU>2.3.CO;2)
- Sutanta, H., Rajabifard, A., & Bishop, I. (2010). Integrating spatial planning and disaster risk reduction at the local level in the context of spatially enabled government. Retrieved from <https://minerva-access.unimelb.edu.au/handle/11343/28949>
- Tacloban City Government. (2013). The Comprehensive Land Use Plan for 2013-2022.
- The Water Code of the Philippines, Presidential Decree No. 1067 (1976). Retrieved from <http://www.gov.ph/1976/12/31/presidential-decree-no-1067-s-1976/>
- UNISDR. (2012, December 5). Philippines early warning system saves lives as thousands flee Typhoon Bopha. Retrieved from <http://www.unisdr.org/archive/29954>
- UNOCHA. (2013, November 12). Philippines: Typhoon Haiyan Action Plan - November 2013. Retrieved from <http://www.unocha.org/cap/appeals/philippines-typhoon-haiyan-action-plan-november-2013>
- Vidal, J. (2013, November 8). Typhoon Haiyan: what really alarms Filipinos is the rich world ignoring climate change. *The Guardian*. Retrieved from <http://www.theguardian.com/commentisfree/2013/nov/08/typhoon-haiyan-rich-ignore-climate-change>
- World Bank. (2014). *Pursuing Inclusive Growth through Sustainable Reconstruction and Job Creation. Poverty Reduction and Economic Management Unit*. Poverty Reduction and Economic Management Unit, Philippine Country Office East Asia and Pacific Region, World Bank.

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