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Social Vulnerability Assessment of Barangays Located in Flood-Prone Areas of the Major Watersheds in the Island of Negros, Philippines

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Abstract

A social vulnerability assessment was conducted to identify which of the watersheds in the Island of Negros, Philippines are most likely to be negatively affected by flood based on the underlying social and demographic characteristics of the population located in flood-prone areas. Assessment at a watershed scale is a challenge considering that it is a hydrologic unit, while the population relies on a political unit. To increase accuracy and address comparability of data, the assessment was first conducted at the barangay level covering 199 villages using government data which were aggregated for the final assessment of 33 major watersheds. An indicator-based approach utilizing 19 indicators was used to capture the level of exposure, sensitivity, and adaptive capacity of the communities, while an index-based method was used to establish the differential social vulnerabilities across barangays and watersheds through a flood social vulnerability index (FSVI). A spatial analyst tool was used to compute the FSVI for easier representation of numerical values in a spatial map and five different vulnerability formulas were compared. The FSVI values revealed that watersheds have low vulnerability due to highly resilient populations attributed to existing government programs for disaster preparedness, response, and recovery, as well as available evacuation centers, medical services, and trained rescue volunteers. Watersheds were then prioritized and clustered according to their level of vulnerability for management intervention of the provincial government.

Keywords: vulnerability assessment, flood social vulnerability, exposure, sensitivity, resilience

Introduction

Flooding is a global phenomenon that causes great, widespread destruction, economic damages, and even loss of human lives. Extreme precipitation events as a result of global warming and land development associated with population growth within the watershed have been increasing concerns for many regions throughout the world as they aggravate flood risk. People living in floodplains and downstream areas of the watershed are more exposed to flooding. Most urban centers and populated communities are also located in these marginal areas. It was found that the number of casualties is greater in areas with higher percentages of socially vulnerable populations (Zahran et al., 2008; Cutter, 1996) and floods have also resulted in much damage which have long-term implications on governance, communities, and the natural environment (Fatti & Patel, 2013). More so, due to the country's hazard-prone location, most of its watersheds are naturally prone to environmental disasters (DENR-EMB, 2011; Tiburan et al, 2012). And because the downstream areas of the watersheds are usually at higher risk of flooding, it is important to assess the level of vulnerability of the population found in these areas.

Vulnerability has been defined in many contexts by different scientific groups. It is broadly defined as the potential for loss and is an essential component in the development of hazard mitigation strategies at different levels (Cutter, 1996). Vulnerability also refers to the degree to which a system is susceptible to or unable to cope with adverse effects of natural or man-made hazards (Fussel and Klein, 2006). The Intergovernmental Panel on Climate Change (2001) describes the vulnerability of any system to external stress as a function of exposure, sensitivity, and adaptive capacity. Most vulnerability assessments have used social conditions in coming up with indicators that would capture social vulnerability to floods across spatial and temporal scales (Rygel et al., 2006; Balica et al., 2009; Cutter et al., 2003; Koks et al., 2015). Assessment of social vulnerability leads to the identification of sensitive populations that may be less likely to respond to, cope with, and recover from a natural disaster (Cutter and Finch, 2007).

A social vulnerability assessment at a watershed scale is a challenge due to problems on the defined spatial boundary, availability and comparability of data, and aggregation problems. Flooding is a result of combined hydrological processes that exist within a watershed; hence a watershed is the most logical unit of study. However, it is not a political unit, so this poses a challenge on how to accurately characterize the social conditions in a flood-prone area. A watershed's boundary could be shared by two or more political units or one political unit could cover two or more watersheds. To understand the differences in vulnerability of watersheds at a larger scale, another challenge is the need to use indicators from standardized data to allow some comparability. But most of the watersheds are not characterized, and very few were studied hydrologically, which presents a problem of limited and/or unavailable data (Chakraborty et al., 2005). And lastly, vulnerability has been conceptualized in different ways and used in different contexts (Angcog et al., 2015; Thywissen, 2006), resulting in its measurement using different sets of scales and formulas. The uncertainty is not only in its components but also in the operationalization and measurement of these components (Daño and Fortus, 2015; Chakraborty et al., 2005).

Recognizing the need to determine the vulnerability of communities in flood-prone areas of the watersheds, a flood social vulnerability assessment was conducted in 33 major watersheds (Fig.1). To capture the social vulnerability at a watershed scale, this study proposes that assessment be first conducted in flood-prone barangays to increase accuracy. To address the problem of data availability and comparability, the study utilized government statistics and primary data. Moreover, to determine the best way to combine the three vulnerability dimensions to solve for FSVI, five formulas were compared. Factors that magnify or intensify the impacts of flood on highly vulnerable watersheds were also identified. Watersheds were prioritized based on their degree of vulnerability. Understanding the differences in vulnerability of watersheds at a provincial level and identifying potentially vulnerable population could help the provincial government set its priorities and reflect on its management approaches to maintain or improve watershed resilience in response to climate change.

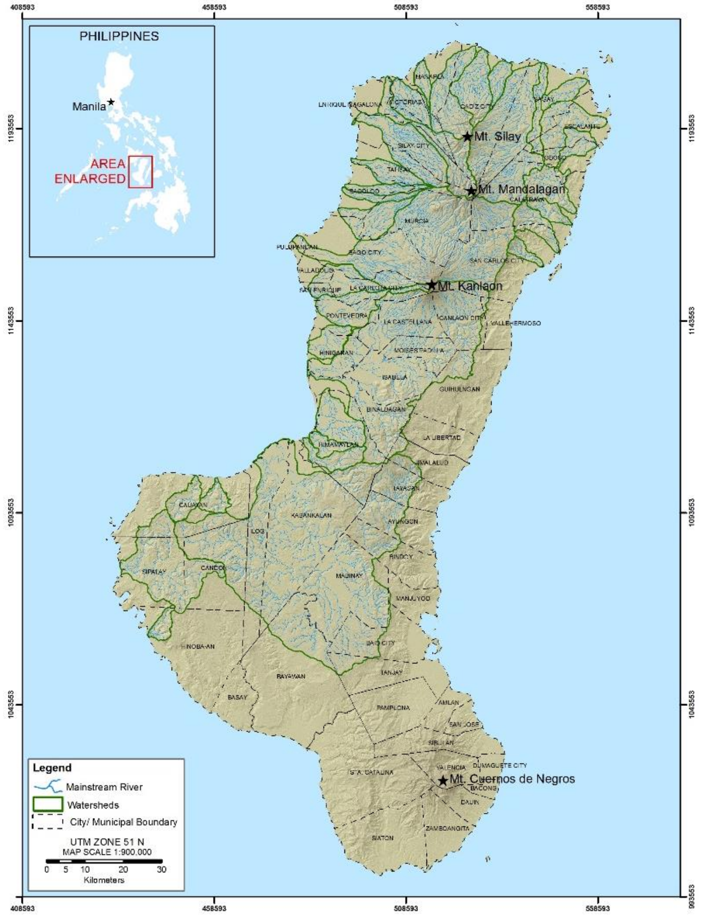

Figure 1. Location of the Major Watersheds

2. Methodology

2.1 Study Area

The Island of Negros is the fourth largest island in the Philippine archipelago comprising of two provinces (Negros Occidental and Negros Oriental), one highly urbanized city (Bacolod City), 18 component cities, 38 municipalities, and a total of 1,219 barangays (Figure 1). It is a volcanic island that is predominantly an agricultural region. More than 57 percent of its total land area is cultivated with sugarcane as its main crop, making it the country's main producer of sugar.

Most cities and towns of Negros Occidental can be found in the coastal areas where a total of 109 rivers, with stream order of two and above, empty into the bigger body of water. Of these rivers, the study covered 33 major watersheds with river systems having stream orders of more than three. Only major rivers whose main outlets are located at the western and north-eastern coasts of the island were chosen. Additionally, they were purposively chosen based on their large catchment size and reported recurrence of floods at their downstream areas. These watersheds have catchment areas ranging from 30 to 2,100 km2 with outlets found in 25 coastal cities and municipalities of the province of Negros Occidental.

2.2 General Methodology

A flood social vulnerability assessment was conducted in 33 watersheds based on the idea that not all watersheds will be affected equally by flood and will have varying levels of vulnerability. An indicator-based approach (Balica et al., 2009; Tapsell et al., 2011; Lundgren & Jonsson, 2012) using selected indicators and an index-based method were used to come up with a flood social vulnerability index (FSVI), while the geospatial method was used to calculate and map out the spatial differences in social vulnerability across barangays and watersheds.

Choosing covered barangays. Barangays found near the river mouth and the river banks of the downstream section of the main river were identified as flood-prone areas within the watershed. Using the Digital Elevation Model, an elevation threshold of 10 meters above sea level was set to identify these flood-prone barangays and their areal extent. The identified flood-prone barangays were validated using the digitized flood susceptibility map prepared by the Mines and Geosciences Bureau. A total of 199 barangays were identified.

Identifying vulnerability indicators. The assessment was based on the concept of vulnerability as a function of exposure, sensitivity, and adaptive capacity (IPCC, 2001; Balica, 2012). Nineteen social vulnerability indicators were used to gather information at a barangay level (Table 1). Indicators were chosen based on the following considerations: most-commonly cited in the literature and therefore capture flood vulnerability condition, availability and consistency of data, and easy recollection for the interviewees. There are five indicators for exposure, nine for susceptibility, and five for resilience – making up a set of composite indicators to determine the FSVI.

Table 1. List of indicators for flood sSocial vulnerability assessment

Indicator	Definition
EXPOSURE	
Population in a flood-prone area (PN)	Number of people exposed to flood hazard
Cultural heritage (CH)	Number of historical sites, religious places, important landmarks in danger when flooding occurs
Population growth (PG)	Percentage of population growth in the last 10 years
Population density (PD)	Number of people in a given area exposed to flood hazard
Urbanized area (UA)	Whether the area is classified as urban or rural
SENSITIVITY	
Persons with Disability (PW)	Percentage of population with any kind of disabilities
Awareness/Preparedness (AP)	Are the people aware and prepared for floods? IEC and flood warning system?
Spatial planning/maps (SP)	Do they integrate flood hazard maps in planning?
Elderly (EL)	Percentage of population who are elderly (> 60 years old)
Children (Ch)	Percentage of younger population (<14 years old)
Poverty incidence (PI)	The proportion of poor population to the total population found in a flood-prone area
Unemployed (UE)	Percentage of population who are unemployed
Housing type (HT)	Percentage of household with walls made of light materials
Education (ED)	Percentage of population with no high school diploma
ADAPTIVE CAPACITY	
Evacuation shelters (ES)	Number of evacuation centers near the flood-prone area
Past experience (PE)	Number of floods they experienced in the past 10 years
Access to water supply (WS)	Percentage of households with access to water supply for drinking
Government program (GP)	With government program for people affected by flood
Medical services (MS)	Number of health clinics, hospitals, rescue units, ambulance, rescue volunteers

Sources of data. The scale of vulnerability assessment is at a watershed level but the extent of data gathered was at a barangay level. To maintain data consistency all across barangays, whenever data at the barangay level were unavailable, data at the municipal level were utilized. Population and demography data came from the 2010 government census accessed from the Philippine Statistics Authority of the National Statistics Office. Other information was taken from key informant interviews conducted with the designated head of the Disaster Risk Reduction and Management Office of the cities/municipalities covered within the 33 watersheds.

Generating the vulnerability scale. Consistent with the government's guideline on watershed vulnerability assessment (DENR-ERDB, 2011), the same 1-5 scale was used to standardize all collected qualitative and quantitative data with different units. A guide in the scaling of factors was prepared to assess the exposure, sensitivity, and adaptive capacity level of each barangay based on the determined quantitative and qualitative values (Appendix 1). The range of values for quantitative data was determined using the standard deviation classification in ArcGIS™, while qualitative data were based on the rating given by the DRRM officer and from the interview. Indicators were assigned with a rating from 1 to 5 with 1 indicating very low exposure/sensitivity/adaptive capacity and 5 indicating very high exposure/sensitivity/adaptive capacity.

Assigning weights to indicators. Not all indicators have equal importance so a subjective application of weights was based on the expert method. This study recognizes the importance of local knowledge integrated into the assessment since vulnerability is highly dependent upon local conditions (Lundgren & Jonsson, 2012). The Provincial DRRM Officer of Negros Occidental and four other City/Municipal DRRM officers were invited to form the expert group who evaluated the level of importance of each indicator using the analytic hierarchy process (AHP).

Pair-wise comparison, normalization, and computation of priority vector for the composite indicators of the three vulnerable factors were done using a Microsoft Excel template developed by Goepel (2013). The aggregated individual judgments based on the weighted geometric mean of all participants' judgments was consolidated. The computed relative weights were based on the Eigenvector method (EVM) using the power method algorithm with a fixed number of 12 iterations. Two consistency indices were also calculated, consistency ratio (CR) and geometric consistency index (GCI). The level of consistency was set at $\alpha=0.1$ and the computed values of 0.02 for Exposure, 0.09 for Sensitivity, and 0.06 for Adaptive Capacity (CR values$\leq$0.1) did not exceed the threshold, hence inconsistency in the judgments are acceptable, and calculated relative weights were used.

Aggregating composite indicators. The value of each indicator (Ii) was multiplied by its relative weight (Wi) to get the flood social vulnerability index FSVIi by the indicator (Equation 1). FSVI for the Exposure component was determined by Equation 2, the Susceptibility component by Equation 3, and the Adaptive capacity component by Equation 4.

1) FSVIi = Ii * Wi
2) FSVE = FSVPN+FSVCH+FSVPG+ FSVPD+FSVUA
3) FSVS = FSVCh+FSVEL+FSVPW+FSVUN+ FSVED+ FSVHT+FSVPL+FSVSP+FSVAP
4) FSVS = FSVGP+FSVES+FSVMS+ FSVWS+FSVPE

where,

FSVI:	flood social vulnerability index
I:	indicator
W:	relative weight
FSVE:	aggregated FSVI for exposure indicators
FSVS:	aggregated FSVI for sensitivity indicators
FSVAC:	aggregated FSVI for adaptive capacity indicators

Computations were done using the raster calculator of map algebra, a spatial analyst tool in ArcGIS which could help perform geographic analysis. This allowed easier representation of numerical values to spatial map. Index values and the FSVI values were interpreted in two ways. The first one is the use of government (DENR-ERDB, 2011) vulnerability scale, where: <2.1 – very low, 2.1-2.79 – low, 2.8-3.49 – moderate, 3.5-4.19 – high, and >4.2 – very high. For better comparison, the final vulnerability index values were also classified and mapped based on the standard deviation from the mean value (z-value) (Cutter et al., 2003). Classification was done in GIS so the values could be automatically represented in a map. A high z-score indicates high social vulnerability to flood and a low z-score means low vulnerability.

All watersheds have more than one flood-prone barangays. To capture the overall social vulnerability of the watershed, the index value by a factor of a barangay was multiplied by the proportion of its area covered within the delineated flood-prone areas of the watershed and combined with other flood-prone barangays found within the said watershed (Fig. 2).

Integration of Vulnerability Components. There are many ways to combine the sub-indices to form the overall aggregate vulnerability index. The final FSVI values were solved using five different equations.

Equation 5 aggregates the components based on equal weight (Cutter & Finch, 2008; Chakraborty et al., 2005), the simplest way and maintains the status quo (Vincent, 2004). Equation 6 was mentioned in the study of Allison et al. (2009) where vulnerability score is weighted one-half to adaptive capacity and one-quarter each to exposure and sensitivity. Equations 7 and 8 were used by Ancog et al. (2016) and also found in the work of Hahn et al. (2009) and Deressa et al. (2009). Equation 9 was modified from the computation of the World Risk Index (Welle and Birkmann, 2016).

5) $FSVI = (E+S+LoAC)/3$

6) $FSVI = (0.25E+0.25S)$

7) $FSVI = (E+S)-AC$

8) $FSVI = (E-AC)S$

9) $FSVI = E(1/2(S+LoAC))$

where,

E:	exposure
S:	sensitivity
AC:	adaptive capacity
LoAC:	lack of adaptive capacity

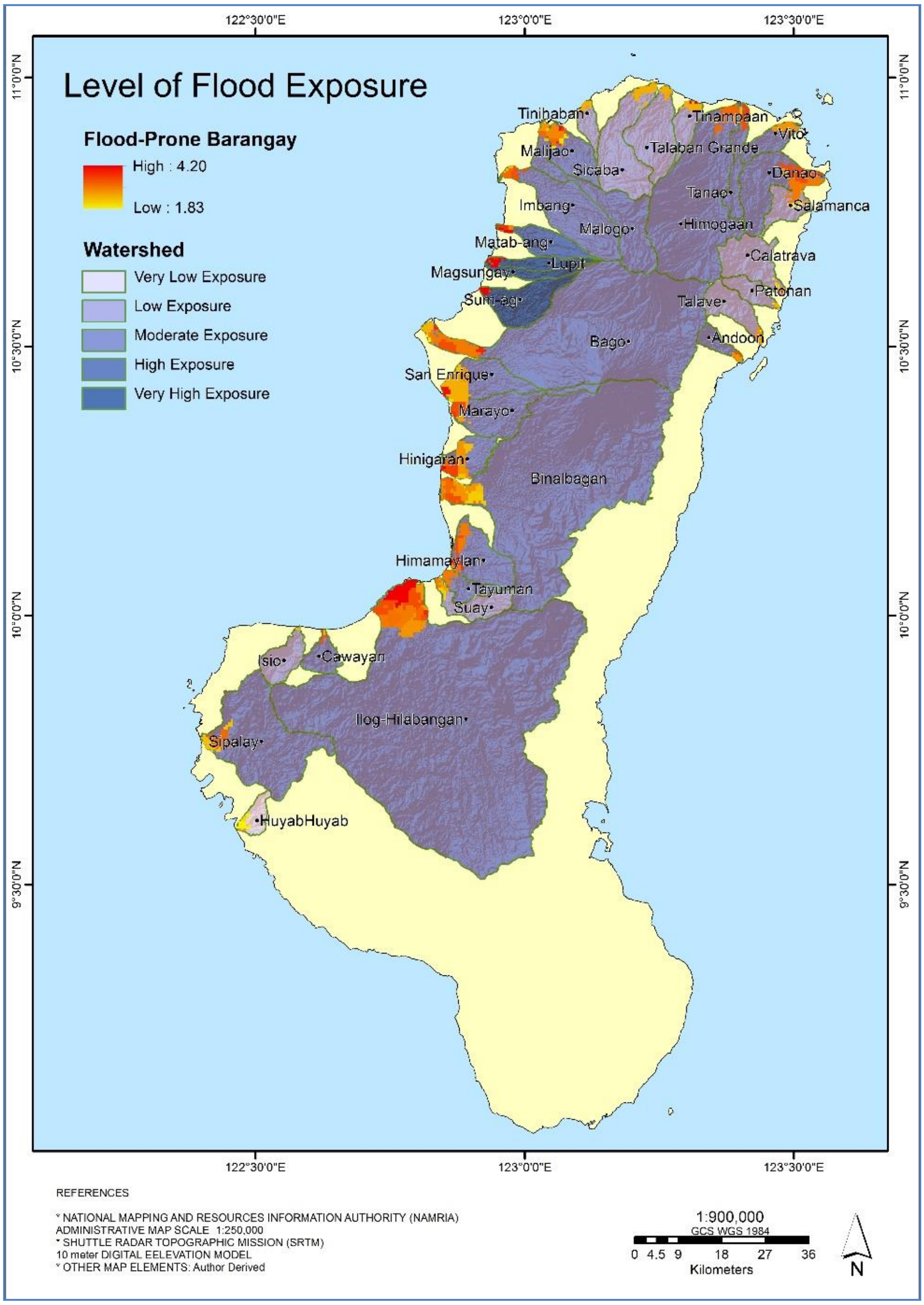

Figure 2. Flood exposure level of flood-prone barangays and major watershed

3. Results and Discussion

3.1 Flood Exposure

The result of the quantitative measurement of the barangays' level of exposure to flooding shows an exposure index ranging from 1.83 to 4.30 (Figure 2) and an overall mean index value of 2.87±0.54. Following the DENR weighted scale, half of the flood-prone barangays (50%) have very low to low level of exposure, while the other half were rated to have moderate to very high level of flood exposure. This relatively low exposure index value could be attributed to fewer numbers of historical sites, religious places, and important landmarks in danger when flood occurs and fewer urban barangays.

The 22 barangays with high to very high flood exposure level are classified as urban barangays located within 10 major watersheds. They have high population, density, and growth. These indicators have high contribution to the overall mean flood exposure index of all barangays. In most cases, urban areas are more exposed to floods than rural areas as economic and political centers were mostly established near river systems with fertile river delta and access to fluvial transportation for goods and other services. These economic centers have encouraged more migration and rapid expansion of land areas for further urban development leading to higher population density and population growth. The increased concentration of population and assets as well as high population growth rate in urban centers have further sped up the transformation and degradation of natural environments leading to new hazard patterns and increased risk to greater disaster impact (Balica et al., 2009). Moreover, high land and house markets in urban areas and loss of income due to environmental degradation in rural areas push the poorer city dwellers and incoming populations to settle in even more risky and hazard-prone urban fringes like in flood plains and cleared estuarine and riparian zones of the river systems, increasing the exposure level of the population (Hallegatte, 2015; Annan, 2013).

At a watershed scale, one watershed was found to have very low exposure to flooding, 17 watersheds with low exposure, and 15 watersheds with moderate exposure. The exposure index level values range from 1.96 to 4.19 with a mean value of 2.82±0.50 indicating most watersheds at moderate level of flood exposure. Lupit (4.19), Masungay (4.15), and Sum-ag (3.99) watersheds recorded the highest flood exposure index values. These watersheds have river systems draining the capital city of the province, with high population number, density, and growth rate values. Population number and distributions were found to have contributed to population exposures to a variety of hazards and Cutter and Finch (2008) were able to identify population growth as a single variable which tends to increase social vulnerability.

3.2 Flood Sensitivity

The sensitivity index values of barangays range from 1.48 to 3.53 with a mean value of 2.72±0.34, indicating a moderate level of sensitivity of the population to flood (Figure 3). Comparing the contribution of each variable to the level of sensitivity in terms of the mean rating among barangays and the weight of importance assigned by the experts, the proportions of population which are children and elderly have the highest contribution to the overall mean sensitivity value of the barangays. Cutter et al. (2003) also identified these two demographic groups contributing significantly to the variance among their studied countries. Children are considered vulnerable as they cannot easily move out of harm's way and they do not have necessary resources, knowledge, or life experiences to effectively cope with flood (Flanagan et al., 2011). As for the elderly, their mobility constraint is a major concern. In other words, these two demographic groups are highly sensitive due to their greater physical fragility and dependency (Holand et al., 2011).

The assessment showed that more than half (56%) of the barangays have very low to low sensitivity to flooding, while 87 (43%) have moderate sensitivity and only one got high sensitivity index value based on government scale. Barangay Vista Alegre got the highest sensitivity value (3.53) due to its relatively high percentage of population which are elderly and with disability, high poverty index, and high percentage of households with houses made of light materials. Barangay Bantayanon and Patun-an came next with sensitivity values of 3.43 and 3.40, respectively. These high values are mainly due to their socio-economic condition. Their poverty incidence of 50.23% is high compared to the mean poverty incidence of the 199 barangays of 34%. Also, the percentage of households with houses made of light materials is very high, 56%, compared with the mean value of 32%. This manifests low socio-economic status of the population. The poorest population is the most sensitive to flood for they often live in marginal lands and poorly constructed houses (Lal, 2009). These conditions even engender a range of immediate 'unsafe conditions' which make them even more sensitive to other natural hazards (White, et al. 2004).

The studied watersheds have sensitivity index values ranging from very low to medium sensitivity levels following the government scale. But when compared with their group mean, Figure 3 shows that three watersheds have very low sensitivity, one low, 18 moderate, 10 high, and one has very high sensitivity to flooding. Three watersheds draining the capital of the province got the lowest sensitivity values as their population exhibited relatively better socio-economic conditions. Most of the watersheds with high to very high sensitivity values could be found in the south-western and north-eastern sides of the province. Patunan watershed got the highest sensitivity value of 3.38 with very high poverty incidence, proportion of children, and population without high school diploma. In the country, poverty is considered the single most important factor in determining disaster vulnerability (Shepard et al., 2013) as poor population is highly sensitive to the impacts of natural hazards. Ballesteros (2012) also found a correlation between income per capita and vulnerability of the provinces in the country. Cutter and Finch (2008) describe social vulnerability as a reflection of the geography of inequality and poverty. Research shows that higher levels of vulnerability are correlated with higher levels of poverty (Chakraborty et al., 2005). Most of them also rely on livelihood that could be easily destroyed by flood and live in houses made of light materials. They have few possessions which could also be easily damaged or lost, straining further their economic capacity to replace their livelihood, shelter, and possessions. They would eventually resort to informal settlements and other livelihoods where risk is even higher.

The intricate link between poverty and watershed degradation has been widely discussed (Dasgupta, 1993; Jodha, 1998; Scherr, 2000) and could be attributed to the conflicts between different income groups in the use of natural resources, market and institutional failures, and unsustainable use of natural resources (Duraiappah, 1996). With continued unabated watershed degradation, the capacity of the natural resource base to provide its ecological services is at peril and would even contribute to the increased physical susceptibility of the watershed for bigger and more frequent floods.

Another measure of the social status of population is the level of education. It is closely associated with income and poverty (Flanagan et al., 2011). A higher proportion of population without high school diploma would mean a higher sensitivity of the population due to its limited ability to understand warning information and act upon varied hazard information from preparation to recovery (Holand et al., 2011; Tierney, 2006).

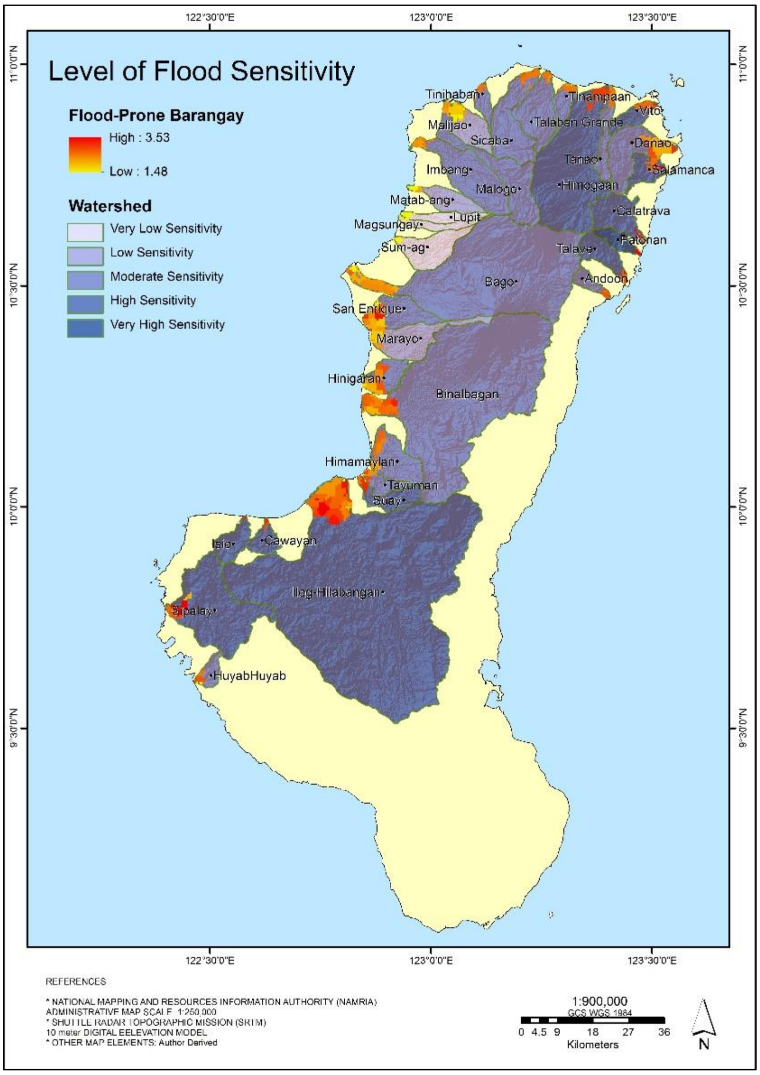

Figure 3. Flood sensitivity level of flood-prone barangays and major watersheds

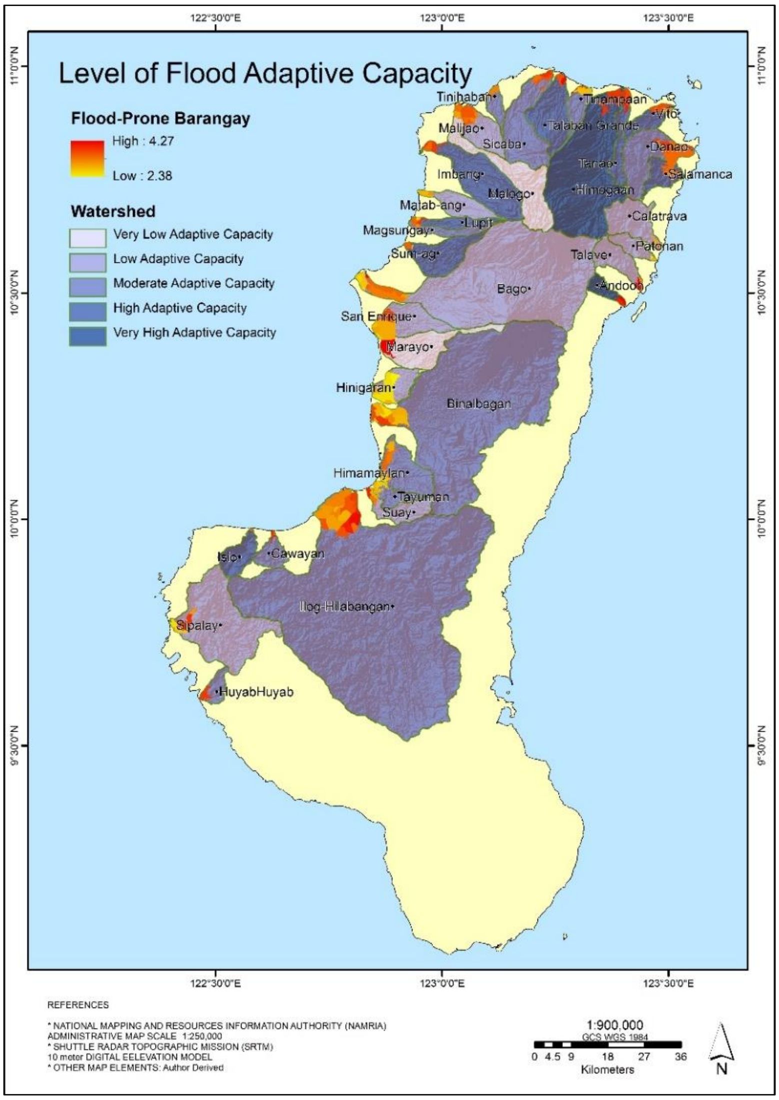

Figure 4. Flood adaptive capacity level of flood-prone barangays and major watersheds

3. Level of Adaptive Capacity

The assessment of the level of adaptive capacity of flood-prone barangays showed that population has high resilience to flooding. Their adaptive capacity level index values ranged from 2.38 to 4.27 and interpreted using the DENR-EMB standard as low resilience to very high resilience. Their mean adaptive index of 3.42±0.38 indicates a highly resilient population attributed to existing government programs for disaster preparedness, response, and recovery, as well as high number of available evacuation centers (Fig. 4). Data for these indicators were taken from interviews with local DRRM officers and they gave high ratings. They identified programs reflected in their DRRM plans as mandated by the Republic Act No. 10121 or the Philippine DRRM Act of 2010 and also mentioned about the available calamity fund given to each LGU to help them organize programs for disaster mitigation, preparedness, and quick response activities.

Since the enactment of the law, DRRM officers confirmed that improved government programs and services have reached the population, such as capacity-building activities, conduct of public information and trainings, and purchase of necessary rescue equipment in their locality.

Of the five resilience indicators, four are qualitative data extracted from interviews and three are related to government services. The assessment from the interview of a government representative is subjective and reflects only the government perspective. Hence, relatively high ratings were observed for these indicators as well as high relative importance values assigned by the local experts. The response to these questions would possibly differ when taken from the perspective of the local community as to whether they are reached by flood-related government programs.

At watershed scale, 18 watersheds have moderate adaptive capacity rating and 15 have high adaptive capacity index values. Their mean adaptive capacity index value of 3.52±0.28 signifies a relatively resilient population. Figure 4 presents the spatial distribution of watersheds according to their comparative adaptive capacity level. Andoon and Himogaan watersheds are considered the most resilient population as they have more evacuation shelters and available medical services, and have experienced past flooding events. Hinigaran, and Malogo watersheds received the lowest rating. Hinigaran watershed has fewer evacuation shelters and has more than 40% of its population with limited access to potable water, while Malogo has fewer government programs and designated evacuation shelters compared with other catchments.

Availability of adequate number of evacuation shelters, medical services, and trained rescue volunteers contributes to the level of preparedness of the local community and thus increases their level of resilience. With Republic Act No. 10121, the local government is now empowered to strengthen its local capability to build the local community's resilience in preparing for and coping with floods.

The adage "experience is the best teacher" provides an added value to the resilience level of those who have experienced flooding in the past. A previous flood experience could provide lessons for people to easily come up with solutions to avoid or cope with floods (Veenstra, 2013), making them more resilient. Bhattacharya-Mis & Lamond (2014) explored the role of flood memory in the system's socio-economic complexities. They mentioned about the concept of "watery sense of place," that through the community's processed flood memories and shared flood heritage, they could learn how to live with water and its risks and establish a collective understanding of characteristics, distinctiveness, and identity of their place. This is a local knowledge that could provide a wealth of learning insights and be further used on how communities prepare for and recover, from floods (McEwen et al., 2012).

4. Flood Social Vulnerability of the Watersheds

Having derived the composite index for each vulnerability component, five equations (Eq. 5 to Eq. 9) were utilized to solve for FSVI following the IPCC framework for all watersheds. Appendix 3 presents varying FSVI values. Equations 5, 7, and 8 are examples of a balanced-weighted approach where the major component values equally contributed to the FSVI value (Birkmann and Welle, 2016; Cutter and Finch, 2008; Chackraborty, 2005). On the other hand, Equations 6 and 9 were derived from an unbalanced weighted approach where factors were found to have varying contributions to the final vulnerability value (Adger and Vincent, 2005). Equations 5, 6, and 7 also follow the additive approach in combining the variables, while Equations 8 and 9 take on the multiplicative approach. In the additive approach, FSVI values depend on all three components and generally result in relatively lower and closer values. Based on the computed mean, standard deviation, and variance values, the multiplicative approach resulted in generally higher values and variance. Most selected watersheds scored higher in the level of adaptive capacity, and when used in formulas where subtraction is involved, final values yielded negative FSVI values (Equations 6, 7, and 8).

FSVI values from the five equations were correlated with one another (Table 2). Equation 8 showed the lowest correlation values compared with other equations, while Equation 7 exhibited the highest correlation, followed by Equation 5 and Equation 9.

Table 2. Correlation matrix of five compared equations

	Eq5	Eq6	Eq7	Eq8	Eq9
Eq5	1	.921(**)	-1.00 (**)	.740(**)	.932(**)
Eq6		1	-.921(**)	.648(**)	.774(**)
Eq7			1	-.742(**)	-.934(**)
Eq8				1	.871(**)
Eq9					1

**Correlation is significant at the 0.01 level (2-tailed)

These five equations were also compared based on four criteria chosen: (1) exhibit high correlation with other formulas, (2) easy to use and remember, (3) values have higher variation for better comparability, and (4) result in positive values to avoid confusion over the interpretation of negative values. Table 3 presents the criteria used and the rank of each equation assigned for each criterion.

In equation 5, the balanced weighted average approach was chosen to solve for FSVI values. It allows for the combination of Exposure, Sensitivity, and Lack of Adaptive Capacity values with equal contribution to FSVI.

Table 3. Comparison of vulnerability components aggregation formulas based on selected criteria

	High Correlation	Easy to Use	High Variation	Positive Values	Sum of Score
Eq5	2	1	5	2	9
Eq6	4	5	5	4	18
Eq7	1	2	3	4	10
Eq8	5	3	1	4	13
Eq9	3	4	2	2	11

Table 4. Flood social vulnerability index (FSVI) values of the studied watersheds

Watershed	FSVI	Level	Rank
Magsungay	2.59	Very High	1
Patonan	2.54	Very High	2
Ilog-Hilabangan	2.53	Very High	3
Hinigaran	2.49	High	4
Sipalay	2.49	High	5
Cawayan	2.48	High	6
Matab-ang	2.47	High	7
Suay	2.47	High	8
Sum-ag	2.46	High	9
Lupit	2.45	High	10
Bago	2.45	High	11
Himamaylan	2.45	High	12
Talave	2.45	High	13
Calatrava	2.44	High	14
Malogo	2.43	High	15
Danao	2.42	Moderate	16
Binalbagan	2.38	Moderate	17
Tayuman	2.36	Moderate	18
San Enrique	2.33	Moderate	19
Tanao	2.32	Moderate	20
Himogaan	2.31	Moderate	21
Imbang	2.31	Moderate	22
Sicaba	2.30	Low	23
Salamanca	2.29	Low	24
Malijao	2.28	Low	25
Tinihaban	2.26	Low	26
Vito	2.24	Low	27
Tinampaan	2.21	Low	28
Marayo	2.21	Low	29
Andoon	2.20	Low	30
Isio	2.19	Low	31
Talaban	2.13	Very Low	32
Huyabhuyab	2.10	Very Low	33
Mean	2.36	SD	0.13

The computed flood social vulnerability index values of the watersheds in Table 4 above shows the relative differences in the level of vulnerability of the population to flooding across watersheds within the province. Following the suggested vulnerability scale of the government, all FSVI values which range from 2.10 to 2.59 could be interpreted to have low vulnerability to flooding. This is due to their generally very high resilience index values. But to compare the level of vulnerability among catchments and for ranking, a different scale using z-score value was utilized. Three watersheds have populations that have very high social vulnerability, 12 have high vulnerability, six have moderate vulnerability, nine have low vulnerability, and two have very low social vulnerability to flood.

Magsungay, Paton-an, and Ilog-Hilabangan watersheds recorded the highest overall social vulnerability. Magsungay is an urban watershed with very high exposure and moderate adaptive capacity to flooding. Paton-an is a small catchment with the highest sensitivity and the lowest resilience to flood among the studied watersheds. Ilog-Hilabangan is the biggest watershed in the province and one of the major river basins in the country. In terms of area, it has the biggest combined flood-prone area and the highest number of population that could be affected by flood. It is one of the watersheds assessed with high exposure and sensitivity to flooding. Talaban and Huyabhuyab watersheds got the lowest vulnerability index values. These are medium-sized watersheds with low to very low flood exposure and high adaptive capacity to flood.

Figure 5 presents the relative exposure, sensitivity, and adaptive capacity levels of the major watersheds. The larger map shows the overall relative flood social vulnerability of the 33 watersheds based on the integrated exposure, sensitive, and adaptive capacity indices.

Watersheds are differentially exposed, sensitive, and adaptable to floods. To have an idea on how these three dimensions contribute to the total vulnerability of the watersheds, composite indices by components were compared. Figure 6 shows that most of the watersheds have low to moderate levels of exposure and sensitivity and very low lack of adaptive capacity based on government weighted scale values (in red broken lines). The watersheds exhibit more variability in their exposure values as indicated by their longer whiskers as compared with their sensitivity values but most of them have generally higher sensitivity values than exposure values. All watersheds have very low lack of adaptive capacity which contributed greatly in the lowering of all FSVI values into low overall vulnerability with low variations. The relatively higher exposure and sensitivity values were canceled out by very low lack of adaptive capacity values. Two watersheds were identified as outliers, Lupit watershed has extremely high flood exposure while the Magsungay watershed has extremely low sensitivity value. These are urban catchments close to each other.

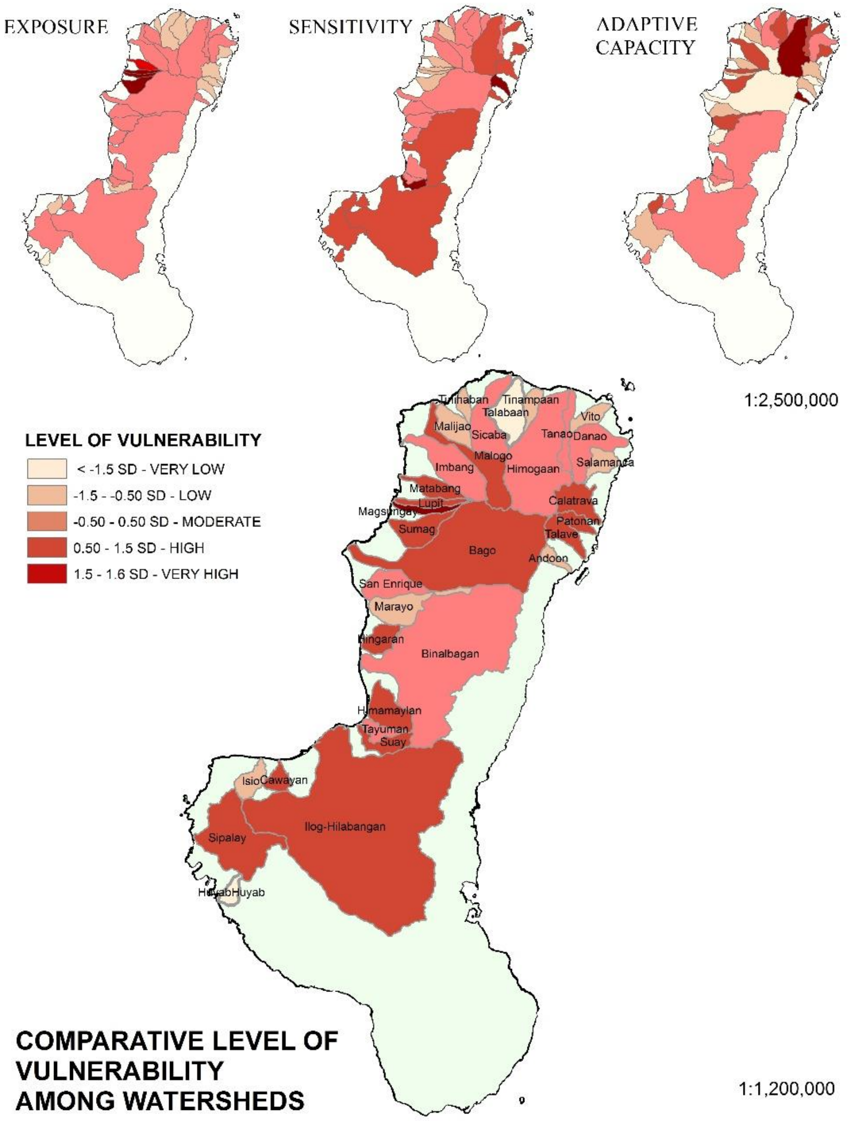

Figure 5. Comparative vulnerability of major watersheds based on the computed FSVI

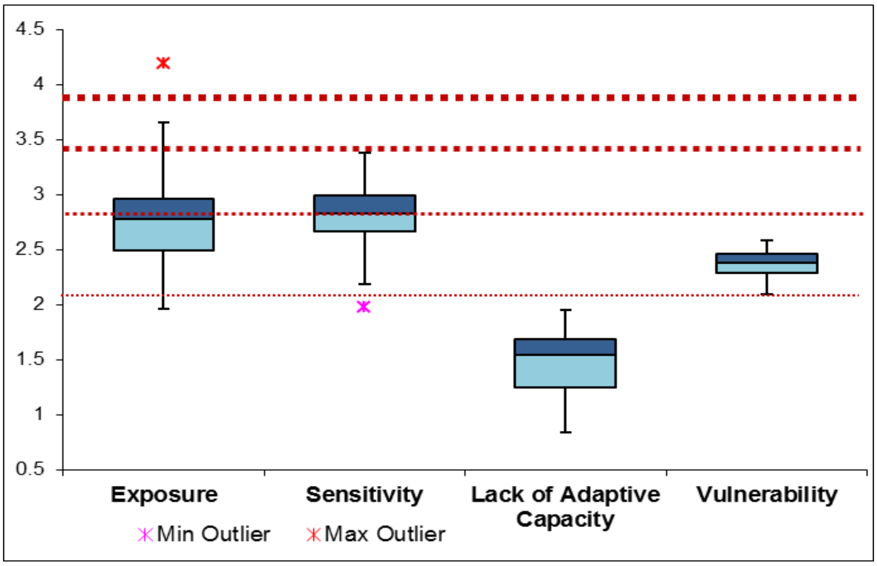

Figure 6. Composite index values by vulnerability component

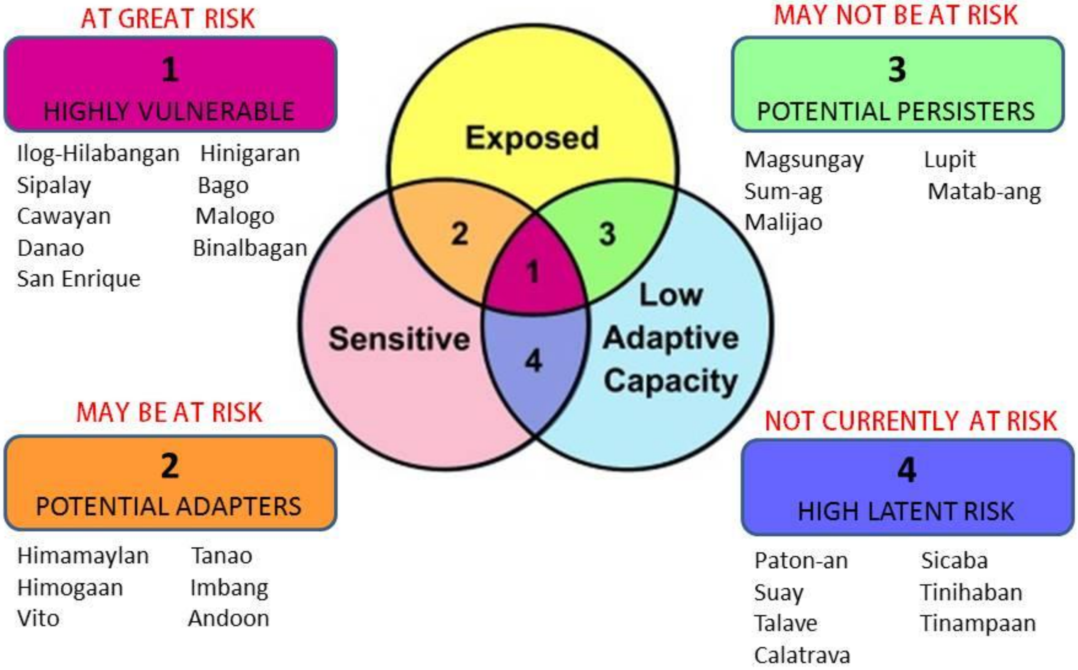

Figure 7. Four classes of vulnerability

Foden et al. (2013) prepared a framework combining the three dimensions of climate change vulnerability to identify four classes of climate change vulnerable species. The approach served as a guide in identifying species according to their level of vulnerability in three dimensions necessary for species conservation prioritization and strategic planning. Following this framework, watersheds were also classified into four distinct groups. Figure 7 presents the four distinct groups of watersheds according to their vulnerability level relative to one another. The 27 watersheds were classified as they are the watersheds with the highest vulnerability rating. Nine other watersheds were found to have relatively low rating in all vulnerability components and would not fit into these four categories.

Watersheds belonging to the first group have populations that are exposed and sensitive to floods and with relatively low adaptive capacity. They are at great risk and are considered as priority watersheds where further study and interventions are generally needed. Nine watersheds were identified under this group with Ilog-Hilabangan and Hinigaran watersheds leading the rank.

The second group with six watersheds are those that may be at risk but are "potential adapters." Their population is sensitive and exposed to flooding but they have good adaptive capacity.

The management strategy suggested for this group is to monitor and support their adaptive responses, especially the provision of socially-based services that would enhance their capacity to respond and adapt to flooding.

Magsungay, Matab-ang, Lupit, and Sum-ag, four urban watersheds, together with Malijao watershed, are considered as "potential persisters" as they have population which are likely exposed to flooding and have low adaptive capacity but are not sensitive because they have better socio-economic conditions. Since they may be at risk, there is a need to monitor their population growth and their distributions, especially in hazard-prone areas.

The last group has seven watersheds. Paton-an, Suay, Calatrava, Talave, Sicaba, Tinihaban, and Tinampaan watersheds have population with "high latent risk" to flood. They have relatively low adaptive capacity and are sensitive to flooding; however, they are not exposed to inundations. Although they are not currently at risk, with typhoons increasing in frequency, intensity, and magnitude, they could be vulnerable to the changes in the hydrologic regime of their river systems. Hence, a management approach suggested for this group of watersheds is to monitor changes in the environment, particularly the riverine system.

6. Conclusions and Recommendations

Based on the government vulnerability scale, the studied watersheds were assessed to be only slightly vulnerable to flood due mainly to their very high adaptive capacity index values. This is attributed to having more evacuation shelters, available medical services, past flood experiences, and government programs. The watersheds have also relatively low flood sensitivity, though some showed moderate sensitivity levels which could be attributed to high poverty incidence and high proportions of population which are children, elderly, and without high school diploma. Most watersheds have also low exposure to flooding and only those watersheds found in urban areas exhibited high exposure levels to flood due to high population number, density, and growth rate values.

Using a different scale, 15 watersheds were identified to have high to very high vulnerability levels that should be considered as priority watersheds for management. To better understand the vulnerability conditions, as well as the contributing dimensions of vulnerability and possible management approach, four classes of vulnerable watersheds, were formed. The maps, the quantitative analysis, and the watershed classification and prioritization are significant contributions to local planning. The provincial government could design programs that would properly address the causes of vulnerability, i.e., responding to indicators of sensitivity, exposure, and resilience. These social causes of vulnerability should be addressed in all stages of disaster: mitigation, preparedness, response, and recovery.

Social vulnerability assessment at a watershed level was made easier and with relatively higher degree of accuracy by recognizing and assessing the varying vulnerabilities of the barangays found within the flood-prone areas of the watershed. The use of government data also allowed data consistency and objectivity and comparability of the result. The study also addressed the challenge in combining multiple variables to form composite and aggregate vulnerability indices with the use of an analytic hierarchy process, IPCC framework of vulnerability, and simple formula that could capture the relative contribution of each vulnerability dimension in the absence of an established formula.

The importance of the computed FSVI is not on its absolute value per se but on its ability to quantitatively represent the vulnerability condition of a watershed to compare, rank, and map the watersheds according to their varying levels of vulnerability. Since the watershed is a dynamic system, the values provide only a snapshot of the condition particular to the area at that particular time.

While the study has generated useful information for regional planning purposes, results can be further improved with methodological refinements, including the use of more appropriate scale of values for quantifying vulnerability levels, consideration of the perspective of the local people as important data sources, and use of government vulnerability scale in the interpretation of calculated values.

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