Vulnerability Assessment and Participatory Modeling: The Talisay City, Philippine Case

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Abstract

Incidence of strong typhoons, threatened small islands to sea level rise and storm surges and inundation of low lying areas to flooding are just a few of possible disasters in the Philippines as identified by climatologists and policy makers within the next 10 years. The most vulnerable regions are in the Central Visayan provinces. Talisay City in the central province of Cebu, with its coastal zone is always buffeted by strong waves during southwest monsoon season (June-October) affecting three-four communities and within the last twenty years had also experienced a major flooding from its Mananga River. Its varied topography from steep slopes to low-lying and constantly flooded coastal barangays represents a very unique characteristic making it susceptible to flooding and landslides. The study assessed and determined natural and man-made hazards of Talisay City, Cebu through participatory approaches and developed a modeling for disaster risk reduction management. Specifically, it identified and determined natural and man-made hazards of the area and identified critical factors affecting these vulnerabilities Secondly, it developed a scenario-building program which can be used in disaster risk management and test out this program in participatory disaster risk management exercises with different stakeholders. It used a combination of participatory approaches in disaster risk reduction among stakeholders like GIS-assisted vulnerability index mapping and participatory mapping. It enabled the user to improve the forecasting of future events and their impacts, particularly those where the disaster management actions might be affected by changing environmental conditions. The GIS-assisted modeling of disaster risk management was applied with critical factors such as rainfall erosivity index, soil erodibility, slope length factor, slope gradient, cover factor, erosion control and other factors. Vulnerability Index mapping was maximally used in finalizing the disaster risk management of Talisay City. Materials developed like maps, scenario or possible development options facilitated group decision-making and activity implementation.

Key words

vulnerability assessment, participatory approaches and GIS-assisted modeling

1. Introduction

In the Philippines, several problems resulting from climate change have been observed already. Most of these problems are also manifested in various areas of the country which include landslides, flooding, drought, biodiversity loss, health risks and many other kinds of environmental risks and hazards (Tiburan, et al, 2008). Before any development intervention can be initiated it is important that we should know the vulnerabilities of our communities. Hence, this study aimed to develop a model that can be used to evaluate area vulnerability to climate change under Philippines condition.

Central Philippines, more specifically Region 7 are listed as no. 7 among the most vulnerable regions to a 1-meter sea level rise. (Greenpeace, 2007). Incidence of strong typhoons threatened small islands to storm surges and inundation of low lying areas are just a few of possible disasters identified by climatologists and policy makers within the next 10 years. Reports of landslides, severe erosion and drought were also reported within the last 5 years. This is also reflected in Talisay City, a component city of Metro Cebu (Figures 1).
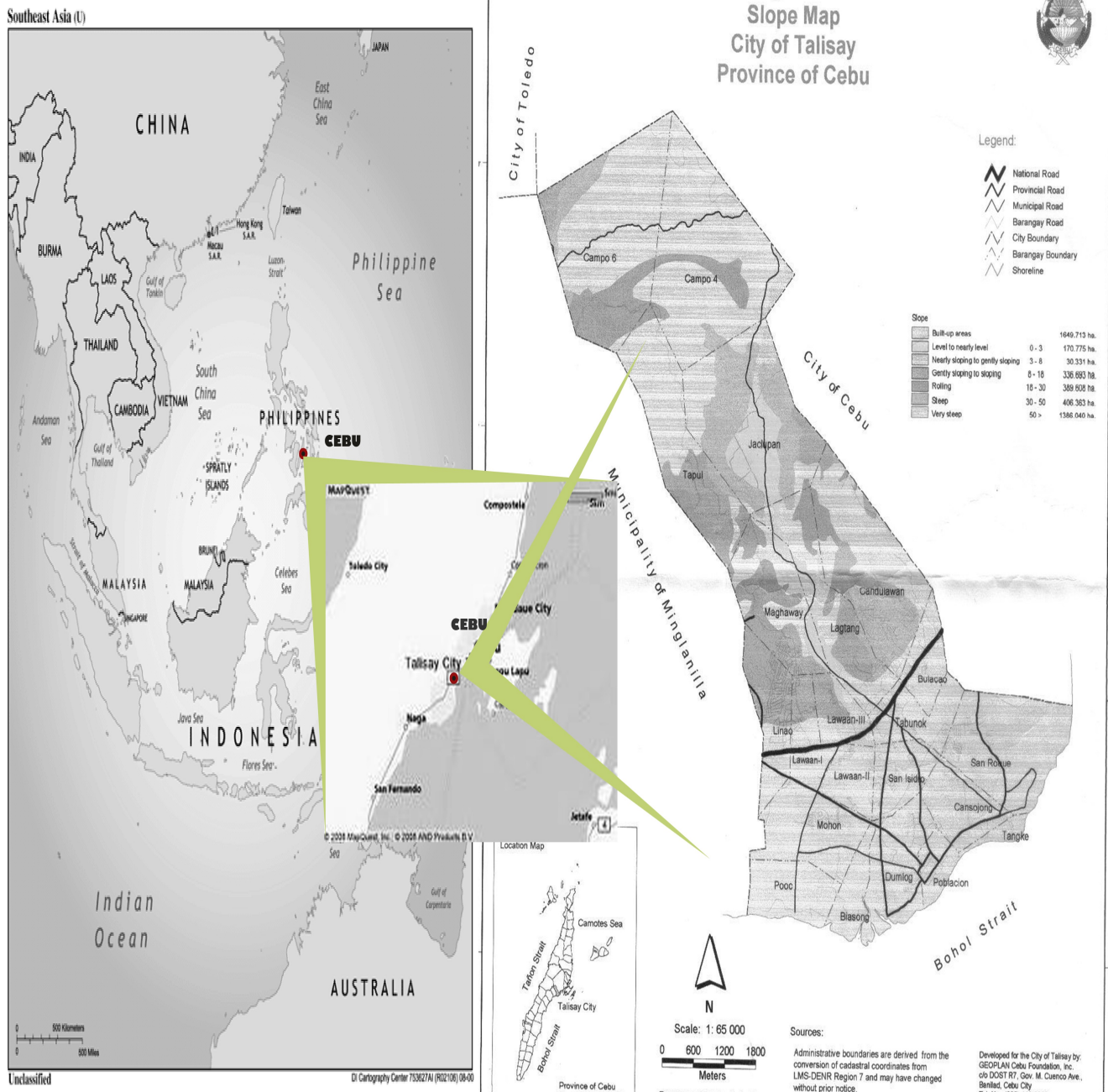
Figure 1: Location of Talisay City and Cebu Province.

Its coastal zone is always buffeted by strong waves during southwest monsoon season (June-October) affecting four-six barangays and within the last twenty years had also experienced a major flooding from its Mananga river. Its varied topography from steep slopes to low-lying and constantly flooded coastal barangays represents a very unique characteristic that makes it susceptible to flooding and landslides.

Objectives. The initiative assessed and determined natural and man-made hazards of Talisay City, Cebu through participatory approaches and developed a GIS-assisted modeling for disaster risk reduction management. Specifically, it 1) assessed and determined natural and man-made hazards of the area and identified critical factors affecting vulnerability to natural and man-made hazards such as erosion, landslide, flooding and storm surges; 2) mapped out vulnerability levels of Talisay City to natural and man-made hazards; 3) developed a participatory modeling/mapping which can be used in disaster risk management and test out this program in participatory disaster risk management exercises with different stakeholders; and 4) formulated mitigating measures to risk reduction and policy recommendations to local government units and support institutions.

2.The Community-based Disaster Risk Reduction Process and the use of three-dimensional modeling or mapping

Involving local communities is a prerequisite to sustainable disaster risk reduction. Community-based disaster risk reduction (CBDRR) fosters the participation of threatened communities in both the evaluation of risk (including hazards, vulnerability and capacities) and ways to reduce it (Gaillard J & Maceda E, 2009). Among development facilitators, there was also a growing realization that CBDRR should integrate all stakeholders including the local government units, line agencies, and other resource institutions. This was essential to integrate local and scientific knowledge.

Oxfam-Britain in its CVA (Community Vulnerability Assessment) framework also emphasized that community residents, local government units and other support institutions should come up with a common CBDRR. In its CVA framework it uses three major categories in analyzing a community's capacities and vulnerabilities: social or organizational, the attitudinal or motivational aspects and the physical or material. In their work with rural depressed communities in eastern Philippine provinces, they put particular emphasis on socio-political processes and structures which can either make people and communities vulnerable to disasters, or contribute toward disaster management. Working through both the formal and informal political structures, community leaders and relations among neighbors and organizations was viewed us the only viable way of developing the community's ownership of the disaster management plan. The second dimension looked into how people perceive, understand and interpret events happening in their community. They can either be fatalistic or

pro-active and having a communitarian or collectivistic or individualistic attitude. The third variable was on topography, resources and physical improvements of the place.

Maps are used as part of CBDRR activities for participatory learning among rural and urban communities. Participatory mapping enables communities to delineate areas they perceive as vulnerable and prone to hazards, and to plot desired and useful risk reduction measures (Gaillard J and Maceda E., 2009). However, the two-dimensional sketch maps from government agencies are usually limited in size, and in some instances are quite difficult to interpret by ordinary community residents.

Participatory three-dimensional modeling or mapping can help in attempting to overcome these shortcomings. This is done by coming up with scaled relief maps made of available materials with thematic layers of geographical information (Rambaldi and Callosa-Tarr, 2002). Through this process, communities are able to plot landforms, land cover, and use, and anthropogenic features. It was used as the foundation in Talisay City's community-based disaster risk reduction.

The approach employed follows a 4-step methodology which combined mapping activities and other participatory tools in assessing and reducing disaster risks (listing, ranking, calendars, transects and problem trees) with data analysis of GIS-assisted vulnerability index mapping and simulation modeling.

Step 1: Situation analysis of vulnerability. Community profiling and analysis of threats and vulnerabilities were discussed in several community meetings. This was done through the presentation of relief maps and for community residents to check these with land use and settlement, erosion, drainage, incidents of storm surges, landslides and flooding. This was made possible through technical assistance of city and regional planners who put the key physical and biological processes into a spatial context using the Geographic Information System (GIS).

This support group was able to come up with a number of indices to assess the vulnerability or sensitivity of the area to threats from various perturbations as popularized by Cooper (1997). Included are biological features, base rock and slopes of the coastline and upland areas, erosion and attrition, land forms, policy and planning and anthropogenic variables like population changes, sand mining, infrastructure development and settlements (Floren 2006).

Each indicator was given a scale from 1 to 5 to indicate the degree of vulnerability of that indicator in the area (please see Appendix 1). A scale of 1 indicates resilience while a scale of 5 signifies high vulnerability An ID system was also designated for each indicator to easily identify their component and aspect from the others. (Tiburan, C. et al., 2008). The threshold levels of the scales in each indicator were determined using one or a combination of the

following methods—Kolmogorov-Smirnov (K-S) test, spatial-based methods and indices and literature reviews (for a more detailed discussion please sees Appendix 2). Table 1 show the general vulnerability category and classification of the area based on the results of OVP (Overall vulnerability Point) computation.

Table 1: Overall vulnerability classification and category used

Category	Overall Classification	Overall Vulnerability Point
5	Extremely vulnerable	➢ 85
4	Highly vulnerable	70-85
3	Vulnerable	55-70
2	At risk	40-55
1	Resilient	< 40

Table 1 also shows the general vulnerability category and classification of the watershed based on the results of the OVP computation. These results, together with the scaling distribution, were also organized using a template report

Step 2: Analyzing causes of vulnerability. The output of vulnerability classification was applied in both coastal and communities along the Mananga River. Delineating hazard-prone areas and identifying most vulnerable households became the main agenda in most community meetings. The communities were also able to differentiate between three types of floods: tidal floods and storm surges, river floods and rain-fed floods. Focused group discussions, the use of timelines and analysis of critical community incidents crystallized the causes and root causes of vulnerability and became the basis for community planning.

Step 3: Analysis of community action. Multi-stakeholder group discussions took place using the vulnerability maps and became the venue for community actions taking into account their organizational capacities. Resources and external support. It was also through this process that communities were able to critically look into their disaster preparedness and response system. It enabled them to define and improve measures to be in times of crisis. Using the map, they discussed warning signals, plot out meeting points, safe evacuation routes and shelters.

Step 4 – Data from CBDRR was integrated into the City Disaster Preparedness and Response Plan. This was done by incorporating the disaster risk reduction plans in each community development plan which became the basis of the overall City Development Plan. Concerns affecting two or more communities like macro plans of converting of some upland areas into residential/settlement areas, coastal reclamation, quarrying and water use are now being looked into by different stakeholders.

3.   Results & Discussions

Vulnerability Index mapping and participatory modeling were maximally used in finalizing the disaster risk management of Talisay City. Materials developed like maps, scenario or possible development options facilitated group decision-making and activity implementation (Figures 2-8).
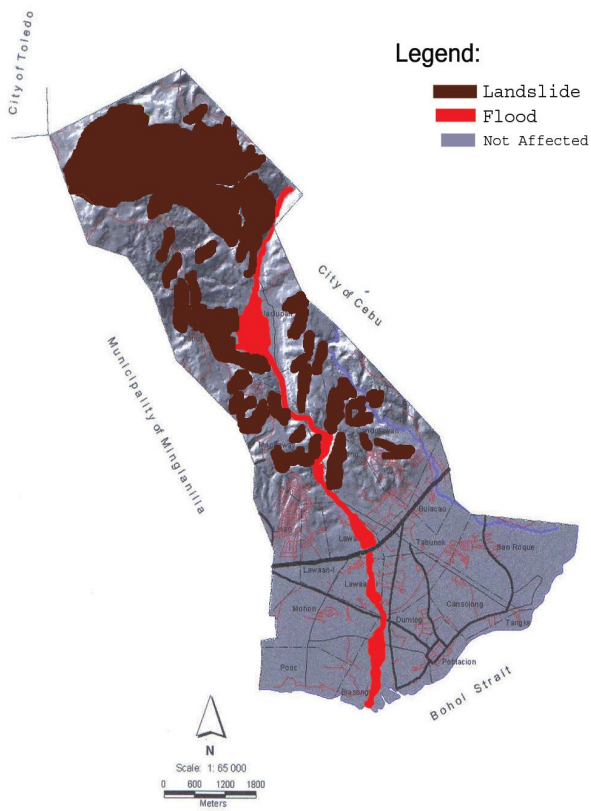
Figure 2

Flood Susceptibility Map

Legend:
- Barangay Boundary
- City Boundary
- River/Shoreline
- Road
- Very High
- High
- Medium
- Low
- No Data

Legend:
- Landslide
- Flood
- Not Affected

Figure 3

Type of Flooding Map

Legend:
- Barangay Boundary
- City Boundary
- River/Shoreline
- Road
- Flash Flooding
- Riverine Flooding
- Flash Flooding/Riverine Flooding
- Coastal Flooding/Riverine Flooding
- Sheet Flooding
- Sheet Flooding/Flash Flooding
- Sheet Flooding/Riverine Flooding
- Sheet Flooding/Storm Surge

Scale: 1 : 60,000

Figure 4

Landslide Susceptibility Map

Legend:
- Barangay Boundary
- City Boundary
- River/Shoreline
- Road
- Very High
- High
- Medium
- Low
- No Data

Figure 5

Campo VI, Campo IV, Jaclupan, Tapul, Candulawan, Maghaway, Lagtang, Bulacao, Linao, Lawaan III, Tabunok, Lawaan I, San Isidro, San Roque, Lawaan II, Cansojong, Mohon, Tangke, Dumlog, Poblacion, Pooc, Biasong

Municipality of Minglanilla
Cebu City

Scale: 1 : 60,000
1000 0 1000 2000
Meters

Hydrodynamics Erosion/Accretion Map

Legend:
- Barangay Boundary
- City Boundary
- River/Shoreline
- Road
- Very High
- High
- Medium
- Low
- No Data

Figure 6

Campo VI, Campo IV, Jaclupan, Tapul, Candulawan, Maghaway, Lagtang, Bulacao, Linao, Lawaan III, Tabunok, Lawaan II, San Isidro, San Roque, Mohon, Cansojong, Dumlog, Poblacion, Pooc, Biasong, Tangke

Municipality of Minglanilla
Cebu City

Scale: 1 : 60,000
1000 0 1000 2000
Meters

Anthropogenic Variable Sand Mining/Quarrying Map

Legend:
- Barangay Boundary
- City Boundary
- River/Shoreline
- Road
- Very High
- High
- Medium
- Low
- No Data

Campo VI, Campo IV, Jaclupan, Tapul, Candulawan, Maghaway, Lagtang, Bulacao, Linao, Lawaan III, Tabunok, Lawaan I, San Isidro, San Roque, Lawaan II, Cansojong, Mohon, Tangke, Dumlog, Poblacion, Pooc, Biasong

Municipality of Minglanilla
Cebu City

Scale: 1 : 60,000
1000 0 1000 2000
Meters

Figure 7

Anthropogenic Variable Urbanization Map

Legend:
- Barangay Boundary
- City Boundary
- River/Shoreline
- Road
- Very High
- High
- Medium
- Low
- No Data

Campo VI, Campo IV, Jaclupan, Tapul, Candulawan, Maghaway, Lagtang, Bulacao, Linao, Lawaan III, Tabunok, Lawaan I, San Isidro, San Roque, Lawaan II, Cansojong, Mohon, Tangke, Dumlog, Poblacion, Pooc, Biasong

Municipality of Minglanilla
Cebu City

Scale: 1 : 60,000
1000 0 1000 2000
Meters

Figure 8

Knowledge Collaboration & Learning for Sustainable Innovation
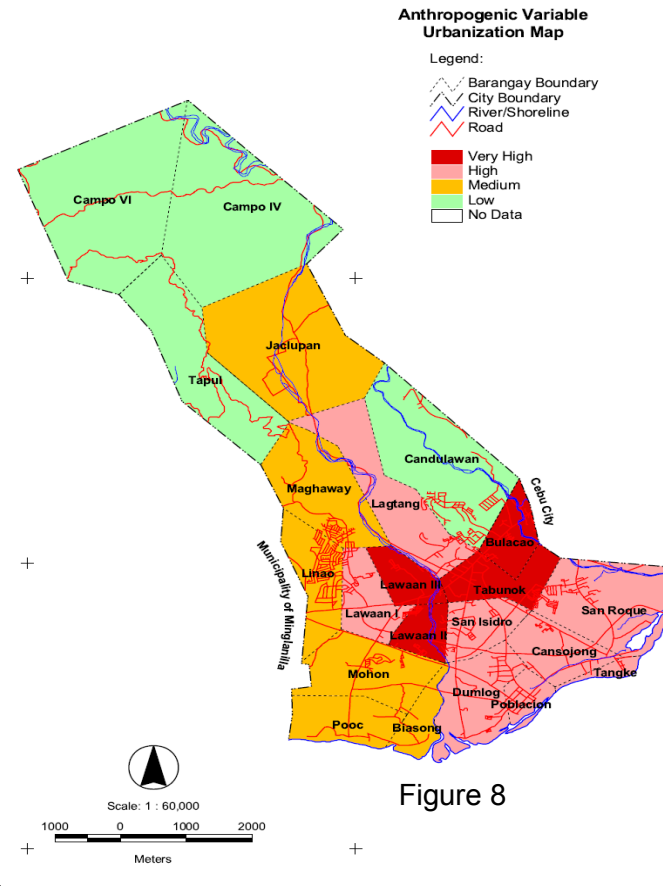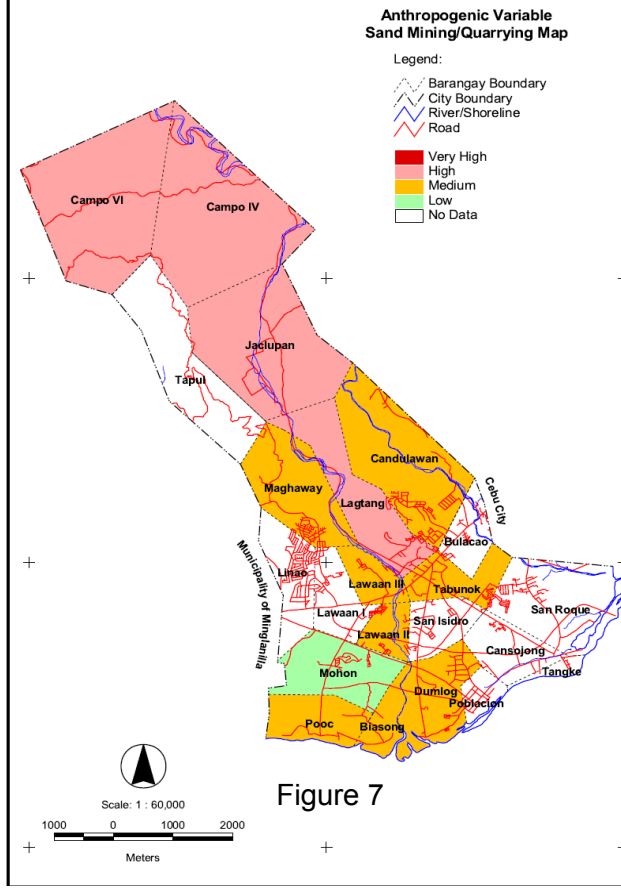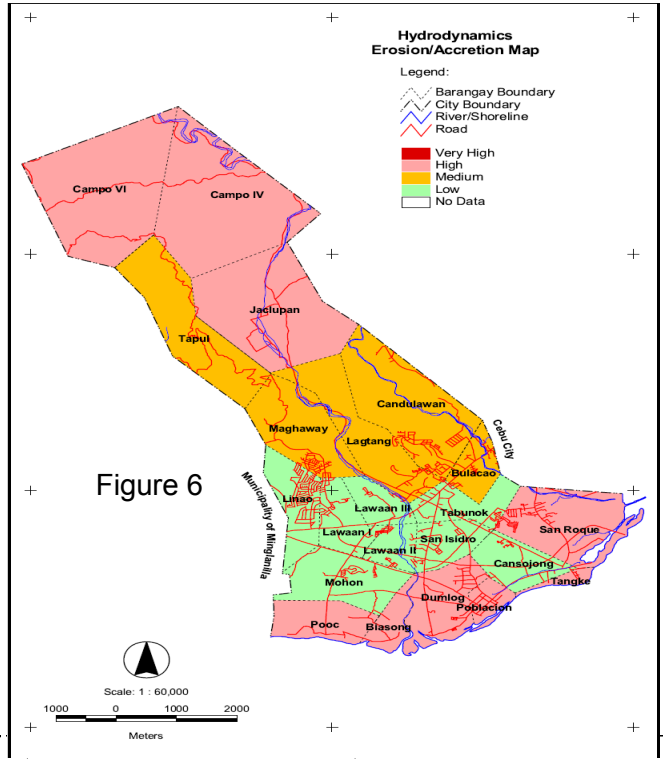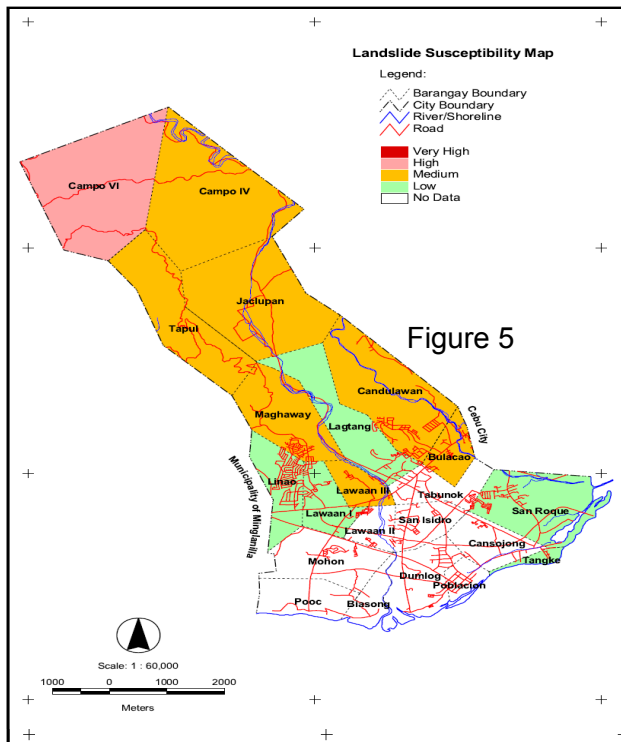ERSCP-EMSU Conference Delft The Netherlands October 25-29 2010

Based on the Overall Vulnerability Indices, ground truthing and community discussions, eight (8) communities were rated as vulnerable (High). Five of these are in coastal areas (San Roque, Tanke, Poblacion, Dumlog and Biasong). Variables like exposure to strong waves, limited mangroves and other vegetative cover and absence of easement made them vulnerable to storm surges and flooding (Table 2) The river communities of Lagtang and Jaclupan & Bulacao were also classified in this category. Factors like riverbank easement, unchecked quarrying, limited vegetative cover and increasing settlement (e.g. spread of squatter colonies and conversion of sloping areas   into subdivisions) made these areas very sensitive to hazard events. All other communities ('barangays') were classified as moderately vulnerable due to episodic flooding, landslides and erosion in sloping and upland areas, limited vegetative cover, increasing population and economic activities, absence of adequate drainage and conversion of low-lying areas into commercial and residential zones.

Table 2: Overall Vulnerability Indices.

Name of Barangays		OVP	Interpretation
COSTAL	San Roque	58.8	Vulnerable
	Tangke	61.3	Vulnerable
	Poblacion	62.5	Vulnerable
	Dumlog	65	Vulnerable
	Biasong	60	Vulnerable
	Pooc	57.5	Vulnerable
INLAND	Cansojong	41.3	At Risk
	San Isidro	41.3	At Risk
	Bulacao	48.8	At Risk
	Lawaan 1	41.3	At Risk
	Linao	41.3	At Risk
RIVERBANK	Mohon	47.5	At Risk
	Lawaan 2	55	Vulnerable
	Lawaan 3	56.3	Vulnerable
	Tabunok	53.8	Vulnerable
	Lagtang	60	Vulnerable
	Jaclupan	61.3	Vulnerable
	Manghaway	60	Vulnerable
	Campo 4	61.3	Vulnerable
	Campo 6	61.3	Vulnerable
UPLAND	Cadulawan	45	Vulnerable
	Tapul	37.5	Resilient

The communities have undergone several learning exercises in profiling, participative mapping and the use of vulnerability maps. They also contributed in the collection of spatial information and to capture the perception of people regarding disasters and evolve their mechanism in handling such disruptive events.

In the later stage, the potential of the participatory maps for planning of evacuations in the case of floods were appreciated and taken up by social development groups and local Disaster Risk Committees. It was also used in community meetings to discuss related issues like livelihood, land tenure and resource management.

4.   Socio-economic Significance

Participatory methods and the use of participatory three-dimensional modeling/mapping are well suited to be implemented in a vulnerability assessment and are also crucial for the success of disaster risk management and adaptation (Figures 9-12).
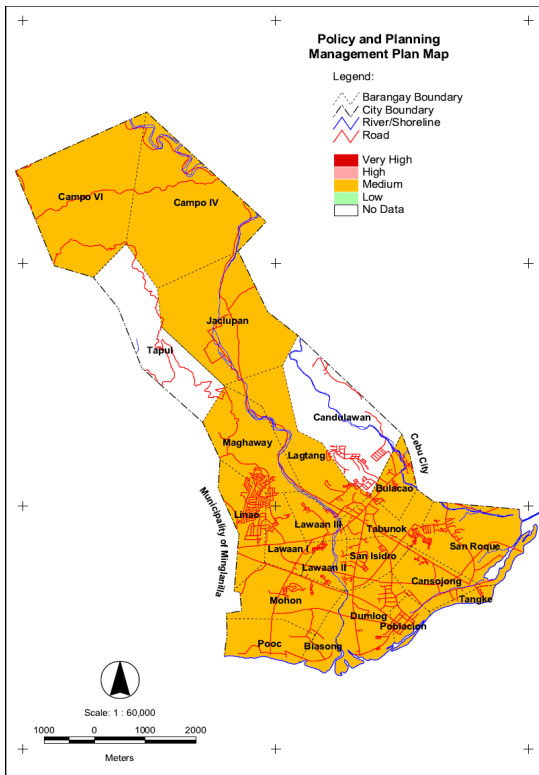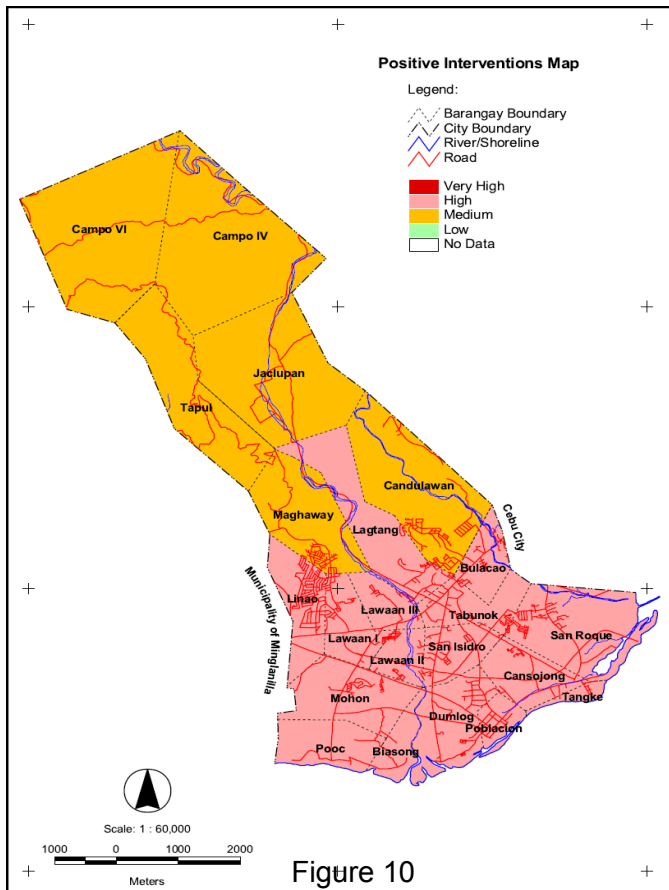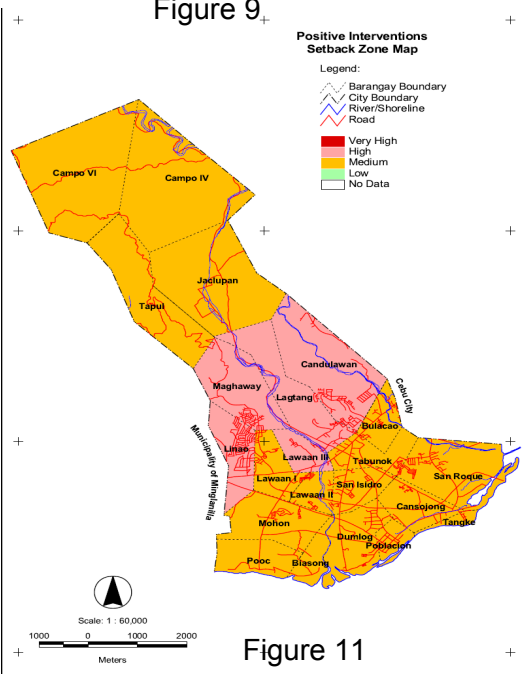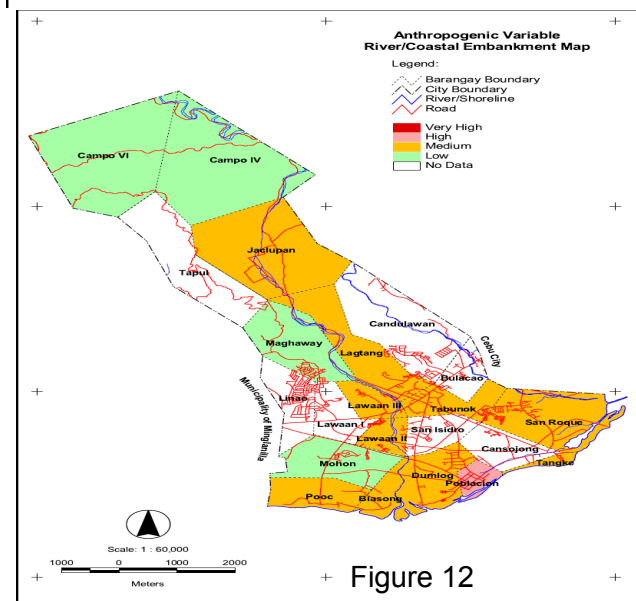
Figure 9

Figure 10

Figure 11

Figure 12

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Previously, participation did not go beyond public consultations and communities were viewed as mere recipients of services. Participatory vulnerability assessments before possible disaster events should have the objective of preparing communities and to come up with preventive measures. Community participation up to the local government and regional levels should become the norm in responding to climate change.

However, to successfully integrate this approach and to address the various scales of vulnerability assessments more prerequisites are necessary:

- An enabling environment where opportunities for people to participate in local governance;
- Transparency is a very crucial determining factor for its success. An open line of communication between local government units, line agencies and other support institutions is a basic requirement. Political will and community advocacy are important ingredients in assuring information flow. A network which is based on trust and good practice is necessary;
- Involvement of local people. They understand the complexity of their environment and this will make or break the initiative.

Potential for Application and Commercialization

The participatory disaster risk management approach and the use of modeling can be replicated by our local government units facing similar problems on climate change hazards and in exploring adaptation measures.

References:

Baran, E. & T. Jantunen, 2006. *Stakeholder Consultation for Bayesian Decision support Systems in Environment Management* **Models in Ecological and Environmental Studies**, Esmail, A.I. et al (eds.) Pulau Pinang: Penerbit Universiti Sains Malaysia

Cooper J.A.G. & McLaughlin, S. 1997. *Contemporary Multi-disciplinary Approaches to Coastal Classification and Environmental Risk Analysis.* **Journal of Coastal Research**, 14 (2), 512-524

Gaillard, J.C & E. Maceda 2009. Participatory Three-Dimensional Mapping for Disaster Risk Reduction' IIED Volume 60 No.1 Dec. 2009

Greenpeace 2007 **The Philippines: A Climate Hotspot: Climate Change impacts and the Philippines.** Manila: Greenpeace

Floren, J.O. 2006 *Environmental Vulnerability Index Mapping in Alcoy, Cebu, Philippines: Implications for the Management of Coastlines*. **Journal of Natural Sciences** Vol. 11: 151-178. Iloilo: University of the Philippines- Visayas

IIED 2009 *Community based Adaptation to Climate Change* **Participatory Learning and Action** London: IIED

K.S.Kavi Kumar & S. Tholkappian 2006 Relative *Vulnerability of Indian Coastal Districts to Sea-level Rise and Climate Extremes.* **International Review for Environmental Strategies** Vol.6 No. 1 Tokyo: IGES

Lanuza, R.L. 2009 **Vulnerability Assessment of Mananga Watershed, Cebu, Philippines** Cebu: DENR-Region 7, Philippines

Tiburan, C.L. Jr., et al 2008 **Geospatial-Based Vulnerability Assessment of Watersheds in the Philippines** Available at: **http://blue.for.msu.edu/meeting/proc2/**

Victoria, L. 2003 **Community based Disaster Management in the Philippines: Making a Difference in People's Lives** Bangkok: Asian Disaster Preparedness Center

Appendix A: Kolmogorov-Smimov (K-S) test

After the indicators have been given their scales, the overall vulnerability of the area is determined by computing its overall vulnerability point (OVP). The OVP was computed using this equation:

$$
OVP = \frac{\frac{1}{n} \sum_{t=L}^{n} S_i}{S\ max} \times 100
$$

Where: S_i –scale of indicator i

S_{max} – maximum scale in the model

n- total number of indicators used in the assessment

Appendix B: The Vulnerability index of the different variables

The study looked into the key physical and biological processes, anthropogenic influences and policy interventions compounding the entire city of Talisay and then put the information into a spatial context using a Geographic Information System (GIS).

The many factors influence the coastline, riverbank and upland areas, but they can be roughly classified into the natural environment (physical and processes) and human environment (socio-economic and legal basis).Here vulnerability maybe defined as the exposure of social (and environmental) systems to stress as a result of the impacts of environmental change. This environmental change may be some combination of natural or anthropogenic factors (Adger 1999 in Pethick et. Al 2000).

A number of indices have been developed with the intention of assessing the vulnerability or sensitivity of the area to threats from various hydrodynamic, climatic and anthropogenic perturbations (Cooper 1997). The presence of a combination of human and physical processes applying pressure in coastal, flat and upland areas demands a holistic approach to any assessment of sensitivity (Malvarez and Pollard 2000). The principal aims are to examine the development of the area in recent years and to construct a scientific tool based on holistic sensitivity index that characterizes coastal stress and has the potential for application in similar situations where human processes are profound (Malverez et al. 2000) GIS was used to provide a mechanism by which variable of a heterogeneous can be geo-referenced and combined (Stanbury & Starr, 1999). The variables were based on the local area and adapted from those of Malvarez & Gornitz (1990).

A vulnerability map that attempts to illustrate spatially the relative importance and priority of cells or segments within a predefined area was used to make informed decisions about proposed developments as well as assess the environmental impacts of real and hypothetical events, thus building up a cumulative index of the area. The environmental vulnerability of a particular segment of the coastline, riverbank and watershed area, its biological sensitivity, and the intensity of environmental processes acting upon it.

The study identified variables in order to examine the level of vulnerability to attrition and erosion. This information provided a baseline upon which key policy and management interventions can be based. The levels of vulnerability were divided into five categories from very low to very high within each of the fifty-meter width cells.

Variable I: Anthropogenic factors

Four main indicators were used to measure anthropogenic factors. Population growth was chosen to represent human changes, while the degree to which structures have been built in the 20-metter foreshore area (coastal) and along the river banks were also used evaluated. Evidence of sand and mineral collection was also included. For population growth, the only data which appeared useable were the most recent data sets from the National Statistics Office that of the 2000-2007 data set.

Indicator 1 – Population growth. A fast growing population at the community level gave a high sensitivity while decreasing population gave a low sensitivity value.

Indicator 2- Level of urbanization- This measured the population per area of each community with the town. A high population per unit of area gave a high sensitivity.

Indicator 3- Protective structures- Described the degree to which structures had been built into the 20 m foreshore/riverbank area. No structures gave a low sensitivity index, with an ascending scale of wooden structures, to protruding structures reaching beyond the foreshore zone giving a very high sensitivity rating.

Indicator 4- A final indicator measured the level of sand extraction that was taking place on the beach. Collection of sand constitutes a very high sensitivity of the area to erosion, and no evidence of collection gave a low sensitivity rating.

Variable 2: Biological indicators

Living plants provide significant value in terms of buffering against physical processes, thus providing stability for the substrate (coastal) / river embankment. In shallow waters, Mangroves act as a direct buffer to the impact of waves and storms, and bind the sediment and sand with their roots. On shore, trees and help to bind sand and sediments at the top of the beach.
Indicator 1- Fringing vegetation- a variety of hardy plants and trees (coconut, cocos nucifera) were found fringing at the back of the coastline binding sediment and sand. For river embankment, Bamboo and related plants were also considered. High cover was considered as giving the substrate/embankment a low sensitivity whereas low vegetation gave a high rating. Plants and trees can prevent b ach/embankment erosion by stabilizing silt and sand, with certain species having roots that spread laterally thereby effectively protecting the shoreline/embankment.

Indicator 2- Mangrove (coastal), bamboo and related plants (upland). Mangroves are communities of salt-tolerant wooden plants that occur primarily along more sheltered coastal areas in the inter-tidal zone. Mangroves trap and retain sediments, absorb coastal storm and wave energy, provide shelter and assimilate nutrients to convert to plant tissue. A high area of coverage gives a low sensitivity and a low cover area gives a high sensitivity rating. Bamboo and related plants were used for river embankment areas.

Variable 3: Policy and planning

In order to manage a coastline and rivers, a very important pre-requisite is that the main government agencies mandated to manage the area have a clear analysis of the status of the area. This plan has a balance of "hard" and "soft" shoreline or river embankment engineering techniques. For upland and flat/lowland areas the focus is on managing land utilization and conversion.

The policy and planning environment were separated into two indicators.

Indicator 1- A clear management laid out with clear strategies for land management had been budgeted and were being implemented. A clear plan with budget for implementation gave a low sensitivity.

Indicator 2- The second variable was the clarity of jurisdiction, i.e. who manages the coastline, riverbank and watershed areas. An area with multiple overlapping jurisdictions proves to be much more difficult to manage, especially given the country's archaic legislation. The areas classed as most sensitive were those with multiple agency jurisdictions.

Variable 4: Positive interventions

Several shoreline management best practices were identified which were considered to have a positive impact on the area.

Indicator 1- Tree planting along the shoreline/river embankment/watershed areas by local residents gave an area a low sensitivity index.

Indicator 2- Marine and upland protected areas gave extra degree of protection to coral/seagrass and watershed and riverbank resources.

Indicator 3- Clear setback zone implemented.

Variable 5: Erosion and Attrition (hydrodynamics) Assessment of the prevailing winds (and therefore transport of sediment) along the coastline was made. ……for upland and watershed areas. Strength and direction of the Southwest monsoon winds strongly affects the city's coastal areas.

Indicator 1- A simple model was used to identify the maximum potential drift, deposition and erosion portions of the town.

Variable 5: Morphology/land form

For shoreline areas, the width and breath of the beach indicates high sensitivity while in upland areas, steep slopes indicate high sensitivity.

Indicator 1- Wide and narrow beaches and riverbanks which are very narrow were considered as most sensitive due do their limited sand storage capabilities providing only slight protection from physical forces. Large and steep cliffs were also considered in riverbanks and watershed areas.

Variable 6: Lithology of the coastline

Two indicators were chosen to represent lithology

Indicator 1- Different sediment/rock types have different erosion rates. Smaller sands and sediments will be more sensitive to erosion hence the classification was based on grain size, with sediment being the most sensitive and rocky outcrops the least sensitive.

Indicator 2- The slope of the beach was taken into consideration. A high slope beach was considered as being more sensitive than that of a small slope.