# GIS-BASED VULNERABILITY ASSESSMENT OF HOUSEHOLDS TO EXTREME RAINFALL-INDUCED FLOOD HAZARD IN BARANGAY 2, CABADBARAN CITY

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**ABSTRACT:** Floods are a natural phenomenon on earth and becoming a widespread problem as the global temperature rises. During the tropical storms Sendong, Seniang, and Agaton hit the Philippines, Cabadbaran City was one of the affected areas by floods, and the vulnerability of each household was not yet determined. Thus, in assessing the vulnerability of each household, the socio-economic aspects in different flooding scenarios were used. Analytical Hierarchy Process was used as the medium for the prioritization of weights. Three domains were considered in this study, such as sensitivity, adaptive capacity, and exposure. The equation and ratings gathered from NEDA were used, and the vulnerability of each household was then calculated using GIS. The six (6) classifications used in this study of flood vulnerability of each household were 0, 0.20, 0.40, 0.60, 0.80, and 1.0, where 0 was considered as not vulnerable, 0.20 as very low, 0.40 as low, 0.60 as moderate, 0.80 as high and 1.0 as very high. The outputs of this study were the different levels of vulnerability of each household in different flooding scenarios through a series of maps.

## 1. INTRODUCTION

Floods are a natural phenomenon on earth and are becoming a widespread problem as the global warms. Concerning the loss of lives and property damaged, floods were considered behind tornadoes as the top natural disaster (Redd, 2017). The causes of widespread flooding through tropical storms. Mindanao is the most affected when the rivers overflow through heavy rains during Sendong, Sendong and Agaton in the Philippines (M.Santillan, J.Santillan, 2015). In Cabadbaran City, flooding occurs when there is excessive rain and causes the Cabadbaran River to overflow.

In this study, the use of a Geographic Information System (GIS) could be helpful for people to understand relationships, patterns, and trends by visualizing, analyzing, and interpreting data. (Williams, Robert, 1987). Vulnerability assessment plays an essential role in disaster management. It was considered as the key for effectively reducing disaster risk in vulnerable areas. The exposure, sensitivity, and adaptive capacity should be considered as the function in approaching vulnerability. Exposure refers to the number of times a household has been exposed. Sensitivity is the degree to which a system is affected adversely or beneficially by a given exposure. Adaptive capacity is the ability of a system to adjust to potential damage. The level of vulnerability depends upon the value of sensitivity, exposure, and adaptive capacity (Thi Phuong Dung Le, 2015).

However, the CSU Phil-LiDar 1 project created a map that showed the situation of Cabadbaran City when flooding occurs. The maps represented flood hazards at different flooding scenarios, specifically 2-year flooding, 5-year flooding, 10-year flooding, 25-year flooding, 50-year flooding, and 100-year flooding. Since there was already a generated flood hazard map, vulnerability assessment was conducted of every household. It focused more on the socio-economic aspects.

The main objective of this study is to assess the vulnerability of each household affected by floods. Specifically, this study aimed to determine the different factors used in vulnerability assessment, identify the affected household in different flooding scenarios, and generate maps that show the level of vulnerability of each household in different flooding scenarios.

This study played an essential role in identifying the extent and levels of vulnerabilities and the coping capacity to disaster within the community in Cabadbaran City. This study is also beneficial to the government of Cabadbaran City on the vulnerability of every household. The latter should then feedback into improving vulnerable communities' resilience and reducing future flood risks leading towards sustainable development. Lastly, a GIS-based flood vulnerability assessment of households would undoubtedly help the city find better solutions and adaptation strategies to reduce the damage due to flood, particularly to the people of Cabadbaran City.

## 2. MATERIALS AND METHODS

### 2.1 Data Gathering

The data used in this study was composed of geospatial datasets such as household, barangay boundary, and flood hazard shapefile at different flooding scenarios. The considered census data needed indicators in assessing the vulnerability of every household. All the gathered geospatial datasets from Geosafer-Agusan Project.

#### 2.1.1 Flood Hazard Shapefile

Flood hazard shapefile is a geospatial dataset generated to show the hazard level at different flooding scenarios. The classification is according to the depth of floodwater, specifically high, moderate, and low. CSU Phil-LiDar 1 project conducted a study that determined the level of flood hazard in Cabadbaran City. The project had created a flood hazard shapefile that can be used in this study to assess each household's flood vulnerability.

#### 2.1.2 Household Shapefile

Household shapefile is a geospatial dataset representing buildings/households, which can be used for overlay analysis. Household shapefile is essential, especially in this study. The CSU Phil-LiDar 1 Project generated a household shapefile which was used in this study. Before finalizing the household map, a field validation survey was conducted since there were changes in settlements around Barangay 2, Cabadbaran City.

#### 2.1.3 Census Data

Census data contains information about the population. These data can help study issues that can affect people. Since the study considered the socio-economic status of the people as a significant factor, census data played an essential role in assessing the vulnerability of each household. A field interview was conducted to gather information on each household.

### 2.2 Weighting of Factors

According to (Saaty T.L., 2008), Analytical Hierarchy Process (AHP) used a hierarchical framework to depict a problem and then developed priorities for alternatives based on the experts' judgments. It is a method of deriving ratio scales from paired comparison criteria and dealing with the consistency of the judgment of the experts. All those data that were gathered from the field interview were subjected to Analytical Hierarchy Process (AHP). Five different agency experts were chosen to rate the indicators, namely, NEDA, DENR, OCD, CDRRMO, and the Geosafer-Agusan Project. A pairwise comparison matrix was created for the computation of weights. The weight of every indicator was calculated by determining the nth root first, as shown in Equation 1 below.

$$\text{Nth root} = (X1 * X2 * \ldots\ldots\ldots\ldots Xn)(1/n) \quad (1)$$

where:

X = Rating of expert in pairwise comparison
n = Number of Indicator

The weight of each indicator was represented by eigenvector value. Eigenvector was calculated using Equation 2 below.

$$\text{Eigenvector} = \text{Nth root}/\sum(\text{Nth root}) \quad (2)$$

Another factor to be considered in conducting AHP was the consistency ratio, which refers to the consistency of judgment of experts. The consistency ratio was calculated using the value of the consistency index and the random index. The consistency index was calculated using Equation 3 below.

$$CI = (\lambda - n) / (n-1) \quad (3)$$

Once the consistency index was calculated, the consistency ratio can now be calculated by using Equation 4:

$$CR = CI/RI \quad (4)$$

where:

CI = Consistency Index

RI = Random Index

The required consistency ratio should not be greater than 0.20. The last part was to get the average eigenvector value of each indicator from five different experts to determine the final weight of each indicator.

### 2.3 Spatial Analysis

The geospatial datasets underwent spatial analysis upon integrating it with the census data gathered from the field interview using Arcmap version 10.4. The census data was inputted in an excel file, and thus, it was easily exported in Arcmap. Using the join tool in ArcMap, the census data was integrated with the geospatial datasets. A spatial analysis was conducted to determine the affected household in different flooding scenarios by using the selection tool in ArcMap. All households who were not affected by the flood would be given a value of zero. Each household that had been affected by floods would be given the value based on their socio-economic status. NEDA developed those values during the study of DENR in assessing the area's vulnerability near the Agusan River. The generated weights from AHP were also integrated with the census data in ArcMap. All indicators had an assigned weight belonging to different domains such as the sensitivity, exposure, and adaptive capacity domains. The sensitivity domain and adaptive capacity domain had an assigned weight of 35%. In comparison, the exposure domain had an assigned weight of 35%, while the exposure domain had 30%.

This study aimed to create a sensitivity map, adaptive capacity map, and exposure map in different flooding scenarios. Using the field calculator in ArcMap, each household's sensitivity and adaptive capacity were calculated using the weighted mean equation since the domain had several indicators. The exposure map was directly created because there was only one indicator that was considered. The vulnerability of each household was calculated using Equation 5 developed by NEDA and used by DENR in their study, as shown below.

$$\text{Vulnerability} = \text{Sensitivity} + \text{Exposure} + \text{Adaptive Capacity} \quad (5)$$

Using the field calculator again in the ArcMap, the vulnerability of each household was created in different flooding scenarios.

## 3. RESULTS AND DISCUSSION

### 3.1 Generation of Weights

There were too many factors that were considered in this study, and an Analytical Hierarchy Process (AHP) was conducted to assign weights to the indicators relative to their impact on the vulnerability of each household. The total weight of all indicators under the sensitivity domain equals 1. The vegetative cover indicator had the highest score of 0.1868, while the predominant land use indicator was 0.1182. The vegetative cover had a significant impact on the sensitivity domain compared to other indicators. In the adaptive capacity domain, there were 11 selected indicators, and access to early warning system ranked number 1 with the weight of 0.2504.

In contrast, access to financial assistance got the lowest score of 0.0268. The access to an early warning system had the highest impact in terms of adaptive capacity against other indicators. The weight of every indicator played a massive role in assessing the vulnerability of every household.

### 3.2 Vulnerability Assessment

All households which fall to very high sensitivity and high exposure tended to be highly vulnerable. However, that would not directly determine the vulnerability of each household because adaptive capacity should also be considered. All households which fall to very high adaptive capacity were very low invulnerability. Hence, combining these three (3) domains should be done to determine the overall flood vulnerability of each household in different flooding scenarios. Figure 1 shows the 2-year flood vulnerability map. Its flood vulnerability household statistics was shown in Figure 2, there were 35 households considered as moderately vulnerable, 15 as low, and 73 households were considered as not vulnerable.

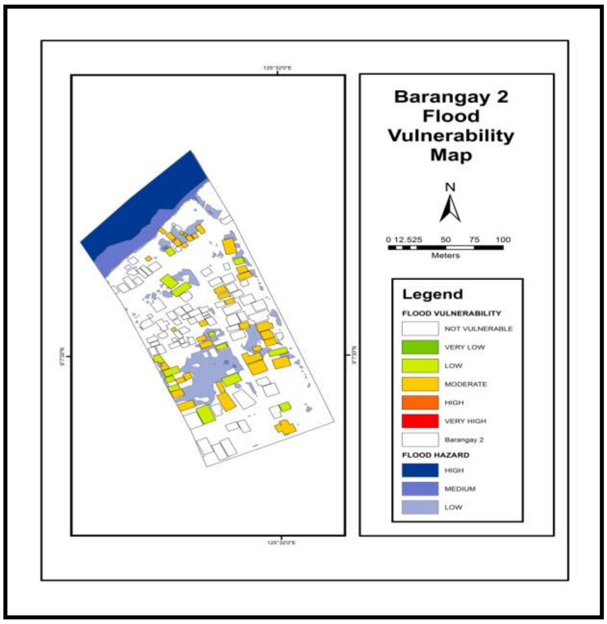


Figure 1. 2-year Flood Vulnerability Map

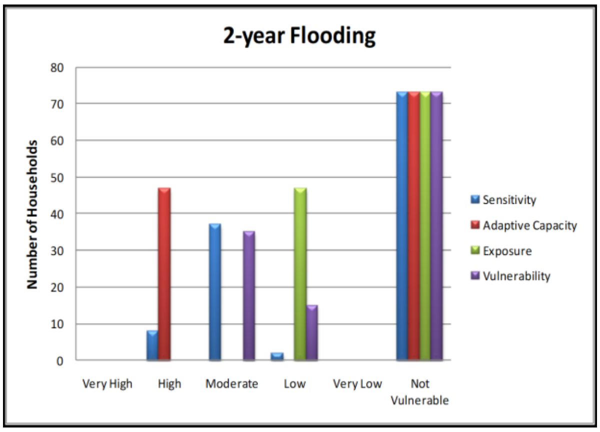


Figure 2. 2-year Flood Vulnerability Household Statistics

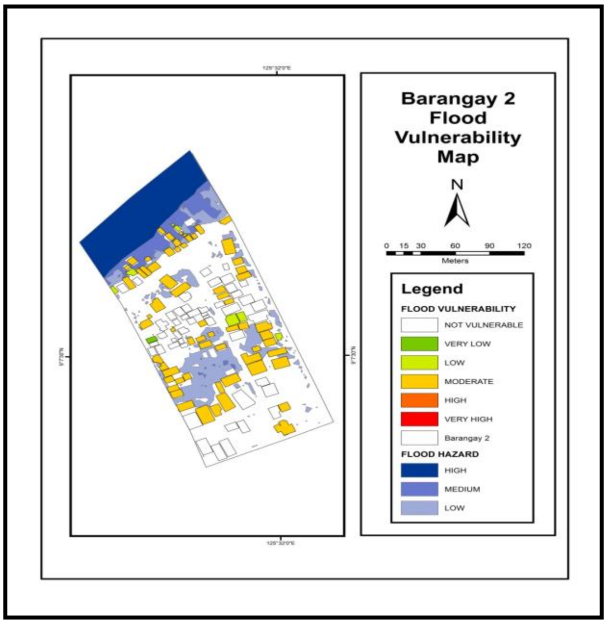


Figure 3. 5-year Flood Vulnerability Map

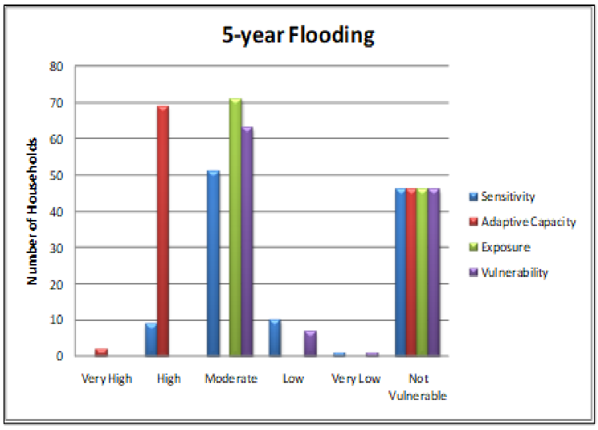


Figure 4. 5-year Flood Vulnerability Household Statistics

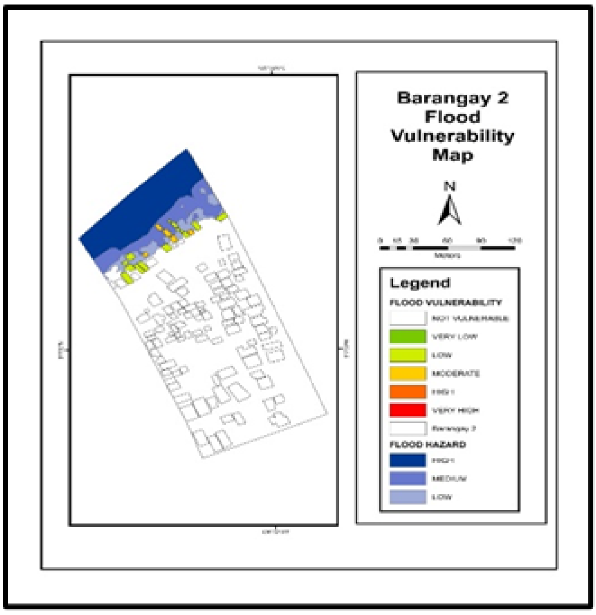


Figure 5. 10-year Flood Vulnerability Map

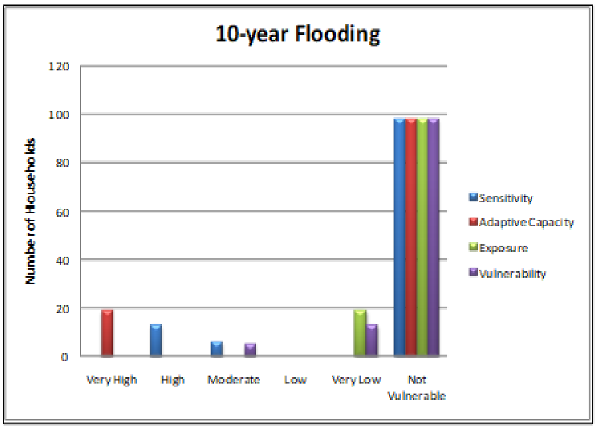


Figure 6. 10-year Flood Vulnerability Household Statistics

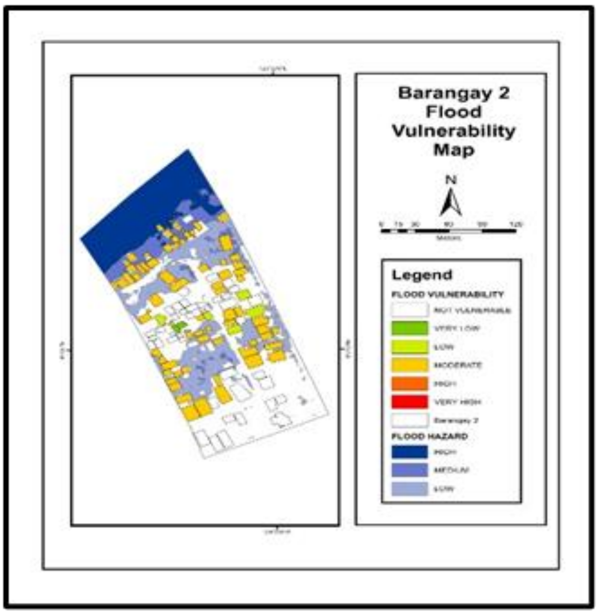


Figure 7. 25-year Flood Vulnerability Map

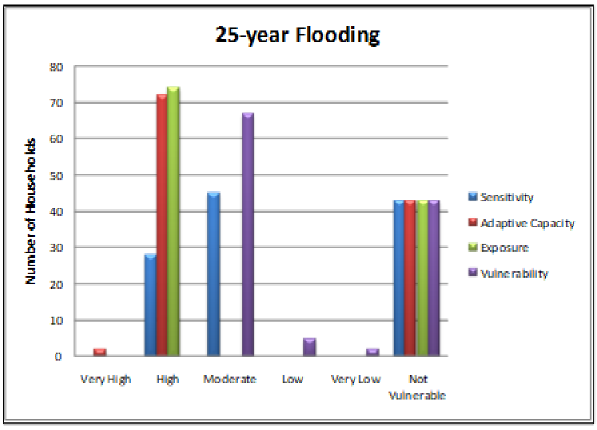


Figure 8. 25-year Flood Vulnerability Household Statistics

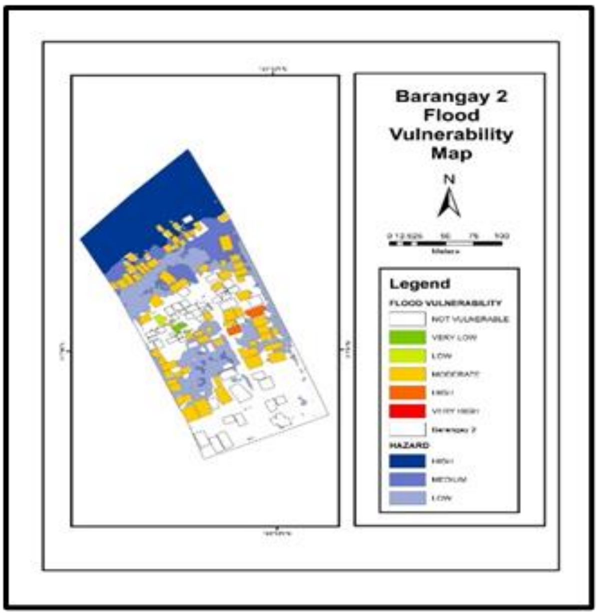


Figure 9. 50-year Flood Vulnerability Map

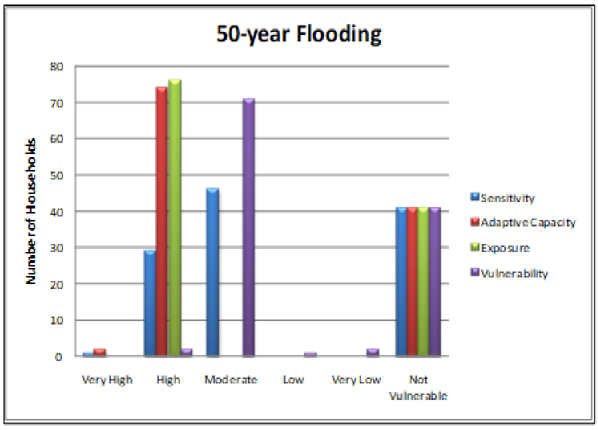


Figure 10. 50-year Flood Vulnerability Household Statistics

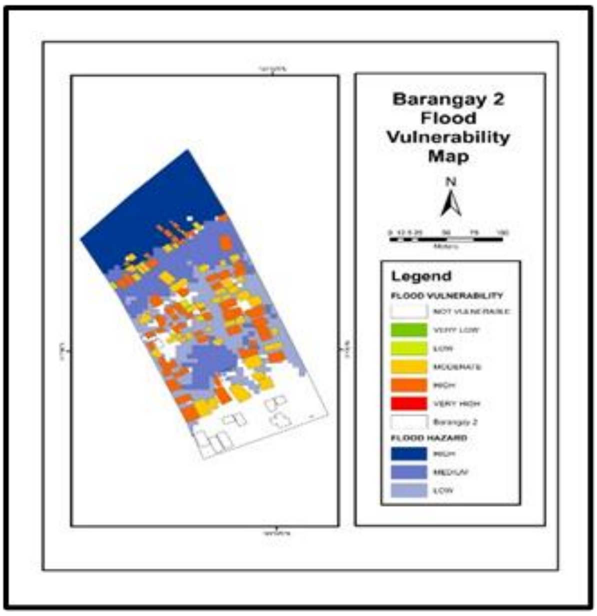


Figure 11. 100-year Flood Vulnerability Map

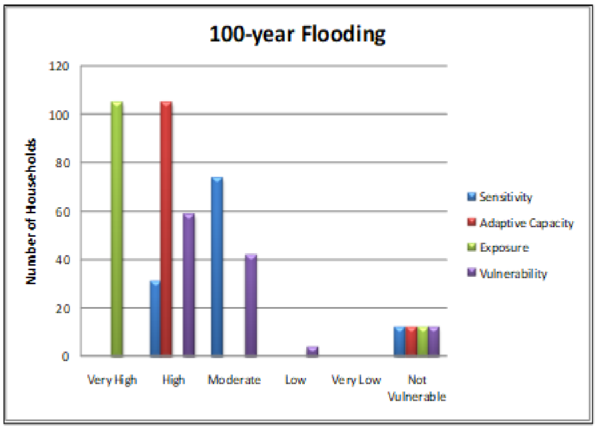


Figure 12. 100-year Flood Vulnerability Household Statistics

In Figure 3, the number of households who belonged to different categories in 5-year flooding and 5-year flood vulnerability household statistics was shown in Figure 4. The households considered as moderately vulnerable are 63, 7 as low, one household as very low, and 46 were not vulnerable.

For 10-year flooding, as shown in Figure 5 and 10-year flood vulnerability household statistics as shown in Figure 6, 5 households were moderately vulnerable, 13 as very low, and 98 were not vulnerable. In 25-year flooding as shown in Figure 7 and 25-year flood vulnerability household statistics as shown in Figure 8, 67 households were considered as moderately vulnerable, 5 as low, 2 as very low, and 43 were not vulnerable.

On the other hand, Figure 9 and Figure 10 shows that there were 2 households considered as highly vulnerable, 71 as moderate, 1 as low, 2 as very low, and 41 were not vulnerable. Figure 11 and Figure 12 shows that 59 households were considered as highly vulnerable, 42 as moderate, 4 as low, and 12 as not vulnerable.

Finally, the number of households that were highly vulnerable increases as the scenario of flood leveled up. The vulnerability of each household has been analyzed and assessed using different factors that may contribute to their vulnerability to flooding.

## 4. CONCLUSION

The study results show that the damage of floods could be lethal to the residents of Barangay 2, Cabadbaran City, as the level of flooding scenario goes high. The researcher found out that referring to flood hazards only does not give accurate information to determine the vulnerability of each household. Some households were considered very low, low, or moderately vulnerable even if they belonged to high hazards. Some households were highly vulnerable, even if they were in low-hazard areas due to the socio-economic aspects of each family. The researcher also found out that having so many adaptive capacity factors could lessen the overall vulnerability of each household since adaptive capacity is the reciprocal of vulnerability.

To further improve this study, the researcher recommends adding more factors under the sensitivity, exposure, and adaptive capacity domains to provide more accurate results. It is also recommendable to apply the study to a wider area since it is usable in determining the vulnerability of each household. Lastly, considering environmental and physical components aside from social and economic components would also provide detailed results.
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