



Climate,
Disaster and
Development
Journal

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Volume 3 Issue 1 December 2018
ISSN No. 2467-6926





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Climate, Disaster and Development (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 promoting 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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Volume 3 Issue 1 December 2018

ISSN: 2467-6926

DOI: <https://doi.org/10.18783/cddj.v003.i01>

Publishing and Dissemination

The Oscar M. Lopez Center for Climate Change Adaptation and Disaster Risk Management Foundation, Inc.

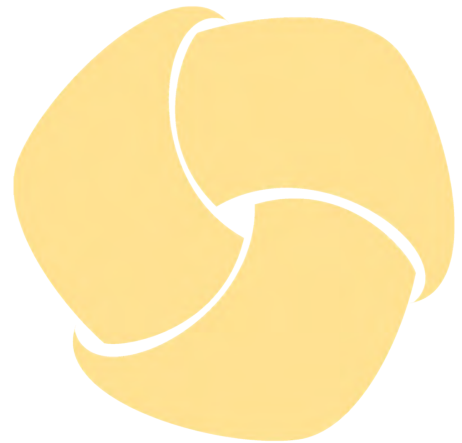
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Aims and Scope

The 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.

Table of Contents

Modeling of degraded reefs in Leyte Gulf, Philippines in the face of climate change and human-induced disturbances	1
Barron Cedric A. Tan, Jonathan A. Anticamara, Maria Ching S. Villanueva	
Hydrological modeling to assess water resources resilience towards climate change impacts in Tacloban, Philippines	13
Rita Marteleira, Maria José Roxo, Rodel Lasco, Pedro Santos Coelho	
Assessment of Adaptation to the Impacts of Typhoon Pablo (Bopha) in Eastern Mindanao, Philippines	23
Jesse B. Manuta, Elena A. Eugenio, Paula Beatrice M. Macandog	
Transportation Resilience in the Global South: A Post-Haiyan Investigation in Tacloban, Philippines	39
Iderlina Mateo-Babiano	
Adaptive capacity of local communities to flash floods and landslides: Comparison of indigenous and non-indigenous people in Eastern Mindanao	51
Elena A. Eugenio, Lilibeth A. Acosta, Damasa B. Magcale-Macandog, Paula Beatrice M. Macandog, Edwin R. Abucay, Jesse B. Manuta, Rowee Joy S. Decena, Jonel R. Palanas, Marivic B. Hayana, Louela T. Araquil, Jemimah Mae A. Eugenio	



Modeling of degraded reefs in Leyte Gulf, Philippines in the face of climate change and human-induced disturbances

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Received: 07 February 2017 / Accepted: 08 June 2017 / Published online: 07 August 2017

Abstract

Philippine reefs are mega-diverse but, to date, few ecosystem models have been developed to understand their dynamics and functioning. This study assessed the status of reefs in 12 municipalities of Leyte Gulf, Philippines. It is an important fishing ground experiencing degradation and impacts of super-typhoons—strongest to date being Haiyan (local name: Yolanda). Empirical and literature data were used to develop Ecopath (trophic) models and Ecosim simulations to evaluate the impacts of reduction and increase in coral cover or productivity on the Leyte Gulf Reef (LGR) ecosystem. Results showed that the LGR's ecosystem is in a degraded state—dominated by small-medium herbivores and carnivores, with most productivity immediately returned to detritus. In addition, a comparative study of two Ecopath models showed that reduction in the coral cover (e.g., by Super-Typhoon Haiyan) will result in a decline in biomass of many functional groups. Changes in LGR's productivity (e.g., eutrophication) will also strongly impact most functional groups (e.g., shift to overdominance of herbivores that take advantage of algal growth and extirpation of coral reef-dependent species). Moreover, additional climate-related or human-induced disturbances on the degraded LGR will further decrease the reef's productivity. Therefore, effective recovery and management of degraded reef ecosystems is needed to sustain the LGR's productivity (e.g., reef fisheries production).

Keywords: conservation · climate change · ecological modeling · fisheries · Philippine reefs

DOI: <https://doi.org/10.18783/cddj.v003.i01.a01>

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Introduction

Ecosystem Models (EcoMs such as Ecopath with Ecosim EwE) are popular tools for understanding ecosystem dynamics and are useful in management (Cisneros-Montemayor, Christensen, Arreguin-Sanchez, & Sumaila, 2012; Longo et al., 2015; Plagányi & Butterworth, 2004). EcoMs provide an opportunity to explore scenarios regarding ecological systems' responses to change that is often difficult to test in the field for logistical, political, or financial reasons. With the increasing knowledge of coral reef ecosystem processes and the rise in computing power, dynamic trophic EcoMs are becoming widely used in assessing the effects of natural and anthropogenic stressors on reef ecosystem functions (Christensen & Walters, 2003; Christensen, Walters, & Pauly, 2005).

In tropical countries with high diversity such as the Philippines, however, EcoMs are not well explored or applied as management tools in fisheries and coastal management. The main reasons for the general lack of Philippine EcoM exploration and applications are the deficiency of (1) independent data from regular biological and environmental surveys (e.g., systematic reef fisheries surveys); (2) basic life-history data for many species (e.g., reproduction and population growth of many Philippine reef species); (3) localized species diet composition or trophic relationship studies; and (4) reliable catch or productivity data from reef ecosystems. To date, publications on Philippine EcoMs such as EwE are few and very limited (Aliño et al., 1993; Bacalso & Wolff, 2014; Campos, 2003). The EwE model presented in this paper is different from the previous model for Leyte Gulf (e.g., Campos, 2003) for the following reasons: (1) the current model uses a more detailed underwater reef fish survey data for 12 municipalities along Leyte Gulf; (2) it simulates the impacts of super-typhoon Haiyan (local name: Yolanda); and (3) it examines the effects of productivity changes (eutrophication).

This study achieved the following: (1) produced a current estimate of the status (i.e., diversity and biomass) of reef fishes in LGR using standardized Underwater Visual Census data; (2) gained insights on the current trophic relationships and functioning of the LGR ecosystems using the static component of EwE (i.e., Ecopath Models); and (3) predicted the trajectories of changes in biomass of trophic functional groups in LGRs when subjected to super-typhoons such as Haiyan or eutrophication using the dynamic component of EwE (i.e., Ecosim).

Materials and Methods

Study Area

This paper presented EwE models of a depleted coral reef ecosystem in the Philippines (Anticamara & Go, 2016; Go et al., 2015). The modeled reef areas focused on 12 municipalities within Leyte Gulf (approximately 130 km north-south and 60

km east-west), from the municipality of Balangiga in Eastern Samar up to the municipality of Abuyog in Leyte (Figure 1).

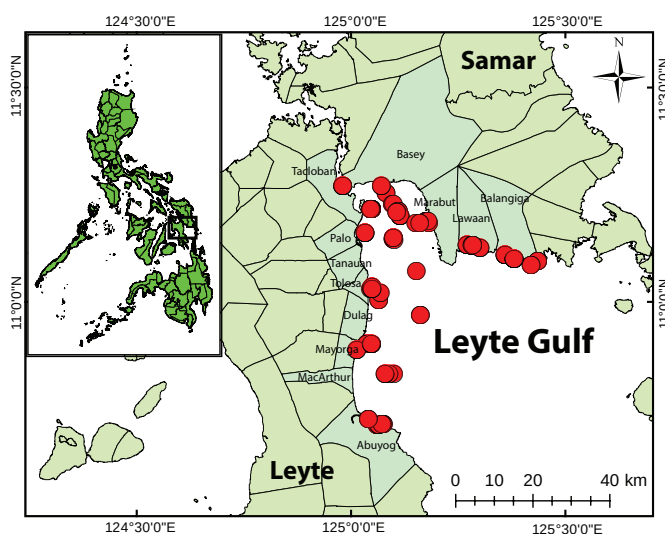


Figure 1. Map of Leyte Gulf and the 12 municipalities along with the locations of surveyed belt transects (red circles)

The sites were chosen because these reefs are: (1) important fishing grounds with many coastal fishers heavily dependent on these for their main source of food, income, and livelihood in municipalities that are among the least developed in the Philippines (Leyte Gulf municipalities), (2) already degraded and suffering fisheries decline based on previous studies (Anticamara & Go, 2016; Go et al., 2015), and (3) prone to super-typhoons passing through the Pacific side of the Philippines—the strongest was super-typhoon Haiyan. Thus, these reef study sites are ideal for evaluating impacts of climate change (such as super-typhoon) on already degraded but still heavily exploited reefs. Results from this study should be useful in providing insights on how to manage LGRs.

The modelled area of Leyte Gulf was surveyed from September to October in 2015 using standardized Underwater Fish Visual Census (UVC). It was conducted over 133 belt transects (Figure 1), 20 x 5 m each (Anticamara & Go, 2016). All belt transects were placed parallel to the reef slopes with depths ranging from 4 to 20 m. Most of the surveyed reefs were in shallow areas of about 4 to 7 m depth, with the exception of a few reef areas found at depths of about 15 to 20 m. All UVCs were conducted during daylight from around 9:00 am to 3:00 pm for 20 minutes per transect. During each UVC, all encountered non-cryptic reef fish were identified, counted, and measured in size (to nearest cm).

Model Construction

A trophic model of the reef ecosystem was constructed using the EwE software (ver. 6.4.11414.0, freely downloadable

at <http://ecopath.org/>) (Christensen & Walters, 2003; Christensen et al., 2005; Pauly, Christensen, & Walters, 2000). The basic equation for the Ecopath process is expressed as a linear equation (1) with all its components explained and summarized in Table 1.

$$B_i \cdot \left(\frac{P}{B}\right)_i \cdot EE_i - \sum_{j=1}^n B_j \cdot \left(\frac{Q}{B}\right)_j \cdot DC_{ji} - Y_i - E_i - BA_i = 0 \quad (1)$$

Defining the Ecopath Model Compartments

The Ecopath model was constructed based on 18 functional groups (Table 2) divided into 7 fish and 11 non-fish components. All functional groups were defined based on major taxonomic grouping (i.e., fish, invertebrate, or plankton), ecological function (i.e., producer or consumer), and similarities of feeding behavior (i.e., trophic guilds).

Ecopath Model Inputs and Data Sources

Fish biomass (B) per species was computed using equation (2) where L is fish length data from the UVC surveys and a - b are Length-Weight (L-W) relationship data taken from FishBase. FishBase is the most comprehensive database that compiles and provides biological (e.g., growth, feeding, reproduction), ecological (e.g., population dynamics, trophic interactions), genetic, and taxonomic information of all known fish species in the world (Frøese & Pauly, 2014; <http://www.fishbase.org>).

$$B = a \cdot L^b \quad (2)$$

For species with no known L-W relationships, the closest counterpart of the same maximum size was used. The fish species were then assigned their appropriate functional

Table 1. Variables used for the Ecopath basic equation (1).

Variable	Name	Description
B_i	Biomass	Biomass of prey i
B_j	Biomass	Biomass of prey j
$\frac{P}{B}$	Production/Biomass	Equivalent to the instantaneous rate of total mortality (Z) used by fisheries biologist (Allen, 1971)
EE	Ecotrophic Efficiency	The fraction of the production that is used in the system, i.e., either passed up the food web, used for biomass accumulation, migration or export
$\frac{Q}{B}$	Consumption/Biomass	Intake of food by a group over the time period considered
DC_{ji}	Diet Consumption	Fraction of prey i in the diet of predator j
Y	Catch	Fishing mortality
E	Emigration	Net migration rate
BA	Biomass Accumulation	Calculated as the difference between biomass at the beginning of the year and at the beginning of next year

Table 2. Diet matrix of the Leyte Gulf Ecopath model.

No.	Prey \ predator	1	2	3	4	5	6	7	8	9	10	11	12
1	Piscivore	0.105											
2	Carnivore	0.140							0.050	0.002			
3	Herbivore	0.173							0.080	0.002			
4	Corallivore	0.010							0.010	0.001			
5	Planktivore	0.050							0.020	0.001			
6	Benthos feeder	0.020											
7	Detrivore	0.080											
8	Cephalopods	0.100	0.150						0.040	0.002			
9	Crustaceans	0.100	0.165		0.015		0.100		0.150	0.050			
10	Molluscs	0.100	0.150		0.010		0.010	0.005	0.210	0.120			0.050
11	Sea cucumber	0.020	0.045				0.020	0.001					
12	Urchin	0.020	0.050		0.010		0.010	0.001		0.002			0.050
13	Benthos	0.082	0.245	0.040	0.020	0.004	0.700	0.035	0.120	0.220	0.150		0.200
14	Coral		0.100	0.005	0.700		0.050					0.005	
15	Zooplankton		0.020	0.040	0.055	0.490	0.005	0.005	0.150	0.100	0.250	0.200	
16	Phytoplankton		0.020	0.035	0.050	0.405	0.005	0.005	0.150	0.100	0.200	0.245	
17	Macrophytes		0.005	0.800	0.090	0.001		0.100		0.100	0.050	0.100	0.400
18	Detritus		0.050	0.080	0.050	0.100	0.100	0.848	0.020	0.300	0.350	0.450	0.300
19	SUM	1	1	1	1	1	1	1	1	1	1	1	1

group conventions according to their diet. Next, fish mean weight (or biomass) was averaged across all surveyed transects. Mean biomass values for fish species belonging to the same functional group were summed to get the estimate of the total biomass (t/km^2) per functional group.

Fish production/biomass ($\frac{P}{B}$) and consumption/biomass ($\frac{Q}{B}$) ratios were taken from the fish life-history data available in Fishbase (Frøese & Pauly, 2014). Where the life-history data were insufficient or lacking, the missing parameters were calculated from Allen's (1971) equation for production/biomass, while consumption/biomass rates were estimated using Palomares and Pauly's (1998) empirical formula.

The $\frac{P}{B}$ and $\frac{Q}{B}$ values (Appendix Table 1A-B) for the non-fish functional groups were taken from literature on similar reef ecosystem models elsewhere in the Philippines (Aliño et al., 1993; Bacalso & Wolff, 2014; Bundy & Pauly, 2001; Campos, 2003).

Diet composition data (Table 2) for the fish groups were obtained from Fishbase (Frøese & Pauly, 2014). For the non-fish species, published diets from similar systems in the Philippines were used (Aliño et al., 1993; Bacalso & Wolff, 2014; Bundy & Pauly, 2001; Campos, 2003).

Since the linear equation (1) of Ecopath represents a mass-balanced system, any missing parameters can be solved assuming three of the four input parameters (B , $\frac{P}{B}$, $\frac{Q}{B}$, EE) are present (Christensen & Walters, 2003; Christensen et al., 2005). Ecotrophic Efficiency (EE) is a proportion of the production used in the system. EE values for exploited fish and benthic species would have values close to 1 depending on their importance in the fisheries and/or as preys. Biomass for the rest of the non-fish groups were solved by providing EE values as suggested by Guenette (2014). Macrophytes and its component groups were given EE values of less than 0.3. Phytoplankton, often seen to usually die off in systems where heavy blooms occur, was given an EE value of 0.5.

For the fishing effort, data were based on simple and standardized field surveys from randomly selected or referred fishers to identify frequented fishing grounds and area, duration and frequency, gear used, catch weight, species catch composition, and income. Annual catch per fishing gear was calculated as the product of the mean catch per unit effort, the estimated number of days it is operated within a year, and the observed number of fishing gears operating in the defined fishing area per municipality.

Ecopath Model Parameterization and Balancing

To balance the Ecopath model, the EE value for all functional groups should lie in the acceptable range between 0 and 1. Groups with EE s exceeding 1 should be adjusted starting from the group with the highest EE value. Adjustments were made in the unbalanced groups' original basic input parameters and diet composition in

$\pm 5\%$ increments beginning with the less precise input values (i.e., those groups with no empirical biomass estimates from UVC).

Ecopath Model Quality Checking

Tests used to verify the realism of the Ecopath model included the Pedigree Index (PI) (Funtowicz & Ravetz, 1990), Mixed Trophic Impact (MTI) (Ulanowicz & Puccia, 1990), and Summary Statistics (SS) generated by the software after Ecopath model balancing. The generated SS was then used for comparison with other Ecopath-modeled systems in the Philippines.

Varying Coral Biomass and Ecosim Simulations

To simulate the effects of a climate hazard such as a super-typhoon or a human disturbance like destructive fishing practices to the ecosystem, a second Ecopath model was constructed wherein the coral biomass was halved. This was based on field observations and analyses on the impacts of super-typhoon Haiyan, which reduced most corals in Leyte Gulf by half of the pre-typhoon cover (Anticamara & Go, 2016). For the second model, $\frac{P}{B}$, $\frac{Q}{B}$, and EE for all functional groups were used as basic inputs (Anticamara & Go, 2016). All other biomass values for living groups were left for estimation by Ecopath, except for the coral biomass, which was set to $9.7 \text{ t}/\text{km}^2\text{yr}$ based on the status of corals in the area and literature information. SS, flow diagram, MTI, and other Ecopath outputs were compared between the original Ecopath Model 1 and Model 2 to simulate how a sudden degradation of the corals affects the various functional groups.

After food web-trophic interactions and fisheries were defined in Ecopath, Ecosim was then used to predict biomasses for each modelled group through time (Christensen et al., 2005). To evaluate changes in system production due to climate change or other anthropogenic activities, forcing functions for primary production were simulated for 50 years starting from 2016 up until 2065. Twelve scenarios were applied to the model to represent changes in primary productivity from a decrease of 30% to an increase of 30% in 5% decrements or increments relative to the base Ecopath model. Ecosim outputs were then used to map-out which functional groups respond greatest to changes in productivity and to quantify their relative rates of change.

Results

Community Structure, Trophic Flows, and Interactions

From the UVC of 133 transects across Leyte Gulf, a total of 21,120 fish individuals were recorded, comprised of 152 distinct species belonging to 28 fish families. For EwE modeling purposes, the 152 fish species were assigned to

seven fish functional groups based on their feeding habits as identified in Fishbase (Table 2 and Appendix Table 1A-B).

The balanced Ecopath model indicated that the Leyte Gulf ecosystem was heavily supported by trophic levels 1 to 3 in terms of biomass, for both the original Ecopath model 1 and the halved coral biomass Ecopath model 2 (Figure 2A-B). Although there were no visible differences in the food web ecosystem structure as depicted in the trophic flow diagram of Ecopath models 1 and 2 outputs (Figure 2A-B), the biomass of most major functional groups were reduced to about half in Ecopath model 2 when the coral biomass was halved (Appendix Table 1A-B).

Both Ecopath models 1 and 2 showed that the LGR ecosystem was heavily supported by macrophytes, benthos, phytoplankton, molluscs, and coral in terms of biomass (Appendix Tables 1A-B). In terms of fish biomass, both Ecopath models 1 and 2 indicated that the ecosystem was heavily supported by the carnivores and herbivores (Figure 1A-B, Appendix Tables 1A-B). Most of the major contributors to the LGR ecosystem biomasses

(both fish and non-fish functional groups) suffered great reductions to about half when coral biomass was reduced (Appendix Tables 1A-B).

In addition, both Ecopath models 1 and 2 showed that the majority of the primary production and detritus consumed by the upper trophic levels (TLs) were immediately recycled back to detritus and a relatively small portion of Total System Throughput (TST) was passed through the next higher TLs (III-V)—indicating a relatively short food chain and rapid biomass recycling (Figure 3A-B).

Moreover, for both Ecopath models 1 and 2, the MTI plots showed that detritus had a strong positive impact on other functional groups in the LGR ecosystem, while fish carnivores had strong negative impacts on other functional groups in the LGR ecosystem (Figure 4A-B).

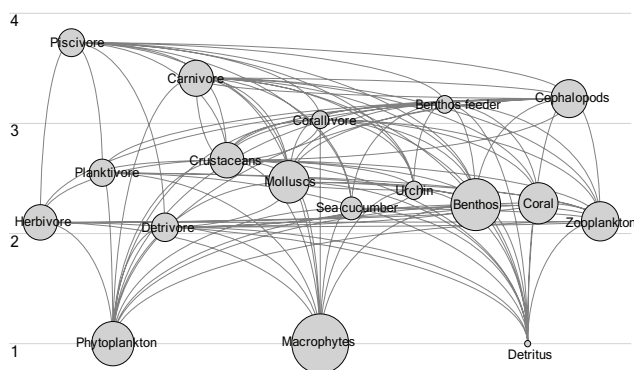
Ecopath Model System Properties

The balanced Ecopath models 1 and 2 showed a TST value of 16,922 and 8,665 t/km²yr, respectively (Table 3). About one third of the annual TST of Leyte Gulf was recycled back to the detritus as flows, while about one third of TST supported the consumption and exports of the ecosystem (Table 3). The Total Net Primary Production (NPP) of Leyte Gulf ecosystem was about less than half of the TST for both Ecopath models 1 and 2 (6,799 and 3,479 t/km²yr, respectively) (Table 3). Estimated Finn's Cycling Index (FCI) for both Ecopath models 1 and 2 was 4.96 (Table 3). The Connectance Index (CI) was similar (0.38) for both Ecopath models 1 and 2 (Table 3). The system Omnivory Index (OI) was quite similar for both Ecopath models (0.25 and 0.24, respectively) (Table 3). When compared to published reef Ecopath models, the current Ecopath models 1 and 2 showed lower FCIs, but higher TST values compared to both Danajon Bank and San Miguel Bay and lower TST compared to Bolinao (Table 3). In addition, when compared to other reef ecosystems in Asia, Pacific, and Caribbean, Ecopath models 1 and 2 showed much lower TST values (Table 3). Overall trends in terms of sum of consumption, exports, and flows to detritus appeared generally similar between LGR and other Philippine Ecopath models in terms of proportion relative to TST (Table 3).

Ecopath Model Quality

Ecopath models 1 and 2 showed no functional group having an EE value of greater than 1 when balanced (Appendix Table 1). All EE values lie in reasonable ranges, with the highest TLs (apex predators) having smaller EEs; and conversely, small organisms or lower TL groups with considerable predation pressures had EEs closer to 1. No functional group had a gross food conversion efficiency or $\frac{P}{B}$ value higher than 0.3 and all $\frac{P}{B}$ were less than the net efficiency.

(A) Model 1: Original model



(B) Model 2: Model with coral biomass halved

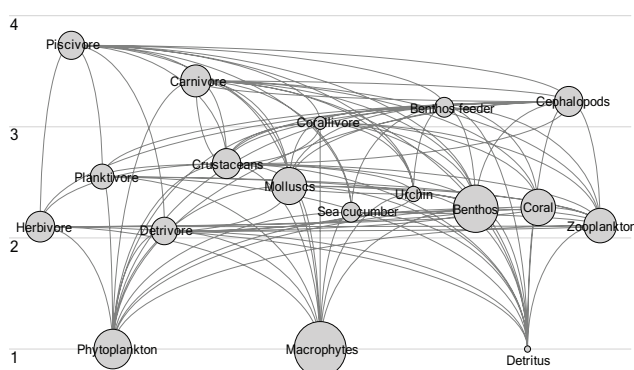
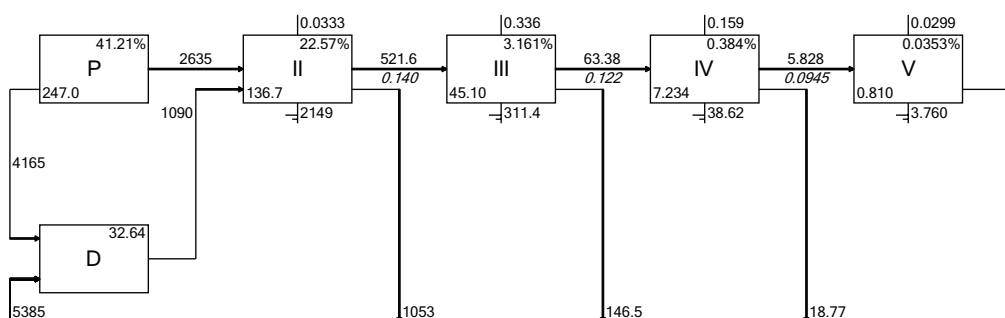


Figure 2. Flow diagrams showing the trophic level (y-axis) and the relationships between the functional groups (bubbles) in models 1 (A) and 2 (B). Bubble size represents biomass values.

(A) Model 1: Original model



(B) Model 2: Model with coral biomass halved

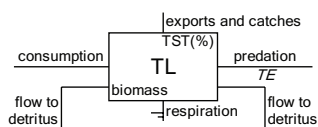
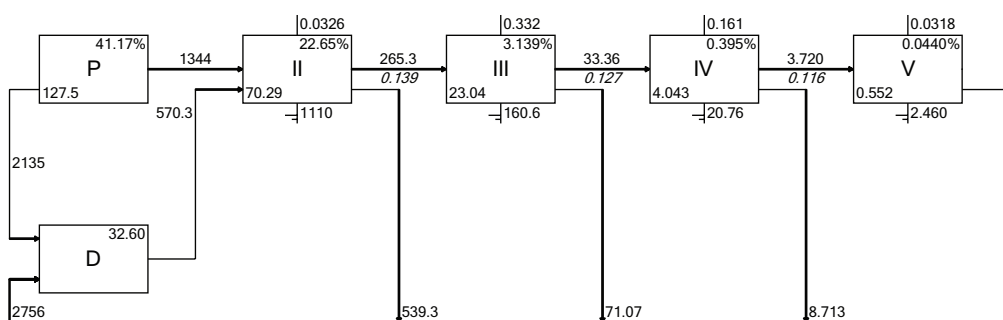
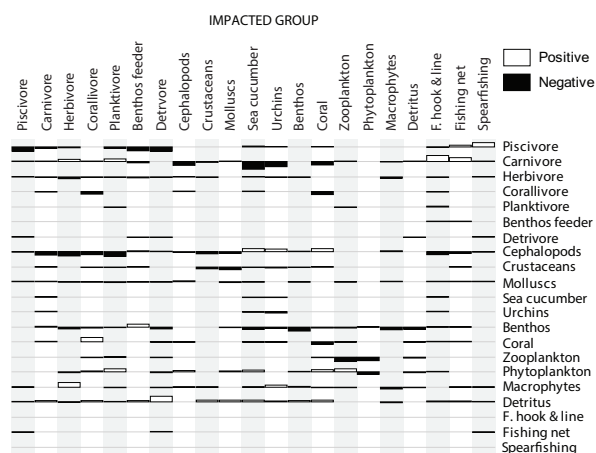


Figure 3. Lindeman spine diagrams for models 1 (A) and 2 (B) showing the transfer of energy flows and energy cycling along the trophic levels in the system (see schematics for additional legends).

(A) Model 1: Original model



(B) Model 2: Model with Coral biomass halved

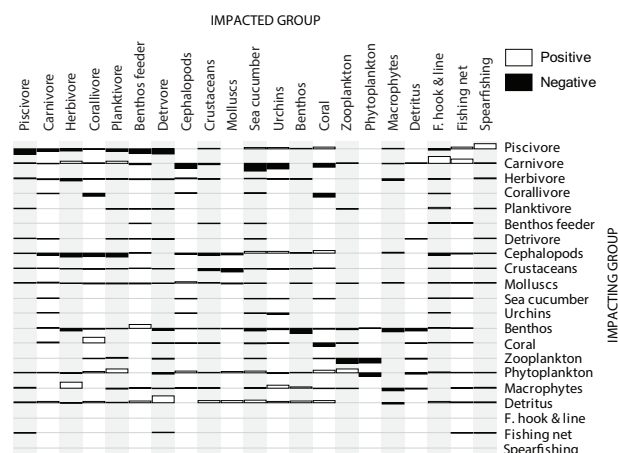


Figure 4. Mixed trophic impact (MTI) plot indicating how an increase in the biomass of an impacting group (rows) can affect the biomass of the impacted groups (columns); Positive impacts are displayed by white bars above the line, while negative impacts are displayed by black bars below the line

Biomass estimates for fish groups in both Ecopath models 1 and 2 constructed here were based on primary sourced UVC fish survey data. $\frac{P}{B}$ and $\frac{Q}{B}$ values were taken from similar ecosystems. From our sensitivity analyses, both Ecopath models 1 and 2 have PIs of 0.536 (Table 3). Based from Morissette's (2007) worldwide compilation and study of 150 published Ecopath models whose PI's ranged from 0.164 to 0.675, the current Ecopath models 1 and 2 were considered good and was situated within the higher ranges of PI values.

Ecosim Simulations of Primary Productivity and Associated Changes

Ecosim simulations of reduced productivity (i.e., all scenarios from -5 to -30%) indicated that the functional groups in Leyte Gulf ecosystem would decrease in biomass from about

15 to 30% (Figure 5). In particular, herbivores, cephalopods, macrophytes, urchins, and planktivores showed an average 30% reduction in biomasses. It is also observed that an important decrease (simulated decreases of 5% decrements) in productivity will lead to greater corresponding biomass reduction of sensitive functional groups (Figure 5).

On the other hand, Ecosim simulations of increased productivity (i.e., all scenarios from +5 to +30% increase) indicated that most (90%) functional groups would show greater than or equal to 20 to 40% increases in biomass, in particular the low trophic ones (Figure 5). Benthos feeder, piscivore, cephalopods, detritivores, and urchin were the top five functional groups that showed the greatest increases when productivity was increased.

Table 3. Summary statistics for both LGR Ecopath Models 1 and 2 compared with summary statistics from other modelled reef areas

Ecosystem attribute	High fisheries catch				Low fisheries catch				
	Nanwan Bay Taiwan	Bolinao Pangasinan	S. Miguel Bay South Luzon	Danajon Bank Bohol	Leyte Gulf Model 1	Leyte Gulf Model 2	Fr. Polynesia Pacific	Tampalam Mex. Carrib.	Floreana Isl. Galapagos
Sum of all Consumption	8,373.00		769.00	1,653.00	4,738.01	2,430.77		18,347.00	51,600.00
Sum of all Exports	16,200.00		516.00	378.00	4,295.83	2,185.84		3,376.00	5,412.00
Sum of all Respiratory Flows	4,629.00	19,965.00	382.00	875.00	2,503.49	1,296.58		11,226.00	27,638.00
Sum of all Flows to Detritus	20,115.00	18,405.00	931.00	900.00	5,385.25	2,755.54		12,253.00	21,024.00
Total System Throughput (TST)	49,317.00	39,307.00	2,599.00	3,805.00	16,922.57	8,665.73		42,202.00	94,850.00
Total Net Primary Production (NPP)	20,199.00		898.00	1,253.00	6,799.31	3,479.36	11,350.00	14,293.00	13,250.00
Sum of all Production	21,553.00	1,938.00	1,081.00	1,701.00	8,086.24	4,130.39		18,053.00	17,337.00
Net system production	15,570.00		516.00	378.00	4,295.83	2,185.78		3,067.00	14,388.00
Biomass: TST ratio (B:TST)	0.04	0.05	0.01	0.04	0.03	0.03		0.02	0.03
TPP: Total Respiration Ratio (PP:R)	4.40		2.35	1.43	2.72	2.69	1.10	1.30	0.50
TPP: Total Biomass Ratio (PP:B)	9.90		28.65	8.27	15.57	15.43		14.10	5.10
FCI (% of TST)	3.50		7.50	7.24	4.96	4.96	58.00		
Connectance Index			0.34	0.29	0.38	0.38			
System Omnivory Index			0.17	0.18	0.25	0.24			
Ecopath Pedigree index	0.586			0.536	0.536	0.536			

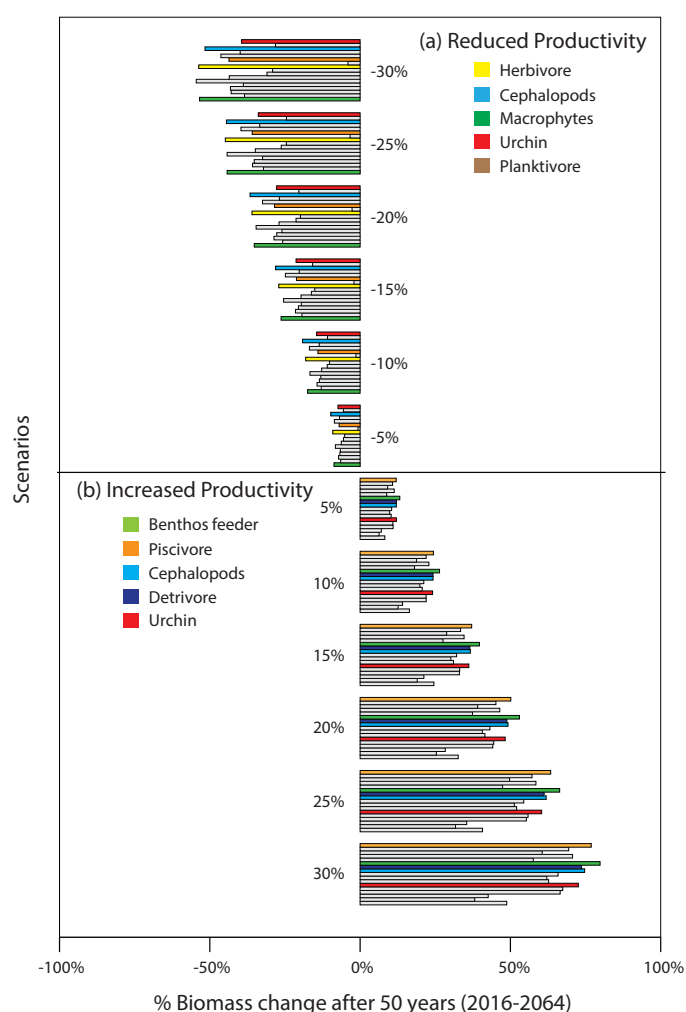


Figure 5. Projected biomass value changes in response to different scenarios of decreasing and increasing (-30 to +30%) primary productivity after a simulation period of 50 years (2016-2064). Functional groups for each scenario are arranged top-down as they also appear numbered in Table 2. Colored bars are selected functional groups that had the greatest mean response to primary productivity changes.

Discussion

LGR Ecosystem: Structure, Flow, Interactions, and Properties

Overall, Ecopath models 1 and 2 showed that the Leyte Gulf ecosystem is a degraded system as evident in the following: (1) the dominance of small-medium herbivorous and carnivorous fish species, (2) the low TST levels compared to other relatively healthy reef/coastal ecosystems, (3) short food chain and low biomass accumulation at higher TLs, and (4) rapid conversion of most productivity back to the detritus.

Based on the UVC conducted across Leyte Gulf, most of the reefs and coastal areas included in the surveys had low

fish density and biomass, and were mostly dominated by small- to medium-bodied species (e.g., parrotfishes, snappers, surgeonfish, wrasses, and rabbitfishes) (Anticamara & Go, 2016; Anticamara, Go, Ongsyng, Valdecañas, & Madrid, 2015; Go et al., 2015). In addition, majority of the reefs that were surveyed had low coral cover, partly due to destructive fishing in most reefs (e.g., use of dynamite and bottom trawl) and the frequency of strong typhoons impacting the reefs in Leyte Gulf in recent times (Anticamara & Go, 2016).

TST estimates based on Ecopath models 1 and 2 confirmed the degraded state of the ecosystem compared to other reefs in the Caribbean and the Pacific (Arias-Gonzalez, Delesalle, Salvat, & Galzin, 1997; Arias-González, Nuñez-Lara, González-Salas, & Galzin, 2004; Okey et al., 2004). When compared to other Philippine Ecopath models, TST estimates indicated that LGR is less degraded compared to other reefs modelled in the Philippines such as Danajon Bank (Bacalso & Wolff, 2014) and San Miguel Bay (Bundy & Pauly, 2001), but appeared to be more degraded compared to the outdated Bolinao Ecopath model (Aliño et al., 1993). Field observations of Bolinao based on recent UVC indicated that it seems as degraded as Leyte Gulf to date (Anticamara et al., 2015; Go et al., 2015).

Moreover, Ecopath models 1 and 2 indicated that the ecosystem operated through a short food chain, where most of the productivity was rapidly converted back to detritus, and only a small amount of lower TL group biomasses was assimilated by higher TL groups. Other reefs in the Caribbean have also demonstrated similar trophic structure and flows which may suggest a typical functioning of a reef (Arias-Gonzalez et al., 1997; Arias-González et al., 2004). However, in the case of LGR, the rapid recycling of biomass back to detritus was driven mainly by the lack of top and intermediate TL species that can optimize energy assimilation and conversion to higher TLs.

Ecopath models 1 and 2's CIs, OIs, FCIs also suggested the degraded state of the LGR ecosystem compared to other less exploited sites (Table 3). However, it is very difficult to interpret most of the current estimates and ecosystem properties obtained here because of the lack of comparable Ecopath models of intact and more mature ecosystem in the area. Most of the Marine Reserves (MRs) or no-take zones that were surveyed in Leyte Gulf did not have marker buoys on their boundaries so it is hard to determine which sites were inside the well-enforced MRs and which ones were outside.

Effects of Halving Corals on LGR Ecosystem

Comparison of outputs of Ecopath models 1 and 2 gave insights on possible responses of functional groups in the ecosystem when coral biomass is halved. The results showed that most of the LGR ecosystem structure, trends in energetic flows, strength in interactions, and system properties were somewhat roughly maintained, but mostly

just slashed to half their original values in Ecopath model 1. This is important to know since, in recent times, the LGR ecosystems have been subjected to super-typhoons that halved the coral cover in most reefs after impacts (Anticamara & Go, 2016). In addition, after every typhoon, most of the relief and government agencies that responded to the impacted areas in Leyte Gulf supported affected populations by giving more fishing boats and motor engines. This support is ironic since the scenario implemented in Ecopath model 2 suggested that such an investment will simply be wasted, as fish production in the system will considerably decrease due to heavy coral cover destruction in the areas after the typhoon. Perhaps diversified alternative livelihoods or post-typhoon reef recovery plans will be better investments in the LGR ecosystem, or in the Philippines in general, while waiting for the corals and the reef productivity to recover after a typhoon.

Simulations of Primary Productivity Changes and Impacts on LGR Ecosystem

Ecosim simulations showed that reductions in primary productivity of LGR across various defined scenarios led to reductions in biomasses of many important functional groups in the area. Specifically, a range of productivity reduction scenarios from -5 to -30% was predicted to have mostly greater than or equal to 30% biomass reduction in the top five productivity-sensitive functional groups of LGR. In contrast, Ecosim simulations of productivity increases in LGR yielded greater than or equal to 37% increases in biomasses of most functional groups in the system. This is an important insight since it was observed from field surveys that most of the reef ecosystems in Leyte Gulf had experienced increases in algal cover, especially after strong rainy days and typhoons, due to the nutrient run-off from nearby agricultural lands and urban areas. In addition, most of the coastal areas of Leyte Gulf have lost its forest cover from the conversions of vast expanse of coastal forests into coconut plantations. This means that most likely, in the following years, the nutrient run-off in Leyte Gulf will intensify as (1) more agricultural lands are fertilized indiscriminately; (2) more urban areas will dump untreated sewage into the coastal ecosystem; and (3) more coastal forest are denuded in the area. Ecosim predicted that the most likely response to primary productivity increases (the most plausible scenario for Leyte Gulf) will be a general increase in biomasses of most functional groups. However, it was not determined what exactly will be the implications in terms of coastal phytoplankton blooms (e.g., harmful algal blooms [HABs]), changes in ecosystem structure and functioning or other potential related ecosystem responses after intensified primary productivity increases, in areas where most consumers of excess primary productivity were mostly depleted. Several HABs have been reported in coastal areas of the Philippines, but most of these reports have not quantified trophic impacts and even the dynamics of phytoplankton and zooplankton communities during and after the bloom (Azanza & Taylor, 2001; Hallegraeff, 1993; Wells et al., 2015)

LGR ecosystem EwE models: Implications

Ecopath models 1 and 2 provided insights on how such a degraded and depleted ecosystem is functioning in terms of trophic structure, flow, interactions, and system properties. In addition, they provided useful perspectives on the current state of reef degradation and the need to closely monitor the endangered reef ecosystems in Leyte Gulf in case of further climate-related changes and overfishing impacts. The current state of the Leyte Gulf ecosystem calls for implementation of effective recovery and management strategies such as the following: no-take MRs, fishing closures for depleted populations, active recovery of coral cover, and prevention of unregulated nutrient run-off of the inputs into the system.

Conclusions

There are three key findings about the current and plausible scenarios for Leyte Gulf ecosystem: (1) LGR ecosystems are in a degraded state dominated by few and small-medium herbivores and carnivores; (2) reduction in live coral cover due to typhoons will cause a decline in biomass of many functional groups in LGR; and (3) changes in productivity (e.g., eutrophication) will impact most functional groups in LGR. Thus, there is a great need to improve the recovery and management of coastal and marine resources in the area to sustainably support the increasing demands for fisheries production and livelihood in Leyte Gulf, while mitigating further ecosystem degradation. This study also suggests that there is a great need to develop appropriate management responses and recovery and adaptation strategies in Leyte Gulf considering the depleted status of its coastal marine resources and the impending further declines brought by climate change and human-induced disturbances. Moreover, this study highlights the need to develop systematic monitoring of coastal marine ecosystems and trophic structure and functioning in Leyte Gulf in order to generate sufficient empirical data useful for developing more accurate EwE models and effective recovery and management strategies in the area.

Acknowledgements

Field work expenses was mainly supported by the Resilience and Preparedness for Inclusive Development (RAPID) – Natural Resource Assessment (NRA) project, implemented by Dr. Ariel Blanco of the UP Training Center for Applied Geodesy and Photogrammetry (UP TCAGP) and supported by the Philippine Climate Change Commission (CCC).

Additional support came from the University of the Philippines Office of the Vice-Chancellor for Research and Development (OVCRD) Open Grant Project No 141406OG, and the Foundation for Philippine Environment (FPE). We also thank Pio Angelo C. Ballesteros, Mark Angelo B. Pontica, and Marlon P. Gutierrez for their help during the field work for this study.

Appendix Table 1A. Input and output (in brackets) parameters, and data sources for the Leyte Gulf model 1

#	Functional group	<i>TL</i>	<i>B</i>	<i>P/B</i>	<i>Q/B</i>	<i>EE</i>	<i>P/Q</i>	<i>NE</i>	<i>OI</i>
1	Piscivore	3.73	(3.12) ^a	(1.10) ^b	(6.35) ^b	0.69	0.17	0.22	0.34
2	Carnivore	3.18	(9.58) ^a	(1.07) ^b	(7.04) ^b	0.91	0.15	0.19	0.27
3	Herbivore	2.27	(8.81) ^a	(1.53) ^b	(25.51) ^b	0.98	0.06	0.08	0.11
4	Corallivore	2.70	(0.76) ^a	(2.20) ^b	(21.04) ^b	0.92	0.11	0.13	0.26
5	Planktivore	2.43	(2.98) ^a	(1.67) ^b	(18.16) ^b	0.71	0.09	0.12	0.31
6	Benthos feeder	2.52	(0.76) ^a	(0.98) ^b	(7.23) ^b	0.57	0.14	0.17	0.18
7	Detrivore	2.42	(3.39) ^a	(1.10) ^b	(15.28) ^b	0.43	0.07	0.09	0.07
8	Cephalopods	2.94	12.03	(2.85) ^c	(9.81) ^c	(0.50)	0.29	0.36	0.42
9	Crustaceans	2.28	8.72	(5.70) ^c	(18.75) ^c	(0.80)	0.30	0.38	0.46
10	Molluscs	2.16	22.90	(3.16) ^c	(8.26) ^c	(0.80)	0.38	0.48	0.33
11	Sea cucumber	2.12	1.66	(2.71) ^c	(11.76) ^c	(0.80)	0.23	0.29	0.20
12	Urchin	2.21	0.88	(7.51) ^c	(20.70) ^c	(0.80)	0.36	0.45	0.37
13	Benthos	2.11	80.20	(4.82) ^c	(20.13) ^c	(0.80)	0.24	0.30	0.25
14	Coral	2.17	19.51	(1.66) ^d	(9.39) ^d	(0.80)	0.17	0.22	0.23
15	Zooplankton	2.06	14.55	(45.50) ^c	(136.90) ^c	(0.80)	0.33	0.42	0.11
16	Phytoplankton	1.00	28.03	(137.60) ^c		(0.50)			
17	Macrophytes	1.00	218.95	(13.44) ^c		(0.24)			
18	Detritus	1.00				0.20			0.30

Appendix Table 1B. Input and output (in brackets) parameters, and data sources for the Leyte Gulf model 2 with Coral halved

#	Functional group	<i>TL</i>	<i>B</i>	<i>P/B</i>	<i>Q/B</i>	<i>EE</i>	<i>P/Q</i>	<i>NE</i>	<i>OI</i>
1	Piscivore	3.73	3.12	(1.10)	(6.35)	(0.69)	0.17	0.22	0.34
2	Carnivore	3.18	5.34	(1.07)	(7.04)	(0.90)	0.15	0.19	0.27
3	Herbivore	2.27	4.55	(1.53)	(25.51)	(0.98)	0.06	0.08	0.11
4	Corallivore	2.70	0.34	(2.20)	(21.04)	(0.71)	0.11	0.13	0.26
5	Planktivore	2.43	2.00	(1.67)	(18.16)	(0.57)	0.09	0.12	0.31
6	Benthos feeder	2.52	1.01	(0.98)	(7.23)	(0.43)	0.14	0.17	0.18
7	Detrivore	2.42	2.88	(1.10)	(15.28)	(0.50)	0.07	0.09	0.07
8	Cephalopods	2.94	4.11	(2.85)	(9.81)	(0.50)	0.29	0.36	0.42
9	Crustaceans	2.28	4.16	(5.70)	(18.75)	(0.80)	0.30	0.38	0.46
10	Molluscs	2.16	10.42	(3.16)	(8.26)	(0.80)	0.38	0.48	0.33
11	Sea cucumber	2.12	1.05	(2.71)	(11.76)	(0.80)	0.23	0.29	0.20
12	Urchin	2.21	0.53	(7.51)	(20.70)	(0.80)	0.36	0.45	0.37
13	Benthos	2.11	41.32	(4.82)	(20.13)	(0.80)	0.24	0.30	0.25
14	Coral	2.17	(9.76)	(1.66)	(9.39)	(0.80)	0.17	0.22	0.23
15	Zooplankton	2.06	7.39	(45.50)	(136.90)	(0.80)	0.33	0.42	0.11
16	Phytoplankton	1.00	14.23	(137.60)		(0.50)			
17	Macrophytes	1.00	113.25	(13.44)		(0.24)			
18	Detritus	1.00				0.20			0.30

Model inputs are in parenthesis; biomass (*B*, t/km²); production/biomass ratio (*P/B*, yr⁻¹); consumption/biomass ratio (*Q/B*, yr⁻¹); ecotrophic efficiency (*EE*); gross food conversion efficiency or production/consumption ratio (*P/Q*); Net efficiency (*NE*) and Omnivory index (*OI*).

^a Underwater visual census (UVC)

^b Fishbase (Froese & Pauly, 2014)

^c Aliño (1993), Bacalso & Wolff (2014), Bundy and Pauly (2001), Campos (2003)

^d Bozec et al. (2004), Okey et al. (2004), Tesfamichael (2012)

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Hydrological modeling to assess water resources resilience towards climate change impacts in Tacloban, Philippines

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Received: 15 June 2017 / Accepted: 15 January 2018 / Published online: 13 February 2018

Abstract

Tacloban, Philippines, the city most devastated by typhoon Haiyan in 2013, faces severe water supply constraints, particularly on the relocation sites that are expected to accommodate 40% of Tacloban's population by 2018. This region's hydrological system was modeled using QSWAT to evaluate the impacts of climate change, namely, rising temperatures and variation of rainfall patterns, on three rivers (Binahaan, Pongso, and Cabayugan). These rivers are the potential sources of water for the two supply solutions currently being considered. Thus, it is essential to assess their resilience as sources of water. Two climate scenarios were generated for 2020 and 2050 using the Change Factor (CF) method, and the system response was compared to the baseline data (1979–2010).

Results show that, regardless of the chosen supply solution, for certain time periods (most severely for the quarter of March to May), the percentage of days in which the river flows were insufficient to meet the proposed water catchment flows was significant (reaching up to 25%). Outputs also suggest that Binahaan River, where the current water catchment is located, may fail in providing sufficient water to the region for future scenarios. However, it should be noted that Pongso and Cabayugan Rivers in northern Leyte can represent a resilient water source to supply the new resettlement areas.

Keywords: climate change adaptation · hydrological modeling · QSWAT · resilience · typhoon haiyan · water resources management

DOI: <https://doi.org/10.18783/cddj.v003.i01.a02>

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Introduction

Climate change (CC) has recently become a matter of the utmost importance in water studies, as it is capable of altering water availability worldwide due to variation of rainfall patterns. The potential impacts include the changes in timing and magnitude of surface runoff, stream discharge, evaporation, and flood events (Neupane & Kumar, 2015). Several studies have demonstrated that even small perturbations in the frequency and/or quantity of precipitation can have significant impacts in terms of watershed runoff (Minville, et al., 2008).

However, coupling hydrological and climate studies is a relatively young discipline (Teutsschbein, 2013). CC impact studies on hydrological systems faced the obstacle of the Global Circulation Models (GCMs), which were used to simulate future climate scenarios but did not provide sufficiently detailed outputs. This obstacle was surpassed only with the use of dynamic downscaling tools, namely, Regional Climate Models (RCMs), even though some bias correction is still recommended when using directly RCM outputs on hydrological studies (Fowler & Kislby, 2007).

The concept of resilience, initially coined for an ecological context, has conquered prominence in CC discussions, particularly those regarding adaptation. In brief, the resilience of a system can be defined, for a certain system, as the “ability to reduce both the magnitude and the duration of the deviation from the equilibrium stadium” (Proag, 2014). Likewise, in the context of disaster resilience, Klein, Nicholls, and Thomalla (2003) claim that the concept of resilience sits under the broader concept of “adaptive capacity” as one of the numerous factors capable of influencing it. Hence, resilience appears as an idea with direct application potential, especially when moving from disaster recovery (as for this particular case study) towards hazards prediction, or disaster prevention and preparedness (Klein et al., 2003).

Resilience indicators for water resources focus mostly on water scarcity or quality degradation issues. Possible indicators for water scarcity are average precipitation, average river discharge, and average soil moisture or groundwater level—these are examples of components that can be accurately studied through hydrological modeling, facilitating the benchmarking of various scenarios and the development of a sensitivity analysis to better understand the weight of each variable. The sensitivity of a system to water scarcity is therefore determined by the influence of the stress factor (e.g., CC): for example, in some basins, a reduction of rainfall can result in a reduction in water availability, whilst in other basins, it can have only a negligible impact on stream flow. Other possible indicators are the changes in water demand for future scenarios, comparatively to a reference period (and the possible disaggregation by water users and sectors); the loss of industrial and agricultural production (or jobs), income, and livelihoods; desertification; and land degradation (Elis, 2014).

Case Study Presentation

The Republic of the Philippines is one of the most vulnerable territories to CC, given its geographic location in the Tropical Pacific, archipelagic formation, and population distribution. In recent years, this country was ranked highest in the world in terms of vulnerability to tropical cyclone (TC) occurrence and third in terms of people exposed to seasonal events (Climate Change Commission, 2012). The Philippines has already experienced noticeable adverse effects in recent years, with the observed changes in its climate in most recent times having never been seen in the past 140 years. Climate trends evaluated for the 1951–2009 period (using reference data from 1971 to 2000) revealed an increase in the annual mean temperature by 0.65°C, with an increase of 0.36°C and 0.1°C in terms of maximum and minimum temperatures, respectively. The trends of rainfall (extreme rainfall intensity and frequency) are not so clear, with very little spatial coherence, varying between islands and regions (increasing in some, while decreasing in others). These climate simulations were obtained by the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) using the project Providing Regional Climates for Impact Studies (PRECIS), an RCM developed by the UK Met Office Hadley Center for Climate Prediction and Research, considering boundary data from the ECHAM4 and HadCM3Q0 Global Climate Models. For this downscaling, three emission scenarios were assumed: A2 (high range), A1B (medium range), and B2 (low range) (PAGASA, 2011).

Although there is still no sound evidence of an overall nationwide increase in the frequency of TCs, for the Visayas region, TCs seem to have increased from 1971 to 2000, as compared with previous periods. Moreover, a slightly superior number of extreme cyclones have been observed (from the typhoon category, with winds above 150 km/h (PAGASA, 2011). These observations are partially sustained by the work of Cinco et al. (2016), stating that, for the period of 1951–2013, there have actually been fewer typhoons reaching the country, but there is an increase in the frequency of the most extreme ones.

The city of Tacloban is located at the northeastern coast of Leyte island, Visayas region, Philippines, between the San Juanico Strait and the island’s highlands—Sta. Helena and Naga-Naga mountain ranges—that reach above 450 m of altitude (Wernstedt & Spencer, 1967). To most authors, the climate in this region resembles a Type II climate, with no dry season and a period of relatively more intense rainfall from November to February. From the analysis of local climatological patterns for the period of 1987–2006, Tacloban’s annual average rainfall totaled 2,600 mm. The Philippines coincides with the typhoon belt, with around 20 storms crossing the country per year and the strongest ones being registered from July to October (Gultiano, et al., 2003). However, on November 8, 2013, super typhoon Haiyan, the strongest registered so far to ever make landfall, roared ashore over Tacloban, causing catastrophic destruction and over 6,000 casualties (NDRRMC, 2014), with its outrageous proportions being often linked to CC causes. Being one of the major cities hit by the 6-m tsunami-like storm surge, Tacloban soon became the focus of world media attention and international relief operations.

To the present day, the city is undergoing major relocation efforts towards the north that will create new residential, institutional, and commercial areas on a supposedly storm-surge-safer zone. Leyte Metro Water District (LMWD), the local water utility, is responsible for supplying Tacloban City and the seven surrounding municipalities of Dagami, Palo, Pastrana, Sta. Fe, Tabontabon, Tanauan, and Tolosa. Despite only 25% of the city's households being actually connected to this utility, "due to political disputes, LMWD does not intend to increase their service area within the City of Tacloban" (United States Agency for International Development [USAID], 2015). However, a proposal to expand the city's network has been submitted, which relies mostly on the Binahaan River catchment, towards the northern relocation areas. Until the submission of this article, this resettlement area that will accommodate 40% of Tacloban's population in 2018, was still lacking a solid water supply solution and other proposals were being evaluated—some advanced by the local government unit (LGU) of Tacloban.

As a consequence, relocated families are fleeing back to the city, rebuilding their homes in markedly dangerous flood-prone areas, as Santos, Toda, Orduña, Santos, and Ferrão, (2016) have foreseen. The impacts of this typhoon also affected the region's vegetation (Carlos, et al., 2016) and water resources (Tolentino, et al., 2016).

Therefore, the goal of this research is to quantify the impacts of CC on the hydrological system on which Tacloban relies for water supply purposes. A closer look was given to the three waterways currently considered for water extraction: the already explored Binahaan River and the Pongso and Cabayugan Rivers, pointed out by the USAID as possible water sources to supply the new resettlement areas. Furthermore, this work is expected to contribute to the enforcement of the role of hydrological models in CC impact studies—specifically in developing countries where data collection is scarcer—and to support the resilience-enhancing practices on local water resources management.

Materials and Methods

Hydrological Modeling with QSWAT

In order to replicate Tacloban's surrounding water lines behavior under CC impacts, a QGIS-based version of the Soil and Water Assessment Tool (SWAT) was used. This is a widely used hydrological model from the US Department of Agriculture, i.e., QSWAT. Since it has the nature of a continuous-time model (not as adequate to simulate single-event but rather long-term changes), SWAT enables users to address gradual environmental problems—being increasingly used for CC contexts all over the globe. For instance, the model is capable of simulating the impacts of temperature changes and soil water deficit on vegetation growth and erosive response, besides the effects of global CCs on hydrological balance and, therefore, on the processes that determine surface and base flow generation (Serpa et al., 2015).

QSWAT interface presents a three-step configuration to be followed by the user in order to prepare the SWAT simulation (Dile, et al., 2016), followed by a fourth step for output analysis. Step 1: Delineate Watershed, where the user selects the elevation map grid to be used and can optionally burn an existing stream network and a predefined watershed. In this step also, the threshold for creating subbasins is set, either by area or number of cells. Step 2: Create Hydrological Response Units (HRUs), where the user sets the conditions to delineate HRUs. The HRUs are smaller partitions of the subbasins, which share a unique land use, soil, and slope; therefore, in this step, both land use and soil maps are required, together with their respective look-up tables that should be previously prepared if the user is not using the default ones. Step 3: Edit Inputs and Run SWAT, where the input tables containing climatic data are provided by the user. Step 4: Visualize, in which, to analyze the simulation outputs, the user may choose from static data, animation, or plotting. For more details on QSWAT functioning, setup and outputs visualization options, refer to the work of Dile et al. (2016).

Data Sources

QSWAT requires both maps and table data as inputs. In Step 1 of the setup, the watersheds are delineated based on elevation layers and a stream network. The Digital Elevation Model (DEM) raster file was obtained from Earth Explorer, a database from the US Geological Survey. The 30-m resolution grid was then clipped to show only Tacloban City and its surroundings (this allowed faster simulations; hence, the model had a smaller area to process). As for the streams shapefile, it was obtained from the online database DIVA-GIS and again clipped to show only the interest area. After a few attempts, it was determined that a threshold of 50 km² for delineating watersheds was adequate to match the created stream network, providing sufficient detail for the objectives of the study.

Land use and soil maps were required in Step 2 for the creation of HRUs. The land-use layer was downloaded from the WaterBase database, a service provided by the United Nations University with the aim of advancing the practice of Integrated Water Resources Management in developing countries, while the soil map used was one from the Food and Agriculture Organization (FAO) of the UN. Only clipping and reprojecting operations were then necessary to have these maps ready for the simulation. The standard land use and soil lookup tables used, compatible with the maps from this database, were by default included on QSWAT.

Climate variables for QSWAT simulations (introduced as table data) provide the moisture and energy inputs that affect the water balance and determine the relative importance of its various components. Tacloban City weather station is installed 2.71 m above the sea level in the peninsula that hosts the city airport (11°12'32.21"N, 125°01'29.92"E) and is managed by PAGASA. Daily data records from this

station were collected for the following variables, according to the model requirements: precipitation (in millimeters), temperature (min and max, in degree Celsius), relative humidity (in percentage) and wind speed (in meters per second). These series corresponded to the period of January 1, 1979, to December 31, 2010. The solar radiation series was extracted from the Global Weather database; hence, these records were not available for Tacloban. This database hosts data for any given location, which are already displayed in a compatible format. The “stations” on this database, however, do not correspond to real stations but to points of a matrix of a weather generating model. The point 1111250 was chosen as being closest to Tacloban’s PAGASA station (only 16 km apart and with an elevation of 4 m). It was assumed that using solar radiation data from a different station would not have significant impacts on the modeling outputs, considering the proximity of the stations, similar elevation, and no relevant orographic occurrences between them. Moreover, from all the climatic variables, solar radiation is believed to be the one with the lowest expected spatial variability and not as influenced by local factors. Finally, the Weather Generator Tables (WGEN for the different scenarios) were created according to the model description of Neitsch, Arnold, Kinity, and Williams (2011; for further detail on the creation of these tables, refer to these authors’ work).

It should be noted that QSWAT uses the SCS-CN method to estimate superficial runoff, balancing for each hydrological unit its soil characteristics, which loses some accuracy when applied to larger basins. However, the lack of spatially distributed rainfall data for the study area did not allow the use of other methods that could enhance the accuracy of this impact study.

Statistical Validation of Precipitation Series

The rainfall records registered by a meteorological station are statistically defined as random variables (assuming that rainfall events are independent from each other), thus being only useful if validated through a statistical analysis. If a sufficiently long series of rainfall records is available, one can determine which probability distribution function is closer to the empirical distribution of the data. One of the main advantages of adjusting such function is that it further allows extrapolating values with a return period larger than the one of the analyzed sample (with a comfortable confidence degree, usually around $1-\alpha=0.95$). The normal distribution (or Gaussian Law) is reportedly adjusted to annual average records, while the Gumbel Law is used to describe the distribution of extreme data (Lencastre & Franco, 2006).

The quality of fit of these adjustments was analyzed recurring to analytical methods such as the Chi-squared and the Kolmogorov–Smirnov tests. For more detail on these statistical procedures, refer to the work of Lencastre and Franco (2006).

Scenarios and CC

CC can be simulated with SWAT by manually manipulating the climatic daily data series and then running the model using them as input data to assess changes in the hydrological system (Neitsch et al., 2011). This method is frequently defined in specialized literature as the CF method. In essence, this method modifies the observed historical time series by affecting it with the projected differences between future and current climates, computed by climate models, either GCMs or RCMs (Chen, et al., 2011). These perturbation factors are computed on a monthly basis, for each future time period (Equations 1 and 2; Minville et al., 2008). With regards to generating future temperature daily series ($T_{fut,d}$), the CF method involves adjusting the observed daily records ($T_{obs,d}$) by adding the difference in monthly averages ($\bar{T}_{fut,m}$ and $\bar{T}_{obs,m}$) predicted by the climate model between the future horizon and the reference period.

$$T_{fut,d} = T_{obs,d} + (\bar{T}_{fut,m} - \bar{T}_{obs,m}) \quad (1)$$

As pointed out by Chen et al. (2011) and Minville (2008), for the precipitation series, the adjusted precipitation on the horizon period ($P_{fut,d}$) is obtained by affecting daily observed records ($P_{obs,d}$) by the precipitation ratio between monthly averages ($\bar{P}_{fut,m}$ and $\bar{P}_{obs,m}$).

$$P_{fut,d} = P_{obs,d} \times (\bar{P}_{fut,m} \div \bar{P}_{obs,m}) \quad (2)$$

Despite being frequently used to strategic-scale assessments of hydrological impacts of CC, this method is not without problems: statistically, the baseline and scaled series are different in their means, maxima, and minima, but all the other properties of the data remain unchanged (such as range and variability). Thus, the CF method application to the precipitation series does not affect the number of rainy days—meaning that the temporal sequence of wet and dry days remains unchanged, limiting the method’s efficiency in circumstances of persistent droughts, for example, which are important in impacts assessment. Furthermore, the procedure fails by admitting that the spatial pattern of the present climate remains unchanged (Diaz-Nieto & Wilby, 2005). Nonetheless, assuming that it should not be used to make projections of precipitation on a daily basis as the temporal structure of the series remains constant, the CF method is still largely used in quantifying the impacts of CC on hydrology, and its application is enforced when equivalent observational and GCM/RCM data exist for comparison purposes.

CC scenarios for this modeling exercise were created consistently with PAGASA’s official projections for Leyte, as summarized on Table 1. These climate trends were obtained via the UK Met Hadley Center RCM data

Table 1. Seasonal temperature increases (°C) and rainfall variation.

	Temperature Projections			Rainfall Projections		
	Baseline (°C)	2020 (°C)	2050 (°C)	Baseline (mm)	2020 (%)	2050 (%)
DJF	24.6	+0.9	+1.8	689.5	+3.0	+9.4
MAM	27.8	+1.2	+2.3	342	-8.9	-18.9
JJA	28	+1.1	+2.2	568.7	+9.5	+19.6
SON	27.7	+1.0	+1.9	725.5	+7.4	+19.5

(from the project Providing Regional Climates for Impacts Studies or PRECIS). This downscaling to the Filipino territory was performed using a grid resolution of 25 km, considering a baseline period from 1971 to 2000. For Leyte, rainfall is expected to increase in all seasons except from March to May, and for the same period, temperature increases are expected to be the highest (PAGASA, 2011).

Taking the Tacloban's weather station data series (for precipitation and maximum and minimum temperatures), the daily records were affected by these variations to obtain two new series for projected CC scenarios of 2020 and 2050, which are designated as CC2020 and CC2050, respectively. For the remaining climatic variables (relative humidity, wind speed, and solar radiation), the same records as the original series were used due to lack of projections for future scenarios.

Modeling Calibration and Validation

The calibration and, if possible, the validation of any modeling exercise outputs are essential steps to assure that the chosen model is accurately describing the real system. Thus, both calibration and validation are often processed by comparing obtained data with real empiric observations.

The QSWAT modeling results for Tacloban were calibrated using a series of observed monthly average flow gauge records for the Sapiniton Gauging Station, from 1985 to 2003, available on the referred USAID report (hence, there were no flow measurements available for Binahaan, Pongso, and Cabayugan Rivers). This gauging station (refer to Figure 1 for its location) corresponded to a drainage area of 204 km². Although relatively smaller (with only 147 km²), for calibration purposes, subbasin 3 was considered as correspondent. To assess the similarity of observed and obtained results, simple correlation functions were applied.

Resilience Analysis

Quantitative indicators of water supply are limited by the premise that there is either sufficient or insufficient water to suppress a certain demand. The modeling output daily flows, from the three rivers relevant to the considered supply solutions, were the subjects of a resilience analysis.

This analysis comprised the referred modeling scenarios: baseline (1980–2010), CC2020 (2007–2036), and CC2050 (2037–2065).

As a resilience indicator, the number of days in which the river flows were lower than the proposed water withdrawal was determined, expressed in a percentage of total days and discretized into four quarters to assess possible seasonal variations of water availability (Equation 3).

$$\% \text{ of days} = \frac{N_r \text{ days where flow} < \text{threshold on trimester}}{\text{Total } N_r \text{ days of trimester}} \quad (3)$$

In accordance with the supply constraints that Tacloban faces and the supply proposals currently considered, two supply solutions were evaluated:

- the “business-as-usual” scenario, in which LMWD keeps extracting water from Binahaan River to supply the whole community (including Tacloban City and the seven supplied municipalities of Dagami, Palo, Pastrana, Sta. Fé, Tabontabon, Tanauan, and Tolosa) plus the Tacloban North resettlement areas, considering the existing withdrawal rate of 0.72 m³/s; and
- the USAID-proposed complementary solution of resorting to the northern Leyte rivers (with an extraction rate of 0.58 m³/s), i.e., Pongso and Cabayugan, to supply only the new resettlement areas, while the City of Tacloban and surrounding municipalities continue to receive water from the Binahaan River.

Results and Discussion

Data Series and Statistical Validation

Tacloban's station daily precipitation records for the baseline series were arranged to obtain the total annual and annual daily maximum series. The former was adjusted using a Gaussian distribution function, while the latter was adjusted using a Gumbel Law function. The quality of these adjustments was validated through the Kolmogorov–Smirnov and Qui-squared tests, the results of which are presented on Table 2.

Both the adjustment tests resulted in the positive for the two data arrangements. The daily precipitation series was considered robust and trustworthy to be used on the subsequent modeling exercise.

Hydrological Modeling with QSWAT

Twelve watersheds were delineated by QSWAT for the study area, using a threshold of 50 km². From these, the most relevant ones were the subbasins 1, 3, and 5, the first two corresponding to the NGO-proposed supply solution for Tacloban North (from Pongso and Cabayugan Rivers) and the third one to Binahaan River, where the current catchment is located.

The characteristics of these basins are summarized in Table 3.

Noticeably, for the three basins, the most common land-use occupation is cropland, mostly a mix of crops and woods, also with a small percentage of forest. This non-urban occupation of the watersheds can be beneficial in terms of watershed management and for the safeguard of the water quality from both point or diffuse pollution sources. As

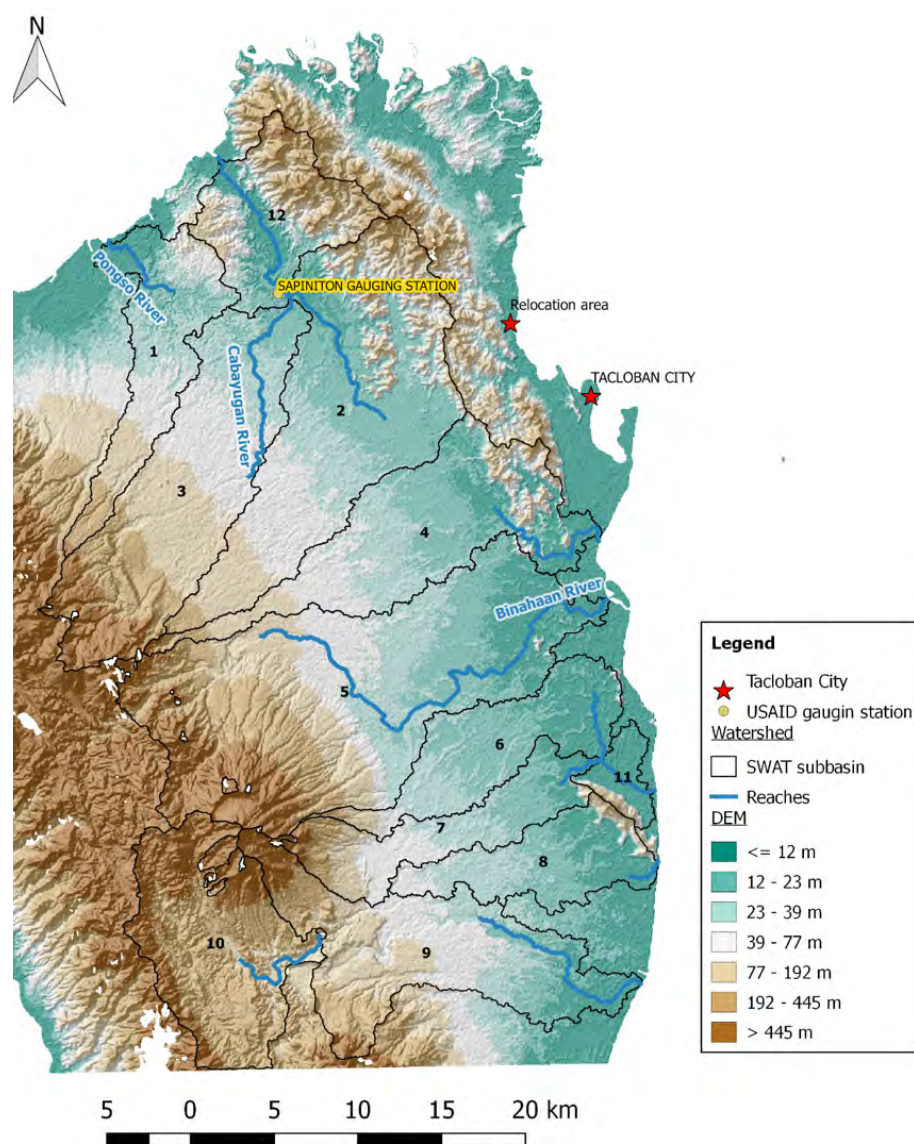


Figure 1. Delineated subbasins and rivers by QSWAT modeling.

Table 2. Statistical validation of precipitation series.

Data Series	Average	Std Dev	Adjusted Distribution Function	Kolmogorov-Smirnov Test Results	Qui-squared Test Results
Total Annual rainfall (mm)	2563.07 mm	576.22 mm	Gaussian	Accepted ($D_{max_{tab}} = 0.169 > D_{max_{calc}} = 0.127$)	Accepted ($\chi^2_{tab} = 11.07 > \chi^2_{calc} = 7.60$)
Daily maximum rainfall (mm)	129.07 mm	28.33 mm	Gumbel Law	Accepted ($D_{max_{tab}} = 0.145 > D_{max_{calc}} = 0.111$)	Accepted ($\chi^2_{tab} = 11.07 > \chi^2_{calc} = 8.40$)

Table 3. Selected subbasins characterization.

Subbasin #	Corresponding Waterway	Area (km ²)	Land-use Classes	Main Soil Classes**
1	Pongso River	70.6	89.33% CRWO 19.00% CRDY 6.97% CRIR 1.19% FOEB	55.75% Af14-3-c 39.77% Fo8-2ab 2.17% Jc4-2a
3	Cabayugan River	146.9	76.63% CRWO 15.32% CRIR 6.60% FOEB 1.45% CRDY	56.67% Fo8-2ab 42.75% Af14-3-c 0.58% Jc4-2a
5	Binahaan River	262.5	92.36% CRWO 4.97% FOEB 2.66% CRIR	55.69% Fo8-2ab 38.63% Af14-3-c 3.62% Jc4-2a

*Land-use classes: CRDY, dryland cropland and pasture; CRIR, irrigated cropland and pasture; CRWO, cropland/woodland mosaic; FOEB, evergreen broadleaf forest.

**Soil classes (FAO Classification): Af14-3-c, Ferric Acrisol (Hydrologic group C); Fo8-2ab, Ortic Ferrasol (Hydrologic group C); Jc4-2a, Calcaric Fluvisol (Hydrologic group D).

for the soil classes present on these watersheds, the hydrologic groups varied between C and D, the first corresponding to fine to very fine textured soils, with characteristically low permeability, and group D to clay soils with characteristically high-water tables and very low infiltration rates (Neitsch, 2011).

QSWAT includes SWAT-Check, a tool used to summarize results from simulations and to provide warnings that can help to improve results. The ratios between different water balance components, for instance, are vital to provide an easy understanding of the hydrological system studied (Dile, et al., 2016). Table 4 displays these ratios obtained for Tacloban's simulations.

Table 4. Hydrology Tab result from SWAT-Check.

Water Balance Ratios/Scenario	Baseline	CC2020	CC2050
Streamflow/Precipitation	0.59	0.60	0.62
Baseflow/Total Flow	0.41	0.40	0.39
Surface runoff/Total Flow	0.59	0.60	0.61
Percolation/Precipitation	0.23	0.23	0.23
Deep Recharge/Precipitation	0.01	0.01	0.01
Evapotranspiration/Precipitation	0.39	0.37	0.35

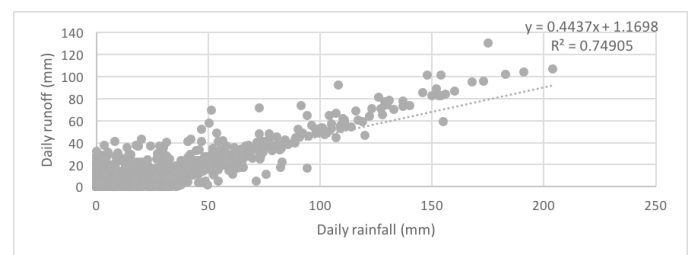
Surface runoff volume is computed in SWAT using a modification of the SCS curve number method, in which the curve number varies non-linearly with the moist content of the soil (near 0 as the soil approaches the wilting point and near 100 as it approaches saturation; Neitsch et al., 2011). The model returned an average curve number of 77.99, which is consistent with the obtained ratios. The clay-like texture of the majority of soils in the watersheds, for example, can be a factor in the appreciable Streamflow/Precipitation or Surface Runoff/Total

Flow ratios, as well as in the lower Percolation/Precipitation ratio. Some of the ratios tend to rise for CC scenario for 2020 and subsequently for 2050, which may be explained by the overall increase of rainfall. In turn, Evapotranspiration ratio tends to drop, despite the general temperature increases, possibly due to the rise of the amount of water that integrates the immediate runoff and thus does not reach evapotranspiration processes.

Modeling Calibration and Validation

The comparison between the flow series generated by QSWAT and the USAID measurements returned encouraging correlations. This was true for the monthly average series (in cubic meters per second), which returned a correlation of 0.899 and for the watershed runoff (in millimeters), determined for the two subbasins (obtaining a correlation of 0.830). The ratio obtained between the averages of these runoff series (167.2 and 132.9 mm for the USAID and QSWAT series, respectively) was of 0.79, which was consistent with the ratio between the two compared subbasins areas of 0.72. Intuitively, hence, the subbasin delineated by QSWAT was relatively smaller, so it should be the amount of superficial runoff generated to the same extent, which was verified.

Additionally, a regression analysis was performed between the daily rainfall and runoff series, obtaining again a high coefficient (of circa 0.8), as shown on Figure 2. This is indicative of a positive performance by QSWAT in simulating this hydrological system's behavior, which strengthens the importance of the role that hydrological modeling can play in CC impact studies.

**Figure 2.** Linear regression results between daily rainfall and runoff series.

Based on these satisfactory correlations, it was assumed that no further calibration measures were required and that the modeling results were valid and trustworthy.

Resilience Analysis

The resilience of Binahaan, Pongso, and Cabayugan Rivers as water sources for Tacloban was evaluated as, for a certain time period, the percentage of days in which the river flows did not meet the water extraction rates predefined for that river catchment. Table 5 summarizes the obtained results.

Table 5. Resilience of supply results: percentage of days below extraction rate.

	Water Extraction rate/Quarter	Binahaan River 0.72 m ³ /s	Pongso + Cabayugan Rivers 0.58 m ³ /s
Baseline	DJF	0.7%	0.6%
	MAM	16.2%	16.8%
	JJA	20.3%	26.4%
	SON	1.3%	1.2%
	TOTAL	9.7%	11.3%
CC2020	DJF	0.7%	0.5%
	MAM	17.7%	18.1%
	JJA	16.7%	21.6%
	SON	0.8%	0.9%
	TOTAL	9.0%	10.4%
CC 2050	DJF	0.5%	0.3%
	MAM	19.3%	19.5%
	JJA	15.2%	20.2%
	SON	0.2%	0.4%
	TOTAL	8.9%	10.2%

For the supply solution based solely on Binahaan River, the baseline period of 9.7% days does not match the water extraction rate of 0.72 m³/s, with DJF and SON being the most favorable quarters (only 0.7% and 1.3% of days, respectively). However, for this 1980–2010 series, the MAM and JJA quarters evidence some water shortage probability, with 16.2% and 20.3% of days, respectively, with the river flow of Binahaan being insufficient.

Overall, i.e., on a yearly basis, nevertheless, this situation tends to evolve favorably due to the general increase of precipitation with CC, with the yearly number of supply gaps decreasing from 9.7% to 9.0% for the CC2020 scenario and to 8.9% for CC2050. However, the breakdown in quarters revealed that, for the MAM period, due to the PAGASA's forecasted decrease in rainfall, the availability of water actually worsens.

From these results, it becomes evident that Binahaan River, during the March to August period, cannot be considered a resilient water source. Therefore, considering an additional water catchment from the northern rivers to supply the Tacloban resettlement areas, as proposed by the development agency USAID, may be seen as a pertinent alternative. Assuming an extraction rate of 0.58 m³/s, a similar response to the one aforementioned for Binahaan River was observed: the yearly resilience of these rivers to be used as supply sources evolved from 11.3% of days not meeting the demand, for baseline data, to 10.4% for the CC2020 scenario and 10.2% for CC2050—results of the same order of magnitude as the ones obtained for the Binahaan River, assuming also a similar seasonal behavior. Once more, these rivers alone are not resilient water sources but both solutions could complement each other: Binahaan River supplying Tacloban City and neighboring municipalities, and a catchment up north to supply the resettlement areas.

Accordingly, either for Binahaan or Pongso and Cabayugan Rivers as solutions, the significant percentage of days pointing to water scarcity for the MAM and JJA quarters was indicative of the necessity of a flow regulation infrastructure, such as a small dam, to ensure the region's water supply resilience. The pre-dimensioning of such structures as a function of the existing flow regimes is one possible future development of this work. Moreover, the evolution of water demand, as a consequence of demographic growth, or its variability within quarters, should be addressed. Likewise, considering land cover changes could be also interesting, hence, as demonstrated by Tolentino et al. (2016), after Haiyan, the reduction of forests on these watersheds conducted to a decrease of a third of the groundwater infiltration—thus increasing the potential runoff.

Conclusion

Tacloban's regional hydrological system was modeled using QSWAT to evaluate the impacts of CC and thus assess these water resources' resilience as supply sources. Results show that, regardless of the chosen supply solution, for certain time periods (most severely for the quarter of March to May), the percentage of days in which the river flows were insufficient to meet the proposed water catchment rates was significant. Outputs suggest that Binahaan River, where current water catchment is located, may fail in providing sufficient water to the region for future scenarios. However, it should be noted that Pongso and Cabayugan Rivers in northern Leyte can represent a complementary water source to supply the new resettlement areas. Moreover, it is likely that this development would also bring benefits to the quality of the supply in Tacloban City itself, as it eases the burden on the existing network by reducing the number of service connections. This is particularly pertinent if one considers the expected demographic growth for this region, as well as the long-term impacts of CC.

Further work should focus on the design and sizing of dams on the studied waterways, which are proven necessary by this study to increase the system resilience and assure water supply to the city of Tacloban and its surroundings—with a special relevance on the months of March, April, and May. Another interesting analysis would be the cross-over of the determined resilience indicator with the population's perception or the existing infrastructures resilience.

Bearing in mind the encouraging consistency between modeling outputs and field data, this work has reinforced the importance of the emerging role of hydrological modeling in CC impact studies. Hence, it is strongly recommended that the evaluation of the dependable flow of waterways should be used to support water districts decisions as well as local (or even national) water resources management policies.

Acknowledgements

The authors would like to thank the Portuguese Foundation of Science and Technology for the support of this research through the grant PD/BD/114299/2016, awarded in the context of the Doctoral Program in Climate Change and Sustainable Development Policies. Likewise, a word of appreciation should also be given to the Oscar M. Lopez Center's team, mainly to Rafaela Jane Delfino, Kristoffer Kendrick Co, and Carlos Tito Santos, who have greatly contributed to the accomplishment of this research.

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Assessment of Adaptation to the Impacts of Typhoon Pablo (Bopha) in Eastern Mindanao, Philippines

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Received: 09 March 2017 / Accepted: 7 July 2018 / Published online: 28 August 2018

Abstract

The paper identified adaptation gaps in the post-Typhoon Pablo (Bopha) recovery and reconstruction based on two assessment approaches: (1) roundtable discussion participated in by representatives of people's organizations, international and national non-government organizations, civil society organizations, and national and local governments; and (2) survey and conjoint analysis of communities' preferences on adaptation assistance and risk reduction measures in three villages of New Bataan, Compostela Valley Province. The first assessment recommended a set of actions for adaptation and risk reduction, while the second provided the adaptation preferences of the affected communities. The results revealed that, on the one hand, some adaptation preferences of the communities do not support the action points from the roundtable discussion. On the other hand, some action points do not reflect the adaptation concerns of the communities. These results suggest the critical need to increase the representation of disaster-affected communities in future discussions and to build the disaster risk reduction (DRR) awareness of all vulnerable communities in the region. With regard to risk governance, results from both the roundtable discussion and survey are consistent. Both assessments recommend participatory governance in the implementation of recovery and reconstruction programs, with the governments providing overall guidance to the stakeholders.

Keywords: adaptation · conjoint analysis · disaster risk reduction · Eastern Mindanao · risk governance · Typhoon Pablo (Bopha)

DOI: <https://doi.org/10.18783/cddj.v003.i01.a03>

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Introduction

Typhoon Pablo (Bopha), which entered the Philippine Area of Responsibility (PAR) at 6:00 PM on December 2, 2012, rapidly intensified into a Category 5 Super Typhoon on 3 December 2012 (Philippine Atmospheric, Geophysical and Astronomical Services Administration [PAGASA], 2012). During its landfall over Baganga, Davao Oriental, in the wee hours of the morning of 4 December 2012, it reached an average speed of 185 kilometers per hour (kph) and gusts reaching 210 kph (Lagmay et al., 2013). Typhoon Pablo was the most powerful storm to have hit the island of Mindanao, Southern Philippines, in more than 100 years of recorded storms. It affected over 6.2 million people, destroying livelihood and shelter, food sources and natural resources in the eastern seaboard of Mindanao—this included the provinces of Davao Oriental and Compostela Valley in Region XI and the provinces of Surigao del Sur and Agusan del Sur in Region XII (Office for the Coordination of Human Affairs [OCHA], 2013). Some 1,146 people were recorded dead, and 834 people were reported missing (Lutheran World Relief [LWR], 2013). The human disaster that is Typhoon Pablo accounted for 19.7% of the global disaster mortality in 2012 (Guha-Sapir, Hoyois & Below, 2013). Reducing the risk of future disasters is imperative for the Philippines, which is considered as one of the top five countries that are highly vulnerable and susceptible to natural disasters (Guha-Sapir et al., 2013).

Disasters provide an opportunity for communities and governments to “build back better” following an extreme event. As a framework and approach in post-disaster recovery and reconstruction, “building back better” improves the community’s physical, social, environmental, and economic conditions to create more resilient and adaptive communities (Birkmann, 2013; Mannakkara & Wilkinson, 2014; United Nations Office for Disaster Risk Reduction [UNISDR], 2015; Twigg, 2007).

For instance, the government’s recovery programs are critical steps towards increasing the adaptive capacity of vulnerable communities. The post-Typhoon Pablo government recovery and reconstruction programs were: (1) the “Moving up after Pablo (MAP) New Bataan Comprehensive Rehabilitation and Recovery Program (MAP New Bataan CRRP)” of the municipal government of New Bataan, (2) the “Reconstruction and Development Framework 2013-2016” of the regional government of Davao Oriental (Davao Oriental RDF 2013-2016), and (3) “Post-Pablo Livelihood Cluster Action Plan for Davao Oriental and Compostela Valley Province” of the Department of Agriculture (DA) (Post-Pablo LCAP). To reduce vulnerability, however, these programs should be able to address the adaptation needs of the communities. Mismatches between the policy implementation and societal goals that are largely influenced by preferences resulted in adaptation gaps (Olhoff, 2014).

This paper aims to assess the relevance of the government’s adaptation measures to the affected communities in Eastern Mindanao. The two levels of assessment conducted for this study consisted of (1) a roundtable discussion participated in by representatives from national government agencies (NGAs),

local government units (LGUs), non-government organisations (NGOs), and civil society organisations (CSOs); as well as (2) a household survey of residents in the municipality of New Bataan, which sustained the most damage from the typhoon. Based on these assessments, the paper identified the challenges to recovery and reconstruction programs and the gaps in adaptation measures, which need to be addressed to enhance people’s resiliency and adaptive capacity to deal with similar disasters in Eastern Mindanao in the future.

Methods

Case Study Area

The case study area is the region of Eastern Mindanao, which consists of eight provinces located in the southeastern part of the Philippines (Figure 1). This region has been known to be socially vulnerable, even before the onslaught of Typhoon Pablo. For example, food insecurity in Eastern Mindanao is between medium and high levels (Food and Agriculture Organization [FAO] & World Food Programme [WFP], 2013). The provinces of Davao Oriental and Compostela Valley

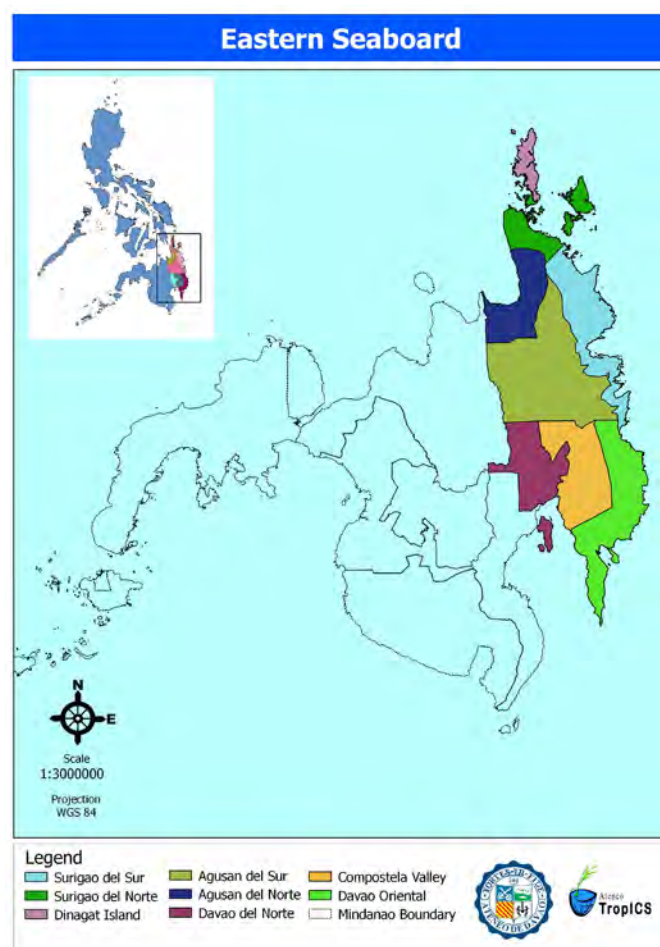


Figure 1. Map of the Eastern Seaboard of Mindanao (Manuta, 2013)

have acute and chronic malnutrition rates that are above the national average (Department of Science and Technology [DOST], 2011). Davao Oriental and Agusan del Sur are two of the poorest provinces in the Philippines (National Statistics Coordination Board [NSCB], 2009). Further, Conservation International Philippines reported that Eastern Mindanao, dubbed as the “timber and mining corridor of the Philippines,” is environmentally vulnerable (Conservation International Philippines [CIP], 2013). Most of the area’s remaining rainforests are currently under logging concessions, leading to the loss of forest cover, soil erosion, and river sedimentation. Forestlands have also been converted into agricultural land, one of the sources of livelihood for large parts of the provinces. Agriculture is an important economic sector in most of these provinces.

Typhoon Pablo caused approximately PhP 31 billion (USD 0.756 billion) worth of damage on agriculture and infrastructure (Table 1), in addition to the loss of human lives and damage to property. This made the Philippines one of the top countries in the world that incurred the highest economic losses in 2012 (Guha-Sapir et al., 2013). In January 2013, the Post-Typhoon Pablo Inter-Agency Emergency Food Security, Nutrition and Livelihoods Assessment for Typhoon Pablo provided details on the estimated damage to major crops in the region (Table 1). Damage to livestock and poultry, fisheries infrastructure, and irrigation facilities were estimated at PhP 327,000 (USD 8,000), PhP 53 million (USD 1.3 million), and PhP 829 million (USD 21 million), respectively (OCHA, 2013). The extent of damage on agriculture and property was observed during the ocular visit of the authors (Figure 2).

Table 1. Extent of the impact of Typhoon Pablo on Eastern Mindanao

Human Impacts*	Estimated Loss and Damage	
Total number of deaths	1,067	
Total number of affected people	6.2 million	
Total number of missing people	800	
Number of houses damaged	216 thousand	
Infrastructure destroyed	3.4 billion PhP	
Private property destroyed	18.3 million PhP	
Damaged Crops**	PhP	USD
Banana	20 billion	500 million
Coconut farms	7.22 billion	193 million
Rice	197 million	5 million
Corn	362 million	9 million
Farms growing high-value crops***	2 million	50 thousand
Abaca plantations	233 thousand	6 thousand

Sources: *NDRRMC (2012); **OCHA (2013).

***These include coffee, cacao, vegetables, rubber, and fruit trees.

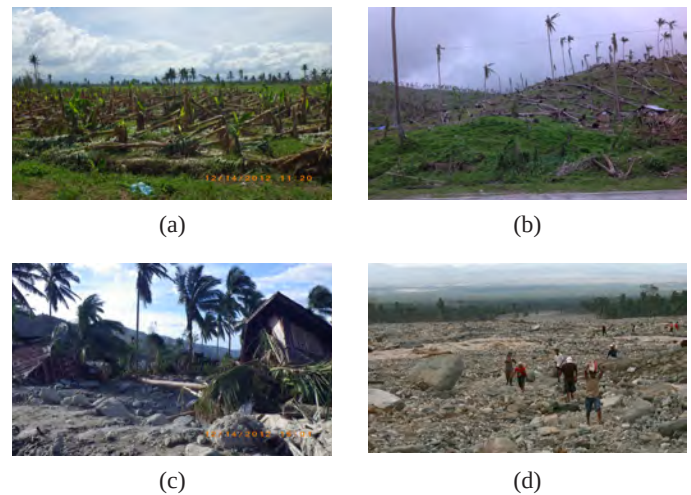


Figure 2. Destroyed (a) banana and (b) coconut plantations; (c) damaged property in Compostela Valley; and (d) rubble of houses and other structures swept away by wind and water in the village of Andap (Manuta, 2013; Bacongco, 2012)

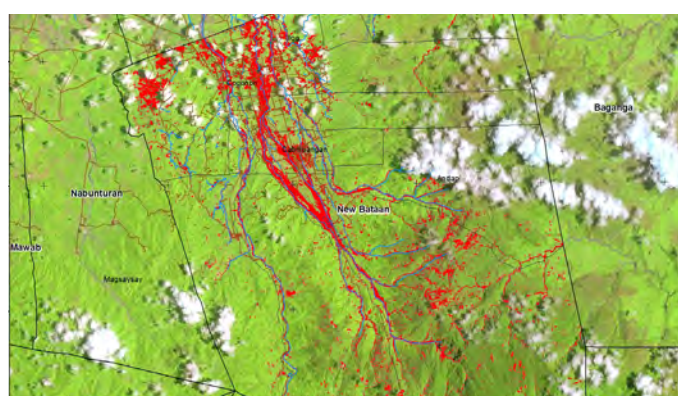
Photos (a), (b), (c) by Mr. Glenn D. Depra; (d) by Ms. Ruby Thursday More

Among the eight provinces, Compostela Valley (Comval) did not only experience the most economic damage, it also had the greatest human mortality. Almost half of the total deaths in Mindanao were recorded in Comval’s New Bataan municipality. Huge volumes of water reportedly came down from the mountain slopes, causing heavy mud floods and landslides. Thick mud, logs, and large rocks blocked the roads, making it difficult for rescuers to reach the municipality after the disaster (Acosta et al., 2016). Figure 3 shows the extent of the debris flow resulting from floods and landslides in New Bataan.

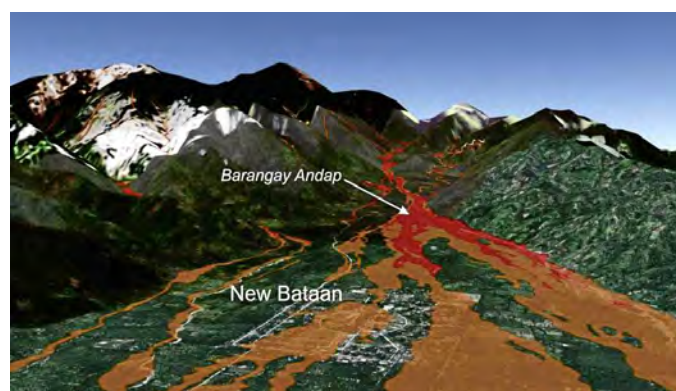
Among the New Bataan villages, Andap was the most affected—houses and public facilities were destroyed as mud flowed and rocks rushed down (Figure 2, Figure 3). Post-Pablo studies in Andap (Lagmay et al., 2013; Acosta et al., 2016) revealed the physical and social processes conditioning the vulnerability of the people and their livelihood: Andap is located at the mouth of a mountain drainage network, at the base of steeply-sided slopes, and on the exact path of the debris flow (Figure 3). Andap sustained at least 70 deaths, 290 missing persons, and 1,250 damaged houses after the typhoon (Acosta et al., 2016). The other two most affected villages were Cabinuangan, the urban center, and Cogonon, the poorest village in New Bataan.

Analytical Tools and Data

The enormous impact of Typhoon Pablo on the environment, economy, infrastructure, and livelihood prompted the Philippine government to develop recovery and reconstruction programs to enhance the resilience and adaptive capacity of the local communities to respond to similar disasters in the future. This paper assessed the three most relevant government programs (Annex 1 for details):



(a)



(b)

Figure 3. Satellite image (a) and 3D image (b) of the debris flow from floods and landslides in New Bataan, Compostela Valley (Acosta et al., 2016; Lagmay et al., 2013)

1. Municipal government: “MAP New Bataan Comprehensive Rehabilitation and Recovery Program (MAP New Bataan CRRP)”
2. Regional government: “Reconstruction and Development Framework 2013-2016” in Davao Oriental (Davao Oriental RDF 2013-2016)
3. National government: DA’s “Agriculture’s Post-Pablo Livelihood Cluster Action Plan for Davao Oriental and Compostela Valley Province” (Post-Pablo LCAP)

The assessments were conducted using two participatory approaches – a roundtable discussion with experts from Eastern Mindanao and a household survey with affected communities in New Bataan (Figure 4). The discussion assessed the efficiency of the strategies in the three programs based on livelihood and agriculture support, hazard monitoring and information system, environment, risk governance and basic service provisions. From this discussion came sets of recommended actions to address the recovery and reconstruction challenges.

The survey assessed the affected communities’ preferences in terms of adaptation measures. To identify adaptation gaps, a comparison between the expert-recommended adaptation measures and communities-preferred adaptation measures was made.

Roundtable Discussion

The roundtable discussion provided a platform for the national and local government officials to discuss with NGOs and local/indigenous people’s organizations (POs) the challenges and opportunities in the recovery and reconstruction of the region’s economy and livelihood (Manuta, 2013). Reports of international and local NGOs were also presented and discussed.

Entitled “Challenges and Opportunities for Building Back Better and Resilient Post-Pablo Economy and Communities in Eastern

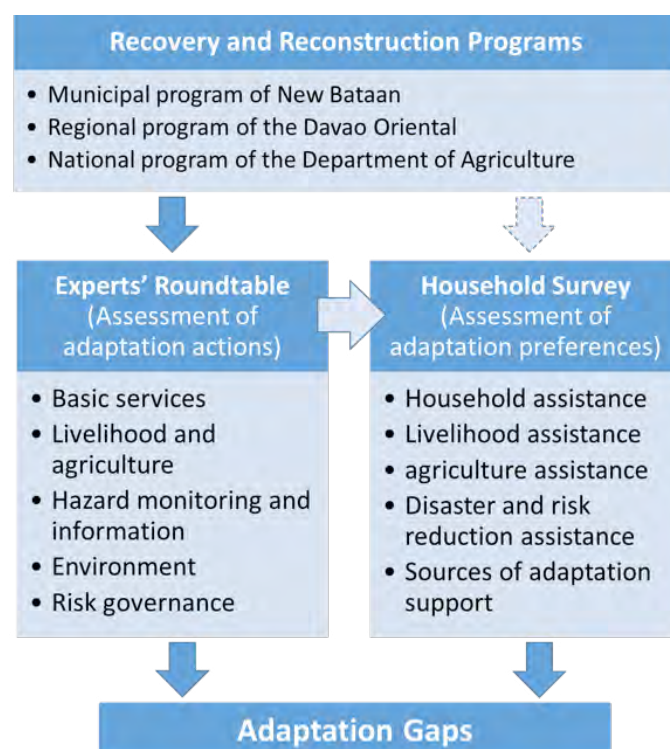


Figure 4. Analytical framework for the assessment of adaptation actions and preferences

Mindanao,” the roundtable discussion was held on 27 February 2013 at Ateneo de Davao University, Davao City, Philippines. Municipal officers of New Bataan and Laak from Compostela Valley and Caraga and Baganga from Davao Oriental represented the LGUs. The NGA representatives were from the DA, Department of Environment and Natural Resources (DENR), Mines and Geosciences Bureau (MGB), DOST, National Disaster Risk Reduction and Management Council (NDRRMC), Climate Change Commission (CCC), National

Economic Development Authority (NEDA), and Mindanao Development Authority (MINDA).

Among the international NGOs who participated were World Vision, Oxfam, Catholic Relief Services, Lutheran Relief, Handicap International, and Humanitarian Response Consortium. The local NGOs were represented by the Foundation for the Philippine Environment, Mindanao Migrant Center, Davao River Initiatives, Interface Development Interventions (IDIS), and Sustainable Integrated Area Development Initiatives in Mindanao-Convergence for Asset Reform and Development, Inc. (SIMCARRD).

Participants from the academe were from Ateneo de Davao University, University of Mindanao, and University of the Philippines-Mindanao, University of Southeastern Philippines, Holy Cross College, and University of the Immaculate Conception.

Other participants were from the United States Agency for International Development (USAID), United Nations Development Programme (UNDP) and various churches. The profile of the 128 participants is in Table 2.

Household Survey

Data collection. Household surveys in the villages of Andap, Cabinuangan, and Cogonon in New Bataan were conducted in November 2013. The survey questionnaire covered, among others, typhoon-induced disaster experiences, disaster recovery and adaptation strategies, and conjoint choices. Multiple-stage sampling was applied in selecting survey respondents. The first stage involved stratification at the municipal level wherein stratification criteria included level of damage and economic characteristics. The second stage of the sampling was determining the sample size at the village level. The sample size was calculated using the Cochran method at a 95% confidence level and 8% confidence interval. The resulting sample size (n) was 140, allocated to the three villages as follows: Andap - 35, Cabinuangan - 70, and Cogonon - 35. The third sampling stage involved stratification at the village level to capture different livelihood sources (e.g., agriculture [major crops and livestock], non-agriculture jobs) in the survey. Stratification at this level aimed to determine whether the nature of livelihood influences preferences for adaptation strategies. Finally, random sampling (i.e. random number generator) was employed in identifying respondents to be included in the survey.

Data analysis. Conjoint analysis is widely applied in academe and industry to measure preferences of individuals and assess trade-offs on goods and services (Hanley, Wright & Adamowicz, 1998; Lee, Choi, Lee & Kang, 2006; Green & Srinivasan, 1990). It has been used in different fields of study including environmental valuation (Farber and Griner 2000). In conjoint analysis, a set of attributes of environmental goods and services is used to describe the choices that are presented to individuals. The individuals' preferences on presented choices

Table 2. Profile of the participants of the roundtable discussion

Participants	Number of Participants		Total
	Male	Female	
LGUs Compostela Valley Province	12	1	13
LGUs Davao Oriental Province	7	5	12
CSOs Compostela Valley Province	1	-	1
CSOs from Davao Oriental	1	2	3
International NGOs	25	17	42
Local NGOs	9	8	17
Academe	8	7	15
NGAs	5	2	7
Other sectors	15	3	18
Total	83	45	128

Note: Local government units (LGUs), national government agencies (NGAs), non-government organisations (NGOs), and civil society (or people's) organisations (CSOs)

are assumed to be influenced by their subjective perceptions of these attributes. This implies that preferences are a function of an individual's economic, social, and cultural conditions (Acosta et al., 2016). In this paper, there are five attributes that define the choices for the conjoint analysis, which include household assistance, livelihood assistance, agriculture assistance, sources of assistance, and risk reduction measure for flood/landslide impacts (Table 3). The levels of the attributes conform to the adaptation recommendations from the roundtable discussion and represent the most relevant livelihood and agriculture support and risk reduction plans for the communities in the government's recovery and reconstruction programs. The choice tasks in the conjoint surveys are defined by the attribute levels. The combinations of the attribute levels were generated using a conjoint survey software called Sawtooth (<http://www.sawtoothsoftware.com/>). In addition to the construction of choice tasks for the questionnaire, Sawtooth was also used to compute the conjoint utilities. The utilities measure the relative desirability or worth of an attribute level (Orme, 2010a; Orme, 2006), which imply that attribute level with the highest utility value received the highest level of preference among survey respondents. The Hierarchical Bayes Choice-based Conjoint (HBCBC) model in the Sawtooth was used to analyze the utilities of the respondents (Orme, 2009).

Table 3. Attributes and attribute levels of the conjoint questionnaire

Level Number	Attributes				
	Household assistance	Livelihood assistance	Agriculture assistance	Sources of assistance	Risk reduction measure
1	Food supply	Crop production	Machine/Tools	Relatives/Friends	Prevent logging
2	Medicine supply	Livestock production	Seed/Seedlings	Farm associations	Stop mining
3	Shelter/ Housing	Agro-forest production	Livestock/Animals	Government	Regulate squatters
4	Money/Loan	Family business	Pesticides/Fertilizers	NGOs	Reforestation
5	Alternative livelihood	Non-agriculture job	Crop insurance	Church	Reduce soil erosion

Note: The attribute levels represent the types of adaptation assistance and measure that are relevant for the adaptation and risk reduction of the communities after the typhoon disaster. The attribute levels were identified from literature review (including the recovery and reconstruction programs, results of the roundtable discussion) as well as pre-testing of the questionnaire. The term “levels” do imply any ordinal sequence or logical order of the measures, but it is a jargon used in conjoint analysis.

Results

Highlights of Recovery and Reconstruction Programs

The responses of government, civil society, and the humanitarian community run the gamut from prompt support to ecosystem restoration: immediate, life-saving assistance to affected or displaced peoples; temporary and permanent shelter provisions; early re-establishment of livelihood; capacity-building for government and community to prepare for and respond to emergencies; and ecosystem restoration, among others (Manuta, 2013). Transitioning from the immediate, life-saving assistance at the initial stage of relief operations to the early reestablishments of livelihoods, the focus of attention in the Typhoon Pablo-affected areas is on long-term reconstruction and rebuilding processes.

“The Reconstruction and Development Framework 2013-2016” of the Municipalities of Baganga, Cateel, and Boston in Davao Oriental underscored the need to revisit and review the “Provincial Development and Physical Framework Plan,” and the “Municipal Comprehensive Land Use Plan (CLUP).” The “MAP New Bataan Comprehensive Rehabilitation and Recovery Program,” a convergence initiative of the LGU, NGAs, humanitarian and development agencies and CSOs, also echoed the same theme of ‘building back better.’ All recovery and reconstruction programs encouraged the participation of CSOs and NGOs in the implementation of community programs and projects to promote transparency, accountability, and participatory governance.

Post-Pablo recovery and reconstruction programs in Davao Oriental and Compostella Valley provided a window for “disaster-and climate-proofing” development and investment plans at the provincial and local levels. Disaster - and climate - proofing development and investment plans require mainstreaming of

Local DRR and Climate Change Adaptation (CCA) Management in the review and updating of the CLUP, Comprehensive Development Plan, and the Annual Investment Plan.

Both the “MAP New Bataan CRRP” and the “Post-Pablo LCAP for Davao Oriental and Compostella Valley Province” provided specific strategies for the recovery of the agricultural livelihood of the communities, including crops, livestock, and fisheries. Further, the LCAP of the two provinces included the provision of entrepreneurial and capacity building programs, which could help communities to diversify into non-agricultural businesses.

Adaptation Recommendations from the Roundtable Discussion

The main outcomes of the roundtable discussion were sets of action points for adaptation, which at the same time supported risk reduction initiatives. Participants recommended a number of regional action points that should have contributed to building a more resilient and adaptive economy and communities. These action points addressed fundamental issues on risk reduction. They thus supported ongoing recovery efforts in the region that aimed to reduce risk and vulnerabilities and strengthened capacities towards building better and resilient economies and communities.

The action points were grouped into four themes: (1) Livelihood and Agriculture, (2) Hazard Monitoring and Information, (3) Environment, and (4) Risk Governance (Table 4). A fifth theme referred to the provision of basic services, such as Education, Roof-a-School, and Health.

Livelihood and agriculture. Since the regional economy is primarily agricultural, recovery and reconstruction need to restore food security in such a way as to make the

livelihoods of the communities less vulnerable to these types of events in the future. Moving towards climate-smart agriculture and disaster-ready farming systems require economic approaches that incorporate changing climate patterns, such as crop suitability and land resources crop valuation, among others. This entails a change in direction for the local agricultural economy planning, which needs to account for market access, technical support, and low-cost fair capital inputs, among others. Regional livelihood diversification reduces the risks of

the region to extreme events. Diversifying agriculture crops and livelihoods in the region as well as increasing people's productivity ensures risk reduction in the future.

Hazard monitoring and information. Extreme weather events are not only occurring more often, they are also increasing in severity due to climate change. Climate change will result in the frequency and intensity of extreme weather events, as well as significant impacts for more gradual and creeping change (Intergovernmental Panel on Climate Change [IPCC], 2012; Turnbull, Sterrett & Hilleboe, 2013). Communities need to be more prepared: information on the risks and the occurrences of hazards should be made available and accessible to all, especially to the poor and the marginalized who most often live in the highest-risk areas. Early warning systems should be institutionalized and tools for hazard monitoring and mapping must be maximized so that local governments and communities can make informed decisions in planning and living their lives. Managing risks require a mindset that accommodates a high level of preparedness. The state and the private sectors also contribute to risk reduction by providing social instruments and programs for social protection and risk sharing, such as affordable crop insurance.

Environment. The reduction of forest cover in Eastern Mindanao has contributed to the vulnerability of the region to extreme events, such as Typhoon Pablo. Logging, mining, and plantation industries, among others, have contributed to the reduction of forest cover. The reduction of regional risks to hazards (extreme events) requires a critical review and assessment of the forest cover and land (resource) use in the region. This is seen as resulting in a framework that will promote reforestation using indigenous species to complement more sustainable land use practices. There is a need to review regional development policy and frameworks related to logging, mining, and plantation industries as well as the implementation and enforcement of the policy framework. The review should be done through the DRR-CCA lens to address the risks to and vulnerabilities of the community and environment. There is a need to prepare proactive plans to restore forest cover, diversify agricultural products to reduce vulnerability to economic and environmental impacts, minimize downstream impacts of economic activities (i.e., siltation of rivers), increase agricultural productivity and value so as to reduce the amount of land required to support the local population while increasing income for the local population.

Risk governance. Reducing regional risks of extreme events is primarily a governance issue. Mainstreaming DRR-CCA requires funding and political will. Existing land uses, zoning plans, and investment plans will need to be reviewed with a view to reducing vulnerabilities while increasing capacity. The review and assessment should be informed by lessons learned from the current situation and by interpolations of future risks brought about by the changing climate and other drivers.

Table 4. Action points for building resilience in Eastern Mindanao

Themes	What/How (Action Points)
1. Livelihood and Agriculture*	• Livelihood technology training (expertise-based) • Irrigation • Sustainability/Organic farming (education and training, and policies) • Assistance for full recovery • Debris management in rural and upland areas • Policy review of crop insurance • Community enterprise from recyclables • Land resources crop evaluation (science-based), crop suitability assessment • Risk transfer sharing mechanism (social protection) • Banana industry (present threats) • Accessing World Bank, Global Environment Facility funds (loans) • Work Animal welfare • Cash for work/resources (seedlings, carabaos) for upland farmers • Rehabilitation plan for farms and forest
2. Hazard Monitoring and Information	• 3D hazard mapping and flood inundation models • Automatic Weather Station/rain gauges • Short messaging system (SMS)-based early warning systems • Information, education and communication (IEC) on disaster • Information sharing
3. Environment	• Revisiting of policies on mining, logging • Protected areas: watersheds, forests • Damaged ecosystems • Greenhouse gas management
4. Risk Governance	• Fund support/ action-planning for mainstreaming DRR-CCA • Review of land use/zoning plans • Sustainability mechanisms (state, civil society, business sector coordination) • Resources monitoring • Immediate training on DRR-CCA integration in programs, policies, activities • Vulnerability assessments to determine priorities

*Including concerns of the indigenous people

The roundtable discussion recommended three guiding principles (GPs) for operationalizing the action points. These principles are related to governance issues including partnership for resiliency (GP1), rights-based resilience (GP2), and participation of communities/peoples' organizations (GP3). The GP1 emphasizes that the main drivers in recovery and reconstruction are the LGUs together with the communities. The Governors and the Mayors, along with their respective administrators, should be driving the overall strategy while coordinating the efforts of all stakeholders. The partnerships must be equitable; arrangements and agreements must be transparent and fair, ensuring that raising the standard of living for those in the lowest socioeconomic percentiles closes the current equity gap. The GP2 emphasizes the need to address the issues of inequality and social justice that underpin the vulnerability and disproportionate risk and uncertainty of the poor and marginalized in Eastern Mindanao. The indigenous peoples, the migrants, the farmers, fisherfolk, women and children are the main vulnerable sectors that need to be included in the planning and implementation of the process. Finally, the GP3 recognizes the "culture of disaster" and "culture of coping" in the Philippines. This culture facilitates an understanding and appreciation of disaster as a result of the convergence of a hazard and people's vulnerabilities, including their resilience and existing capacities (Bankoff, 2007). It puts people at the forefront and at the core of DRR and adaptation programs. The active participation of the CSOs is essential to Building Back Better programs in Compostela Valley and Davao Oriental. The participation of the disaster-affected communities, peoples' organizations, and CSOs in the implementation of recovery and reconstruction projects is necessary to promote transparency and accountability in disaster risk governance.

Community Adaptation Preferences

Figure 5 and Table 5 present the results of the conjoint analysis. The former summarizes the importance of the different types of adaptation assistance, landslide risk

reduction and sources of adaptation and risk reduction assistance, while the latter reveals more details about the specific forms of household, livelihood and agricultural assistance as well as risk reduction measures preferred by the respondents. Conjoint "importance" measures the relative importance of the attributes to each other and, just like any percentages, has a meaningful zero point (Orme, 2010b). The attribute with the higher level of importance (or percentage) received higher preference among respondents. The results indicate that, with the conjoint importance of 44%, the household assistance is the most important type of adaptation support for the respondents across the different villages after flood and landslide events (Figure 5). This is because most of the respondents' houses and properties were heavily or totally destroyed by the flash floods and landslides (Eugenio et al., 2016). The next preferred adaptation support is livelihood assistance (conjoint importance of 18%) because many sources of livelihood particularly crop and livestock productions were devastated by the disaster.

Except for money or loan, all forms of household assistance are statistically significant (Table 5). Food supply is the most significant form of household assistance for the respondents. Relative to the food supply, other forms of household assistance are less important as shown by their negative coefficients. For livelihood assistance, only crop production has statistically significant positive coefficient indicating its relative importance for the respondents. Machine and tools are the specific forms of assistance that the respondents would prefer to receive for their agricultural production. The coefficients of all other forms of risk reduction measures are statistically insignificant. Only the reduction of soil erosion is considered important by the respondents. During the survey, respondents agreed that logging and mining are important causes of landslides in their villages. Nonetheless, control of logging and mining is not considered as important risk reduction measures because these provide them sources of livelihoods. Moreover, agro-forestry is not preferred livelihood assistance and deforestation is not preferred risk reduction measures.

Table 5. Logit estimation results of the utilities for the different forms of adaptation support

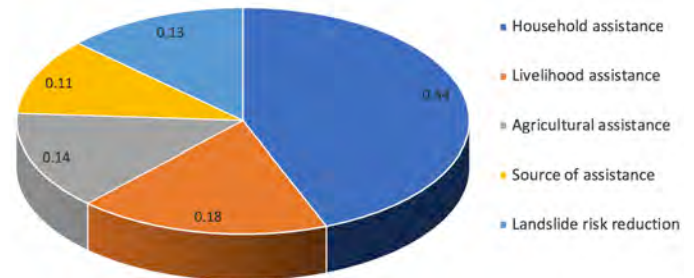
Assistance	Estimate	t-ratio	Assistance	Estimate	t-ratio
Household			Agricultural		
Food supply	0.328***	4.561	Machines/Tools	0.074*	0.993
Medicine supply	-0.075*	-0.971	Seed/Seedlings	-0.040	-0.519
Shelter/Housing	-0.086*	-1.112	Livestock	-0.004	-0.047
Money/Loan	-0.034	-0.438	Fertilizers	0.036	0.482
Alternative livelihood	-0.134**	-1.701	Crop insurance	-0.067*	-0.872

Table 5. Continued

Assistance	Estimate	t-ratio	Assistance	Estimate	t-ratio
Livelihood			Risk reduction		
Crop production	0.119**	1.602	Prevent logging	-0.016	-0.216
Livestock production	-0.074*	-0.957	Stop mining	0.041	0.533
Agro-forest production	-0.061	-0.789	Regulate squatters	-0.050	-0.645
Family business	0.004	0.046	Do reforestation	-0.058	-0.751
Non-agriculture job	0.013	0.166	Reduce soil erosion	0.083*	1.113

Note: Asterisks indicate coefficients significantly different from zero at different levels of significance $\alpha=0.025$ (***), $\alpha=0.10$ (**), and $\alpha=0.20$ (*), respectively. The attribute values with positive utility values are preferred by the respondents, where the higher the positive values the higher the preference level. In contrast, those with negative utility are not preferred, where the higher the negative values the lower the preference level. The signs and values of the utilities thus measure the level of preferences for each attribute level.

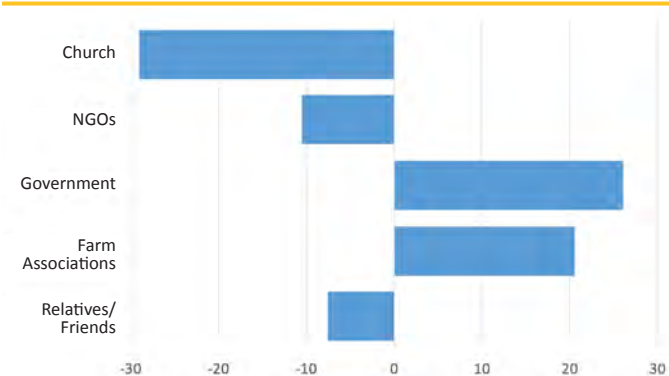
The conjoint importance of the sources of assistance is low at 11% (Figure 5). The utilities of the sources of assistance are all insignificant, which imply that the communities which were surveyed are not too particular about where the assistance is coming from. This can be explained by the fact that they have received different types of support from various organizations for almost a year (Annex 2). The survey also revealed that most of the funds (44.7%) for the reconstruction of their houses came from donations of religious organizations, NGOs, and cooperatives. In terms of order of importance, however, governments ranked first with a positive utility of over 25 (Figure 6). Church turned out to be the least important source of adaptation assistance. This reflects the Church's limited ability to provide the types of support the communities require.

**Figure 5.** Conjoint importance by type and source of adaptation support

Gaps and Challenges in Adaptation Measures

A comparison of the roundtable-recommended action points with the results of the survey and conjoint analysis reveals the critical need to increase representation of affected people in future roundtable discussions and awareness building of all vulnerable communities in the region. Below are some discrepancies between the roundtable-recommended actions points and the results of the survey and conjoint analysis.

- Actions on livelihood and agriculture (Theme 1) should consider the livelihood preference (e.g., crop production) and support (e.g., farming tools) of the target beneficiaries.
- Actions on crop insurance (Theme 1), which is important for social risk management, has very low preference among the surveyed communities.
- Actions on hazard monitoring and information (Theme 2) is crucial to encourage more people in vulnerable areas to evacuate their families to the government-designated sites, where they have easy access to relief goods and services.
- Actions on logging and mining (Theme 3) did not turn out to be important for the communities.
- Actions on restoration of forest coverage (Theme 3) will not be easy to implement as communities express little importance and very low preference for agro-forestry.

**Figure 6.** Conjoint utility values for the sources of adaptation assistance.

Note: The values are zero-centered. Negative values are less preferred sources, and positive values are more preferred sources of adaptation assistance.

On the one hand, the adaptation preferences of the communities do not support the recommended action points from the roundtable discussion. To address the adaptation gaps, which are crucial to risk reduction efforts, the communities need to have increased awareness of the need to reduce logging and mining, restore forest cover, and have access to crop insurance.

On the other hand, the recommended action points do not reflect some of the adaptation concerns of the communities. The action points do not include any strategy for relief support (i.e., household assistance) after disasters. The conjoint analysis reveals that this is the most important adaptation for the communities, particularly food supply. Moreover, the communities prefer support for reducing the soil erosion problem, which was not specifically identified in the action points. While soil erosion can be subsumed into the rehabilitation of damaged ecosystems, capacity building on sustainable farming practices that will reduce soil erosion will address this adaptation gap.

As regards governance for risk reduction (Theme 4), the results of the conjoint survey turned out to be consistent with the preferences of the communities. While the roundtable recommended partnership among various stakeholders, the participants emphasized the key role of government at various levels in driving the strategy and coordinating the efforts for recovery and reconstruction. Similarly, while the surveyed communities do not have particular preferences on the sources of adaptation assistance, they consider the government as the most important source of assistance. This implies that the recovery and reconstruction programs should be implemented under participatory governance, with the government providing overall guidance to the stakeholders.

Conclusions

The immediate future is critical as new investments and projects for reconstruction and rehabilitation start pouring into the region. Rebuilding a better and safer post-Typhoon Pablo development environment requires that these investments, projects, and funds for the recovery and rebuilding of people's lives and livelihoods in Eastern Mindanao are implemented correctly to address both the root causes of the issues that have been exposed due to the impact of Typhoon Pablo and the gaps in adaptation measures.

Awareness building and active participation of communities and POs in risk reduction programs are essential in addressing the gaps in the adaptation measures. Awareness building can be combined with capacity building on entrepreneurship and alternative livelihoods because the lack of alternative livelihood is one of the major reasons for logging and mining in New Bataan. The active participation and engagement of the communities and PO's in the different phases of risk reduction and adaptation programs—from preparedness to relief to recovery and reconstruction—contribute to a better

understanding of the root causes of peoples' vulnerabilities and the structures or conditions that generate them.

Regular monitoring and assessment not only of the recovery and reconstruction efforts but also of the needs and preferences of Typhoon Pablo-affected communities are essential to ensure that interventions and efforts undertaken both at the local and regional levels are geared towards what development and humanitarian communities call "disaster-proofing" the development trajectory in the region. This is crucial for enhancing people's resiliency and adaptive capacity to deal with similar disasters in Eastern Mindanao in the future.

Acknowledgement

The authors would like to thank the people who participated and local government units and institutions who supported the conduct of the study. For the Roundtable Discussion and Forum on "Building Back Better and Resilient Post Pablo Communities, Livelihoods and Environment in Eastern Mindanao" on 27 February 2013 in Davao City, the authors would like to thank the support of the University Research Council (URC), Ateneo Institute of Anthropology (AIA) and Tropical Institute for Climate Studies (TropICS) of Ateneo de Davao University, Oxfam in the Philippines, and the Humanitarian Response Consortium (HRC). For the household survey, the authors would like to thank their colleagues in the project on Livelihoods Vulnerabilities to Typhoon-Associated Hazards in Southeast Asia: A comparative study in Taiwan and the Philippines. The project received funding support from the Integrated Research on Disaster Risk – International Center of Excellence (IRDR-ICoE), Academia Sinica, Taiwan. The authors would like also to thank Mr. Edwin R. Abucay of the University of the Philippines-Los Baños for the support and assistance in the production of the maps and Mr. Glenn D. Depra of Ateneo de Davao University and Ms. Ruby Thursday More of MindaNews for sharing the photos used in the manuscript.

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Annex 1 Recovery and Reconstruction Programs in Eastern Mindanao

A. Moving Up After Pablo (MAP) New Bataan Comprehensive Rehabilitation and Recovery Program

Overview

The onslaught of Typhoon Pablo at the breaking of dawn on December 4, 2012, has tremendously devastated the remote yet promising town of New Bataan in Compostela Valley Province. The place was marred with unimaginable damage and loss of lives. As Typhoon Pablo left the barely flattened town of New Bataan, humanitarian assistance and relief operation activities coming from both government and non-government sectors also quickly flooded in.

Moving-up After Pablo (MAP) Program is a convergence initiative of the Municipal Local Government Unit (MLGU) of New Bataan, the Department of Agriculture- Support to Emergency Livelihood Assistance Program (DA-SELAP), Oxfam, Humanitarian Response Consortium (HRC), and SIAD in Mindanao-Convergence for Asset Reform and Regional Development (SIM-CARRD) that basically intends to draw a comprehensive rehabilitation and recovery plan for New Bataan after the calamity caused by Typhoon Pablo.

Goal

- Good and equitable socio-economic program for recovery instituted.
- Objectives for recovery and rehabilitation assistance anchored in honest and judicious socio-economic reform, good governance and poverty reduction.
- Assistance for the recovery program, activities and projects harmonized.
- Livelihood projects and programs for sustainable development promoted and prioritized.

Objectives

- To assist the local government unit of New Bataan in crafting a comprehensive recovery and rehabilitation program after the calamity caused by Typhoon Pablo that will serve as a roadmap and master plan for sustainable development.
- To harmonize humanitarian assistance and relief operation activities and recovery program based on the LGU's identified quick-fix interventions and recovery plan base on a short-term, medium-term and long-term framework.
- To help identify priority-assistance through the LGU's barangay/s development plans (BDPs) vis-à-vis calamity report.
- To organize local teams/clusters that will facilitate and supervise the delivery of assistance and implementation of rehabilitation and recovery projects, activities and programs.
- To assist the LGU in the identification and organizing typhoon-affected individuals, families, and communities for an equitable, orderly and systematic distribution of relief

goods and services as well as proper implementation of rehabilitation and recovery programs.

- To match and knit the identified priority and felt needs of the LGU and its community to the Convergence Program of the national government and of the humanitarian community for recovery and rehabilitation.

Top Priorities for Agriculture

1. Provision for corn, rice and vegetable seeds, farming tools and equipment.
2. Livestock and poultry production.
3. Planting materials especially for cacao, coconut, and coffee production.
4. Inputs for inland fish farming.
5. Training and assistance for organic agriculture and organic feeds and fertilizer production.

Top Priorities for Social Infrastructure

1. Rehabilitation of water system facilities.
2. Housing and socialized shelters.
3. Rehabilitation of farm to market roads.
4. Rehab or replacement of damaged hanging bridges.
5. Rehabilitation of irrigation systems.
6. Water spring development projects.
7. Evacuation Centers

HEALTH

1. Medicines and health care program
2. Establishment of Health Centers with medical supplies.
3. Continued feeding program for children.
4. Replacement of Barangay Ambulance.
5. Establishment of "Botica sa Barangay".

Education

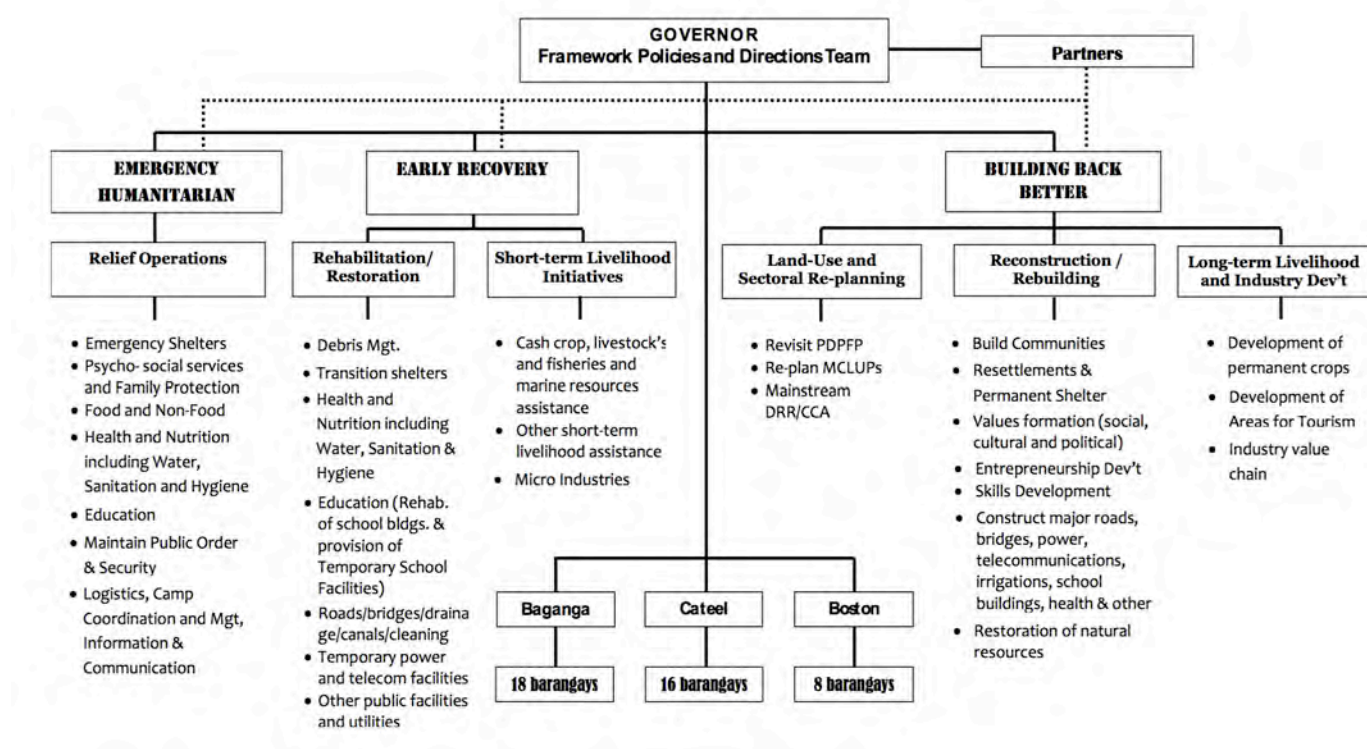
1. Rehabilitation and repair of damaged school buildings including furniture and fixtures.
2. Provision for additional school desk and chairs.
3. Provision for textbooks and school supplies.
4. Provision for schools tools and materials for home economics, carpentry, and gardening.
5. Scholarship program.
6. Continued counseling, stress-debriefing, and psychosocial activities.

B. Reconstruction and Development Framework 2013-2016 in Davao Oriental (Municipalities of Baganga, Cateel, and Boston)**Reconstruction and Development Framework**

Stages	Action Agenda	Timeline
Emergency Humanitarian Response	• Relief Operation	Dec 2012- June 2013
Early Recovery	• Rehabilitation and Provision of Food	January 2013-December 2013
Building Back Better	• Land Use and Sectoral Planning (Mainstreaming Disaster Risk Reduction and Climate Change Adaptation) • Reconstruction • Livelihood and Industry Development	January 2013- December 2016

Building Back Better Stage

Tasks	Goods and Services
Revisiting the approved Provincial Development & Physical Framework Plan (PDPFP)	• Data updating, land use modification, and re-zonification
Re-planning of the Municipal Comprehensive Land Use Plan (MCLUP)	• Mainstreaming the DRR-CCA • Identification of opportunities for development (e.g. agriculture, industry, tourism, and environment)
Pursuing Appropriate Legislative Actions	• Adoption of an updated land use plan • Zoning ordinances
Project Development	• Project proposals
Provision of goods and services for agriculture, industry and tourism development	• Development of agricultural areas for permanent crops • Development of industry value chain • Development of areas for tourism

Davao Oriental Convergence Framework

C. Post Pablo Livelihood Cluster Action Plan for Davao Oriental and Compostela Valley Province

Background

Davao Oriental and Compostela Valley Province are rich in natural resources with the fertile agricultural land, rich in fishing grounds and mineral deposits. The major products in agriculture and fishery are coconuts, pomelo, mango, rice, corn, banana, abaca, and fish, among others. Davao Oriental is known nationwide to be the largest area with coconut planted with a total area of 155,905 hectares (BAS, 2011).

In Compostela Valley Province, typhoon Pablo devastated around 75,887.6 hectares of agricultural lands planted with rice, corn, coconut and high-value crops (for export) like banana, rubber, cacao, coffee, and vegetables palm oil, among others; 296.0 hectares in fishery; and 30,758.0 hectares of forestry (PAGRO Compostela Valley Province, 2013). The total damage of agriculture, fishery, and forestry is pegged at PHP 14.4 Billion and the production losses in the agriculture sector are estimated at PHP 7.5 Billion. The assessment of

losses in the agriculture sector in the province was based on the computed difference between the pre-disaster and post-disaster production volume multiplied by the farm gate prices of specific commodities.

In Davao Oriental, the estimated damage in the agriculture, fishery, and forestry is PHP 747 Million and the production losses are PHP 624 Million.

The recovery and reconstruction framework is anchored on the building-back-better and safer principles. Initiatives are geared toward restoring the capacity and capability of the affected sector to act and move-on inconsiderable amount of disaster risk planning and development, thus helping communities to help themselves.

Objectives:

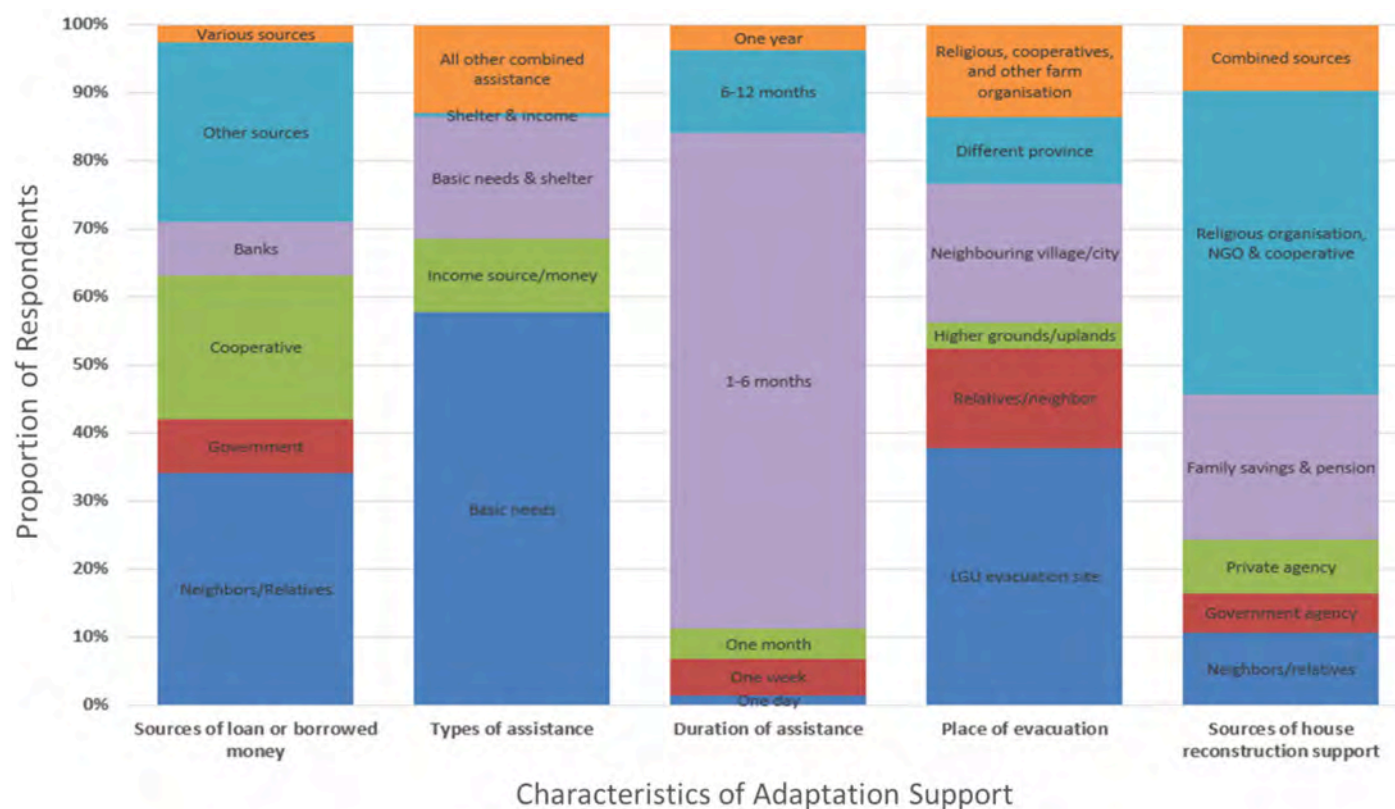
- (1) To rehabilitate and protect the typhoon- damaged agro-forestry plantations, livestock and fishery industries; and
- (2) To provide livelihood opportunities and expand the income base of affected communities.

Brief Descriptions of Strategies, Major Programs, and Projects

Sector	Areas	Short Term	Medium Term	Long Term
Agriculture	Crop Production	1. Rehabilitation of damaged crop farms	1. Continuous production of crops	
		2. Production of crops e.g. banana, coconut, rice, corn & cassava, sweet potato, cacao, coffee, peanuts, vegetables, soybeans, abaca, bamboo, rubber	2. Provision of machinery, equipment and harvest facility	1. Continuous production of crops
	Forestry	1. Reforestation (including bamboo)	1. Continuous reforestation	1. Continuous reforestation
	Livestock & Poultry	1. Rehabilitation of damaged livestock farms	1. Reconstruction of slaughterhouses	1. Continuous breeding of livestock and poultry
		2. Restocking of breeders	2. Provision of animal health programs	
Fishery		1. Rehabilitation of damaged fish sanctuaries and mangroves	1. Continuous rehabilitation of fish cages and provision of fishing gears	1. Continuous rehabilitation of fish cages and provision of fishing gears
		2. Restocking of fingerlings		
		3. Provision of fishing boats and gears		
Industry, Trade and Services		1. Provision of entrepreneurial and capacity training program	1. Continuous provision of entrepreneurial and capacity training program	1. Continuous provision of entrepreneurial and capacity training program
		2. Provision of shared service facilities	2. Continuous provision of shared service facilities	2. Continuous provision of shared service facilities
		3. Provision of credit assistance	3. Continuous provision of credit assistance	3. Continuous provision of credit assistance 4. Marketing assistance

Source: Draft post Disaster Needs Assessment Report for Typhoon Pablo Davao Region as of 18 February 2013

Annex 2 Experiences with disaster assistance and house reconstruction of the surveyed communities in New Bataan, Compostela Valley



Source: Author's own computation from survey data

Note: The color on the figure represents the range of the data and is described by the characteristics written on each data range.



Transportation resilience in the Global South: A post-Haiyan investigation in Tacloban, Philippines

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Received: 07 February 2017 / Accepted: 15 August 2018 / Published online: 31 August 2018

Abstract

Environmental disasters reveal the fragile condition of transport systems, particularly its capacity to address mobility and accessibility needs of people and communities immediately after an extreme event. This fragility surfaces particularly in resource poor regions, exposing the limited governance capabilities of formal institutions to effectively respond to challenges associated with people's mobility and accessibility requirements after a disaster. Post-Haiyan offers a unique opportunity to study the transport dimension of disaster governance in the post-disaster recovery phase. By conducting systematic reviews, this study provided insights into how transport poverty is experienced by people and communities in Tacloban, Philippines as a result of a weakened transport system as well as the extent to which transport resilience is manifested in remobilization efforts. Moreover, the study tried to comprehend the extent to which mobility and accessibility challenges within the context of post-disaster recovery initiatives have been addressed and adequately mitigated. Results show that remobilization efforts can still be vastly improved to achieve a more resilient transport system. These insights are vital to better address mobility and accessibility needs, realize more resilient systems, and improve local level disaster planning and governance in future disaster scenarios.

Keywords: transport · vulnerability · climate change adaptation · disaster · resilience · Philippines

DOI: <https://doi.org/10.18783/cddj.v003.i01.a04>

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Introduction

Environmental disasters reveal the fragile condition of a city, including its transportation system. Particularly in a developing city setting, when transport infrastructure is heavily damaged after a disaster, disruptions may manifest in different forms (Mattsson & Jenelius, 2015). It can be minor such as the temporary interruption of transport services, or major such as isolating communities from the rest of the world (Lum & Margesson, 2014). These situations create a series of stresses, compounding the already heightened disaster impacts, particularly of those who in the first place are already transport-poor and disadvantaged (World Bank, 2001; Carruthers, Dick & Saurkar, 2005).

In 2013, Super Typhoon Haiyan (local name: Yolanda), one of the strongest tropical cyclones to impact the Philippines, made landfall in Tacloban City. The city was one of the hardest hit areas, hence offers an important lens with which to examine the Haiyan experience. This paper is the first to investigate the transport dimension in disasters in an attempt to understand how transport challenges were addressed during rehabilitation and recovery to promote community resilience (Cutter et al., 2008).

The paper, therefore, evokes important questions on the performance of transport and how a tropical cyclone demobilizes and remobilizes individuals and communities. It asks how people and communities were demobilized, as they move from their homes to safer places, as a result of the paralyzation of the transportation sector; and how they were remobilized through efforts initiated by various actors and agencies, both at the national and local levels. Creating such understanding contributes towards a better comprehension about people's mobility needs (i.e. refers to the ability to move goods and people) and access options (i.e. ability to reach desired opportunities, including activities, destination, goods and services), two key functions of transport, within the context of disasters (Litman, 2003). At the same time, it helps inform the development of a new framework to enhance disaster planning and post-disaster recovery processes, and the transformation of transport into a more (ecologically) resilient system (Reggiani, Nijkamp & Lanzi, 2015), filling an important and critical knowledge gap and producing an original albeit different lens with which to understand the post-Haiyan experience.

Transport Resilience in Disaster Context: A Framework for Analysis

Engineering versus Ecological Perspective of Transport Resilience

Current scholarly work on transportation in disaster context is scant. But there is exciting yet still fragmented scholarly work that is starting to emerge in the extant literature which explores the capability of transportation systems to facilitate better movement in disaster contexts (Mattsson & Jenelius, 2015; Wang, 2015; Marsden, Anable, Shires & Docherty, 2016),

through the improvement of connectivity and accessibility (Reggiani et al., 2015), better access to lifesaving facilities, and demonstrating the potential of transport in ameliorating vulnerabilities and enhancing spatial resilience during extreme events (Cummings, 2011).

Litman (2006) has called for the need for resilience to be built into planning and policymaking processes of communities. However, it was Wang (2015) who clearly framed resilience thinking within the domain of transport planning. Wang (2015) purports that current disaster transport planning has narrowly focused on infrastructure solutions to address transport stresses brought about by a weakened transport infrastructure (Regmi & Hanaoka, 2011). Often, the intent of post-disaster recovery strategies is to restore systems into pre-disaster conditions to produce "efficient, constant and predictable" systems in the face of disruption (Holling, 1973; Murray-Tuite, 2006; Holling, 1996; Walker & Salt, 2006; Walker, Anderies, Kinzig & Ryan, 2006; Reggiani, 2013). Wang (2015), however, cautioned that defining resilience mainly on engineering grounds will not only restrict recovery processes to achieve pre-disaster functional condition but may lead to a reduction in resilience from other dimensions. Further echoed by Marsden et al. (2016), and Mattsson and Jenelius (2015), both groups of authors argued that a critical aspect of comprehensive resilience is the ability for a system to transform into a form, which may lead to a completely different system but with a more desirable "equilibrium state" (Wang, 2015, p.190), or what is known as "ecological resilience". Ecological resilience encourages a more holistic rehabilitation of the transportation network to support effective disaster recovery. It is a kind of recovery that goes beyond the technical, but is more concerned with the need for social and ecological rehabilitation to restore the vitality of communities (Tobin, 1999; Xu, Marinova & Guo, 2015) particularly in addressing poverty in transport (Carruthers et al., 2005) after an environmental disaster, to achieve more effective recovery, reliability and sustainability of communities.

Transport Poverty and Resilience

The alternative concept of poverty, which has been reconceptualized and advanced by Sen (1981), places emphasis on the individual's multiple capabilities. To date, its application in transport has not been fully articulated, yet there is a mutual concern of the far-reaching negative consequence of the lack of transport on individuals and communities in both developed and developing contexts (Lucas, Mattioli, Verlinghieri & Guzman, 2016). Multiple capabilities approach posits that people require a larger scope of capabilities, beyond enjoying adequate income, to effectively function in society.

This paper presents a pioneering attempt to articulate the impact of transport on community in a disaster setting. Translating Sen's capabilities approach to examine transport poverty, or the level of vulnerability, will help highlight our understanding

of ecological transport resilience. To date, several definitions of transport poverty have been put forward by various researchers in an attempt to create a common and consistent understanding of the term in both academia and policy (Currie & Delbosc, 2011; Lucas, Mattioli, Verlinghieri & Guzman, 2016; Jeekel & Martens, 2018) yet within these extant literature, the notion of transport poverty, inequality and disadvantage within a disaster setting is non-existent. Table 1 integrates and defines several authors' conceptualization of transport poverty, as manifested in four key transport poverty dimensions: affordability, availability, accessibility and acceptability, and its opportunities to demonstrate resilience in disaster.

Summary

Transport, a derived demand, depends on a person's desire to access opportunities. In the context of disaster, transport that supports the mobility of disaster victims and makes them access crucial destinations is vital to achieving transport resilient systems. This desire should be pitted with a suitable transport service provision. Although consensus exists that strengthening the transport system reduces post disaster impacts (Hoffman, 2014), knowledge gaps still persist in a system's ability to

withstand transport vulnerabilities, and in the degree to which these systems can recover (or level of transport resilience). Hence, there remain two key barriers to achieving ecologically resilient transport: (1) the continued mismatch between disaster-affected people's transport requirements and the transport being supplied; and (2) the limited understanding on how the transport system is affected by disaster events, which results in increased vulnerability. As such, this section introduces transport poverty, broadly defined as a person's lack of resource to satisfy their (daily) basic activity needs and opportunities (Lucas et al., 2016), a framework to potentially explain community vulnerability and resilience due to transport in disaster context.

Methodological Design

Systematic reviews (SR) were conducted to address this paper's objective of evaluating the performance of transport in disaster context. SRs enabled a comprehensive literature search of important sources of information beyond the published literature and scholarly databases. The approach included government reports, media coverage, unpublished studies and thesis dissertations.

Table 1. Dimensions of transport poverty in disaster context

Poverty Dimension	Expressions of Transport Poverty	Expressions of Transport Resilience	References
Accessibility	This describes the difficulty of reaching certain activities and opportunities both for people and goods, e.g. disaster emergency response services (health and medical services), basic needs (food, shelter), economic and social opportunities (education, jobs, health services, retail/commercial) at practical cost, ease, and time.	Ease with which all categories of passengers can have improved access to health, medical services, basic needs, and economic and social opportunities; hence also refers to the ability of transport to be equitable and inclusive.	Lucas et al. 2016
Affordability	This refers to the financial aspect of one's journey which places either the person or household in a position of making sacrifices in order to travel, or the extent to which they do not have adequate financial resources to travel when and where they want to.	Increased capability and resources to be able to afford to travel via several transport options if and when one wants to.	Carruthers et al., 2005; Litman, 2017; Lucas et al., 2016
Availability	This refers to the general lack of transport (in terms of mode, frequency, route, timing or ease in getting information about travel options) creating difficulties to one's need for mobility and limiting the use of transport, often connected to a lack of service or non-working infrastructure during or right after disasters.	State of improved mobility provides freedom to do something or go somewhere.	Lucas et al., 2016
Acceptability	The quality of public transport as a function of travelers' standards based on cultural and/or social appropriateness or one's personal preference. For instance, passengers may be discouraged from using public transport because of personal safety on buses and trains; socially/culturally unacceptable way of traveling.	Increased ability of transport system to be socially, culturally, economically and environmentally responsive.	Carruthers, 2005; UN-Habitat, 2013

Firstly, search parameters and criteria were defined to guide the collation of information from different sources. Several systematic searches were iterated using the following keywords “Yolanda” or “Haiyan”; and “Leyte” “Tacloban”; and “transport” “travel” “mobility” “access” “cycling” “walk” “ride” “road”. Secondly, the databases in which search were conducted included scholarly databases such as Google Scholar, Scopus, Social Science Citation Index, Transportation Research Information Service, and Web of Science; online media articles from Inquirer.net and Global Media Arts (GMA) News online; policy documents from both Philippine government agencies and local government units (LGUs); online reports issued by international non-government organizations (NGOs); and unpublished studies, thesis and dissertations. These materials were then analyzed on how these documents answered the paper’s objective.

Case Study: Tacloban City

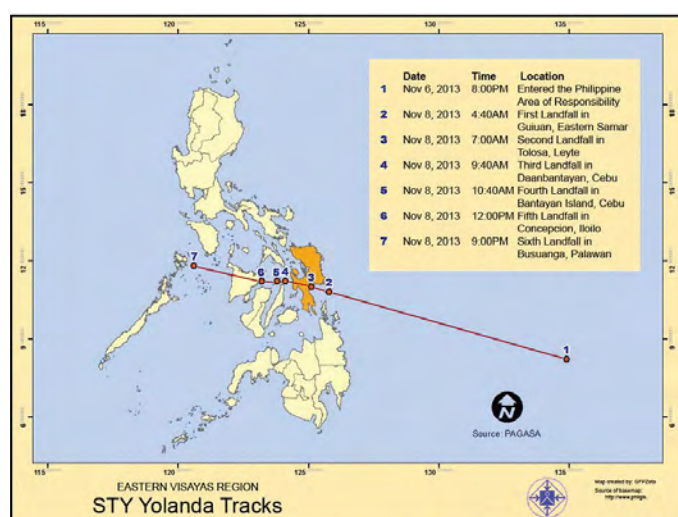


Figure 1. Location map of Tacloban City, Philippines, indicating the track of Typhoon Yolanda (Paragas, Rodil & Pelingon, 2016)

The Philippines is an archipelagic country which is situated within the so-called “Ring of Fire”. Considered as one of the most disaster-prone nations (see Figure 1), there are about 20 cyclones entering its area of responsibility on an annual basis (United Nations University Institute for Environment and Human Security [UNU IEHS], 2011). In 2013, an exceptionally strong typhoon with the international name Haiyan and a storm strength equivalent to Category 5 arrived within the Philippine’s Area of Responsibility. It made landfall in Tacloban City, the capital of Eastern Visayas. With wind speeds of up to 378 km/hr, it resulted in storm surges of 4 to 6 meters high. Sherwood, Bradley, Rossi, Guam and Mellicker (2015) estimate that the country suffered about 7,000 deaths, approximately 4 million people displaced and USD 36 billion in damages. Figure 1 shows the location of Tacloban City in relation to the Philippines, the different climate impacts that the city experienced,

which include landslide, storm surge, flooding and drought, and the track of Typhoon Haiyan (Figure 2).

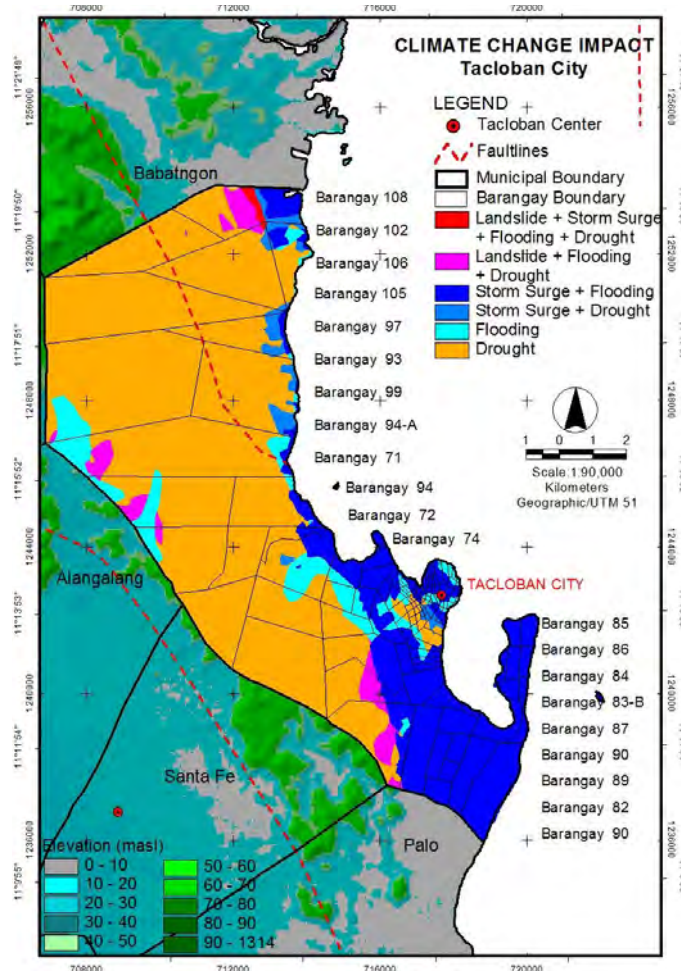


Figure 2. Tacloban City’s climate change impacts (Yap and Garcia, 2014)

Table 2 illustrates the number of affected people, the level of damage to properties of the regions in the Philippines which suffered the highest number of fatalities and damaged houses. Compared with other Haiyan-affected regions, the lower average income and the higher poverty levels reported in Region VIII have further aggravated Haiyan’s impacts on households and individuals. In Tacloban City alone, 2,524 were declared dead and 594 people were missing (equivalent to 1.22% of the city’s population and 44% of the fatalities in Region VIII) while a total of 28,734 houses were totally damaged and 17,643 were partially damaged (Tacloban Recovery and Sustainable Development Group [TRSDG], 2014).

The annual population growth rate of Tacloban is 2.73% and its average household size is 4.13. The land area of Tacloban City is approximately 97.06 sq.km. The city has a total of 138 barangays, with 17 in rural and 121 in urban areas. A notable spatial change was observed in Tacloban City’s population

Table 2. Post-Haiyan number of affected people, property damages, income, and poverty incidence by region

Region	Affected people ²	No. of casualties ¹	Displaced people ²	Damaged houses ²	Damage & loss (Transport) ³	Average income (PhP) ⁴	Poverty incidence ⁴
XIII	69,956		22	6704		219,000	43.9%
IV-B	450,930	19	1,960	33,510		141,000	29.8%
VI	3,796,092	294	2,242,958	482,280		159,000	30.5%
VII	5,881,352	74	205,937	120,694		184,000	30.5%
VIII	3,797,471	5,785	1,537,932	492,095		160,000	47.3%
IX	5,000		0	21		166,000	39%
TOTAL	14,000,801	6,172	3,988,809	1,135,304	6,251.10		

Source: ¹(DSWD, 2014a); ²(DSWD, 2013); ³(National Economic and Development Authority [NEDA], 2013a); ⁴(Philippine Statistics Authority [PSA], 2015)

before and after Haiyan (Mas et al., 2015). Tacloban's population prior to Haiyan was 255,301 (2012 Comprehensive Land Use Plan estimate) and went down to 188,828 (2014 figures), implying that Tacloban's overall population decreased by 26% (66,473). The city's coastline and downtown area, which is also surrounded by bodies of water on three sides, experienced a decrease in population while northern Tacloban, the identified resettlement area, saw an increase in population (Department of Social Welfare and Development [DSWD], 2014b).

Haiyan brought in its wake a myriad of challenges, including the massive destruction of critical transport infrastructure systems. Roads and bridges were severely destroyed causing congestion at key transport hubs (such as ports, airports and ferry crossings), limiting access, hindering humanitarian response, and presenting significant challenges to manage waste more effectively.

Results

Demobilities and Remobilities: Transport Infrastructure Performance

This section discusses the way transport became incapacitated post-Haiyan. Typhoon Haiyan affected more than 170 cities and municipalities in 6 regions (see Table 2). The Eastern Visayas region, which mainly consists of the provinces of Leyte and Samar, incurred massive transport-related loss and damage. This was magnified by the storm surge, making recovery and reconstruction a very challenging exercise. The Reconstruction Assistance on Yolanda, the strategic plan to guide recovery and reconstruction in Haiyan-affected areas in the country, reported that 42% of the total length of national primary arterial roads (6,728 km), 36% of the total length of national secondary roads (5,583 km) and 38% of the total length of local roads (65,000 km) were affected at varying degrees (NEDA, 2013b). This would mean that local roads including those which provide

critical local access to barangays or villages as well as farm-to-market roads, municipal roads, city roads and provincial roads were damaged, in poor condition, and virtually impassable with piles of debris and waste materials littering the streets and clogging the drainage (TRSDG, 2014). This has hampered the movement of people and goods within as well as into and out of communities or barangays. Barangays are considered the smallest political and administrative unit in the Philippines. Moreover, at the national level, about 3,357 bridges (approximately 42% of the national total) were structurally stressed, referring to the level of physical damage that may cause serious disruptions to area-wide mobility and access (NEDA, 2013a). The Department of Public Works and Highways (DPWH) estimated that the structural damages to road networks and bridges amount to approximately PHP 202,674,000.00 (=USD 4,034,116) (TRSDG, 2014).

However, the typhoon only slightly damaged San Juanico Bridge, considered as the longest-bridge in the Philippines which connects the provinces of Samar and Leyte. San Juanico Bridge demonstrated strong "engineering" resilience during and after post-disaster Haiyan. Because of this, it also served multiple roles: as gateway for community access and humanitarian intervention and an important transportation backbone linking Leyte and Samar province along the Pan-Philippine highway, hence demonstrating "ecological" resilience.

Aside from roads and bridges, the city's three major transportation facilities – airport, seaport and public transport terminal, which also served as key entrepôts to the city – were severely damaged and barely operational immediately after the disaster. Daniel Z Romualdez Airport covers 45 hectares of land and accommodates approximately 12 flight trips per day (TRSDG, 2014). The airport was heavily destroyed by the storm surge, which rose to 4.2 meters (Lagmay et al., 2014) from both sides of the peninsula. After the typhoon, the airport was opened mainly for aid deployment and passengers leaving Tacloban (GMA, 2013a). The 5.3-hectare seaport was

immediately opened 10 days after Haiyan's aftermath although it also sustained some damage. The main port area was spared of any major structural damage and became an important post-disaster hub. It was extensively used mainly for the deployment of relief goods and other humanitarian efforts including ferrying people who assisted in the relief operations and moving the residents out of the city immediately after the disaster. The Abucay Tacloban Bus Terminal served as the key land-based transportation hub for the city, the province, and the region. It catered to multiple transport and mobility needs accommodating not only inner city and inter-city routes but also inter-provincial and inter-regional transport movements (connecting Luzon and Mindanao to the Eastern Visayas region). It became the busiest transport hub for the city and the province. While the facility was severely damaged following the typhoon, it nevertheless continued to move goods and people in and out of the city but was also temporarily used as a dumpsite.

Through these major transport facilities, it was possible to observe intra-regional movement, including the transport mode used by land, sea or air. Migration Outflow Desks were strategically located at key intra-regional entry as well as exit points of Cebu, Guiuan, Manila, Roxas, Ormoc, and Tacloban by the International Organization for Migration and DSWD. This was open a week after Haiyan until middle of December when outflows went back to pre-disaster levels. Moreover, because the Visayas Region is composed of several islands, movements were via air and water, rather than land. Between 15 and 22 November, a week after Haiyan's landfall, about 17,000 person-trips were generated (and recorded) as the Philippine military provided free air flights into Manila from disaster-affected areas (Protection Cluster Philippines, 2013). On a daily basis, out of the 5,000 recorded person-trips moving out of Eastern Visayas, approximately 30% (1,500 person-trips) were by air leaving Tacloban City while others took the "roll-on roll-off" inter-island transport from severely affected islands. According to the Port Authority, approximately 5,000 people were crossing daily with the majority of people coming from the city of Tacloban (Assessment Capacities Project, 2014). While most individuals originating from Tacloban travelled to Manila or Cebu, residents from Guiuan (site of the first Haiyan landfall) tended to move to Tacloban or Cebu, indicating that these intra-regional movements were largely dictated by the transport mode and transport services available at the disposal of these individuals.

Extreme events impose significant physical stresses to a city, including its transport networks. The identification of priority infrastructures to be reconstructed is as important as gaining an improved understanding of the extent to which a weakened infrastructure can increase vulnerability of those who are already disadvantaged by the transportation system. Examining the dimensions of transport poverty help shed light on how to ameliorate transport poverty.

Assessing Transport Poverty and Resilience in Disasters

This section describes how an already disadvantaged population

was further affected by a weakened transportation system in the context of the Haiyan experience. Mobility can place a significant impact on individuals and communities. This impact may be gleaned from the four dimensions, namely: accessibility, availability, affordability, and acceptability.

Transport Accessibility

Transport accessibility is described as the extent to which all categories of passengers can participate in emergency response activities; opportunities to access basic needs and provisions (food, shelter); the movement of goods to reach the most disadvantaged sector; and during the recovery period, the extent to which individuals can access economic and social opportunities (education, jobs, health care, shopping/grocery) within reasonable ease, time and cost.

Forced evacuation is a mechanism employed by the government to prepare for a disaster as well as in post-disaster recovery. A day prior to Haiyan's landfall, the national government ordered the forced evacuation of residents in high risk danger zones such as those in flood-prone and landslide-prone areas (GMA, 2013b). In the wake of Haiyan, rising waters prompted the evacuation and relocation of people to temporary shelters. However, there was unavailability of public transport to ferry people to shelters. This was compounded by the fact that almost everyone, including public transport drivers and operators, became disaster victims. In the first instance, they had to care for themselves and their immediate families. Majority of the road networks was damaged from the storm surge. They were blocked because of flooding with piles of debris on roads which severed access (Gelineau & Teves, 2014). Vehicles were made inoperable due to the storm surge further aggravating the already existing vulnerabilities.

Similarly, post-Haiyan experience further demonstrated Tacloban residents' "access-poverty". Drawing from Sherwood et al. (2015), the study used stratified sampling (considering residential location, poverty level and damage caused by Haiyan) in identifying 4,518 survey respondents who are most vulnerable residents of Region VIII (Sherwood et al., 2015). During the survey, 75% of the respondents were reported to be internally displaced persons, 52% experienced some form of tenure insecurity, and the rest experienced economic hardship.

This gap analysis provided useful information on specific "transport disruptions" (80%) and clarity on "meeting transport needs" of the sample populace (100%) (Sherwood et al., 2015). Table 3 compares the self-reported information on the accessibility and availability of basic services for both displaced and non-displaced subgroups, before and after Haiyan while Table 4 presents explanations for the difficulty in accessing basic goods and services.

As reflected in Table 3, results from the focus groups of residents in relocation sites and bunkhouses showed their concern on the limited accessibility and availability of basic

Table 3. Availability and accessibility of basic goods and services pre/post-Haiyan*

BASIC SERVICES	Before		TOTAL	After		TOTAL
	YES	NO		YES	NO	
Availability (displaced)	242,467	10,377	252,844	242,248	10,596	252,844
Percent (%)	95.90	4.10	100	95.81	4.19	100
Availability (not displaced)	82,821	1,033	83,854	82,533	1,321	83,854
Percent (%)	95.90	4.10	100	98.42	1.42	100
Accessibility (displaced)	238,197	14,467	252,844	237,001	15,843	252,844
Percent (%)	94.21	5.79	100	93.73	6.27	100
Accessibility (not displaced)	80,136	3,718	83,854	78,372	5,482	83,854
Percent (%)	95.57	4.43	100	93.46	6.54	100

*Adopted from Sherwood et al. (2015)

services. This was more of a problem for those located in remote relocation sites. For those who were not displaced, a difference of 288 participants reported that basic goods/services became unavailable after the typhoon while an additional of 1764 participants said that goods/services became inaccessible after the typhoon. For those individuals who were displaced, 219 reported that basic goods/services became unavailable after the typhoon and 1,196 more reported that goods/services were inaccessible after the typhoon.

In the study of Sherwood et al. (2015), focus group discussion (FGD) participants reported that in one of the transitional shelters, free bus transport to Tacloban City was provided but the service was stopped only after a short period. When posed with the question on the reasons for difficulty in accessing basic services, majority (93.36%) of those surveyed reasoned “lack of money” while only 3.68% considered basic services as “too far” to access (refer to Table 4). Coastal residents have been resettled far from their place of origin, limiting their opportunities to seek for temporary work, or gain access to basic and critical services. These individuals (who originally worked as fishermen prior to Haiyan) lamented that “the sea was now too far and too expensive to access, forcing them to face another form of readjustment” (see Sherwood et al., 2015 for the complete survey results).

Organizations and institutions heavily rely on effective transport networks to enable them to conduct search and rescue operations, deliver emergency supplies, and transport victims to hospitals or temporary shelters. Weakened or non-existent transportation has severely inhibited and physically hindered the institutions from immediately responding to the needs of affected communities (Gonzalez, Hidalgo & Barabasi, 2008).

The extensive damage brought about by the supertyphoon on the transport system has severely limited the access of several organizations responding to the needs of highly affected areas,

Table 4. Participant explanation for the difficulty in access to basic services*

Reasons Provided	Population Estimates	Per Cent
Lack of money	191,462	93.36
Too far	7,543	3.68
Lost home/land due to typhoon	1,970	0.96
Old age or illness	1,288	0.63
Political affiliation	1,205	0.59
Others	770	0.38
Newcomers	539	0.26
Religious affiliation	124	0.06
Don't know	184	0.09
TOTAL	205,085	100%

*Adopted from Sherwood et al. (2015). This question was posed to participants who responded that they had difficulty in accessing services.

particularly those in isolated communities. This was further exacerbated by the archipelagic nature of Leyte, placing severe constraints on ensuring more responsive logistical operations. Another layer of challenge was in the collation of information and communication of condition of transport infrastructure during and after the disaster, overall hampering relief efforts, limiting the capacity and capability of humanitarian groups to provide for the logistical requirements to support more effective disaster response. This has caused a complex web of congestion of and stretched capacities in various parts of the transport network particularly at key hubs such as ferry crossings, airport terminals, and ports (Philippines Humanitarian Country Team, 2013).

Transport Availability

Ensuring accessibility and mobility service options are vital requisites for an effective disaster management response. For instance, mobility-related post-disaster recovery strategies must be explicitly identified at the tactical, operational and organizational levels. However, the lack of clear mandate on planning and management to adequately address disasters of major catastrophic scale has reinforced transport mobility and accessibility issues in Haiyan's aftermath. Also, a systematic rationalization of transportation's supportive but critical role has been sorely absent from disaster planning and governance tools in Tacloban.

Individual mobility was severely hampered as people had to move within their communities or be relocated to evacuation centers. The main reasons for this were that road network were blocked due to the piles of debris on roads and majority of the road network were damaged from the storm surge (Gelineau & Teves, 2014).

In the context of disaster, the capability of a transportation system to enable people's mobility and access is crucial to be able to achieve effective disaster management response. However, it is also true that in disaster events, there is the possibility that one or more transport options would not work. In this case, it is important to provide a variety of mobility options, or what is called redundant transport (Wang, 2015). The provision of alternative modes in the instance that the main transport failed is an important part of any disaster plan. Moreover, it became clear that, at least in the Haiyan experience, active transport like walking and bicycling, is vital as it may sometimes serve as the only viable means for individuals to move around immediately after a disaster (Osaragi, 2013; Litman, 2010). As public transport modes were unavailable and roads were blocked, people could only walk, ride a bicycle or use cycle rickshaws (pedicabs) as means of mobility within areas. While it would take longer relative to other transport modes for people to go where they needed to go, it was still the only reliable and viable means. Walking and riding the bicycle are not dependent on fuel availability, flexible, as people could meander through different routes as well as inclusive, as anyone who was physically able to walk or ride the bicycle regardless of age, gender or socio-economic status can participate in walking. Several studies have already examined walking, one of which is Osaragi (2012) who examined people's walking behavior as a result of the temporary closure of the public transport system in the aftermath of the 2011 Tokyo earthquake.

Transport Affordability

Intensifying the vulnerability of individuals and communities is the unaffordability of travel. The financial burden of journeying puts one in a position of having to make sacrifices in other parts of their lives just to travel. In the first few days after Haiyan struck, public transportation fares increased more than double in Tacloban and the rest of the province. Operators and drivers were overcharging passengers. This was, again, a complex web of cause and effect as fare increases were largely

a response to high fuel costs resulting from limited fuel supply. Immediately after the disaster, fuel rationing was imposed in areas that were hardest hit. While, 83 of 128 petrol stations within the area were operational, there was a cap placed by the Energy Department. Its Director reported that sales were limited to PHP500 (=USD9.93) per transaction as a strategy to extend availability (Sydney Morning Herald, 2013).

Although the Land Transportation Office in coordination with the Land Transportation Franchising and Regulatory Board monitored erring public utility vehicle drivers who overcharge passengers (DVM, 2013), still, this did not deter operators and drivers to exploit immediate opportunities. This has placed several households in a position that they did not have adequate financial resources to travel when they want to, which was a key problem among disaster victims, and then survivors were relocated to sites that were further away from their place of work. Transportation costs skyrocketed. In a study undertaken by Sherwood et al. (2015), respondents reported that their children had to temporarily stop schooling because of the steep transport costs. This lack of educational opportunities forced some young individuals to leave school and move to another urban center such as Manila. While in one resettlement village, households must spend an exorbitant amount, about PHP 100 per day (=USD 1.99), to be able to get to school. This became unsustainable particularly to families who lack stable income or source of livelihood (Sherwood et al., 2015).

Transport Acceptability

The need for transport to be culturally and/or socially appropriate, hence acceptable, to its users has long been recognized as an important attribute of disaster response efforts. Col (2007) cautioned that a mismatch between vulnerability realities and planning may result in an evacuation process that is significantly flawed (Col, 2007). This was demonstrated when disaster planners in New Orleans before Hurricane Katrina's landfall approximated that about 100,000 up to 130,000 people would have no access to private transportation (Wolshon, 2002) but incorrectly assumed in the emergency plan for New Orleans that these individuals would evacuate using their own private transport. Sheller (2013), writing on the Haiti earthquake of 2010, recognized that the impacts of transport system failures would be different among various groups, but would somehow have greater impact on the poor and marginalized sectors of society who generally have lower network capital while those who have higher network capital can flee the disaster zone.

There is an acknowledgment that resilient transportation is a key, albeit missing pre-requisite in integrated, holistic disaster risk management. Wang (2015) suggested that the need for an integrated suite of transport options that goes beyond the engineering aspects, captures social-ecological aspects, ensures that mobility needs of the community for the movement of both passenger and goods, within the context of an extreme event happening, would adequately and appropriately addresses future climatic situations (Amdal & Swigart, 2010).

Discussion and Conclusion: Achieving Transport Resilience

This paper's knowledge contribution is two-fold: first, it was able to develop and introduce the concept of and articulate transport poverty and resilience within a disaster setting, highlighting the vital role that transportation plays in terms of individual as well as community mobility and access; and two, it was able to comprehensively examine the fragile condition of transport within a disaster scenario by drawing upon demobilization of individuals and communities as well as the remobilization strategies employed by various actors, immediately after the super Typhoon Haiyan had made its landfall.

The paper highlighted that while LGUs are mandated to be the first responders immediately after an extreme event, the experience of Tacloban illustrated that they were unable to effectively take on this directive due to two main reasons: one, because they were disaster victims themselves, and therefore exposed to the same transport-related stresses like others after the disaster; and two, their overall capabilities to effectively respond to transport-related stresses after a disaster may already be limited, hence a solid framework to address such challenges must be put in place. This became much more challenging when considered within a large-scale environmental disaster, as what was experienced in Tacloban in 2013. Although preparations were undertaken both by the national and local governments, the intensity of its impact left communities much more unprepared. In the context of increasing disaster impacts, this paper recommends that governments, at different levels, along with humanitarian agencies, should provide solid planning frameworks earmarked to tackle issues of transport mobility and accessibility, which can serve as vital lifelines in critical disaster situations.

In the case of Tacloban, institutional and regulatory frameworks to enhance resilience to disasters have already been put in place yet its articulation of how transport can be made more resilient remains limited, particularly at the tactical and operational levels. For instance, there is the Tacloban Recovery and Rehabilitation Plan (TRRP), which is a key document that can help guide the development of policy and planning processes as well as improve disaster governance and planning. TRRP envisions a "resilient, vibrant and liveable city". The slogan of building back better guides the implementation of the TRRP. In fact, post-disaster rehabilitation and recovery strategies have mainly focused on the improvement of existing transport assets and infrastructure as well as the proposal of new infrastructure, but not clearly understanding the type of transport services that would be most effective in supporting community resilience when the next disaster occurs. Therefore, results from this study could help improve our understanding that post-disaster rehabilitation and recovery is not about the return to earlier forms of infrastructure, but more importantly, provide guidance on how to achieve more effective transport services through better access and mobility strategies during post disaster scenarios, a fact recognized and acted upon in

previous disasters (e.g. Tōhoku earthquake and tsunami in 2011, hurricane Katrina in New Orleans in 2005).

In Haiyan's aftermath, one key program prioritized by the national government is resettlement for displaced families. The TRRP identified Tacloban North, an area which is 16 kilometers north of Tacloban downtown, as the city's planned resettlement area that would cater for more than 16,000 families. While Tacloban North's urban master plan is yet to be finalized, the implementation of resettlement projects has already been ongoing, yet this has been incremental and piecemeal. These relocation sites therefore are beset with challenges, while those relocated continue to be insecure and are mostly concerned about how they would earn their living. Through this study, it is important to highlight that resettlement is not only about the provision of shelter but it is also about the provision of safe and secure communities for its residents, who will have access to critical social infrastructures, economic opportunities and basic social services. Transportation could play an enabling role in such situations.

As a recommendation, the design of a post-disaster recovery plan must always place people first in the agenda and provide them with a diverse set of transport options. As it has been shown, transport mobility and accessibility needs must be initially addressed as part of a holistic post-disaster recovery program. Thus, the current TRRP display limitations but also provide a platform for opportunities. In addition, by using the concept of transport resilience, remobilization efforts of formal institutions were examined to comprehend the extent to which mobility and accessibility challenges within the context of post-disaster recovery initiatives have been addressed and adequately mitigated by recovery plans. However, results show that remobilization efforts can still be vastly improved to achieve a more resilient transport system.

The current approach demonstrated by post-Haiyan in Tacloban primarily focused on the recovery phase, thus, calls for opportunities for a more proactive disaster management, which would strengthen current mitigation and preparedness strategies, in the understanding of a more intense and more frequent environmental disasters. These insights are vital to: better addressing mobility and accessibility needs, realizing more resilience, and improving local level disaster planning and governance in future disaster scenarios.

While this paper has demonstrated useful insights into the topic of disaster and mobility, there are some limitations. First, time and resources were key constraints. Second, there has not been much research on the specific issue of individual and community mobility in a disaster context, particularly in developing cities.

As a next step, results of this study could be enhanced when supplemented by primary data collection:

1. Interviews of persons affected by the disaster to further understand transport demand;

2. An audit of transportation networks to understand how to improve transport supply (e.g. blocked road networks, alternative modes during disasters);
3. Appraisal of pre-, actual and post-disaster transport infrastructure conditions may be undertaken as part of a rapid damage assessment (see for instance, Mas et al., 2015, which used satellite imagery); and
4. Documentation and breakdown of the transport modes that international, national and NGOs used for mobility of goods and passengers.

As a result of climate change impacts, more and more disasters are expected to occur and could affect urban areas in different ways and at different scales. Understanding mobility and accessibility needs in a disaster context must be a priority and an important focal topic of cities. As such, there is therefore a need to fund more research on this issue especially in developing Asia, the most disaster-prone region worldwide. The dynamics of disaster recovery focuses on the “gaps”, “speed” within the context of unmet needs (in terms of scale as well as level of recovery) and “timeliness” (relates to the swiftness of recovery). The potential to recognize recovery as a pathway to resilience building, is therefore crucial, particularly in understanding the role of transport as derived from the reported need of demobilized people and goods. Remobilization efforts by governments, private sector and civil society, must listen to the voice of the community, adhering to their needs. Purposes, scales of movement, and needs vary. Acknowledging these needs and motivations for travel is critical if we aim to promote more resilient communities.

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Adaptive capacity of local communities to flash floods and landslides: Comparison of indigenous and non-indigenous people in Eastern Mindanao

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Received: 20 April 2017 / Accepted: 21 November 2018 / Published online: 13 December 2018

Abstract

The paper assessed and compared the adaptive capacity of indigenous peoples (IPs) to non-IPs in five villages that were affected by Typhoon Bopha (Pablo) in Eastern Mindanao in 2012. The flash flood and landslide disasters were caused by exposure to heavy rainfall combined with sensitivity of the environment in the region. Because these climatic and ecological risks are expected to persist in the future, it is necessary to assess the capacity of the communities to adapt to the socio-economic impacts of disasters. The assessment was based on survey data that were analyzed using factor and cluster analyses. The factor analysis was used to identify the most relevant factors affecting adaptive capacity and cluster analysis was used to develop typologies of adaptive capacity. The results revealed that a higher number of IPs have low and very low adaptive capacity than non-IPs. The main factor that lowers the adaptive capacity of the former is (lack of) access to resources including education and calamity support as well as skilled and contract-basis types of employment. The IPs have low adaptive capacity to both short- and long-term impacts of typhoon-induced floods and landslides. Education and capacity building are essential to improving IPs' access to resources and thus increasing adaptive capacity.

Keywords: adaptive capacity · climate change · disaster · indigenous people · Philippines · vulnerability

DOI: <https://doi.org/10.18783/cddj.v003.i01.a05>

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Introduction

Adaptive capacity is one of the three dimensions of vulnerability. The Intergovernmental Panel for Climate Change (IPCC) (IPCC, 2001, 2007) defines vulnerability as the “degree to which a system is susceptible to, and unable to cope with, the adverse effects of climate change, including climate variability and extremes”. It is a function of adaptive capacity, sensitivity and exposure. On the one hand, exposure in the Philippines is significantly linked to the impacts of climate change, in particular the increasing intensity and frequency of tropical cyclones that make the country one of the most vulnerable worldwide. According to the German Watch, the Philippines ranked fourth in the Long-Term Climate Risk Index with annual average of 862 deaths, USD 2.76 billion losses, and 0.63% gross domestic product (GDP) lost for the period 1996-2015 (Kreft, Eckstein & Melchior, 2016). An average of 20 tropical cyclones enter the Philippine Area of Responsibility (PAR) every year, which is about 25% of the global occurrence of tropical cyclones (Faustino-Eslava, 2011; Huigen & Jens, 2006). On the other hand, sensitivity is caused by environmental degradation, in particular significant deforestation in upland and coastal areas. The environment has been substantially degraded from anthropogenic activities resulting in the decline of mangrove forests by 80% in the last 50 years, and of upland forests by about 21 million hectares between 1900 and 1990 (Eugenio et al., 2016). Like in many parts of the Philippines, forest areas in Eastern Mindanao are largely denuded mainly due to illegal logging, irresponsible mining and widespread land use conversion (i.e. forest to agriculture). For example, illegal logs with an equivalent value of USD 68,000 (Php 3.4 million) were confiscated by the government in Compostela Valley Province in 2005, farms increased by 10.9% in Caraga or Region XIII from 1991 to 2002, and mining sites of 116,546 hectares proposed for 50 Mineral Production Sharing Agreements in Eastern Mindanao in 2008 are forest areas (Philippine Eagle Foundation, Conservation International-Philippines & Department of Environment and Natural Resources [DENR], 2008).

On December 14, 2012, Eastern Mindanao was devastated by Bopha (locally known as Pablo), one of the strongest typhoons in the Philippines with an average speed of 185 km/hr and gusts of up to 210 km/hr (National Oceanic and Atmospheric Administration [NOAA], 2012). Bopha was a category five typhoon, the highest scale under the Saffir-Simpson Hurricane Wind Scale of the National Oceanic and Atmospheric Administration (NOAA). The National Aeronautics and Space Administration or NASA (2012) estimated that heaviest rain of over 240 mm (~9.4 inches) was located near the coast of eastern Mindanao including Compostela Valley. The amount of rainfall exceeded the mean monthly rainfall of 206 mm in the province (Narisma et al., 2014) and far above the minimum of 70 mm daily rainfall that was estimated as a threshold for early landslide advisory (Nolasco-Javier, Kumar, Arlene & Tengonciang, 2015). The heavy rain fell on the upland watershed area in Andap causing flash floods (Mines and Geosciences Bureau [MGB] & DENR, 2012).

The geomorphological landforms in Andap and surrounding areas consist of thick fluvial deposits consisting mostly of unconsolidated clay, silt, sand and rock boulders (MGB & DENR, 2012), which can be easily washed out by heavy rainfall. The landslide susceptibility map shows that the province is mostly marked red or high risk and has several portions marked purple or very high risk (Villanueva, 2012). The flash floods and landslides caused by Bopha affected more than 6 million people, killed at least 1,000 people, damaged more than 200,000 houses, and destroyed about 1 billion US\$ of agricultural products, infrastructure and private properties in Eastern Mindanao (Eugenio et al., 2016). New Bataan in the Compostela Valley Province was the most affected municipality, where thick mud and huge rocks covered largest areas of many villages, burying lives and livelihoods of many people (Acosta et al., 2016; Manuta, Eugenio & Macandog, 2018).

Like in many parts of Mindanao, New Bataan is home to many migrants from other islands in the Philippines, but also to many indigenous peoples (IPs) (Tigno, 2006). Although the IPs are officially recognized by the Philippine Constitution and the Indigenous Peoples' Rights Act, there are no accurate figures on the population of the IPs due to absence of formal census. Data on IPs in the Philippines continue to be based on estimates, which are around 10-20% of the total population or 102.9 million (Hansen, Jepsen & Jacquelin, 2017) and living in 65 out of 78 provinces (Carino, 2012). About 61% of the IPs live in Mindanao, as compared to only 33% in Luzon and 6% in the Visayas (ADB, 2002). The importance of Mindanao as home to many IPs makes it an interesting case study for assessing adaptive capacity to flash floods and landslides. Most Philippine IPs continue to live based on their traditional and livelihood practices (Sobrevila, 2008; Balilla, Anwar-McHenry, McHenry, Parkinson & Banal, 2012) and in remote areas far from access to basic social services and economic opportunities (Hansen et al., 2017). But with the increased migration from other regions and mobility of local population in Mindanao, many of the IPs have been influenced into the non-traditional forms of livelihood (i.e. cash crop farming, commercial fishing, logging, and mining) of the non-IPs including migrant settlers and lowlanders (Philippine Eagle Foundation et al., 2008). The lack of access to social services and economic opportunities as well as change in livelihood practices could have an impact on the IPs' capacity to address climate change impacts.

Only few studies investigated the adaptive capacity or adaptation practices of IPs in the Philippines (e.g. Bernardo, et al., 2014; Hiwasaki, Luna, Syamsidik & Marçal, 2015; De los Santos et al., 2017) and none so far in the Compostela Valley. Since the landslide and flash flood events in 2012, no systematic study has been conducted to compare the adaptive capacity of IPs and non-IPs in New Bataan's most affected communities. This paper contributes to the assessments of adaptive behaviour with the ultimate goal of stimulating adaptation support to the most vulnerable people. In particular, it aims to identify the sources of vulnerabilities and the level of adaptive capacity between

these two community groups. It is an important extension of the study on loss and damage by Eugenio et al. (2016) in the same municipality. This paper highlights the differences between IPs and non-IPs in terms of their adaptive capacity to recover from the impacts of household and livelihood losses and damages.

Materials and Methods

Case Study and Survey Area

The municipality of New Bataan, which is about 689 square kilometres, accounts for 14.8% of the total land area in Compostela Valley (National Statistical Coordination Board [NSCB], 2014). It is the province's second largest municipality in terms of land area but the fourth smallest in terms of population (47,470 people or 6.9% of total population). There are 12,562 households living in 16 villages in New Bataan, with an average household size of 5 persons (NSCB, 2014). Agriculture is an important sector in New Bataan covering 24.57% of its total land area and employing half of the economically active population. The Municipal Office of New Bataan reported about 450 retrieved casualties and 8,000 damaged houses in April 2013 (Eugenio et al., 2016). The case study villages include Andap, Bantacan,

Cabinuangan, Cogonon and Kahayag. The human losses and property damage were highest in the villages of Andap and Cabinuangan. In Andap, the village center was covered by debris flows which buried houses, school, resorts, health centers and other village facilities. The main characteristics of the five villages are described briefly below.

Andap is situated at the mouth of a mountain drainage network at the base of steeply slopes. It is nestled on an alluvial fan, normally found at the base of mountains where water drains, making the village very vulnerable to floods and landslides. Andap is a rural area, covering the largest area of the municipality (20.32% of the total land area) (Table 1). Before the disaster, it was a popular tourist destination with its beautiful resorts (i.e. the famous Bamboo inland resort) and mountainous surroundings. After Typhoon Bopha, it sustained the most impacts in terms of deaths (70), missing people (290) and damaged houses (1,250) in the municipality of New Bataan.

Bantacan is bounded on the south of Cogonon. There were at least three casualties and one injured in Bantacan after the typhoon and about 600 houses were partially or totally damaged. At the time of writing, there are still 148.34 hectares of the damaged land area that cannot be utilized for agricultural purposes.

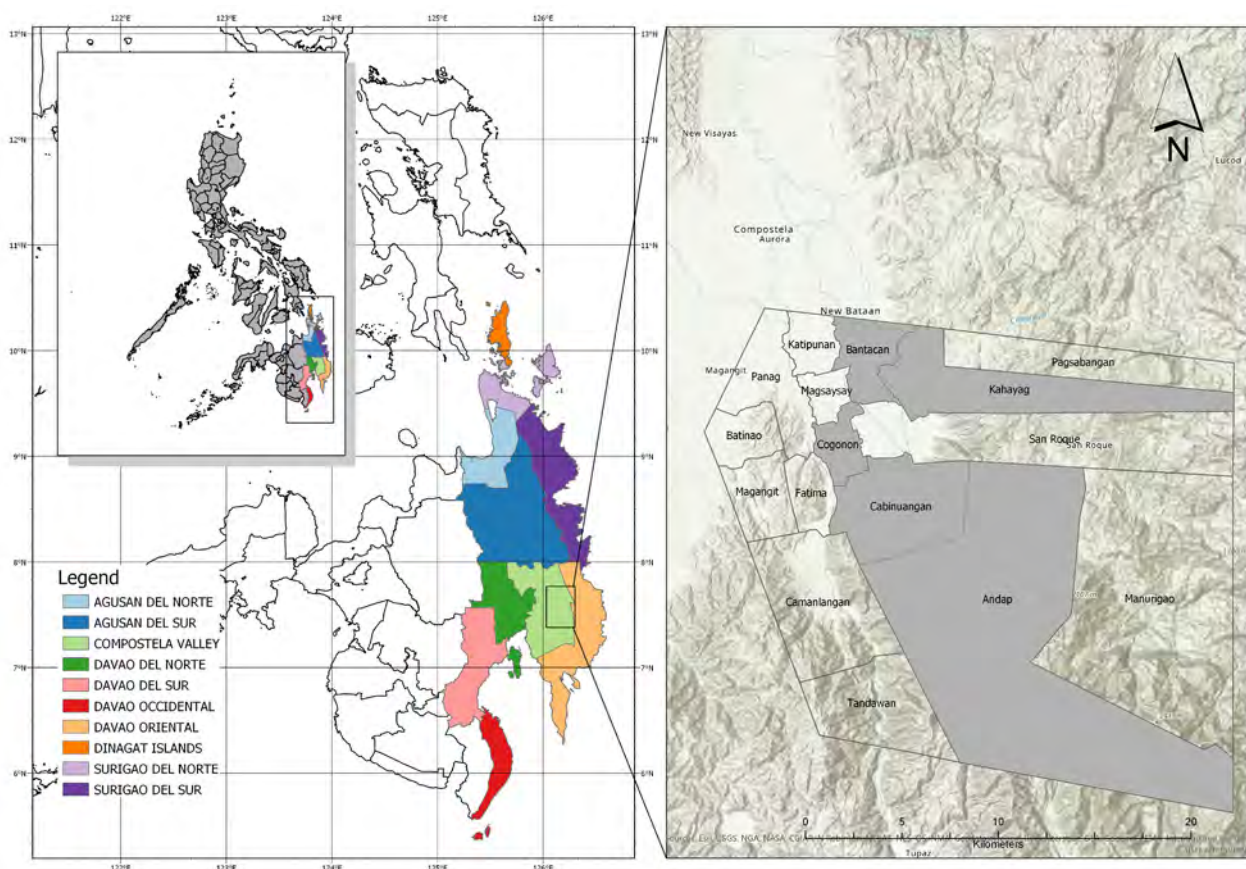


Figure 1. Location of case study villages in the municipality of New Bataan

Cabinuangan is the main growth center in New Bataan. It is the urban area in the municipality with the largest number of population (10,390). It has a total land area of 2,998 hectares where only 3.24% is forest area. Second to Andap, it has experienced the largest impacts from typhoon disasters with 66 deaths, 144 missing people and about 1,900 damaged houses.

Cogonon is one of the smallest villages in the municipality with only 1.18% of the total land area. Cogonon was not as severely damaged, but it is one of the poorest communities in New Bataan because of little non-agricultural income opportunities.

Kahayag used to be part (i.e. sitio) of Bantacan and was formerly known as Simsimin. The village was later renamed Kahayag which means “enlightenment.” Pioneer residents in the area were indigenous communities of Mandaya and Matikadongs. As early as 1958 many logging companies settled in the area and built bridges and roads for its logging concessions. After Typhoon Bopha, there were no reported casualties in the village, but around 400 houses were damaged.

The study used a structured survey questionnaire combining multiple choice and open-ended questions. The questionnaire covered among others: (1) socio-economic and demographic profiling, (2) overview of livelihood activities, (3) typhoon-induced disaster experiences, (4) disaster recovery and adaptation strategies, and (5) health and social networks. The household surveys were conducted on November 18-21, 2014 and March 16-20, 2015. Multiple-stage sampling was applied in selecting survey respondents. The first-stage sampling involved stratification at the municipal level wherein stratification criteria included level of damage and economic characteristics. The second-stage sampling aimed at determining the sample size at the village level which was calculated using the Cochran method at a 95% confidence level and 8% confidence interval (Cochran, 1997). The third-stage sampling involved stratification at the village level to capture different livelihood sources. Stratification at this level aimed at determining how the nature of livelihood (non-agriculture versus agriculture, i.e. coconut, banana and other perennial crops, abaca, and others) influences preferences for adaptation strategies. Finally, random sampling was employed in

identifying the survey respondents. The main socio-economic characteristics of the respondents and IPs are presented in Table 2. The total number of respondents is 438, with the IPs accounting for 31%. The number of female respondents was higher because their husbands are usually working during daytime. The survey covers, however, questions about the household, so information about the work of the spouses was also considered in the analysis. Many of the surveyed IPs have moved from remote to more accessible villages in New Bataan. This explains why there is slightly less IPs who are living in their villages for over 30 years as compared to the non-IPs (Table 2). During the conduct of the survey, it was not possible to travel to very remote areas due to security reasons including political conflict and landslide risk.

Analytical Framework and Tools

Awareness-Ability-Action framework

We framed society’s behavior to adapt to the impacts of flash floods and landslides based on IPCC concept of adaptive capacity: “the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences” (IPCC, 2001, 2014). This paper has mainly drawn from the work of Acosta et al. (2013), who developed their concept based on many previous studies (Moss, Brenkert & Malone, 2001; Yohe and Tol, 2002; Luers, Lobell, Sklar, Addams & Matson, 2003; Ivey, Smithers, de Loe & Kreutzwiser, 2004; Brooks and Adger, 2004; Haddad, 2005; Adger and Vincent, 2005; Alberini et al., 2006; Tol and Yohe, 2007; Acosta-Michlik, Kumar, Klein & Campe, 2008; Carpenter and Brock, 2008; Sharma and Patwardhan, 2008; Gupta et al., 2010; Acosta and Galli, 2013). Eugenio et al. (2016) modified the Awareness-Ability-Action framework to make it more suitable for local case study analysis. Here, the system refers to a society that has to cope with the consequences of climate extremes particularly typhoons and heavy rains causing flash floods and landslides. The framework considers three interrelated human dimensions of adaptive capacity – awareness, ability, and action. Eugenio et al. (2016) identified determinants for each dimension, i.e. knowledge and experience and social learning

Table 1. Characteristics of the case study villages in New Bataan

Village	Land area (hectares)	Population (number)	Households (number)	Damage and losses from typhoon
Andap	11,241	7,591	1,655	70 deaths, 290 missing, over 1,250 damaged houses
Bantacan	1,117	2,932	2,609	3 deaths, 600 damaged houses
Cabinuangan	2,998	10,390	2,364	66 deaths, 144 missing people, 1,900 damaged houses
Cogonon	652	1,223	285	No casualty, 300 damaged houses
Kahayag	3,644	1,494	330	No casualty, 400 damaged houses

Sources: Barangay Development and Security Plan 2011-2015; Consolidated Area Assessment Operation Pablo as of January 28, 2013, Municipality of New Bataan.

Table 2. Socio-economic characteristics of the survey respondents, New Bataan

Respondent Profile	Village					Community		All Respondents
	Andap	Cabinuangan	Cogonon	Bantacan	Kahayag	Indigenous	Non-Indigenous	
Number of Respondents	114	105	79	70	70	136	302	438
Years of age								
30 and below	23.9	14.3	11.4	5.8	12.9	15.4	14.2	14.7
31-50	50.4	55.2	53.2	50.7	50.0	60.3	48.0	52.1
51-70	22.1	26.7	29.1	40.6	28.6	22.8	31.5	28.4
71 and above	3.5	3.8	6.3	2.9	8.6	1.5	6.3	4.8
Years of residence								
5 and below	20.0	8.6	12.7	9.1	10.4	19.4	9.5	12.6
6 to 15	11.8	17.1	12.7	21.2	14.9	20.1	12.9	15.2
16 to 30	28.2	30.5	31.6	30.3	26.9	29.9	29.2	29.5
31 to 50	33.6	35.2	24.1	25.8	37.3	21.6	36.3	31.6
50 and above	6.4	8.6	19.0	13.6	10.4	9.0	12.2	11.0
Level of Education								
No formal Education	4.4	3.8	3.8	5.8	5.8	11.0	1.7	4.6
Elementary	41.2	37.1	26.6	31.9	37.7	47.8	29.8	35.6
High School	44.7	34.3	57.0	43.5	49.3	33.8	50.3	45.0
Vocational/technical	4.4	7.6	1.3	1.4	1.4	2.9	4.0	3.7
College/University graduate	5.3	17.1	11.4	17.4	5.8	4.4	14.2	11.2
Gender								
Male	32.5	52.4	45.6	30.4	54.3	30.9	48.5	42.8
Female	67.5	47.6	54.4	69.6	45.7	69.1	51.5	57.2
Civil Status								
Single	3.5	3.8	3.8	7.2	2.9	4.4	4.0	4.1
Married	76.3	83.8	68.4	73.9	78.3	75.0	77.5	76.6
Widow/Widower	11.4	8.6	19.0	13.0	8.7	8.1	13.6	11.9
Others	8.8	8.9	5.8	3.8	10.1	12.5	5.0	7.3
Community type								
indigenous	31.6	34.3	17.7	42.9	28.6	-	-	31.1
non-indigenous	68.4	65.7	82.3	57.1	71.4	-	-	68.9

Note: The values refer to the percentage of respondents in each variable category and each village.

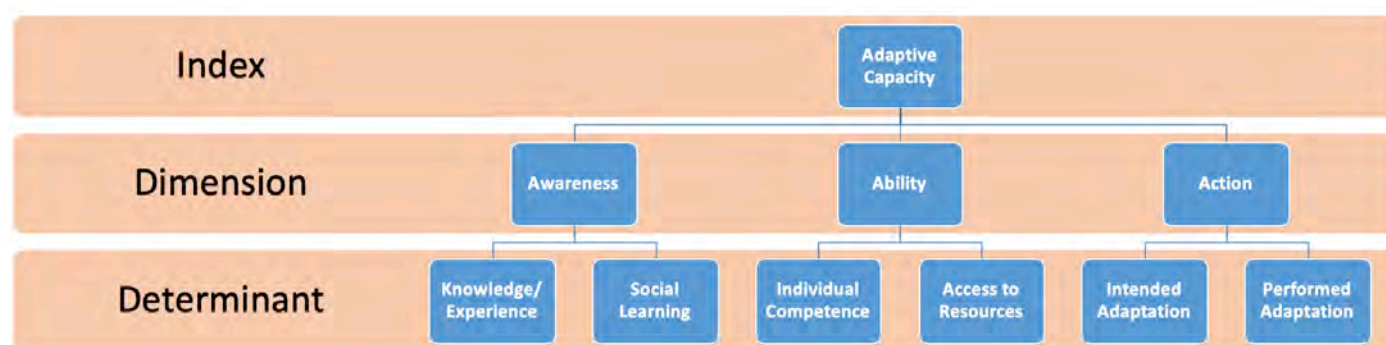


Figure 2. Determinants and dimensions of adaptive capacity based on Awareness-Ability-Action framework

for awareness, individual competence and access to resources for ability, and intended adaptation and performed adaptation for action (Figure 2). The dimensions and their determinants are discussed in details in Eugenio et al. (2016) and described briefly below.

Awareness. Awareness provides knowledge that creates an individual's ability to plan an adaptation action. Any action performed provides an experience, which then adds up to the knowledge that may lead to an increased, or even changed, awareness of an individual. Social learning is important due to the role of social structures for the exchange of knowledge and behavioral change, which support the development and diffusion of adaptations.

Ability. Unless cognitive barriers are addressed, a high level of adaptive capacity of individuals will not automatically facilitate adaptive behavior. Competence, which results from the linkage between information, knowledge, and action, can help to remove cognitive barriers and thus enable an individual to adapt. But competence alone is not sufficient to produce one's ability to cope with landslides disaster. Access to resources is a necessary condition to take adaptation actions.

Action. Following the IPCC (2001, 2014) definition, two types of adaptation actions were identified for the framework – intended and performed adaptation. Intended adaptation refers to the intention of an individual to perform a set of adaptation actions based on the expected climatic stimuli or their effects. Performed adaptation is the realization of adaptations or performance of the intentional actions. The translation of intended adaptations into performed adaptations depends on similitude of expectations to the actual climatic stimuli or their effects, reliability of available resources when a disaster occurs, and extent of loss and damage are not beyond adaptation. Finally, performed adaptations create new knowledge or experience that improves the competence of an individual in performing future adaptations.

Statistical Tools

Two types of analytical tools were applied in this paper, factor and cluster analyses. Cluster analysis was the main quantitative tool used to identify the adaptive capacity of respondents in the three villages in New Bataan. However, the wide range of data on socio-economic variables and disaster-related experiences that were collected from the survey would have rendered the analysis quite complex and unmanageable. To improve interpretability of the results, factor analysis was first conducted to reduce the number and identify the most relevant input variables for the cluster analysis. A total of 51 socio-economic variables representing the different determinants of adaptive capacity were used. The “factors” generated from factor analysis were used as input to the cluster analysis. The statistical results from the factor and cluster analyses are presented in Appendix 1. The results were used for identifying the typologies of adaptive capacity (e.g. high adaptive capacity, low adaptive capacity) for each cluster. Statistical Package for the Social Sciences (SPSS) was used for conducting both factor and cluster analyses.

Results and Discussion

Flood and Landslide Disasters

Impacts on Household

About 58% of the respondents consider lack of food as the most important impact of flood and landslide on households in New Bataan (Table 3). This result is followed by lack of drinking water, which caused problem among 28% of the respondents. While the number of IP and non-IP respondents who suffered from lack of drinking water was almost the same, there were more IPs (64.7%) who expressed concern about lack of food. This is likely due to poor access to the remote areas where the houses of many IPs are located. The slightly higher problem on availability of drinking water among non-IP respondents is due to the contamination of water and damage

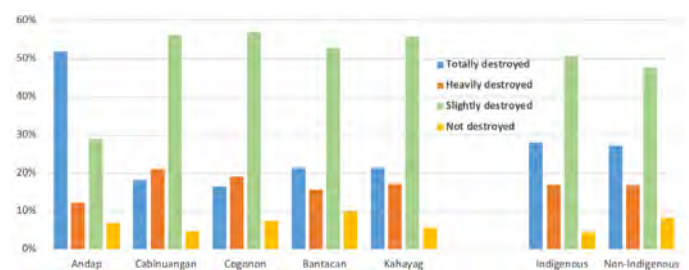
Table 3. Most important impacts of the disaster on households, New Bataan

Experience	Village					Community		All Respondents
	Andap	Cabinuangan	Cogonon	Bantacan	Kahayag	Indigenous	Non-Indigenous	
Lack of food	46.5	67.6	46.8	64.3	65.7	64.7	54.6	57.5
Lack of drinking water	25.4	25.7	45.6	20.0	24.3	26.5	28.6	28.1
Loss of livelihood	7.0	0.0	3.8	5.7	1.4	2.2	4.3	3.7
Homelessness	8.8	0.0	0.0	1.4	1.4	2.2	3.0	2.7
Damages of house	0.9	5.7	0.0	0.0	1.4	0.7	2.3	1.8
Lack of electricity	1.8	1.0	0.0	1.4	2.9	1.5	1.3	1.4
Destruction of farm	0.9	0.0	0.0	4.3	0.0	0.7	1.0	0.9
Temporary shelter	0.0	0.0	2.5	1.4	1.4	0.0	1.3	0.9
House relocation	1.8	0.0	0.0	1.4	0.0	0.0	1.0	0.7
Lack of medicine	1.8	0.0	0.0	0.0	0.0	0.0	0.7	0.5
Lack of transportation	0.9	0.0	0.0	0.0	0.0	0.0	0.3	0.2
Destruction of roads	0.9	0.0	0.0	0.0	0.0	0.0	0.3	0.2
Destruction of forest	0.0	0.0	1.3	0.0	0.0	0.0	0.3	0.2
Elementary	41.2	37.1	26.6	31.9	37.7	47.8	29.8	35.6
Number of respondents	114	70	105	79	70	136	302	438

Note: The values refer to the percentage of respondents in each village and community who considered the experience as the most important causes of discomforts or problems in their households.

on water system from floods and muds in the lowland areas. The highest number of respondents who were affected by lack of drinking water was found in the village of Cogonon. Those affected by lack of food were mostly residing in Cabinuangan, Bantacan, and Kahayag. Because Andap was most devastated by landslides and flash floods, food relief was concentrated on this village. In case of Cogonon, the village is small, and most households are accessible for post-disaster emergency support as compared to the other four villages. Loss of livelihood (7.0%) and homelessness (8.8%) are largest in Andap because the village is located at the foot of the mountain where the landslide impacts were highest.

House damages were highest in Cabinuangan because it is the most urbanized village with very high housing density (Table 3). About 5.7% of the respondents in this village considered damages on their houses as a serious problem. This percentage is higher than in Andap where only 0.9% of the respondents complained about house damages. Figure 3 reveals, however, that houses of more than 50% of respondents in Andap were

**Figure 3.** Extent of house damages from flood and landslide in New Bataan

Note: The percentage values refer to the proportion of respondents in each village and community who experienced the property impacts.

totally destroyed. In contrast, only less than 20% experienced total destruction of houses in Cabinuangan. The respondents in Andap considered house damages as a less important disaster impact because they were most affected by the deaths and injuries of family members, relatives, and neighbors. The extent of property damages in the rest of the villages was almost similar, both for IPs and non-IPs (Figure 3). Across all villages, less than two percent of the respondents consider house relocation, lack of medicine, lack of transportation, destruction of roads, and destruction of forest as important impacts of flood and landslide (Table 3).

Impacts on Livelihood

The main livelihood of the respondents is farming particularly among the IPs (Table 4). About 54% of IP respondents are farmers, and the number decreased by about 2% after the disaster. In contrast, there are only about 31% farmers among the non-IP respondents which decreased by about 5% after the disaster. Business, sales or self-employment are the other means of livelihood of the non-IPs, which slightly increased from 20.07 to 22.70% after the disaster. In contrast, these types of livelihood are less common among the IPs. Some IPs work in mining (3.68%), and the number of IP miners are higher both before and after the disaster. While there are only a few shifts in the types of livelihood among the IPs, changes in livelihoods are prevalent among non-IPs. Fishing and livestock raising turned out to be new sources of livelihood for both IPs and non-IPs. Part-time employment increased among IP respondents and decreased among non-IP respondents after the disaster. Jobs in mining, carpentry, local governments and school, offer new sources of livelihoods for some non-IP respondents. The negative impacts of disaster on the non-IPs are higher, with the number of non-IP respondents with no sources of livelihoods increasing from 7.57 to 11.18%.

Figure 4 further shows the extent of loss of livelihoods among the non-IPs. A higher number of non-IP respondents lost their livelihoods because their lowland farms were buried in rocks carried by the flash floods, while the IP respondents continued their farming activities because most of them were in the uplands. Consequently, the decrease in income was also lower among IP than the non-IP respondents (Figure 4). At the village level, loss of livelihoods was highest in Cogonon and Andap, but more respondents in the latter village had the capacity to change their livelihoods after the disaster. The decrease in income was lowest among respondents in Cabinuangan because only a few of them depended on agriculture-related livelihoods.

Typologies of Adaptive Capacity

Using the factor values for the cluster analysis resulted in four clusters, which represents varying levels of adaptive capacity of the respondents. Figure 5 shows the mean values across factors of adaptive capacity, with clusters 1 and 2 showing positive mean values and clusters 3 and 4 showing negative mean values. The

Table 4. Types of livelihood of IPs and non-IPs before and after the disaster, New Bataan

Types of livelihood	IP		Non-IP	
	Before disaster	After disaster	Before disaster	After disaster
Farmer	53.68	51.47	30.92	25.66
Fisher	-	-	-	0.33
Livestock raiser	-	0.74	-	0.33
Firewood-gatherer	2.21	2.21	0.66	0.33
Charcoal maker	-	-	0.33	0.33
Forest products gatherer	1.47	1.47	1.32	0.99
Copra producer	2.21	2.21	1.97	1.97
Miner	3.68	3.68	2.96	3.29
Carpenter	0.74	0.74	2.63	4.28
Part-time employee	4.41	5.88	6.58	3.95
Contract employee/ Laborer	3.68	3.68	9.21	9.54
Laundry/Maid	1.47	1.47	1.64	0.99
Mechanic	2.21	0.74	3.95	1.64
Driver	3.68	3.68	3.62	3.62
Business/Salesman/Self- employed	6.62	6.62	20.07	22.70
Official, teacher	2.21	2.94	1.32	3.62
Pensioner	0.74	1.47	1.64	1.64
Others, specify	0.74	0.47	0.33	0.99
Several livelihoods	5.15	5.15	3.29	2.63
No sources of livelihood	5.15	5.41	7.57	11.18

The values refer to the percentage of respondents in each community who are engaged in particular type of livelihood.

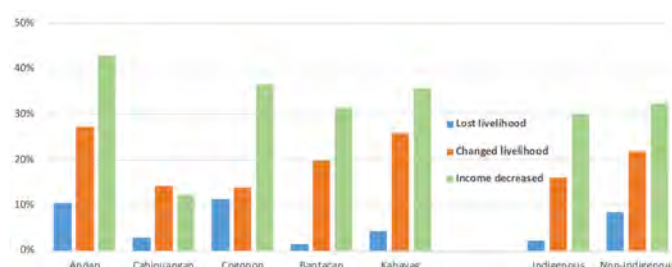


Figure 4. Impacts of flood and landslide on livelihoods in New Bataan

Note: The percentage values refer to the proportion of respondents in each village and community who experienced the property impacts.

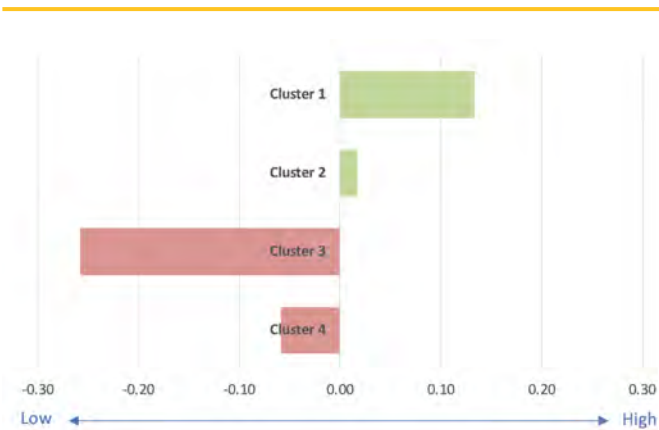


Figure 5. Mean value for all factors of adaptive capacity (AC), by cluster

Note: Cluster 1 has very high AC having a higher positive mean value; Cluster 2 has high AC having a lower positive mean value; Cluster 3 has very low AC having a higher negative mean value; and Cluster 4 has low AC having lower negative mean value. The specific determinants that contributed to the mean value in each cluster are presented in Table 5.

factors represent variables that have “eigenvalues” greater than one and highest contribution to the variance in the determinants of adaptive capacity (Appendix 1). High factor value implies that the respondents in a particular cluster have high capacity on specific determinants. Positive values thus mean higher adaptive capacity, while negative values mean lower adaptive capacity. Respondents in Cluster 1 with higher positive mean factor of 0.13 have very high level of adaptive capacity, and those in Cluster 2 with lower positive factor of 0.02 have only high level of adaptive capacity. In contrast, respondents in Cluster 3 with higher negative factor of 0.26 have very low adaptive capacity, and those in Cluster 4 with lower negative factor of 0.06 have low adaptive capacity.

Table A3 in the Appendix describes the two most important factors for each determinant and variables for each factor, which were identified from the factor analysis. The two factors (F1, F2) for each of the six adaptive capacity determinants are as follows:

- (1) previous landslide experience (F1) and level of knowledge (F2) for knowledge and experience
- (2) membership in organizations (F1) and information from the community (F2) for social learning
- (3) ability to support household (F1) and level of self-confidence (F2) for individual competence
- (4) access to adaptation support (F1) and reliable sources of household income (F2) for access to resources
- (5) effectiveness of community measures (F1) and household measures (F2) for intended adaptation
- (6) number and relevance of external support (F1) and success of implementing family support (F2) for performed adaptation.

The factors consist of two or three variables, except for factor 1 of social learning (i.e. membership in organizations) which has five variables. Moreover, Table A3 presents the mean values of

the factors for each cluster and determinant of adaptive capacity. Based on the average values of the two factors, we ranked the clusters from 1st to 4th, with 1st having the highest capacity for the respective determinants. Among the four clusters, Cluster 1 ranks 1st in social learning and 2nd in three other determinants of adaptive capacity including access to resource, intended and performed adaptations. Although Cluster 2 ranks 1st in access to resources and performed adaptation, it ranks only 3rd and 4th in four other determinants. Cluster 3 ranks 1st in both knowledge/experience and individual competence but, like Cluster 2, it ranks only 3rd and 4th in four other determinants. Finally, Cluster 4 ranks 1st in intended adaptation and 2nd in three other determinants.

Table 5 compares the mean values of the determinants of adaptive capacity for IP and non-IP respondents in the four clusters. Social learning, intended adaptation, and performed adaptation contribute to the very high adaptive capacity of both IPs and non-IPs in Cluster 1. Access to resources among the IPs is much lower than the non-IPs because of the IP respondents' lack of crop failure insurance, education support, and calamity support as well as less number of household members with skilled related income sources and employment contract. These can be attributed to the lack of education among the IPs with almost 60% without formal education or reaching only elementary education (Table 2). As compared to the non-IPs in Cluster 1, the IPs in the same cluster have relatively higher knowledge and experience on the local environment. About 45% of all IPs belong to Cluster 1 with very high adaptive capacity as compared to 35% of the non-IPs (Table 5). The determinants that differentiate Cluster 1 and Cluster 2 among the IP respondents are lower social learning, intended adaptation, and performed adaptation, while those for the non-IP respondents are knowledge and experience as well as social learning. Only 11% of the IP respondents have high adaptive capacity. This percentage is small compared to the 30% of the non-IP respondents.

Access to resources, intended adaptation, and performed adaptation are the determinants that contribute to the very low adaptive capacity for both the IP and non-IP respondents in Cluster 3 (Table 5). Also, non-IP respondents have very low social learning, particularly on membership in organizations. Intended adaptation is higher for Cluster 4 than Cluster 3, contributing to slightly better adaptive capacity of the IP and non-IP respondents in the former cluster. There are more IPs with low and very low adaptive capacity than the non-IPs. Figure 6 reveals that the largest number of IPs with very low adaptive capacity are in Bantacan, while those of non-IPs are in Kahayag. More than 50% of the IPs in Cabinuangan, Cogonon, and Kahayag have very high adaptive capacity. The majority of non-IPs with very high adaptive capacity are living in Cogonon. Overall, IPs and non-IPs in Cabinuangan and Cogonon have better adaptive capacity, with relatively low number of respondents with a low and very low level of adaptive capacity.

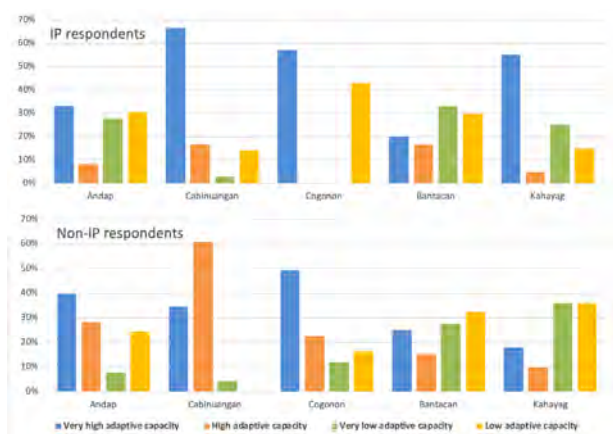
Table 5. Mean values of the determinants of adaptive capacity (AC), by community

Determinants	IP Cluster				Non-IP Cluster			
	1	2	3	4	1	2	3	4
	Very high	High	Very low	Low	Very high	High	Very low	Low
Knowledge & experience	0.03 (0.51)	0.02 (0.36)	0.25 (0.58)	-0.04 (0.58)	-0.01 (1.02)	-0.13 (0.45)	0.08 (0.70)	0.03 (0.69)
Social learning	0.38 (0.51)	-0.52 (0.48)	0.10 (0.65)	0.04 (0.95)	0.39 (0.49)	-0.60 (0.39)	-0.15 (0.79)	0.00 (0.71)
Individual competence	-0.18 (0.77)	-0.13 (0.69)	0.08 (0.65)	0.04 (0.76)	-0.19 (0.82)	0.10 (0.55)	0.27 (0.54)	0.14 (0.62)
Access to resources	-0.16 (0.24)	0.17 (0.78)	-0.01 (0.71)	-0.16 (0.23)	0.06 (1.10)	0.18 (0.65)	-0.03 (0.56)	-0.14 (0.30)
Intended adaptation	0.17 (0.65)	0.09 (0.85)	-0.86 (0.48)	0.44 (0.57)	0.15 (0.62)	0.15 (0.51)	-0.91 (0.50)	0.13 (0.59)
Performed adaptation	0.28 (0.57)	0.22 (0.61)	-0.61 (0.60)	-0.48 (0.55)	0.36 (0.55)	0.41 (0.41)	-0.70 (0.68)	-0.51 (0.55)
Percent of respondents	45%	11%	19%	25%	35%	30%	15%	20%

Notes:

The level of adaptive capacity of the clusters is based on the overall values of the factors in Figure 5. The mean factor values in Table 5 reveals the specific determinants of adaptive capacity that contributed to the overall level of adaptive capacity.

Values in parentheses are standard deviation. Lower standard deviation means that the values in this cluster are relatively close to each other, and higher standard deviation means the opposite. The latter implies that the answers of the respondents to the questions included in the factor analysis have high variance. Lower standard deviations are thus preferred than higher ones.

**Figure 6.** Distribution of respondents by level of adaptive capacity and by village

Conclusions

The paper aimed to assess the adaptive capacity of IPs by comparing them to the non-IPs. The results revealed that a higher number of IPs have low and very low adaptive capacity than non-IPs. The main factor that lowers the adaptive capacity of the former is (lack of) access to resources including education and calamity support as well as skilled and contract-basis types of employment. Most IPs rely on agriculture-related livelihoods which are most vulnerable to floods and landslides. Only very few of them shifted to other types of livelihoods or diversified their sources of livelihoods. There are two possible reasons for the lack of flexibility or diversification among IPs.

First, many of them live in the upland area so that although their farms suffered from erosion, they could still be cultivated after the disaster. This is in contrast with many farms of the non-IPs in the lowland areas that were covered with thick sand and large stones. Second, the IPs have lower level of education and cannot easily find alternative non-agriculture livelihoods that require skills. These reasons are observed to have long-term implications on the adaptive capacity of the IPs. Considering the increasing risk from typhoons and high landslide risk in Compostela Valley, the IPs will need to shift or diversify their sources of income. Education and capacity building are key to increasing access to resources among the IPs, who have lower levels of education than the non-IPs. These will increase their ability to gain access to local government support and diversify their sources of livelihoods.

Acknowledgements

The authors would like to thank the people who participated and local officials who supported the conduct of the survey and participatory rural appraisal. They also acknowledged the support of faculty members from the Compostela Valley College in conducting the survey, particularly Nerivic H. de Asis, Khristine L. Callano, Glory Jean C. Coloner, Franz Josef B. Gonzales, Joeyna M. Jamero, Queenie Mae L. No, Karolyn O. Palingcod and Kristyl Aiah S. Uchang (in alphabetical order). The paper is based on the project on Agent-based Modeling of sustainable livelihoods for vulnerable people to adapt to the impacts of flood-related landslides in the Philippines with funding support from The Oscar M. Lopez Center for Climate Change Adaptation and Disaster Risk Management Foundation Inc.

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Appendix 1 Description and results of statistical analyses

Factor analysis

Following the Awareness-Ability-Action framework in Figure 1, six-factor analyses were conducted using sets of variables corresponding to knowledge and experience, social learning, individual competence, access to resources, intended adaptation, and performed adaptation. The details of the 51 variables included in the factor analyses are presented in Table A1. To check how well the variables have loaded (or bundled) together, the authors used the Bartlett's Test of Sphericity to determine the level of significance of the correlation matrix. The criteria for acceptability of a factor solution were based on exclusion of items with factor loadings less than 0.60. The Kaiser-Meyer Olkin (KMO), a method that compares the observed with the partial correlation coefficients, was used to check the appropriateness of the data for the cluster analysis. A KMO with a value of 0.50 and higher were considered as

appropriate. KMO values far below 0.50 mean that the factor group is not good and individual variables should be checked (i.e. using anti-image matrix) and, if necessary, eliminated. The authors ran the models several times to come up with acceptable KMO values by eliminating redundant variables. The method applied for extracting the factors is the principal component analysis. The extraction is based on eigenvalues greater than 1. The eigenvalue measures the strength of a factor. Only factors with eigenvalues above one were considered to have met the minimum criteria for the analysis, i.e. correlation between the variables. Those selected factors with higher variances will be more useful for the cluster analysis. Finally, the authors used the rotated component matrix to allow us to identify the variables that loaded together. The method used for the factor rotation is varimax, which minimizes the number of variables that have high loading on a factor.

Table A1. Description of the variables included in the factor analysis

Variables	Question	Answer (numbers in parenthesis are the codes)
Awareness		
Knowledge & Experiences (KE)		
KE1	Number of years residing in the barangay	(1) Five years and below, (2) 6 to 15 years, (3) 16 to 30 years, (4) 31 to 50 years, (5) 50 years and above
KE2	Respondent's Age	(1) 30 years and below, (2) 31-50 years, (3) 51-70 years, (4) 71 years and above
KE3	Respondent's education level	(0) No formal Education, (1) Elementary, (2) High School, (3) Vocational/Technical School, (4) College/University graduate, (6) MS, PhD
KE4	Have you experienced floods or landslides in your Barangay before this flood/landslide (i.e. 2012 in Davao)?	(0) No, (1) Yes
KE5	If yes, please describe those previous floods or landslides with this one.	(0) No, (1) Knee level, (2) Waist level, (3) Head level, (4) Above head
KE6	Do you think that your household members are knowledgeable in performing the necessary actions during calamities?	(0) No, (1) Maybe, (2) Yes
KE7	Do you think there is a probability that such calamities will happen again in your community?	(0) No, (1) Maybe, (2) Yes
Social Learning (SL)		
SL1	Does your community/tribe have regular activities?	(0) No, (1) Yes, once a month, (2) Yes, once a week, (3) Yes, more than once a week
SL2	How often do you go to your church or mosque? Please tick your answer(s).	(0) Almost never, (1) Once a year, (2) After several months, (3) Once a month, (4) Once a week, (5) Several times a week, (6) Others
SL3	Are you a member of any organization, including your tribal organization(s)?	(0) No, (1) Yes
SL4	If yes, please provide the following information about your membership in this organization(s). Type of organization	

Table A1. Continued

Variables	Question	Answer (numbers in parenthesis are the codes)
SL3	Are you a member of any organization, including your tribal organization(s)?	(0) No, (1) Yes
SL4	If yes, please provide the following information about your membership in this organization(s). Type of organization	
SL5	Position in the Organization	(0) None, (1) Member, (2) Officer
SL6	Participation in the organization - before	(0) Question not relevant, (1) Inactive, (2) Active
SL7	Participation in the organization - after	(0) Question not relevant, (1) Inactive, (2) Active
	What sources of information about the consequences of flood/landslide?	(0) No, (1) Before the disaster, (2) After the disaster, (3) Both after and before the disaster
SL8	Municipal Officials	
SL9	Barangay Officials	
SL10	Friends	
SL11	Neighbors	
SL12	Non-government organizations (NGOs)	
Ability		
Individual Competence (IC)		
IC1	Total number of HH members (i.e. respondent, spouse, children, others) with physical and mental disabilities	(1) 7 and above, (2) 5-6 persons, (3) 3-4 persons, (4) 2 persons, (5) 1 person, and (6) None
IC2	Total number of HH members (i.e. respondent, spouse, children, others) with chronic diseases	(1) 7 and above, (2) 5-6 persons, (3) 3-4 persons, (4) 2 persons, (5) 1 person, and (6) None
	What kinds of support does your family usually get from/ give to your relatives, friends, or neighbors? Please tick your answer(s).	(0) No, (1) Get from others, (2) Give to others, (3) Both above
IC3	taking care of children	
IC4	farm activities	
IC5	financial support	
IC6	selling family harvest	
	Rank 3 important feelings on devastation	(1) Most important, (2) Important, (3) Less important, (4) Not important
IC7	Fear	
IC8	Self-pity	
IC9	Loss of hope	
IC10	What is the size of your household?	(1) more than ten persons, (2) 7-9 persons, (3) 4-6 persons, and (4) 1-3 persons
IC11	Total number of small/minor children (18 years and below)	(1) 7 and above, (2) 5-6 children, (3) 3-4 children, (4) 2 children, (5) 1 child, and (6) None
	Total number of children with education in high school and below	(1) 7 and above, (2) 5-6 children, (3) 3-4 children, (4) 2 children, (5) 1 child, and (6) None
IC12	How will you describe the structure of your household?	(0) Single, (1) Nuclear, (2) Extended

Table A1. Continued

Variables	Question	Answer (numbers in parenthesis are the codes)
Access to resources (AR)		
AR1	education support	
AR2	calamity support	
AR3	crop failure insurance	
AR4	Total number of HH members (i.e. respondent, spouse, children, others) with skilled related income sources	(1) None, (2) 1 person, (3) 2 persons, (4) 3 persons, (5) 4 persons and above
AR5	Total number of HH members (i.e. respondent, spouse, children, others) with employment contract related income sources	(1) None, (2) 1 person, (3) 2 persons, (4) 3 persons, (5) 4 persons and above
AR6	Total number of HH members (i.e. respondent, spouse, children, others) with external income sources	(1) None, (2) 1 person, (3) 2 persons, (4) 3 persons, (5) 4 persons and above
AR7	Total number of HH members (i.e. respondent, spouse, children, others) with no sources of income	(1) None, (2) 1 person, (3) 2 persons, (4) 3 persons, (5) 4 persons and above
	Rank 3 important feelings on devastation	(1) Most important, (2) Important, (3) Less important, (4) Not important
IC7	Fear	
Action		
Intended Adaptation (IA)		
	What set of procedures would you follow in case there is an emergent calamity?	
IA1	House procedure	(0) None, (1) Stay at home/indoors, (2) Pray, (3) Be informed about typhoon, (4) Alertness/preparedness, (5) Prepare/pack things, (6) Prepare and evacuate to safe place, (7) Go to people who provide support, (8) Others
IA2	Barangay procedures	(0) None, (1) I do not know, (2) Wait for instruction/news from officials, (3) Contact officials/ask for help or information, (4) Follow warning and officials, (5) Information dissemination [i.e. roving, meeting, seminar], (6) Evacuation/Relocation, (7) monitor situation [i.e. flood watch, water gauge], (8) others
IA3	Municipal procedures	(0) None, (1) I do not know, (2) Wait for instruction/news from officials, (3) Contact officials/ask for help or information, (4) Follow warning and officials, (5) Information dissemination [i.e. roving, meeting, seminar], (6) Evacuation/Relocation, (7) monitor situation [i.e. flood watch, water gauge], (8) others
IA4	Are there systematic ways of informing the public regarding the sudden occurrence of calamities in your community?	(1) Do not know, (2) No, (3) Yes
Performed Adaptation (PA)		
	What support and measures did you give/do on the actual incident of the flood/landslide to your:	
PA1	Family	(0) None, (1) stayed at home, hid somewhere safe, (2) Helped the family, gave clothing, (3) evacuated to LGU-assigned evacuation center (i.e. school), (4) Went to relatives/neighbor's house, (5) evacuated to the church, (6) Went to the roof, (7) Received food/assistance from relatives/organizations, (8) Ran to higher grounds, (9) Climbed coconut trees, (10) Prayed, (11) Combination of 8 & 10, (12) Evacuated to neighboring barangay/city

Table A1. Continued

Variables		Question	Answer (numbers in parenthesis are the codes)
PA2	Property		(0) None/ left the property without packing their things, (1) Stayed at home, (2) Packed things, placed in elevated parts and left home, (3) Followed officials' warnings, (4) Packed their bags and brought it with them
PA3	Did you seek for a loan or borrow money after the flood/landslide?		(0) No, (1) Yes
PA4	Did you receive any assistance from any programs that aim to assist disaster victims?		(0) No, (1) Yes
	If yes, please describe the disaster assistance program. Please use the corresponding codes below.		TYPE: (1) Food, (2) Medicine, (3) Drinking water, (4) Clothing, (5) Temporary shelter, (6) Housing relocation, (7) Money, (8) Cooking utensils, (9) Employment, (10) Livelihood support, (11) Others SOURCES: (1) Barangay office, (2) Municipal government, (3) Provincial government, (4) Religious Organization, (5) NGO's, (6) Private organization, (7) Private company, (8) Politician, (9) Others TIMING: (1) During the flood/landslide, (2) Directly after flood/landslide, (3) One week after flood/landslide, (4) One month after flood/landslide, (5) Few months after flood/landslide, (6) One year after flood/landslide, (7) Others DURATION: (0) No, (1) One day, (2) One week, (3) One month, (4) One to 6 months, (5) 6 to 12 months, (6) One year USEFULNESS: (1) Not useful, (2) Slightly useful, (3) Moderately useful, (4) Very useful, (5) Extremely useful
PA5	Total number of programs		(0) No programs, (1) 1 program, (2) 2 programs, (3) 3 programs, (4) 4 programs, (5) 5 programs, (6) 6 programs
PA6	Total types		(1) Food, medicine, drinking water, clothing, cooking utensils, (2) Temporary shelter, housing relocation, (3) Money, employment, livelihood support, others, (4) Combination of 1 & 2, (5) Combination of 2 & 3, (6) Combination of 1 & 3, (7) Combination of 1, 2 & 3
PA7	Total source		(1) Barangay office, Municipal Government, Provincial government, Politician, (2) Religious Organization, (3) NGO's, (4) Private organization, Private company, (5) Others, Relief goods, (6) Combined
PA8	Did you relocate your residence or do you have any plan to relocate your residence?		(0) No, (1) Yes
PA9	Were you able to reconstruct your house?		(0) No, (1) Yes

The factors were used as inputs to the clusters, which became the basis for developing typologies of adaptive capacity. The Bartlett's Tests in Table A2 show that the level of significance of all models is very high at less than 1% level. Moreover, the variables in most models loaded to 3 factors, except for access to resources and intended adaptation with only two factors each. The authors checked the variance of the factors to determine how well the variables contributed to the variation in each model. Factors with very high variance are preferred inputs to the cluster analysis because they can reveal the difference in adaptive attribute and behavior of respondents. Table A2 shows that the first two factors alone already contribute to about 50% of the variance in the models, except for the individual

competence and access to resources. For this reason, for each determinant, the authors only used Factors 1 and two as inputs to the cluster analysis. This is to facilitate better interpretation of cluster results.

Table A2. Total variance of factors and results of KMO and Bartlett's Test for each determinant

Factors	Initial Eigenvalues			Rotation Sums of Squared Loadings			Kaiser-Meyer-Olkin (KMO)	Bartlett's Test of Sphericity	
	Total	% Variance	Cumulative %	Total	% Variance	Cumulative %		Chi-Square	Sig.
Knowledge and experience									
Factor 1	1.938	27.686	27.686	1.889	26.984	26.984	0.508	713.504	0.000
Factor 2	1.410	20.149	47.835	1.407	20.097	47.081			
Factor 3	1.146	16.374	64.208	1.199	17.127	64.208			
Social learning									
Factor 1	4.630	38.580	38.580	4.601	38.344	38.344	0.855	4577.847	0.000
Factor 2	2.001	16.672	55.251	1.666	13.880	52.224			
Factor 3	1.107	9.222	64.473	1.449	12.073	64.297			
Individual competence									
Factor 1	2.123	17.690	17.690	2.109	17.578	17.578	0.607	533.581	0.000
Factor 2	1.457	12.144	29.834	1.405	11.709	29.287			
Factor 3	1.235	10.290	40.124	1.258	10.484	39.771			
Access to resources									
Factor 1	2.364	21.488	21.488	1.765	16.043	16.043	0.515	1478.563	0.000
Factor 2	1.877	17.064	38.553	1.748	15.887	31.930			
Factor 3	1.552	14.109	52.662	1.743	15.849	47.780			
Intended adaptation									
Factor 1	1.716	42.910	42.910	1.714	42.839	42.839	0.567	193.020	0.000
Factor 2	1.053	26.322	69.232	1.056	26.393	69.232			
Performed adaptation									
Factor 1	2.430	27.005	27.005	2.112	23.472	23.472	0.665	592.625	0.000
Factor 2	1.388	15.425	42.430	1.703	18.925	42.397			
Factor 3	1.143	12.697	55.127	1.146	12.731	55.127			

Cluster analysis

Cluster analysis is a convenient method for identifying homogeneous groups of objects, cases, and observations called clusters, where objects share many characteristics within a particular cluster and are very dissimilar to objects belonging to other (outside) cluster. Hierarchical grouping procedure was applied to determine the optimal number of clusters evident in the data. The authors checked its dendrogram, which gives an idea of how great the distance is between cases (i.e. respondents) that are clustered (i.e. the closer the distances, the

smaller the differences in between the cases, and vice versa). The authors used the number of clusters indicated by the dendrogram as input to the two-step clustering procedure. The two-step clustering algorithm used was log-likelihood distance measure because, unlike Euclidean Distance, it can handle both continuous and categorical variables. Figure A1 presents the cluster membership of the respondents generated from the two-step clustering. Cluster 1 has the largest number of respondents (37.3%) and Cluster 3 has the smallest number of respondents (16.6%). After identifying the cluster memberships of the cases in the clusters, a tabular analysis of the clustered attributes was

used to conduct matrix scoring (Table A3). Factor 1 in social learning has the largest number (5) of variables, while the rest of the factors have between 2 and 3 number of variables. The factors represent variables that have “eigenvalues” greater than one and highest contribution to the variance in the determinants of adaptive capacity (Table A2). High factor value implies that the respondents in a particular cluster have high capacity on specific determinants. Positive values thus mean higher adaptive capacity, while negative values mean lower adaptive capacity. The results of matrix scoring revealed that Cluster 1 has very high adaptive capacity and Cluster 2 has a high adaptive capacity. In contrast, Cluster 3 has very low adaptive capacity and Cluster 4 has low adaptive capacity.

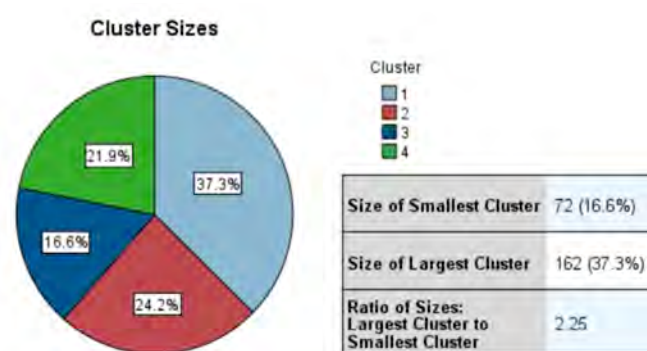


Figure A1. Cluster sizes and distribution

Table A3. Mean values of factors for the different determinants of adaptive capacity, by cluster

Factors of determinants		Description of the variables*		Cluster**			
				1	2	3	4
				Very High AC	High AC	Very Low AC	Low AC
Knowledge and experience		3rd	4th	1st	2nd		
Factor 1 - Previous landslide experience	Height of mud during previous landslide experience [1], Previous experience on landslide [2]	0.12 (1.41)	-0.18 (0.11)	0.05 (0.98)	-0.06 (0.58)		
Factor 2 - Level of knowledge	Years of age [1], Years residing in the village [2]	-0.11 (0.99)	-0.04 (0.86)	0.22 (1.09)	0.08 (1.07)		
Social learning		1st	4th	3rd	2nd		
Factor 1 - Membership in organizations	Membership in organizations [1], Active participation before [2] and after [3] the landslide, Position in the organization [4], Type of the organization [5]	0.92 (0.51)	-0.82 (0.52)	0.02 (0.99)	-0.74 (0.58)		
Factor 2 - Information from the community	Most important sources of information include neighbors [1] and friends [2]	-0.15 (0.78)	-0.36 (0.63)	-0.14 (0.92)	0.77 (1.31)		
Individual competence		4th	3rd	1st	2nd		
Factor 1 - Ability to support household	Characteristics of the household in terms of the number of small/minor children [1], children with low education [2], and household members [3]	-0.10 (0.98)	-0.12 (0.92)	0.23 (1.01)	0.13 (1.09)		
Factor 2 - Level of self-confidence	Feeling of self-pity [1] and fear [2] during typhoons	-0.28 (1.36)	0.26 (0.65)	0.18 (0.61)	0.07 (0.64)		
Access to resources		2nd	1st	3rd	4th		
Factor 1 - Access to adaptation support	Availability of crop failure insurance [1], education support [2], and calamity support [3]	0.03 (1.34)	-0.12 (0.42)	0.15 (1.21)	-0.03 (0.41)		
Factor 2 - Reliable sources of household income	Number of household members with skilled related income sources [1] and employment contract [2]	-0.06 (0.84)	0.48 (1.47)	-0.21 (0.70)	-0.26 (0.54)		
Intended adaptation		2nd	3rd	4th	1st		
Factor 1 - Effectiveness of community measures	Procedures to follow in case of calamities at the village [1], municipal [2], and house levels [3]	0.22 (0.92)	-0.17 (0.75)	-1.25 (0.54)	0.75 (0.66)		
Factor 2 - Effectiveness of household measures	Systematic ways for informing community [1] and House procedures to follow [2] in case of calamities	0.10 (1.09)	0.45 (0.78)	-0.54 (0.80)	-0.27 (0.92)		

Table A3. Continued

Factors of determinants	Description of the variables*	Cluster**			
		1	2	3	4
		Very High AC	High AC	Very Low AC	Low AC
Performed adaptation		2nd	1st	4th	3rd
Factor 1 - Number and relevance of external support	Number [1], types [2] and sources [3] of assistance programs received after the landslide, Recipient of disaster assistance programs	0.40 (0.88)	-0.08 (0.66)	-0.67 (1.34)	-0.11 (0.89)
Factor 2 - Success of implementing family support	Relocated the family after the landslide [1], Type of support/measure given to family during the landslide [2], Reconstructed the house after landslide [3]	0.25 (0.90)	0.85 (0.75)	-0.66 (0.61)	-0.88 (0.52)

Notes:

*Values in brackets refer to the number of the variables in the factor analysis.

**Values in parentheses are standard deviation. Lower standard deviation means that the values in this cluster are relatively close to each other, and higher standard deviation means the opposite. The latter implies that the answers of the respondents to the questions included in the factor analysis have high variance. Lower standard deviations are thus preferred than higher ones.

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