Assessing the Vulnerability of Agricultural Crops to Riverine Floods in Kalibo, Philippines using Composite Index Method

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Abstract: Evaluating the vulnerability of a system can serve as an effective planning tool in increasing resilience to a certain hazard. In this study, a vulnerability assessment of agricultural crops to river flooding in Kalibo, a municipality in Aklan, Philippines, was performed. The analysis included physical, agro-ecological, and socio-economic indicators clustered under the components of exposure, sensitivity, and adaptive capacity. Indicators relevant for a composite index measuring degree of vulnerability to flooding were identified and corresponding weights were determined using Analytic Hierarchy Process (AHP). Various datasets were acquired using Light Detection and Ranging (LiDAR) remote sensing and participatory methods such as focus group discussions (FGDs) and key informant interviews (KIIs). The barangay-level (village-level) and gridded (500m x 500m) vulnerability maps produced using Index Method and GIS were validated through field surveys and by comparison with historical accounts of disasters and their corresponding impacts on agricultural productivity. It was concluded that the most exposed barangays were those near bodies of water and having vast agricultural land cover. Though the physical and environmental attributes of an area are substantial in determining risk, the vulnerability of the subject area was shown to be influenced by its internal (exposure) and external (sensitivity and adaptive capacity) factors. Thus, knowing and acting on indicators that are within human influence is essential in minimizing the effects of inevitable and uncontrollable phenomena.

1 INTRODUCTION

Climate change involves processes that are complex and diversified. However, it is mainly characterized by the intensification of the water cycle, which results in the occurrence of extreme weather phenomena like excessive rainfall, flooding, storms, drought, etc. (Heng et al., 2013).

Due to the Philippines' geographical location and physical environment, it has become highly vulnerable to the impacts of natural disasters, including the global incidents of the effects of climate change (Senate Economic Planning Office [SEPO], 2013). According to the SEPO (2013), the Philippines is one of the most hazard-prone countries in the world. In the recent World Risk Index published by the United Nations University - Institute of Environment and Human Security [UNU-EHS] (2016), the Philippines ranked third as the most disaster risk country worldwide with a Risk Index of 26.70 percent. Risk Index is the computed disaster risk of a country taking into account its exposure, vulnerability, susceptability, coping capabilities and adaptive capacities to natural disasters such as storms,

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flooding, earthquakes, droughts and sea level rise (UNU-EHS, 2016).

In the context of climate change, the impact of flooding on socio-ecological systems is of global significance (Doch et al., 2015). Flooding is one of the most frequent, typical, and costly natural disasters which causes abrupt damage on these systems. It occurs when a body of water rises or overflows beyond its normal confines, which then causes inundation in adjoining areas that are usually dry lands (Doch et al., 2015).

Modifications in rainfall pattern have a very significant effect on the water level, especially of basins (Heng et al., 2013). Intensified increase in the water level may cause run-off, resulting in flooding of nearby zones. When this phenomenon, i.e., sustained heavy rainfall over a specific river basin takes place, river flood materializes.

In the last decade, the Centre for Research on the Epidemiology of Disasters [CRED] (2016) recorded around 196 significant damaging natural disasters in the Philippines – 72 of which were flooding. Of the 72 flooding events, 41 were classified as riverine flooding. River flooding alone resulted in 565 casualties and an estimated USD 16 billion worth of damages. With fluvial flooding accounting for almost 21 percent of the total number of disastrous events in the past 10 years, researches on their occurrence and the vulnerability of specific areas should be given considerable attention.

The staggering effects of climate change, particularly the effect of flooding on agricultural crops, has become a very serious concern worldwide (Mallari, 2016). A consensus had been established that inter-annual, monthly, and daily variations in the distribution of climate variables such as temperature, radiation, precipitation, water vapour pressure, wind speed, and rainfall patterns may consequently reduce agricultural productivity due to a number of physical, chemical, and biological processes (Cuesta and Rañola, 2009; Parry et al., 2007). Damage occurs because flooding causes depletion of soil oxygen which is crucial for normal metabolism, growth and development of crops; moreover, it causes intensification of nitrogen losses and disease infections which reduce stands and yields (Butzen, n.d.).

However, assessment of flooding is not only based on the physical and environmental indicators, but also on the interaction between flooding and other agro-ecological, socio-economic factors and human activities (Dang et al., 2011). Therefore, changes in the current situation of society like population density, population ageing, population literacy, population income source, existing mitigation measures, road density, access to crop insurance, access to typhoon forecasting information, access to planting calendar bulletins, and others contribute to the vulnerability of a society to the natural hazard (Dang et al., 2011; Doch et al., 2015; Heng et al., 2013; Mallari, 2016).

2 STUDY AREA

The municipality of Kalibo, Aklan (Figure 1) encompasses the mouth of Aklan River. On the north, it is bounded by the Sibuyan Sea, and on the other borders by other municipalities of Aklan. Kalibo has a total land area of 5,075 hectares which is divided into 16 barangays (PSA, 2016). The first inset map in Figure 1 shows the location of Panay Island in the Philippines. The island is consist of the provinces of Aklan, Antique, Capiz and Iloilo. The location of Kalibo, Aklan is outlined in red in the second inset map.

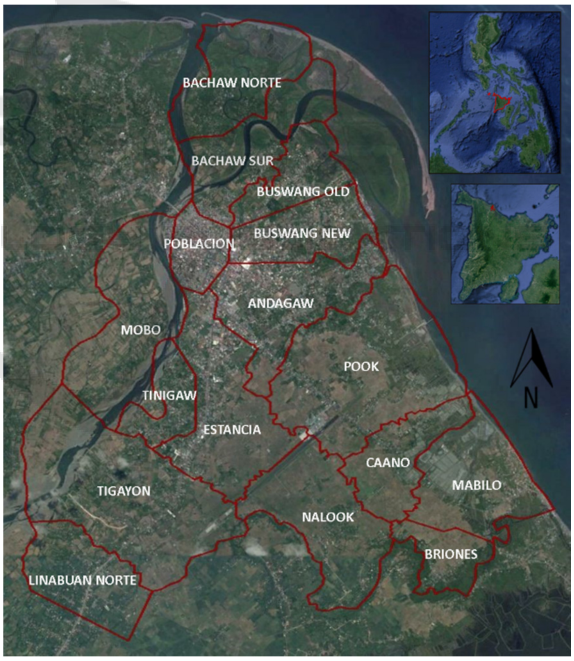


Figure 1: The study area of Kalibo, the capital municipality of Aklan (Google Earth, 2016). Red lines indicate political boundaries acquired from the National Statistics Office (NSO) thru the National Mapping and Resource Information Authority (NAMRIA).

Kalibo is predominantly an agricultural domain, as such, agricultural lands cover the biggest portion of the municipality. Around 1,111 hectares (21.89%) of soil in Kalibo is suitable for diversified forest crops. An estimated area of 1,555 hectares (30.64%) was declared highly suitable for tree crops, while another 1,150 hectares (22.66%) is highly suitable for and currently planted with rice (Municipality of Kalibo, 2016). Thus, the major thrust of the local government of Kalibo is to make it the center of agriculture-based economic industry and eco-tourism (Municipality of Kalibo, 2016).

The agricultural areas are highly vulnerable to flooding according to the records of the Municipal Agriculture Office of Kalibo (2008; 2012). Based on the damage reports (MAO, 2012), Typhoon Quinta destroyed more than 350 hectares of agricultural crops costing more than PHP 1.2 million in damages. In July 2008, Typhoon Frank, one of the strongest typhoons to hit Kalibo, resulted in crop losses amounting to PHP 23.4 million (MAO, 2008).

3 METHODOLOGY

Agricultural vulnerability assessment to flooding was performed using composite index method. Having dimensions reflected by various indicators, an index is described as a composite measure of any social phenomena (Mallari, 2016). Calculating composite indices from indicators is a common way of quantifying and communicating vulnerability to hazards, which is visualized using maps (Wiréhn et al., 2015).

Vulnerability is the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (IPCC, 2014).

According to Doch et al. (2015), vulnerability links the social and biophysical dimensions of environmental change.

Vulnerability is most often conceptualized as being constituted by the degree of exposure of the system to the hazard, sensitivity of the system to change, and its adaptive capacity to the changes in the environment (Heng et al., 2013; Bogardi et al., 2005) A vulnerability assessment of the agricultural sector in Mabalacat City relative to Typhoon Santi was performed considering such components and using GIS to generate vulnerability index maps, identify the barriers to adaptation, and to provide planning recommendations (Mallari, 2016). The same composite index method was used by Heng et al. (2013) and Doch et al. (2015) to gauge the vulnerability of agricultural production to flooding in the Sangkae River watershed in Battambang province, Cambodia.

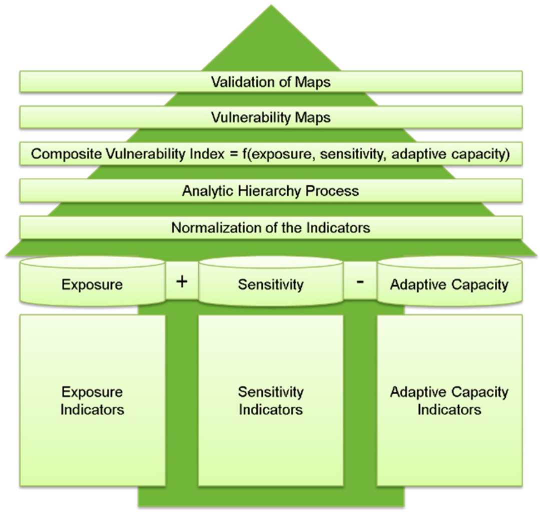


Figure 2: The methodological framework for the agricultural vulnerability assessment.

In this research, the vulnerability assessment of agricultural crops to flooding in Kalibo was based on indicators clustered into respective components, namely exposure, sensitivity, and adaptive capacity. Literature reviews, internal meetings, discussions with experts in the academe, local and national government agencies, focus group discussions (FGDs) and key informant interviews (KIIs) were performed for the assessment, review, validation, and finalization of indicators.

3.1 Data Collection and Preparation

Data collection commenced once the list of indicators was finalized. Collection of primary socio-economic datasets was done through farmer household (HH) surveys. Survey materials consisted of questions investigating the status and characteristics of the farm lands and the socio-economic and agro-ecologic attributes of the farmer households.

Since there was no available official list with the number of farmer households per barangay, as many farmer households as possible were interviewed during a one-week fieldwork in Kalibo. A total of 243 farmer households were interviewed, coming from 14 barangays. No HH survey was conducted in barangays Poblacion and Andagaw because there were no agricultural crops in the area, therefore assuming that there were no farmer households. This was verified using the detailed LiDAR-derived agricultural land cover maps and with the barangay officials. The lack of agricultural crops in the area was attributed to the urbanization of these two barangays.

The flood hazard maps of Kalibo were obtained from the Disaster Risk and Exposure Assessment for Mitigation (DREAM) Program of the University of the Philippines (UP) and the Department of Science and Technology (DOST). Flood models were generated using LiDAR data, Synthetic Aperture Radar (SAR) DEM and other datasets such as river water level and discharge, soil shapefile, land cover, meteorological data from Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) and DOST-Advanced Science and Technology Institute (DOST-ASTI), and the software FLO-2D GDS Pro (DREAM, 2016).

Agricultural features, i.e., land use/land cover (LULC) including crop distribution, were extracted from LiDAR datasets and orthomosaics. Derivative layers (e.g., DTM, DSM, nDSM, CHM, intensity, number of returns, etc.) that were used for classification were prepared using LAStools. LULC was extracted from these derived layers, orthomosaics, object-based image analysis (OBIA) and SEparability and THresholds (SEaTH). Accuracy assessment was also performed to validate the results; training and validation points were collected from fieldworks, and visual inspection and interpretation of orthomosaics and LiDAR data was conducted. Figure 3 shows the generated LULC map of Kalibo, Aklan.

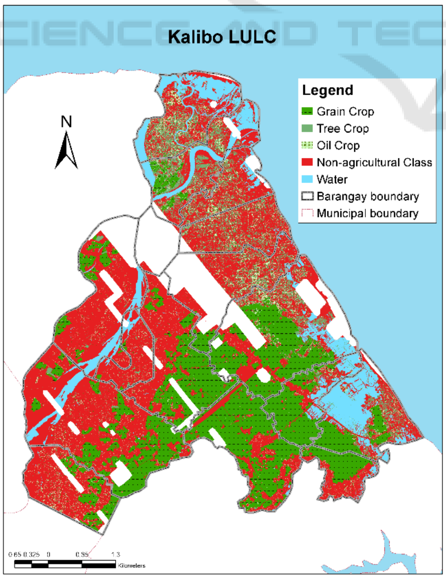


Figure 3: LULC Map of Kalibo, Aklan derived from LiDAR datasets and orthomosaics.

Since the LULC map does not cover the entire municipality, exposure computation of the agricultural classes was based on the processed LiDAR data area, rather than the entire boundary area. The implications of performing calculations based on the processed LiDAR data area would be minimal since most of the area without LiDAR data belongs to residential, commercial, and industrial zones, as verified with the general land use map of the municipality of Kalibo (Municipality of Kalibo, 2015). Further, areas with the least LiDAR coverage, i.e., Poblacion and Andagaw, were previously tagged as non-agricultural barangays.

In addition to the primary datasets, secondary datasets were requested and acquired from government-funded research projects, non-government organizations (NGOs), and the local planning and agriculture office.

3.2 Normalization

To make all the indicator values comparable and congruent, they were standardized to fit within the range zero (0) to one (1) using either linear normalization or Z-score, depending on the type of data. Linear normalization was done using the formula:

$$Z_{ij} = (X_{ij} - X_i^{min})/(X_i^{max} - X_i^{min}) \quad (1)$$

Where:
Z_{ij} = normalized value of indicator i to barangay j
X_{ij} = original value of indicator i to barangay j
X_i^{max} = highest value
X_i^{min} = lowest value

For ordinal data, i.e., hierarchical arrangement but without meaningful interval, standardization using Z-score was applied using the online calculator Measuring U (www.measuringu.com/pcalcz.php)

3.3 AHP

To compute for the composite index, which is defined as the weighted average of all the normalized indicator values, weights were determined and assigned using Analytic Hierarchy Process (AHP.

AHP, which is also called Saaty Method, is a complex decision making tool introduced by Thomas Saaty (1980). It is a theory of measurement primarily performed through pairwise comparisons and relies on the judgements of experts to derive priority scales (Saaty, 2008; Mendoza et al., 2014).

AHP was used to determine the weights of indicators in every component of the composite index. The same weighting method was utilized in assigning the exposure weights of the land cover classes.

The selection of experts is crucial as the credibility of the results substantially depends on it. The criteria for expert selection were familiarity with the agricultural characteristics of the barangays and/or municipality and sufficiency of knowledge on flooding and its impact on the agricultural sector. Thirteen to fifteen experts were consulted per indicator type to rate the indicators for exposure, sensitivity, adaptive capacity, and the LULC classes.

According to Saaty (1980, 2008), for a set of ratings to be considered acceptable, its computed consistency ratio (CR) should be less than or equal to 0.1, otherwise, ratings should either be repeated or disregarded. However, Kluhto (2013) and Alonso and Lamata (2006) argued that the tolerance value can be raised to 20 percent which corresponds to an acceptable CR of less than 0.2. This research used a CR threshold of 0.2.

3.4 Vulnerability Indicators

The indicators were finalized based on the judgement of experts from different fields and on the availability of data. Experts included barangay agriculture technicians, barangay and municipal agricultural officers, representatives from farmer organizations, researchers conducting VA studies, and representatives from agricultural schools, among others. A total of 30 indicators were determined: 5 for exposure, 13 for sensitivity, and 12 for adaptive capacity.

3.4.1 Exposure

Exposure, an external factor, is the nature or degree to which a system is exposed to significant climatic variations taking into account the frequency, duration, and/or extent in which the system is in contact with a hazard (Locatelli et al., 2008; Heng et al., 2013; Doch et al., 2015).

Inputs in the flood hazard and flow depth models (see Figure 4) provided by DREAM in September 2016 include data from three (3) PAGASA RIDF (rain intensity, duration, and frequency) stations located in Romblon, Roxas City and Iloilo City. Moreover, precipitation data was derived from 14 DOST-ASTI ARG (automated rain gauge) stations distributed throughout the province of Aklan – two of which are located within Kalibo. The produced vector layers have 10-meter resolution showing floods for storm events with a five-year return period (i.e., 20 percent chance of occurrence in any given year).

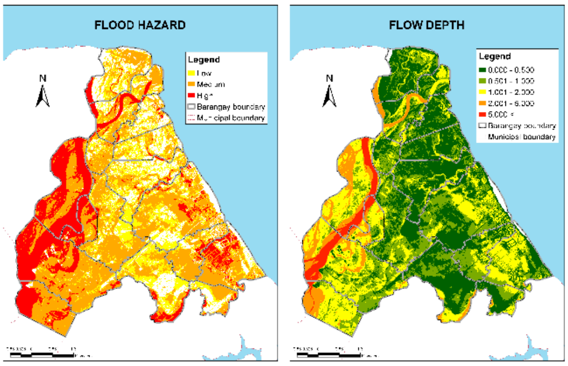


Figure 4: Flood hazard map (left) and flow depth map (right) from DREAM Phil-LiDAR 1.

The flood hazard data was divided into three levels based on the flood height and the product of velocity and height (VH); these levels were as follows:

- Low (flood height of 0.1m to 0.5m and VH of $0.1m^2/s$ to $0.5m^2/s$)
- Medium (flood height of 0.5m to 1.5m or VH of $0.5m^2/s$ to $1.5m^2/s$)
- High (flood height of more than 1.5m or VH greater than $1.5m^2/s$)

Two indicators were derived from the flood hazard data; one accounted for the area covered by the hazard while the other provided the level of the hazard.

On the other hand, flow depth data was divided into five (5) classes with the following ranges: less than 0.500m, 0.501m to 1.000m, 1.001m to 2.000m, 2.001m to 5.000m and more than 5.000m.

LULC was also included in the exposure component. Classes were divided into non-agricultural features, grain crops, tree crops, and oil crops. Each class was assigned an exposure weight based on the ratings of experts. Exposure weight per LULC in the area should be identified as crop reaction and/or response to flooding varies.

Out of the 15 experts consulted to rate the degree of exposure of LULC classes to fluvial flooding, 13 expert ratings were able to meet the tolerance value of 20 percent. The computed weights using AHP are shown in Table 1.

Table 1: Weights of LULC classes.

LULC	Weight
Non-agricultural features	0.0000
Grain crops	0.5695
Oil crops	0.1617
Tree crops	0.2688

Resulting weights indicated grain crops as the most exposed crop at almost two times more exposed than tree crops and almost four times more than oil crops. Some of the factors that affected the ratings were the degree of resilience of the crops to flooding, the sturdiness of the crops, and the degree of potential damage to the crops based on cropping period.

The finalized exposure indicators were based on the ratings of the 13 experts, 11 of which were considered consistent. The list of exposure indicators and their corresponding weights are shown in Table 2.

Table 2: Computed weights of exposure indicators.

Indicator	Weight
Flood hazard (area)	0.2429
Flood hazard (level)	0.2869
Flow depth	0.1582
LULC	0.3120

3.4.2 Sensitivity

Sensitivity, an internal factor, is the degree to which a system is affected, either adversely or beneficially, by a hazard (Locatelli et al., 2008). It is also defined as the extent to which a system can absorb impacts without having a significant change in state (Heng et al., 2013).

For the study, 13 sensitivity indicators as listed in Table 3 were determined and rated by the experts; most of these indicators were collected through KIIs with farmer households. Five experts (out of the 14 local experts) met the required 0.2 CR value.

Table 3: Sensitivity indicators identified by the experts and corresponding weights determined using AHP.

Indicator	Description	Weight
Population density[2]	Ratio of the number of people per $1km^2$	0.1040
Dependence ratio[1]	Ratio of the number of unemployed HH members to total number of HH members	0.0646
Human sensitivity[1]	Ratio of number of HH members that are elderly (65y/o<), children (>5y/o), PWD (person with disability), pregnant, with chronic illness to total number of HH members	0.0786
Hunger incidence[2]	Households were asked if they experienced hunger in the past three months	0.0562
Poverty rate[2]	Number of households meeting the poverty threshold of the province over the total number of households	0.0490
Level of education[1]	HH member with highest educational attainment	0.0381
Tenurial status[1]	Ownership of the agricultural land (i.e. owned, leased, tenant, etc.)	0.1008
Membership[1]	Membership in a farming organization	0.0691
Percent agri income[1]	Percent of income from agriculture over total income	0.1128
Percent debt[1]	Percent of debt over total income	0.0983
Access to PHF[1]	Access to post-harvest facilities	0.0954
Access to roads and bridges[1]	Access to various transportation media	0.0761
Road density[3]	Ratio of road area to land area	0.0570

Legend

1	Gathered from HH surveys
2	From CBMS (Community-Based Mapping System)
3	Derived from LULC

3.4.3 Adaptive Capacity

Adaptive capacity, an external factor like exposure, is the ability of a system to adjust to a hazard (Locatelli et al., 2008) or evolve (Doch et al., 2015) in order to accommodate environmental hazards and neutralize potential damages, or to take advantage of opportunities of planning to expand its range of variability for coping. The data for the 12 adaptive capacity indicators (Table 4) were gathered from HH surveys and were consistently rated by 13 experts.

Table 4: Adaptive Capacity indicators identified by the experts and corresponding weights determined using AHP.

Indicator	Description	Weight
Percent non-agri income	Percent of income from non-agriculture activities over total income	0.1004
Percent savings	Percent assets/savings over total income	0.0932
Access to loan	HH access to loans or credits	0.0969
Access to financial aid	HH access to financial aid from government and/or non-government organizations	0.0878
Access to rehabilitation	HH access to rehabilitation and aid	0.1210

Table 4: Adaptive Capacity indicators identified by the experts and corresponding weights determined using AHP (cont.).

Indicator	Description	Weight
Access to training courses	HH access to training courses focused particularly on climate variability and farming	0.0685
Farming experience	Length of farming experience of the HH	0.0646
Crop selection	Whether crop selection is determined by season/potential hazards	0.0746
Level of mechanization	Level of agricultural mechanization (e.g. use of machineries)	0.0846
Insurance	Insurance of agricultural land and/or crops	0.1045
Disaster and hazard policy	Disaster preparedness	0.0557
Means of transportation	Means of transportation of the HH (motorized and non-motorized)	0.0482

3.5 Vulnerability Index

The overall vulnerability index of the agricultural crops was computed using the formula:

$$\text{Vulnerability } \boldsymbol{V} = [(\text{Exposure } \boldsymbol{E} + \text{Sensitivity } \boldsymbol{S}) - (\text{Adaptive Capacity } \boldsymbol{A})] \quad (2)$$

It was acknowledged by Doch et al. (2015) that vulnerability is scale dependent since the scale of analysis affects the result and the pattern being identified. Because the datasets have different scales, the level of analysis was set to barangay level and with a 500m x 500m grid. Political boundaries acquired from NSO were intersected with a generated 500m x 500m fishnet to produce clipped tiles based on the agricultural barangay boundaries. Calculations were made per tile. Moreover, area weighted average per barangay was also computed and a comparison of the results was then performed.

3.6 Validation of Vulnerability Maps

To validate the results of the vulnerability index, historical accounts and damage reports were requested from the local planning and agriculture office of the municipality. Farmer HHs were interviewed regarding the frequency and magnitude of flooding in the area and the damage caused to the agricultural sector. First-hand experiences were also recorded to aid in the analysis and validation of the vulnerability maps.

4 RESULTS AND DISCUSSION

A model was created in ArcMap to automate the processing of datasets from data pre-processing to the production of exposure, sensitivity, adaptive capacity and vulnerability shapefiles. Scripts were also provided for the normalization of exposure data.
Using the constructed model, values of exposure, sensitivity, adaptive capacity per agricultural barangay were calculated as illustrated in Figure 5. The stacked bars depict the vulnerability index equation. The first set of bars represents the potential impact, i.e., the combined effects of exposure and sensitivity, which may be caused by the hazard. The vulnerability ratings of the barangays were obtained by subtracting the positive implications of adaptive capacity from the potential impact.

As observed in the results, Tinigaw was tagged to be the most vulnerable barangay with a rating of 0.7286 followed by Mobo with 0.7081. Linabuan Norte and Tigayon were not far behind with ratings of 0.6878 and 0.6393, respectively. Another barangay above the 0.6 vulnerability rating was Caano with 0.6149.

When the flood hazard, flow depth, and LULC maps were inspected, four out of the five most vulnerable barangays were found to be located along the river. Since overflow of water from the river is one of the primary drivers of flood hazard in the subject area, barangays adjacent to the river were expected to be more vulnerable, as supported by the produced maps. Furthermore, based on actual interviews with the farmers, the effects of riverine flooding in their barangays were certainly prominent especially when the water level in the river became higher than usual, further amplified by heavy rains brought by typhoons.

Caano is the only barangay not located along the river. It is mostly covered with agricultural crops, particularly grain crops which were scored as the most vulnerable to flooding. This pulled the exposure rating of the said barangay since LULC has the highest weight for the exposure component.

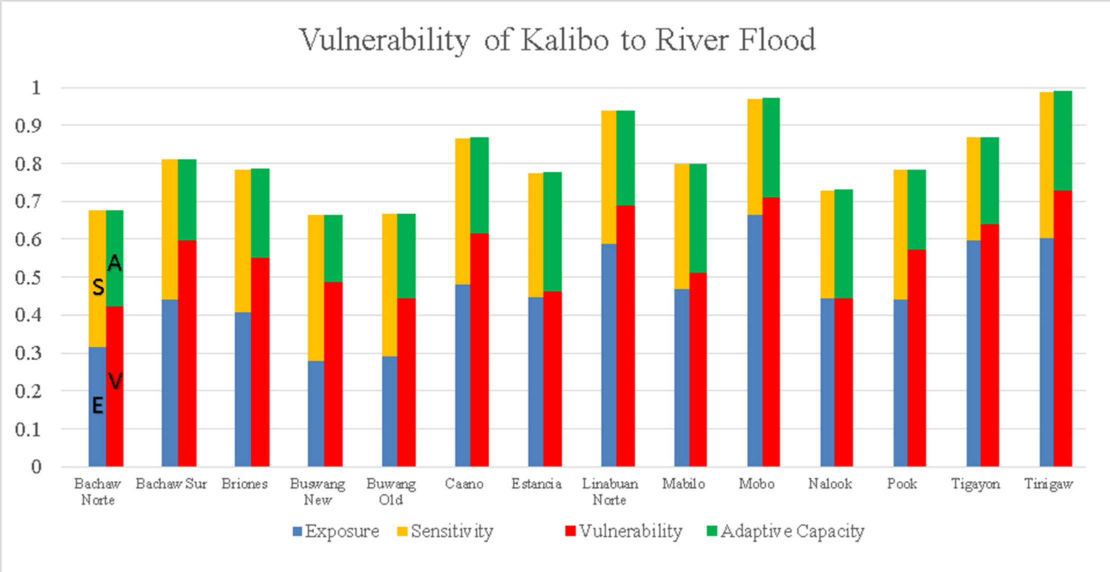


Figure 5: Computed values of every agricultural barangay. Blue bars indicate the exposure (E) rating of the barangays, yellow bars represent sensitivity (S), green bars portray the offset caused by adaptive capacity (A), and red bars show the computed vulnerability (V) ratings of the barangays.

When the exposure ratings alone were inspected, a great difference between the values of the top two most vulnerable barangays was observed. Mobo, in fact, was more exposed by more than 0.06. However, the populace of Tinigaw was considered more sensitive.

The next barangays in the ranking, Bachaw Sur, Pook, and Briones, showed the same trend having relatively similar values of exposure, sensitivity, and adaptive capacity. Also, these barangays have the same geographical features, i.e., are near water bodies and are covered by agricultural crops.

Mabilo and Buswang New, the succeeding barangays in the ranking, are coastal barangays. Based on the previously discerned trends, it could be assumed that these barangays should have the same vulnerability rates with the other barangays near water bodies, in close proximity to either the river or the sea. However, the results diverged from these deductions, with the reason perceived to be the land cover of the area. Since agricultural crops are not very prominent in the area, the land cover was not subject to much exposure.

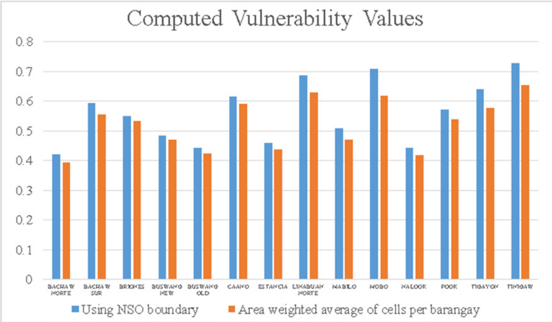
In the case of Estancia, its computed hazard (exposure and sensitivity) was almost 0.8 – near the hazard value of Pook which ranked 7th. However, its vulnerability score was not as high due to the counter effect of its adaptive capacity.

Nalook, on the other hand, is situated far from bodies of water. Though covered mostly by agricultural crops, Nalook was not perceived to be vulnerable because of its relatively greater distance away from the river and the sea.

The least vulnerable barangays, Buswang Old and Buswang New, have the exact opposite situation from that of Nalook. Both barangays are near the river and are coastal barangays. Additionally, very few agricultural crops were planted in the area. This was also verified during the HH survey as less than ten farmer households were known to the barangay offices.

These results were validated with the agricultural crops damage report prepared by the Kalibo agriculture office (2008). Based on the report during Typhoon Frank, Mobo was the most devastated barangay with damages amounting to almost PHP 7 million. In addition to that, more than PHP 3 million worth of agricultural products and infrastructure were destroyed in Linabuan Norte, and Tigayon. The farmers' first-hand experiences corroborated the results of the map with almost 75 percent of the respondents confirming the destruction brought by Frank.

The computed area weighted average of cells per barangay was compared with its corresponding vulnerability value computed using the NSO boundary. Identical rankings were observed in both datasets, although the results using grids were consistently lower as illustrated by the bar graph in Figure 6. Further, discrepancies in the data increase as the vulnerability values for both scales increase.



Figures 6: Vulnerability index values computed using two different scales.

The observed trends may be attributed to the generalization of the barangay data. Since an assumption was made that the primary HH data gathered applied to the entire barangay, generalizing the inputs amplified the effect of the indicators. Setting a smaller grid size may further decrease the vulnerability values. Thus, it is recommended for future studies to conduct geotagging during the farmer HH interviews for a more accurate dataset coverage. Moreover, participatory mapping will be beneficial especially in analysing the results. Further researches on the effect of scale in the computation of vulnerability indices is recommended.

Vulnerability maps representing the results of the composite index are shown in Figures 7 and 8.

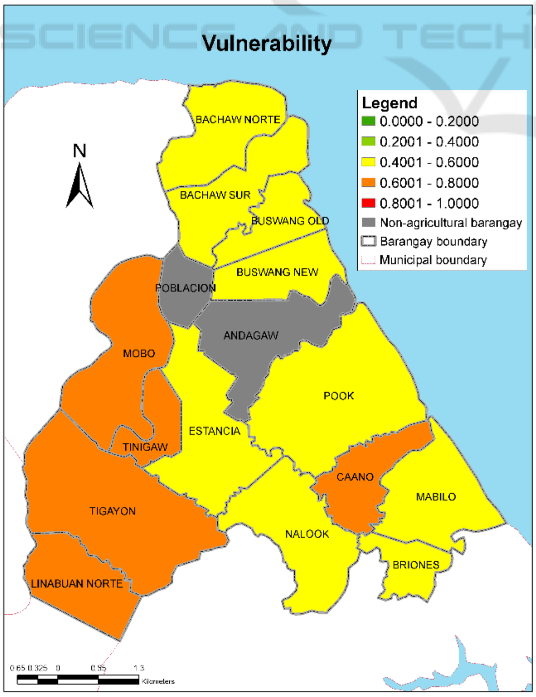


Figure 7: Barangay-level vulnerability of agricultural crops to floods in Kalibo.

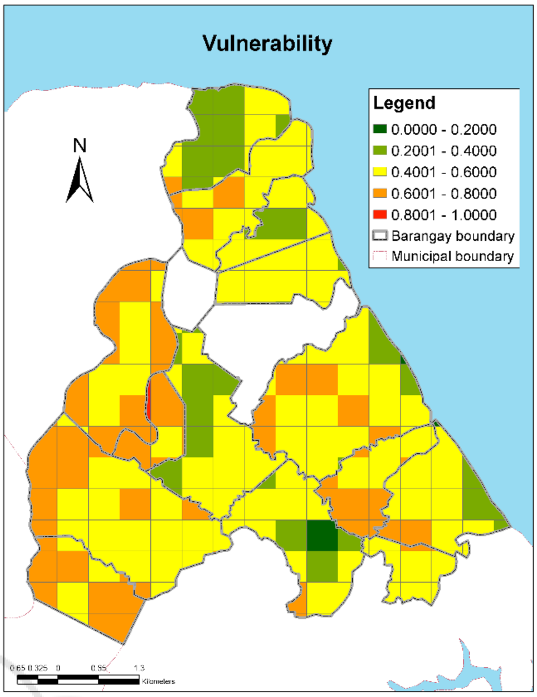


Figure 8: Vulnerability of agricultural crops to floods in Kalibo using 500m x 500m grid.

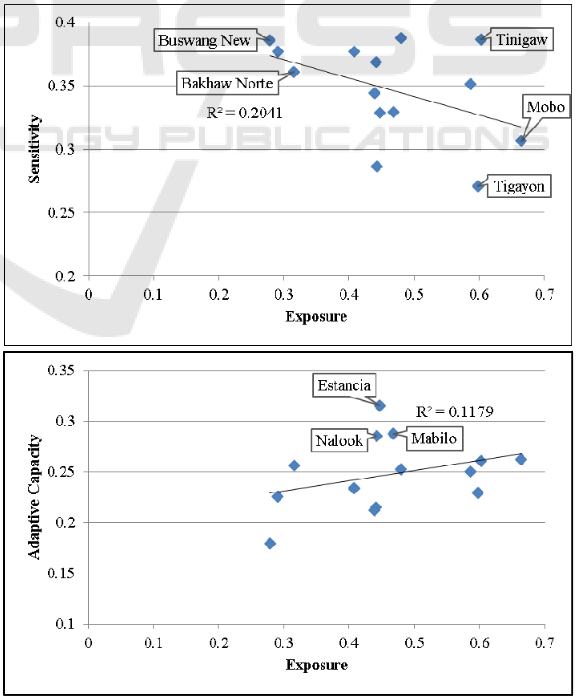


Figure 9: Plot of exposure vs. sensitivity values (top) and exposure vs. adaptive capacity values (bottom).

Shown in Figure 9 are scatter plots of the computed component values per barangay. The plots show the distribution of exposure values versus sensitivity and adaptive capacity values. In the first plot, it can be observed that the most vulnerable barangays were also the most exposed. These kinds of values often lead to the common misconception of exposure equating vulnerability and sensitivity. However, when the data was analysed such as in the case of Bachaw Norte, the data showed that although it was not the least exposed, it was the least vulnerable. This was due to its relatively lower sensitivity. A number of barangays were tagged as having moderately high vulnerability because of the linear relationship between exposure and sensitivity ($R^2 = 0.2041$). To counteract the effect of exposure, sensitivity should be low, i.e. a plot of the two should form a steep inverse slope.

In the second plot (Figure 9), Estancia, Nalook, and Mabilo have lower vulnerability ratings despite their high exposure values because of their adaptive capacity values. Lower vulnerability ratings are attained when the plot of exposure versus adaptive capacity forms a steep slope.

In general, the relationships of exposure to sensitivity and adaptive capacity as shown in Figure 9 provide indication that Kalibo and its barangays over the years have somehow adapted to some degree in dealing with flood hazards. Barangays with greater exposure have higher sensitivity and some barangays, which have higher exposure, have relatively lower sensitivity. It can also be said that barangays with relatively higher exposure have developed ways such that they have higher adaptive capacity.

5 CONCLUSIONS

Vulnerability of the agricultural sector to fluvial flooding is influenced by a number of factors. External factors alone do not dictate the state of the municipality. The socio-economic and agro-ecologic status of the affected community greatly contributes to the overall condition of the subject area. Thus, internal factors i.e. factors that are within the control of the community must be identified, assessed, and addressed. Moreover, identifying the factors affecting the vulnerability of Kalibo and assessing them are crucial in improving the condition of the municipality through planning, effective decision making and imposing policies that can ameliorate the coping capabilities and adaptive capacity of the community.

As illustrated by the case of Estancia, vulnerability was alleviated because of the adaptive measures of either the households or the barangay. For a more efficient response to force majeure, a collective effort from both the farmers and the local government unit is required. Likewise, vulnerability maps, plans, and policies are useless when they are not utilized and followed. Therefore, action from and coordination of all involved individuals and groups is essential. Although vulnerability assessment is not a panacea, this study can serve as a practical guide in alleviating the damage caused by riverine flooding in the agricultural sector of Kalibo, Aklan.

The results will be provided to local government units and stakeholders to aid in the decision making process for generating policies and/or programs that may improve the adaptability of the agricultural system during the occurrence of flooding.

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