Coastal Vulnerability Assessment: The Case of Davao del Norte, Philippines

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Date received: March 6, 2018
Revision accepted: May 21, 2018

Abstract

Coastal vulnerability assessment is essential in formulating strategies to reduce adverse impacts of climate change. Thus, this study was conducted to help local government units (LGUs) and other concerned agencies and communities to identify priority areas for disaster risk reduction and management in the province of Davao del Norte, Philippines. It measures the degree of sensitivity, exposure and adaptive capacity of coastal resources in all coastal areas in the province using the Coastal Integrated Vulnerability Assessment Tool (CIVAT) adopted from Marine and Resources Foundation, Inc. (MERF). The study revealed that there were six natural disturbances of coastal areas. These include heavy rainfall, tropical cyclone, El Niño, flood, coastal erosion, and strong wind or habagat. Majority of the coastal areas were moderately exposed, sensitive, and adaptive to adverse impacts of natural hazards. In general, coastal areas in the province were moderately vulnerable to natural hazards except for Barangay Dadatan in Island Garden City of Samal (IGCS), which was highly vulnerable. In terms of prioritization for disaster risk reduction and management interventions, barangays Tambo, Ballet, San Isidro, Tagpopangan, San Miguel, La Suerte Lapaz, Pangubatan, Poblacion Kaputian, Tagbaobo, Taba, JP Laurel, San Jose, Tagbay, Poblacion-Libertad, and Aumbay should highly be prioritized.

Keywords*:* coastal vulnerability, natural hazards, sensitivity, exposure, adaptive capacity

1. Introduction

The Philippines is considered as one of the highly vulnerable areas to the adverse impacts of climate change. In fact, the country ranked seventh as the

most vulnerable based on long-term exposure and extreme events from 1990 to the present (Harmeling, 2011). Climate change threatens coastal zones and considered as key sector hotspot (IPCC, 2001). The expected major coastal effects of this event are permanent inundation of low-lying areas, increased flooding due to extreme weather events and greater erosion rates affecting beaches and cliffs (Nicholls *et al*., 2007). The changing climatic condition could also lead to salt-water intrusion, wet-land damage and bio-diversity loss (IPCC, 2007).

The growing uncertainties of adverse impacts of climate change lead to the government's continuous efforts in exploring and developing adaptation measures to help coastal communities to be resilient and climate-responsive. To help local and national government to identify highly vulnerable areas, this study was conducted. The main intention of this investigation was to assess the vulnerability of coastal areas in Davao del Norte to climate-induced hazards at the local and community scale. Specifically, it aimed to determine the natural hazards affecting coastal areas; level of sensitivity, exposure and adaptive capacity of physical resources; the potential impact and vulnerability indices of coastal barangays; and the least and utmost priority areas for natural disaster risk reduction and management actions in Davao del Norte.

2. Methodology

This study utilized descriptive research design of quantitative research. Both primary and secondary data were used in the assessment of coastal vulnerability. Primary data included beach assessment and monitoring based on the observations of household-respondents living in coastal zones for at least five years. On the other hand, secondary data like climatic events and Google maps were considered as supplementary data. The study adopted the survey instrument known as CIVAT (MERF, 2013). A quota sampling was applied in the selection of respondents and key informants. At least three informants/respondents were considered for every coastal barangay. A total of 109 local informants were interviewed during the field survey. Further, these respondents were mostly LGU officials or employees like barangay chairman, *kagawad*, treasurer, secretary and/or Barangay Disaster Risk Reduction and Management Officers (BDRRMOs). There were also respondents from environmental groups and local households residing in the area for at least 10 years.

To determine the climatic hazards affecting the coastal areas of the province, frequency and percentage distribution of descriptive statistics was employed. On the other hand, bar graph was used in presenting the secondary data. As to the level of exposure, sensitivity and adaptive capacity, Likert scale of 1 to 5 (5 being the highest) was adopted based on best available data, expert advice, or knowledge of long-time coastal residents. In measuring the exposure, sensitivity and adaptive capacity of coastal areas, the study followed the systematic procedure of CIVAT version 1.0. The formula below was used in vulnerability assessment.

$$Vulnerability\ Index = Potential\ Impact\ Index\text{-}Adaptive\ Capacity\ Index \quad (1)$$

where:

$$Potential\ Impact\ Index = \frac{Total\ Potential\ Impact\ Score}{Total\ Max\ Potential\ Impact\ Score}$$

$$Adaptive\ Capacity\ Index\ \frac{Total\ Adaptive\ Capacity\ Score}{Total\ Max\ Adaptive\ Capacity\ Score}$$

The categories used in the study are present in Table 1.

Table 1. Score range and descriptive rating for coastal vulnerability assessment

	Score Range	Descriptive Rating
Exposure:		
	3 – 7	Low
	8 – 11	Medium
	12 -15	High
Sensitivity:		
	9 – 21	Low
	22 – 33	Medium
	34 – 45	High
Adaptive Capacity:		
	5 – 11	Low
	12 – 18	Medium
	19 – 25	High
Potential Impact:		
	12 – 28	Low
	29 – 44	Medium
	45 - 60	High

To determine the range and classification of vulnerability, a cross-tabulation method suggested by Siringan *et al.* (2013) was adopted. The decision matrix is presented in Table 2.

Table 2. Decision matrix of coastal vulnerability assessment

		Adaptive Capacity		
		Low	Moderate	High
Potential Impact	Low	Moderate	Low	Low
	Moderate	High	Moderate	Low
	High	High	High	Moderate

Adaptive capacity-urgency inter-relational matrix was also used in plotting the most and least priority coastal barangays in the region. In the prioritization, the potential impact was the bases in measuring the urgency. Both, urgency (y-axis) and adaptive capacity (x-axis) were used to determine the first, second, third and fourth priority areas. The two variables were categorized into low, moderate and high based on descriptive statistical analysis such as mean, standard deviation, minimum and maximum. Lastly, Geographic Information System (GIS) was utilized to develop maps for sensitivity, exposure, adaptive capacity, potential impacts and vulnerability of coastal areas.

3. Results and Discussion

3.1 Natural Hazards of Coastal Areas in Davao del Norte

A natural hazard is a natural phenomenon that might have a negative effect on people or the environment. Natural hazards are grouped into two broad categories, the geophysical hazards and biological hazards. Geophysical hazards encompass geological and meteorological phenomena such as earthquakes, volcanic eruption, wildfire, cyclonic storms, flood, drought, and coastal erosion. Majority of these geophysical hazards are interrelated such as earthquakes that can cause tsunamis which can lead to coastal flooding and erosion. These will expose resources and communities to risk of property damage, loss of life and environmental degradation in lowland, upland, and coastal areas. In Davao del Norte, six natural hazards affect coastal areas in previous years. These include heavy rainfall, tropical cyclone, El Niño, flood, coastal erosion, and strong wind (Table 3).

Table 3. Distribution of natural hazards experienced by municipality/city

Natural Hazard	Municipality/City							
	Carmen	%	Panabo City	%	Island Garden City of Samal (IGCS)	%	Tagum City	%
Tropical Cyclone	2	20	2	25	7	11	20	39
Heavy Rainfall	6	60	3	38	21	33	21	41
Coastal Erosion	1	10	1	13	6	9	0	0
El Niño	1	10	1	13	26	41	0	0
Flood	0	0	1	13	0	0	10	20
Strong wind/*Habagat*	0	0	0	0	4	6	0	0
Total*	10	100	8	100	64	100	51	100

*Multiple responses

3.1.1 Heavy Rainfall

In general, heavy rainfall is the most common and frequently experienced natural hazard across coastal areas of the province except for IGCS. Rain is classified as heavy if intensity is more than 100mm per 24 hours. This event is usually accompanied by substantial changes in the climatic condition and expected to vary continuously in the coming years (Bates *et al*., 2008; Gutowski *et al*., 2008). Based on the secondary data from PAGASA, monthly average rainfall of the province is over 100 mm since 2011 to 2015. Heavy rainfall generally occurs during the months of May to July and November to January which exceeds 200 mm. Last January 2017, the province was declared by the government in state of calamity due to heavy rainfall that flooded various areas. This extreme rainfall event can give many impacts on the integrity of coastal system and vegetation by affecting the stability of soils and the erosion, transport, and deposition of sediments (Cahoon, 2006; Cahoon *et al.*, 2009).

3.1.2 Tropical Cyclone

According to state weather bureau PAGASA, the Philippines was visited by at least 20 tropical cyclones every year. The weather bureau typically categorize tropical cyclones according to 1) tropical depression (less than 63km/h maximum winds); 2) tropical storm (62km/h-88km/h maximum winds); 3) severe tropical storm (89km/h-117km/h maximum winds); 4) typhoons (118km/h-220km/h maximum winds); and 5) super typhoons (more than 220km/h maximum winds). The occurrence of typhoons and other severe storms in the country are likely local manifestations of global climate trends (Amadore, 2005).

3.1.3 El Niño

The El Niño is often associated with drought and stresses on water resources. This climatic event is due to fewer tropical cyclones, delayed onset of the rains, and weak monsoon activity. One of the significant drought events happened in April 2016 wherein Panabo City was declared under the state of calamity (Regalado, 2016). This is also the primary hazard affecting coastal areas in IGCS that causes problem on the availability and access to potable water, agriculture and other household use. Increasing drought event in some coastal areas could lead to higher rates of evapotranspiration, increased groundwater withdrawals, and eventually, water shortages among coastal communities (Hatfield *et al*., 2008).

3.1.4 Flood

The study also found that flood is the fourth natural hazard that hit the province. Flood is a natural event wherein dry land areas of suddenly get submerged under water. Flooding is sometimes resulting from a coastal storm, dam break, or a heavy rainfall within coastal zones (Kirschen *et al*., 2008; Moser and Tribbia, 2006). This is usually experienced in Panabo City and Tagum City but rarely happened in coastal areas of Carmen and IGCS. In 2017, PAGASA placed Davao del Norte into blue alert status after experiencing heavy rainfall due to the tail end of the cold front that flooded several communities and displaced hundreds of families (Revita, 2017). This natural hazard continuously disrupts social and economic activities as well as physical assets; thus, considering it as the significant problem for many areas (Arctic Climate Impact Assessment, 2005; Polyak, *et al*., 2010; United States Government Accountability Office, 2009). With this, developing and protecting floodplains in the province is necessary to help preserve the natural functions of ecosystems and to prevent loss of life and property from damaging in the future.

3.1.5 Coastal Erosion

Local households and experts also cited coastal erosion in shorelines of Davao del Norte as one of the natural hazards experienced in previous years. According to the respondents, coastal erosion occurred in response to smaller-scale events, such as storms, regular wave action, tides and winds, excluding human activities. This is occasionally experienced in Carmen, Panabo City and IGCS while no reports were found in Tagum City. In IGCS, coastal erosion is prominent in the north and western portion of the island (Figure 1).

Figure 1. Deeply eroded shoreline in the Northwestern portion of IGCS
(Source: Department of Environment and Natural Resources (DENR) - Region XI)

The absence of mud or sand and continued exposures of coralline materials would denote coastal erosion. For this reason, many of the resort owners has established coastal protection structures such as groynes and sea walls in the past to protect their beaches or at least retain a portion of sandy beach. Based on Google Earth imageries, there are 168 coastal protection structures, mainly groyne, jetties and seawall in north and western side of the island compared to seven in the combined areas of eastern and southern portion.

Generally, coastal erosion in the province is concentrated in the most sensitive coastlines like along sand and gravel beaches. This physical hazard was directly correlated to climatic condition. For instance, erosion of coastal cliffs in eastern Newfoundland, Canada is correlated to wind direction and the temperature condition (Brake, 2008; Ingram, 2004; Catto *et al*., 2003; Speller, 2001; White, 2002).

3.1.6 Strong Wind/*Habagat*

Key informant and survey respondents stated that moderate to strong winds that blew from northeast to northwest causes moderate to rough coastal waters in the province. This event usually happened in IGCS while no response found in Carmen, Panabo City and Tagum City. This event is normal in IGCS as it is fronting to the southern border of Davao Gulf. This island is also protecting the coastal and mainland areas of Panabo, Tagum and Carmen as buffer zone from direct hit of strong wind or *habagat*.

3.2 Level of Exposure, Sensitivity and Adaptive Capacity of Coastal Areas in Davao del Norte

3.2.1 Exposure

Coastal areas of Davao del Norte are moderately exposed to climatic hazards with an overall mean of 8.67. Moreover, the degree of exposure differs

according to municipal or city's jurisdiction as reflected in Figure 2. In the municipality of Carmen, coastal areas of barangay Taba and Lapaz are moderately exposed to hazards as perceived by the key informants. In addition, Panabo City was found to have low exposure to natural hazards. Specifically, barangay San Pedro and JP Laurel are exposed in low extent while barangay Cagangohan is exposed in moderate extent. In IGCS, coastal barangays are moderately exposed to disastrous climatic conditions. Barangay San Isidro; San Isidro, Kaputian; Aundanao; San Miguel; Catagman; Adecor; Cawag; Peñaplata; Poblacion, Libertad; Tagbay; Limao; Tagbabao; Canaan; Poblacion-Kaputian; Aunbay; San Remideo; Kinawitnon; Tagpopangan; Miranda; Tambo; Villarica; and Camudmud have moderate exposure to climatic hazards. In contrast, Barangay San Jose; Pangubatan; Caliclic; Ballet; Libuak; as well as Barangay Sta. Cruz and Dadatan of Talikud are exposed in low extent.

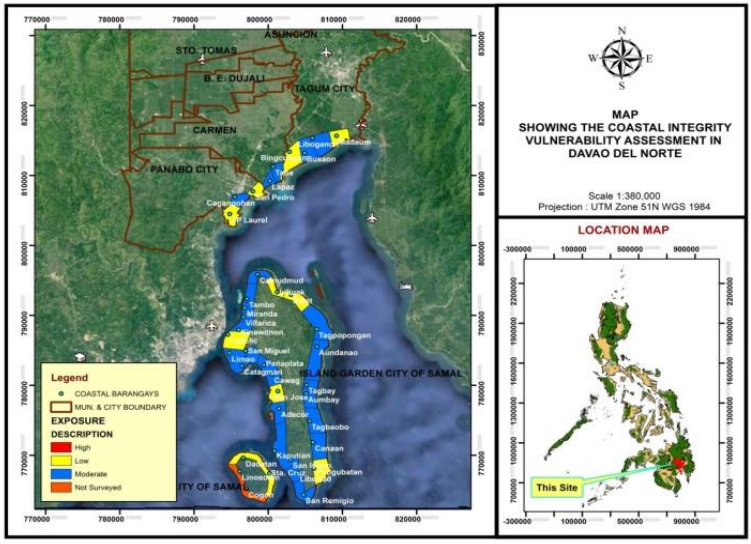

Figure 2. Level of exposure of Davao del Norte towards natural hazards

In Tagum City, two barangays are moderately exposed to natural hazards such as Liboganon and Busaon. Contrary to that, barangay Bingcungan and Madaum are found to have low exposure. These marks Tagum as low exposed to natural climatic hazards with mean score of 7.96. A moderate level of vulnerability to natural hazards of the province can be attributed to an increasing sea level rise as observed by the informants of the study. It can be explained also by a moderate exposure of the area to wave action with open coast facing away from prevailing winds most especially in IGCS. It is also

important to note that IGCS is relatively exposed to natural hazards compared to Panabo City, Tagum City and Carmen as it was constrains by strong wind and tidal waves (Siringan *et al*., 2013). In general, these findings suggest that coastal areas of Davao del Norte are exposed to threats from adverse climate impacts which conform to the results of Klein and Nicholls (1999) and Furlan *et al.* (2011).

3.2.2 Sensitivity

The sensitivity describes the degree to which coastal barangays are closely affected by natural climatic stress that positively correlated to the vulnerability (Gallopin, 2006). The present study revealed that the province is moderately sensitive to natural hazards. These can be explained by existing coastal landforms, rock type, beach recovery, slope, reef flat, beach vegetation, structures and activities. The study also discovered that all coastal barangays of Carmen are moderately sensitive to natural hazards. This is also true in a barangays of Panabo City, Tagum City, and ICGS except Sta. Cruz and Dadatan of Talikud Island (Figure 3) which are less sensitive.

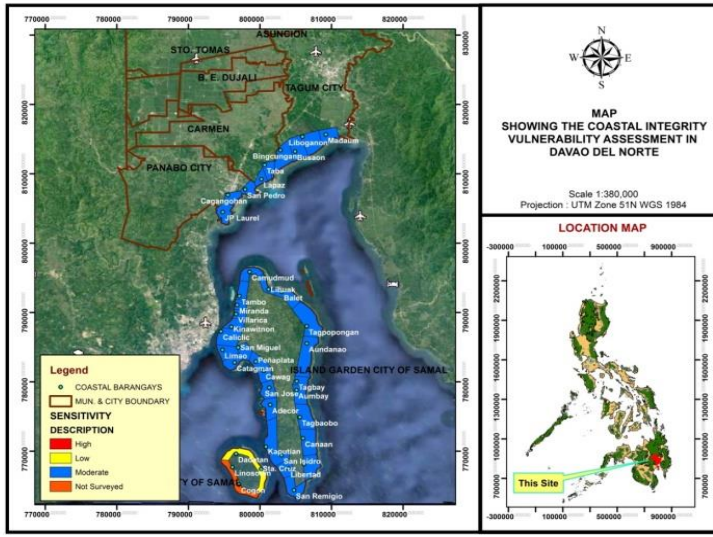

Figure 3. Extent of sensitivity of coastal areas in Davao del Norte

It was also discovered in the study through ocular observation that some foreshores are constructed by short groins, short solid-based pier and seawalls of 5 to 10 meters length. These groynes and jetties are observed to have accelerated coastal erosion in these areas and this became a heated issue between resort owners, LGUs and DENR. Human-induced alteration of the

landscape, including the erection of industrial, commercial and residential structures within the sight of the coastline in Davao del Norte is increasing at increasing rate. Alarming is the fact that most of these structures violates the Presidential Decree No. 1067 or the Water Code of the Philippines. Despite the existence of regulatory policy, illegal structures built along coastlines are still apparent. For this reason, the LGUs attempted to demolish these structures and to replace them with more environment friendly structures through legislative actions. On the other side, presence of natural habitats like coral reefs and mangrove are still visible in different areas. These mangroves will play potential role as natural buffers of coastal areas and communities towards tropical cyclones, storm surges, tsunamis impacts and other risks posed by climate change. Some of the areas with significant species of mangroves are presented in Figure 4.

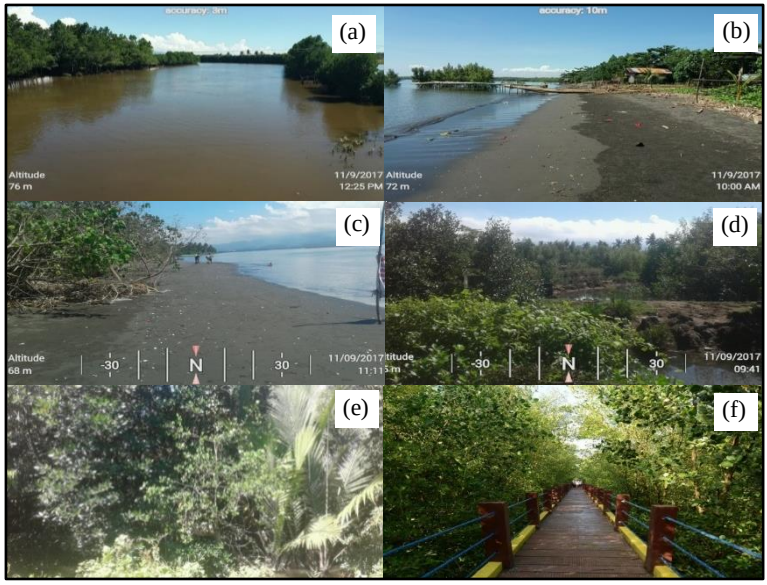

Figure 4. Mangrove areas in selected coastal barangays of Davao del Norte: (a) Bingcunga, (b) Busaon, (c) Libuganon, (d) Madaum, (e) San Isidro, and (f) JP Laurel

3.2.3 Adaptive Capacity

This element measures the ability of coastal areas and resources in avoiding certain impacts and in coping or handling with unavoidable impacts as well as taking advantage of opportunities from altered conditions. The study exposed that the coastal barangays of Davao del Norte have the capacity to adapt adverse impacts of natural hazards in a moderate extent. It was also revealed

that Panabo and Tagum City; IGCS; and Carmen are moderately adaptive to hazards (Figure 5). At the barangay level, barangay Taba in the municipality of Carmen has low level of adaptive capacity while La Suerte, Lapaz is moderately adaptive to natural threats. In Panabo City, barangay JP Laurel is found highly adaptive while barangay Cagangohan and San Pedro have moderate and low adaptive capacity to hazards caused by nature. In addition, all coastal barangays of Tagum considered in the study have moderate adaptive capacity except Busaon, which is found to have low ability to adapt climatic hazards. In the IGCS, Barangay Adecor, Peñaplata, Poblacion Libertad, Tagbabao, Aumbay, and Tagpopangan coastal areas with high level of adaptive capacity.

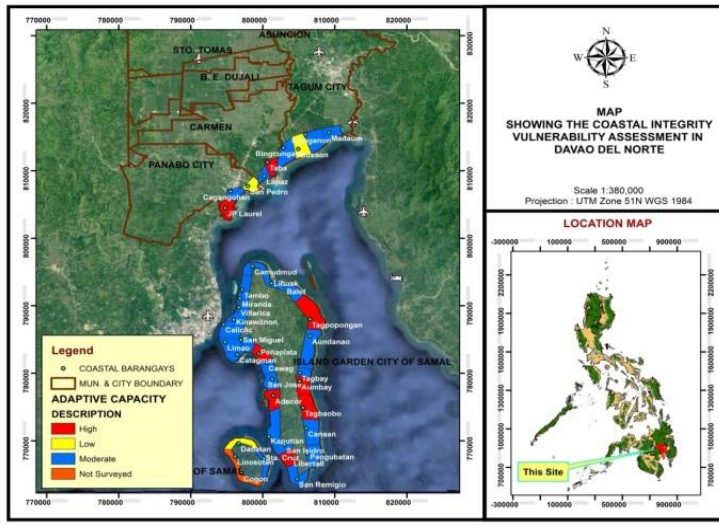

Figure 5. Extent of adaptive capacity of coastal areas in Davao del Norte

In contrast, barangay Dadatan of Talikud is discovered to be low adaptive while the rest of the barangays in the City are moderately adaptive to natural hazards. A moderate adaptive capacity of the coastal areas in the province could be attributed to its physical set up as well as the community's awareness, observance and compliance to national and local guidelines in coastal structure construction and development. When it comes to long-term shoreline changes, coastal areas in the province are perceived to be highly adaptive as majority is stable and less eroding. For instance, the Google Earth map of barangay Tambo indicated that an accretion of as much as 60 meters since 1950s to 2010 happened on this area. In addition, barangay Camudmud of IGCS is noted to have an estimated 70 meters accretion in RMPC compound, and 50 meters accretion in the area of Marina. In contrary, barangay Balet's

mangrove shoreline to its north retreated between 30 to 60 meters in the past 13 years reflecting incidence of coastal erosion which reduces its capacity to adapt impacts of natural hazards. Results suggest that there is a need to observe protection as an adaptive strategy to control negative climate related changes in the natural systems of coastal areas. Common engineering preventive options are the construction of seawalls, breakwaters, groynes, and emplacement of rip-rap and gabions as well as grading coastal bluffs and planting and maintaining existing vegetation (Catto, 2009).

3.3 Vulnerability of Coastal Areas in Davao del Norte Towards Natural Hazards

3.3.1 Potential Impact

An assessment study revealed that natural hazards have moderate potential impacts to selected coastal barangays in the province (Figure 6). This is consistent to the findings of Ingles (2014) wherein he found out that natural hazard moderately affects selected coastal barangays in IGCS.

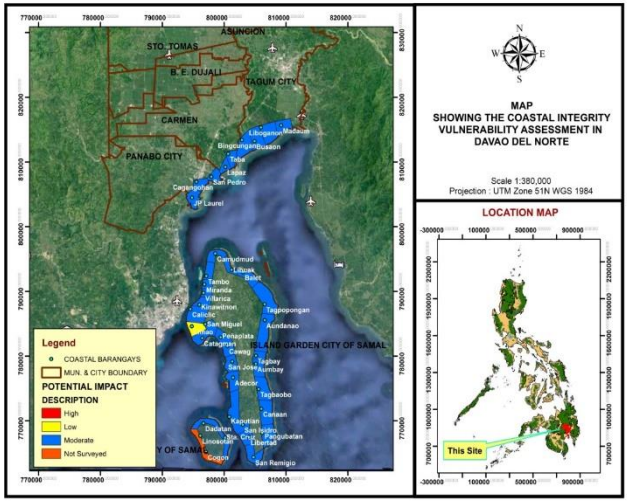

Figure 6. Potential impacts of natural hazards in coastal areas of Davao del Norte

3.3.2 Vulnerability

Barangay Taba in the municipality of Carmen is found less vulnerable to natural hazards while barangay La Suerte – Lapaz is moderately vulnerable. In Panabo City, coastal barangays like Cagangohan and San Pedro are moderately vulnerable while JP Laurel has low level of susceptibility to natural hazards. On the other hand, Tagum City coastal barangays like Adecor,

Peñaplata, Poblacion Libertad, Tagbaobo, Caliclic, Libuak and Sta Cruz have low level of vulnerability to hazards. Contrariwise, barangay Dadatan of Talikud Island was discovered to have high level of vulnerability while the remaining barangays are moderately vulnerable to natural threats. On the average, coastal areas in the province are moderately affected by natural hazards (Figure 7). This result agrees with the findings of Perez (1999) that coastal resources in the Philippines are in highly stressed conditions and vulnerable to adverse impacts of changing climate. The result is also supported by the findings of Saroar and Routray (2012), United States Environmental Protection Agency (2012), Takagi *et al.* (2012), Njaya and Howard (2006), Anwar (2003), and Ellis (2000).

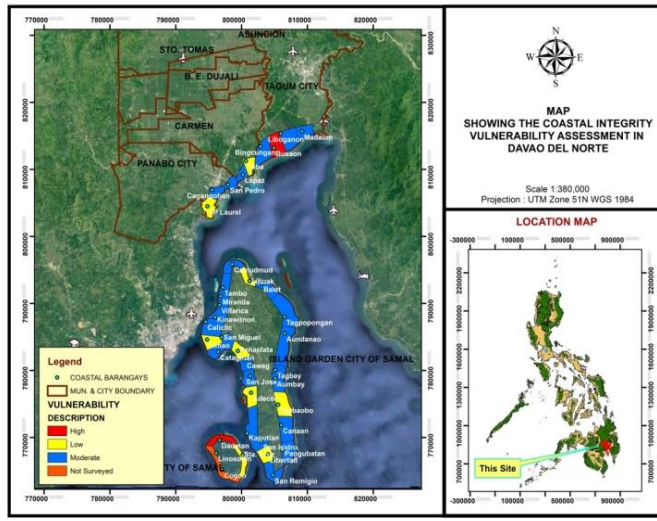

Figure 7. Vulnerability of coastal areas in Davao del Norte

This means that the province still need to enhance their adaptive capacity and use its physical strengths and opportunities of resources to reduce or prevent societal losses in the future (Cutter *et al*., 2007; Hoffman *et al*., 2010; Pielke *et al*., 2008; Schmidt *et al*., 2010). Vulnerability could be reduced by maintaining or improving physical environmental conditions, intensification of natural resource protection and development activities, and adherence to national and local policies, projects and programs that improve adaptive ability and reduce potential risks or impact of hazards brought by natural phenomena.

3.4 Priority Area for Vulnerability Management in Davao del Norte

Figure 8 displays the priority actions to reduce vulnerability. The actions are viewed on an inter-relational diagram or matrix where their scores for urgency (y-axis) are plotted against their scores for level of adaptive capacity in geo-physical and physical assets (x-axis). The plot reveals priority actions, i.e. actions with highest urgency and can be implemented using highest adaptive capacity are considered Priority 1 (upper right quadrat); actions addressing an urgent need, but which implementation is challenged by low adaptive capacity are Priority 2 (upper left quadrat); actions which results are impeded by low adaptation capacity, but address a relatively less urgent need are Priority 3 (lower left quadrat); and actions that may be implemented with high adaptive capacity and target a relatively less urgent need are Priority 4 (lower right quadrat).

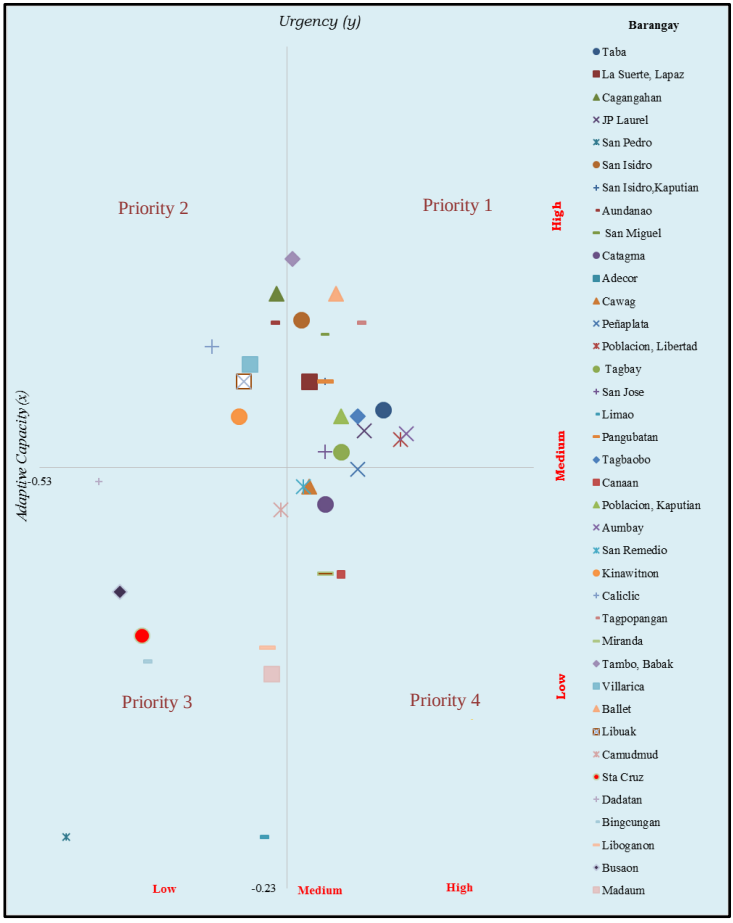

Figure 8. Priority barangays for vulnerability actions in Davao del Norte

As revealed, most of the coastal barangays in Davao del Norte need immediate actions and be prioritized. The first priority barangays include Tambo, Balet, San Isidro, Tagpopangan, San Miguel, La Suerte-Lapaz, Pangubatan, Poblacion Kaputian, Tagbaobo, Taba, JP Laurel, San Jose, Tagbay, Poblacion-Libertad, and Aumbay. These barangays require immediate interventions by maximizing adaptive potentials of coastal assets to minimize impacts of natural hazards. On the other hand, barangay Cagangohan, Aundanao, Villarica, Libuak, Kinawitnon and Caliclic fall under second priority. This would imply that vulnerability may reduce by improving the weak adaptive capacity of geophysical and physical coastal resources by considering infrastructure projects that reduces coastal erosion. Proper and strict implementation of coastal policies and ordinances to monitor, prevent or minimize coastal sediment supply as well as proper zoning ordinance on setback zones, coastal structure and development. Third priority barangays are Camudmud, Liboganon, Madaum, Limao, Bingcungan, Sta. Cruz, Busaon, and San Pedro. These barangays are less (3rd) priority given that it has less urgent need. However, there is still a need to conduct intervention programs that will enhance their adaptive capacity to become less to non-vulnerable in the future. Last priority barangays are Peñaplata, San Remedio, Cawag, Catagman, Miranda, and Canaan. Being least priority is attributed to the fact that these barangays are highly adaptive in nature and less impacted to potential hazards in the future.

This data will guide provincial-wide actions that are well-coordinated and complemented among barangay LGUs. This would allow more efficient ecosystem-based decision making when allocating for technical and financial support.

4. Conclusions and Recommendation

The following are recommended actions that consider the reduction of potential impacts and/or enhancing adaptive capacity of natural and man-made physical resources in coastal areas of Davao del Norte.

In general, the risk from natural hazards cannot be eliminated but vulnerability can be minimized or avoided depending on the proximity or location of human/communities to possible adverse events. Thus, it is recommended that habitations in hazard-prone or high-risk coastal areas of Davao del Norte (i.e. habitation in sea cliffs and coastlines that are highly susceptible to erosion)

are strictly prohibited and restricted. Strategic relocations of communities that are directly and highly exposed to sea level rise, waves, and tidal range should be instigated as early as possible to reduce potential risks that may occur in the future. However, there is a need to support the socio-economic side of these relocated populations as relocation and restriction approach may inhibit the community's usually economic way of life.

The coastal reforestation and rehabilitation activities (mangroves) should be intensified, and declaration of marine protected areas (MPAs) should be expanded to increase natural barriers or buffer zones that would reduce sensitivity to natural disasters like sea level rise, *tsunami*, flooding, and landslide.

There is a need to intensify the monitoring and policing illegal developments to reduce adaptive capacity of coastal communities. Proper zoning and observance of setback zones have to be developed and imposed firmly by local government units to possibly improve adaptive capacity.

If coastal development could not stop due to its economic importance, hence a consideration of disaster-resilient engineering structure and design is the last option. It is necessary to revisit or amend the building codes of the country to make sure it is disaster-ready or resilient to absorb or recover from actual or potential adverse events.

Aside from physical and structural considerations in reducing vulnerability, it is also highly recommended that non-structural planning has to be systematically installed in a manner that supports community involvement. Non-structural approach could be the establishment of coastal buffer zones, creation of elevated relocation and evacuation sites and installation of early warning systems in low-lying coastline areas around the province of Davao del Norte. However, for these strategies to be successful, it should be planned, implemented well in advance, monitored and evaluated over time by highly capable and well-trained individuals from different coastal communities in the province. Greater concern for disaster risk reduction management should be given to barangays that are highly vulnerable to natural hazards such like Barangay Dadatan of IGCS and Busaon of Tagum City.

5. References

Amadore, L.A. (2005). Crisis or Opportunity: Climate Change Impacts and the Philippines, Greenpeace Southeast Asia.

Anwar, S.M. (2003). Effects of shrimp culture on ecology in the coastal areas of Bangladesh. Human Landscape Ecology. Selected Term Papers, 2004, 65-76.
Arctic Climate Impact Assessment. (2005). Cambridge, UK, and New York: Cambridge University Press, 1042. Retrieved from http:// www.acia.uaf.edu /pages/scientific.html.

Bates, B.C., Kundzewicz, Wu, S., & Palutikof, J.P. (Eds.). (2008). Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva, 210.

Brake, K.K. (2008). An All-hazard Assessment of the Marystown Area, Burin Peninsula, Newfoundland and Labrador (Thesis). Department of Environmental Science, Memorial University, Newfoundland and Labrador, Canada.

Cahoon, D. (2006). A review of major storm impacts on coastal wetland elevations. Estuaries and Coasts, 29(6), 889-898.

Cahoon, D.R., Reed, D.J., Kolker, A.S., Brinson, M.M., Stevenson, J.C., Riggs, S., Christian, R., Reyes, E., Voss, C., & Kunz, D. (2009). Coastal wetland sustainability. In: Titus, J.G., Anderson, K.E., Cahoon, D.R, Gesch, D.B., Gill, S.K., Gutierrez, B.T., Thieler, E.R., and Williams, S.J., Coastal Sensitivity to Sea-Level Rise: A Focus on the Mid-Atlantic Region. U.S. Environmental Protection Agency, Washington DC, 43-56.

Catto, N.R. (2003). Erosion at Cape St. Mary's Ecological Reserve. Report to Tourism, Recreation, and Parks, Government of Newfoundland and Labrador.

Catto, N.R. (2009). Water Resources Public Infrastructure Vulnerability Assessment for Placentia, Newfoundland. PIEVC Climate Change Infrastructure 109 Vulnerability Assessment, Report to Engineers Canada and Environment and Conservation, Government of NL.

Cutter, S.L., Johnson, L.A., Finch, C., & Berry, M. (2007). The U.S. Hurricane Coasts: Increasingly Vulnerable? Environment, 49(7), 8-20.

Department of Environment and Natural Resource – Region XI, (2017). Foreshore Area Development and Management Plan (2018-2024). Unpublished Report. Davao City, Philippines.

Ellis, F. (2000). The determinants of rural livelihood diversification in developing countries. Journal of Agricultural Economics, 51(2), 289-302.

Furlan, A., Bonotto, D.M., & Gumiere, S.J. (2011). Development of environmental and natural vulnerability maps for Brazilian coastal at São Sebastião in São Paulo State. Environmental Earth Sciences, 64(3), 659-669.

Gallopin, G.C. (2006). Linkages between Vulnerability, Resilience, and Adaptive Capacity. Global Environmental Change. Retrieved from https://www.pik-potsdam.de/research/projects/projectsarchive/favaia/presentationsvulws/gallopin.pdf

Gutowski, W.J., Hegerl, G.C., Holland, G.J., Knutson, T.R., Mearns, L.O., Stouffer, R.J., Webster, P.J., Wehner, M.F., & Zwiers, F.W. (2008). Causes of observed changes in extremes and projections of future changes. In: Karl, T.R., Meehl, G.A., Miller, C.D., Hassol, S.J., Waple, A.M., and Murray, W.L. (Eds.), Weather and Climate Extremes in a Changing Climate; Regions of Focus: North America, Hawaii, Caribbean, and U.S. Pacific Islands Synthesis and Assessment Product 3.3. U.S. Climate Change Science Program, Washington, DC, 81-116.

Harmeling, S. (2011). Global Climate Risk Index 2011: Who suffers most from extreme weather events? Weather-related loss events in 2009 and 1990 to 2009. A Briefing Paper published by Germanwatch e.V. 24.

Hatfield, J., K. Boote, Fay, P., Hahn, L., Izaurralde, C., Kimball, B.A., Mader, T., Morgan, J., Ort, D., Polley, W., Thomson, A., & Wolfe, D. (2008). Agriculture. In: The effects of climate change on agriculture, land resources, water resources, and biodiversity in the United States. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. Washington, DC., USA, 362.

Hoffman, R.N., Dailey, P., Hopsch, S., Ponte, R.M., Quinn, K., Hill, E.M., & Zachry, B. (2010). An estimate of increases in storm surge risk to property from sea level rise in the first half of the twenty-first century. Weather, Climate, and Society, 2, 271-293.

Ingles, J. (2014). Opportunity to undertake major fisheries policy reform. Retrieved from http://wwf.panda.org/?230941/EU-warning-on-Philippines-A-rare-opportunity-to-undertake-major-fisheries-policy-reform.

Ingram, D. (2004). Coastal geomorphology, erosion, and anthropogenic stresses, Sandbanks Provincial Park, Southwestern Newfoundland (Thesis). Department of Geography, Memorial University of Newfoundland. Newfoundland and Labrador, Canada.

Intergovernmental Panel on Climate Change (IPCC). (2001). Climate Change 2001: Impacts, Adaptation, and Vulnerability. Cambridge, UK: Cambridge University Press.

Intergovernmental Panel on Climate Change (IPCC). (2007). Summary for Policy Makers. Cambridge, UK: Cambridge University Press, 7-22.

Kirschen, P., Watson, C., Douglas, E., Gontz, A., Lee, J., & Tian, Y. (2008). Coastal flooding in the Northeastern United States due to climate change. Mitigation and Adaptation Strategies for Global Change, 13(5-6), 437-451.
Klein, R.J.T & Nicholls, R.J. (1999). Assessment of coastal vulnerability to climate change. Ambio 28(2), 182-187.

Marine Environment and Resources Foundation (MERF). (2013). Vulnerability Assessment Tools for Coastal Ecosystems: A Guidebook. Quezon City, Philippines: Marine Environment and Resources Foundation, Inc.

Moser, S.C., & Tribbia, J. (2006). Vulnerability to Inundation and Climate Change Impacts in California: Coastal Managers' Attitudes and Perceptions. Marine Technology Society Journal, 40(4), 35-44.

Nicholls, R.J., Wong, P.P., Burkett, V.R., Codignotto, J.O., Hay, J.E., McLean, R.F., Ragoonaden, S., & Woodroffe, C.D. (2007). Coastal systems and low-lying areas, Contribution of Working Group II to the Fourth Assessment Report of the ntergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press, 315-356.

Njaya, F., & Howard, C. (2006). Climate and African fisheries. Tiempo, 59, 13-15.

Perez, R.T., Amadore, L.A., & Feir, R.B. (1999). Climate change impacts and responses in the Philippine coastal resources sector. Climate Research, 12, 97-107.

Pielke, R.A. Jr., Gratz, J., Landsea, C.W., Collins, D., Saunders, M.A., & Musulin, R. (2008). Normalized hurricane damage in the United States: 1900-2005. Natural Hazards Review, 9(1), 29-42.

Polyak, L., Andrews, J., Brigham-Grette, J., Darby, D., Dyke, A., Funder, S., Holland, M., Jennings, A., Savelle, J., Serreze, M., & Wolff, E. (2010). History of sea ice in the Arctic. Quarterly Sciences Review, 1-22.

Regalado, E. (2016). Davao region under state of calamity due to El Niño. The Philippine Star. Retrieved from http://www.philstar.com/nation/2016/04/16/ 1573220/davao-region-under-state-calamity-due-el-nino.

Revita, J. (2017). Hundreds displaced in Davao flooding, red alert on Thursday. Sunstar. Retrieved from http://www.sunstar.com.ph/davao/local-news/2017/02/16/ hundreds-displaced-davao-flooding-red-alert-526228.

Saroar, M.M., & Routray, J.K. (2012). Impacts of climatic disasters in coastal Bangladesh: Why does private adaptive capacity differ? Regional Environmental Change, 12(1), 169-190.

Schmidt, S., Kemfert, C., & Höppe, P. (2010). The impact of socio-economics and climate change on tropical cyclone losses in the USA. Regional Environmental Change, 10, 13-26.

Siringan, F.P., Sta. Maria, M.Y.Y., Samson, M.I., Licuanan, W.R.Y., & Rollon, R. (2013). Chapter 5: Coastal Integrity Vulnerability Assessment Tool. In: MERF. 2013. Vulnerability Assessment Tools for Coastal Ecosystems: A Guidebook. Marine Environment and Resources Foundation, Inc., Quezon City, Philippines.

Speller, R. (2001). Coastal Management Issues, Cape St. Mary's, NL. M. Environmental Science, report, Memorial University of Newfoundland, Newfoundland and Labrador, Canada.

Takagi, H., Thao, N., Esteban, M., Tam, T., Knaepen, H., & Mikami, T. (2012). Vulnerability of Coastal Areas in Southern Vietnam Against Tropical Cyclones and Storm Surges. Retrieved from https://www.researchgate.net/publication/279524971_Vulnerability_of_coastal_areas_in_Southern_Vietnam_against_tropical_cyclones_and_storm_surges.

United States Environmental Protection Agency. (2012). Vulnerability assessments in support of the Climate Ready Estuaries program: A novel approach using expert judgment, Volume I: Results for the San Francisco Estuary Partnership. National Center for Environmental Assessment, Washington, DC; EPA/600/R-11/058a. Available from the National Technical Information Service, Springfield, VA. Retrieved from http://www.epa.gov/ncea.

United States Government Accountability Office. (2009). Alaska Native Villages: Limited Progress Has Been Made on Relocating Villages Threatened by Flooding and Erosion. GAO-09-551.

White, M. (2002). A preliminary assessment of slope stability and rockfall hazard, St. Brendan's, Bonavista Bay, Newfoundland.