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Measuring social vulnerability to climate change-induced hazards in the Philippines

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Measuring social vulnerability to climate change-induced hazards in the Philippines

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Abstract

As the reality of climate change slowly sinks in the psyche of human society through the undeniable deterioration of human security among and within nations resulting from its impacts, we are now on a race against time to be prepared and proactive to mitigate its undesirable consequences on the population. One of the key tasks at hand is to better understand risk and its components of hazard, exposure, and vulnerability, which is crucial to mitigating loss and damage resulting from climate-related extremes. The Philippines is currently ranked 2nd in terms of risk according to the recent World Risk Report (Welle et al. 2014) due to its comparatively high exposure to a number of hazard types globally – typhoons, floods, earthquakes, volcanic eruptions, sea level rise, etc.

Because of its natural propensity to biophysical hazards due to its de facto exposure to a multitude of hazards, this thesis seeks to develop and test an index for social vulnerability derived from raw census data for the Philippines. As it is rare to gain access to disaggregated census data for a country, the research was allowed to formulate a social vulnerability index that is truly adapted to a particular country setting and it is unprecedented that such a rich database had been available for social vulnerability metrics. Furthermore, the research has a nationwide coverage at its most basic level of governance, the barangay, which allowed the comprehensive mapping of social vulnerability at such a detailed geographic scale. The further availability of census data from previous years also gave an added opportunity to compare social vulnerability trajectories over time.

Together with social vulnerability, the component of hazard exposure is an equally important aspect of risk and in the context of climate-change induced hazards; it also needs to be determined and delineated so that a proper assessment of these a priori measurable elements of risk can be evaluated together.

The resulting index scores were then validated against previous hazard events to determine if higher social vulnerability index scores have any influence or relationship on the outcome of disasters, in particular coastal river flooding. Another investigation then looked at the possible influence of a recurrent hazard such as typhoons on the state of vulnerability of a community.

The results reveal pretty alarming trends in terms of trajectories of vulnerability at the barangay level. Rural barangays, which tend to be dominate the very high vulnerability categories have also remained consistently in the same high vulnerability states compared to their urban counterparts. At very local scales of analysis, expected relationships between vulnerability states and loss and damage incurred during extreme flood events have resulted in findings that oppose conventional literature. Finally, although there is seemingly an initial inverse relationship between typhoon hazard exposure and social vulnerability, a geographic partitioning of the samples reveal inconclusive trends.

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Special acknowledgements to the victims of various climate-related disasters in the Philippines in the recent years. It is because of them that I was moved to pursue this line of research, inspired by their capacity and resolve to rebuild their lives against all odds despite all that they have lost. I hope that my work can have some positive impact on their lives and the lives of other communities living precariously in hazard-prone areas throughout the Philippines.

I thank God for this opportunity to be of service to His people while enriching my life with these experiences that I shall always treasure.

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List of Acronyms and Abbreviations

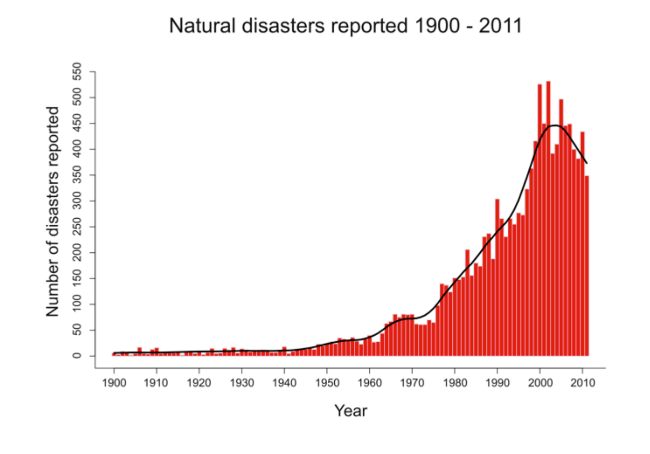
CRED	Center of Research on the Epidemiology of Disasters
CRFH	Coastal River Flood Hazard
DEM	Digital Elevation Model
DRRMO	Disaster Risk Reduction and Management Office
DSH	Direct Storm Hits
ESSC	Environmental Science for Social Change
GADM	Global Administrative Areas
GIS	Geographic Information Systems
QGIS	Quantum GIS
HFA	Hyogo Framework for Action
IBTrACS	International Best Track Archive for Climate Stewardship
IPCC	Intergovernmental Panel on Climate Change
IUSSP	International Union for the Scientific Study of Population
JPL	Jet Propulsion Laboratory

MGB-DENR	Mines and Geosciences Bureau – Department of Environment and Natural Resources
MIMAROPA	MIndoro, MArinduque, ROmblon, PAlawan
NAMRIA	National Mapping and Resource Information Authority
NASA	National Aeronautics and Space Administration
NEDA	National Economic and Development Authority
NOAA	National Oceanic and Atmospheric Administration
NSCB	National Statistical Coordination Board
OLS	Ordinary Least Squares
PAGASA	Philippine Atmospheric, Geophysical and Astronomical Services Administration
PCA	Principal Components Analysis
PIA	Philippine Information Authority
PSA	Philippine Statistics Authority
PSGC	Philippine Standard Geographic Code
SES	Socio-Ecological System
SRTM	Shuttle Radar Topography Mission
SVI	Social Vulnerability Index
TS	Tropical Storm
UN	United Nations
UNEP	United Nations Environment Programme
UNISDR	United Nations International Strategy for Disaster Reduction
UNU-EHS	United Nations University Institute for Environment and Human Security
USA	United States of America

1 Introduction

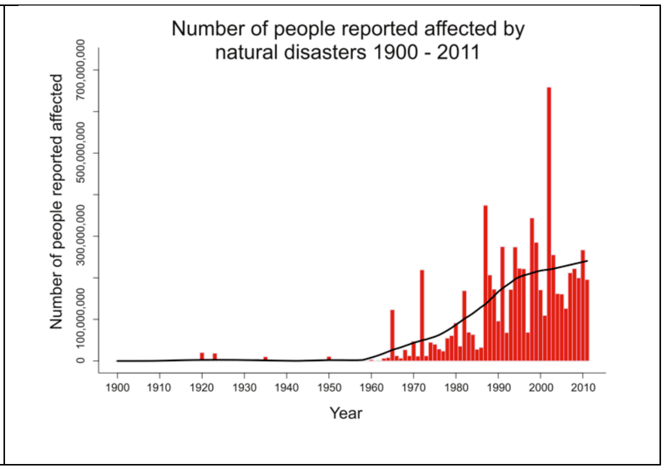
With the onset of climate change and its adverse effects, there has been a growing focus on disaster risk reduction and management. Climate related extremes are on the rise and with these come their escalating impacts on human populations (Oliver-Smith 2008). Although these extremes are increasing in quantity and magnitude, it is only when a sizeable number of people are impacted that there are disasters. UN Secretary-General Kofi Annan puts it well in his message to the International Day for Disaster Reduction in 2003, that hazards are a part of life and that they only become disasters when people's lives and livelihoods are swept away (Annan 2003). The Center for Research on the Epidemiology of Disasters (CRED) through its online EM-DAT Disaster Database presents an increasing trend of reported natural disasters and the corresponding affected persons as a result from 1900-2011 (Figures 1-1 and 1-2).

Figure 1-1 Number of reported natural disasters from 1900-2011



Source: EM-DAT 2014

Figure 1-2 Number of people affected by natural disasters from 1900-2011



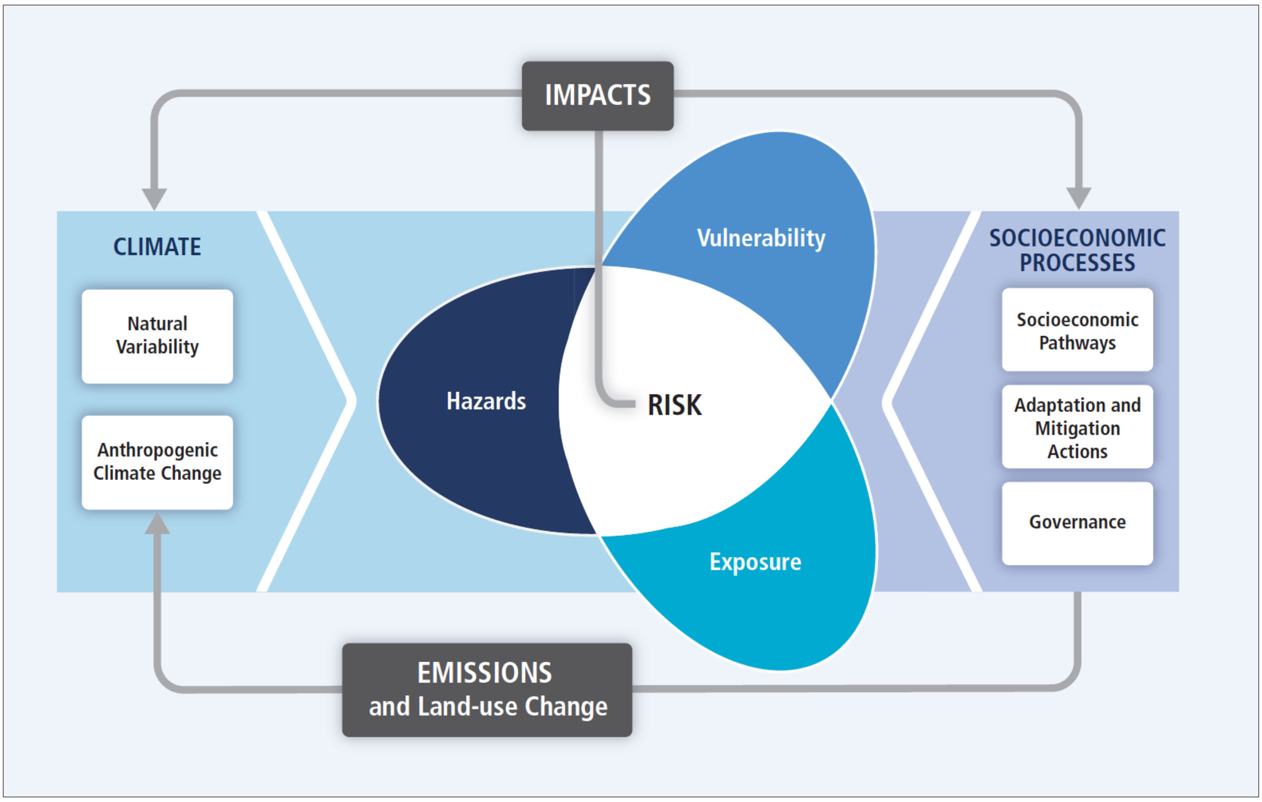
Source: EM-DAT 2014

A recent report of the New England Journal of Medicine adequately explains this increasing trend in disasters:

> "Although better communications may play a role in the trend, the growth is mainly in climate-related events, accounting for nearly 80% of the increase, whereas trends in geophysical events have remained stable. During recent decades, the scale of disasters has expanded owing to increased rates of urbanization, deforestation, and environmental degradation and to intensifying climate variables such as higher temperatures, extreme precipitation, and more violent wind and water storms. The effects of disasters on populations include immediate death and disabilities and disease outbreaks caused by ecologic shifts. For example, the 2010 earthquake in Haiti and Cyclone Nargis, which hit Myanmar in 2008, killed 225,000 and 80,000 people, respectively, in a matter of minutes; destroyed health care facilities; and left many homeless." (Leaning & Guha-Sapir 2013, p.1836)

With the high percentage of the increasing trend of disasters attributed to climate-related extremes, there is an increasing need to investigate the actual impacts of climate-related hazards, particularly in relation to climate change. With greater certainty regarding the severity of climate change than previously declared, its expected adverse effects have recently been adjusted correspondingly by the Intergovernmental Panel on Climate Change (IPCC 2013). As a result of this development, there has been an equivalent increase in focus on disaster risk reduction and management. In its special report on managing risks to advance climate change adaptation, this foremost international body for the assessment of climate change states that hazard events are not the sole driver of risk. It declared that the resulting levels of adverse effects are to a great degree determined also by the vulnerability and exposure of societies and socio-ecological systems (IPCC 2012). Figure 1-3 presents the most recent illustration of the relationships among hazard, exposure, and vulnerability to date in the most recent 5th Assessment Report of the IPCC. It shows that disaster risk lies in the convergence of hazard events, vulnerability and exposure – indicating that disasters occur when all three elements are present.

Figure 1-3 Key concepts involved in disaster risk management (taken from Field et al. 2014)



Areas of natural hazards, defined as threats having the potential to do harm on people and places (NRC 2007), are increasingly being delineated as part of the Hyogo Framework for Action declaration (UNISDR 2005) in order to develop, periodically update and disseminate risk maps and related information to stakeholders (see Box 1). The term vulnerability appears frequently in a multitude of disciplines of applied research, but because of this diversity there is not a common working definition for the term (Birkmann & Wisner 2006). Vulnerability in the context of this thesis describes the degree to which a socio-ecological system is either susceptible to harm resulting from the impact of natural hazards (Oliver-Smith 2008; Ford 2002).

The ongoing challenge now is how can the research community respond to the call of the HFA to more systematically quantify and map out disaster risk, particularly the component of vulnerability that deals more with the human element of risk, i.e. the social factors that contribute to differential impacts involving hazard risk on the population. The main intent of the HFA is in the reduction of losses associated with disaster risk and it is this objective that this thesis seeks to address.

Box 1. The Hyogo Framework for Action (HFA)

In 2005 the United Nations convened the Second World Conference on Disaster Reduction in Kobe, Hyogo, Japan. This was held as a follow-up ten years after the adoption of the Yokohama Strategy for a Safer World: Guidelines for Natural Disaster Prevention, Preparedness and Mitigation (1994), the preceding World Conference on Disaster Reduction. During this conference the Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters (HFA) was negotiated and adopted by 168 countries shifting the paradigm for disaster risk management from post disaster response to a more comprehensive approach that would also include prevention and preparedness measures. The HFA is the key instrument for implementing disaster risk reduction, adopted by the Member States of the United Nations. Its overarching goal is to build resilience of nations and communities to disasters, by achieving substantive reduction of disaster losses by 2015 – in lives, and in the social, economic, and environmental assets of communities and countries. The HFA five priority areas for action are:

1. Ensure that disaster risk reduction is a national and a local priority with a strong institutional basis for implementation.
2. Identify, assess and monitor disaster risks and enhance early warning.
3. Use knowledge, innovation and education to build a culture of safety and resilience at all levels.
4. Reduce the underlying risk factors.
5. Strengthen disaster preparedness for effective response at all levels.

A third conference is scheduled for March 2015 in Sendai, Japan and will have the following objectives:

a. To complete the assessment and review of the implementation of the HFA;
b. To consider the experience gained through the regional and national strategies/institutions and plans for disaster risk reduction and their recommendations as well as relevant regional agreements under the implementation of the HFA;
c. To adopt a post-2015 framework for disaster risk reduction;
d. To identify modalities of cooperation based on commitments to implement a post-2015 framework for disaster risk reduction;

To determine modalities for periodic review of the implementation of a post-2015 framework for disaster risk reduction.

According to the World Risk Report of 2014 the Philippines is now ranked second in terms of risk globally out of a total of 171 countries assessed (Welle et al. 2014). This means that among countries globally, there is greater likelihood that its population will suffer loss and damage from various hazards such as floods, typhoons, earthquakes and sea level rise. With the population topping 100,000,000 officially as of 27 July 2014 (Rappler 2014) and 41.5 per cent of the population living on less than US$2 per day (The World Bank 2012), poverty is widespread both in urban and rural areas, though having a higher incidence in the latter (Reyes et al. 2010). Having a population growth rate of 1.9 per cent in 2010 (Philippine Statistics Authority 2012), the number of poor is only expected to increase. The prevalence of poverty in the country indicates that socially the population is inherently vulnerable and in this context is considered to be independent to a society's exposure to hazard risk (Brooks 2003).

1.1 Objectives

The main objective of this dissertation is to measure social vulnerability of communities by developing a social vulnerability index (*SVI*) based on disaggregated census data for the Philippines that could capture the inherent (endogenous) vulnerabilities of the population at its most basic unit of governance – the *barangay*. Indicators of vulnerability based on the existing literature are derived from the census data fields and combined to form the *SVI* of each barangay – the unit of analysis for this research. Three levels of information are available from the official Census of Population and Housing of the Philippines, i.e. individual members, households, and housing units. Each level yielded corresponding sub-indices of social vulnerability that were later combined into an overall *SVI* for each barangay.

The derived *SVI* sub-indices and the overall scores from two consecutive census years (2000 and 2010) were categorized into quintiles ranging from Very Low, Low, Moderate, High, to Very High values and were mapped out to present the geographical distribution of social vulnerability throughout the Philippines in order to detect patterns or trajectories of change (or lack thereof) between the two census years. Data on urban or rural classification of barangays put an added value in the analysis by showing in which classes (urban or rural) the extreme levels of vulnerability are concentrated, thus serving as a means of validation of the index scores for both census years. The comparisons and resulting analyses are presented using various graphs as well as maps to allow an objective basis to compare both the states of social vulnerability between the two census years as well as the relative distribution of social vulnerability geographically throughout the Philippines.

The resulting *SVI* scores for the most recent census (2010) were then validated against actual disaster events to see whether there is any correlation between social vulnerability status and loss and damage resulting from the impacts of a hazard event on the exposed population.[1] As risk is evaluated as a multiplicative composite

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[1] Loss and damage refers to negative effects of climate variability and climate change that people have not been able to

of hazard, vulnerability, and exposure (IPCC 2012), delineation of areas of hazard exposure were likewise crucial in the analysis since it is only in areas where the population is exposed that the impact of hazards on the social vulnerability of the population can be evaluated. For this reason, exposure zones for coastal river flood hazard were derived in order to evaluate the strength of relationships between the derived social vulnerability index scores and the outcome of this type of flash flood phenomenon. These relationships are comprehensively evaluated through multiple regression models for a specific flood episode triggered by Tropical Storm (TS) Washi in Northern Mindanao in mid-December of 2011. Levels or extents of exposure of each barangay were evaluated simultaneously with the corresponding *SVI* scores to assess how the two influence the outcomes of the associated flood disasters. Since the two elements of social vulnerability and exposure can be determined *a priori*, the resulting relationships, if found to be statistically significant, have very important implications in terms of proactive planning at the local level given the high spatial resolution of the available data.

Finally, typhoon exposure was derived for the entire country in order to establish if increasing levels of exposure have any influence on the levels of vulnerability of communities. For this part of the research, regression analysis was also chosen, but with *SVI* as an outcome variable to exposure in order to establish if there is any statistically significant relationship between level of exposure and the magnitudes of the measured *SVI* for typhoon hazard.

1.2 Literature Review

This section presents the review of the existing literature on the particular areas of research covered in this thesis. As vulnerability has origins in such diverse fields of research as political ecology, human ecology, physical science, etc. (Cutter 1996; Miller et al. 2010), a presentation of the plurality of definitions and relationships is devoted to the first part. The second part deals with the evolution of the sub genres of vulnerability and introduces the concept of social vulnerability. The third part gives a brief presentation of vulnerability frameworks in an attempt to understand the progression of theory and practice related to vulnerability and its assessment. A section follows on measuring social vulnerability and the key bases driving efforts towards this undertaking. The next part tackles census-based social vulnerability measurements and the current state of the art in this emerging field. A rundown on vulnerability assessments in the Philippines follows after, presenting the various strengths and weaknesses of efforts to date. The final part presents the element of hazard exposure and the more notable research that relate it with vulnerability, albeit at relatively coarse levels of detail.

It is important to note at this early stage of this thesis that this body of research is hinged on the precepts of sustainability science, which fundamentally considers the close coupling of social-ecological or human-environment systems. In essence, sustainability science is science, technology, and innovation in support of sustainable development—meeting human needs, reducing hunger and poverty, while maintaining the life support systems of the planet (Kates 2010; Turner et al. 2003). As sustainability science focuses on the dynamic interactions between nature and society (Kates & Clark 2001), it provides a solid framework on which this research is grounded and takes advantage of the integrative power of interdisciplinary research in promoting sustainability.

1.2.1 Definitions and Disciplinary Perspectives of Vulnerability

Throughout the literature, there are various interpretations and definitions of vulnerability. This section presents the diversity and complexity of the state of scholarly research on vulnerability in an attempt to focus on a suitable set of constructs that effectively advances the primary objectives of this thesis.

Vulnerability has its etymological roots from the Latin word *vulnus* meaning 'a wound' or *vulnerare* meaning 'to wound'. In line with the rudimentary sense of the word, Kates (1985) puts forth vulnerability as a society's 'capacity to be wounded' in response to a perturbation. The literature abounds with other unique definitions of vulnerability (Cutter 1996; Brooks 2003; Janssen & Ostrom 2006; Hinkel 2011), which is in part due to the diversity of disciplines that deal with the concept (Füssel 2010). An initial attempt of Cutter (1996) lists a selection of definitions of vulnerability from different authors (see Box 2). It is evident from this that at that early stage, there had not been a common takeoff point in positing a common understanding of vulnerability as a concept. Thywissen (2006) in her comparative glossary of terms related to risk lists 35 discrete definitions of the concept , while Brooks (2003) mentions an array of bewildering terms in the literature. These definitions either share similar ideas such as risk, sensitivity and fragility or inversely similar ideas as in resilience, marginality, adaptability, adaptive capacity and stability (Hinkel 2011; Liverman 1990; Füssel & Klein 2006). This wide variety of interpretations and constructs of the notion of vulnerability coming from multiple disciplinary roots has contributed to the present day "Babylonian confusion" in our understanding of the term (Hinkel 2011; Thywissen 2006; Janssen & Ostrom 2006). Given this diversity of interpretations, a manual compilation and systematic review of all publications on vulnerability is impossible given the large number of publications between 1960 and 2005 and the multiplicity of disciplines involved (Janssen et al. 2006). As early as 1981, Timmermann had already stated that "vulnerability is a term of such broad use as to be almost useless for careful description at the present, except as a rhetorical indicator of areas of greatest concern". Birkmann (2006c) succinctly states that we are dealing with a paradox in terms of vulnerability – we aim to measure it, though we cannot define it precisely.

Box 2. Selected definitions of vulnerability (adapted from Cutter 1996)
Gabor and Griffith (1980) Vulnerability is the threat (to hazardous materials) to which people are exposed (including chemical agents and the ecological situation of the communities and their level of emergency preparedness). Vulnerability is the risk context.
Timmerman (1981) Vulnerability is the degree to which a system acts adversely to the occurrence of a hazardous event. The degree and quality of the adverse reaction are conditioned by a system's resilience (a measure of the system's capacity to absorb and recover from the event).
UNDRO (1982) Vulnerability is the degree of loss to a given element or set of elements at risk resulting from the occurrence of a natural phenomenon of a given magnitude.
Susman et al. (1983) Vulnerability is the degree to which different classes of society are differentially at risk.
Pijawka and Radwan (1985) Vulnerability is the threat or interaction between risk and preparedness. It is the degree to which hazardous materials threaten a particular population (risk) and the capacity of the community to reduce the risk or adverse consequences of hazardous materials releases.
Bogard (1988) Vulnerability is operationally defined as the inability to take effective measures to insure against losses. When applied to individuals, vulnerability is a consequence of the impossibility or improbability of effective mitigation and is a function of our ability to detect the hazards.
Mitchell (1989) Vulnerability is the potential for loss.
Liverman (1990) Distinguishes between vulnerability as a biophysical condition and vulnerability as defined by political, social and economic conditions of society. She argues for vulnerability in geographic space (where vulnerable people and places are located) and vulnerability in social space (who in that place is vulnerable).
Downing (1991) Vulnerability has three connotations: it refers to a consequence (e.g., famine) rather than a cause (e.g., drought); it implies an adverse consequence (e.g., maize yields are sensitive to drought; households are vulnerable to hunger); and it is a relative term that differentiates among socioeconomic groups or regions, rather than an absolute measure of deprivation.
Dow (1992) Vulnerability is the differential capacity of groups and individuals to deal with hazards, based on their positions within physical and social worlds.

Smith (2013) Risk from a specific hazard varies through time and according to changes in either (or both) physical exposure or human vulnerability (the breadth of social and economic tolerance available at the same site).
Alexander (1993) Human vulnerability is a function of the costs and benefits of inhabiting areas at risk from natural disaster.
Cutter (1993) Vulnerability is the likelihood that an individual or group will be exposed to and adversely affected by a hazard. It is the interaction of the hazards of place (risk and mitigation) with the social profile of communities.
Watts and Bohle (1993) Vulnerability is defined in terms of exposure, capacity and potentiality. Accordingly, the prescriptive and normative response to vulnerability is to reduce exposure, enhance coping capacity, strengthen recovery potential and bolster damage control (i.e., minimize destructive consequences) via private and public means.
Blaikie et at. (2004) By vulnerability we mean the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard. It involves a combination of factors that determine the degree to which someone's life and livelihood are put at risk by a discrete and identifiable event in nature or in society.
Bohle et al. (1994) Vulnerability is best defined as an aggregate measure of human welfare that integrates environmental, social, economic and political exposure to a range of potential harmful perturbations. Vulnerability is a multilayered and multidimensional social space defined by the determinate, political, economic and institutional capabilities of people in specific places at specific times.
Dow and Downing (1995) Vulnerability is the differential susceptibility of circumstances contributing to vulnerability. Biophysical, demographic, economic, social and technological factors such as population ages, economic dependency, racism and age of infrastructure are some factors which have been examined in association with natural hazards.

It is important to note that it is not the intention of this study to immerse in the already confusing discourse regarding definitions of vulnerability. There have been numerous publications devoted to the conceptualization of vulnerability and the reader is directed to the works of Timmermann (1981), Liverman (1990), Cutter (1996), Hewitt (1997), Kasperson et al. (2001), UNEP (2003), Ford (2002), Turner et al. (2003), Prowse (2003), and Kasperson and Archer (2005). Other work on the conceptualization of vulnerability specifically in relation to climate change research include Adger (1999), Adger and Kelly (1999), Olmos (2001), Moss et al. (2010), Brooks (2003), Downing et al. (2003), and O'Brien et al. (2009).

This study will focus on the commonalities rather than the differences among the various schools of thought in relation to the concept of vulnerability and adopt a working framework that best suits the objectives of this thesis, which is focused on assessing/measuring social vulnerability to aid in the more effective management of hazard risk in the context of climate change.

1.2.2 Social Vulnerability

To date, the most popular definition of vulnerability has been from the IPCC Fourth Assessment Report:

> "Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity." (Parry & Canziani 2007, p.21)

This definition is arguably the most authoritative and widely used in the context of climate change research and has been the basis of a wide range of research in assessing vulnerability (Hinkel 2011). However, as Hinkel points out, the IPCC definition is poor in that the defining concepts themselves are quite vague and difficult to operationalize, with some terms being just as imprecise as the concept of vulnerability itself or having strong normative or subjective connotations.

In all this diversity and confusion of definitions of vulnerability, there is a general agreement that in the basic indicative sense it means the capacity of a system to suffer harm in response to a stimulus (Ford 2002). Brooks (2003) further notes that what stands out in all the confusion is a consistent notion that vulnerability is a function of a system's exposure and sensitivity to hazardous conditions and its ability, capacity or resilience to cope, adapt or recover from the adverse impacts of those conditions.

Gallopín (2006) provided a comprehensive systemic analysis of the related terminologies of vulnerability, resilience, and adaptive capacity within the context of the coupled socio-ecological system (SES), which he defined as human (social) and biophysical (ecological) subsystems in mutual interaction (Gallopín 1991). There is a seemingly evident dual categorization of the concept of vulnerability – one in terms of external or biophysical vulnerability (sometimes referred to as risk) and another in terms of internal/inherent or social vulnerability (Brooks 2003). As Brooks points out, vulnerability definitions particularly in the climate change research domains tend to fall into the two broad categories of biophysical vulnerability and social vulnerability. The former is concerned more with eventual impacts of exogenous hazard events while the latter deals with the inherent property of a system arising from its endogenous characteristics.

Biophysical vulnerability deals with the ultimate impacts of a hazard event and is normally assessed in terms of the level of damage a system incurs resulting from an encounter with the hazard (Brooks 2003). Social vulnerability on the other hand can be considered as an inherent property of a human system based on its internal characteristics (Adger 1999; Adger & Kelly 1999). Social vulnerability has been the main focus of field research and vulnerability mapping projects, which are generally centered on identifying the most vulnerable in society, as well as looking at differential vulnerability between or within geographic units that may experience similar hazards (Downing et al. 2003). The result of social vulnerability and its interplay with a hazard is then assessed using economic measures and deaths and injuries (Brooks & Adger 2003) and in this way, social vulnerability can be seen as one of the determinants of biophysical vulnerability (Brooks 2003).

Brooks explains quite clearly the relationship between social vulnerability and hazard exposure:

> "The nature of social vulnerability will depend on the nature of the hazard to which the human system in question is exposed: although social vulnerability is not a function of hazard severity or probability of occurrence, certain properties of a system will make it more vulnerable to certain types of hazard than to others. For example, quality of housing will be an important determinant of a community's (social) vulnerability to a flood or windstorm, but is less likely to influence its vulnerability to drought. So, although social vulnerability is not a function of hazard, it is, to a certain extent at least, hazard specific – we must still ask the question 'vulnerability of who or what to what?' Nonetheless, certain factors such as poverty, inequality, health, access to resources and social status are likely to determine the vulnerability of communities and individuals to a range of different hazards (including non-climate hazards). We may view such factors as 'generic' determinants of social vulnerability, and others such as the situation of dwellings in relation to river flood plains or low-lying coastal areas as determinants that are 'specific' to particular hazards, in this example, flooding and storm surges." (Brooks 2003, p.4)

From this presentation, social vulnerability has both external (specific) and internal (generic) elements that determine the degrees of vulnerability of a population. The exposure to a type of hazard is then the specific determinant to social vulnerability while generic determinants relate more to social conditions mentioned above. This integrated view of social vulnerability as having a geographic component determined by the hazard type and severity and an internal social response that impinge a population's ability to respond is shared by Cutter (1996).

The vulnerability discourse is extremely complex given the diversity of disciplines that utilize the concept in various applications and this is seen in the collection of definitions throughout the literature. Given this apparent dissonance, it seems practical to adopt a definition of our approach to vulnerability that fits best one's particular objective, without further adding to the confusion by positing yet another construct or idea in the universe of interpretations. Furthermore, a new conceptual definition of vulnerability can demand a separate doctoral thesis in itself.

Since the primary aim of this research is to measure social vulnerability to natural hazards, it is logical that the perspective of Brooks (2003) as quoted above be the basic approach to vulnerability in that it does define the relationships between hazard exposure and social vulnerability quite well. This definition is likewise in consonance with the IPCC Framework on Disaster Risk Management mentioned earlier (see Figure 1-3), which has emerged as the integral perspective for hazard risk management in the context of climate change.

Finally, in the context of effective hazard risk management it is necessary to concretely define hazard type (i.e. "what we are vulnerable to") so as to arrive at concrete responses that translate to vulnerability reduction and risk mitigation for a population with respect to specific hazards.

1.2.3 Vulnerability Frameworks

Vulnerability assessments had originally been largely focused on biophysical or structural properties of a hazard and thus dealt with features of the natural and built landscape (Zahran et al. 2008). It was O'Keefe et al. (1976) who put forth the idea that the increasing global vulnerability to hazards and disasters was caused by social, political and economic pressures that magnified vulnerability and eventually the impact of the hazard by affecting how people respond to and cope with disasters. Blaikie et al. (1994) and Wisner (2003) developed the Pressure and Release Model which ties vulnerability to "the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist and recover from the impacts of a natural hazard."

Cutter in 1996 developed the Hazards of Place Model which presents the place-based interaction between hazard exposure and social vulnerability in an overall determination of the differing social burdens of hazards and how this relationship has distinct temporal and spatial dimensions. Turner et al. (2003) provides a framework for vulnerability that links the local with regional and global biophysical and geopolitical dynamics, thus providing this larger context of the interconnectivity of the local with broader scale dynamics.

Birkmann (2006b) presents a comprehensive list of conceptual frameworks for vulnerability in the context of measuring vulnerability to promote disaster resilience. He lists ten conceptual frameworks from the literature that presents different views of vulnerability in the light of disaster risk and introduces an additional framework of his own. As it is beyond the scope of this thesis, the reader is referred to his work for further information.

1.2.4 Measuring Social Vulnerability

> "The starting point for reducing disaster risk and for promoting a culture of disaster resilience lies in the knowledge of the hazards and the physical, social, economic and environmental vulnerabilities to disasters that most societies face, and of the ways in which hazards and vulnerabilities are changing in the short and long term, followed by action taken on the basis of that knowledge." (UNISDR 2005, p.12)

The quote above is taken from the preamble of the HFA and is also the main starting point of this research. As successful response depends on the comprehensive understanding of the phenomena involved and more importantly the complex interplay of biophysical and social elements within the coupled SES.

Birkmann (2006c) points out that rather than defining disasters primarily as physical phenomena which require mainly technological solutions, it is better viewed as the complex interaction between the hazard events (e.g. typhoons, floods, earthquakes, etc.) and a society's vulnerability – its infrastructure, economy and environment – all of which are determined by human behavior. This does not diminish the need for understanding the physical elements that contribute to risk, but it highlights the often-neglected aspect of social vulnerability that is a major component of risk.

Measuring social vulnerability is increasingly regarded as an important component of effective disaster risk reduction and building resilience (Birkmann & Wisner 2006). It is in the context of mounting disasters and environmental degradation that vulnerability measurement is seen as crucial if science is to support the transition to a more sustainable world (Kasperson et al. 2001).

1.2.5 Census-based Social Vulnerability Measurements

Collapsing a complexity of human facets into one measure, such as an index, is faced with many empirical challenges (Eakin & Luers 2006a), but if done properly, it becomes a powerful tool in portraying social conditions such as people's vulnerability to natural hazards (Gall 2007). By its textbook definition, an index:

> "…is a measure of an abstract theoretical construct in which two or more indicators of the construct are combined to form a single summary score. …is simply an additive composite of several indicators. …simply assumes that all the items reflect the underlying construct equally, and therefore, the construct can be represented by summing the person's score on the individual items." (Carmines & Woods 2003, p.485)

As indices attempt to condense a complex reality into simple terms, they can be good measures (Diener & Suh 1997). There is, however, much disagreement in terms of indicator selection and statistical downscaling, as well as the incorporation of scale and time in current social vulnerability indices (Hill & Cutter 2001). Many studies stress the importance of scale in vulnerability assessments and how it changes depending on the degree of aggregation being considered (O'Brien et al. 2004; Eakin & Luers 2006b; Fekete et al. 2010). Gall (2007) also points out that most case studies that deal with social vulnerability indices utilize very few indicators (at times only one). Despite the general consensus regarding overall factors that influence social vulnerability to natural hazards, scientists and professionals tend to disagree on selecting the specific indicators (Gall 2007).

Few also have ventured into a downscaling of vulnerability assessments to natural hazards at the country extent using data provided by the national census. The two most notable due to their comprehensive coverage are Cutter (1996) and Fekete (2009) using data from the census bureaus of the USA and Germany respectively. Both adopted the method of principal components analysis (PCA) developed by Cutter as the main tool to reduce the number of indicators used in the model and to come up with a single score for social vulnerability. PCA is a mathematical technique that is applied to high dimensional data as a form of dimension reduction by creating linear combinations of the original data to form axes, or principal components, and selecting the axes that contain the greatest variance and ignoring the ones that are comparatively of negligible influence (Holand 2008). The data available in the cases mentioned above are data summaries available from the respective census bureaus down to the census block level for the USA and the county/district level for Germany. Due to legal constraints on privacy in countries such as the USA, only predefined data summaries at the most basic census subdivisions at best are available to the public (U.S. Census Bureau 2008).

The availability of disaggregated (100%) census data from the Philippine Statistics Authority allowed this research much greater flexibility in defining indicators that are specific to the Philippine context. The data available has both a high spatial resolution (at the barangay level) as well as a high level of flexibility in formulating custom indicators from the existing census fields. This is by far the most comprehensive social vulnerability assessment in terms of spatial resolution and the quality of the data available (at the individual, household, and housing levels) using census data for an entire country at its most basic level of governance.

Vulnerability measurement is an important prerequisite to reducing disaster risk, but requires an understanding of the different vulnerabilities to hazards of natural origin, which determine risk in the first place (Birkmann 2006a). Measuring vulnerability can be done as a static exercise, but measured over time it can reveal trends, which in turn can guide efforts at risk reduction and eventually contribute to building resilience. Cutter and Finch (2008) in their PCA methodology compared social vulnerability measurements over six decadal census years for the USA at the county level using a set of predefined variables in an attempt to monitor how social vulnerability to natural hazards can change over time.

1.2.6 Vulnerability Assessments in the Philippines

There have been a growing variety of initiatives to assess natural hazard risk in the Philippines, each with its own specific objective and application. Acosta-Michlik (2005) developed a province-level national vulnerability assessment as a means to identify pilot areas for detailed vulnerability studies. The Manila Observatory (2005) presented a similar provincial scale analysis of more general hazard vulnerability maps for the country. Fano (2010) developed a flood risk index also at the provincial level based on a combination of biophysical and social indicators. Several web-based initiatives followed that mainly focused on biophysical assessment and identification of hazard risk areas (ESSC & MGB-DENR 2012; National Institute of Geological Sciences 2012; Department of Science and Technology 2012).

From what is presented above, there are two elements that are inadequately given consideration in the prevailing approach to managing and reducing risk in the Philippines. These are the two crucial elements of localization and the incorporation of social factors that influence vulnerability. For example, while the very coarse resolution of the provincial scale provides a wealth of information on the social conditions of the population, it does not provide enough bases for intervention on the ground. Because hazards are uniquely local in nature (Cutter et al. 2008), provincial (and even municipal) scale data and analyses are inadequate for local level action or response. The issue of scale is a major factor that will determine concrete initiatives in mitigating risk on the ground. So far none of the currently available work mentioned addresses these two elements simultaneously that would allow a proper characterization of social vulnerability down to the community level. The importance of this body of work is in the comprehensiveness of the local level assessment of social vulnerability that can be appraised vis-à-vis the local impact of hazards.

1.2.7 Hazard Exposure

Hazard exposure is an important element in determining risk and it actually clearly defines zones where there is a potential for communities and individuals to be at risk. It is where these exposure zones and communities intersect that potential for disaster can occur, depending on the gravity of the hazard and the inherent state of vulnerability of these communities. For this reason, the HFA stressed on the development of systems of indicators of disaster risk and vulnerability at national and sub-national scales that will enable decision-makers to assess the impact of disasters on social, economic and environmental conditions and disseminate the results to decision makers, the public and populations at risk (UNISDR 2005). A major part of the effort of this research is to respond to the identified needs raised by the HFA, particularly in improving on indicators for vulnerability and more innovative means of defining and mapping out zones of hazard exposure on the ground.

Attempts have already been made to map out and quantify physical exposure and the subsequent risks on the exposed populations. The work of Peduzzi, et al. (2009) is among the most notable of such recent attempts, which combined tropical cyclone, earthquake, drought and flood hazards (accounting for 94% of all reported hazards between 1980-2006) with population distribution to derive physical exposure for countries at the global scale. A total of 23 vulnerability indicators were then tested such as the Human Development Index, GDP per capita and other readily available country-level datasets which were eventually streamlined using regression analysis in order to retain the most useful indicators for their analysis. The resulting disaster risk model that was developed was validated using actual data reported from global data providers such as EM-DAT (CRED 2012). It revealed strong statistical relationships between vulnerability and disaster impacts for countries at the global scale.

Cardona (2007) developed a complex series of indices for the Americas that would allow decision-makers to compare disaster risk propensity and management capacities among countries and across time scales. Choosing which indicators to include in index development is in the end determined by the availability of data across all units being analyzed – a given challenge in this type of research (Fekete 2009; Cardona 2007).

Comparisons among nations have great value in understanding the relationships among hazards, exposure and vulnerability leading towards a prioritization of needs for prevention and development (Peduzzi et al. 2009). But due to the relatively large within-country variance of vulnerability and the locale-specific nature of hazards themselves (Cutter et al. 2008) it is necessary to downscale the focus on disaster risk to reveal specific areas of exposure and the levels of vulnerability of the corresponding local populations. Fekete (2009) notes in the literature a host of past attempts at sub-regional and sub-national depictions of social vulnerability, though none have attempted to validate these vulnerability measures against the impacts of hazards, citing a number of challenges. Furthermore, these attempts at comprehensively measuring social vulnerability at sub-national scales still lack the needed resolution to capture actual communities at risk to localized hazards such as flash floods. The challenge at this higher level of detail is the availability of consistent and accurate data for analysis. The temporal dimension is also important for periodic updates, which can allow a monitoring of changes in vulnerability over time.

Given the implications of local level risk analysis in focused risk management efforts, the need for detailed information at the most basic levels of governance is crucial in guiding and strengthening community capacities in anticipation and response to hazards where they are exposed. Following the disaster risk management framework of the IPCC (2012), what is critical in this local scale of intervention is the identification of areas of exposure to specific hazards and an accompanying assessment of the vulnerability of the resident population. Determining to what extent these two factors influence the outcome of hazard events is an important research question that this thesis seeks to explore.

1.3 Structure of the Thesis

After the introduction and literature review presented here in Chapter 1, the remaining chapters are structured as follows:

Chapter 2 gives a comprehensive presentation of the study area as well as the associated data covering the different scales of analysis. It is in this chapter where detailed descriptions of the data used for the analyses are presented.

Chapter 3 details the methodologies employed to process and combine the raw data datasets for developing the *SVI* as well as the derivative data used for validation. The first part of this chapter describes the bases for comparing the derived *SVI* scores from the two census years of 2000 and 2010. It then details the process to arrive at the delineation of coastal river flood hazard and typhoon frequency zones, which are the chosen elements that define exposure. The statistical tools employed for the validation of the *SVI* vis-à-vis disaster outcome for flooding and typhoon exposure and its potential influence on *SVI* are then explained in detail.

Chapter 4 presents the results of the modeling, initially presenting a comparison between the outputs based on the two census years as well as distinctions between rural and urban barangays. It then presents the results of the various tests conducted as outlined in chapter 3 to determine what kinds of relationships have emerged.

Chapter 5 present the conclusions that can be drawn up from the analyses and ends with perspectives and potentials of further exploration and ongoing research.

1.4 Research Process Matrix

In order to systematically pursue the objectives of this research, a methodological process matrix was developed (Figure 1-4). This research process chart relates the thesis objectives with the data, the key methods employed as laid out in the succeeding chapters, and the results. It also provides a basis to relate key outcomes throughout the thesis that substantiate the conclusions.

The chart contains a visual summary of the primary and specific objectives on the upper left hand side. The specific objectives are divided into the five main components of this dissertation, i.e. the development of an *SVI*, the delineation of coastal river flood hazards and typhoon exposure based on frequency of occurrence, validation of flood hazard exposure using actual disaster data as case studies, and the investigation of possible relationships between hazard exposure and levels of social vulnerability. Each of the five specific objectives has been assigned a color that corresponds to the various related elements in the main process chart. The process chart itself is divided into three main groups, corresponding to the main chapters of the thesis – data, methodology, and results. Each of the elements of the groups is color-coded with the specific objectives that they correspond to. The branches of each of the three main groups (i.e. Data, Methodology, and Results) will be presented at the beginning of the corresponding chapters which then makes this process chart the main reference throughout the thesis text and serves as a guide in the various stages of the research and to keep the reader focused on the relationships among the different elements and outcomes of the research and its specific objectives.

Figure 1-4 Research process matrix relating the objectives with data, methods, and results

Primary Objective:
To develop and validate a high spatial resolution social vulnerability index (SVI) based on disaggregated census data for the Philippines

Specific Objectives	Data (CHAPTER 2)	Methodology (CHAPTER 3)	Results (CHAPTER 4)
1. Develop Social Vulnerability Index at the National Level	Census of Population and Housing (2.2.1) Political Boundaries (2.2.2) Urban and Rural Classification of Barangays (2.2.3)	Development of a Social Vulnerability Index (3.1) – Indicator selection and SVI Sub-index construction – Combining SVI Sub-indices into Overall SVI	SVI Modeling Results and Comparative Analysis (4.1) – Graphical Comparison of 2000 and 2010 SVIs in Urban vs. Rural Areas through Charts – Cartographic Comparison of 2000 and 2010 SVIs
2. Delineate Exposure Zones at the National Level	Digital Elevation Model - Shuttle Radar Topography Mission (2.2.5) Watershed Boundaries (2.2.6) Historical Typhoon Tracks (2.2.7)	Defining Zones of Flood Exposure (3.2.1) – SRTM - 2% slope and 10m from MSL – Watersheds with at least 20% mean slope and area < 1,800 sqkm Delineating Typhoon Exposure Using Frequency of Direct Storm Hits (3.2.2)	
3. Validate SVI and Flood Hazard Exposure with Loss and Damage Case Study	Site Descriptions and local GIS Data (2.3.1) Local Data on Loss and Damage (2.3.2)	Regression Analysis for Determinants of Flood Impact using SVI and CRFH (3.3)	Regression Results for Social Vulnerability and Exposure Contribution to Flood Impact (4.2)
4. Investigate Relationship between SVI and Typhoon Exposure		Regression Analysis for Typhoon Frequency Relationship with SVI (3.4)	Regression Results for Typhoon Frequency vs. SVI (4.3)

1.5 Publication Strategy

This dissertation draws on a number of published and yet to be published papers by the author. The aspects of defining and delineating flood hazard zones was originally published in the 17th edition of the United Nations University Institute for Environment and Human Security (UNU-EHS) SOURCE (Studies Of the University: Research, Counsel, Education) Publication in 2013 (Ignacio & Henry 2013). The section on *SVI* validation on hazard outcomes is an article that has been accepted for the Vienna Yearbook on Population Research for their 12th volume to be published in 2015. The portions on comparing *SVI* measurements across the census years of 2000 and 2010 were originally presented at the XXVII IUSSP International Population Conference held in Busan, Korea in August 2013. The paper is now in the process of being submitted to a peer-reviewed journal. Finally, the work on establishing relationships between typhoon exposure and *SVI* outcomes is planned for submission to a local scientific journal in the Philippines after a few more possible enhancements.

2 Study Area and Associated Data

This research has two levels of focus – an extensive national level treatment where all barangays in the Philippines are considered in the modeling of social vulnerability and hazard exposure zones using best available data and an intensive local level investigation on specific case study areas for validation.

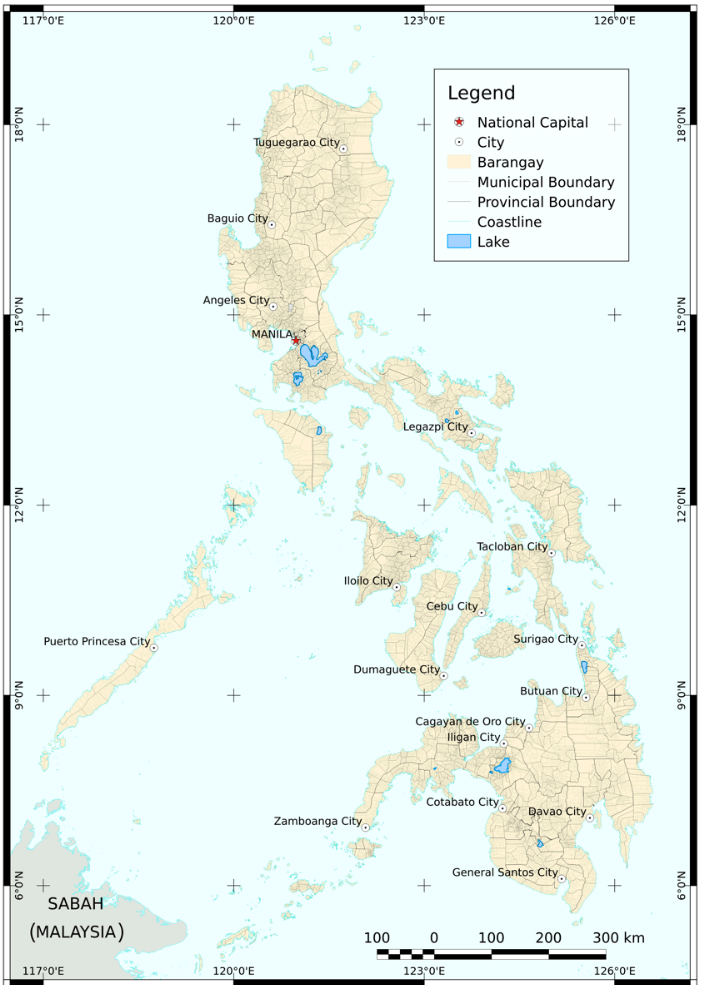
2.1 The Philippines

The Philippines is an archipelago composed of over 7,000 islands with a total land area of 300,000 square kilometers (Figure 2-1). It ranks 4th globally in terms of the length of coastline for a country, having a total of 36,289 km (Central Intelligence Agency 2012). This puts it at a relatively high risk to sea level rise, particularly in areas of high population density along the coast. The Philippines also lies along the typhoon belt of the Pacific through which an average of 20 tropical cyclones pass per year (PAGASA 2012a). Rainfall variability throughout the Philippines ranges from less than a meter to over four meters per year (PAGASA 2012b). Adding to the list, it sits along the Pacific Ring of Fire which exposes it further to volcanic and tectonic risks (Yumul et al. 2011).

2.2 Countrywide Datasets

Countrywide data used in this research are broadly classified into socio-political and biophysical types. The socio-political data came in geographic information system (GIS) and tabular database formats, the latter of which contain fields that allowed them to be linked with the former thus giving geographic reference to the flat data. The biophysical data came in proper GIS formats, which were readily georeferenced. Figure 2-2 shows the data subsection of the overall process map. It highlights the various data obtained and used in this section, which also color-coded according to the color themes to correspond with the specific objectives of this research.

Figure 2-1 Local governance units and major cities of the Philippines



Source: Global Administrative Areas (GADM)

Figure 2-2 Data sub-section of research process matrix

Specific Objectives	Data (CHAPTER 2)
1. Develop Social Vulnerability Index at the National Level	Census of Population and Housing (2.2.1) Political Boundaries (2.2.2) Urban and Rural Classification of Barangays (2.2.3)
2. Delineate Exposure Zones at the National Level	Digital Elevation Model - Shuttle Radar Topography Mission (2.2.5) Watershed Boundaries (2.2.6) Historical Typhoon Tracks (2.2.7)
3. Validate SVI and Flood Hazard Exposure with Loss and Damage Case Study	Site Descriptions and local GIS Data (2.3.1) Local Data on Loss and Damage (2.3.2)
4. Investigate Relationship between SVI and Typhoon Exposure	

2.2.1 Census of Population and Housing

The Philippine Statistics Authority (PSA), formerly known as the National Statistics Office, conducts a census of population and housing every decade as mandated by law and an abbreviated census of population (as the need arises) every five years in between (NSCB 2010; Cruz 2014). The data sets used in this research for the derivation of the SVI for the Philippines are the 2000 and 2010 censuses of household population and housing. The 2000 and 2010 household census datasets contain a total of 76,313,481 and 92,097,978 individual person records respectively, while total housing units have 15,275,046 and 21,745,707 individual records respectively for 2000 and 2010. The data sets are the official public use files provided by the PSA Household Statistics Department. This data is the most comprehensive population data available at the national level and is mandated by governing laws in the Philippines (Household Census Division 2010). See Appendix A and Appendix B for a complete listing of the data fields of the respective 2000 and 2010 Censuses of Population and Housing of the Philippines.

This study derived indicators for social vulnerability at the barangay level from the data fields of the raw, disaggregated 2000 and 2010 Censuses of Population and Housing of the Philippines. The total individual population of the Philippines in 2000 was divided into 38,407,236 males and 37,906,245 females while in 2010 it was divided into 46,458,988 males and 45,638,990 females. Around 37.0% of the 2000 population was less than 15 years old with 57.0% between 15 and 59 years and the remaining 6.0% belonging to the elderly category (60 years old and above) as defined by Philippine law (Republic of the Philippines 1992).

For 2010, a third (33.3%) of the population was less than 15 years old while 59.9% were between 15 and 59 years and the remaining 6.8% belonging to the elderly category. A total of 19,676,163 (25.8%) and 20,456,703 (22.2%) adults had not completed secondary education in 2000 and 2010 respectively. There were a total of 15,275,046 and 20,171,899 households and a total of 14,887,731 and 21,745,707 housing units in 2000 and 2010 respectively.

A total of 41,926 and 42,020 barangays comprised the Philippines as of 2000 and 2010 respectively. This change is accounted for by the creation of new barangays between the two census years, which is normally practiced as a response to population growth in barangays. Given this discrepancy in the total number of barangays between the two census years, this research only considered those that remained common or the same for both years and as a result, a total of 41,919 barangays were retained which amount to 0.017% and 0.240% differences in 2000 and 2010 census years respectively.

In 1977, the Philippine National Economic Development Authority (NEDA) first published the Philippine Standard Geographic Codes (PSGC), a nine character numeric coding system of classifying and coding geographic areas in the Philippines (NSCB 2012). The PSGC continues to be updated due to changes in name, status, and number of geographical sub-units for each local government unit. The PSGC code is divided into four major categories – region, province, municipality/city, and barangay. This code hierarchically identifies and classifies all administrative units of the country and is used in governance-related coding, including the national censuses.

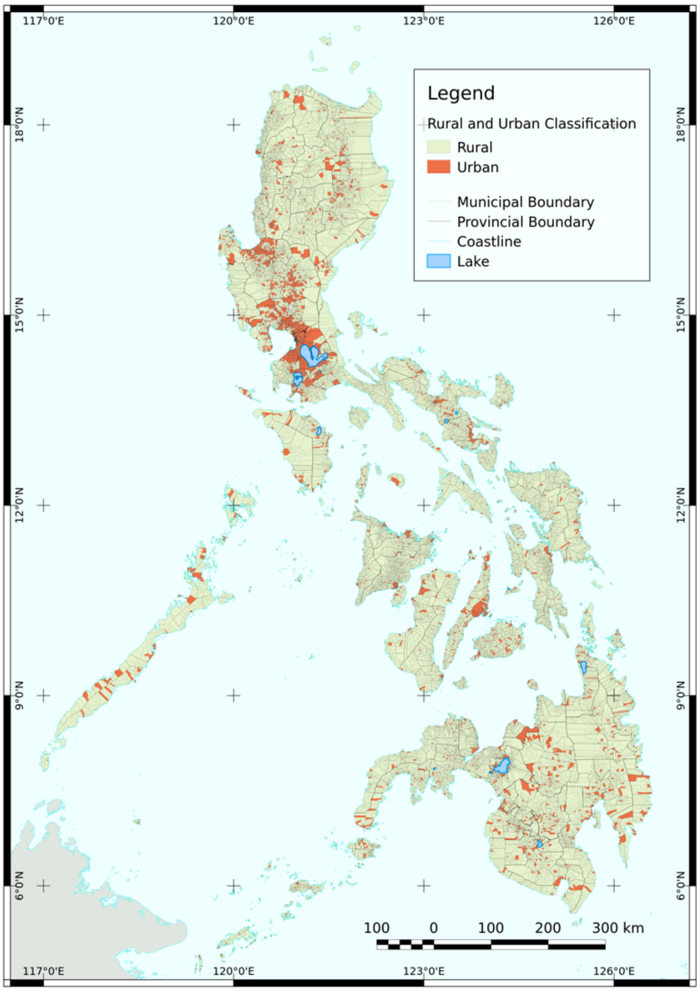
2.2.2 Political Boundaries

This research put together a host of datasets from various sources. First and foremost, a comprehensive technical survey of barangay boundaries for the Philippines has always been a challenge to put in place due to the countless boundary conflicts among local government units at the barangay, municipal and provincial levels (PIA 2012). In 2009 the Global Administrative Areas (GADM) initiative was established as part of a global effort to provide geographic bases for text-based locality descriptions and for mapping census data (GADM 2009). For the first time then, indicative administrative boundary GIS data down to the barangay level for the entire Philippines was publicly made available, mainly provided to GADM by the Department of Agriculture of the Philippine government. Since these boundaries are not based on actual ground-based technical surveys, they are approximate and highly relative, particularly in rural areas such as mountain ranges, agricultural areas, and marshlands. However, urban areas are in most cases, of an acceptable level of accuracy due to boundaries clearly defined by road networks and other anthropogenic and natural features. This dataset nonetheless makes it possible to gain a national overview of local governance jurisdictions and makes it possible to zoom into locales that normally have more accurate local boundary delineations maintained by the respective local government units (at the municipality or city level) for more in-depth analyses needing greater geographic accuracy.

2.2.3 Urban and Rural Classification of Barangays

Barangays were classified in the year 2000 as urban or rural based on the criteria defined in 1970 by the then National Statistics Office. However, since 2003 the PSA had redefined its categorization of urban barangays (Philippine Statistics Authority 2013; Cruz 2014), but the data had not yet been available in time for this research. For comparability and simplicity, however, the urban and rural classifications based on the 1970 definition were used instead for both census years in order to have a more consistent comparison between the two (See Appendix C for a detailed description of the bases for the urban and rural classification).

Figure 2-3 Distribution of urban and rural barangays of the Philippines



Sources: GADM, NSCB

Figure 2-3 maps out the distribution of the urban and rural barangays for the year 2000 across the entire Philippines. According to the classification, there are a total of 9,983 and 31,936 urban and rural barangays respectively (Figure 2-4). As population densities are higher in urban areas, it is evident on Figure 2-4 that a large cluster of urban barangays is located in the Central Luzon area in relative proximity to Metro Manila. Other urban clusters are sparsely spread throughout the rest of the country.

Figure 2-4 Urban and rural classification

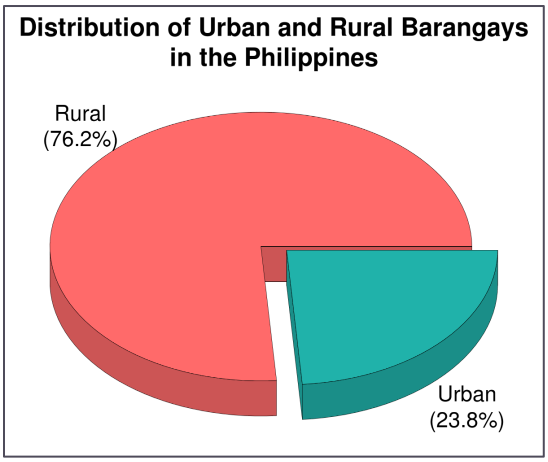
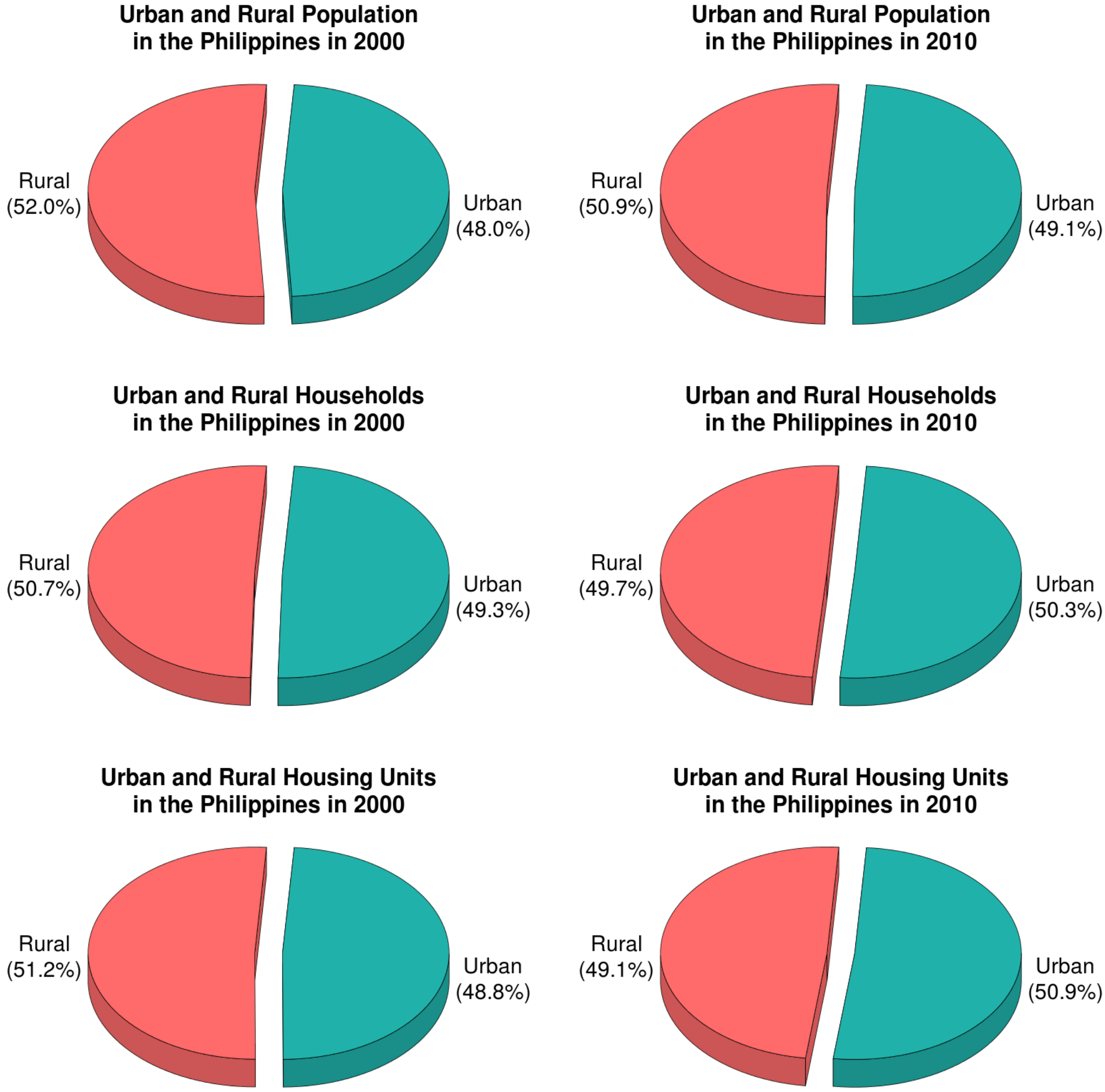


Figure 2-5 presents the distribution of individuals, households, and housing units between urban and rural barangays. As can be seen in the pie charts, the numbers of individuals, households, and housing units of the Philippines are nearly evenly distributed between the two types, with urban households and housing units surpassing those of rural areas within the 10-year period.

Figure 2-5 Distribution of population, households, and housing units



2.2.4 Data Collection, Tools, and Processing Challenges

The Philippine Census of Population and Housing disaggregated database is available for purchase from the Philippine Statistics Authority head office in Manila, whose digital database spans a total of three decadal census years (1990, 2000, and 2010) and two intercensal years (1995 and 2007) in between. The data is provided with a 50% reduction in price for research-based use. The 2000 census database were acquired with the support of the Académie de Recherche et d'Enseignement supérieur (ARES) of the Commission de la Coopération au Développement of the Belgian government through their former Projets Interuniversitaires

Ciblés (PIC) program that supported this researcher.[2] The 2010 census database was provided gratis by the Philippine Statistics Authority (PSA) to this researcher under a special memorandum of agreement that limits its use for this particular research, while at the same time providing special training to PSA staff on how the data was used for social vulnerability metrics.

This research also utilized free and open source software (FOSS) tools – from the relational database management system (PostgreSQL), the statistical package (R), down to the GIS softwares (PostGIS and QGIS). These softwares were installed in an offsite Linux server based in Germany so as not to be affected by power disruptions, which are prevalent in Mindanao where the researcher was based. The system was accessible remotely using graphical user interfaces (GUI) and command line interfaces (CLI) and outputs produced on the remote server were synchronized in real-time using BitTorrent Sync, a free peer-to-peer file synchronization tool based on the popular bit torrent.

There were a number of data processing issues that needed to be addressed to be able to compare the *SVI* results between the census years of 2000 and 2010. First of all, the available GIS data from GADM did not possess the unique PSGC identifier code for each barangay in the Philippines, which would allow a link with the census data. The GADM database only contained alphanumeric fields corresponding to the names of the barangays, municipalities/cities, provinces and regions. All these tens of thousands of barangay names had to be meticulously corrected for spelling errors and character encoding issues in order to match the alphanumeric fields present in the census. Once the names had been properly matched for each province, municipality/city, and down to the barangay unit, there was finally a basis for joining the GADM GIS data with the census data, thus adding the unique PSGC identifier to each GADM barangay polygon.

Another problem encountered between the two census years is that the PSGC codes had changed for more than 10% of the barangays in the Philippines due to the creation of new provinces, municipalities, and barangays themselves from existing ones. These newly coded local government units in the 2010 dataset had to be linked with the former codes of 2000 so that a consistent comparison can be made for almost all the barangays. Similar issues were encountered by others in comparing social vulnerability scores over time (Cutter & Finch 2008).

2.2.5 Digital Elevation Model – Shuttle Radar Topography Mission

A digital elevation model (DEM) for the entire Philippines excised from the Shuttle Radar Topography Mission or SRTM (JPL 2009) was the main dataset processed to identify areas of exposure to coastal river flood hazard (Figure 2-6). The SRTM global DEM has a pixel resolution of 3 arc seconds or an equivalent of

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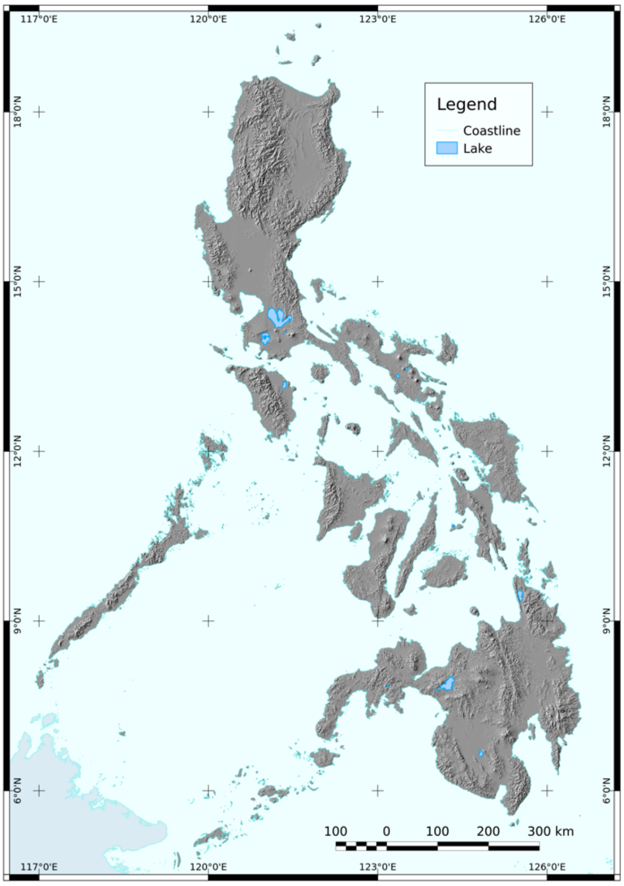
[2] The CUD through their PIC program supported the project entitled *Establishing strategic Partnerships in research to strengthen local governance in land and water management towards greater human security in Mindanao (EPaM)* with Gembloux Agro-Bio Tech, Université de Liège as its lead implementer.

90m on the ground at the equator. Although the 1 arc second (30m) resolution version of the SRTM global DEM had recently been released to the public as announced by the President of the USA at the UN Climate Summit in New York last September 2014 (Buis 2014), the data had not yet been available due to its the gradual regional release over 12 months beginning with the African continent. Nonetheless, the 3 arc second dataset still provided crucial information in determining slope categories of flood-prone areas as well as establishing the slope distribution of contributing watersheds.

2.2.6 Watershed Boundaries

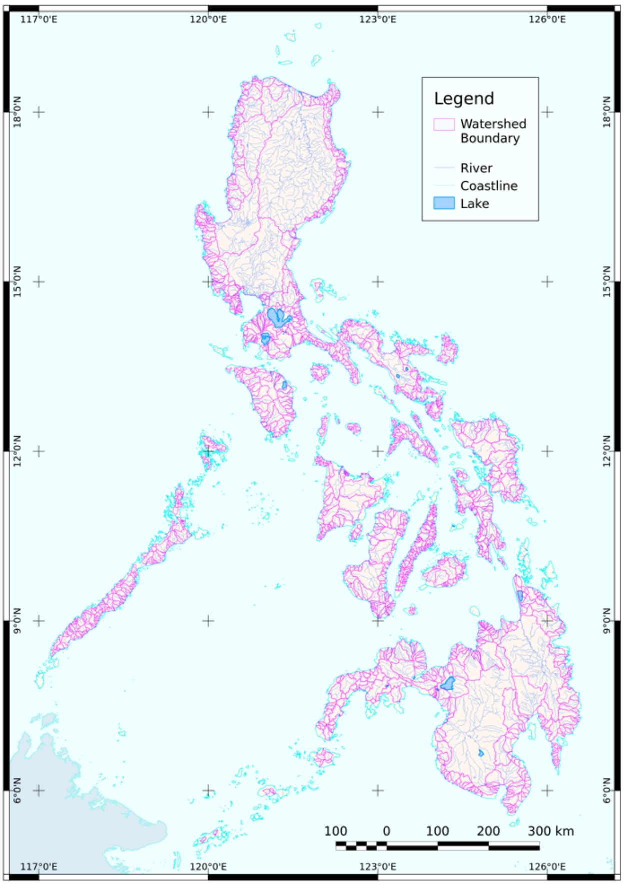
Figure 2-7 maps the watershed boundaries for all coast-draining river systems which were manually derived from 1:50,000 scale topographic maps. This geographic dataset was used to establish the lateral bounds of floodplains derived from the SRTM DEM in order to determine the extents of coastal river flood hazard zones.

Figure 2-6 Shaded Relief DEM for the Philippines



Source: SRTM

Figure 2-7 Philippine coast-draining watersheds



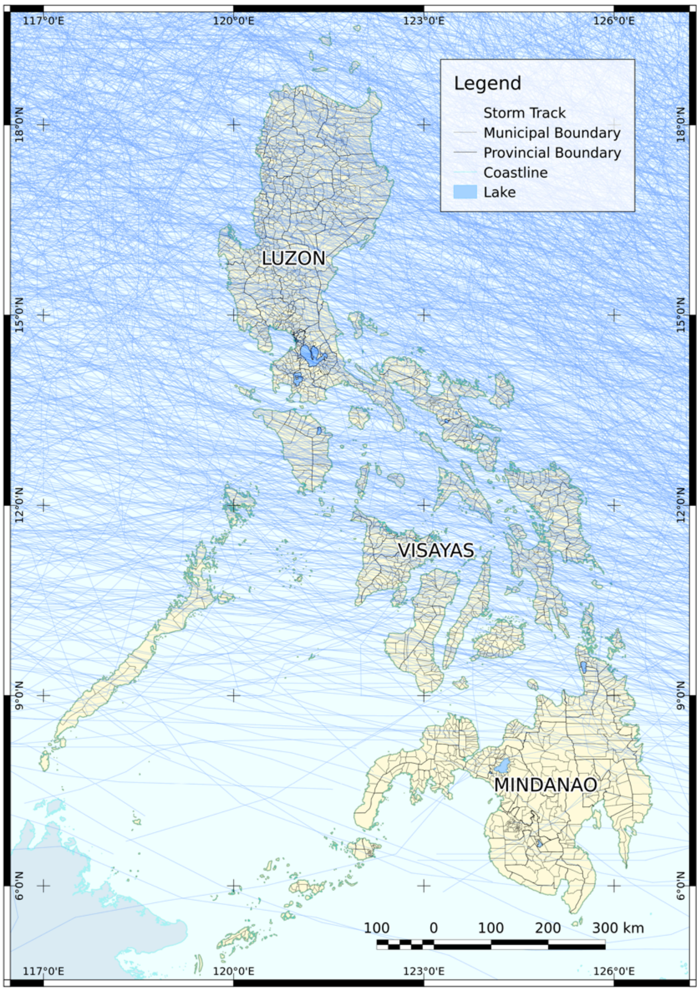
Source: ESSC-derived GIS data from 1:50,000 scale topographic maps

2.2.7 Historical Typhoon Tracks

Historical typhoon paths or track data are available from the International Best Track Archive for Climate Stewardship (IBTrACS) of the National Oceanic and Atmospheric Administration (NOAA) of the USA (NOAA 2014). The database is composed of data contributed by a host of international weather agencies and is one of the most comprehensive collections of available storm track data in the world. The datasets are divided into “basins” with the Philippines belonging to the West Pacific Basin.

Typhoon track data for the West Pacific Basin Philippines begins from 1884, but it is only from 1945 onwards where data about storm parameters (e.g. wind intensity, barometric pressure, etc.) were recorded in the typhoon track database (Figure 2-8). Although it would have been ideal that data on storm parameters could be included in the analysis of typhoon exposure, it was decided that the richness of the historical data from the late 19th century takes precedence over typhoon parameters in establishing typhoon exposure in the Philippines. Considering typhoon parameters limits the number of typhoons that can be analyzed from 1945 up to the present. Typhoon track data dating to as far back as 1884 made it possible to measure general typhoon exposure at the barangay level by providing the basis to assess the frequency of typhoon direct hits for a particular area.

Figure 2-8 Typhoon or storm tracks in the Philippines from 1884 until 2013



Sources: GADM, NOAA-IBTrACS

2.3 Northern Mindanao Local Scale Case Study Sites

2.3.1 Site Descriptions

Three of the most deadly disasters brought about by flooding in the Philippines are presented in Table 2-1. These disasters were triggered by typhoon-related events, which had dumped unprecedented amounts of rainfall into their corresponding watersheds, triggering flash floods, which affected the populations residing within the coastal floodplains of the rivers in these sites. These three flood events are the main drivers for the investigations on coastal river flood exposure and vulnerability, which attempts to understand the elements that contribute to the gravity of such kinds of disasters. The most recent disasters triggered by TS Washi on Iligan and Cagayan de Oro Cities are used as case studies for validation of the *SVI* that had been developed for this research.

Table 2-1. Summary data on the top three most devastating flood disasters in recent Philippine history

Period	Areas Affected	Cause	Dead	Affected	Damages
05/11/91 -08/11/91	Ormoc City	Typhoon Thelma	5,956	647,254	US$100M
29/11/04 - 30/11/04	Infanta, Real and Gen. Nakar in Quezon	Typhoon Winnie	1,619	881,023	US$78.2M
15/12/11 - 18/12/11	Cagayan de Oro and Iligan Cities	TS Washi	1,439	1,150,300	US$38.1M

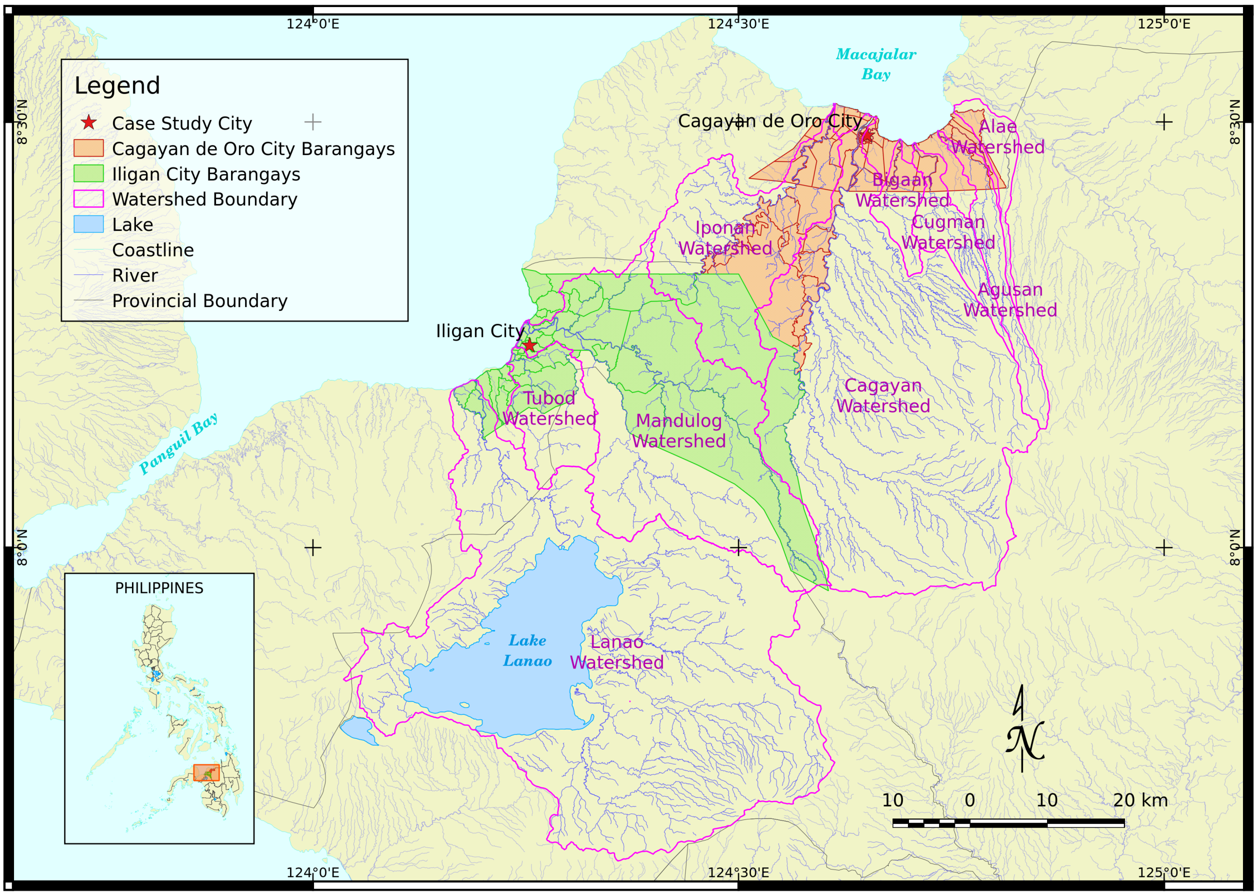
Source: CRED 2012

Figure 2-9 presents a map of the barangays and watersheds of both Iligan and Cagayan de Oro Cities which are both located in the Northern Mindanao Region of the Philippines. Iligan City is comprised of 44 barangays or villages having a total area of 813.37 km^2 and a household population of 321,156 as of May 2010. Three major river systems – the Mandulog, Tubod and Lanao – all empty into the Iligan Bay passing through Iligan City's coastal barangays.

Cagayan de Oro City, on the other hand is located northeast of Iligan City also along the coast of Northern Mindanao. It contains 80 barangays and has a total area of 488.9 km^2 and a household population of 598,803 as of May 2010. Two major rivers run through the western portion of Cagayan de Oro City – the Iponan and the Cagayan – while an adjacent series of smaller coastal watersheds empty into the Macajalar Bay as well.

On 16 December 2012, TS Washi passed through Northern Mindanao in the southern Philippines, an area known to be rarely frequented by typhoons. The storm dumped 180.9mm of rainfall within a 24 hour period, an event with a computed return probability of 75 years (RDC-X 2012). The resulting flash floods affected numerous communities along Northern Mindanao's river outlets draining to the sea, but Iligan and Cagayan de Oro Cities, which are the two most populous urban centers in the region, felt the most severe impacts.

Figure 2-9 Barangays and Watersheds of Iligan and Cagayan de Oro Cities



Sources: Philippine National Mapping Resource Information Authority (NAMRIA) 1:50,000 Topographical maps; Iligan and Cagayan de Oro City Planning and Development Offices; Environmental Science for Social Change (ESSC); and GADM

2.3.2 Local Data on Loss and Damage

The data for the validation case studies were obtained from the Northern Mindanao Regional Disaster Risk Reduction and Management Office (DRRMO) of the Philippine Government located in Cagayan de Oro City, which is the administrative center for Region 10, otherwise known as Northern Mindanao.

From the official data provided by the DRRMO, the total numbers of dead and of missing for Iligan City alone were 148 and 1023 respectively; while a total of 94,611 individuals were affected, most of whom were located within the flood hazard zones of the Mandulog and Tubod Rivers. The flood totally and partially destroyed 4,448 and 5,884 housing units respectively, while 10,582 houses suffered flooding (inundation) damages only. For Cagayan de Oro City, the data revealed 569 and 363 dead and missing persons respectively; while a total of 47,526 individuals were affected, most of who were located within the flood hazard areas of the larger Cagayan River. The resulting flood affecting Cagayan de Oro City totally and partially destroyed 3,998 and 6,162 respectively, while 2,981 houses suffered inundation damages only.

It is important to note that the data from Cagayan de Oro City did not possess the same level of detail and accuracy as Iligan City, particularly for the demographic characteristics of the affected population as well as a significant number of entries with missing locational data. Despite these differences, there was still a wealth of information available to perform statistical analysis on the two flooding case studies. Finally, the Planning and Development Offices of Iligan and Cagayan de Oro Cities provided crucial GIS datasets in the form of more accurate barangay boundaries for the local case studies. The Planning and Development Office of Iligan City further provided TS Washi flood-affected areas for that city while data for Cagayan de Oro City flood zones was provided by the Xavier University Engineering Resource Center (2011). Other geographic data such as elevation, rivers, etc. were taken from standard topographical maps at 1:50,000 scale from NAMRIA, as well as SRTM DEMs and available aerial photographs and satellite imagery from public sources. These data sources formed the basis for geographically determining *a priori* the areas of exposure to coastal flash flood hazards at the local scale.

The following subsections discuss in detail the case study data with respect to the flooding impacts of TS Washi for Iligan and Cagayan de Oro Cities. These discussions on the loss and damage for the population are tackled here instead of Chapter 4 as they are more descriptive in nature and do not affect the intended outcomes of the proposed methodologies.

2.3.2.1 Iligan City

2.3.2.1.1 Missing Persons

Table 2-2 shows the profile of the 1,023 missing persons reported in 19 barangays. Results show that most of the missing were reported in Barangay Hinaplanon (59.3%) and to a lesser extent in Santiago (17.3%) and Santa Filomena (7.2%).

The missing are almost evenly spread between the sexes although we see a slightly proportionate share of the females relative to the males (56% vs 44%). Their mean age is relatively young at around 23 years old with almost no significant difference between the sexes. About 1 in 5 of them are children less than five years old, around 40% are less than 15 years and an equal percentage are in the prime years of 15-59 years. At least 6 percent of those missing are older people aged 60 years and over. Except for the infants (< one year old), which is slightly predominated by males, there are more females than males among the missing for all age groups.

2.3.2.1.2 Dead Persons

A total of 148 cases were reported dead in 12 barangays most of which were found in barangay Hinaplanon (59.4%). Barangay Santa Filomena which shared 13.5 percent of the total reported dead is ranked second highest while Upper Hinaplanon ranked third highest at 10.1 percent share. Similar to the sex structure of the reported missing, slightly more females than males perished as a result of the flooding at 57.4 percent vs. 42.6 percent respectively. The average age of those who died is 30.8 years with women who perished about four years older than their male counterparts (32.7 vs. 28.2, respectively). The gender difference in age is not statistically different, however.

A closer examination of the age structure of the mortality statistics indicates three cases of infant mortality (i.e. those aged less than one) that resulted from this natural disaster. Almost a fifth of those who died were between 1-4 years, with an equal number in the 5-14 age group while 44 percent were in their prime years (15-59). A significant proportion of those who died are older people (17.7%), indicating a disproportionately higher share relative to the sector's share of the entire population. As of the 2010 census, the older people constitute only 5.7 percent of the population in the 12 barangays that reported deaths.

An analysis of the age structure of the mortality by sex also reveals a higher proportionate share of older people among the females relative to the males. Around 10.8 percent of the total dead were elderly females while only 6.7 percent were male. Almost 19 percent of the females who died are elderly as compared to about 16 percent among their male counterparts. This result is indicative of the greater vulnerability of the older people, particularly the females to disaster risks.

2.3.2.1.3 Affected persons

A total of 94,611 individuals were surveyed and registered with the Iligan City government as having been affected by the flooding. Barangay Hinaplanon is consistently the barangay having the most affected individuals (16.5%), followed by Tambacan (10.4%) and Santiago (8.94%). The demographic distribution of the affected persons does not reveal any significant findings in relation to age and sex structures as well as educational attainment (Table 2-3).

Table 2-2 presents the 22 barangays that had registered missing and/or dead individuals with additional information on the number of affected individuals in each barangay together with its 2010 population. An additional 13 barangays not shown in Table 2-2 posted individuals affected by the flood without dead or missing. It is worth noting that there is a significantly high total number of victims (missing, dead, and affected) for Barangay Hinaplanon compared to its projected 2011 population. The projected population based on a geometric growth rate between the census years of 2007 to 2010 should have been only 14,648 while the total number of documented victims amounted to 16,327. The increase can be partly explained by the completion of new housing projects in the barangay as can be seen in multi-date high resolution satellite images analyzed for the area as well as the total number of housing units (Table 2-4).

Table 2-2 Iligan City barangays with registered dead and missing victims

Barangay Name	Total Missing and % of Tot. Pop.		Total Dead and % of Tot. Pop.		Total Affected and % of Tot. Pop.		2011 Pop.*
Hinaplanon	84	0.57%	607	4.14%	15,636	106.74%	14,648
Santiago	11	0.12%	177	1.85%	8,461	88.59%	9,551
Santa Filomena	20	0.26%	74	0.97%	3,074	40.40%	7,608
Mandulog	2	0.07%	38	1.34%	1,647	58.05%	2,837
Upper Hinaplanon	15	0.23%	34	0.51%	5,717	85.78%	6,665

San Roque	5	0.12%	32	0.79%	3,854	95.51%	4,035
Bonbonon	-	-	12	0.81%	872	58.84%	1,482
Digkilaan	1	0.02%	11	0.27%	1,259	30.35%	4,148
Bagong Silang	-	-	10	0.17%	5,153	86.03%	5,990
Abuno	-	-	7	0.15%	139	2.95%	4,717
Tubod	2	0.01%	6	0.02%	8,092	24.20%	33,442
Tambacan	4	0.02%	5	0.03%	9,876	55.62%	17,757
Rogongon	-	-	2	0.04%	1,814	38.07%	4,765
Kalilangan	-	-	2	0.15%	150	11.54%	1,300
Panoroganan	-	-	2	0.05%	163	3.68%	4,424
Dalipuga	-	-	1	0.01%	1,132	5.82%	19,458
Pala-o	-	-	1	0.01%	2,677	28.34%	9,445
Poblacion	-	-	1	0.03%	949	26.42%	3,592
Ubaldo Laya	-	-	1	0.01%	3,569	31.93%	11,179
Luinab	2	0.02%	-	-	392	4.41%	8,893
Santo Rosario	1	0.05%	-	-	1,576	75.05%	2,100
Hindang	1	0.08%	-	-	3	0.24%	1,237
TOTAL	**148**	**0.08%**	**1,023**	**0.57%**	**76,205**	**42.51%**	**179,275**

*Projected from 2007 and 2010 population census data

Table 2-3 Demographics of dead, missing and affected individuals for Iligan City

Population-related field	Dead		Missing		Affected	
	N	% of control[*]	N	% of control[*]	N	% of control[*]
TOTAL INDIVIDUALS	***148***	***0.14%***	***1,023***	***0.63%***	***94,611***	***38.04%***
Gender						
Male	63	0.12%	452	0.56%	48,388	38.90%
Female	85	0.15%	571	0.70%	46,223	37.18%
Dependent population*						
Children (< 15 years)	60	0.17%	424	0.98%	33,910	41.58%
Elderly (≥ 60 years)	26	0.42%	63	0.88%	5,461	37.22%
Adult educational attainment						
Up to secondary only	No Data	-	No Data	-	26,069	55.53%

** 139 entries for Missing have no data for age*

2.3.2.1.4 Damage to Housing

A total of 20,914 housing units were damaged in Iligan City due to the TS Washi flood. Most of the damages occurred in Barangay Hinaplanon at 17.2% followed by Tambacan at 10.3% and Santiago at 8.9%. Table 2-3 provides the full details of the number of housing units that experienced varying degrees of damage per barangay, together with the total number of housing units in 2011 as projected from the 2010 census. Totally damaged houses are totally destroyed or washed out, partially damaged houses sustained damage on parts of the structure itself but is still repairable, while flooded only houses did not incur any structural harm, but had damaged items within such as furniture, appliances and other personal belongings.

[*] *Control* here signifies the percentage over the total population of all barangays that had reported either dead, missing, or affected.

Table 2-4 Iligan City barangays that sustained various degrees of damage to housing units

Barangay	Total Damage and % of Tot. Housing		Partial Damage and % of Tot. Housing		Flooded Only and % of Tot. Housing		Tot. Housing (2011)*
Hinaplanon	1,499	42.17%	1,675	47.12%	417	11.73%	3,555
Upper Hinaplanon	699	49.47%	352	24.91%	158	11.18%	1,413
Santa Filomena	481	27.38%	179	10.19%	41	2.33%	1,757
Santiago	461	19.80%	611	26.25%	793	34.06%	2,328
San Roque	372	39.91%	286	30.69%	282	30.26%	932
Tubod	125	1.73%	505	6.98%	1,205	16.65%	7,238
Tambacan	107	2.79%	352	9.18%	1,698	44.28%	3,835
Mandulog	90	13.82%	77	11.83%	156	23.96%	651
Rogongon	82	7.93%	33	3.19%	223	21.57%	1,034
Digkilaan	79	8.09%	109	11.17%	98	10.04%	976
Mahayahay	77	3.62%	467	21.95%	1,037	48.73%	2,128
Pala-o	77	3.60%	244	11.42%	268	12.54%	2,137
Bonbonon	77	25.16%	70	22.88%	46	15.03%	306
Ubaldo Laya	52	2.02%	232	8.99%	508	19.69%	2,580
Bagong Silang	29	2.01%	227	15.73%	866	60.01%	1,443
Panoroganan	29	4.30%	7	1.04%	5	0.74%	675
Tibanga	23	1.19%	39	2.02%	38	1.97%	1,933
Kalilangan	15	5.62%	1	0.37%	10	3.75%	267
Dulag	13	5.96%	6	2.75%	-	-	218
Puga-an	12	0.74%	46	2.83%	120	7.38%	1,626
Tipanoy	9	0.30%	83	2.73%	401	13.17%	3,044
Luinab	9	0.45%	19	0.94%	64	3.17%	2,022
Mainit	7	1.23%	9	1.58%	3	0.53%	570
Santo Rosario	6	1.04%	12	2.08%	328	56.85%	577
Dalipuga	4	0.08%	28	0.58%	196	4.08%	4,799
Lanipao	4	0.79%	13	2.57%	16	3.17%	505
Abuno	3	0.27%	14	1.26%	14	1.26%	1,115
Del Carmen	2	0.10%	135	6.78%	630	31.63%	1,992
Kiwalan	2	0.14%	7	0.48%	1	0.07%	1,457
Acmac	1	0.07%	4	0.29%	4	0.29%	1,378
Kabacsanan	1	0.22%	2	0.44%	-	-	453
Hindang	1	0.37%	-	-	-	-	269
Poblacion	-	-	20	1.69%	220	18.57%	1,185
San Miguel	-	-	11	1.14%	482	49.90%	966
Villaverde	-	-	9	0.72%	254	20.42%	1,244
TOTAL	**10,582**	**18.06%**	**5,884**	**10.04%**	**4,448**	**7.59%**	**58,608**

**Projected from 2000 and 2010 housing census data*

2.3.2.2 Cagayan de Oro City

2.3.2.2.1 Missing Persons

Table 2-5 shows the profile of the 363 missing persons reported in 17 barangays. Results show that most of the missing were reported in Barangay Macasandig (72.2%), followed way behind by both Barangays 13 and Balulang (both at 7.2%).

The missing are evenly spread between male and female (49% vs 51%) while their mean age is even younger than in Iligan City at around 21.8 years old. About 1 in 4 of them are children less than five years old, around 50.4% are less than 15 years and 36.1% are in the prime years of 15-59 years. At least 13.5 % of those missing are elderly aged 60 years and over. There is a very equal distribution of sexes in the missing across all age groups.

2.3.2.2.2 Dead Persons

A total of 569 cases were reported dead in Cagayan de Oro City. Of this total number, 90 cases had no data on the barangays where they belonged to and as a result only 479 cases were properly located in 24 barangays; most of which were found in barangay Macasandig (42.4%). Barangay 13 which shared 23.8 percent of the total reported dead is ranked second highest while Barangay Balulang ranked third at 15.9 percent share. Slightly less males than females perished as a result of the flooding at 45.5 percent vs. 54.5 percent respectively. The average age of those who died is 32.4 years with women about two and a half years older than their male counterparts (33.5 years vs. 31.1 years, respectively). The gender difference in age is also not statistically significant as in Iligan City.

Looking at the age structure of the mortality statistics we find a higher rate of infant mortality in Cagayan de Oro City at fifteen deaths (3.1%) and only 7.7 percent between 1-4 years. Seventeen percent fall within the 5-14 age group while similar to Iligan City, 43.4 percent were between 15 and 59 years of age. A high proportion of the casualties (24.0%) were elderly citizens (60 years and above), indicating an even higher disproportionate share relative to the sector's share of the entire population compared to Iligan City. As of the 2010 census, the older people constituted only 4.9 percent of the population in the 24 barangays that reported deaths.

An analysis of the age structure of the mortality by sex also reveals only a slightly higher proportionate share of older people among the females relative to the males. Around 12.5 percent of the total dead were elderly females while 11 percent were elderly males. Around 23.2 percent of the females who died are elderly compared to 24.1 percent among their male counterparts. There is no statistically significant difference in sex among the elderly casualties, but as in the Iligan City case the elderly in general were comparatively more vulnerable to the flood risk.

2.3.2.2.3 Affected Persons

A total of 47,526 individuals were surveyed and registered with the Cagayan de Oro City government as having been affected by the flooding. Barangay Carmen is the barangay having the most affected individuals (21.4%), followed by Kauswagan (15.4%) and Balulang (14.2%). The available data for the affected population in Cagayan de Oro City was not disaggregated beyond the barangay level and did not have a further breakdown of demographic characteristics (Table 2-6).

Table 2-5 Cagayan de Oro City barangays with registered dead and missing victims.

Barangay	Total Dead and % of Tot. Pop.		Total Missing and % of Tot. Pop.		Total Affected and % of Tot. Pop.		2011 Population*
Macasandig	203	0.84%	262	1.09%	3,851	15.98%	24,103
Barangay 13	114	4.96%	29	1.26%	1,392	60.52%	2,300

Balulang	76	0.23%	29	0.09%	6,221	19.10%	32,575
Carmen	35	0.05%	12	0.02%	9,376	12.77%	73,420
Barangay 15	11	0.36%	6	0.20%	504	16.47%	3,061
Consolacion	7	0.07%	1	0.01%	1,005	10.02%	10,032
Puntod	4	0.02%	-	-	2,988	16.52%	18,089
Canitoan	3	0.02%	2	0.01%	1,600	10.21%	15,664
Kauswagan	3	0.01%	-	-	6,752	19.23%	35,112
Iponan	3	0.01%	-	-	3,696	16.82%	21,980
Tablon	3	0.02%	-	-	523	2.83%	18,451
Barangay 14	2	0.51%	1	0.25%	-	-	395
Cugman	2	0.01%	-	-	773	3.71%	20,835
Mambuaya	2	0.07%	-	-	3	0.11%	2,726
Patag	2	0.01%	-	-	-	-	17,230
Bayanga	1	0.04%	8	0.28%	8	0.28%	2,849
Camaman-an	1	0.00%	4	0.02%	38	0.15%	25,001
Lumbia	1	0.01%	1	0.01%	100	0.73%	13,640
Barangay 18	1	0.06%	-	-	816	52.82%	1,545
Bonbon	1	0.01%	-	-	536	5.66%	9,478
Barangay 17	1	0.04%	-	-	508	21.36%	2,378
Baikingon	1	0.04%	-	-	184	7.43%	2,476
Bayabas	1	0.01%	-	-	25	0.18%	13,789
Puerto	1	0.01%	-	-	-	-	12,501
Nazareth	-	-	2	0.02%	258	2.44%	10,563
Tumpagon	-	-	2	0.09%	170	7.30%	2,330
Bulua	-	-	1	0.00%	1,477	4.48%	32,988
Gusa	-	-	1	0.00%	617	2.32%	26,571
Pagatpat	-	-	1	0.02%	428	8.03%	5,328
Barangay 22	-	-	1	0.05%	-	-	1,902
TOTAL	**479[@]**	**0.10%**	**363**	**0.08%**	**43,849**	**9.55%**	**459,312**

*Projected from 2007 and 2010 data
[@]There were 90 victims who could not be located by barangay

Table 2-6 Demographics of dead, missing and affected individuals for Cagayan de Oro City

Population-related field	Dead		Missing		Affected	
	N	% of control[*]	N	% of control[*]	N	% of control[*]
TOTAL INDIVIDUALS	***479***	***0.13%***	***363***	***0.13%***	***47,526***	***52.77%***
Gender						
Male	218	0.12%	177	0.13%	No Data	-
Female	261	0.14%	186	0.24%	No Data	-
Dependent population						
Children (< 15 y.o.)	162	0.14%	188	0.23%	No Data	-
Elderly (≥ 60 y.o.)	114	0.56%	49	0.32%	No Data	-
Adult educational attainment						
Up to secondary only	No Data	-	No Data	-	No Data	-

[*] *Control* here signifies the percentage over the total population of all barangays that had reported either dead, missing, or affected.

2.3.2.2.4 Damage to Housing

A total of 20,914 housing units were damaged in Cagayan de Oro City due to the TS Washi-triggered floods. Most of the housing damages occurred in Barangay Carmen at 17.8 percent followed by Barangays Balulang at 13.3 percent and Kauswagan at 9.3 percent. Table 2-7 provides the full details of the number of housing units that experienced varying degrees of damage per barangay, together with the total number of housing units from the 2010 census. It is important to note that Barangay Macasandig had the highest number of houses that were totally damaged while Barangay Kauswagan houses were damaged mainly by inundation.

Table 2-7 Cagayan de Oro City barangays that sustained various degrees of damage to housing units

Barangay	Total Damage and % of Tot. Housing		Partial Damage and % of Tot. Housing		Flooded Only and % of Tot. Housing		Tot. Housing (2011)*
Macasandig	1,013	17.20%	318	5.40%	-	-	5,890
Carmen	845	4.66%	1,499	8.27%	-	-	18,134
Balulang	700	7.36%	1,050	11.04%	-	-	9,515
Barangay 13	308	55.10%	40	7.16%	-	-	559
Iponan	116	1.76%	707	10.75%	26	0.40%	6,577
Kauswagan	102	1.20%	82	0.97%	1,504	17.72%	8,487
Bulua	92	1.15%	221	2.77%	815	10.22%	7,972
Canitoan	90	2.43%	310	8.36%	-	-	3,710
Barangay 15	73	8.90%	11	1.34%	-	-	820
Consolacion	69	2.52%	172	6.28%	-	-	2,739
Tuburan	53	16.51%	18	5.61%	-	-	321
Pagatpat	52	3.56%	107	7.32%	123	8.42%	1,461
Tablon	49	0.96%	84	1.65%	-	-	5,100
Bonbon	39	1.70%	90	3.92%	-	-	2,297
Cugman	37	0.73%	140	2.77%	-	-	5,052
Agusan	36	0.98%	45	1.23%	-	-	3,659
Tumpagon	34	6.10%	-	-	-	-	557
Gusa	31	0.47%	109	1.66%	-	-	6,549
Pigsag-an	29	12.03%	3	1.24%	-	-	241
Puntod	25	0.52%	474	9.91%	-	-	4,783
Nazareth	22	0.75%	10	0.34%	-	-	2,922
Lumbia	20	0.50%	14	0.35%	-	-	3,994
Indahag	17	0.97%	19	1.08%	-	-	1,754
Baikingon	16	2.42%	27	4.08%	-	-	662
Barangay 7	16	11.11%	23	15.97%	-	-	144
Macabalan	15	0.31%	59	1.24%	-	-	4,762
Barangay 6	15	44.12%	7	20.59%	-	-	34
Pagalungan	14	3.16%	2	0.45%	-	-	443
Dansolihon	12	1.01%	4	0.34%	-	-	1,194
Tignapoloan	11	1.12%	1	0.10%	-	-	981
Barangay 10	10	6.85%	56	38.36%	-	-	146
San Simon	9	2.59%	92	26.51%	-	-	347
FS Catanico	9	2.05%	57	12.98%	-	-	439
Barangay 1	7	4.12%	20	11.76%	142	83.53%	170
Barangay 17	3	0.51%	95	16.07%	-	-	591
Barangay 18	2	0.47%	182	42.92%	-	-	424
Camaman-an	2	0.03%	7	0.12%	127	2.13%	5,969
Bayanga	2	0.28%	-	-	-	-	716
Bayabas	1	0.03%	4	0.12%	-	-	3,441
Balubal	1	0.13%	2	0.26%	-	-	779

Mambuaya	1	0.15%	-	-	-	-	683
Lapasan	-	-	1	0.01%	-	-	10,513
Barangay 24	-	-	-	-	139	51.87%	268
Barangay 23	-	-	-	-	85	37.61%	226
Barangay 20	-	-	-	-	11	32.35%	34
Barangay 25	-	-	-	-	9	2.69%	335
TOTAL	**2,981**	2.19%	**6,162**	4.52%	**3,998**	2.93%	**136,396**

3 Methodology

The previous chapter provided a detailed description of the areas covered and the corresponding data used for this research. It likewise included descriptive discussions on some of the datasets, such as the urban and rural areas and the case studies on loss and damage. This section describes how all this information is processed and used to determine whether any relationship exists between *SVI* and the specific hazards of coastal river flooding and typhoons (Figure 3-1). The first subsection describes the method used to develop the social vulnerability sub-indices derived from disaggregated census data using indicators of vulnerability based on existing literature. The next subsections define exposure to the hazards in focus, i.e. coastal river flood and typhoon hazards, and finally the regression models developed to test for their relationships with the loss and damage resulting from of the TS Washi floods and with typhoon exposure. The curved arrows in Figure 3-1 indicate the inputs for the validation. For the final portions on investigating relationships between social vulnerability and hazard impact and exposure, only the results derived from the 2010 census of population and housing were used.

Figure 3-1. Methodology subsection of research process matrix

Specific Objectives	Methodology (CHAPTER 3)
1. Develop Social Vulnerability Index at the National Level	Development of a Social Vulnerability Index (3.1) Indicator selection and SVI Sub-index construction Combining SVI Sub-indices into Overall SVI
2. Delineate Exposure Zones at the National Level	Defining Zones of Flood Exposure (3.2.1) SRTM - 2% slope and 10m from MSL Watersheds with at least 20% mean slope and area < 1,800 sqkm Delineating Typhoon Exposure Using Frequency of Direct Storm Hits (3.2.2)
3. Validate SVI and Flood Hazard Exposure with Loss and Damage Case Study	Regression Analysis for Determinants of Flood Impact using SVI and CRFH (3.3)
4. Investigate Relationship between SVI and Typhoon Exposure	Regression Analysis for Typhoon Frequency Relationship with SVI (3.4)

3.1 Development of a Social Vulnerability Index

Empirical measurements of social vulnerability combine a number of indicators to obtain a characteristic or parameter describing the human system in relation to its potential for harm (Cutter et al. 2008). A *SVI* for the Philippines was developed using the barangay as the unit of aggregation using the total number of persons, households, and housing units as the basic units of analysis. The availability of both population and housing data for this research allows a combination of social and housing-based indicators for the development of a more robust SVI for the Philippines. The variables are extracted from the raw census data (Table 3-1) at the individual level and when possible aggregated at the household level. Housing data is likewise available as a separate database (Table 3-2). The aggregation is done at the barangay level on the basis of input data at the individual, household, and housing unit levels, depending on the indicator. Although there were differences in the fields between the two census years, the indicators were chosen based on consistent fields between the 2000 and 2010.

Table 3-1 Fields of the 2000 and 2010 Philippine Census of Population utilized for this research[3]

2000 and 2010 Code	Description
psgc	Philippine Standard Geographic Code
hhqsn	Household sequence number
rel	Relationship to household head
sex	Gender
age	Age
br	Birth registration status
ms	Marital status
dis	With disability
hgc	Highest grade completed
ow	Overseas worker

Table 3-2 Fields of the 2000 and 2010 Philippine Census of Housing utilized for this research

2000 and 2010 Code	Description
psgc	Philippine Standard Geographic Code
fhhhu	First household in housing unit
roof	Construction materials of the roof
wall	Construction materials of the outer walls
yrbt	Year built
area	Floor area of housing unit
tnur	Tenure status of the lot
repr	State of repair

Utilizing the relevant fields provided by the 2010 raw census data, 18 indicators were derived (Table 3-3) and simple additive indices or composite indicators based on individuals, households, and housing characteristics were developed and computed for the barangays. Many of these indicators were selected based on commonly accepted groups that are associated with high levels of vulnerability. Table 3-3 is a subset from the work of Cutter et al. (2003) illustrating social vulnerability concepts based on existing literature that were possible to capture or measure using the available census fields.

Table 3-3 Social vulnerability concepts and metrics (extract from Cutter et al. (2003))

Concept	Description	Sources
Socioeconomic status (income, political power, prestige)	The ability to absorb losses and enhance resilience to hazard impacts. Wealth enables communities to absorb and recover from losses more quickly due to insurance, social safety nets, and entitlement programs.	Cutter, Mitchell, and Scott (2000), Burton, Kates, and White (1993), Blaikie et al. (1994), Peacock, Morrow, and Gladwin (1997, 2000), Hewitt (1997), Puente (1999), and Platt (1999).

[3] For a complete list of fields and associated values for the 2000 and 2010 Census of Population and Housing, please see Appendix A and Appendix B.

Gender	Women can have a more difficult time during recovery than men, often due to sector-specific employment, lower wages, and family care responsibilities.	Blaikie et al. (1994), Enarson and Morrow (1998), Enarson and Scanlon (1999), Morrow and Phillips (1999), Fothergill (1996), Peacock, Morrow, and Gladwin (1997, 2000), Hewitt (1997), and Cutter (1996).
Race and ethnicity	Imposes language and cultural barriers that affect access to post-disaster funding and residential locations in high hazard areas.	Pulido (2000), Peacock, Morrow, and Gladwin (1997, 2000), Bolin with Stanford (1998), and Bolin (1993).
Age	Extremes of the age spectrum affect the movement out of harm's way. Parents lose time and money caring for children when daycare facilities are affected; elderly may have mobility constraints or mobility concerns increasing the burden of care and lack of resilience.	Cutter, Mitchell, and Scott (2000), O'Brien and Mileti (1992), Hewitt (1997), and Ngo (2001).
Rural/urban	Rural residents may be more vulnerable due to lower incomes and more dependent on locally based resource extraction economies (e.g., farming, fishing). High-density areas (urban) complicate evacuation out of harm's way.	Cutter, Mitchell, and Scott (2000), Cova and Church (1997), and Mitchell (1999).
Residential property	The value, quality, and density of residential construction affects potential losses and recovery. Expensive homes on the coast are costly to replace; mobile homes are easily destroyed and less resilient to hazards.	Heinz Center for Science, Economics, and the Environment (2000), Cutter, Mitchell, and Scott (2000), and Bolin and Stanford (1991).
Renters	People that rent do so because they are either transient or do not have the financial resources for home ownership. They often lack access to information about financial aid during recovery. In the most extreme cases, renters lack sufficient shelter options when lodging becomes uninhabitable or too costly to afford.	Heinz Center for Science, Economics, and the Environment (2000) and Morrow (1999).
Family structure	Families with large numbers of dependents or single-parent households often have limited finances to outsource care for dependents, and thus must juggle work responsibilities and care for family members. All affect the resilience to and recovery from hazards.	Blaikie et al. (1994), Morrow (1999), Heinz Center for Science, Economics, and the Environment (2000), and Puente (1999).
Education	Education is linked to socioeconomic status, with higher educational attainment resulting in greater lifetime earnings. Lower education constrains the ability to understand warning information and access to recovery information.	Heinz Center for Science, Economics, and the Environment (2000).
Social dependence	Those people who are totally dependent on social services for survival are already economically and socially marginalized and require additional support in the post-disaster period.	Morrow (1999), Heinz Center for Science, Economics, and the Environment (2000), Drabek (1996), and Hewitt (2000).
Special needs populations	Special needs populations (infirm, institutionalized, transient, homeless), while difficult to identify and measure, are disproportionately affected during disasters and, because of their invisibility in communities, mostly ignored during recovery.	Morrow (1999) and Tobin and Ollenburger (1993).

Groups such as the very young, the very old, the disabled, single parent households, and low income earners are thus seen as vulnerable (King & MacGregor 2000). The dependent age ranges for very young and very old in the Philippines is patterned after the legal delineation of working age for minors which is 15 years old (Racelis & Salas 2008) and 60 years old for senior citizens (Republic of the Philippines 1992). Additional indicators were considered based on Table 3-3, which include average household size, low adult educational attainment (no secondary school diploma), percent of females and percent of female-headed households. An additional variable was extracted based on the work of Streissnig et al. (2013) which identifies the single variable of the proportion of females aged 20 to 39 having completed secondary schooling or higher as having a distinctly positive influence on lowering vulnerability. As the census data does not include income, proxy variables were derived mainly from the housing database such as poor roofing material, poor walling material, lack of tenure, needing repairs, old structures and small house floor area. Finally, since the raw database was in disaggregated form, other combinations of variables that could measure an aspect of social vulnerability were posited such as households with the head having no high school diploma and households with no support from overseas foreign workers. More than 10% of the population of the Philippines are working abroad (Commission on Filipinos Overseas 2010) and these overseas workers provide additional resources to the household in the form of remittances.

Table 3-4 Social vulnerability proxy variables derived from the 2000 and 2010 census data fields

Variable	**Description**	**Type of Data (per Barangay)**	**Corresponding Vulnerability Concept**
female	% Female	Total individuals	Gender
child	% Children (below 15)	Total individuals	Age
old	% Elderly (60 and above)	Total individuals	Age
nonhsadult	% Non-HS graduate adults	Total individuals	Education
nobirthreg	% With no birth registration	Total individuals	Social dependence
nonhsfem_20to39	% Non-HS graduate females aged 20-39	Total individuals	Education/Gender
femhhh	% With female HH head	Total households	Gender/Family structure
disabhh	% HH with disabled person	Total households	Special Needs population
nonhshhh	% With non-HS grad HH head	Total households	Education
snglhhh	% With single HH head	Total households	Family structure
avghhsze	Average HH size	Total households	Family structure
hhnoofwhh	% HH with no overseas worker	Total households	Social dependence
badroof	% Houses with poor roofing	Total housing units	Residential property
badwall	% Houses with poor walling	Total housing units	Residential property
notenure	% Houses with no tenure	Total housing units	Renters/Social dependence
hsegt30yrs	% Houses older than 30 years	Total housing units	Residential property
repair	% Houses needing repair	Total housing units	Residential property
smlhse	% Houses having area < 10sqm	Total housing units	Socioeconomic status

Abbrev: HH = household, HS = high school

These indicators were then combined into three equally weighted additive sub-indices:[4]

$$SVI_{in} = \frac{(I_{in}^{1} + I_{in}^{2} + \cdots + I_{in}^{i})}{i} \quad (1)$$

$$SVI_{hh} = \frac{(I_{hh}^{1} + I_{hh}^{2} + \cdots + I_{hh}^{i})}{i} \quad (2)$$

$$SVI_{hs} = \frac{(I_{hs}^{1} + I_{hs}^{2} + \cdots + I_{hs}^{i})}{i} \quad (3)$$

where SVI_{in}, SVI_{hh} and SVI_{hs} correspond to individual, household and housing social vulnerability sub-indices respectively and I_{in}^{i} , I_{hh}^{i} and I_{hs}^{i} correspond to individual, household and housing indicators respectively. For this research, a total of six indicators each were derived to compute the respective composite *SVI* sub-indices. As most values of the individual indicators are represented as percentages that correspond directly to increasing vulnerability, the average household size indicator was normalized based on the maxima and minima of the entire national dataset.

The three continuous sub-index scores were then categorized into five classes – Very Low, Low, Moderate, High, and Very High – dividing the data equally into value ranges as quintiles. As the index scores did not possess any particular scale or unit, this discretization of the data allowed a relative ranking of barangays among themselves for each of the census years. The ordered categorization gives the basis to focus on barangays at the extremes of the categorical scale – the Very Low and the Very High.

Data between the two census years are presented through various graphical and statistical means in the next Chapter to allow a comparison between the two decades. Maps are then presented to show the geographic distribution of the data between the two census years and to visualize the patterns that emerge across various geographical regions as well as between urban and rural barangays in the Philippines.

3.2 Delineating Exposure Zones

This section is divided into two – defining and delineating coastal river flood hazard zones and defining and identifying areas of varying typhoon exposure. The former focuses on coastal estuarine zones, which are very specific locales where this type of hazard exists while the latter looks at the entire terrestrial landscape which are by default prone to typhoons.

3.2.1 Defining Zones of Flood Exposure

In defining coastal river flood hazard, it is important to understand how catchment morphology influences the propagation of a flood event:

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[4] These sub-indices were formulated in accordance with the definition of an index discussed in Section 1.2.5.

> "The presence of mountainous terrain (e.g., USGS-NOAA, 1979; NOAA, 1981b) enhances the likelihood of flash-flood occurrence. The combination of heavy rain and steep terrain makes the foothill areas ideal for flash-flood occurrence. Terrain increases the rate of condensation and efficiency of convective systems. The explosive release of the potential energy results. The steep terrain accelerates the flood wave downstream, with practically no attenuation, resulting in the so-called "wall of water" that causes destruction and loss of life at the foothill communities." (Georgakakos 1986, p. 1235)

As one of the key hazard types being investigated in this research is coastal river flood hazard, a simple approach was developed to delineate flood exposure. A combination of two basic parameters extracted from the SRTM DEM defined primary areas of coastal river flood hazard exposure, which as a function of elevation from the coast and slope:

$$CRFH = E_{10m} \cap S_{2\%} \quad (4)$$

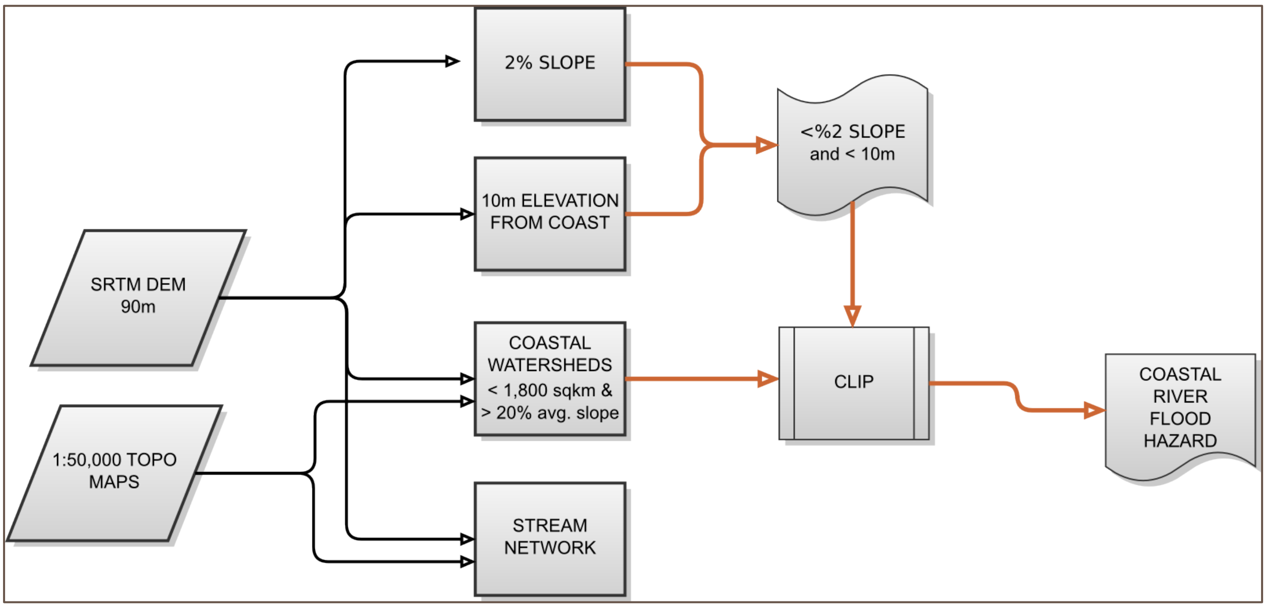
Where *CRFH* is the coastal river flood hazard, E_{10m} is the area up to 10m elevation from the coast and $S_{2\%}$ represents the areas from the coast that have a slope gradient of 2% and below, which typically defines the upper slope limit of a floodplain (Dinesh 2009). The slope was extracted based on the algorithm developed by Zevenbergen and Thorne (1987) which is implemented in the open source GIS application Quantum GIS (QGIS). The *CRFH*, measured in hectares, is a simple yet straightforward attempt at delineating the floodplain areas of coast-draining rivers with flashflood potential using best available data. The *CRFH* zones are then used to identify the flood prone barangays using standard GIS overlay tools. More complex terrain analysis for floodplain mapping have been considered (Nardi et al. 2006; Nardi et al. 2013; Manfreda et al. 2014) as well as the development and application of a spatially distributed physically based hydrologic and geomorphic floodplain delineation approach (Grimaldi et al. 2004; Grimaldi et al. 2012; Grimaldi et al. 2013), but for the hydrogeomorphic setting of the coastal areas of Philippines the selected simple approach based on geometric parameters of differential elevation and slope is already an efficient way of identifying low lying river bottoms and potentially flooded zones given that flat nature of the domain of interest (Nardi et al. 2008).

Coastal watersheds were delineated manually from 1:50,000 scale topographical maps from the National Mapping Resource Information Authority of the Philippines (NAMRIA n.d.). One additional parameter that was extracted from the DEM was the maximum size of the watersheds at 1,800 square kilometers that will typically generate flash flood events. Flash floods normally occur in watersheds of up to 1,000 square kilometers in size (Marchi et al. 2010; Younis et al. 2008), though these estimates are based on European catchments which have different climatic regimes. This maximum size of the watershed that has generated a flash flood event in recent years in the Philippines is the Tagoloan Watershed east of the Cagayan River in Northern Mindanao in October 2006 (Crismundo 2006), with an area of 1,780 square kilometers. With this size, the cutoff for maximum area of coastal watersheds with flash flood potential is 1,800 square kilometers.

Since steeper slope distributions increase the capacity in a watershed for rapid concentration of stream flow, which is one of the key features of flash floods (Marchi et al. 2010), Collier and Fox (2003) defined as one of the criteria for high susceptibility to flash flooding an average watershed or catchment overall slope of 20% or greater. Figure 3-2 presents a flow chart that illustrates the process and operations used to come up with the *CRFH* zones in the Philippines while Figure 3-3 presents a map of watersheds with flash flood potential as defined in the model and the *CRFH* zones that were clipped within their coastal reaches.

Once the *CRFH* Zones had been clearly identified, these areas were then intersected with barangay polygon data in order to identify which barangays contain zones of *CRFH* (Figure 3-4). A total of 5,852 coastal barangays were selected that have zones of exposure to *CRFH*. The total population of these exposed barangays as of 2010 was 13,111,493 or 14.2% of the total. Of these, 1,210 barangays are classified as Urban having a total population of 5,228,452 with the remaining 4,642 Rural barangays having a cumulative population of 7,883,041. Having the disaggregated census data for these barangays gives the opportunity to extract demographic characteristics of the population that can then be crafted to reflect social vulnerability characteristics. It is this type of data that this research aims to put together to come up with a profile of vulnerability for barangays that are predisposed to coastal river flood hazard.

Figure 3-2 Process flow for deriving CRFH zones for the Philippines



As mentioned earlier, the GADM barangay boundaries lack the local accuracy defining barangay areas compared to data maintained by local municipalities and cities. This initial effort is meant to identify “hotspots” and give an overview of potential areas that need more in-depth analysis using more accurate local data.

Figure 3-3 CRFH zones and watersheds with flash flood potential

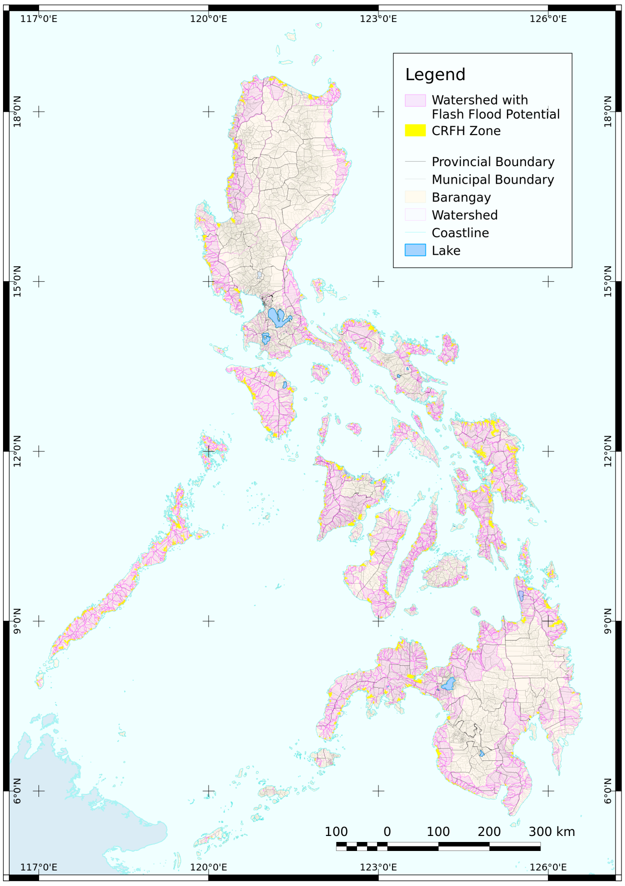
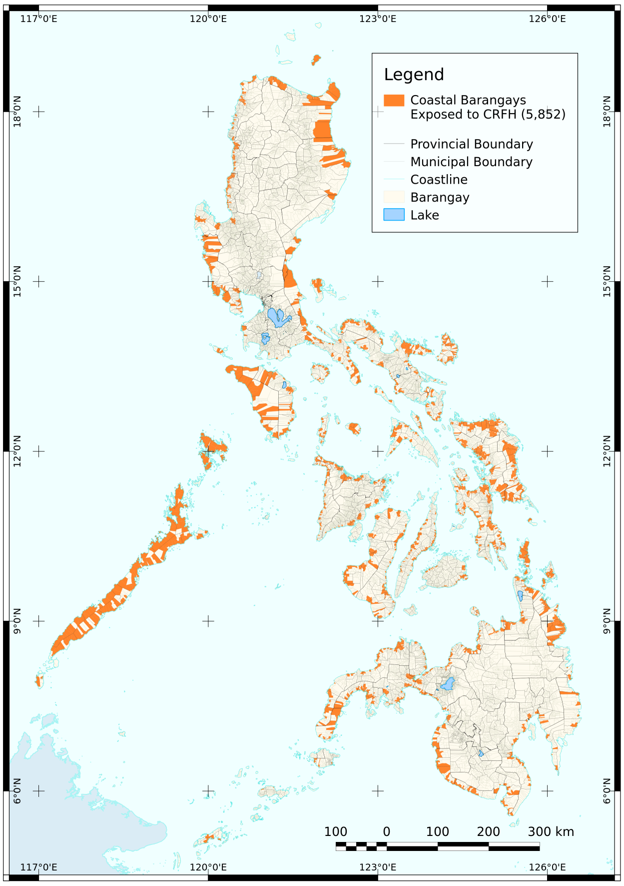


Figure 3-4 Barangay having areas exposed to CRFH



3.2.2 Delineating Typhoon Exposure

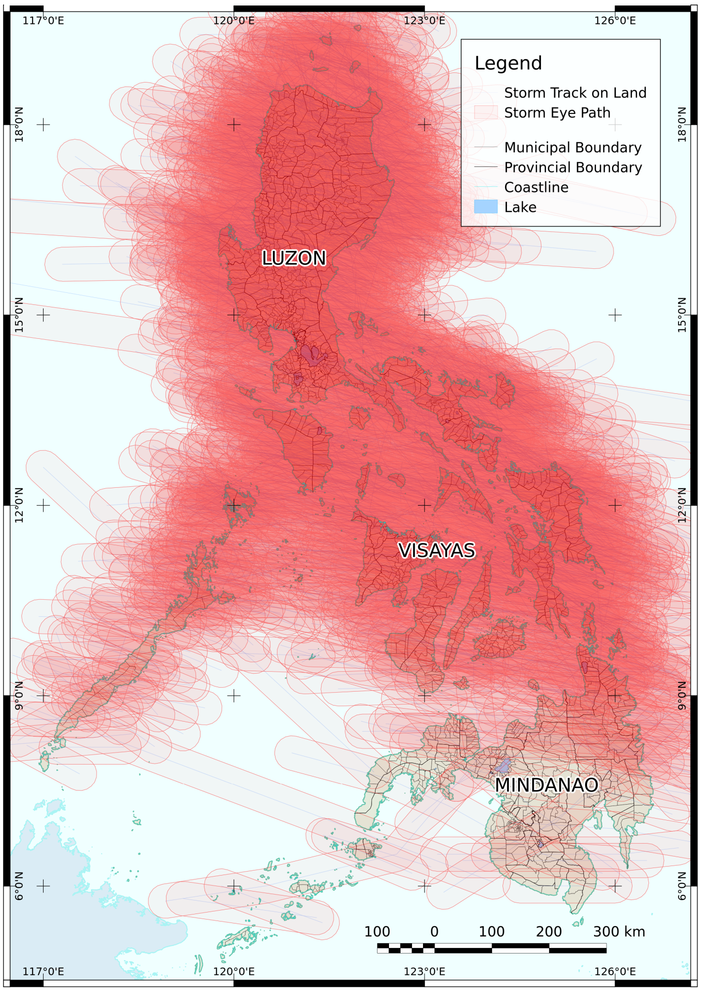
Another key hazard that makes a very significant impact on the country is the typhoon. Typhoons have a wider area of impact than floods, although they can also bring torrential rains that can cause devastating floods in floodplains affecting the population. Typhoons also pack high velocity winds that can reach up to more than 300km/hr (Emanuel 2003) which make them extremely destructive and deadly. Typhoon exposure is determined in order to investigate if the frequency of typhoon occurrence can have an impact on social vulnerability measurements.

The strategy developed to determine typhoon exposure was to overlay storm track data over barangays to determine how many times a barangay had been directly hit by a typhoon. The barangays would then be categorized depending on the number of times it had suffered a direct hit from a typhoon or storm. But as the data available was in the form of lines in a GIS database, it was difficult to establish direct storm hits (*DSH*) due to the very narrow influence of a line crossing over barangay polygons. Rural barangays with larger areas would tend to be intersected more often than smaller urban barangays, even if they are adjacent to each other. As typhoons have a wide area of coverage, it is more realistic to represent the passage of a typhoon as an area, rather than a one-dimensional line. A more effective means of determining typhoon hits on a barangay needed to be developed.

According to Weatherford and Gray (1988), the maximum eye radius of a medium-sized storm is 30km, and it is this distance that was used to buffer the storm paths to come out with the area of impact of an average storm passing through. As the highest intensity winds in a storm are present around the eye (Emanuel 2003), it would be safe to say that a barangay that was touched by the area of impact of an eye had suffered a direct hit from the typhoon. Figure 3-5 shows the derived storm eye paths based on a 30km buffer of the storm tracks for the Philippines. Each time an eye path intersects a barangay, it was counted as a direct hit. The maximum number of direct hits registered for a barangay was 122 while the minimum was nil for the data acquired for this research.

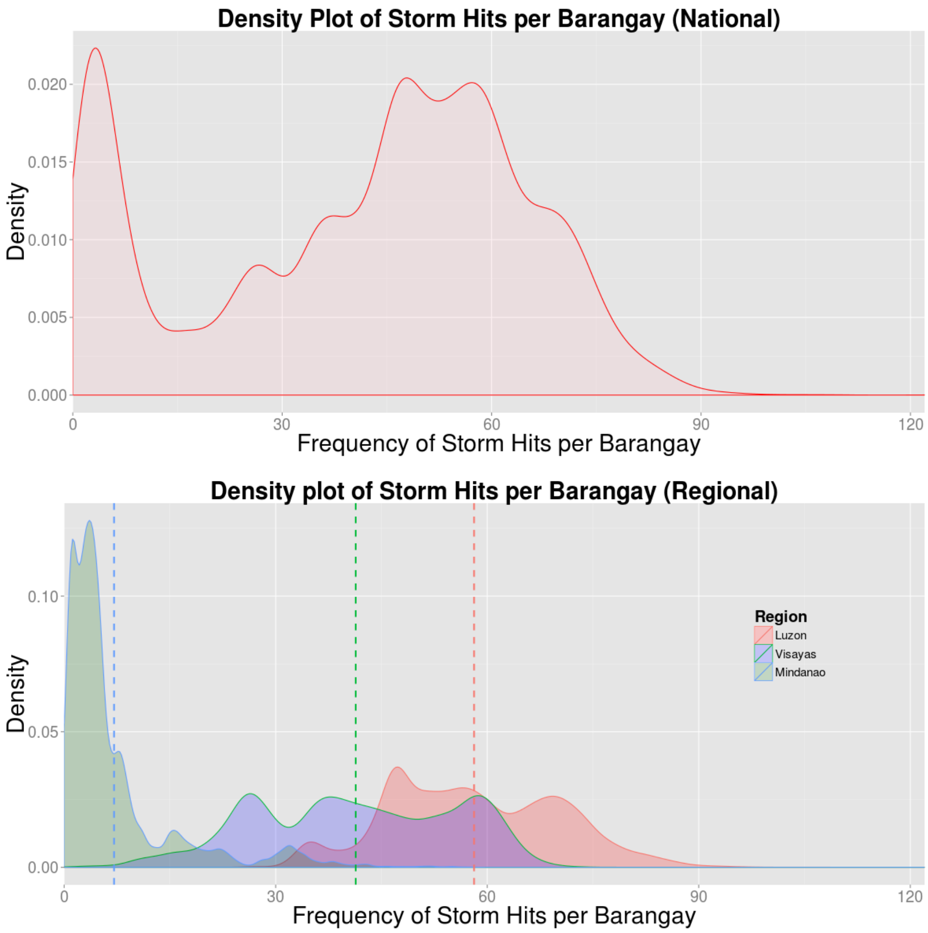
Figure 3-6 shows density plots of the distribution of *DSH* at the national and regional levels. It is evident from the bimodal shape of the national *DSH* density plot that there are quite a number of barangays that have very low frequency storm hits, but beyond a frequency of around 12 direct hits, there is again a gradual increase in number of barangays having higher frequency of storms passing through. This phenomenon is also geographically apparent in Figures 2-4 and 3-4 where there are regions that are rarely visited by typhoons beyond a particular threshold (the typhoon belt) running across the lower half of Philippines from southeast to northwest. Looking at the regional density plot of Figure 3-5, we can see that much of the low frequency direct hits are contributed by barangays from Mindanao.

Figure 3-5 Storm eye paths over land in the Philippines from 1884 until 2013



Sources: GADM and NOAA-IBTrACS.

Figure 3-6 Density plots of *DSH*



3.3 Regression Analysis for Determinants of Flood Impact

Regression analysis was used as a validation method since it is able to test for significance of relationships between independent and dependent variables. It is a robust method that shows various parameters that can help assess the relationships between *SVI* and the outcomes of flood impact.

Given the rich data that had been gathered from the two flood case study sites, a multiple regression analysis was initially planned with the *SVI* variables and *CRFH* acting as predictors and the loss and damage data of dead + missing, affected population, and levels of damage to housing units as outcomes in the regression models. The multiple linear regression models were defined by:

$$y_j = \alpha + \sum_k \beta_k x_k + \epsilon \qquad (5)$$

where y_j represents the outcomes (i.e. number of dead + missing, affected individuals, and levels of damage to housing units) while x_k represents the various predictors (SVI_{in}, SVI_{hh}, SVI_{hs}, and $CRFH$). The number of dead+missing represents a different propulation from affected individuals primarily due to the highly disparate levels of disaster impact depicted by each, hence their treatment as separate variables in the regression analysis.

Table 3-4 shows the Pearson's r correlation matrix among the different predictors for Iligan City and it shows that SVI_{hs} is highly correlated with SVI_{hh} and SVI_{in} with a score of 0.856 and 0.850 respectively. Due to multicollinearity, it was not advisable to combine the different SVI variables in a single model as it can affect its outcome. As these *SVI* variables are measuring different aspects of vulnerability on individual, household, and housing levels, it was worth investigating the independent effects, if any, of each variable on the outcomes. As this approach was conducted on the Iligan City case, it was similarly applied on Cagayan de Oro City data for consistency of method.

Table 3-5 Correlation matrix of predictor variables for Iligan City

	SVI_{in}	SVI_{hh}	SVI_{hs}	*CRFH*
SVI_{in}	1.000			
SVI_{hh}	0.843	1.000		
SVI_{hs}	0.850	0.856	1.000	
CRFH	-0.399	-0.417	-0.395	1.000

As a result of the high correlations, ordinary least squares (OLS) simple regression models were instead developed for each of the variables, defined by:

$$y = \alpha + \beta x + \epsilon \qquad (6)$$

where *y* represents the outcome variables while *x* represents the different *SVI* predictors as well as *CRFH*.

3.4 Regression Analysis for Typhoon Frequency Influence on *SVI*

For this portion of the research, regression analysis is also used to test the statistical significance of relationships between typhoon frequency and *SVI*. This time the *SVI* variables were instead used as outcomes with frequency of direct storm hits, denoted by *DSH* (for direct storm hits), as the predictor in simple linear regression models similar in form to equation (6), but this time having the *SVI* variables as the outcomes for the *DSH* predictor.:

$$y_{SVI} = \alpha + \beta x_{DSH} + \epsilon \qquad (7)$$

where y_{SVI} represents the *SVI* sub-index scores and x_{DSH} represents the number of direct storm hits for the barangays.

4 Results

This chapter begins with a presentation of the results of the *SVI* modeling for both the 2000 and 2010 census databases. The purpose of this first part is to check the comparability of the data across the two census years. It also seeks to validate the consistency of the outputs across time and between urban and rural types of barangays. Figure 4-1 shows the subsections of this chapter and which objectives it is finally addressing.

Figure 4-1. Results subsection of research process matrix

Specific Objectives	Results (CHAPTER 4)
1. Develop Social Vulnerability Index at the National Level	SVI Modeling Results and Comparative Analysis (4.1) – Graphical Comparison of 2000 and 2010 SVIs in Urban vs. Rural Areas through Charts – Cartographic Comparison of 2000 and 2010 SVIs
2. Delineate Exposure Zones at the National Level	
3. Validate SVI and Flood Hazard Exposure with Loss and Damage Case Study	Regression Results for Social Vulnerability and Exposure Contribution to Flood Impact (4.2)
4. Investigate Relationship between SVI and Typhoon Exposure	Regression Results for Typhoon Frequency vs. SVI (4.3)

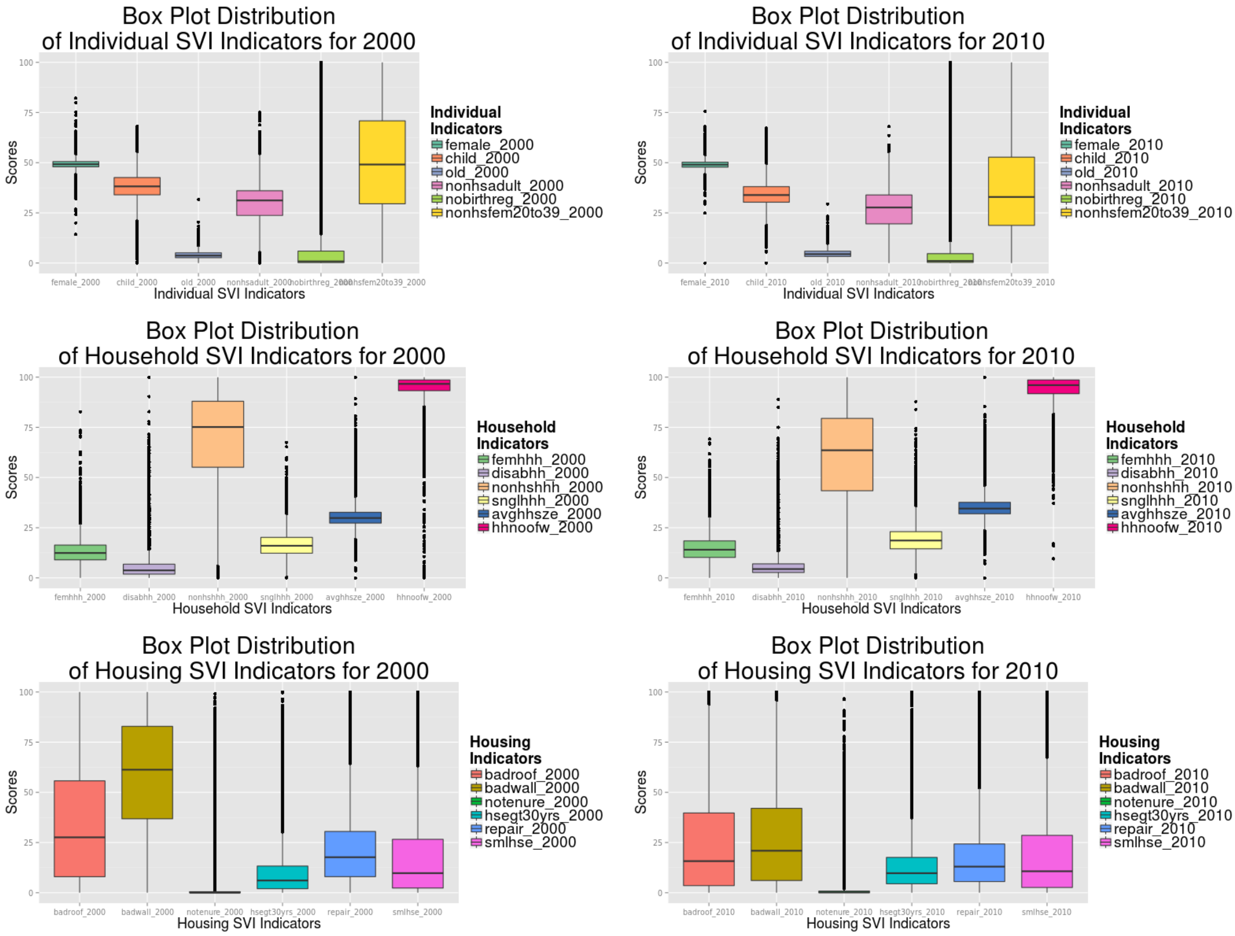
After this comparative assessment, we proceed to the portion on validating the *SVI* outcomes vis-à-vis local case studies for ex post analysis of their relationships with the outcome of flood events triggered by TS Washi in Northern Mindanao in December of 2011. The next portion looks at possible influences of hazard exposure, in the form of typhoon frequency, on the *SVI* outcomes.

4.1 SVI Modeling Results and Comparative Analysis

4.1.1 Statistical Summaries of Indicators and Sub-Indices

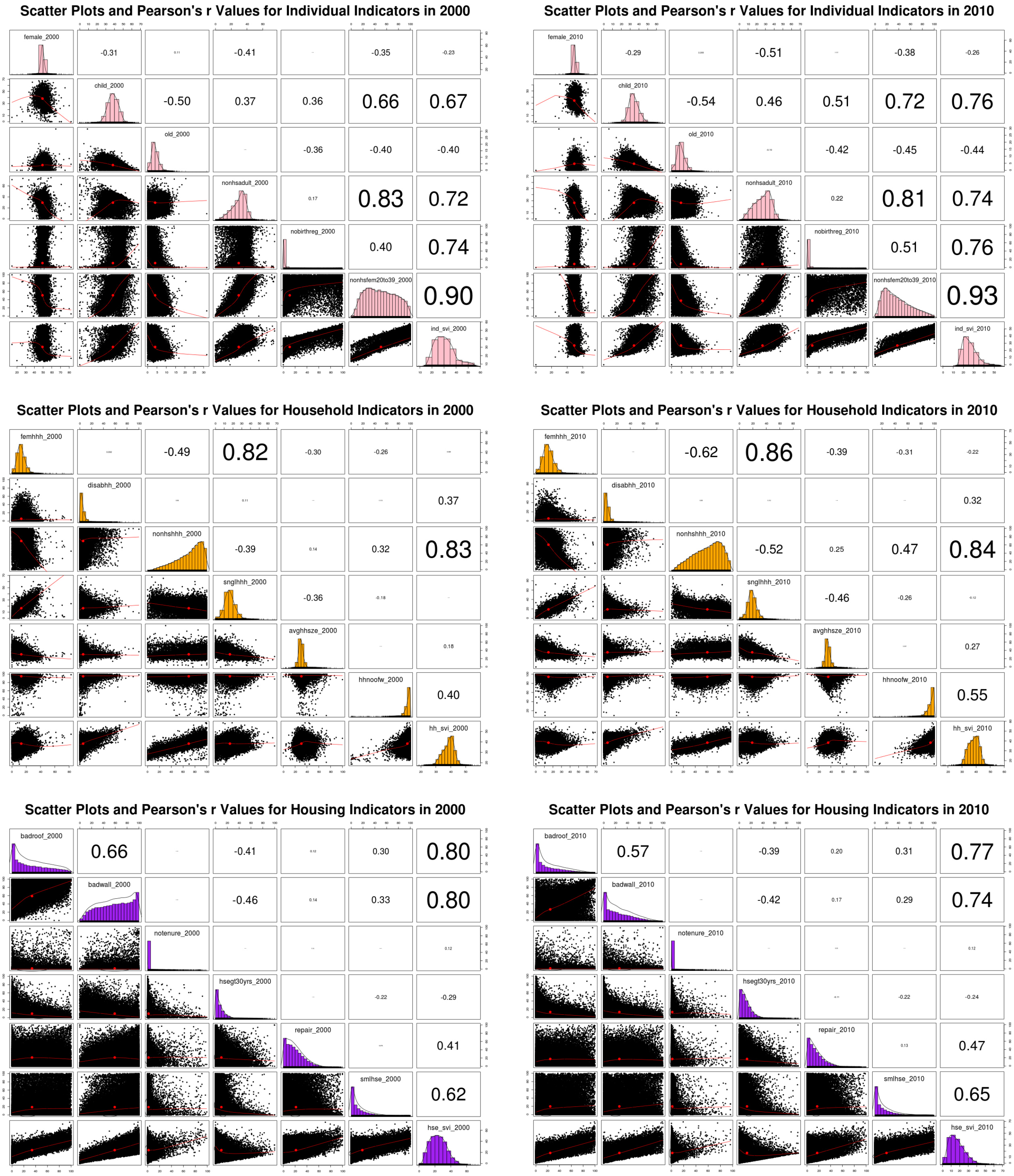
Table 4-1 presents the basic summary statistics of the indicators as well as their composite sub-indices for both the 2000 and 2010 census years. Figure 4-2 presents a graphic presentation of the distribution of the data through box plots, which readily present each variable's quartile distribution as well as other statistical parameters such as the mean, minimum and maximum, etc. Figure 4-3 presents a series of scatterplots, histograms, and Pearson's r correlation coefficients showing relationships among the indicators as well as their corresponding sub-indices. The scatterplots and histograms aim to show the relationships of the indicators relative to one another and to the final sub-index scores, while the Pearson's r correlation coefficient (or product-moment correlation) measures the strength of relationship between two variables.[5]

Figure 4-2 Box plot distribution of SVI sub-indices and their indicators (2000 & 2010)



[5] The equation $r = \frac{\sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \bar{X})^2}\sqrt{\sum_{i=1}^{n}(Y_i - \bar{Y})^2}}$, describes r as the centered and standardized sum of the cross-product of two variables (Lee Rodgers & Nicewander 1988).

Figure 4-3 Scatter plots, histograms, and Pearson's r correlation coefficients of SVI sub-indices and their indicators for 2000 and 2010 (note: Pearson's r values are scaled with increasing correlation)



From Table 4-1 it can be seen that most of the summary statistics for the indicators between the two census years are highly similar. There are, however, a few notable changes such as a decrease in percentage points in the `nonhsfem20to39`[6] and `nonhshhh`[7] indicators for the individual and household sub-indices and it is

[6] Non-high school graduate female from 20 to 39 years old

interesting to note that these are both indicators of educational attainment. Other changes worth noting are the marked decline in the percentage of `badroof`[8] and the `badwall`[9] indicators of the housing sub-index indicating an improvement of building materials through the decade. These same indicators have also the relatively high standard deviation values.

Table 4-1 Summary statistics of SVI sub-indices and their indicators for 2000 and 2010 (n = 41,919)

SVI_{in} **Indicators**	**mean**	**sd**	**median**	**min**	**max**	**se**
female_2000	49.29	2.38	49.23	14.29	82.1	0.01
female_2010	49.07	2.2	49.03	0	75.52	0.01
child_2000	38.19	6.48	38.19	0	68.18	0.03
child_2010	34.43	6.2	33.88	0	67.24	0.03
old_2000	4.01	2.02	3.74	0	31.68	0.01
old_2010	4.68	2.16	4.44	0	29.41	0.01
nonhsadult_2000	29.5	9.08	31.19	0	75.04	0.04
nonhsadult_2010	26.55	9.53	27.69	0	68	0.05
nobirthreg_2000	10.83	22.9	0.82	0	100	0.11
nobirthreg_2010	8.52	19.05	1.03	0	100	0.09
nonhsfem20to39_2000	50.42	24.87	49.1	0	100	0.12
nonhsfem20to39_2010	37.6	22.96	32.91	0	100	0.11
ind_svi_2000	**30.37**	**8.14**	**29.46**	**9.26**	**58.2**	**0.04**
ind_svi_2010	**26.81**	**7.68**	**25.32**	**0**	**57.56**	**0.04**
SVI_{hh} **Indicators**	**mean**	**sd**	**median**	**min**	**max**	**se**
femhhh_2000	13.02	6.01	12.39	0	82.77	0.03
femhhh_2010	14.7	6.76	14.05	0	69.23	0.03
disabhh_2000	5.62	6.77	3.74	0	100	0.03
disabhh_2010	5.67	5.37	4.4	0	88.89	0.03
nonhshhh_2000	69.54	22.62	75.17	0	100	0.11
nonhshhh_2010	60.5	23.08	63.58	0	100	0.11
snglhhh_2000	16.48	6.56	16	0	67.5	0.03
snglhhh_2010	18.99	7.37	18.6	0	87.84	0.04
avghhsze_2000	30.55	5.57	29.83	0	100	0.03
avghhsze_2010	35.43	5.95	34.53	0	100	0.03
hhnoofw_2000	95.07	5.74	96.64	0	100	0.03
hhnoofw_2010	94.35	5.74	96.02	9.52	100	0.03
hh_svi_2000	**38.38**	**4.04**	**38.93**	**18.71**	**58.33**	**0.02**
hh_svi_2010	**38.27**	**3.9**	**38.5**	**16.44**	**58.41**	**0.02**
SVI_{hs} **Indicators**	**mean**	**sd**	**median**	**min**	**max**	**se**
badroof_2000	33.92	28.48	27.59	0	100	0.14
badroof_2010	24.32	24.46	15.73	0	100	0.12
badwall_2000	59.05	27.12	61.29	0	100	0.13
badwall_2010	26.57	23.59	20.91	0	100	0.12
notenure_2000	1.51	6.45	0	0	99.12	0.03
notenure_2010	1.33	4.97	0.17	0	96.59	0.02

[7] Non-high school graduate head of household
[8] House with poor roofing material
[9] House with poor walling material

hsegt30yrs_2000	9.97	11.98	6.09	0	100	0.06
hsegt30yrs_2010	13.17	12.72	9.71	0	100	0.06
repair_2000	21.37	17.31	17.66	0	100	0.08
repair_2010	17.18	15.5	12.99	0	100	0.08
smlhse_2000	18.9	22.98	9.74	0	100	0.11
smlhse_2010	19.82	23.04	10.69	0	100	0.11
hse_svi_2000	**24.12**	**10.5**	**23.53**	**0**	**74.35**	**0.05**
hse_svi_2010	**17.07**	**9.38**	**15.51**	**0**	**69.07**	**0.05**

Sources: Derived from 2000 and 2010 Censuses of Population and Housing of the Philippines. Please see Table 3-3 for details of each indicator.

This statistical presentation of the data shows the inner structure of the data that comprise the indices, showing how the indicators relate to one another and to the final index scores. In and of themselves, the results of the social vulnerability sub-index scores are difficult to evaluate, even between the two census years, except to note the increases or decreases of the final sub-index and in the contributing indicator scores. The addition of the urban and rural variable gave an added insight as to the relative concentrations of the sub-index scores in urban and rural areas. It also gives a strong basis to evaluate the relative consistencies of the sub-index scores among themselves.

Figure 4-4 is a series of bar plots of the number of barangays distributed among the quintile categories and segregated into urban and rural classifications for 2000 and 2010. As the series of plots show, there is a markedly consistent distribution of both urban and rural barangays among the three vulnerability sub-indices. The plots show that there is an increasing number of rural barangays as one moves into the higher vulnerability categories and an increasing number of urban barangays as one moves into the lower vulnerability categories. The green and read lines on the y-axis of the graphs signify the default number of total barangays for urban and rural respectively for one quintile (i.e. total number of barangays for urban and rural divided by 5). These simply mean that if these lines are the default values if there are no discrepancies between the two.

Figure 4-4 Bar plots of barangay distribution per sub index quintile category for urban and rural barangays in 2000 and 2010

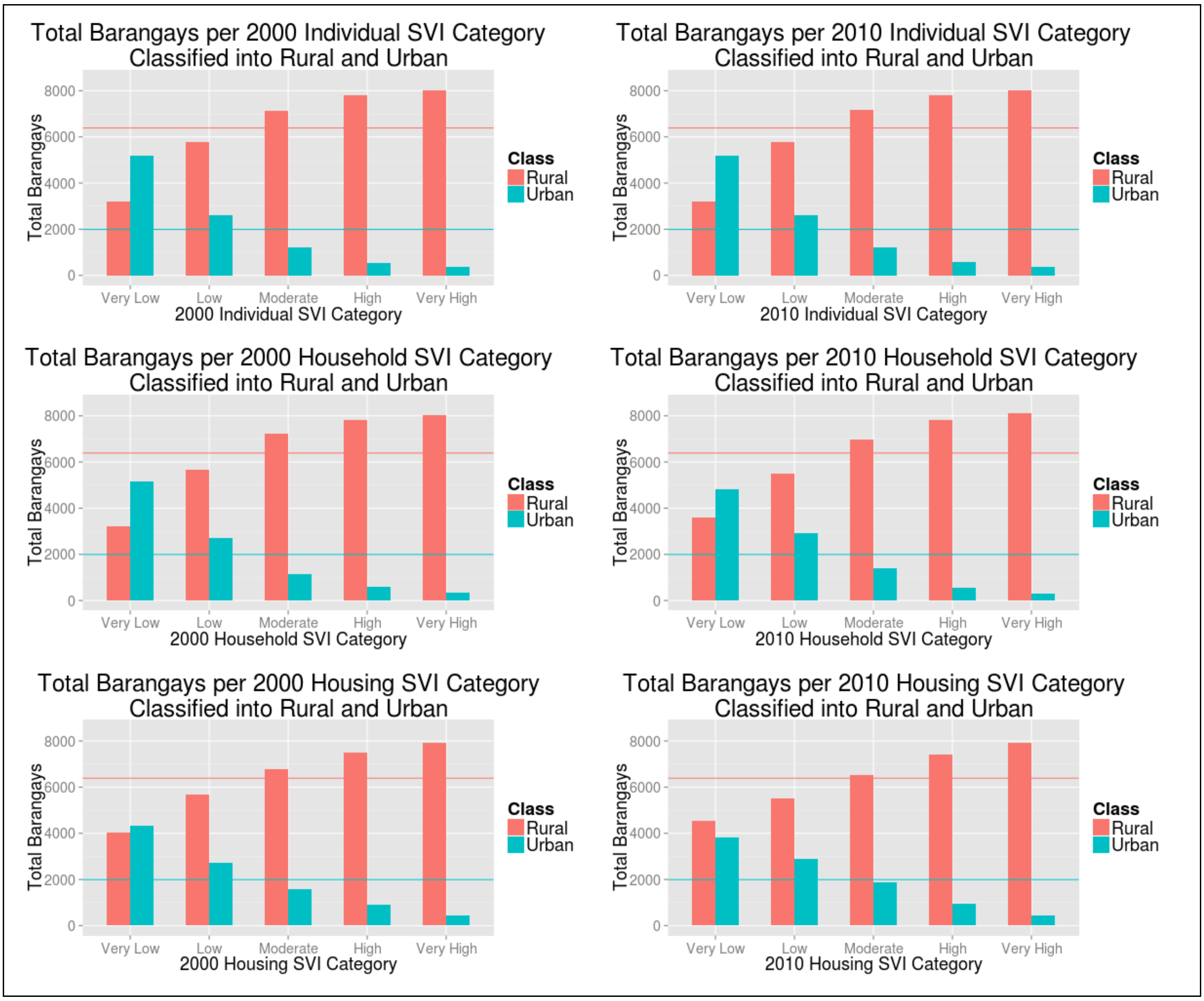
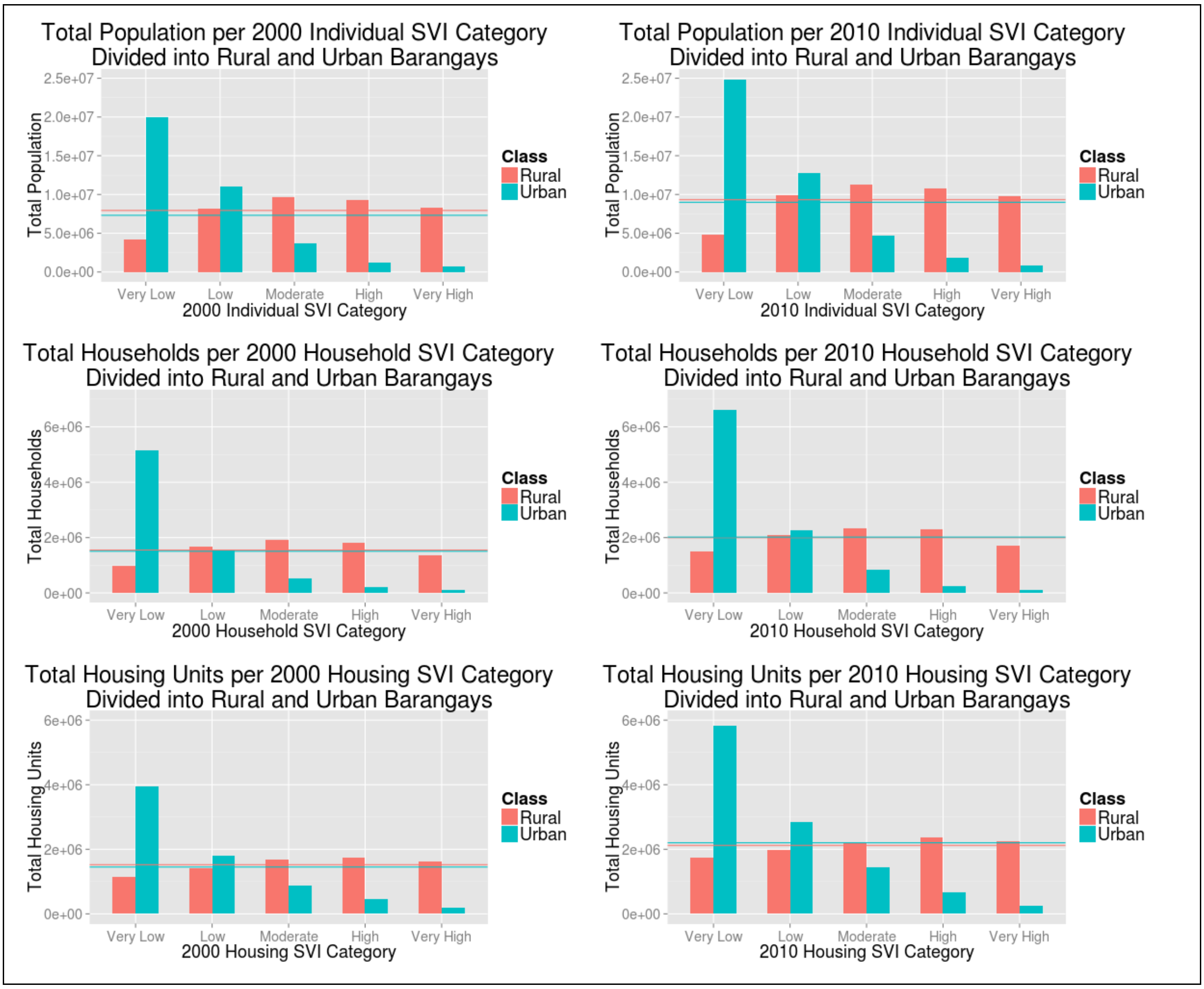


Figure 4-5 presents a similar series of bar plots as Figure 4-4, but this time looking at the totals of individual, household, and housing unit distributions in the quintile sub-index categories for urban and rural areas between the two census years. The plots show that there is less variation for the rural category across the quintiles, though the lowest numbers are in the Very Low categories. On the other hand, there appears to be an exponential decrease of total individuals, households, and housing units as one moves from Very Low to Very High. The green and red lines across the y-axis represent the default number of individuals, households, and housing units for the urban and rural classes across the categories. Figure 4-4 suggests that rural individuals, households, and housing units are roughly evenly distributed among the quintile groups from Very Low to Very High categories compared to their urban counterparts, which are mainly found in the Low to Very Low quintiles.

Figure 4-5 Bar plots of individual, household, and housing unit distribution per sub index quintile category for urban and rural barangays in 2000 and 2010



To check how each indicator that comprises the SVI sub-indices are distributed among their respective quintile categories and between urban and rural areas, similar graphs have been produced and are included in Appendices C, D, and E for reference. These plots were produced so as to check the distribution of the contributing indicator of each sub-index vis-à-vis each other and between urban and rural classes.

4.1.2 An Overall Measure for Social Vulnerability[10]

As there is a consistent pattern emerging in the distribution of scores among the three *SVI* sub-indices relative to the quintile categories and the urban and rural classification, there was compelling basis to combine the three indices into an equally weighted (average) value for overall vulnerability in order to come up with an overall measure of social vulnerability for a barangay:

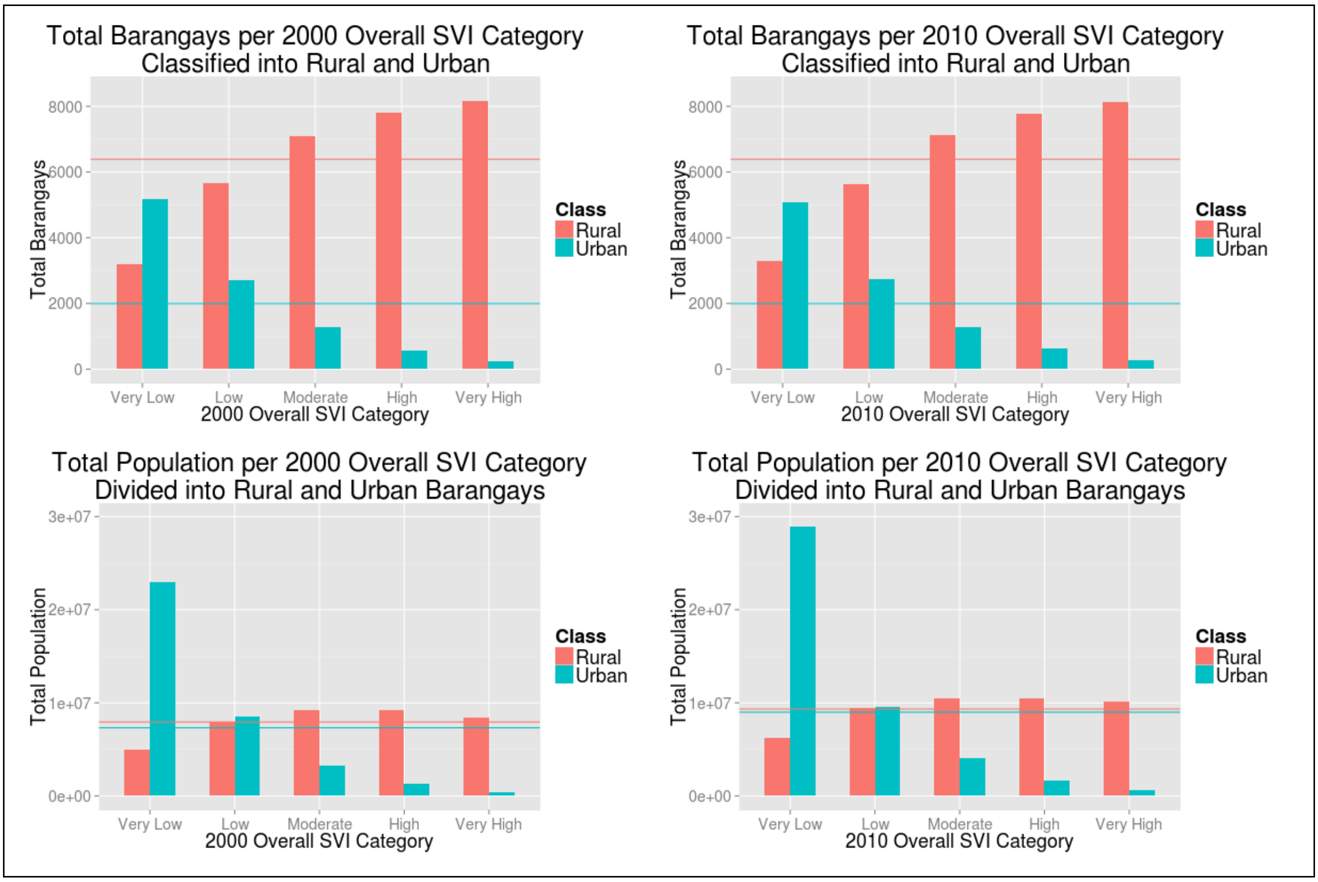
[10] Although this sub-section begins by illustrating a methodology, the author feels that it is more appropriately introduced in this chapter rather than in Chapter 3, as it only becomes evident to combine the 3 sub-indices after recognizing the consistency of outputs of the *SVI* sub-indices.

$$SVI_{tot} = \frac{(SVI_{in} + SVI_{hh} + SVI_{hs})}{3} \quad (8)$$

where SVI_{tot} represents the overall or total SVI for each barangay.

Figure 4-6, presents a combination of bar plots showing overall vulnerability distribution of barangays as well as total individuals for urban and rural areas for the census years 2000 and 2010. The SVI_{fin} measure captures the similar data patterns of the individual, household, and housing SVI sub-indices as can be seen in Figures 7 and 8.

Figure 4-6 Bar plots of barangay distribution and total population per overall SVI quintiles for urban and rural barangays in 2000 and 2010



4.1.3 Cartographic Presentation

Figures 4-7 and 4-8 presents a series of maps showing the distributions of SVI sub-index quintile categories throughout the Philippines based on 2000 and 2010 census data respectively. Note that since rural barangays comprise approximately 90% of the total area of the Philippines[11], they would tend to be over-emphasized in

[11] Since no comprehensive surveyed boundaries for barangays in the Philippines exist, the area computations are based on the indicative GADM boundaries used in this research as described in Section 2.2.2.

the maps compared to their urban counterparts. Nonetheless, these maps still adequately reflect the dominance of rural barangays in the higher SVI categories.

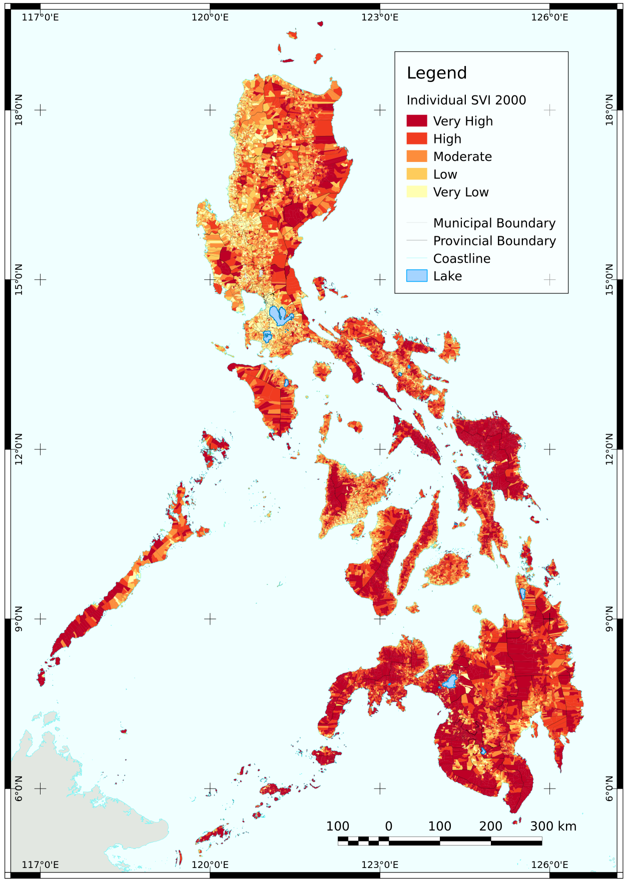
The geographic distribution of the SVI_{in} and SVI_{hs} sub-index scores are visually similar in the maps, particularly the clustering of Very High scores, which are found south of Luzon. These high-scoring areas are found in certain major islands such as Samar in the east of the Visayas, Negros Oriental which is the southern province of Negros Island also in the Visayas, Palawan to the west, as well as a great majority of areas in Mindanao. The SVI_{hh} sub-index scores have a slightly different pattern of distribution showing a significant cluster in Northern Luzon. Even with these differences in geographic distributions, there is still a pronounced trend of consistently high-scoring barangays in certain areas which are mostly located in the south.

In order to zero in on the extremes of the quintile categories, another series of maps are presented that show the distribution of Very Low and Very High scoring barangays in 2000 and 2010 (Figures 4-9 and 4-10). These same maps also highlight the barangays that have consistently remained either in the Very High or in the Very Low quintile categories for both census years.

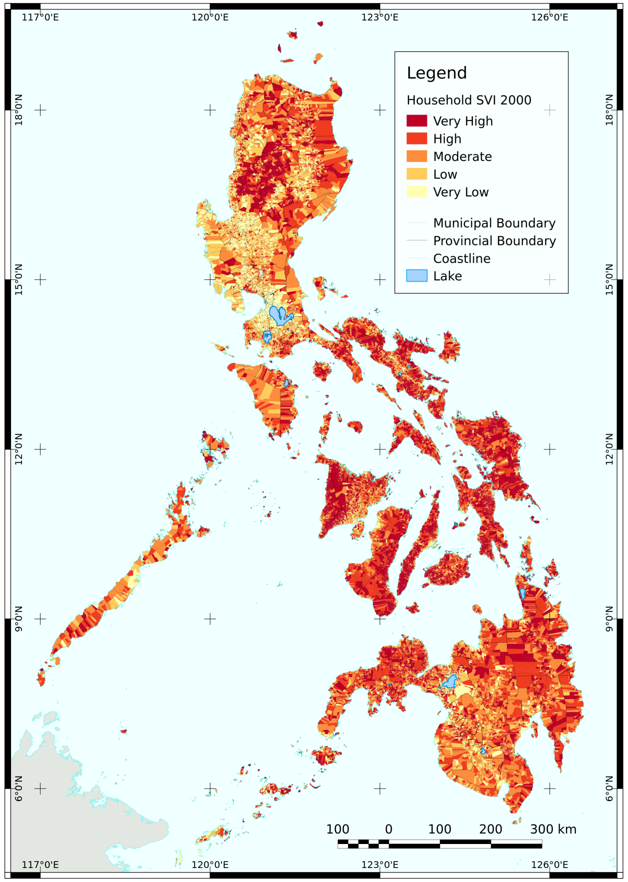
In this set of maps, the previous observations become more pronounced, revealing the concentrations of Very Low and Very High scoring barangays throughout the Philippines. These maps also visualize the geographic spread of the Very Low and Very High categorical extremes presented, particularly their strong associations with urban and rural barangays respectively.

Figure 4-7 Distribution of quintile categories for SVI sub-indices in 2000 and 2010

Individual *SVI* 2000



Household *SVI* 2000



Housing *SVI* 2000

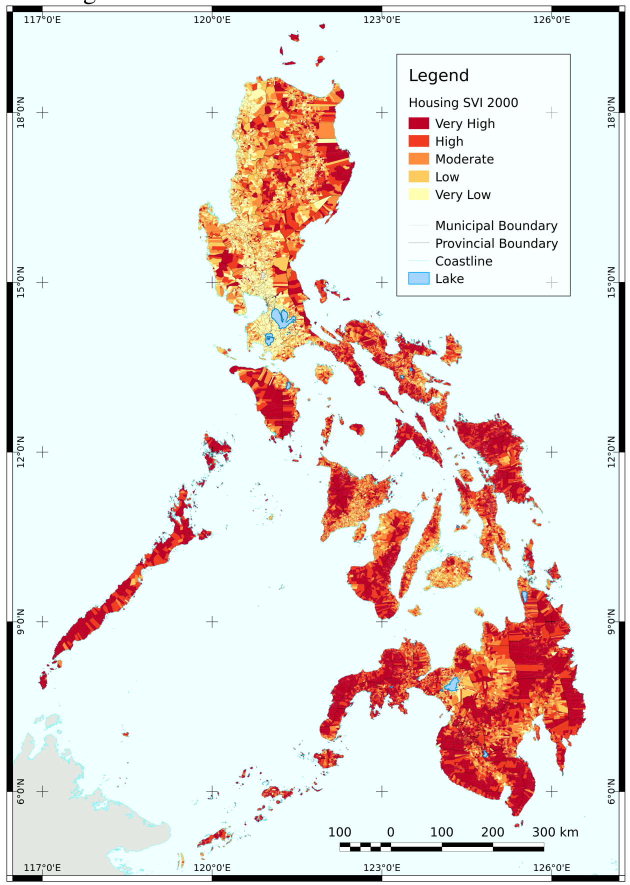
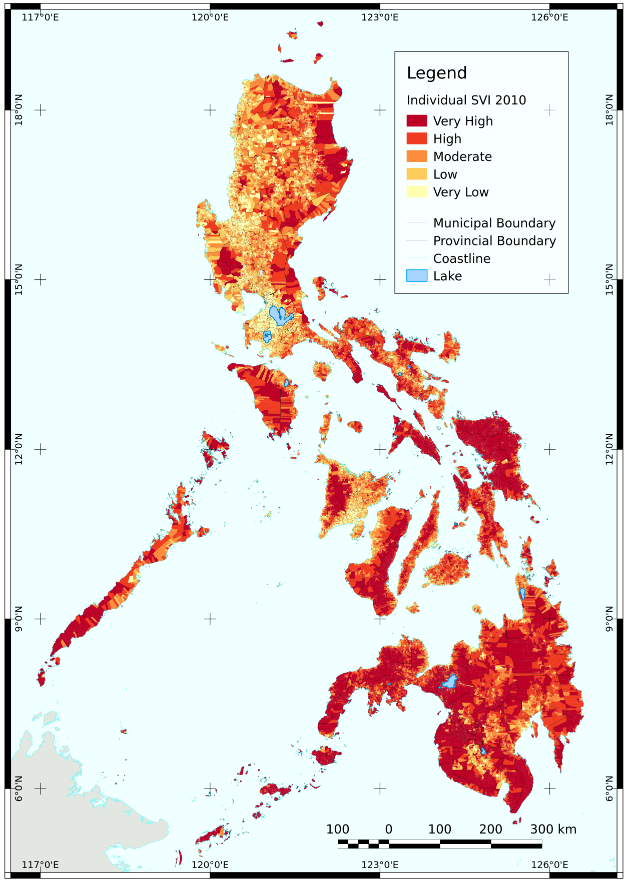
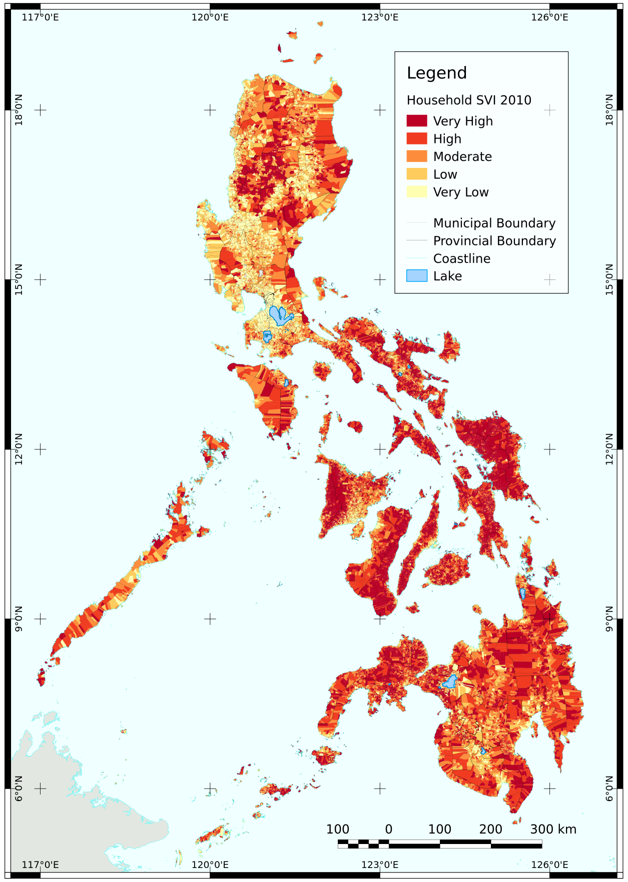


Figure 4-8 Distribution of quintile categories for SVI sub-indices in 2010

Individual *SVI* 2010



Household *SVI* 2010



Housing *SVI* 2010

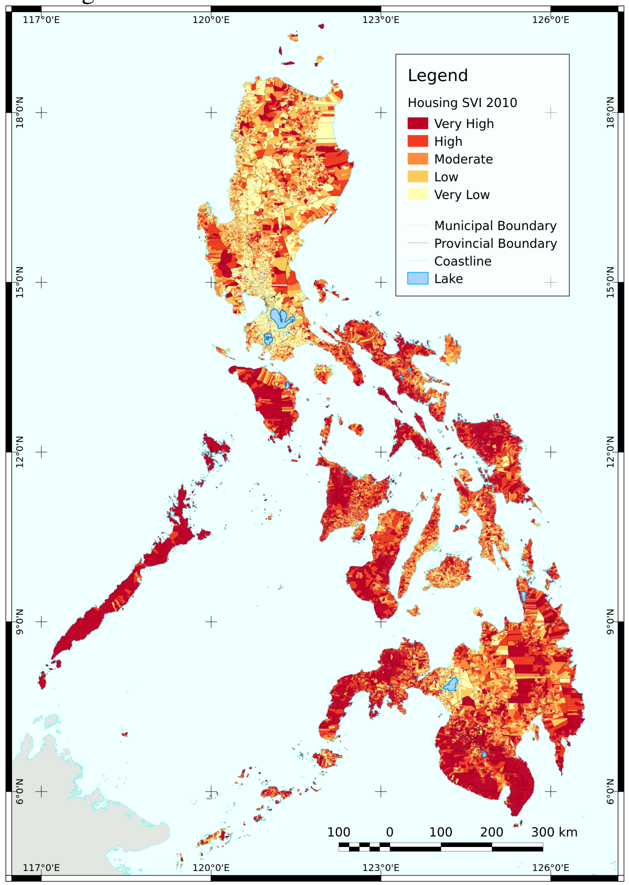
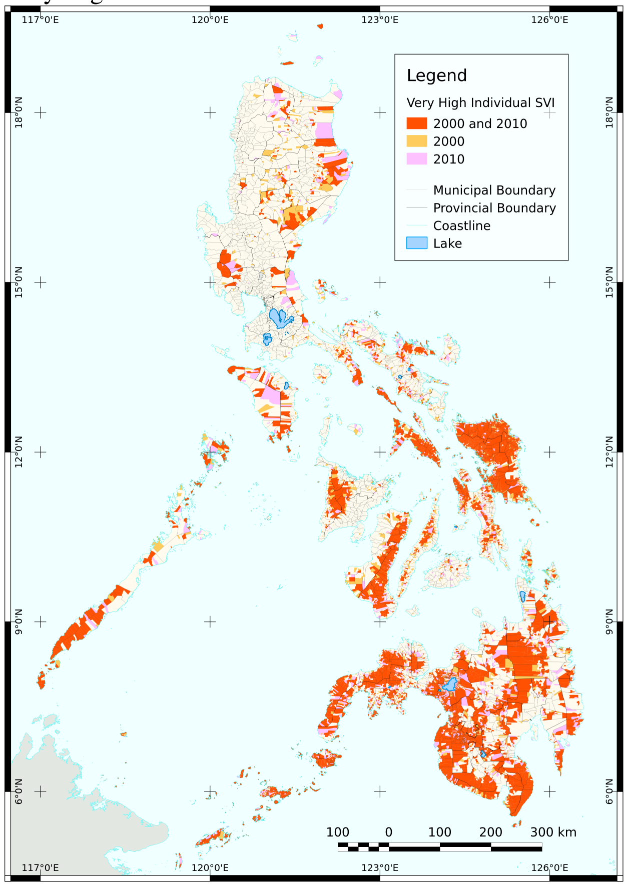
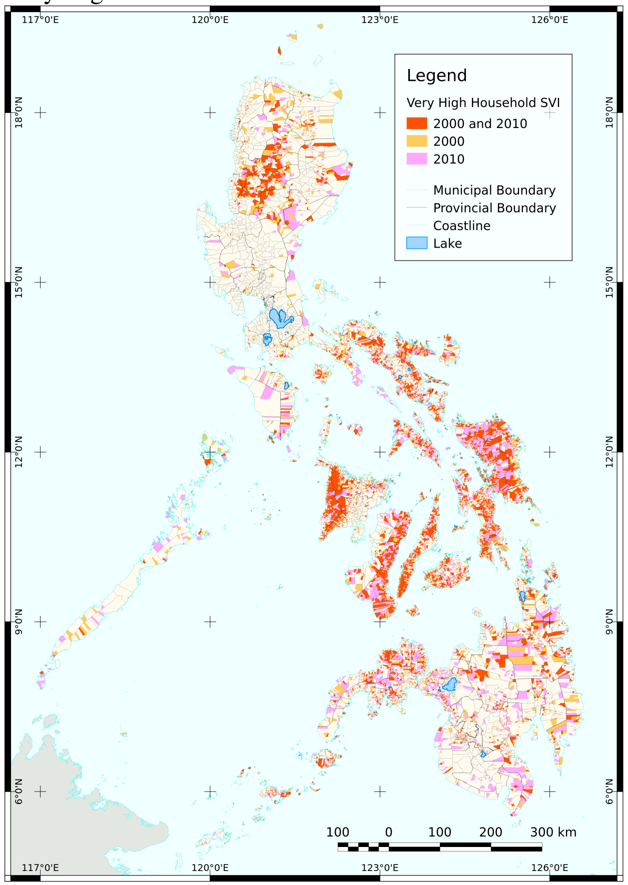


Figure 4-9 Distribution of Very High quintile category for SVI sub-indices in 2000 and 2010

Very High Individual SVI for 2000 and 2010



Very High Household SVI for 2000 and 2010



Very High Housing SVI for 2000 and 2010

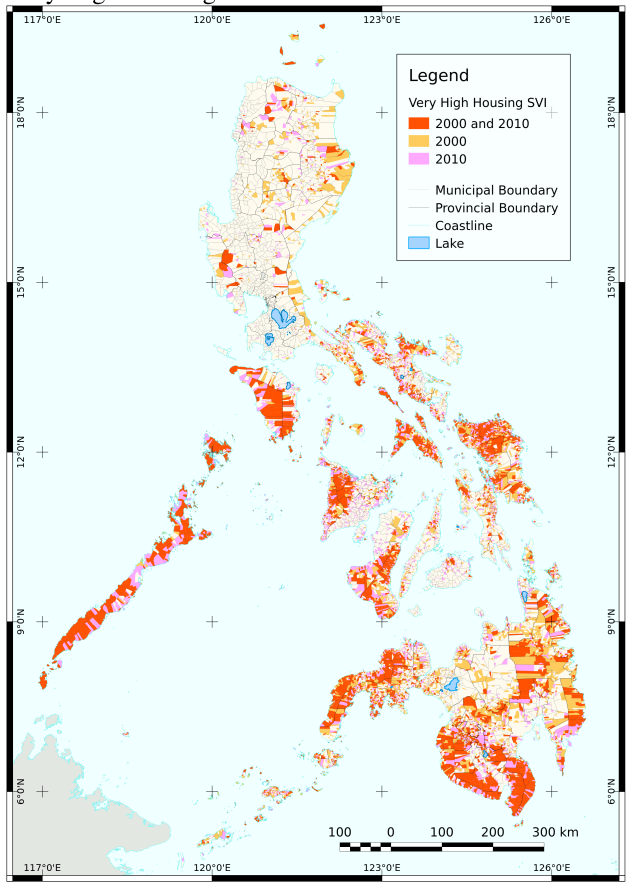
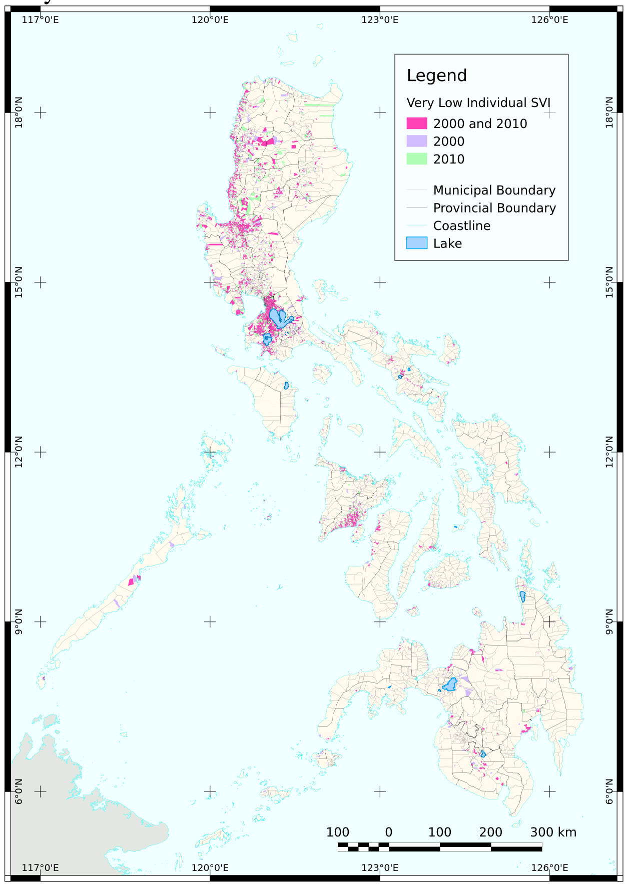
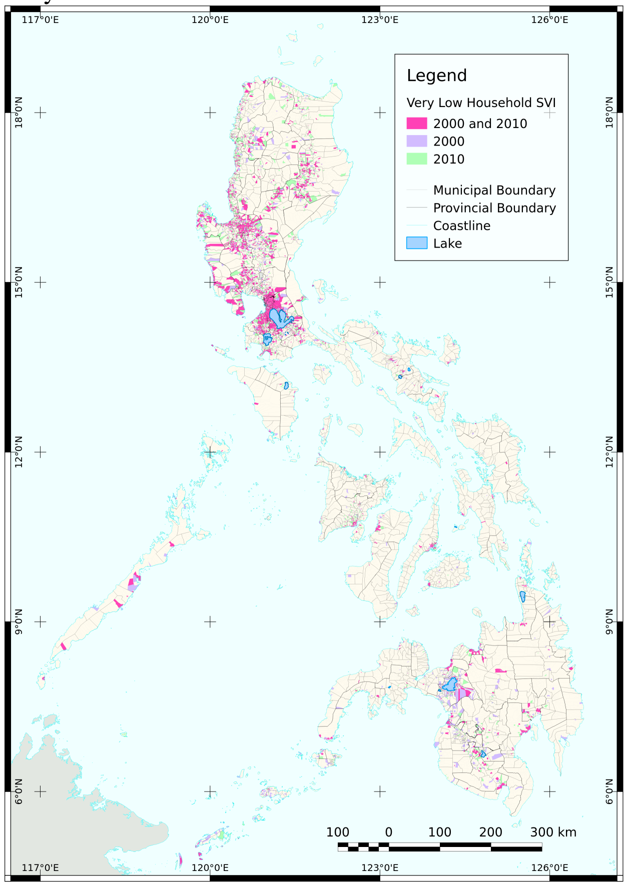


Figure 4-10 Distribution of Very Low quintile category for SVI sub-indices in 2000 and 2010

Very Low Individual SVI for 2000 and 2010



Very Low Household SVI for 2000 and 2010



Very Low Housing SVI for 2000 and 2010

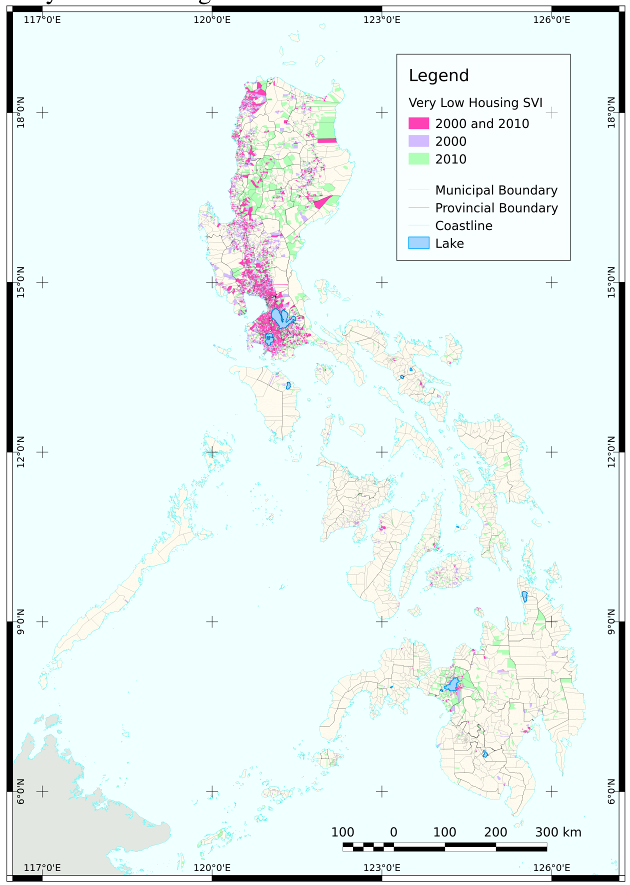
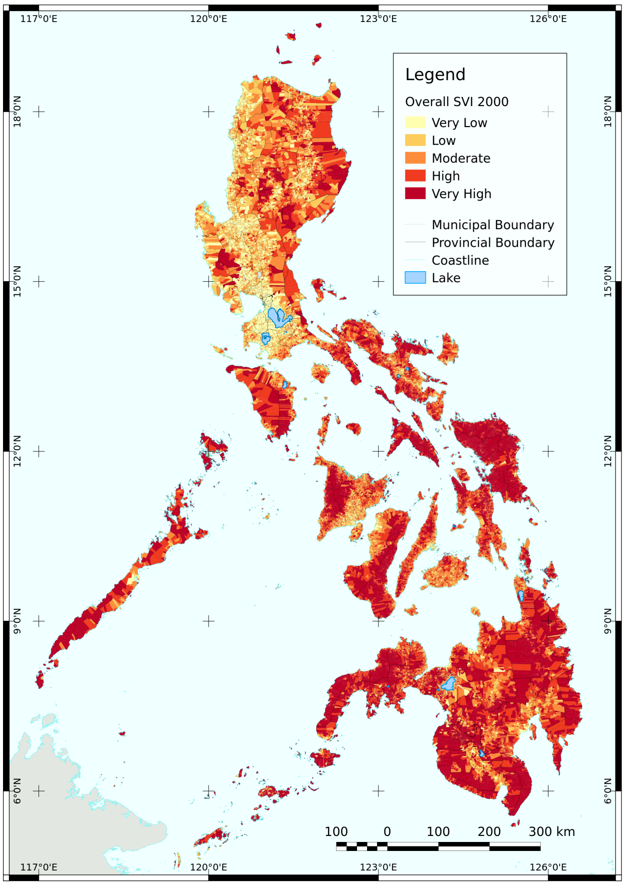


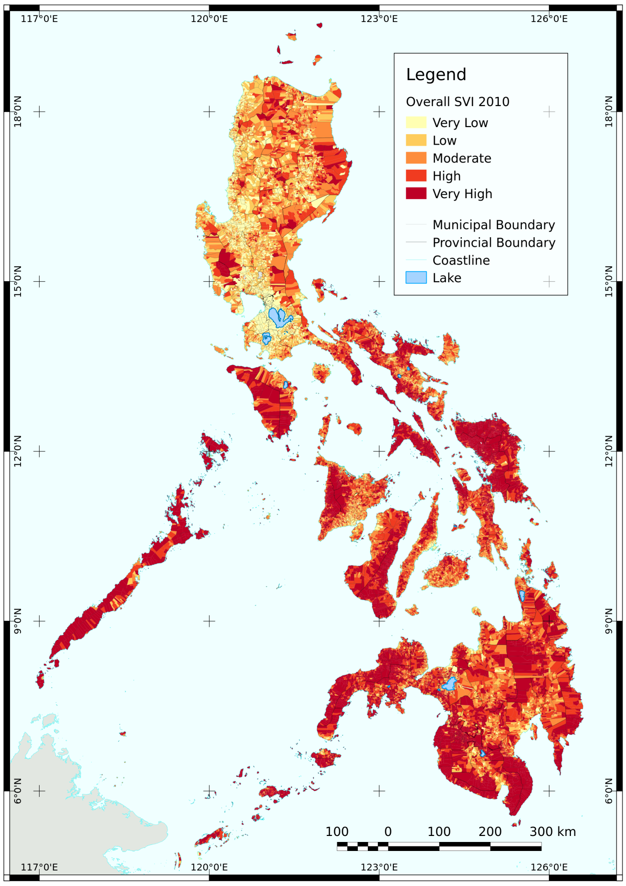
Figure 4-11 shows the geographic distribution of the quintile categories of the Overall *SVI* composite measure (SVI_{tot}) for 2000 and 2010.[12] The patterns again reveal similar trends as their composite sub-indices, clearly showing the prevalence of higher social vulnerability in rural barangays, particularly in areas south of Manila.

Figure 4-11 Distribution of quintile categories for Overall SVI in 2000 and 2010

Overall *SVI* 2000



Overall *SVI* 2010



As a means to check for the cartographic overemphasis on rural barangays over their urban counterparts, mainly resulting from the larger areas of the former compared to the latter, centroids were computed for each barangay polygon and were then shown as points to represent each of the barangays. Figure 4-12 presents this point-based visualization on the Overall *SVIs* of 2000 and 2010. In this presentation, it becomes more apparent that lower *SVI* barangays are concentrated in the northern portions of the country beginning from the central portion of Luzon.

There is also a more obvious improvement of Overall *SVI* for the northern portion of Luzon which can be discerned from the maps, although this trend is also visible in the maps in Figure 4-11. Although the centroid representation brings a more accurate rendition of the concentration of barangays throughout the Philippines, it adds limited value in presenting where the concentrations of *SVI* extremes are clustered compared to the

[12] See Section 4.1.2

polygon shading approach. It also underemphasizes the vast areas covered by higher vulnerability rural barangays.

Figure 4-12 Distribution of quintile categories for Overall SVI in 2000 and 2010 presented as centroid points of polygons

Overall *SVI* 2000 Overall *SVI* 2010

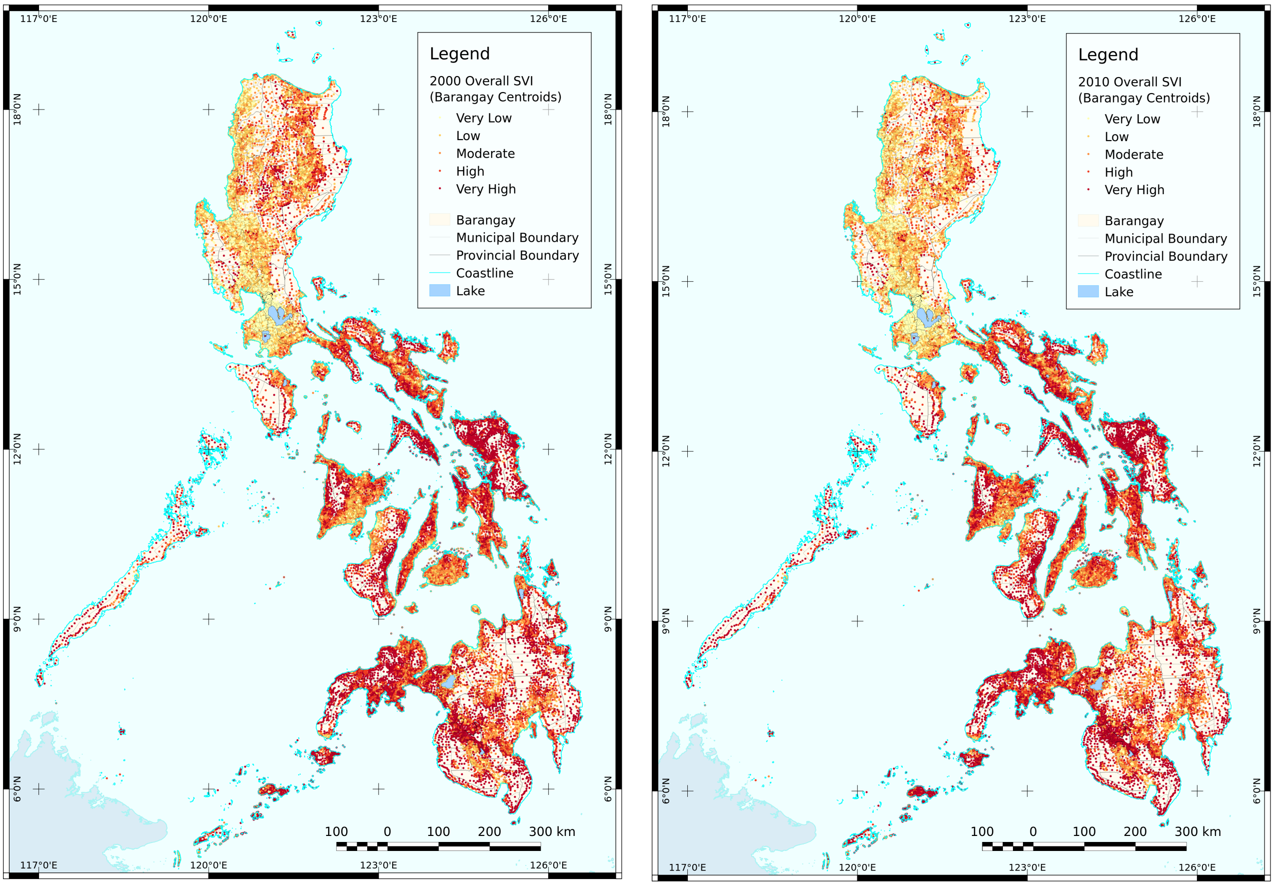
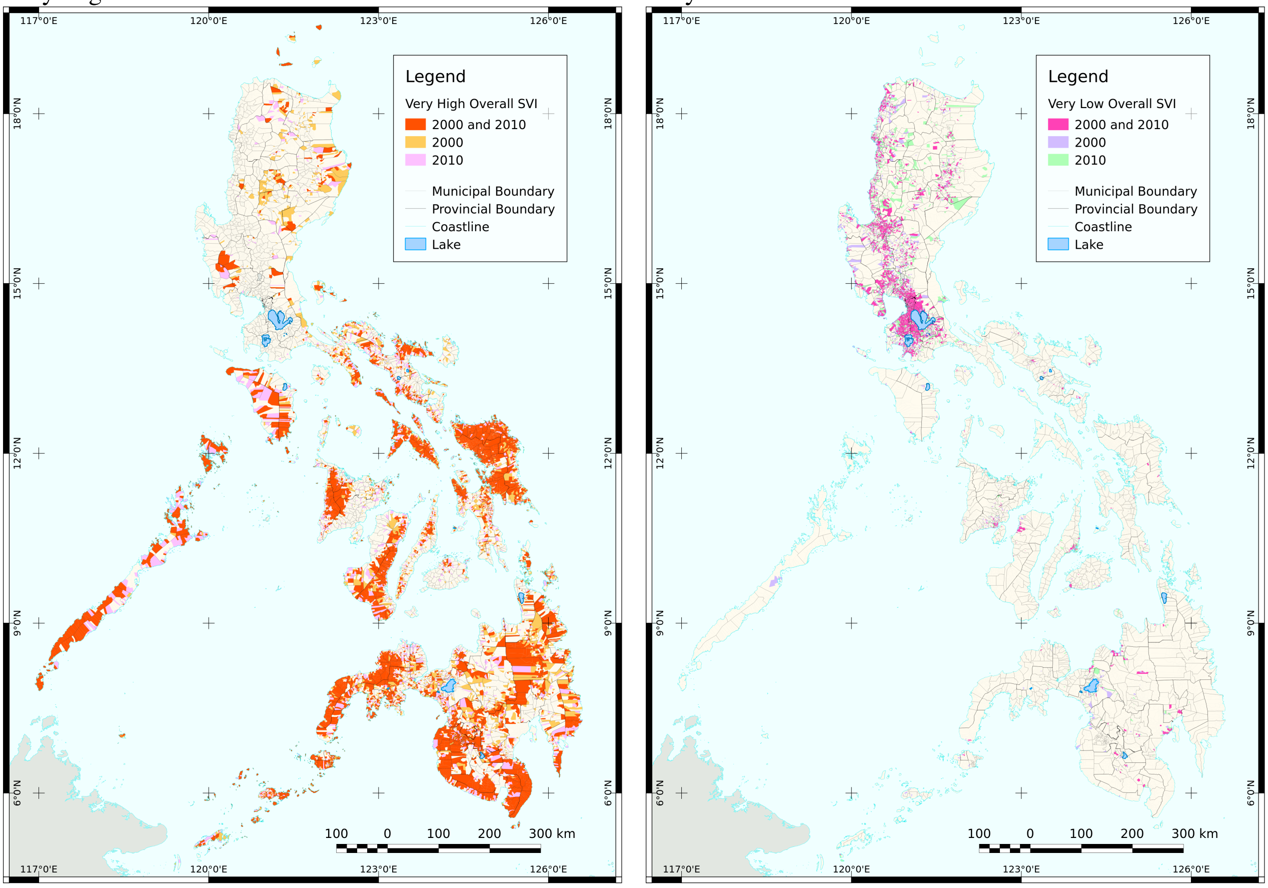


Figure 4-13 presents the distribution of Very Low and Very High Overall *SVI* scores for the two census years and similar to Figures 4-9 and 4-10, the maps highlight the areas of Very High social vulnerability vs. areas in the Very Low category. Again, it is clearly visible that the areas of Very Low social vulnerability are concentrated in the areas around Metro Manila and in the highly urbanized barangays in cities throughout the Philippines.

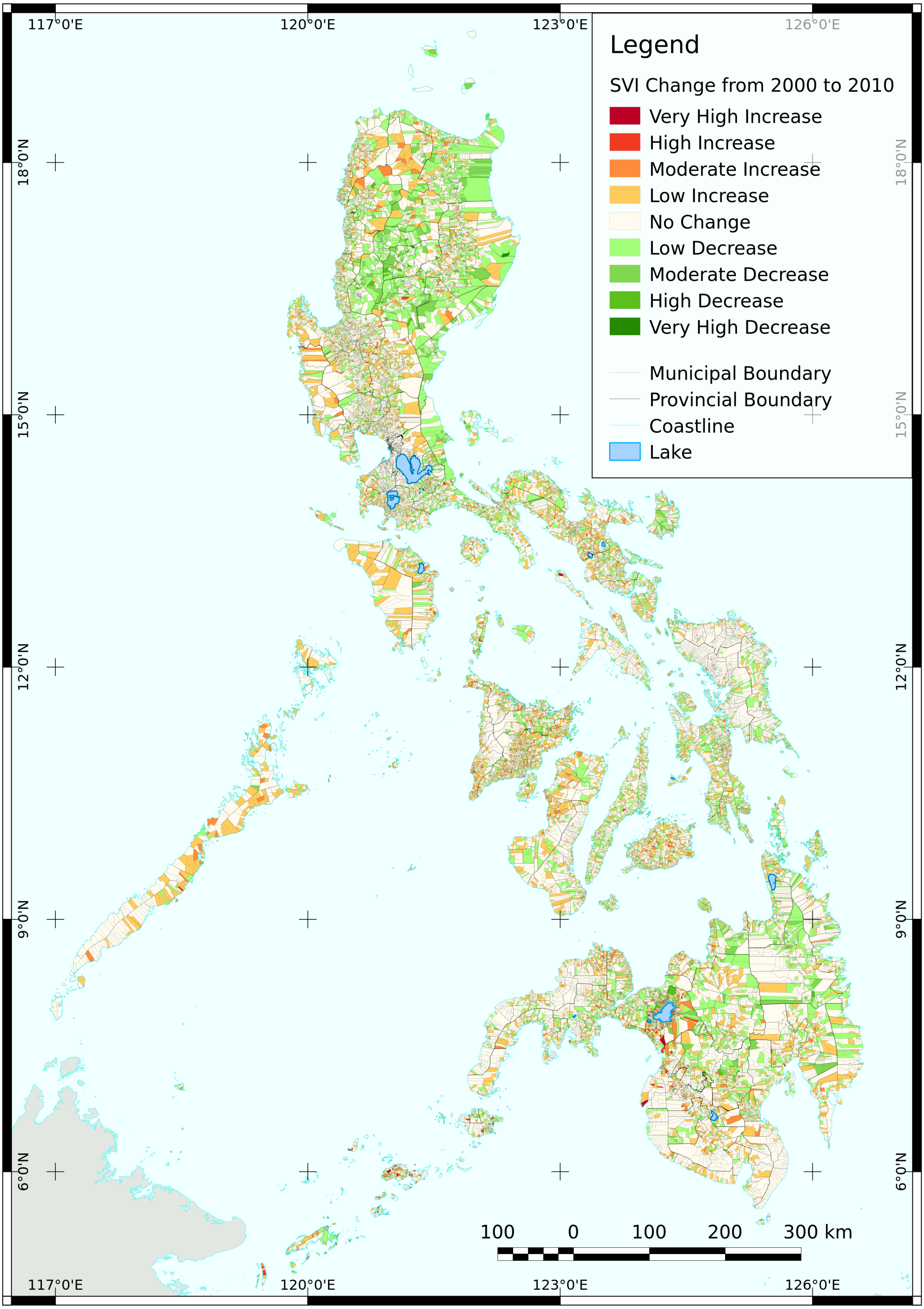
Figure 4-13 Distribution of Very High and Very Low quintile categories for Overall SVI in 2000 and 2010

Very High Overall SVI for 2000 & 2010 | Very Low Overall SVI for 2000 & 2010



After having had a glimpse of the states of social vulnerability throughout the Philippines between the census years of 2000 and 2010, it now possible to ask the obvious question of how social vulnerability has changed for each barangay between the two census years? This question is important in assessing the performance of certain areas in the Philippines in relation to their vulnerability states. Figure 4-14 is an attempt to answer this question by mapping the rates of change in vulnerability between the two census years. This map combines the data shown in Figure 4-11 and notes the types of changes (if any) in *SVI* score from 2000 to 2010.

Figure 4-14 Gradient of change in Overall SVI from 2000 to 2010 for the Philippines



It is quite revealing to see in Figure 4-14 that much of the areas that needed an improvement in social vulnerability state have remained the same, i.e. those that have remained in the Very High category. Out of a total of 41,919 barangays considered in this comparison between the two census years, a total of 23,483 (56.0%) did not show a change in vulnerability status between 2000 and 2010. Of this group, a total of 6,148 (14.5%) were in the Very Low category while 5,746 (13.7%) were in the Very High Category. Figure 4-15 shows the side-by-side comparison of the distribution for urban and rural barangays while Table 4-2 shows the distribution of barangays per category broken down into urban and rural classes. There is a striking difference between urban and rural barangays that remained in the Very High category between the two years as revealed by the final bar plot.

Figure 4-15 Distribution of urban and rural barangays with no change in Overall SVI state in 2000 and 2001

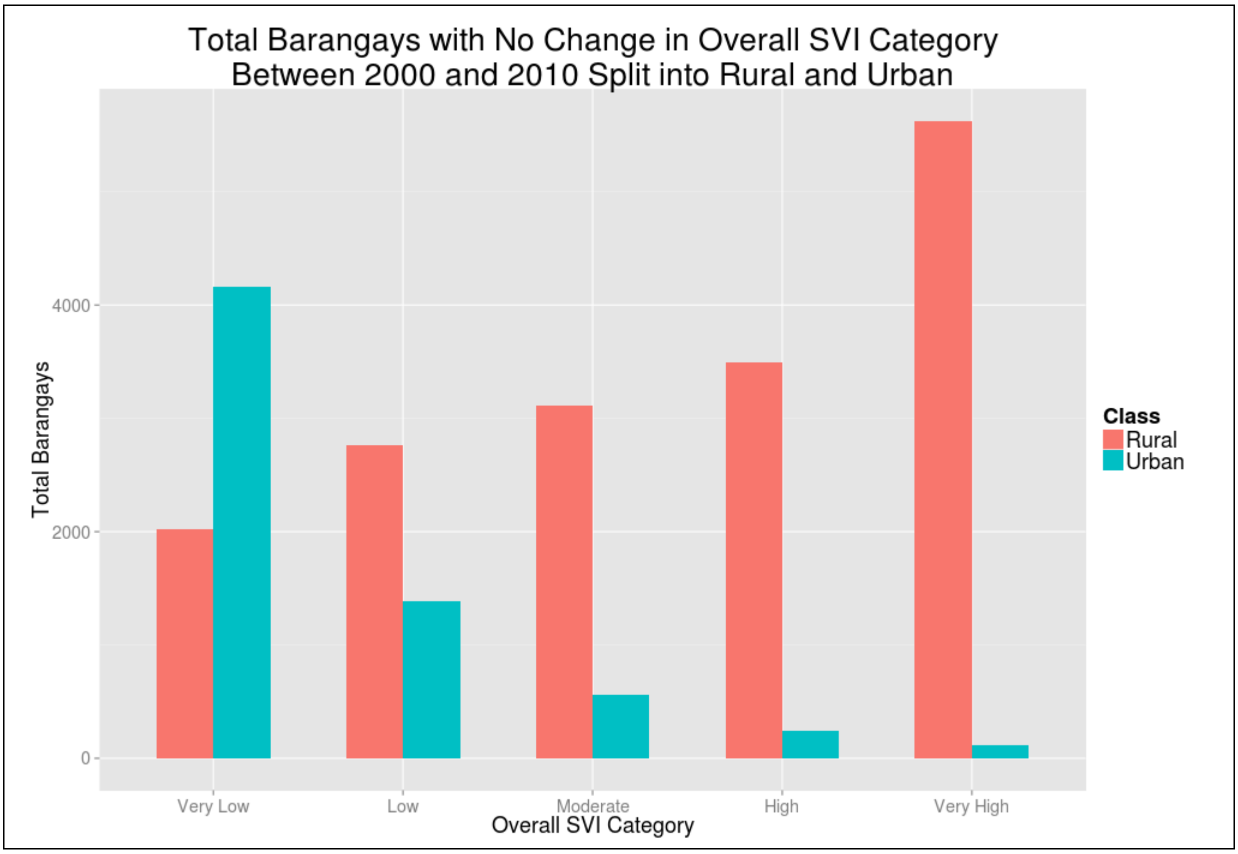


Table 4-2 Distribution of barangays that registered no change in SVI scores between 2000 and 2010, broken down into urban and rural classifications

Overall *SVI* Category	Urban	Rural
Very Low	4,162	2,022
Low	1,387	2,762
Moderate	557	3,112
High	238	3,492
Very High	120	5,626

4.1.4 Conculsions

The earlier part of this section had just presented the statistical distribution of derived *SVIs* as well as their component indicators and had showed how they are distributed between urban and rural areas. It is interesting to see the consistency of the trends of higher vulnerability barangays to be in the rural areas as well as the tendency of the urban population to be in lower vulnerability categories. What is even more alarming to see is the tendency of Very High SVI category rural barangays to remain in that vulnerability state between 2000 and 2010 and that the comparative difference with urban barangays in the same category is huge (Figure 4-14).

The later part of this section then proceeded to present the derived *SVI's* geographical distribution cartographically in an attempt to show how the different categories of *SVI* are distributed throughout the country. It is apparent that the higher *SVI* barangays are concentrated in the more remote rural areas in the Visayas and Mindanao, while barangays in the urban areas closer to Manila in Luzon and in the major urban zones throughout the country have lower *SVI* scores (Figure 4-12).

4.2 Regression Results for Social Vulnerability and Exposure Contribution to Flood Impact

This section now shifts to the validation portion of the derived *SVI* scores using regression analysis as described in Section 3.3. We continue to use the sub-index *SVI* scores in this section to check for consistency of results among the three sub-indices.

As mentioned earlier, the *SVI* data used for this validation portion is based only on the 2010 census data. Tables 4-3 and 4-4 present a statistical summary of the three *SVI* composite variables for Iligan and Cagayan de Oro Cities respectively based on the 2010 census fields. As the scores were based on percentage of individuals, households, or housing units per barangay (except for the average household size indicator), the final scores are comparable across barangays for each individual *SVI* measure. As can be seen in the tables below, the summary statistics show relatively similar values for the means and the medians of each variable between the two cities. The index scores for each barangay served as input predictor variables in the regression models, which will be discussed in detail below.

Table 4-3 Summary statistics of SVI scores for barangays of Iligan City

Variable	n	mean	sd	median	min	max
SVI_{in}	44	26.50	9.84	22.41	16.65	55.69
SVI_{hh}	44	36.10	3.74	34.52	30.40	42.71
SVI_{hs}	44	18.67	7.44	16.78	8.15	40.21

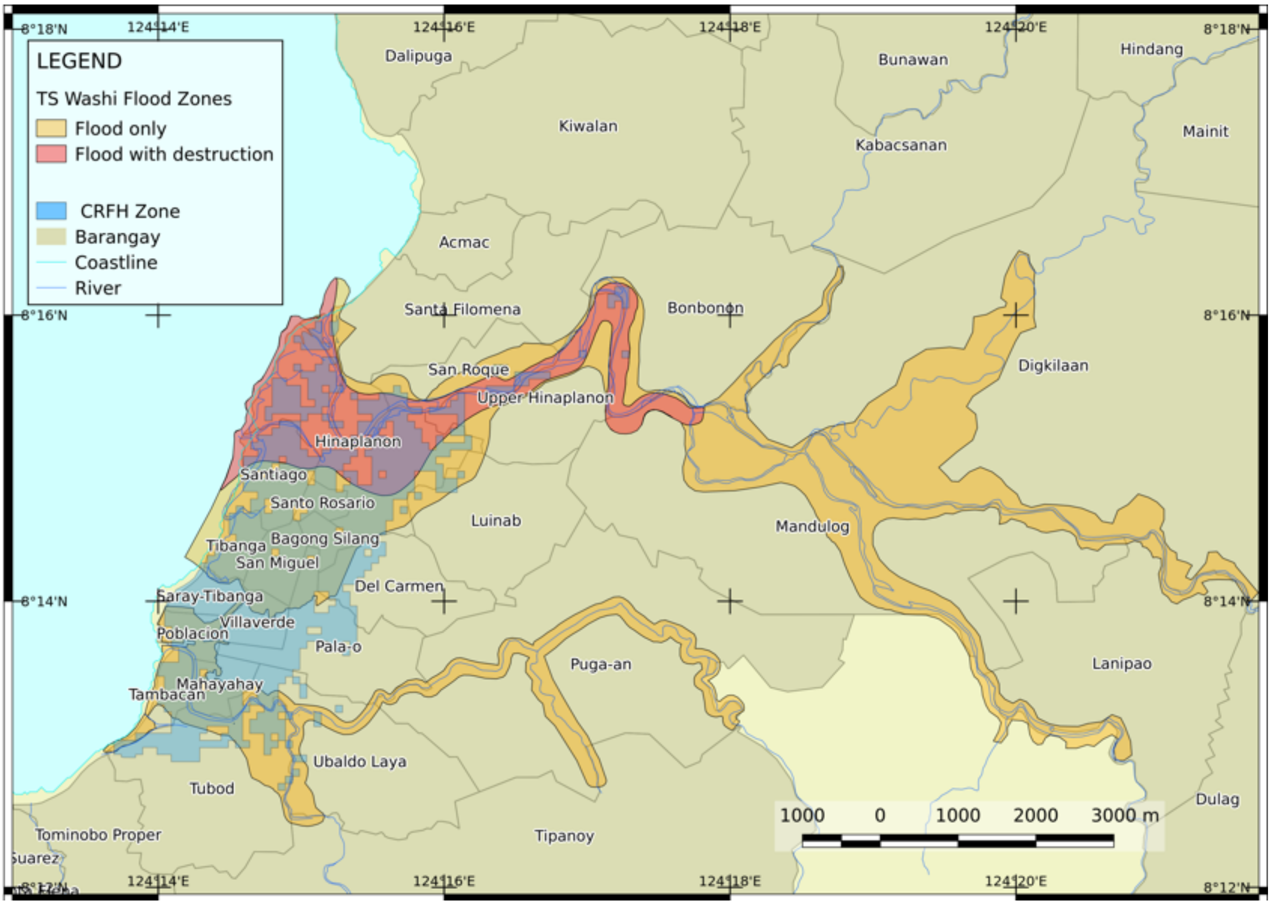
Table 4-4 Summary statistics of SVI scores for barangays of Cagayan de Oro City

Variable	n	mean	sd	median	min	max
SVI_{in}	80	21.45	5.7	20.18	10.42	39.23
SVI_{hh}	80	35.01	3.44	34.65	25.4	44.02
SVI_{hs}	80	19.02	9.09	17.32	5.32	61.49

4.2.1 Geographic Factor – Exposure

Figure 4-16 shows the extent of flood damage to the barangays as surveyed on the ground by the Iligan City Planning office after the disaster. The destructive flooding region, shown in red, mainly occurred along the Mandulog River to the north while the non-destructive flooded zones in orange were distributed in the remaining areas of the Mandulog and along the Tubod Rivers. The accuracy of the surveys was verified using post disaster imagery acquired as presented in Figure 4-20. The *CRFH*[13] areas shown in semi-transparent blue clearly show their relatively high overlap with the flooded zones. Since the *CRFH* areas are identified *a priori* using available data, it was used as a predictor variable in the linear regression model to also assess its influence on the outcomes of the flood in terms of the loss and damage.

Figure 4-16 Flood zones and CRFH areas along the Mandulog and Tubod Rivers in Iligan City



Sources: Iligan City Planning and Development Office; NAMRIA 1:50,000 Topographic Maps

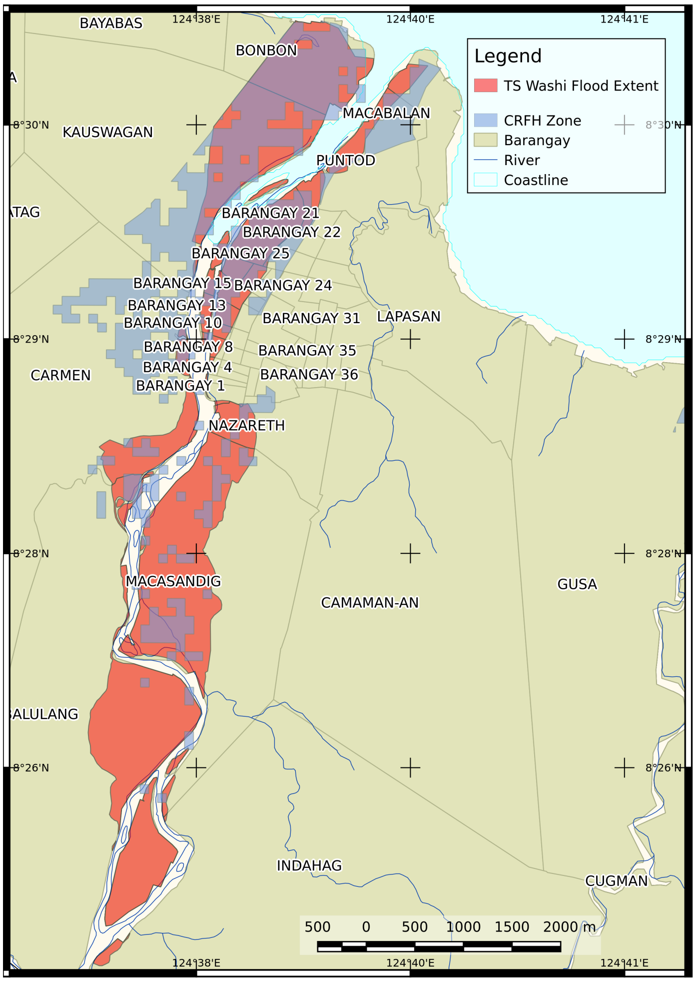
There are 883 hectares of *CRFH* areas within the watersheds of Mandulog and Tubod Rivers. Barangay Hinaplanon has the largest share at 182 hectares (20.6%) followed by Palao with 84 hectares (9.5%) and Santiago with 80 hectares (9.1%). There are 20 barangays that have *CRFH* areas and all these had also

[13] Coastal River Flood Hazard as described in Section 3.2.1

experienced flooding during TS Washi. There were five barangays that had flooded that had no *CRFH* areas, which was mainly due to their relatively far distance inland from the respective river outlets.

A similar mode of analysis was conducted for the Cagayan de Oro City case to derive the *CRFH* areas in the watersheds of the affected barangays as presented in Figure 4-17. Again the *CRFH* areas is clearly coinciding with the actual extent of the TS Washi flood zone.

Figure 4-17 Flood zones and CRFH areas along the Cagayan River in Cagayan de Oro City



Sources: Xavier University Engineering Resource Center; NAMRIA 1:50,000 Topographic Maps

4.2.2 Validation of flood impact with vulnerability and exposure

A number of OLS linear regression models were formulated to test the association between the different outcome variables with the *SVI* index and *CRFH* area variables. As the numbers of samples were limited for the two sites, the distributions of the outputs were highly skewed and the application of the log function to the outcome variables revealed the linear relationship between the predictors and the outcomes as can be seen in Figures 4-18, 4-19 and 4-20. Figure 4-18 visually demonstrates the marked improvements of applying the log function on the variables by comparing the plot pairs of raw vs. log-treated outcomes of dead+missing and affected for the two sites.

Figure 4-19 on the other hand presents SVI_{hs} vs. different housing damage types caused by the flooding, again comparing raw vs. log-treated outcomes of housing damage types. Finally, Figure 4-20 presents *CRFH* area vs. different housing damage types and their log treatments. It is clear from the visual presentations that there is a consistent improvement of the relationships between the variable pairs, which justifies the use of OLS regression models to determine strength of relationships between the predictors and the outcomes.

Table 4-5 shows the results of the simple OLS linear regressions of the log values of the outcomes on each of the predictor variables for each of the case study sites. At this initial level, it is apparent that the regressions of the dead and missing outcome on the predictors do not exhibit statistically significant results, save for the regression on *CRFH* for Iligan City. This weakness of statistical significance can be attributed to the low number of dead and missing victims per barangay. For the affected people on the other hand the statistical significance of the regression estimates are very strong, supported by the more comprehensive data that had been gathered on the survivors of the calamity. Moreover, the number of affected individuals per barangay is much greater than the number of dead and missing for both case study sites (see Tables 2-3 and 2-6). The regression of flood damage types on SVI_{hs} and $CRFH$ reveal strong relationships as well, particularly for the partially damaged house category. SVI_{hs} is also strong for the flooded house variable for Iligan City, while there seem to be not enough cases in Cagayan de Oro City (*n = 10*) to establish a statistically acceptable link.

Figure 4-18 Comparison of scatterplots of SVI and CRFH vs. raw and log of dead+missing and affected showing the corresponding regression line and confidence regions in Iligan and Cagayan de Oro Cities

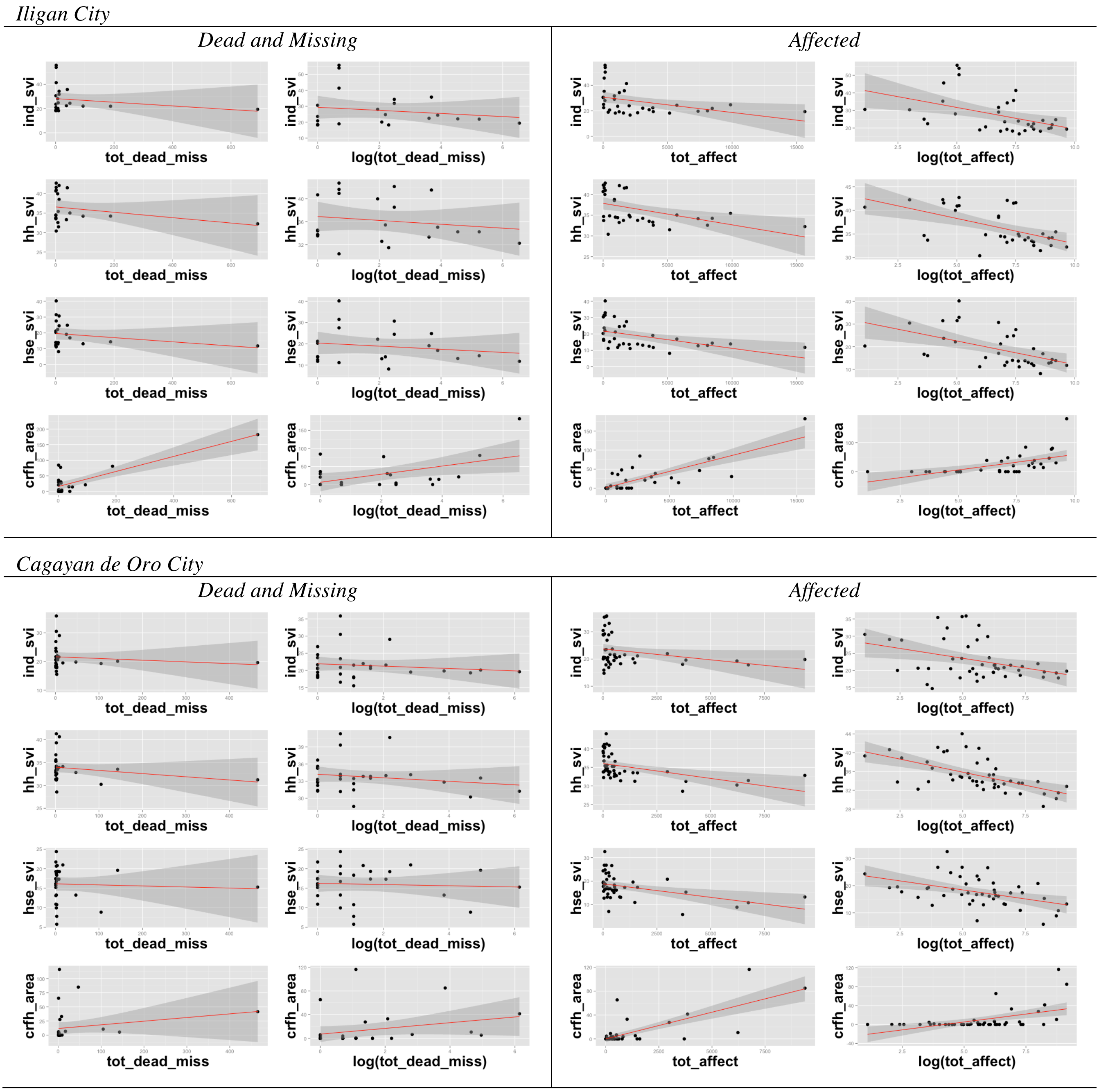


Figure 4-19 Comparison of scatterplots of SVI_{hs} vs. raw and log of housing damage types showing the corresponding regression line and confidence regions for both case study areas

Iligan City | *Cagayan de Oro City*

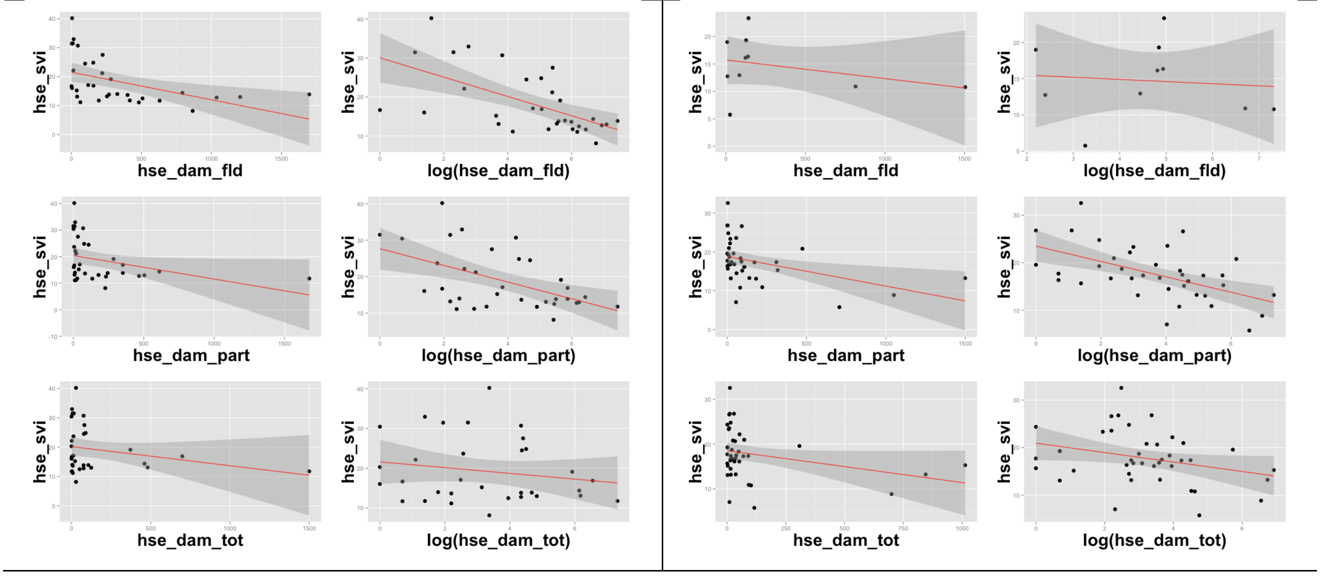


Figure 4-20 Comparison of scatterplots of CRFH vs. raw and log of housing damage types showing the corresponding regression line and confidence regions for both case study areas

Iligan City | *Cagayan de Oro City*

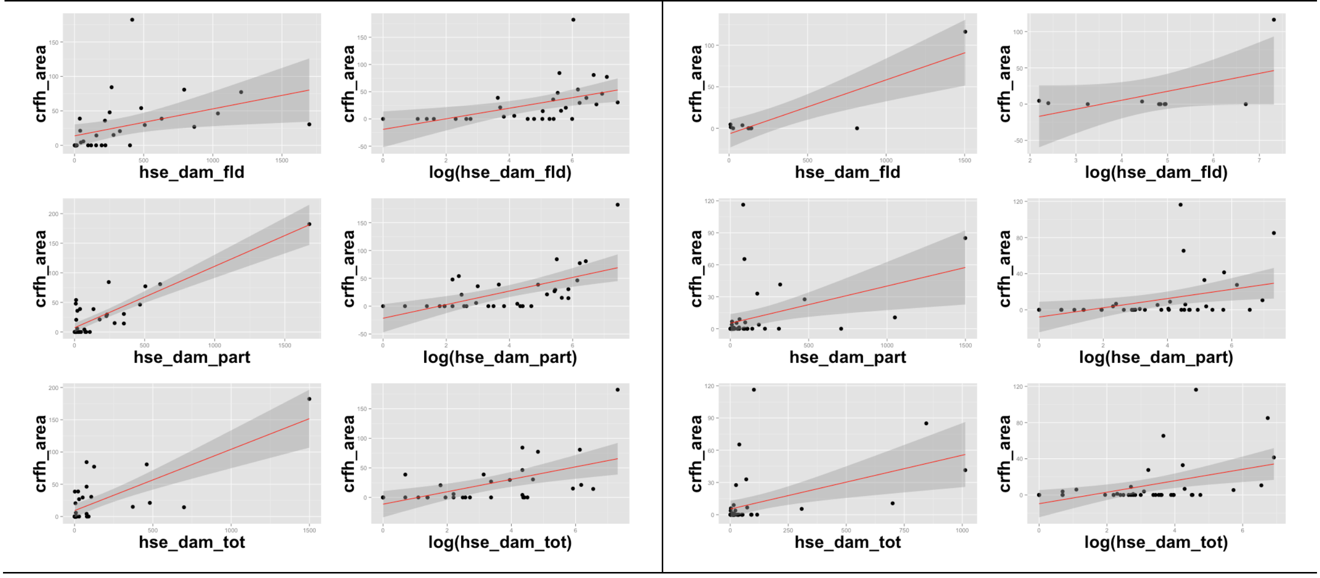


Table 4-5 Simple regression coefficients of loss and damage vs. vulnerability and exposure. Values in parentheses are standard errors. (see Section 3.3 method)

	Predictor Variables			
Outcome Variables	SVI_{in}	SVI_{hh}	SVI_{hs}	$CRFH$
Log Dead and Missing				
Iligan City *n = 22*	-0.0301 (0.0387)	-0.0809 (0.1081)	-0.0411 (0.0520)	0.0219* (0.0086)
Cagayan de Oro City *n = 30*	-0.0497 (0.2314)	-0.1047 (0.1085)	-0.0209 (0.0694)	0.0161 (0.0105)
Log Affected				
Iligan City *n = 35*	-0.0878** (0.0291)	-0.2963*** (0.0759)	-0.1332** (0.0374)	0.0308*** (0.0077)
Cagayan de Oro City *n = 46*	-0.1209* (0.0456)	-0.3124*** (0.0646)	-0.1525** (0.0456)	0.0394*** (0.0099)
Log Flood Housing Damage				
Iligan City *n = 32*			-0.1436*** (0.0353)	0.0245** (0.0080)
Cagayan de Oro City *n = 10*			-0.0310 (0.1137)	0.0253 . (0.0133)
Log Partial Housing Damage				
Iligan City *n = 34*			-0.1180** (0.0336)	0.0288*** (0.0069)
Cagayan de Oro City *n = 39*			-0.1870*** (0.0467)	0.0285* (0.0113)
Log Total Housing Damage				
Iligan City *n = 32*			-0.0452 (0.0449)	0.0294*** (0.0080)
Cagayan de Oro City *n = 41*			-0.0945 . (0.0470)	0.0301** (0.0099)

Significance Codes: 0='***'; 0.001='**'; 0.01='*'; 0.05='.'

As regards the relationships between the variable pairs in the regression models, Table 4-5 consistently shows inverse relationships between the three composite *SVI* sub-index variables and the outcomes for the statistically significant results. These observations are also evident in the scatterplots depicted in Figures 4-17 and 4-18, showing negative slopes of the regression lines of the concerned pairs of variables. These results run opposite to the expected direct relationships between social vulnerability and magnitude of loss and damage. Particularly in the regression of affected individuals and partial housing damage, the statistical significance levels are very strong. The data on affected individuals and housing damage types are also the more reliable datasets in that there had been a better opportunity to conduct a comprehensive survey of the survivors as well as assess the damage to their housing units.

In order to further understand the results from the simple regression models shown in Table 4-5, a succeeding set of regressions were performed but this time on the decomposed *SVI* sub-index variables, i.e. on the six individual indicators that comprise each of the *SVI* sub-indices. Table 4-6 provides the summary of the results of regressing the log of the outcome variables on each of the social vulnerability proxy variables in a series of simple linear regression models. The outputs again demonstrate that the regression results for the dead and missing outcomes show no statistically significant relationships between the variable pairs, except for the *notenure*[14] variable for Iligan City, which also has a relatively high standard error. It is worth noting that education-related regressors (i.e. *nonhsfem_20to39*[15] and *nonhshhh*[16]) for the affected population outcomes show consistent significance in the two case studies. The *badwall*[17] indicator variable for SVI_{hs} also exhibits consistent significance in many of the outcomes. The *hhnoofw*[18] variable is also significant and consistent between the two sites. Relationships for all the mentioned regressors, however, are also consistently inverse in relation to the log of the outcomes, following the same pattern as the initial results in Table 4-5.

Table 4-6 Simple OLS linear regression coefficients for component variables of SVIs for the log of outcomes. Values in parentheses are standard errors.

Outcome Variables	**Predictor Variables**					
	Individual-based Social Vulnerability Indicators					
Log Dead and Missing	female	child	old	nonhsadult	nobirthreg	nonhsfem20-39
Iligan City	0.0388	-0.0107	-0.0500	-0.0168	-0.0128	-0.0113
n = 22	(0.2835)	(0.0723)	(0.1968)	(0.0394)	(0.0149)	(0.0151)
Cagayan de Oro City	0.4857	-0.0709	0.0131	-0.0324	-0.1007	-0.0122
n = 30	(0.2733)	(0.0857)	(0.2779)	(0.0380)	(0.2728)	(0.0196)
Log Affected	female	child	old	nonhsadult	nobirthreg	nonhsfem20-39
Iligan City	0.6417**	-0.1478**	0.1800	-0.1082***	-0.0225 .	-0.0369**
n = 35	(0.1806)	(0.0518)	(0.1618)	(0.0267)	(0.0122)	(0.0111)
Cagayan de Oro City	0.1622	-0.0731	0.0639	-0.0696**	-0.1136	-0.0328*
n = 46	(0.1255)	(0.0481)	(0.1863)	(0.0252)	(0.1294)	(0.0124)
	Household-based Social Vulnerability Indicators					
Log Dead and Missing	femhhh	disabhh	nonhshhh	snglhhh	avghhsze	hhnoofw
Iligan City	0.0074	-0.0740	-0.0060	-0.0194	-0.0069	-0.0358
n = 22	(0.0834)	(0.0916)	(0.0150)	(0.0703)	(0.1134)	(0.1275)
Cagayan de Oro City	0.0273	0.0737	-0.0151	0.0247	-0.1065	-0.0595
n = 30	(0.0675)	(0.1685)	(0.0159)	(0.0590)	(0.1507)	(0.1130)
Log Affected	femhhh	disabhh	nonhshhh	snglhhh	avghhsze	hhnoofw
Iligan City	0.1593**	0.0865	-0.0398***	0.0994 .	-0.0999	-0.2632*
n = 35	(0.0572)	(0.0848)	(0.0102)	(0.0546)	(0.1090)	(0.1056)
Cagayan de Oro City	0.00089	-0.1212	-0.0281**	-0.00697	-0.0529	-0.3281**
n = 46	(0.0357)	(0.1175)	(0.0100)	(0.0296)	(0.0771)	(0.0934)
	Housing-based Social Vulnerability Indicators					
Log Dead and Missing	badroof	badwall	notenure	hsegt30yrs	repair	smlhse
Iligan City	-0.0218	-0.0055	1.0203*	-0.0402	0.0010	0.0134
n = 22	(0.0193)	(0.0159)	(0.4164)	(0.0380)	(0.0484)	(0.0363)
Cagayan de Oro City	-0.0424	-0.0039	-0.0311	0.0012	0.0612	0.0063
n = 30	(0.0403)	(0.0187)	(0.0344)	(0.0312)	(0.0433)	(0.0399)
Log Affected	badroof	badwall	notenure	hsegt30yrs	repair	smlhse
Iligan City	-0.0340*	-0.0436***	-0.0081	0.0400	-0.0473	-0.0422
n = 35	(0.0161)	(0.0107)	(0.2880)	(0.0298)	(0.0340)	(0.0286)
Cagayan de Oro City	-0.0358	-0.0483***	-0.0222	-0.0065	0.0094	-0.0188
n = 46	(0.0263)	(0.0129)	(0.0244)	(0.0241)	(0.0278)	(0.0201)
	Housing-based Social Vulnerability Indicators					
Log Flood Housing Damage	badroof	badwall	notenure	hsegt30yrs	repair	smlhse
Iligan City	-0.0463**	-0.0442***	0.5310	0.0454	-0.0480	-0.0584 .
n = 32	(0.0141)	(0.0110)	(0.3634)	(0.0288)	(0.0349)	(0.0312)
Cagayan de Oro City	0.1263	-0.0098	-0.0739	-0.0575 .	0.0728	0.0553
n = 10	(0.1101)	(0.0404)	(0.2333)	(0.0285)	(0.0470)	(0.0956)

[14] No tenure on the land occupied
[15] Non-high school graduate female from 20 to 39 years of age
[16] Non-high school graduate head of household
[17] Housing unit with poor wall materials
[18] Households with no overseas foreign worker support

Log Partial Housing Damage	badroof	badwall	notenure	hsegt30yrs	repair	smlhse
Iligan City	-0.0361*	-0.0306**	0.1012	0.0070	-0.0391	-0.0450 .
n = 34	(0.0143)	(0.0110)	(0.2637)	(0.0280)	(0.0313)	(0.0261)
Cagayan de Oro City	-0.0225	-0.0582***	-0.0306	0.0020	-0.0348	-0.0290
n = 39	(0.0302)	(0.0142)	(0.0258)	(0.0328)	(0.0323)	(0.0213)
Log Total Housing Damage	badroof	badwall	notenure	hsegt30yrs	repair	smlhse
Iligan City	-0.0107	-0.0150	0.1937	0.0263	-0.0406	-0.0017
n = 32	(0.0175)	(0.0138)	(0.2962)	(0.0507)	(0.0360)	(0.0308)
Cagayan de Oro City	-0.0250	-0.0336*	-0.0007	-0.0107	0.0147	-0.0137
n = 41	(0.0259)	(0.0133)	(0.0243)	(0.0285)	(0.0288)	(0.0194)

Significance Codes: 0='***'; 0.001='**'; 0.01='*'; 0.05='.'
Please refer to Table 4-1 for details of each indicator.

A final battery of models was formulated and applied, but this time combining the component variables for each of the *SVIs* as regressors in a multiple linear regression, defined by the equation:

$$\log y_j = \alpha + \sum_m \beta_m x_m + \epsilon \tag{9}$$

where $\log y_j$ represents the log of the outcomes (i.e. number of dead + missing, affected individuals, and levels of damage to housing units) while x_m represents the various indicators for each of the *SVI* variables as listed in Table 3-3. The purpose of this last test is to check for the simultaneous influence of the decomposed *SVI* variables on the log of the outcomes and to determine which variables come out as significant.

Table 4-7 lists the results of the multiple linear regressions of the log of the outcomes on the decomposed variables. The outputs are expectedly different from the previous simple linear regression models, but what comes out as significantly consistent for the two case study sites are the *nonhshhh* and *badwall* variables for the affected population outcome. These two variables correspond to education attainment and house structure stability respectively and both again exhibit a negative relationship with the affected population dependent variable. For *nonhshhh*, this means that the greater the percentage of household heads who have not finished secondary school, the lower the number of people affected. Similarly for the *badwall* variable, the inverse relationship obtained means that the higher the percentage of houses with poor wall material, the lower the number of people affected. These two variables also figure as highly significant in the previous simple linear regression results in Table 4-6 for both case study sites for the same affected population outcome and exhibiting the same inverse relationships.

Table 4-7 Multiple OLS linear regression coefficients for component variables of SVIs for the log of outcomes. Values in parentheses are standard errors.

Outcome Variables	**Predictor Variables**					
	Individual-based Social Vulnerability Indicators					
Log Dead and Missing	female	child	old	nonhsadult	nobirthreg	nonhsfem20-39
Iligan City	0.1391	0.0957	-0.4736	0.1256	-0.0058	-0.0950
n = 22	(0.6188)	(0.3007)	(0.5273)	(0.2101)	(0.0504)	(0.1089)
Cagayan de Oro City	0.6899	-0.1565	0.3333	0.1162	0.1040	-0.0210
n = 30	(0.5035)	(0.2625)	(0.5264)	(0.1913)	(0.3646)	(0.0766)
Log Affected	female	child	old	nonhsadult	nobirthreg	nonhsfem20-39
Iligan City	0.7436*	-0.2429	-1.0743**	-0.1434	-0.0677*	0.0876
n = 35	(0.3531)	(0.3376)	(0.3376)	(0.1200)	(0.0284)	(0.0607)
Cagayan de Oro City	-0.1007	0.0218	-0.2858	-0.1063	0.0248	0.0095
n = 46	(0.2307)	(0.1019)	(0.2906)	(0.0971)	(0.1511)	(0.0439)

	Household-based Social Vulnerability Indicators					
Log Dead and Missing	femhhh	disabhh	nonhshhh	snglhhh	avghhsze	hhnoofw
Iligan City	0.1815	-0.1083	-0.0294	-0.2401	-0.0707	0.09476
n = 22	(0.4057)	(0.1194)	(0.0544)	(0.2876)	(0.1787)	(0.2806)
Cagayan de Oro City	0.0325	0.1408	-0.0261	-0.0704	-0.0989	0.0114
n = 30	(0.2873)	(0.1903)	(0.0308)	(0.2641)	(0.1743)	(0.1674)
Log Affected	femhhh	disabhh	nonhshhh	snglhhh	avghhsze	hhnoofw
Iligan City	0.1161	-0.0471	-0.0938*	-0.2297	0.0706	0.3145
n = 35	(0.2455)	(0.0804)	(0.0385)	(0.1710)	(0.1190)	(0.2044)
Cagayan de Oro City	-0.0506	-0.0838	-0.0621**	-0.0907	0.0131	-0.0264
n = 46	(0.1691)	(0.1081)	(0.0212)	(0.1320)	(0.0884)	(0.1325)

	Housing-based Social Vulnerability Indicators					
Log Dead and Missing	badroof	badwall	notenure	hsegt30yrs	repair	smlhse
Iligan City	-0.0268	-0.0006	1.0450*	-0.0575	0.0280	0.0376
n = 22	(0.0254)	(0.0235)	(0.4605)	(0.0405)	(0.0447)	(0.0387)
Cagayan de Oro City	-0.1058	0.0179	-0.0487	-0.0374	0.0360	0.0079
n = 30	(0.0737)	(0.0280)	(0.0392)	(0.0395)	(0.0529)	(0.0463)
Log Affected	badroof	badwall	notenure	hsegt30yrs	repair	smlhse
Iligan City	0.0090	-0.0638**	0.0187	-0.0394	-0.0235	0.0300
n = 35	(0.0210)	(0.0202)	(0.2643)	(0.0331)	(0.0312)	(0.0317)
Cagayan de Oro City	-0.0006	-0.0598**	-0.0491*	-0.0369	0.01643	-0.0026
n = 46	(0.0301)	(0.0162)	(0.0225)	(0.0241)	(0.0247)	(0.0204)

	Housing-based Social Vulnerability Indicators					
Log Flood Housing Damage	badroof	badwall	notenure	hsegt30yrs	repair	smlhse
Iligan City	-0.0112	-0.04424 .	0.1951	-0.0201	-0.0154	0.0180
n = 32	(0.0217)	(0.0247)	(0.3410)	(0.0320)	(0.0330)	(0.0397)
Cagayan de Oro City	0.1524	-0.0240	0.1867	-0.0522	0.0653	-0.0670
n = 10	(0.3306)	(0.0816)	(0.4466)	(0.0550)	(0.0612)	(0.1839)
Log Partial Housing Damage	badroof	badwall	notenure	hsegt30yrs	repair	smlhse
Iligan City	-0.0179	-0.0329	0.0337	-0.0582 .	0.0238	-0.0038
n = 34	(0.0213)	(0.0222)	(0.2610)	(0.0321)	(0.0306)	(0.0337)
Cagayan de Oro City	0.0334	-0.07781***	-0.0548*	-0.0133	-0.0154	-0.0009
n = 39	(0.0294)	(0.0171)	(0.0222)	(0.0304)	(0.0278)	(0.0205)
Log Total Housing Damage	badroof	badwall	notenure	hsegt30yrs	repair	smlhse
Iligan City	0.0110	-0.0282	0.2214	-0.0181	-0.0379	0.0298
n = 32	(0.0269)	(0.0263)	(0.3409)	(0.0746)	(0.0395)	(0.0396)
Cagayan de Oro City	-0.0002	-0.0412*	-0.0251	0.0465	0.0296	-0.0050
n = 41	(0.0322)	(0.0177)	(0.0254)	(0.0334)	(0.0306)	(0.0221)

Significance Codes: 0='***'; 0.001='**'; 0.01='*'; 0.05='.'
Please refer to Table 4-1 for details of each indicator.

The result for the education variable can also be interpreted as – the higher the educational attainment of the household heads in the barangay, the higher the number of affected people. Similarly for the housing stability variable – the more stable the walling materials of the houses in the barangay, the higher the number of affected individuals in the barangay. Although these findings initially seem counterintuitive in reference to the literature, upon greater examination of supplementary data such as satellite imagery and field visits conducted on both sites, mainly middle class communities inhabited the zones that were severely affected.

Figures 4-21 and 4-23 present some of the more dramatic changes before and after the floods through satellite imagery obtained from Google Maps and Bing Maps. The images show that much of the areas that were devastated by the floods were actually middle class subdivisions along the banks of the rivers (Figures 4-22 and 4-24). These communities would normally have household heads with relatively higher educational attainment as well as housing units built with sturdy materials. For the cases of Iligan and Cagayan de Oro Cities, it seems that communities that live within the flood hazard exposure zones are not the most socially vulnerable. These zones are apparently not the most marginal areas normally inhabited by the poor, and may in fact be the classified as prime residential or commercial areas as can be discerned in the built-up areas that had been obliterated as can be seen in the images.

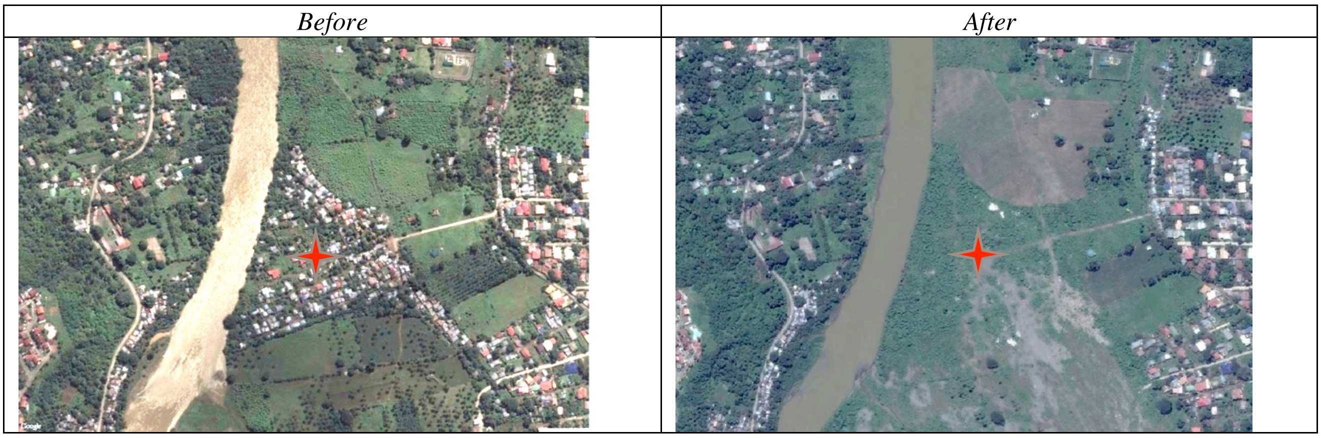
As for the *CRFH* variable which singularly defines the *a priori* exposure for this research, it is consistently the most statistically significant factor that determines the magnitude of loss and damage in the two case study sites.

Figure 4-21 Pre and post TS Washi flood satellite images for Iligan City*

**Red marker indicates the point from where Figure 4-22 was taken*
(Before images © Google; After images © Bing)

Figure 4-22 Panoramic photo facing upstream of the southern bank of the Mandulog River

Figure 4-23 Pre and post TS Washi flood satellite images for Cagayan de Oro City*



**Red marker indicates the point from where Figure 4-24 was taken*
(Before images © Google; After images © Bing)

Figure 4-24 Panoramic photo from the center of a former subdivision looking southwest towards the Cagayan River

4.3 Regression Results for Typhoon Frequency vs. *SVI*

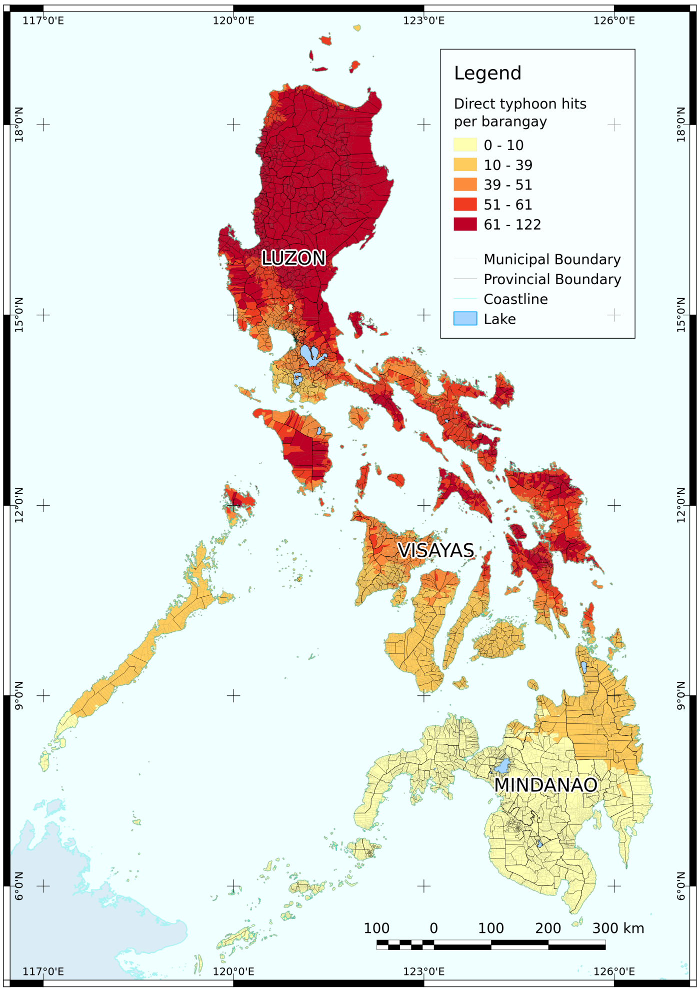
This final section in this chapter shows the results of investigating if frequency of typhoons can have an influence on social vulnerability scores. Please refer to Section 3.4 for the mathematical basis of the modeling conducted in this section.

4.3.1 Initial Results

Figure 4-25 presents a quintile distribution of direct storm hits per barangay for the entire Philippines. As can be seen in this presentation, the barangays in the northern portion of Luzon are the most exposed to typhoons, while there is a tapering trend as one goes in a south-southwest direction. Barangays along the eastern seaboard of Luzon and Visayas are also most exposed to the passage of storms as can be observed on the map.

Table 4-8 provides a summary of the descriptive statistics of the four variables used in this section and Figure 4-26 shows the density plots of the different *SVI* sub-indices. Each of the *SVI* distributions respectively exhibits a slight skew, but on the whole show a relatively normal distribution.

Figure 4-25 Distribution of direct typhoon eye hits per barangay from 1884 until 2013



Sources: GADM and NOAA-IBTrACS

Table 4-8 Summary statistics of DSH[19] and SVIs for all barangays of the Philippines

Variable	n	mean	sd	median	min	max
$\boldsymbol{DSH}$	42020	40.73	23.56	46	0	122
$\boldsymbol{SVI_{ind}}$	42020	27.32	7.63	25.83	0	58
$\boldsymbol{SVI_{hh}}$	42020	38.27	3.9	38.5	16.44	58.41
$\boldsymbol{SVI_{hse}}$	42020	20.9	10.24	19.79	0	75.23

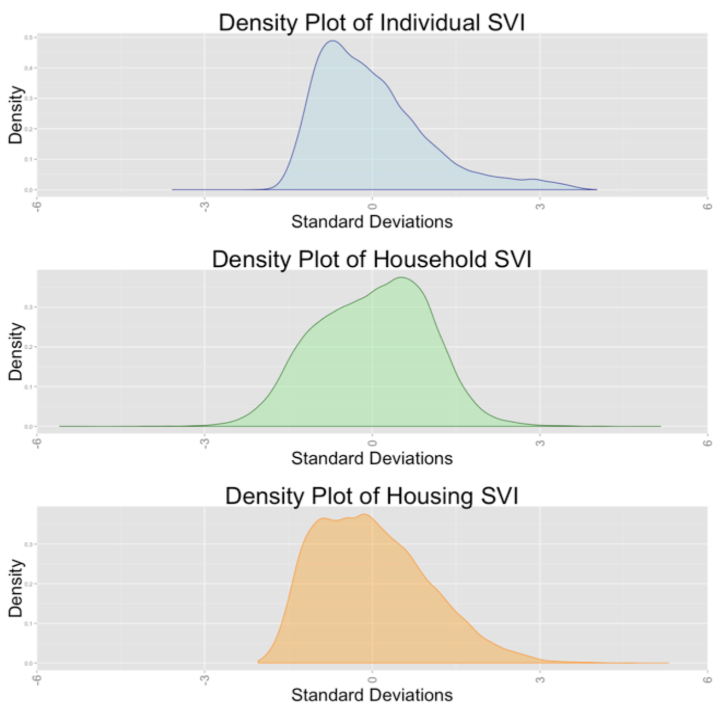
Table 4-9 lists the results of the regression of the different *SVIs* on *DSH*. The results reveal statistically significant relationships between *DSH* and all the three *SVI* sub-indices. Figure 4-27 is a series of scatterplots showing the interactions of *DSH* with each of the *SVI* measures together with the fitted regression model line. The negative slope of the regression line is distinct on each of the scatter plot pairs. This implies that there is a corresponding decrease in each of the *SVI* scores for every additional storm hit for a barangay as shown in Table 4-9.

Table 4-9 OLS linear regression coefficients for regression of *SVIs* on direct storm hits. Values in parentheses are standard errors.

Predictor Variable	**Outcome Variables**		
	SVI_{in}	SVI_{hh}	SVI_{hs}
Philippines			
Direct Storm Hits	-0.1212 ***	-0.0273 ***	-0.1430 ***
n = 42,020	(0.0015)	(0.0008)	(0.0020)
	R^2=0.1398	R^2= 0.0271	R^2= 0.1082

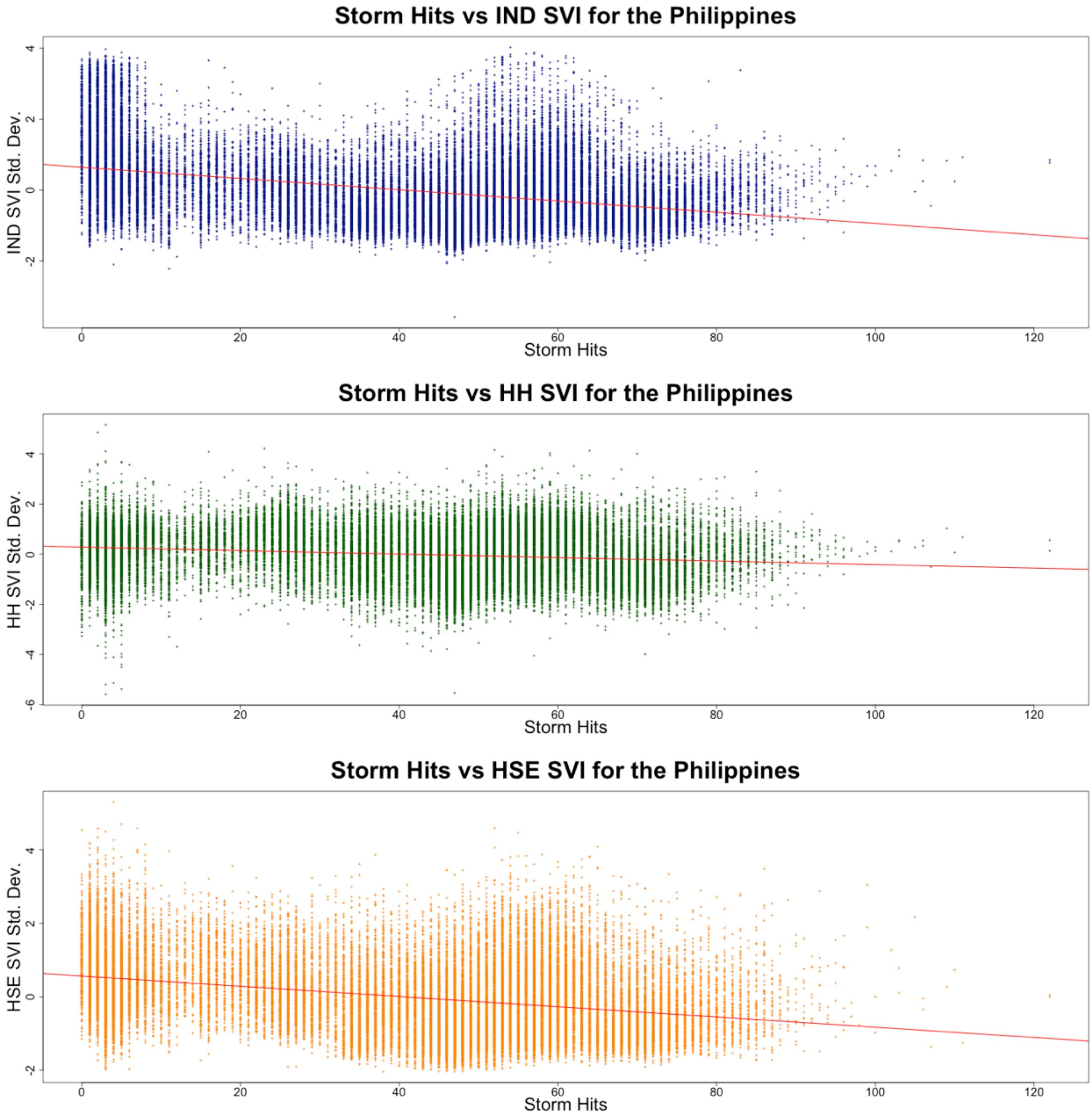
Significance Codes: 0='***'; 0.001='**'; 0.01='*'; 0.05='.'

Figure 4-26 Density plots of *SVI* sub-indices



[19] Direct storm hits

Figure 4-27 Scatterplots of storm hits vs. standardized *SVI* sub-indices

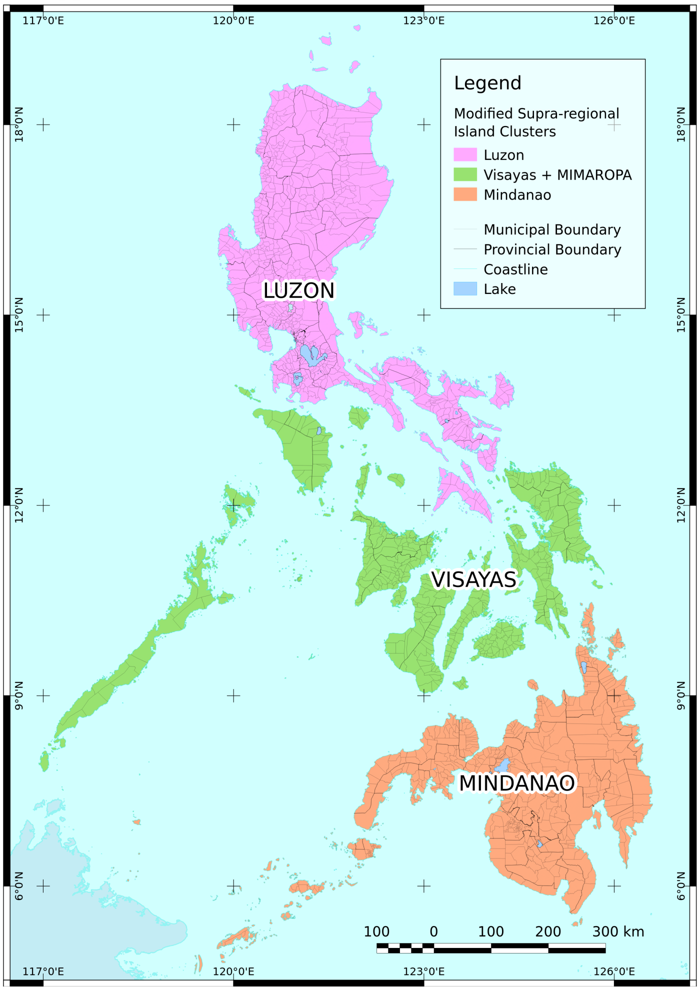


4.3.2 Regional Analysis of Relationships

Investigating this inverse relationship further, a number of approaches were taken to test the statistical validity of the inverse correlation at the national scale. As a means of controlling the variables of the entire population to check the persistence of relationships at a sub-national level, we controlled the variables at the main supra-regional clusters of Luzon, Visayas, and Mindanao. These three geographic regions (as opposed to administrative regions) represent the most geographically and ethno-linguistically distinct island groups in the Philippines. Furthermore, these groupings also share a relatively common experience in terms of typhoon occurrence, Luzon having the highest frequency of storms passing through and Mindanao having the lowest. The island clusters of Palawan (westernmost diagonally-oriented island), Mindoro, Romblon and Marinduque – otherwise known administratively as the MIMAROPA Region – was grouped, for purposes of this research, with Visayas rather than with its administrative assignment as part of Luzon as they are closer in storm hit and latitudinal characteristics with the former as well as their relative proximity with the other Visayan islands (Figure 4-28).

At the 3 regional levels we had defined, there were clearly positive relationships between *DSH* and the three *SVI* sub-index measures as dependent variables, except for the $SVI_{in} \sim DSH$ model for Mindanao which showed an inverse relationship between individual *SVI* and *DSH* (Table 4-10). These results are different from the trends observed at the national level. Figure 4-29 presents a series of combined scatter plots of Luzon, Visayas, and Mindanao regions overlaid with their corresponding regional fitted regression lines as well as the original regression line (dashed red line) for the entire Philippines to visually capture the differences in slope between the regional and the national datasets. From this presentation of the data, it is easier to see the individual tendencies of the regional plots of *DSH* vs. *SVI* vis-à-vis the national population of barangays.

Figure 4-28 Modified supra-regional clusters for the Philippines



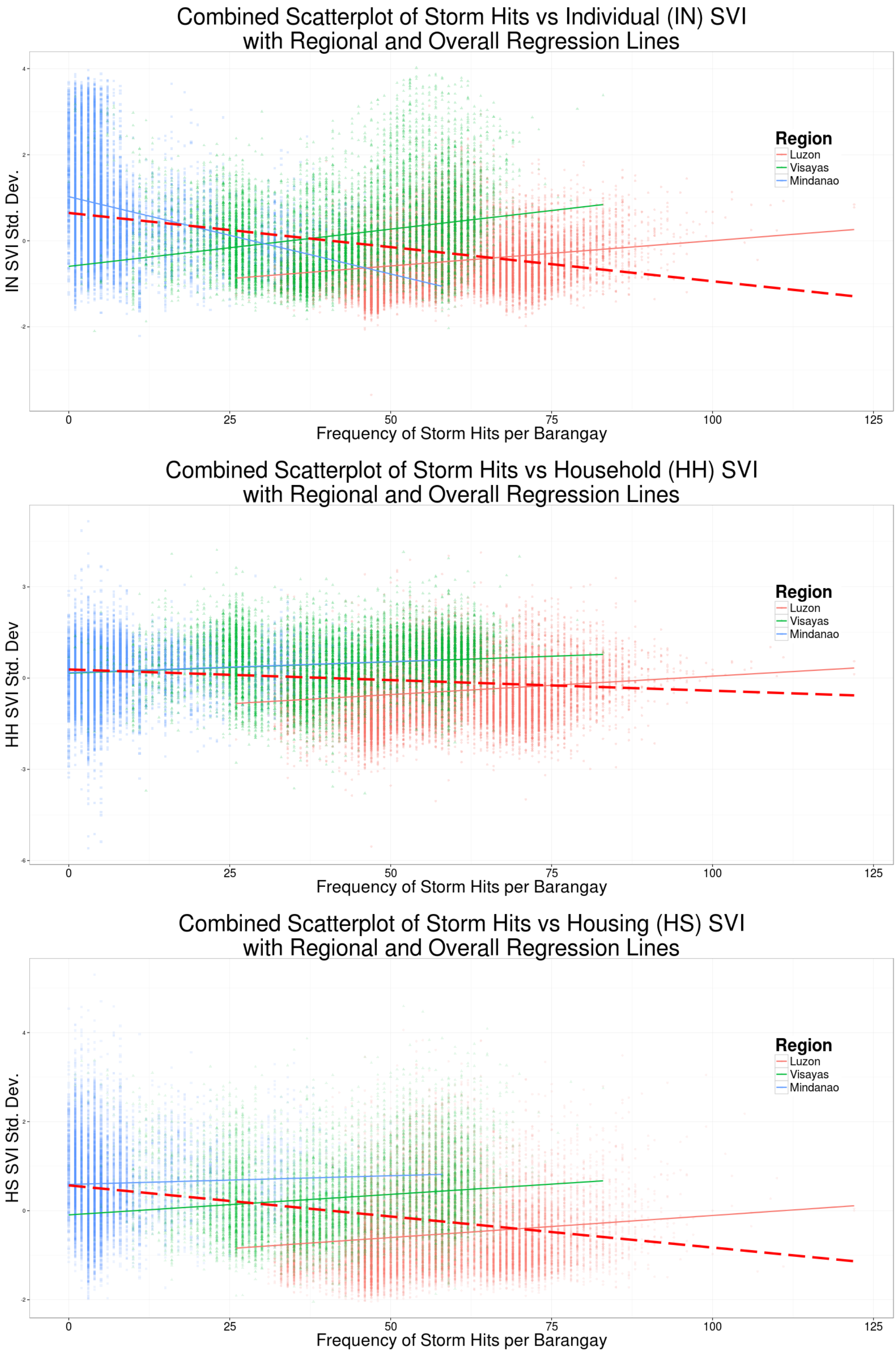
Sources: GADM and the author

The results in Table 4-10 also show that the regional R^2 scores have very low values, particularly for the SVI_{hh} and the SVI_{hs} models, showing that there is even less goodness of fit for the regional subsets compared to the full national dataset, though the SVI_{hh} has consistently performed poorly on the R^2 statistic. As there is not the consistency of results at the regional levels compared to the national, it does not support the initial trend seen at the national level that the more storms that hit a barangay, the lower its social vulnerability measure.

Table 4-10 Linear regression results for storm hits and standardized *SVIs* at regional control levels. Values in parentheses are standard errors.

	Outcome Variables		
Supra-Regional Level	SVI_{in}	SVI_{hh}	SVI_{hs}
Luzon			
Direct Storm Hits	0.0897 ***	0.0473 ***	0.1015 ***
n = 19,039	(0.0028)	(0.0022)	(0.0051)
	$R^2 = 0.0495$	$R^2 = 0.0244$	$R^2 = 0.0201$
Visayas			
Direct Storm Hits	0.1320 ***	0.0289 ***	0.0943 ***
n = 12,899	(0.0041)	(0.0021)	(0.0054)
	$R^2 = 0.0737$	$R^2 = 0.0140$	$R^2 = 0.0233$
Mindanao			
Direct Storm Hits	-0.2742 ***	0.0281 ***	0.0400 ***
n = 10,082	(0.0099)	(0.0040)	(0.0113)
	$R^2 = 0.0711$	$R^2 = 0.0047$	$R^2 = 0.0011$

Figure 4-29 Combined scatterplots of *SVI* and *DSH* with regression lines for national (thick red dashed) and regional levels (colored solid)



5 Discussion

The development of an index for social vulnerability using census data has already been undertaken before as seen in the earlier work of Cutter (2003) and Fekete (2009). This is, however, the first time that raw, disaggregated census data was made available in constructing indicators of social vulnerability covering an entire country and at its most fundamental level of governance. Furthermore, the availability of the discrete fields of the raw census database permitted numerous combinations that produced specific indicators corresponding to social vulnerability concepts already suggested in the literature (Cutter et al. 2003; King & MacGregor 2000; Striessnig et al. 2013), as well as positing new ones to more holistically capture social vulnerability based on the particular national context in the Philippines. In assessing social vulnerability to climate change-induced hazards, it was necessary to identify the geographic zones that are exposed to certain hazards (i.e. coastal river flood hazard and typhoons) since it is in these zones of hazard exposure where the social vulnerability is of particular interest due to the potential for harm, which is the main essence of vulnerability itself (Brooks 2003).

5.1 Comparing Social Vulnerability Levels Over Time and Space

In developing a social vulnerability index adapted to the Philippine context, the availability of disaggregated census data at the most basic level of governance has been a major factor in providing a glimpse of the local states of vulnerability throughout the country. The raw nature of the data also gave a basis to compare between two consecutive census years using the same indicators that can be extracted from the two different census years. A similar comparative analysis for the USA was performed by Cutter and Finch (2008), although their SoVI method in defining the index was PCA using available data summaries at the census tract levels.

Although the output *SVI* scores are indeed comparable between the two census years, it was difficult to assess them without the aid of another reference variable that would place added value in the analysis. For this purpose, the urban and rural classification variable, which is a vulnerability indicator in itself (Cutter et al. 2000), had greatly enhanced the assessment of the *SVI* scores that were obtained and provided a quasi-validation of the census-based *SVI* methodology developed for this research.

The categorization of the *SVI* sub-indices onto quintiles from Very Low to Very High and at the same time partitioning these further into urban and rural barangays gave a very interesting view of the distribution of barangays with low and high social vulnerability states. The results show a consistent pattern of low *SVI* scores for a greater majority of urban barangays, rapidly increasing as one moves to the Very Low *SVI* category (Figure 4-6). The inverse is true for the rural barangays where we find that there is an increase in number of barangays as we move towards the Very High *SVI* category.

The patterns are consistent as well for the number of individuals, households, and housing units in the analysis, and we find an even greater rate of change for the urban category and a less pronounced difference among the rural barangays. This basically means that urban barangays exhibit much lower social vulnerability compared to rural barangays using this approach. This may be attributed to better access to goods and basic services for urban areas, such as housing materials, education, and other social services. A further revelation is that between the two census years, the majority of barangays that should have needed improvements in their *SVI* scores (i.e. ones in the Very High category) had not improved at all and 98% of these are rural barangays (Figure 4-15). These findings are quite alarming and merit further investigation as to why this is so.

The maps reveal the geographic distribution of the different phenomena that have been observed in the data manipulations presented graphically. It is interesting to see how the same clusters of barangays in certain provinces are consistently scoring in the Very High *SVI* categories. From a proactive standpoint at higher echelons of governance, there needs to be a better understanding as to why these same geographic areas are performing consistently high in terms of social vulnerability measures (Figure 4-13). What factors are contributing to the high scores in the *SVI* for these specific areas? These geographical clusters (e.g. Samar, Palawan, southern Negros, and large portions of Mindanao) need to be further understood as to what the factors are that continue to keep them at the high end of the vulnerability scale, such as insurgency/peace and order, poverty incidence, etc.

5.2 *CRFH* and *SVI* Validation

The opportunity to do an ex post validation of the significance of social vulnerability and exposure in determining flood impact at a detailed level in the local case studies has revealed that the element of scale is a major factor to consider when doing such assessments. As highlighted earlier in Chapter 1, risk assessment at national scales using country level data is important for collectively determining risk across nations and in prioritizing needs (Peduzzi et al. 2009; Cardona 2007), but as hazards, particularly flash floods, are spatially defined at the local level, it is important to prioritize the identification of populations that are exposed to such hazards regardless of vulnerability state through methods such as *CRFH* area delineation to aid risk reduction.

Although the levels of social vulnerability may actually be measured accurately through indices such as the ones developed in this thesis, the experience from this research is that the component of flood hazard exposure is more important in determining the magnitude of loss and damage compared to social vulnerability measures. As the regression results revealed (Tables 4-5, 4-6 and 4-7), the statistically significant social vulnerability indicators were even inversely related to the outcomes of the disasters in both case studies. As mentioned earlier in the Results chapter, it is apparent that for the case studies, more relatively well-off households were residing within the highly exposed *CRFH* zones where suburban development and expansion had increased in the recent years in these areas with the added aesthetic value of being along a major river, which may explain the higher concentrations of middle class residences in these areas. The results do not necessarily conclude that there is indeed an inverse correlation between social vulnerability and the tendency to be affected by hazard events, but what these results are saying is that scale is a key factor in such types of analyses (Fekete et al. 2010) and for the case study sites in this thesis, the detailed scale of the investigation has revealed relationships that are contrary to studies conducted at coarser resolutions. The results thus show that the factor of exposure is more influential in determining loss and damage from disasters at this scale of analysis and that other factors may come into play far more integral than social vulnerability.

Fekete (2009) had established that an *SVI* derived for counties in Germany exposed to river flooding showed significance between the vulnerability index scores and the affected groups per county. The nature of the floods that were considered by Fekete, however, were not the same as those investigated in this research (i.e. river floods in Germany), as well as his scale of analysis.

It is important to take the results of this research in the context of the type of event being investigated, i.e. an extreme tropical flood event triggered by an intense rainfall regime with a relatively low return probability (i.e. 75 years) within relatively smaller watersheds. It is possible that due to the very extreme nature of the flood event, differential social vulnerability, as captured in the *SVI* scores, did not figure as significant influences in the outcomes since levels of vulnerability had eventually converged for the population.

The very high significance of the *CRFH* variable seems to support this hypothesis in that what figured notably in the predictors of the different models that were formulated was this sole variable that defined exposure. In the framework of the IPCC model on disaster risk, exposure is one of the major components in the management of risk. In an extreme hazard event such as TS Washi, differential social vulnerability eventually evens out for all and the most important component of the risk management framework shifts to the exposure of the population and how to eventually get out of harm's way. The same can be said for the 2004 Indian Ocean tsunami, the 2011 Tohoku tsunami, and the 2013 Super Typhoon Haiyan in the Central Philippines, just to name the more recent ones. The extreme nature of these events caused the exposure component to be the most significant determinant of loss and damage in that the whole exposed population had eventually become vulnerable, regardless of the varying states of vulnerability of the communities.

5.3 Typhoon Exposure Levels and *SVI*

In seeking to establish a relationship between social vulnerability and recurring hazard exposure over time, the regression analysis initially revealed discernible inverse relationships between the frequency of storm hits vs. *SVI* scores. It thus appeared that barangays that normally experience a higher rate of typhoon exposure would generally tend to have lower social vulnerability, which seemed to make sense in that the more exposed to typhoon hazard the population is, the more adapted they are to the resulting harsh environment in order to survive.

After controlling the variables according to the ethno-linguistic and geographic regional clusters of Luzon, Visayas, and Mindanao, however, the results of the simple linear regressions revealed a positive relationship in almost all regression sub-models (Table 4-10 and Figure 4-26). Furthermore, the regressions showed lower R^2 values for the regional models that further weaken the significance of the relationships. In the end, there is not enough statistical evidence to support the weak positive relationships between storm frequency and *SVI* at the regional scales.

It is evident from the data distributions that looking at the entire country will eventually exhibit a negative relationship between typhoon exposure and *SVI* scores since the clusters belonging to Mindanao and Luzon, which have relatively low and high typhoon frequencies respectively also have locally high and low social vulnerability values respectively. It is also a fact that human development is comparatively lower in Mindanao (thus implying higher vulnerability) than in Luzon due to a number of factors such as the longstanding peace conflicts in the former and the closer proximity and better access of Luzon barangays to Metro Manila, the central economic and political hub of the country. These patterns are very visible in the series of maps in Section 4.1.2 in Chapter 4. These could explain the relatively low *SVI* values in Mindanao, which also happen to be located in a region that is seldom visited by typhoons.

The *SVI* indicators are also poverty proxies in themselves, which further explains the strong relationship of *SVI* to human development. It will be good to include additional parameters such as poverty incidence and other socio-economic variables in the regression in the future to check the validity of this hypothesis. The current dearth of such kinds of consistent data at the finer scale of the barangays prohibits this type of comprehensive analysis for the moment, although it might be possible to conduct a similar analysis aggregated at the next level of governance, which is the municipality/city level where there is a wider variety of consistent data for all the units.

6 Conclusions

As part of the global effort initiated by the Hyogo Framework for Action for building the resilience of nations and communities to disasters, this thesis explored the utility of creating an adapted social vulnerability index based on census data for the second top ranked country in terms of risk in the world (Welle et al. 2014). As climate change-induced hazards are increasingly impacting a greater percentage of the population in the Philippines, there is a race to improve and develop new metrics for hazard exposure and social vulnerability in order to mitigate the adverse impacts on the population.

The development of an *SVI* based on indicators with solid grounding on the literature was made possible by the availability of disaggregated census data for the Philippines. The raw data fields made it possible to develop very specific indicators of vulnerability at the individual, household, and housing unit levels which in turn allowed a multi-faceted view of social vulnerability at these different levels. The three sub-index measures also allowed a means to compare their outcomes among themselves to check for consistency while further comparisons between urban and rural areas provided added value as to the trends in vulnerability across time.

The aspect of the research that compares *SVI* scores between census years has given a rather revealing overview of the social vulnerability conditions of barangays across space (in municipalities and provinces throughout the entire Philippines) and across time. The revelation that the same communities remain in the very high vulnerability states through time indicates that there is no improvement in their condition and are kept vulnerable for certain reasons that need to be further explored. The maps permitted a visual depiction of their geographic distributions, which can also be augmented and validated vis-à-vis other spatial data, both of the social and geophysical types. Other additional correlations can be examined between SVI outcomes and agricultural production or forest cover, for example, which might further reveal other relationships that can help explain the current geographic distribution of vulnerability throughout the country.

A more exhaustive analysis of the interrelated factors that contribute to the vulnerability states could then direct governance efforts to address these issues in order to improve the lives of the most vulnerable communities in the Philippines. Resources can thus be allocated and directed towards communities that need them most, thus giving a more efficient use of limited resources. As the *SVI* measurements employed in this research capture endogenous or generic vulnerabilities of the population, these also measure inherent sensitivities and propensities of the population to other perturbations such as economic stresses and insurgency, to name a few.

An important revelation in the *SVI* and flood hazard analysis is that there tends to be an inverse relationship between social vulnerability and the adverse impacts of *CRFH*. As explained in Chapter 5, these may be caused by the rapid expansion of middle class housing in areas exposed to low return probability and high intensity hazard events. Combining this rich and spatially dense social vulnerability data with hazard exposure zones can also potentially provide decision-makers the necessary tools to prioritize and allocate resources through existing governance structures. This can be of great use to local government and non-government organizations in defining their sectors of focus and their priority programs of engagement. The delineation of *CRFH* areas is important in identifying barangays that are at high risk to this hazard phenomenon. Once identified, government and other interest groups can then prioritize action and resources geared towards preparedness, which can spell the difference between life and death. Early warning protocols and tools for the flood hazard can be developed with the communities and people might even need to be relocated to safer areas away from flashflood danger in the most susceptible areas. A comprehensive delineation of hazard zones can also isolate no-build areas to prevent expansion of habitation into these precarious areas.

Given that weather extremes are possible throughout the Philippines due to its de facto geographical situation, the phenomenon where differential social vulnerability becomes less and less pronounced the more extreme the hazard event; exposure becomes the main factor that determines the magnitude of loss and damage. The comprehensive nature of the geographic coverage and the completeness of the available data allow a very broad impact on Philippine governance, potentially improving the lives of many vulnerable communities through attempts at improving their vulnerability states. The recent release of the 30m resolution SRTM DEM for the world (Buis 2014) will greatly improve the spatial accuracy of the delineation of *CRFH* zones and will make it possible to accurately identify communities at risk to this type of hazard.

It is the lack of consistent and uniform information at the scale of the barangay throughout the country that has prompted the use of census data to develop proxy variables for vulnerability. The effort to derive composite indicators of social vulnerability from the existing census fields is mainly an attempt to help capture aspects of social vulnerability in the population at an unprecedented scale and geographic coverage. But in the end, the census database had been designed with very specific objectives in mind and we will have to accept these limitations when we try to use the data for other purposes it was not originally intended for. Furthermore, as census data is collected every ten years with normally an inter-decadal subset in-between, there might be the need for a more regular and updated survey specifically intended for vulnerability assessment. As climate change impacts are increasingly becoming a major concern, particularly in a country highly exposed to multiple hazards as the Philippines, a regular and focused vulnerability assessment will be a most useful tool in planning and empowering communities to slowly adapt to a rapidly changing environment.

Even if there were no significant statistical relationships resulting between *SVI* and typhoon exposure, the mere fact that a detailed map of typhoon exposure was developed is already a major output in itself, particularly as exposure turns out to be the major factor in disaster risk for highly extreme hazard events. The data can be used as input to other studies involving the relationships between typhoon exposure and other social phenomena.

In conclusion, this research has shown that social vulnerability in itself cannot be defined as merely a static measure. The state of vulnerability of individuals and communities dynamically change depending on the magnitude of a hazard, and in cases of hazard extremes, there exist limits or tipping points that define the possibility of either returning to a previous state or condition, or whether a new state will have to be defined.

7 Perspectives

This research was an ambitious attempt to measure social vulnerability of communities in the Philippines in the face of increasing disasters attributed to climate change. The overall intent of the research is to come up with an analysis having a sound basis on the existing literature that can be used by government and civil society groups in augmenting their efforts towards risk reduction and management, particularly in preemptive action against potentially life-threatening hazards. Vulnerability assessment is not an end in itself, but an increasingly important component in promoting human security.

The research results may be a good start towards this relevant objective, but the current work has opened up much more potentials for investigation than initially envisaged. The methods employed in measuring social vulnerability as well as defining the selected hazard exposure zones are admittedly not the most sophisticated in terms of the current state of the art in modeling in human and physical geography, but they are by no means invalid and can hold their ground scientifically.

As there are other data fields that were not included in this initial investigation, such as ethnicity, migration, and religion, there still exist numerous possibilities for developing additional indicators to augment the current *SVI* measurements and capture other related facets of vulnerability. In addition, combining population with housing fields to come up with hybrid indicators across the different levels might also yield better measures for social vulnerability (e.g. large households living in small housing units, single headed households living in housing units with poor wall materials, etc.). The current indicator set is a simple initial attempt to formulate indicators that can be derived from the available database, but are not necessarily the only indicators that can be used.

What is important for this researcher is that the outputs that have been obtained from these models have exhibited positive and encouraging results from the statistical tests that have been conducted. This means that there are enough bases to pursue this line of research further and to improve on the measures. In the area of social vulnerability metrics, it will be interesting to work towards a more streamlined set of indicators to see which of the current indicators used are not contributing to the final outcome. Moreover, there are other data fields in the existing census databases such as ethnicity, religion, and migration that had not been included in this initial research. These additional fields can reveal other more important relationships in terms of the vulnerability of communities and this opens up exciting possibilities in social vulnerability metrics.

In the area of flood exposure delineation, the recent announcement of the release of the 30m SRTM DEM dataset for the world by the USA government will surely give a highly improved delineation of *CRFH* areas that would provide greater accuracy in identifying communities at risk to this type of hazard. Partnerships with hydrologists specializing in floodplain delineation are now being forged in order to have a more spatially accurate identification of such zones as a response to the HFA objectives, particularly with the release of the higher resolution DEM data (Grimaldi et al. 2013; Manfreda et al. 2014; Nardi et al. 2008).

In the end, what is most crucial is that the initial data derived from this research will be made available to those who can benefit the most from its use, whether they be government or civil society groups. For this to happen, there is sadly a component of politics that will need to be employed to promote its use. As a scientist with decades of experience in applied research, it has become a fact that as one delves into the area of decision-making to influence policy and program focus for government and non-government institutions alike, a proactive strategy will need to be employed in ensuring that the outcomes of this scientific work are utilized and will contribute to actual social change. One can have the most accurate and infallible research findings ever to grace the annals of scientific scholarship, but if there is no appreciation of the new information that has been discovered, particularly to those for whom it is intended, it is of no value; and in the context of sustainability science, on which this whole research is grounded, it would fail miserably in our common pursuit of a more sustainable world.

Having said that, initial talks are underway with this researcher with ESSC, his home research institution in the Philippines, and the Department of Interior and Local Government of the Philippines no how these datasets can be used to help develop a more comprehensive disaster risk reduction program for the country. Numerous perspectives, approaches, and datasets exist, a lot of which are the product of quality research. For the practitioner, however, there is very limited time and energy to evaluate each and every one of these for adoption into their programs. The challenge is to be able to integrate these new ideas and methods into existing programs of governance without disregarding the work that had already been put in. One of the key elements of this strategy that will promote the use of these datasets and approaches is that the information be made available accessible to those who can and will benefit from its use. Only then can it serve the original purpose that this researcher intended it for; and this is best way that its outputs can make the greatest impact in the reducing the vulnerability of Philippine society to the ravages of climate change and its associated hazards.

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9 Appendices

9.1 Appendix A. List of fields in the 2000 Census of Population and Housing

Please refer to Appendix B for a detailed explanation of each variable.

CODE	DESCRIPTION
reg	Region code
prv	Provincial code
prrcd	Highly urbanized city code
mun	Municipal code
bgy	Barangay code
hhqsn	Household questionnaire sequence number
hhsze	Household size
rel	Religion
breg	Birth registration status
age	Age
sex	Sex
ofw	Overseas foreign worker
ms	Marital status
rlgn	Religion
dis	Disability
dtyp	Disability type
eth	Ethnicity
hgc	Highest academic grade completed
r5yr	Residence 5 years ago
fhhhu	First household in the housing unit
type	Housing type
roof	Type of roofing material
wall	Type of outer wall material
repr	State of repair
yrbt	Year built
area	Floor area
tnur	Tenure status
year	Census year
month	Census month

9.2 Appendix B. List of fields in the 2010 Census of Population and Housing (from PSA)

IDENTIFICATION ITEMS

The following are common items for population and housing items with corresponding code and description:

Item	**Codes**	**Description**
REG	01 to 17	Region Code and Name based on Philippine Standard Geographic Code (PSGC) as of March 2010
PRV	01 to 83, 85, 97, and 98	Province Code and Name based on PSGC as of March 2010; Valid province codes and names vary depending on the region; Codes 97 and 98 are used for City of Isabela (component city) and Cotabato City (independent component city), respectively
MUN	01 to 53	City/Municipality Code and Name based on PSGC as of March 2010; Valid city/municipality codes and names vary depending on the province
BGY	001 to 268	Barangay Code and Name based on PSGC as of March 2010; Valid barangay codes and names vary depending on the city/municipality
HUSN	000001 to 999999	Housing Unit Serial Number (HUSN) is a 6-digit code assigned to each housing unit sequentially from 000001 up to the last housing unit in the barangay.
HSN	000001 to 999999	Household Serial Number (HSN) is a unique 6-digit code assigned to each household sequentially from 000001 up to the last household in the barangay. There are special HSNs used for the following: · 777777 is an HSN assigned to a household to indicate that it is occupying a housing unit which is not their usual place of residence; · 888888 is an HSN assigned to a household to indicate that the members such as foreign diplomats, are excluded from enumeration; · 888889 is an HSN assigned to a household to indicate that the housing unit is only used as a vacation/rest house; and · 999999 is an HSN assigned to a vacant housing unit.

POPULATION ITEMS

The following are the population items with corresponding variable name, code, and category:

Item	Variable Name	Code	Category
LNO	Line Number	01 to 99	
P2	Relationship to Household Head	01 02 03 04 21 22 23 24 31 32 33 34 41 42 43	Head Spouse Son Daughter Stepson Stepdaughter Son-in-law Daughter-in-law Grandson Granddaughter Father Mother Brother Sister Uncle
		44 55 56 57 58 65 66	Aunt Nephew Niece Other Relative Non-relative Boarder Domestic Helper
P3	Sex	1 2	Male Female
P5	Single Year-Age Classification	000 to 130	000 to 130
P6	Birth Registration	1 2 3 9	Yes No Don't Know Not Reported
P7	Marital Status	1 2 3 4 5 6	Single Married Widowed Divorced/Separated Common Law/Live-in Unknown
P8	Religious Affiliation	00 to 97, 99	For details, see Annexes A1 and A2
P10	Country of Citizenship	001 to 202, 999	For details, see Annex B
P11	Ethnicity	001 to 182, 999	For details, see Annex C
P12	Disability	1 2 9	Yes No Not Reported
P13A	Functional Difficulty in Seeing	1 2 9	Yes No Not Reported
P13B	Functional Difficulty in Hearing	1 2 9	Yes No Not Reported

P13C	Functional Difficulty in Walking/ Climbing	1 2 9	Yes No Not Reported
P13D	Functional Difficulty in Remembering or concentrating	1 2 9	Yes No Not Reported
P13E	Functional Difficulty in Self-caring	1 2 9	Yes No Not Reported
P13F	Functional Difficulty in Communicating	1 2 9	Yes No Not Reported
P14	Residence 5 Years Ago	0000 0101 to 8599, 9701 to 9804 8887 9999	Same Province Valid province and city/municipality codes; for details, see Annex D Foreign Country Not Reported
P16	Highest Grade Completed	000 010 210 220 230 240 250 260 280 310 320 330 340 350 410 420 430 400-499 810 820 830 840 850 860 500-599 900 999	No Grade Completed Pre-school Elementary Grade 1 Elementary Grade 2 Elementary Grade 3 Elementary Grade 4 Elementary Grade 5 Elementary Grade 6 Elementary Graduate 1st Year High School 2nd Year High School 3rd Year High School 4th Year High School High School Graduate Post Secondary 1st Year Post Secondary 2nd Year Post Secondary 3rd Year Post Secondary Graduate; for details, see Annex E1 1st Year College 2nd Year College 3rd Year College 4th Year College 5th Year College 6th Year College or Higher Academic Degree Holder; for details, see Annex E2 Post Baccalaureate Not Stated
P19	Overseas Worker	1 2 9	Yes No Not Reported

HOUSING ITEMS

The following are housing items with corresponding variable name, code, and category:

Item	Variable Name	Code	Category
B1	Type of Building/ House	1	Single House
		2	Duplex
		3	Multi-Unit Residential
		4	Commercial/ Industrial/ Agricultural
		5	Institutional Living Quarter
		6	Other Housing Units
		9	Not Reported
B2	Construction Materials of the Roof	1	Galvanized Iron/Aluminum
		2	Tile Concrete/Clay Tile
		3	Half Galvanized Iron and Half Concrete
		4	Wood
		5	Cogon/Nipa/Anahaw
		6	Asbestos
		7	Makeshift/Salvaged/ Improvised Materials
		8	Others
		9	Not Reported
B3	Construction Materials of the Outer Walls	01	Concrete/Brick/Stone
		02	Wood
		03	Half Concrete/Brick/Stone and Half Wood
		04	Galvanized Iron/Aluminum
		05	Bamboo/Sawali/Cogon/Nipa
		06	Asbestos
		07	Glass
		08	Makeshift/Salvaged/ Improvised Materials
		09	Others
		10	No Walls
		99	Not Reported
B4	State of Repair of the Building/ House	1	Needs no repair/ Needs minor repair
		2	Needs major repair
		3	Dilapidated/ Condemned
		4	Under renovation/ Being repaired
		5	Under construction
		6	Unfinished construction
		7	Not Applicable
		9	Not Reported
B5	Year Building/ House was Built	01	2010
		02	2009
		03	2008
		04	2007
		05	2006
		06	2001-2005
		07	1991-2000
		08	1981-1990
		09	1971-1980
		10	1970 or earlier
		11	Not Applicable
		12	Don't Know
		99	Not Reported

D1	Floor Area of the Housing Unit	01 02 03 04 05 06 07 08 09 10 11 12 99	Less than 5 sq.m./Less than 54 sq.ft. 5 - 9 sq.m./54 - 107 sq.ft. 10 - 19 sq.m./108 - 209 sq.ft. 20 - 29 sq.m./210 - 317 sq.ft. 30 - 49 sq.m./318 - 532 sq.ft. 50 - 69 sq.m./533 - 748 sq.ft. 70 - 89 sq.m./749 - 963 sq.ft. 90 - 119 sq.m./964 - 1,286 sq.ft. 120 - 149 sq.m./1,287 - 1,609 sq.ft. 150 - 199 sq.m./1,610 - 2,147 sq.ft. 200 sq.m. and over/2,148 sq.ft. and over Not Applicable Not Reported
H8	Tenure Status of the Lot	1 2 3 4 5 9	Owned/Being Amortized Rented Rent-free with Consent of Owner Rent-free without Consent of Owner Not Applicable Not Reported
HUIND	Housing Indicator	1	First household in the housing unit

9.3 Appendix C. Basis for the urban and rural classification of barangays in 2000[20] (Philippine Statistics Authority 2000)

Urban Areas

In the Philippines, “urban” areas fall under the following categories:

1. In their entirety, all municipal jurisdictions which, whether designated chartered cities, provincial capital or not, have a population density of at least 1,000 persons per square kilometer: all barangays;
2. Poblaciones or central districts of municipalities and cities which have a population density of at least 500 persons square kilometer;
3. Poblaciones or central districts not included in (1) and (2) regardless of the population size which have the following:
    - street pattern or network of streets in either parallel or right angle orientation;
    - at least six establishments (commercial, manufacturing, recreational and/or personal services);
    - at least three of the following:
        - a town hall, church or chapel with religious service at least once a month;
        - a public plaza, park or cemetery;
        - a market place, or building, where trading activities are carried on at least once a week;
        - a public building, like a school, hospital, puericulture and health center or library.
4. Barangays having at least 1,000 inhabitants which meet the conditions set forth in (3) above and where the occupation of the inhabitants is predominantly non-farming or fishing.

Rural Areas

All poblaciones or central districts and all barrios that do not meet the requirements for classification of urban.

[20] http://www.nscb.gov.ph/activestats/psgc/articles/con_urbanrural.asp

9.4 Appendix D

Bar plots of individual sub-index indicators distribution per quintile category for urban and rural barangays in 2000 and 2010

9.5 Appendix E

Bar plots of household sub-index indicators distribution per quintile category for urban and rural barangays in 2000 and 2010

9.6 Appendix F

Bar plots of household sub-index indicators distribution per quintile category for urban and rural barangays in 2000 and 2010