

Flood Susceptibility Mapping in the Municipality of Bayombong, Province of Nueva Vizcaya, Philippines

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Abstract

The municipality of Bayombong is one of the municipalities in the Philippines that has greatly suffered from flood impacts. In order to minimize the severe impacts of flood, flood susceptibility map can be formulated. Therefore, this study was conducted to generate a flood susceptibility map of the municipality of Bayombong. It further aimed to determine the areas in hectares for each level of susceptibility to flood based on the chosen flood-influencing factors namely, precipitation, elevation, distance from river, slope, and land cover. Furthermore, the study used the AHP technique and GIS weighted overlay tool in determining the municipality's susceptibility to flood. The five factors were classified into five (5) flood susceptibility level (very low, low, moderate, high, very high). The results presented in this study shows that the majority of the municipality is high susceptible to flood with an area of 5,655.40 hectares. Moreover, Bonfal East, Bonfal West, Bonfal Proper, District 4, Don Domingo Maddela, Don Mariano Marcos, Don Tomas Maddela, Don Mariano Perez, La Torre South, Luyang, Salvacion, San Nicolas, Santa Rosa and Vista Alegre are the most critical, while Buenavista is the least flood susceptible. In addition, the validation conducted with the use of GPS-based field survey and geotagging, indicates that the points validated conforms with the level of flood susceptibility according to the flood susceptibility map generated.

Keywords: Flood susceptibility map, AHP, GIS

Introduction

Flood is a recurring natural hazard that adversely affects the lives and properties of many people around the world. It can be attributed to natural and man-made factors such as climate change, increasing precipitation, deforestation, population growth and urbanization (Edamo et al. 2022).

In the Philippines, major floods were caused by the prevalence of typhoons and heavy rainfalls. The geographic location and physical characteristics of it exposes itself from numerous tropical cyclones every year provoking severe floods especially in low-lying areas. According to the World Bank (2021), an average of 20 typhoons make landfall in the Philippines every year. In 2011 alone, typhoon Sendong and its flooding killed 1,257, injured 6,071, and affected 1,141,252 families in Luzon (ADRC, 2011). To prevent floods or at least lessen the impacts of it, an updated and reliable information is essential. Flood susceptibility map is a crucial piece of information that can be used to mitigate severe flood impacts.

Flood susceptibility mapping is an efficient strategy in flood risk management planning. It shows the areas with a high possibility of getting inundated. Flood-prone maps define areas that may have disastrous flood events while flood-risk maps show the potential risk to the population, economy, and environment due to flooding (Gigovic et al., 2017).

Flood susceptibility mapping can be done by various methods and approaches. One quantitative approach is the Analytical Hierarchy Process (AHP). AHP is a decision-making procedure that combines multiple-choice criteria into hierarchy and these criteria are ranked based on their impacts using Pairwise Comparison Matrix (Yahaya, 2010). Many studies related to flood susceptibility mapping (Edamo et al., 2022; Cabrera et al., 2020) uses the AHP as a multi-criteria decision analysis strategy to map flood-prone zones.

For the past 15 years, three out of 25 barangays namely Ipil-Cuneg, Cabuaan, and Casat are reported to have not suffered from flooding while the remaining barangays severely suffered from it (MDRRMC-Bayombong, 2022). One factor that caused it was typhoons or monsoon rains. In 2016, 2018, and 2020, typhoon Lawin, Ompong, Rosita, and Ulysses hit Bayombong, respectively. Ompong and Rosita happened successively in a year affecting 3,688 and 1,570 people, respectively. On the other hand, Ulysses affected 5,965 people. Furthermore, typhoon Yoyong (2004) and Quiel (2011) were reported to be the strongest typhoons affecting the municipality. An estimate of 30% to 40% of total houses were partially and totally damaged when these two hits (MDRRMC-Bayombong, 2022). However, flood susceptibility mapping for strategic flood risk management planning is still given insufficient attention. The need to define areas in Bayombong with high possibility of being inundated and at risk became important.

Considering the events of flooding caused by typhoons in Bayombong, this study was conducted to create flood susceptibility map within the municipality. Specifically, it aimed to identify flood susceptible areas in terms of the chosen flood indicators in hydrological, morphometric, and Land Cover. This study is significant in flood risk management planning and flood reduction. Also, knowing which areas are highly susceptible to flood helps the authorities in deciding what flood control can be done to mitigate or even prevent flooding in that particular area. For this purpose, the combination of Geographic Information System (GIS) and Analytical Hierarchy Process (AHP) was utilized in mapping and weighing the criterion for the flood susceptibility map, respectively.

Objectives of the Study

The study aimed to map flood susceptible areas of Bayombong through the application of Geographic Information System (GIS).

Other objectives were as follows:

1. To identify the area in hectares for each level of susceptibility to flood based on the following criteria:
 - a. Precipitation for the period 2015-2017
 - b. Elevation
 - c. Distance from river
 - d. Slope
2. To identify the area in hectares for each level of susceptibility to flood based on the Land Cover of the year 2020.
3. To identify the area for each level of susceptibility to flood in each barangay in terms of the overall result of the flood susceptibility map generated.
4. To generate a flood susceptibility map of the municipality of Bayombong.

5. To validate the generated flood susceptibility map of the municipality of Bayombong.

Methods

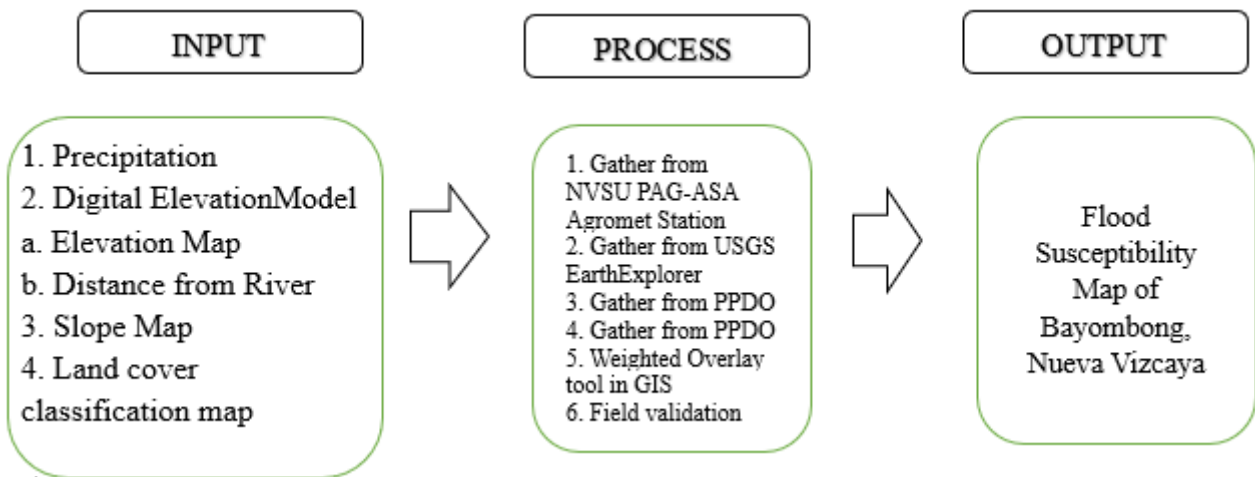
Research Design

The researchers obtained a quantitative data thus this study had a quantitative approach for the research design. Primarily, data such as the Digital Elevation Model (DEM) was collected from the USGS EarthExplorer, while the Land cover classification map, and slope map were obtained from the local Provincial Planning and Development Office (PPDO). The collected data from USGS and PPDO were in the mode of raster data which were forms of quantitative data and can be analyzed through GIS software. Moreover, the precipitation data was in excel format.

Conceptual Framework

The input or the independent variables of this study were the precipitation, Digital Elevation Model, Slope and the Land Cover classification map of the municipality. These data were processed and analyzed using Arc Geographic Information System 10.5 (ArcGIS 10.5). The average rainfall data in mm from 2015-2017 were inputted in GIS to create a rainfall map. The DEM was delineated to determine the elevation and major water drainage for the formulation of elevation map and distance from river thematic map, respectively. Secondly, the slope map and land cover map were obtained from PPDO. Afterwards, an AHP method was used to come up with a weight for each criterion. The weights were adapted from the study of Domanikis et al. (2020). After having the weights of the criterion, the weighted overlay tool in ArcGIS 10.5 was used to create the final output which was the flood susceptibility map. A validation was conducted through a GPS-based field survey and geotagging to investigate true ground points flooded by historical flooding events.

Figure 1: Conceptual Framework of the Study



Research Locale

The municipality of Bayombong is centrally located and is the capital town of the Province of Nueva Vizcaya. It lies between 121d02'08" and 121d13'31" East longitude and between 16d25'30" and 16d33'43" North latitude using the geographic coordinate system, WGS 1984 datum. It is equivalent to between 121d02'03" and 121d13'26" East longitude and between 16d25'36" and 16d33'49" North

latitude when using Philippines Zone III coordinate system, PRS 92 datum. It is bounded on the north by the municipality of Solano, on the east by Quezon, on the south by Bambang and on the west by Ambaguio and Kayapa (Figure 2). The municipality is politically subdivided into 25 barangays categorized into 10 uplands having 13,605.77 which constitute 84.18% of the municipality and 15 lowland barangays of 15.82% or 2,555.83 hectares. The 25 Barangays are known to be Bonfal East, Bonfal Proper, Bonfal West, Buenavista (Vista Hill), Busilac, Casat, La Torre North, Magapuy, Magsaysay, Mason, Paitan, Don Domingo Maddela Pob.(District I), Don Tomas Maddela Pob. (District II), District III Pob (Don Mariano Perez), District IV (Pob.), Banging, Cabuaan, Don Mariano Marcos, Ipil-Cuneg, La Torre South, Luyang, Salvacion, San Nicholas North (Luyang), Santa Rosa, Vista Alegre (B. Baringin). The total land area of the municipality derived through the cadastral survey conducted by the Department of Environment and Natural Resources Region 02 – Land Management System on CY 2012-2013 is 16,161.57 hectares.

The topographic condition of Bayombong is characterized by mountains and plain areas. Forest and forestland have an estimated area of 8,067.01 hectares. Agricultural area has an estimated area of 3,409.18 has. and open space areas which include idle areas and other land use covers an estimated area of 2,730.76 has. Built-up areas consist of residential area, commercial area, institutional area, cemeteries and roads, have an estimated area of 1,319.55 has, while bodies of water and agro-fishery areas have an estimated area of 558.57 and 17.36 has, respectively. On the other hand, Land cover is the physical land type where forest land is 53.80% or 8,694.40 has., and Alienable and disposable land are 7,467.17 has or 46.20% of the total land area and these are lowlands where roads, settlements, agricultural, industrial, and other economic activities are generally concentrated.

The elevation of Bayombong is predominantly 0-500 meters above mean sea level with an area of 9,439.26 has. More or less, 5,124.82 has of the municipality's land area and has an elevation ranging from 500-1,000 MSL. The remaining 1,597.49 has are located in elevations above 1,000 MSL. The highest elevation of 1,700 above MSL is situated in Mt. Palali.

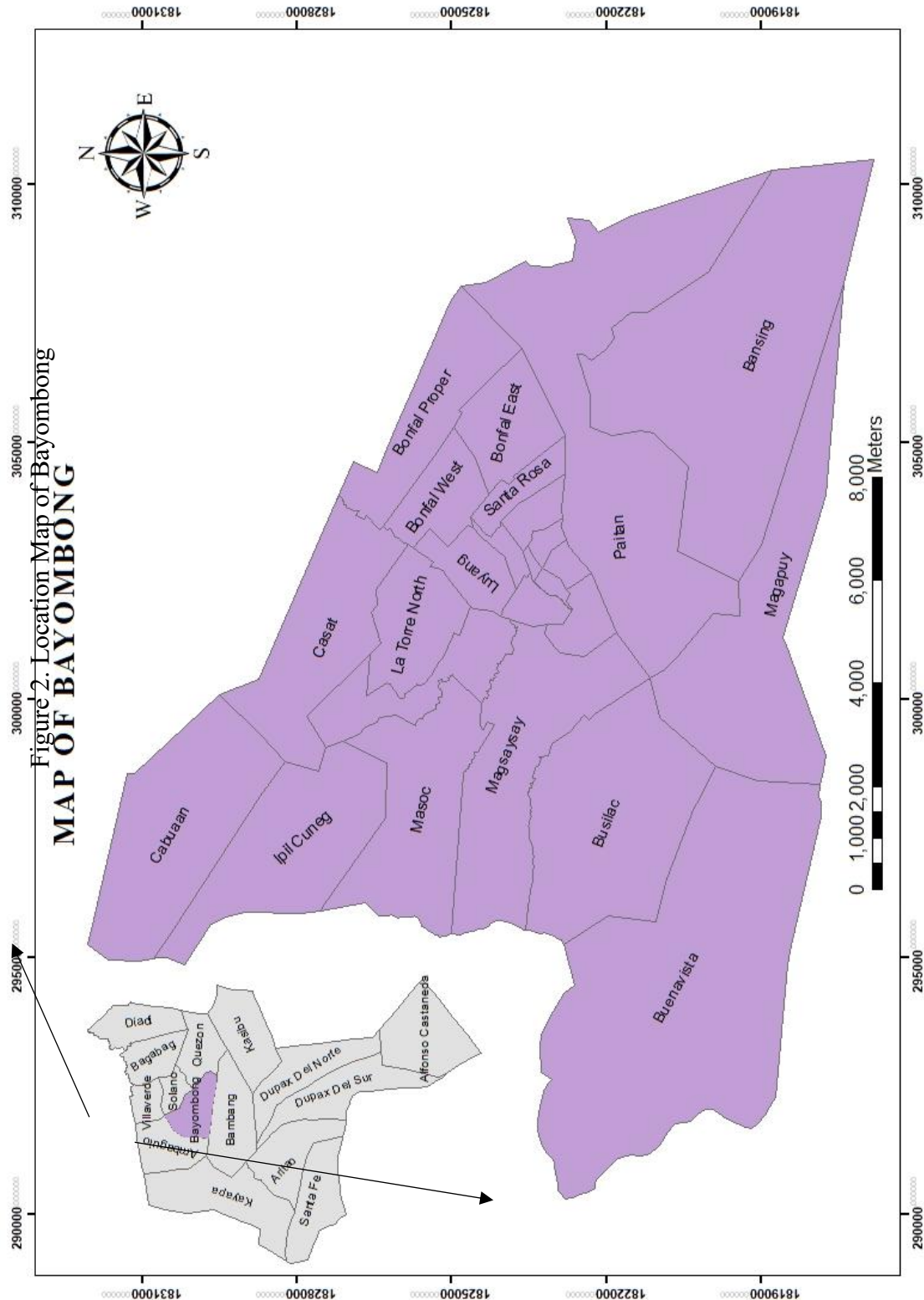


Figure 2. Location Map of Bayombong

Research Instrument

The research instrument of the study were the tools to support the results generated by the GIS. The researchers used a GPS camera and geotagging of photos in validating the areas identified as flood susceptible on the final flood susceptibility map. GPS-based field survey of local people and geotagging

images were carried out along the areas determined to be prone to flood to investigate true ground points flooded by historical flooding events.

Data Gathering Procedure

The data gathering procedure describes the process of gathering the data in preparation for analysis. The data in this study were based on the selected criterion or indicators of flood. The criterion of this study to determine the susceptibility of an area to flood were selected based on various case studies (Domanikis et al., 2020; Yahaya, 2010) and based on the available data in the study area. The criterion includes precipitation, elevation, distance from river, slope, and Land Cover. Thus, the data the researchers used in this study includes precipitation data, Digital Elevation Model (DEM) for the delineation of the distance from river and elevation map, slope map, Land Cover classification map, and lastly Bayombong administrative boundary.

The data were gathered according to the type of data. Table 1 shows the summary of Data, their description, and the sources.

A. Datasets and Data Acquisition

1. Precipitation

The researchers obtained the precipitation data from NVSU PAG-ASA Agromet Station. The rainfall data were from the period 2015-2017. A letter noted by the department chairperson and the dean of the college of engineering was passed on to the office of NVSU PAG-ASA Agromet.

2. Digital Elevation Model (DEM)

The researchers utilized the Shuttle Radar Topography Mission (SRTM) 1 Arc-Second Global DEM of Bayombong. The SRTM 1 Arc-Second Global has a spatial resolution of 30m and was downloaded from USGS EarthExplorer portal. The DEM includes larger region and by the use of the spatial analysis function in ArcGIS 10.5, the DEM of the study area was extracted by mask. The DEM was used in the demarcation of the watershed boundaries to generate major water drainage for creating distance from river thematic maps. Moreover, it was used to create an elevation map.

3. Slope map, Land cover classification map

A letter was sent to the Provincial Planning and Development Office (PPDO) to obtain the slope map, and Land Cover classification map. The mentioned data was in the form shapefile and was converted from polygon to raster using the conversion tool in GIS.

4. Bayombong administrative boundary

A letter was sent to the Provincial Planning and Development Office (PPDO) to obtain the Bayombong administrative Boundary. The Bayombong administrative boundary was in the form shapefile. It was used to demarcate the study area.

Table 1: Data and the source of each dataset.

Data	Description	Source
Precipitation	For the period 2012-2022; in mm/year	NVSU PAG-ASA Agromet
DEM	SRTM 1 Arc-Second Global, 30 m resolution	USGS EarthExplorer
Slope map	In shapefile format	PPDO-NV

Land Cover map	For the year 2020; In shapefile format	
Bayombong Administrative Bdry.	In shapefile format. Projected Coordinate System: WGS 1984 UTM Zone 51N Projection: Transverse Mercator False Easting: 500,000 False Northing: 0	

Statistical Tools

The study utilized the concept of Analytical Hierarchy Process (AHP) as a multi-criteria decision analysis (MCDA) strategy to generate a weight for each selected parameters in creating flood susceptibility map through weighted overlay tool in GIS. The AHP introduced by Saaty (1980) is a decision support tool and multi-criteria decision-making approach that is used to resolve complicated decision issues. Goals, criteria, and indicators are the three main levels of the hierarchical approach used by the AHP to characterize an issue.

The researchers adapted the weight of each criterion in the study of Domanikis et al. (2020) in conducting their study entitled “Flood Susceptibility Mapping in Erythrotamos River Basin with the Aid of Remote Sensing and GIS”. The table 2 and 3 below shows the pairwise comparison matrix from the study and the computation of the factor weights using arithmetic mean.

Table 2: Pairwise Comparison Matrix of the factors that affect flood susceptibility

	Elevation(E)	Slope(S)	Distance fr. River (D)	Land cover (L)	Rainfall (RF)
Elevation	1	2	3	4	5
Slope	1/2	1	2	3	4
Distance fr. River	1/3	1/2	1	2	3
Land cover	1/4	1/3	1/2	1	2
Rainfall	1/5	1/4	1/3	1/2	1
Total	2.283	4.083	6.833	10.5	15

Table 3: Normalized factor weights (Calculation of the factor weights with the use of arithmetic mean.)

	Elevation	Slope	Distance fr. River	Land cover	Rainfall	Mean	Weight (%)
Elevation	0.438	0.490	0.439	0.381	0.333	0.4162	41.62
Slope	0.219	0.245	0.293	0.286	0.267	0.2620	26.20
Distance fr. River	0.146	0.122	0.146	0.190	0.200	0.1608	16.08
Land cover	0.109	0.082	0.073	0.095	0.133	0.0984	9.84
Rainfall	0.088	0.061	0.049	0.048	0.067	0.0626	6.26

Statistical Analysis Procedure

A. Geographic Information System

After weighting the criterion, thematic maps of each criterion were created in ArcGIS 10.5 using spatial analysis tools. Below is the methodology of creating each of the maps.

1. Rainfall Map

For the precipitation or rainfall map, the average total annual rainfall data from 2015-2017 of Bayombong and its neighboring municipality were imported in ArcGIS 10.5. An interpolation method called IDW were used to interpolate the data in order to create the rainfall map of the province of Nueva Vizcaya. The rainfall map of Bayombong was extracted by masked.

2. Elevation Map

For the Elevation map, the DEM from USGS were utilized.

3. Distance From River Map

The distance from river map was derived from the DEM acquired from USGS explorer. The DEM undergone spatial analysis tool in ArcGIS 10.5. The first step was the fill tool, then the flow direction tool, followed by flow accumulation tool. After that, a raster calculator was used to compute the stream directions. Afterwards, a stream link was generated from the stream direction. Then, the stream link was converted to vector using the stream to feature tool. The vector map shows the river/drainage line, and it was used in multi-ring buffer tool as input to generate multiple buffers at a specified distances around the input vector map of river line.

4. Slope Map and Land Cover Map

For the Slope and Land cover map, it was acquired from PPDO in the file format shapefile. A conversion tool in ArcGIS 10.5 was used to convert the vector into raster.

All the thematic map (Rainfall map, elevation map, distance from river map, slope map, and land cover map) was reclassified into 5 classes. The table 4 below shows the distribution of the classes, each class’s ratings assigned, and the level of susceptibility for each class. The classes and ratings for each factor was adapted from the Development Academy of the Philippines (2020) module in Geographic Information System Hazard Modeling Training for Improved Decision Making and Early Warning Action of Local Government Units. Afterwards, the weighted overlay method was performed inputting the weights of the criterion for each factor in ArcGIS 10.5. A final flood susceptibility map was created.

Table 4: Synoptic table presenting the factors, their flood susceptibility classes (DAP, 2020), the rating that was assigned for each class (DAP, 2020) and the weight for each factor that was assigned through AHP methodology (Domanikis et al., 2020)

Factor	Class	Rating	Level of Susceptibility to Flood	Weight (%)
Precipitation (mm)	1,958.70 - 2,058.27	1	Very Low	6
	2,058.27 - 2,157.83	2	Low	
	2,157.83 - 2,257.40	3	Moderate	
	2,257.40 - 2,356.97	4	High	
	2,356.97 - 2,456.54	5	Very High	
Elevation (m)	Above 1500	1	Very Low	42
	1000-1500	2	Low	
	500-1000	3	Moderate	

	250-500	4	High	
	Below 250	5	Very High	
Slope (Degree)	Above 50	1	Very Low	26
	30-50	2	Low	
	18-30	3	Moderate	
	3-18	4	High	
	0-3	5	Very High	
Distance from river (m)	>600	1	Very Low	16
	300-600	2	Low	
	200-300	3	Moderate	
	100-200	4	High	
	0-100	5	Very High	
Land cover	Forest	1	Very Low	10
	Perennial Crops	2	Low	
	Brushland	3	Moderate	
	Grassland/Annual Crops	4	High	
	Built-up/Barren/Open /Inland Water	5	Very High	

B. Validation of the AHP method

The validation of the flood susceptibility map was performed. A number of points were selected from the final flood susceptibility map, and a GPS-based field survey and geotagging were conducted to verify if the location of those points which were identified as flood susceptible areas are really flood susceptible areas.

Results and Discussion

Area in hectares for each level of susceptibility to flood based on the following criterion

1. Precipitation

Based on the results of the study, table 5 and figure 3 shows that an average total annual rainfall from 1,958.70 - 2,058.27 mm which were classified as very low susceptible to flood has an area of 850.35 Has. Places with an average total annual rainfall from 2,058.27 - 2,157.83 mm and were categorized as low susceptible to flood has an area of 10,771.92 Has. An average total annual rainfall from 2,157.83 - 2,257.40 mm which were classified as moderately susceptible to flood has an area of 3,117.51 hectares. Those having an average total annual rainfall of 2,257.40 – 2,356.97 mm and were classified as very high susceptibility to flood covers an area of 886.03 has. Lastly, an average total annual rainfall from 1,958.70 - 2,058.27 mm which were categorized as very low susceptible to flood has an area of 850.35 has.

Table 5: Area coverage of each level of flood susceptibility based on the precipitation

Rating	Average Total Annual Rainfall(mm)	Level of Susceptibility to Flood	Area (Hectares)
1	1,958.70 - 2,058.27	Very Low	850.35
2	2,058.27 - 2,157.83	Low	10,771.92
3	2,157.83 - 2,257.40	Moderate	3,117.51
4	2,257.40 - 2,356.97	High	886.03
5	2,356.97 - 2,456.54	Very High	514.68

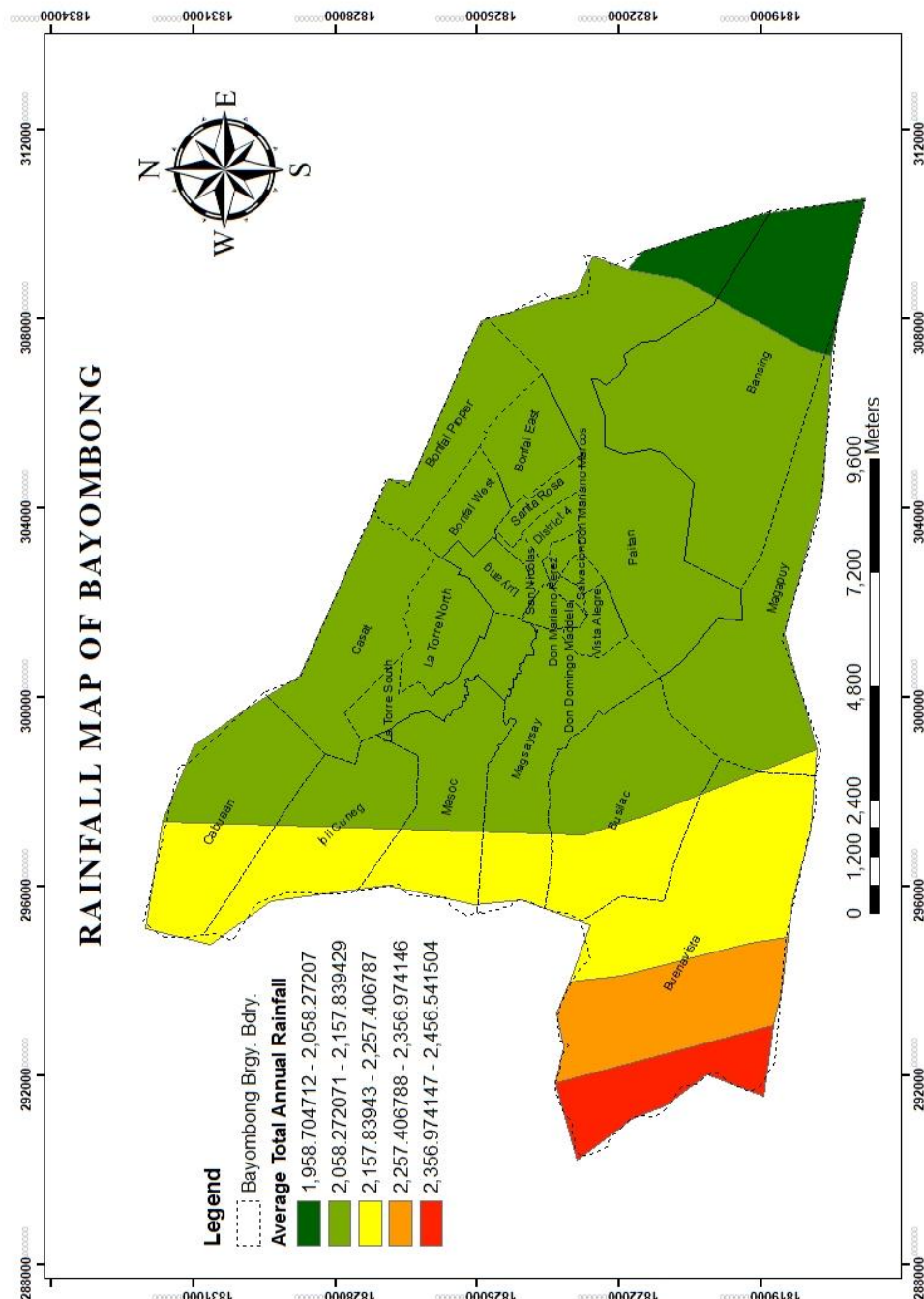


Figure 3: Rainfall Map of Bayombong

2. Elevation

In order to create the elevation map, the researchers obtained a SRTM 1 Arc-Second Global DEM from USGS Earth Explorer with a spatial resolution of 30m. The researchers reclassified the DEM into five levels of susceptibility to flood. The first category having a very low susceptibility to flood were given to an elevation of above 1,500 above datum. The elevation of 1,000-1,500 above datum were given a low susceptibility to flood. The third category having an elevation of 500-1000 above datum were classified as moderately susceptible to flood. Elevations of 250-500 and 0-250 above datum were given a high and very high susceptibility to flood, respectively.

From table 6 and with figure 4, places with very high susceptibility below 250 meters above datum has a total area equal to 0.40 hectares. However, places with an elevation of 250-500 above datum with a high susceptibility to flood has an area of 9,417.97 hectares. Those having an elevation of 500-1000 above datum which were classified as moderately susceptible to flood has an area of 5,060.17. Furthermore, those having a low susceptibility to flood with an elevation of 1,000-1,500 accumulates to an area of 1,633.50. Lastly, an area of 52.46 hectares has a very low level of flood susceptibility.

Table 6: Area coverage of each level of flood susceptibility based on the elevation

Rating	Elevation (Above Datum, WGS 1984)	Level of Susceptibility to Flood	Area (Hectares)
1	Above 1,500	Very Low	52.46
2	1,000-1,500	Low	1,633.50
3	500-1,000	Moderate	5,060.17
4	250-500	High	9,417.97
5	Below 250	Very High	0.40

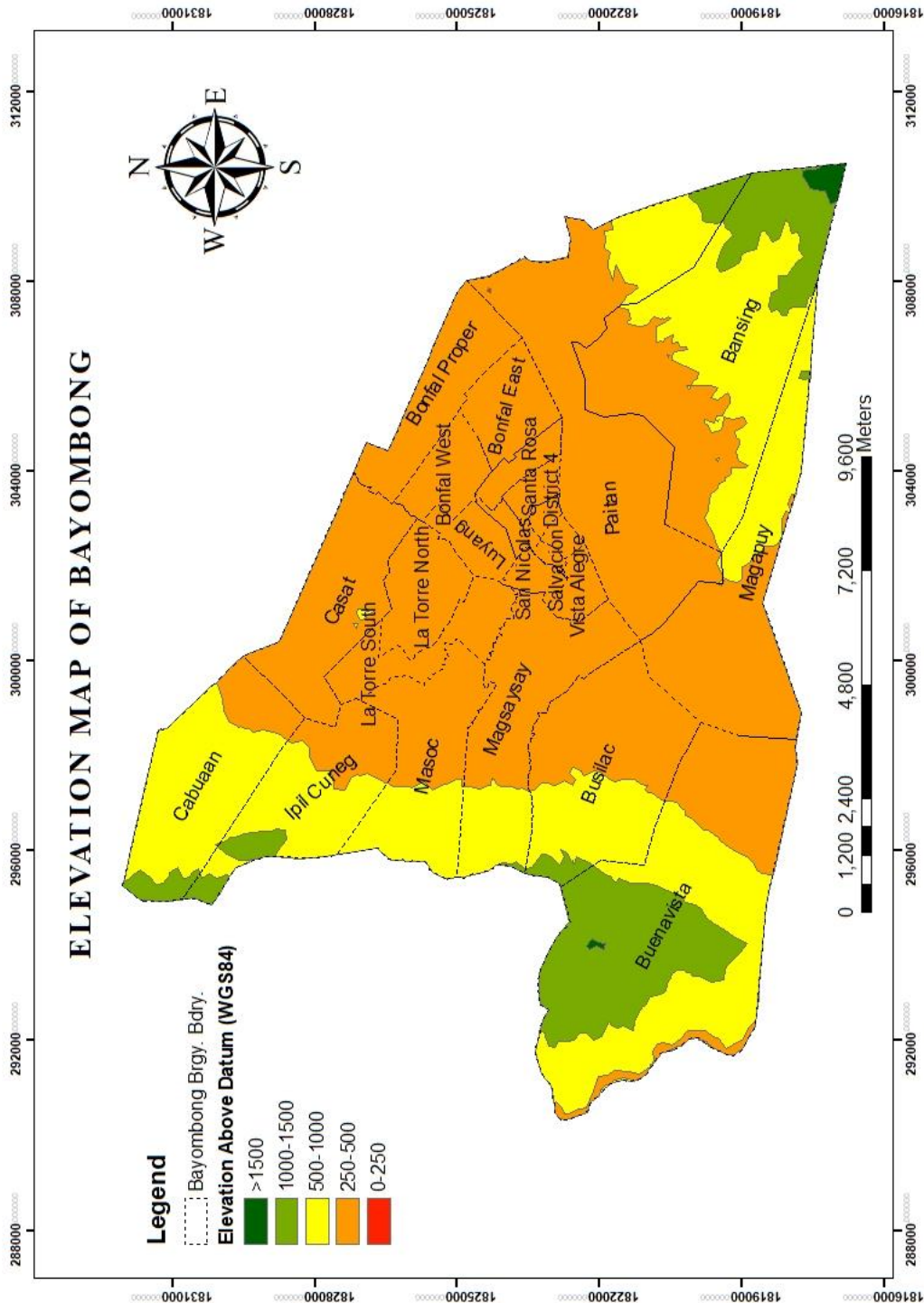


Figure 4: Elevation Map of Bayombong

3. Distance from river

Flooding can occur when water level from rivers rises due to excessive rainfall. The higher the water level, the more area it covers. The researchers considered a distance of 0-100, 100-200, 200-300, 300-600 and above 600 as a classification. From 0-100 meters away from river, they were classified as very high susceptibility to flood. Those 100-200 meters away from river were classified as a high susceptibility to flood. A distance from river of 200-300 meters were classified as moderately susceptible to flood. Lastly,

those having a distance of 300-600 meters and above 600 meter away from the river were given a low and very low susceptibility to flood.

Table 7 and figure 5, shows places with very high level of susceptibility from 0-100 meters away from river have an area of 1844.74 hectares. Those having a distance of 100-200 meters from river have an area of 1559.00 hectares. However, places 200-300m away from river have an area of 1449.03 hectares. Furthermore, those having a low level of susceptibility to flood consists of an area of 1381.05 hectares. Lastly, places above 600 meters away from river have a total area of 5960.25 hectares.

Table 7: Area coverage of each level of flood susceptibility based on the Distance from River

Rating	Distance from River (m)	Level of Susceptibility to Flood	Area (Hectares)
5	Above 600	Very Low	5960.25
4	300-600	Low	1381.05
3	200-300	Moderate	1449.03
2	100-200	High	1559.00
1	Below 100	Very High	1844.74

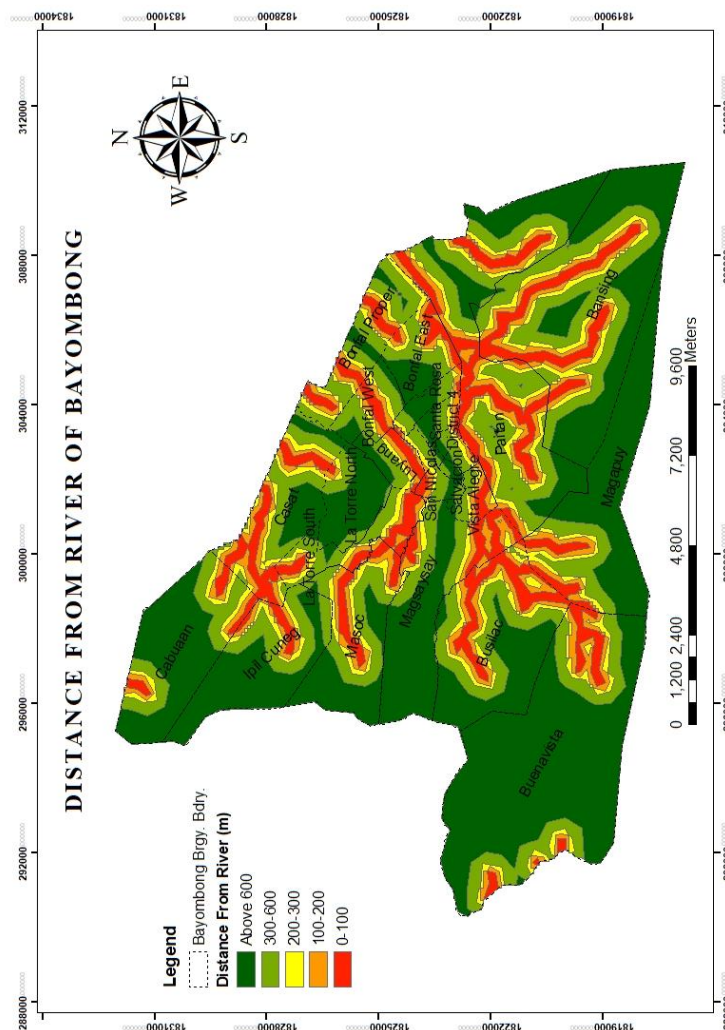


Figure 5: Distance from Rive Map of Bayombong

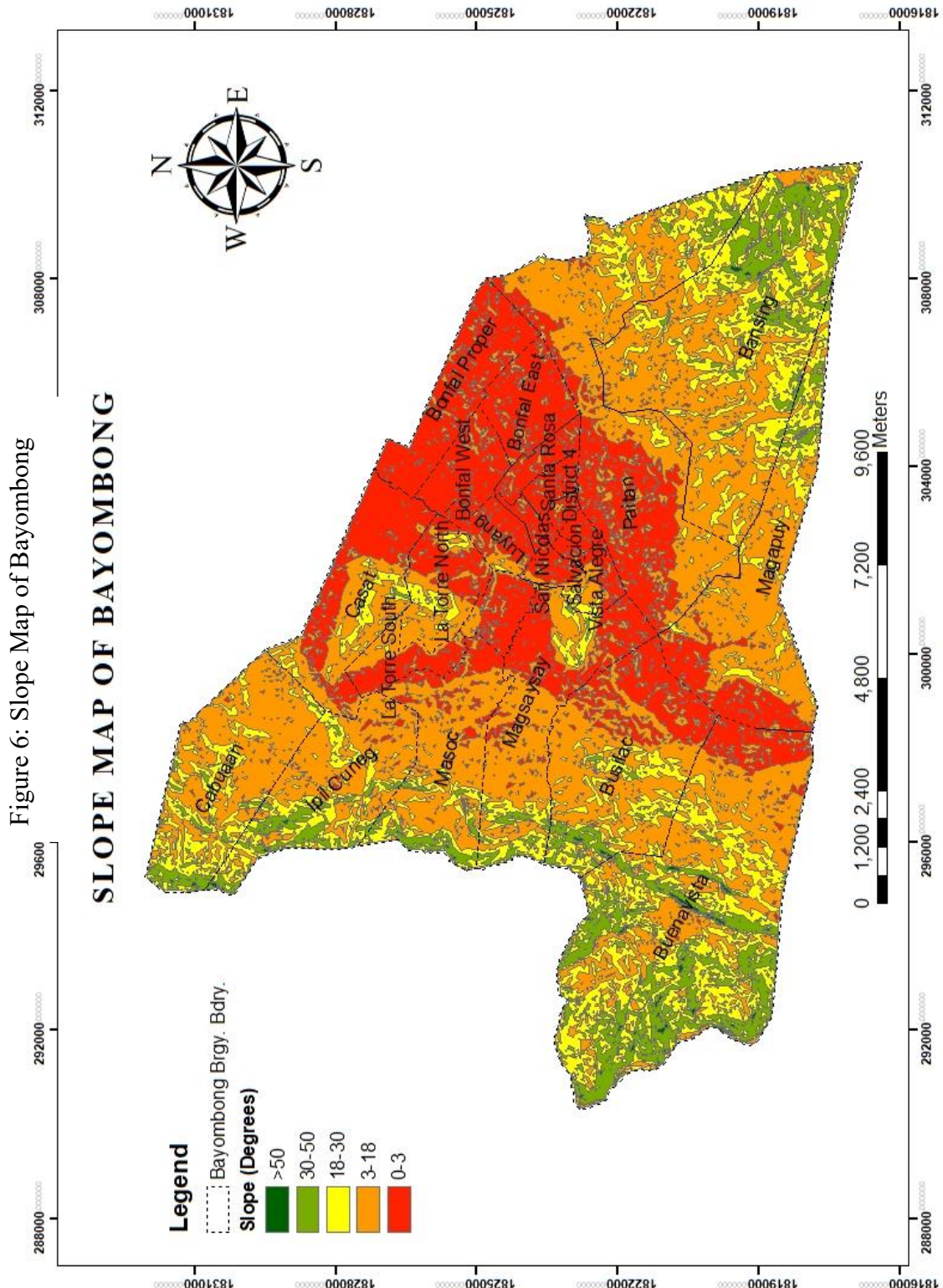
4. Slope

With regards to the slope, the researchers reclassified the slope into five levels. A slope of 0-3 degrees were considered to have a very high level of susceptibility to flood. High level of susceptible to flood was given to a degree of slope 3-18. The slope of 18-30 degrees were classified as moderately susceptible to flood. Slope of 30-50 degrees were given a low level of susceptibility of flood. Slope of 50 degrees above were given a very low level of susceptibility of flood. The table and figure below which is outcome of analyzation in GIS, shows the area in hectares of each level.

As shown in table 8 and figure 6, places with very high level of susceptibility to flood and have a slope ranging from 0 to 3 degrees have a total area of 4,189.69 hectares. While places with a slope ranging from 3-18 degrees with a high level of susceptibility to flood have a total area of 7,252.09 hectares. However, places ranging from 18-30 degrees and were classified as moderately susceptible to flood covers an area of 3,205.94 hectares. Those places with a low level of susceptibility of flood which have a slope ranging from 30-50 degrees have a total area of 1,299.36 hectares. Lastly those having a slope above 50 degrees have an area of 30.97 hectares and were classified as very low level of susceptibility of flood.

Table 8: Area coverage of each level of flood susceptibility based on the Slope

Rating	Degree of Slope (%)	Level of Susceptibility to Flood	Area (Hectares)
1	Above 50	Very Low	30.97
2	30-50	Low	1,299.36
3	18-30	Moderate	3,205.94
4	3-18	High	7,252.09
5	Below 3	Very High	4,189.69



Area in hectares for each level of susceptibility to flood based on the land cover of the year 2020

Land cover is a significant factor in identifying the areas that are susceptible to flood. The researcher reclassified the Land Cover into five classes. The first category, forest which has a very low level of susceptible to flood covers an area of 4397.32 hectares. Category 2, perennial crops which were classified

as low susceptible to flood has an area of 555.86 hectares. However, those in brush land which were classified as moderately susceptible to flood has a total area of 3432.91 hectares. Land cover classification of grassland/annual crop were classified as highly susceptible to flood and has a total area of 6023.59 hectares. Lastly, Built-up/Barren/Open/ Inland Water were classified very highly susceptibility to flood and covered an area of 1,746.16 hectares as shown in table 9 and figure 7.

Table 9: Area coverage of each level of flood susceptibility based on the Land cover

Rating	Land Cover Classification	Level of Susceptibility to Flood	Area (Hectares)
1	Forest	Very Low	4,397.32
2	Perennial Crops	Low	555.86
3	Brushland/Shrub	Moderate	3,432.91
4	Grassland/Annual Crops	High	6,023.59
5	Built-up/Barren/Open/ Inland Water	Very High	1,746.16

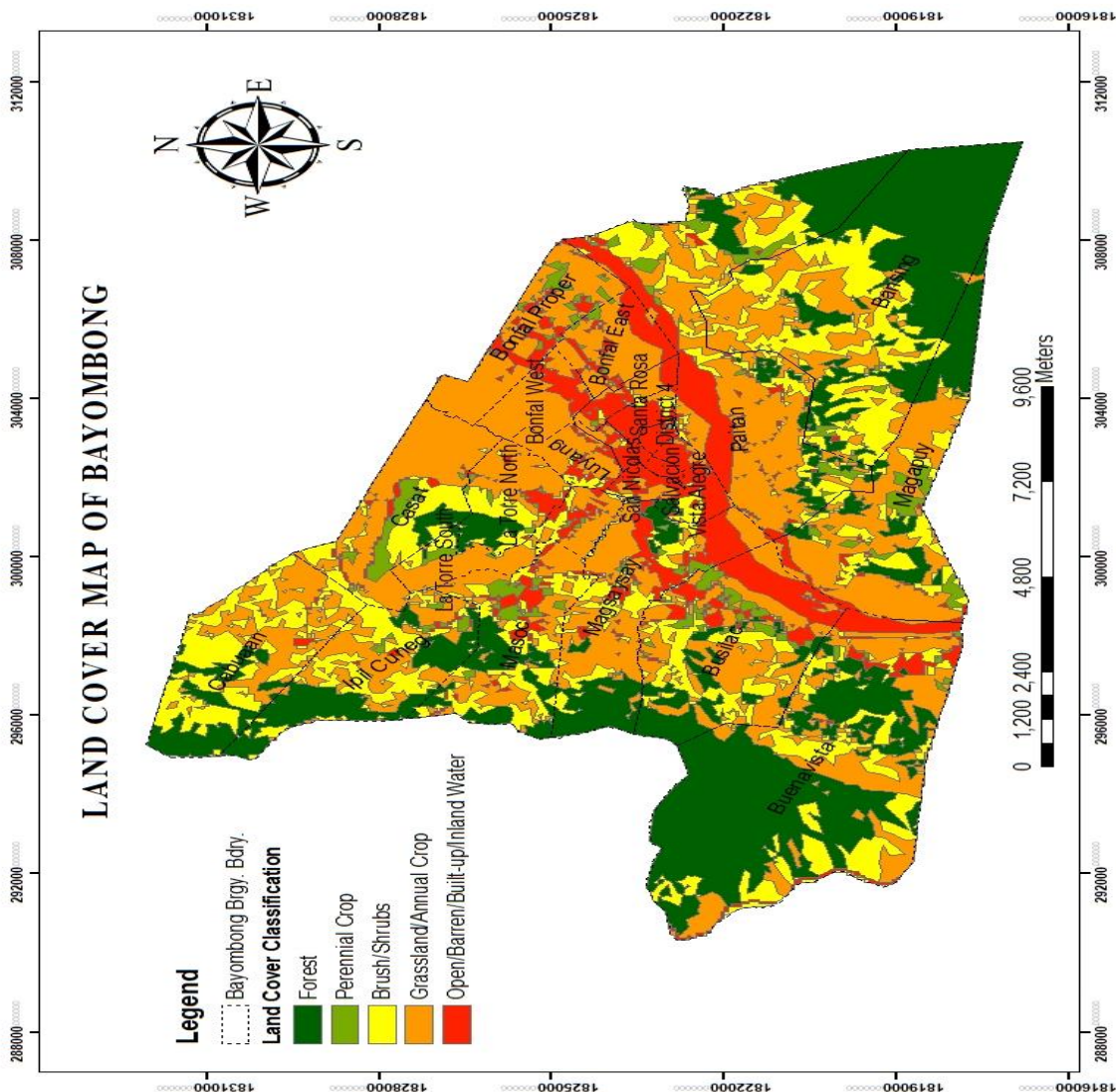


Figure 7: Land Cover Map of Bayombong

Area for each level of susceptibility to flood in each barangay in terms of the overall result of the flood susceptibility map generated

Flood Susceptibility Map

Table 10 shows the overall result of the AHP and GIS weighted overlay analysis integration done in determining the flood susceptibility of the municipality of Bayombong. It showed that a portion of the municipality having an area of 768.31 hectares are very highly susceptible to flood. Although they have low average total annual rainfall, they are evidently located near and at the rivers with a distance 0-300 meters, at low elevated lands of 0-500 meters above datum and at a slope with less than 3 degrees. Moreover, the largest part of Bayombong with an area of 5,655.40 hectares is evaluated as highly susceptible to flood. It is for the reason that these zones are in open and barren lands, built-up areas as well as in grasslands and annual crop lands. These areas are also located approximately 200 meters away from nearby rivers and have low elevations of up to 500 meters above Datum and slope of 0-8 degrees. An area of 5,394.62 hectares of the municipality, however, is regarded as moderately susceptible to flood. On the other hand, an area of 3,359.82 hectares and 784.72 hectares are slightly and very slightly susceptible to flood, respectively. Although these areas receive larger amount of rainfall, they are assessed to be not susceptible to flood mainly because they are located away from main rivers, at higher elevations of above 500 m above datum, at steeper slope above 18 degrees, and at forested areas.

Table 10: Area coverage of each level of flood susceptibility in Bayombong

FLOOD SUSCEPTIBILITY OF BAYOMBONG		
RATE	LEVEL	AREA (Hectares)
1	Very Low	784.72
2	Low	3,359.82
3	Moderate	5,394.62
4	High	5,655.40
5	Very High	768.31

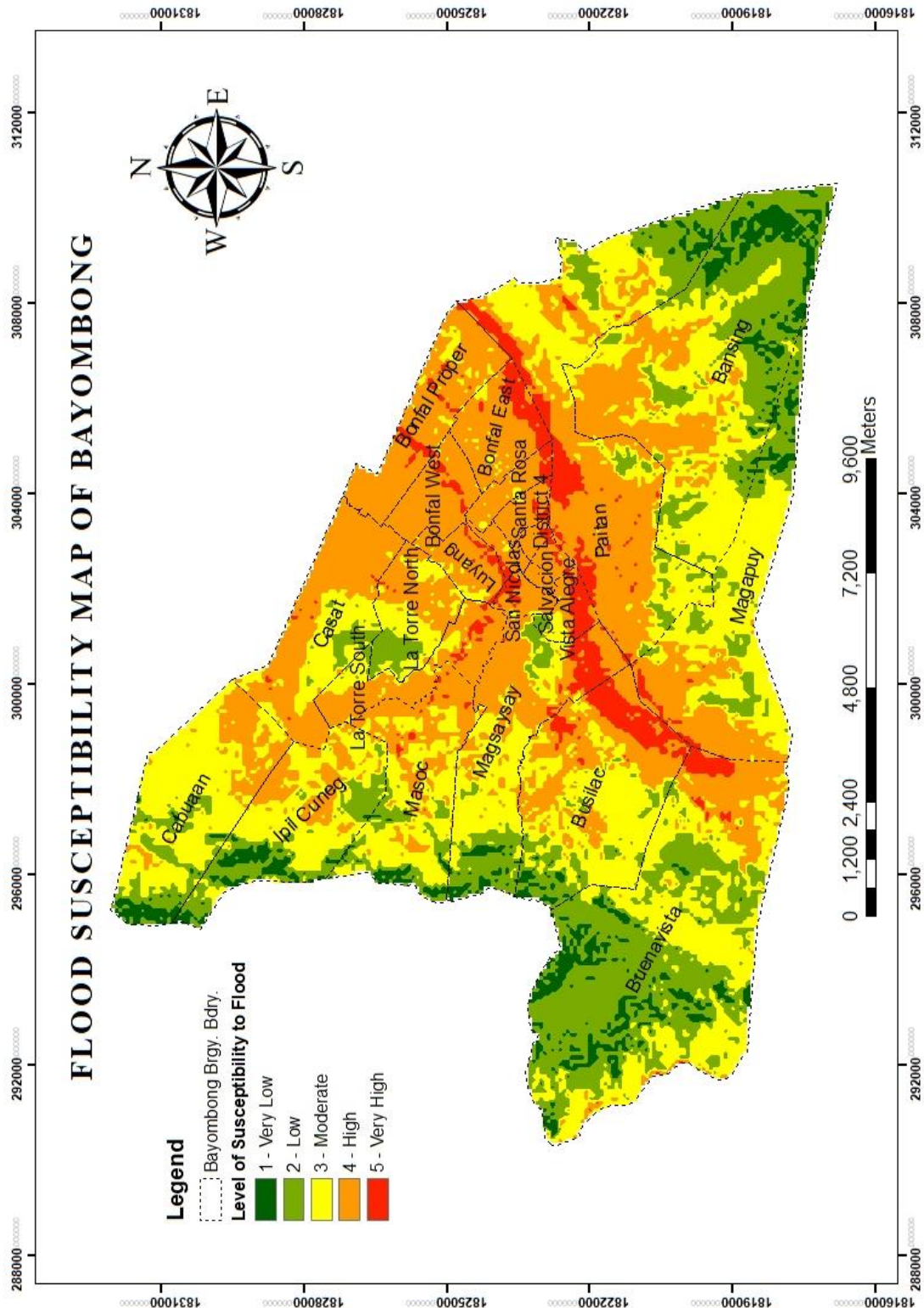


Figure 8: Flood Susceptibility Map of Bayombong

Barangay Bansiug

Table 11 shows the result of the AHP and GIS integration in creating flood susceptibility map emphasizing barangay Bansiug. Bansiug is composed of forest land, brush/shrub land, grassland and annual crop.

However, the result shows that an area accumulating to 492.14 hectares and 733.27 hectares are highly and moderately prone to flood, respectively. It is because these areas lie mostly in the grassland, brush land, and annual crop land cover. On the other hand, an area of 209.19 has and 750.33 has are regarded as low and very low susceptible to flood, respectively, as they are located at high elevations and in forest areas. They also receive lower amount of annual rainfall.

Table 11: Area coverage of each level according to the flood susceptibility map of Barangay Bansing

BANSING		
RATE	LEVEL	AREA (Hectares)
1	Very Low	209.19
2	Low	750.33
3	Moderate	733.27
4	High	492.14

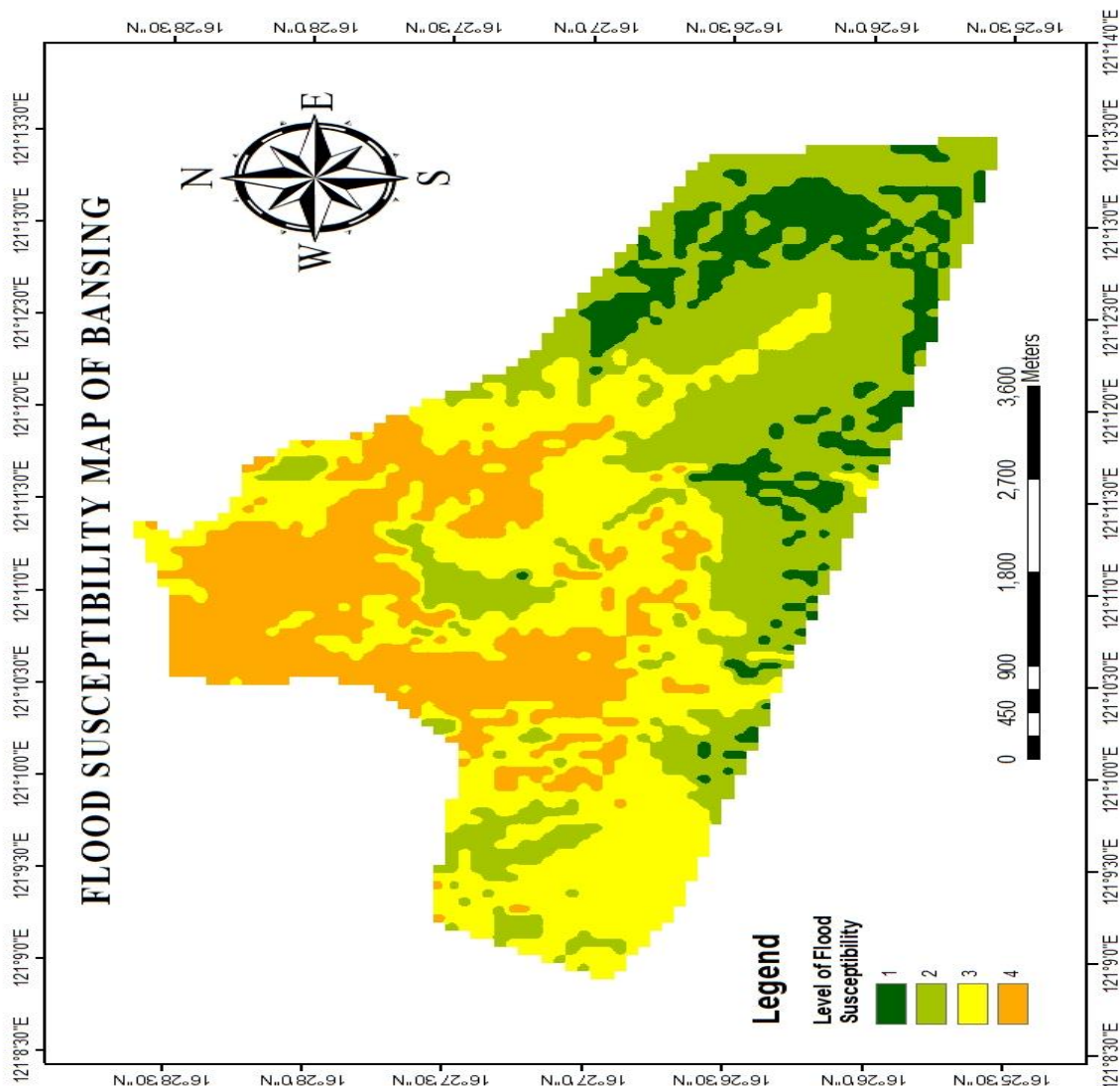


Figure 9: Flood Susceptibility Map of Bansing

Barangay Bonfal East

Barangay Bonfal East is mainly in built-up areas, grassland and annual crop lands. A portion of it is also located near a main river channel. Moreover, it has an elevation of 250-500 meters above datum and has a slope of 0-18 degrees. When it comes to rainfall, it receives a low amount of rain based on the average total annual rainfall from 2015-2017. Therefore, table 12 shows that 64.34 hectares are very highly susceptible to flood, 234.25 hectares are highly susceptible to flood, and the rest of the municipality are moderately susceptible to flood with an area of 17.09 hectares.

Table 12: Area coverage of each level based on the flood susceptibility map of Barangay Bonfal East

BONFAL EAST		
RATE	LEVEL	AREA (Hectares)
3	Moderate	17.09
4	High	234.25
5	Very High	64.34

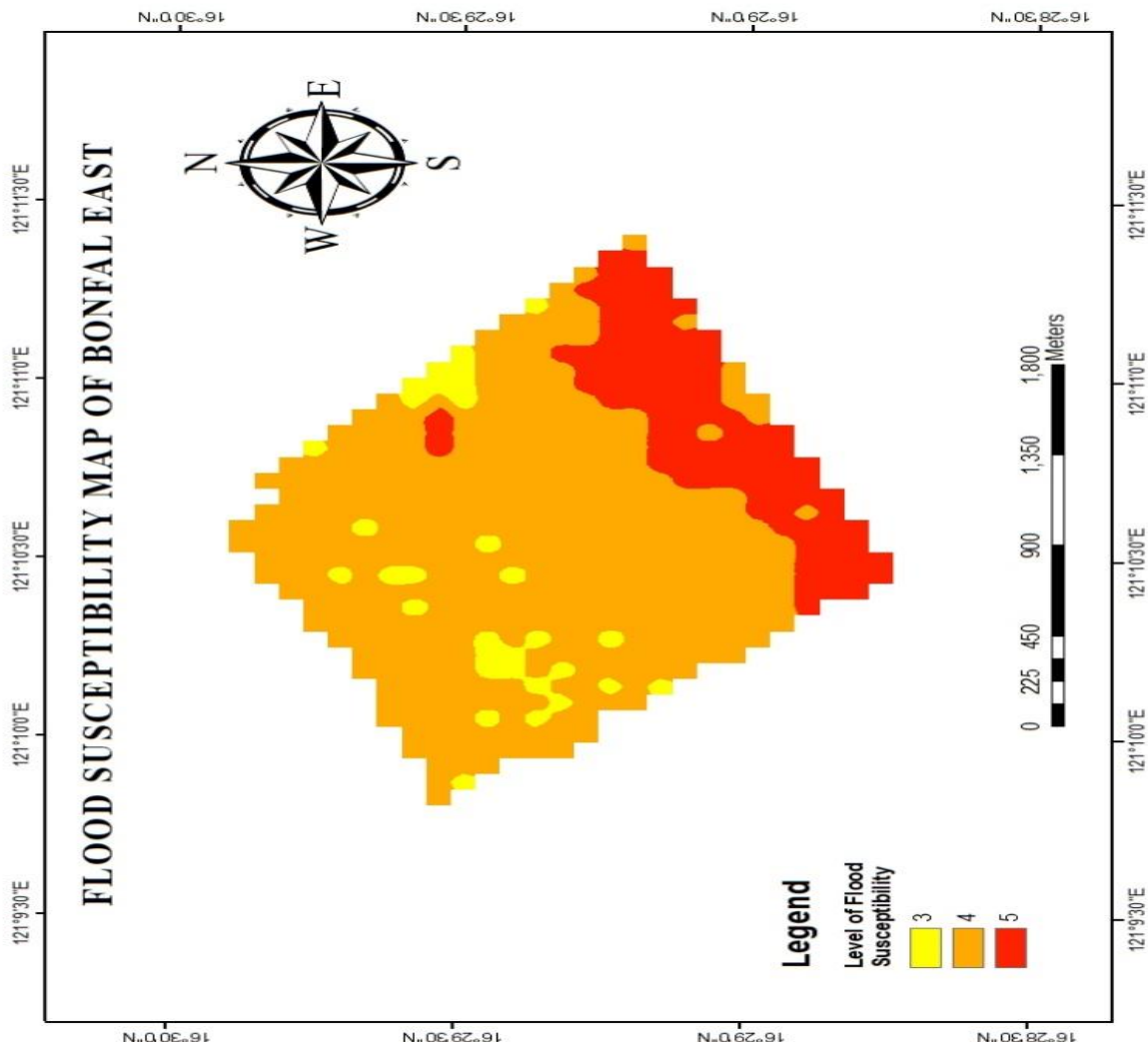


Figure 10: Flood Susceptibility Map of Bonfal East

Barangay Bonfal West

Barangay Bonfal West has a land cover which composed of grassland/annual crop land and open/barren/built-up and inland water. It also has an elevation of approximately 250-500 meters above datum and slope of 0-18 degrees. Moreover, a main river crosses Bonfal West. However, it is among those barangays who receives lower amount of rainfall compared to other barangays. Hence, the table below shows that majority of barangay Bonfal West with an area of 224.24 hectares is labeled as highly susceptible to flood and only an area of 2.07 hectares is determined as moderately susceptible to flood. The rest of the barangay with an area of 16.01 hectares is very highly susceptible to flood.

Table 13: Area coverage of each level based on the flood susceptibility map of Bonfal West

BONFAL WEST		
RATE	LEVEL	AREA (Hectares)
3	Moderate	2.07
4	High	224.24
5	Very High	16.01

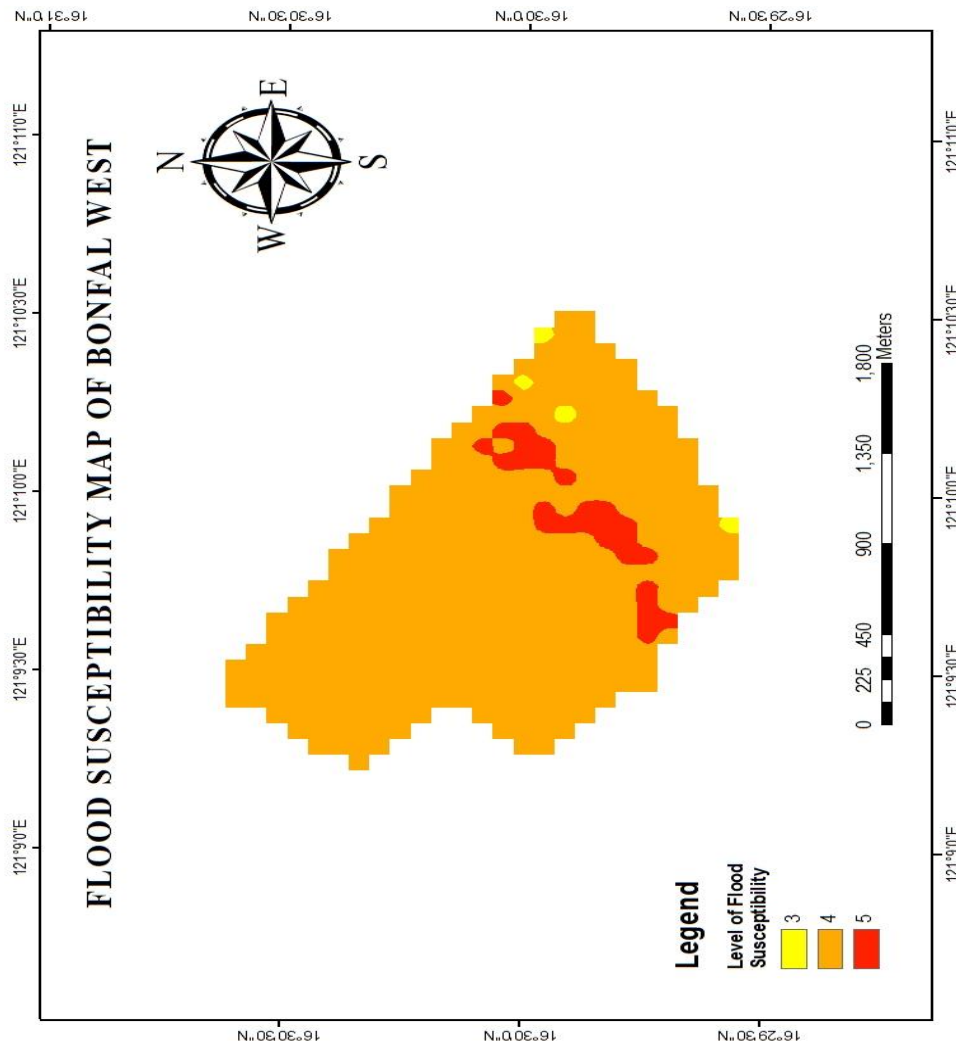


Figure 11: Flood Susceptibility Map of Bonfal West

Barangay Bonfal Proper

Bonfal Proper, like the other Bonfal Region, has a land cover that is grassland/annual crop land and open/barren/built-up and inland water. It also has a river crossing the barangay as well as an elevation of 250-500 meters above Datum, 0-18 degrees slope and a lower average total annual rainfall. Consequently, according to the result of the AHP and GIS weighted overlay tool integration, larger portion of Barangay Bonfal Proper is highly susceptible to flood which accumulates to an area of 427.45 hectares. Following a level of moderate susceptibility with an area of 42.57 hectares. While 31.86 hectares is very highly susceptible to flood.

Table 14: Area coverage of each level based on the flood susceptibility map of Bonfal Proper

BONFAL PROPER		
RATE	LEVEL	AREA (Hectares)
3	Moderate	42.57
4	High	427.45
5	Very High	31.86

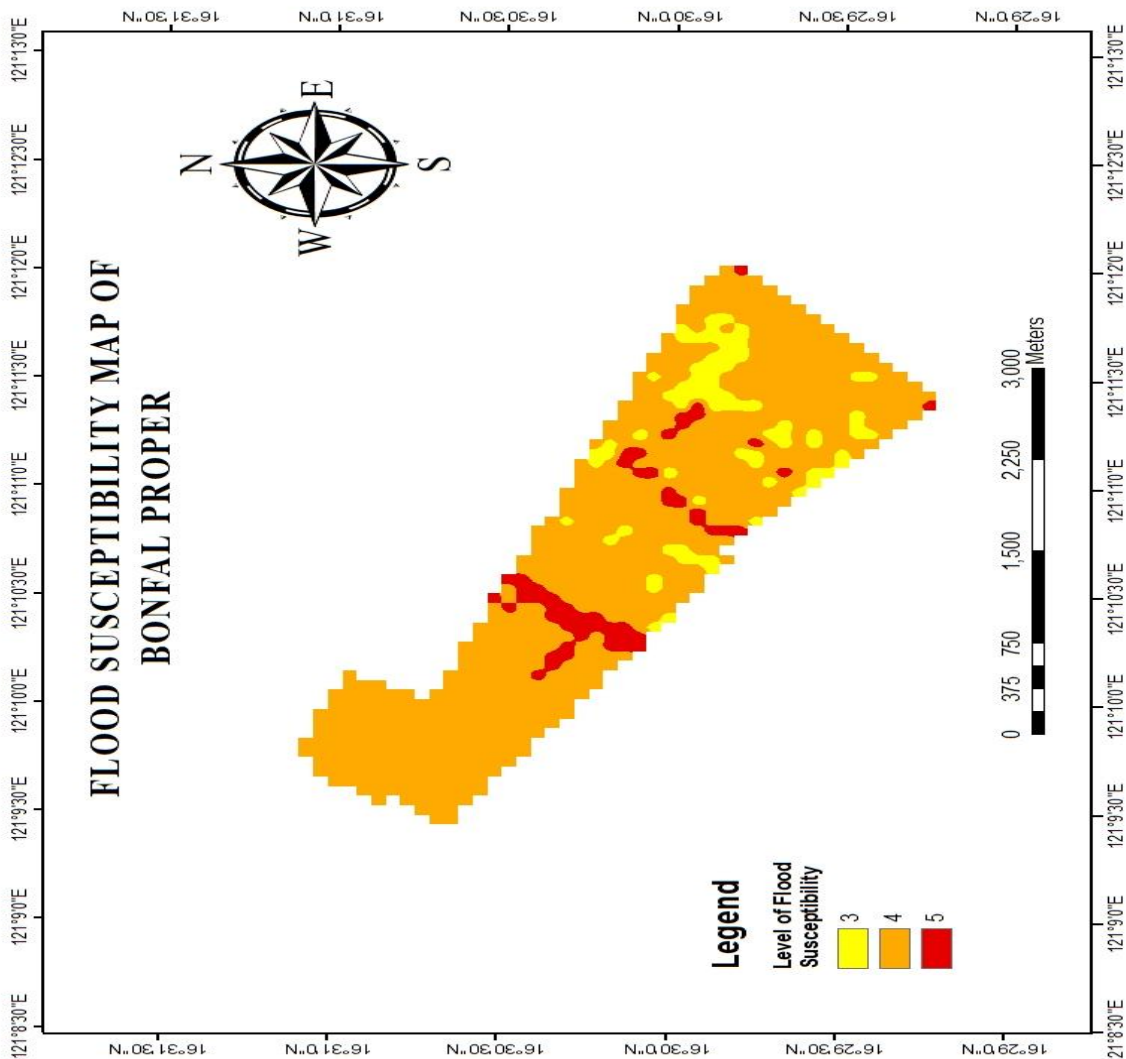


Figure 12: Flood Susceptibility Map of Bonfal Proper

Barangay Buenavista

Barangay Buenavista has the highest average total annual rainfall. However, the steep slope and the forested land areas contradicts the effects of having a high rainfall. Nonetheless, the valleys which has built up areas, grasslands, and annual crop land are the portion of the barangay which are very highly susceptible to flood with an area of 54.50 has. But on table 15, it is evident that Buenavista is moderate to low susceptible to flood. The largest area of 1170.71 has is regarded as low susceptible to flood. Followed by second one with 838.89 has and is moderate susceptible to flood. 271.47 hectares and 257.10 hectares are high and very low susceptible to flood, respectively.

Table 15. Area coverage of each level based on the flood susceptibility map of Buenavista

BUENAVISTA		
RATE	LEVEL	AREA (HAS)
1	Very Low	257.10
2	Low	1,170.71
3	Moderate	838.89
4	High	271.47
5	Very High	54.50

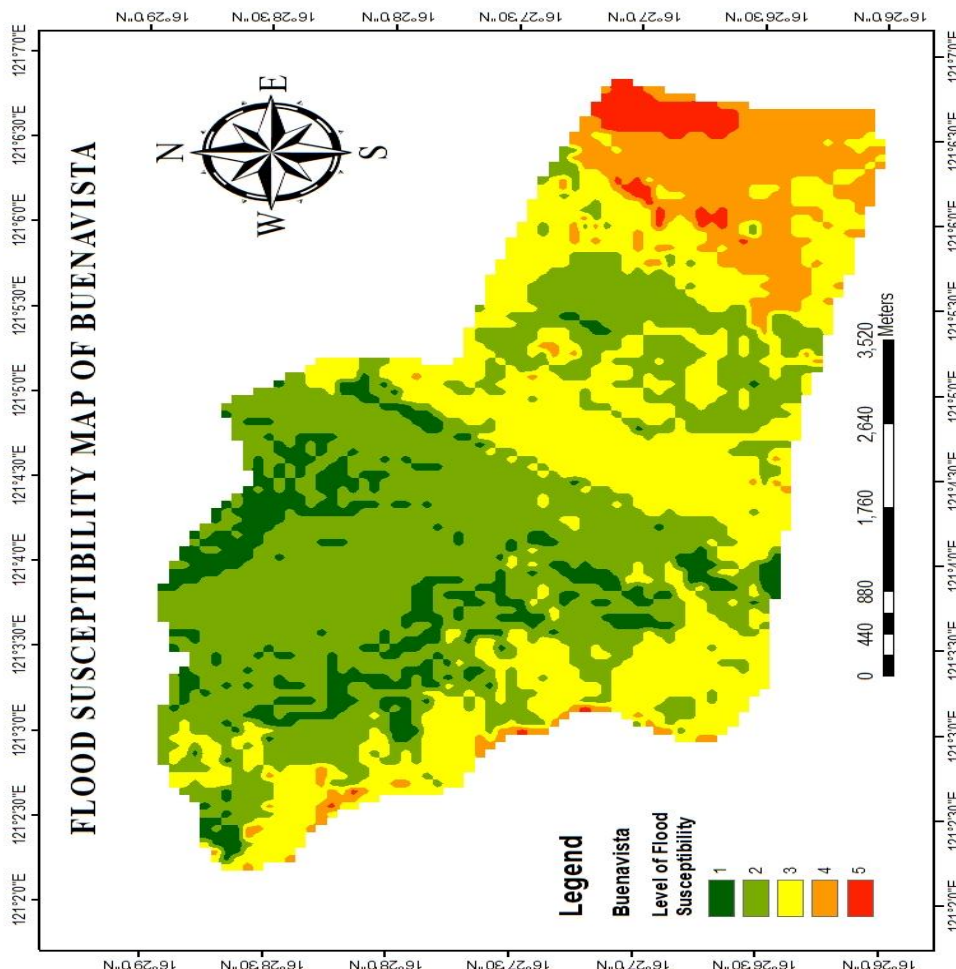


Figure 13: Flood Susceptibility Map of Buenavista

Barangay Busilac

Busilac is mainly a grassland, perennial crop land, brush land, and forest land. It also has a river and built-up area. However, according to the result, from table 16 and figure 14, majority of the barangay is moderately susceptible to flood with an area of 507.69 hectares. Followed by highly susceptible to flood with an area of 380.30 hectares. An area of 137.36 hectares and 140.38 hectares are regarded as low and very high susceptible to flood, respectively. The rest of the barangay which composed of an area 30.71 hectares is very low susceptible to flood.

Table 16: Area coverage of each level according to the flood susceptibility map of Busilac

BUSILAC		
RATE	LEVEL	AREA (Hectares)
1	Very Low	30.71
2	Low	137.36
3	Moderate	507.69
4	High	380.30
5	Very High	140.38

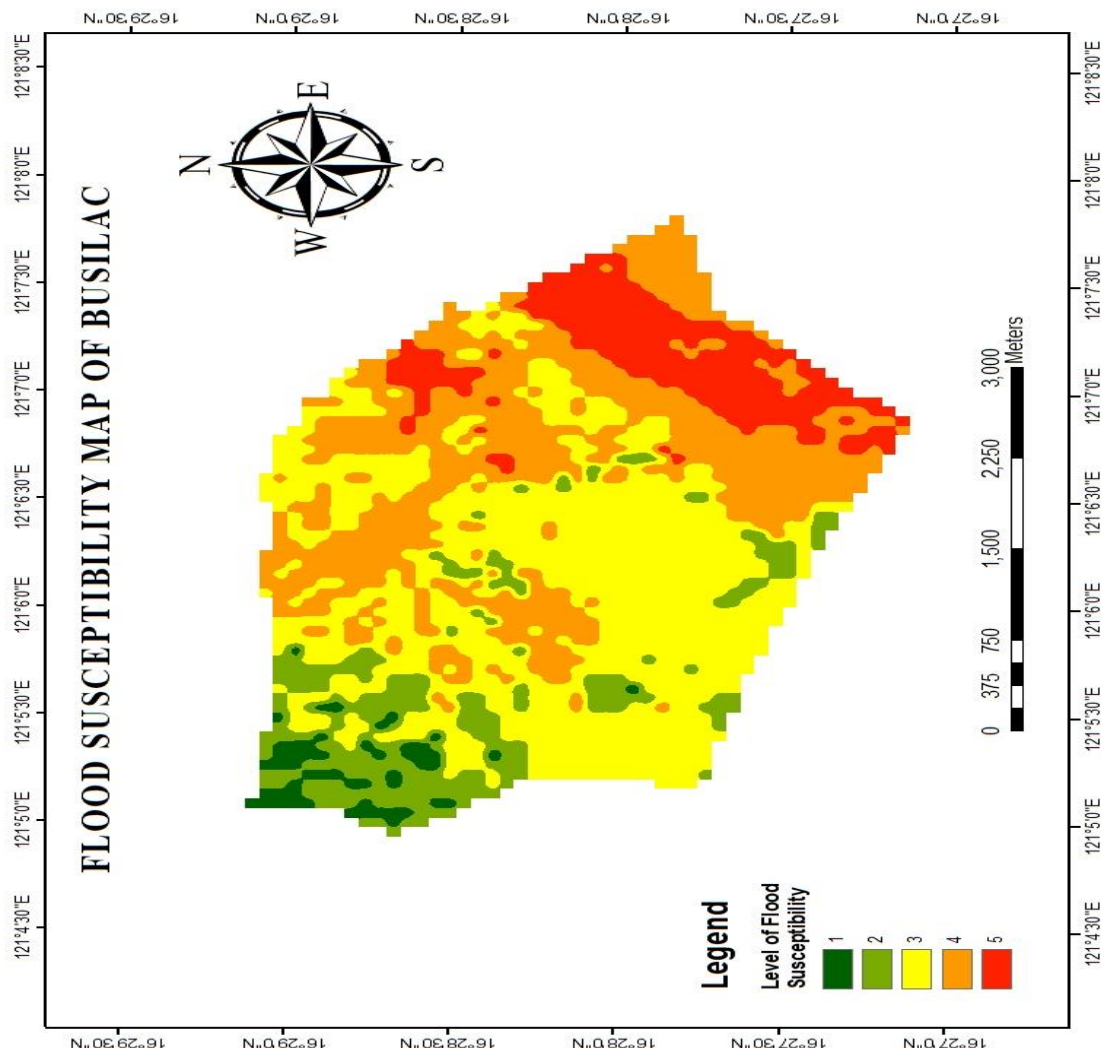


Figure 14: Flood Susceptibility Map of Busilac

Barangay Cabuaan

The table and figure below shows that a larger portion of barangay Cabuaan having an area of 586.10 hectare is moderately susceptible to flood. An area of 180.30 hectares is highly susceptible to flood and 148.93 hectares and 51.90 hectares are low and very low susceptible to flood. Most of the area in Barangay Cabuaan have an elevation of above 500 meters above datum and above 3 degrees slope. It also has forest area and brush land, but majority is grassland and annual crop. There is only a small area of built-up in Cabuaan.

Table 17: Area coverage of each level according to the flood susceptibility map of Cabuaan

CABUAAN		
RATE	LEVEL	AREA (Hectares)
1	Very Low	51.90
2	Low	148.93
3	Moderate	586.10
4	High	180.30

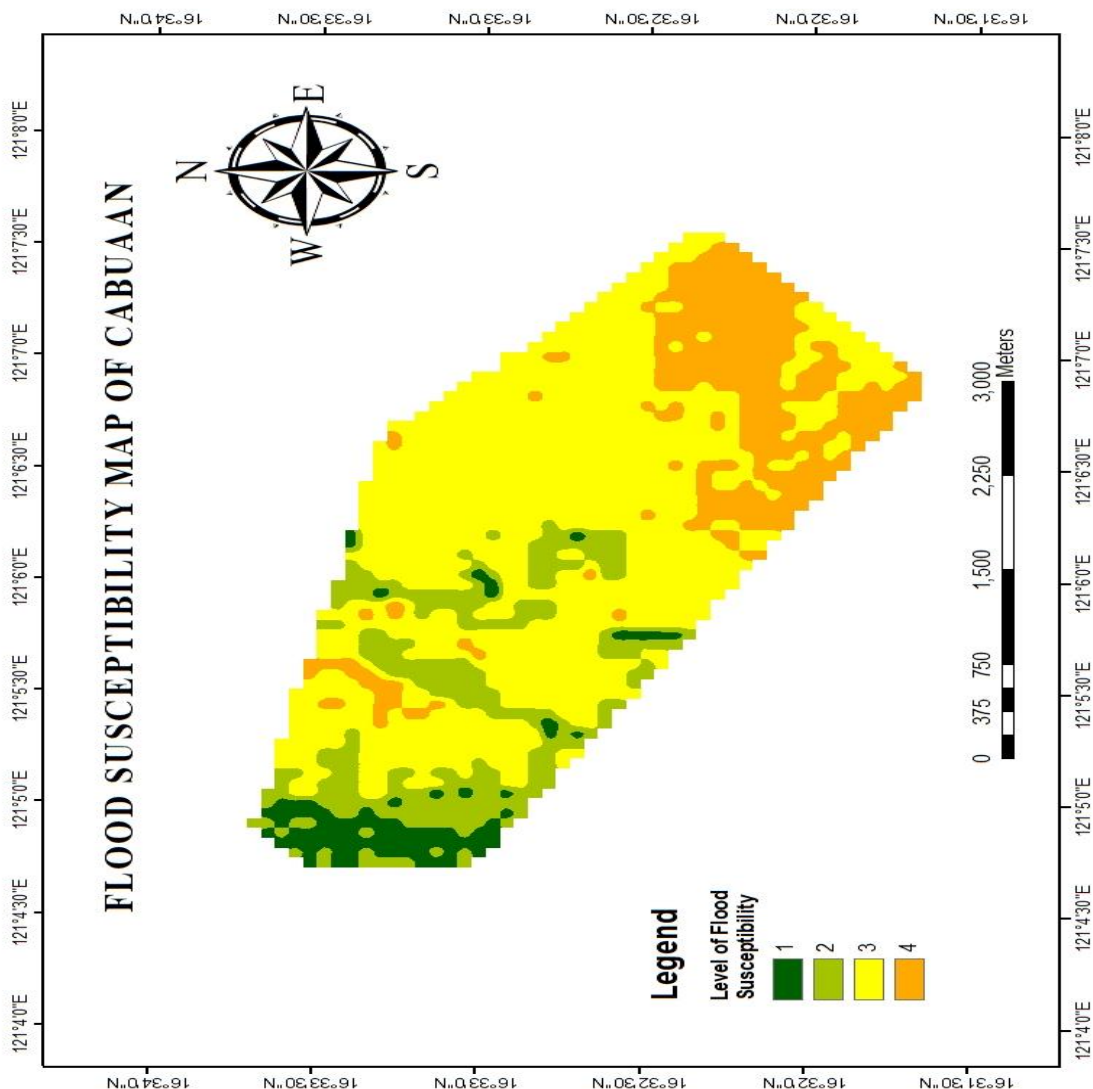


Figure 15: Flood Susceptibility Map of Cabuaan

Barangay Casat

Table 8 with figure 16 illustrates that, large area of Barangay Casat is Grassland and Annual crop. It also has a forest land, perennial crop land and brush/shrub land. Along the foot of the mountain are open/barren/built-up areas. Hence, the table below shows that a total of 6.21 hectares is very highly susceptible to flood and majority is highly susceptible with a total area of 483.31 hectares. The rest of the barangay is moderately and slightly susceptible to flood with an area of 206.91 hectares and 51.81 hectares, respectively.

Table 18: Area coverage of each level according to the flood susceptibility map of Casat

CASAT		
RATE	LEVEL	AREA (Hectares)
2	Low	51.81
3	Moderate	206.91
4	High	483.31
5	Very High	6.21

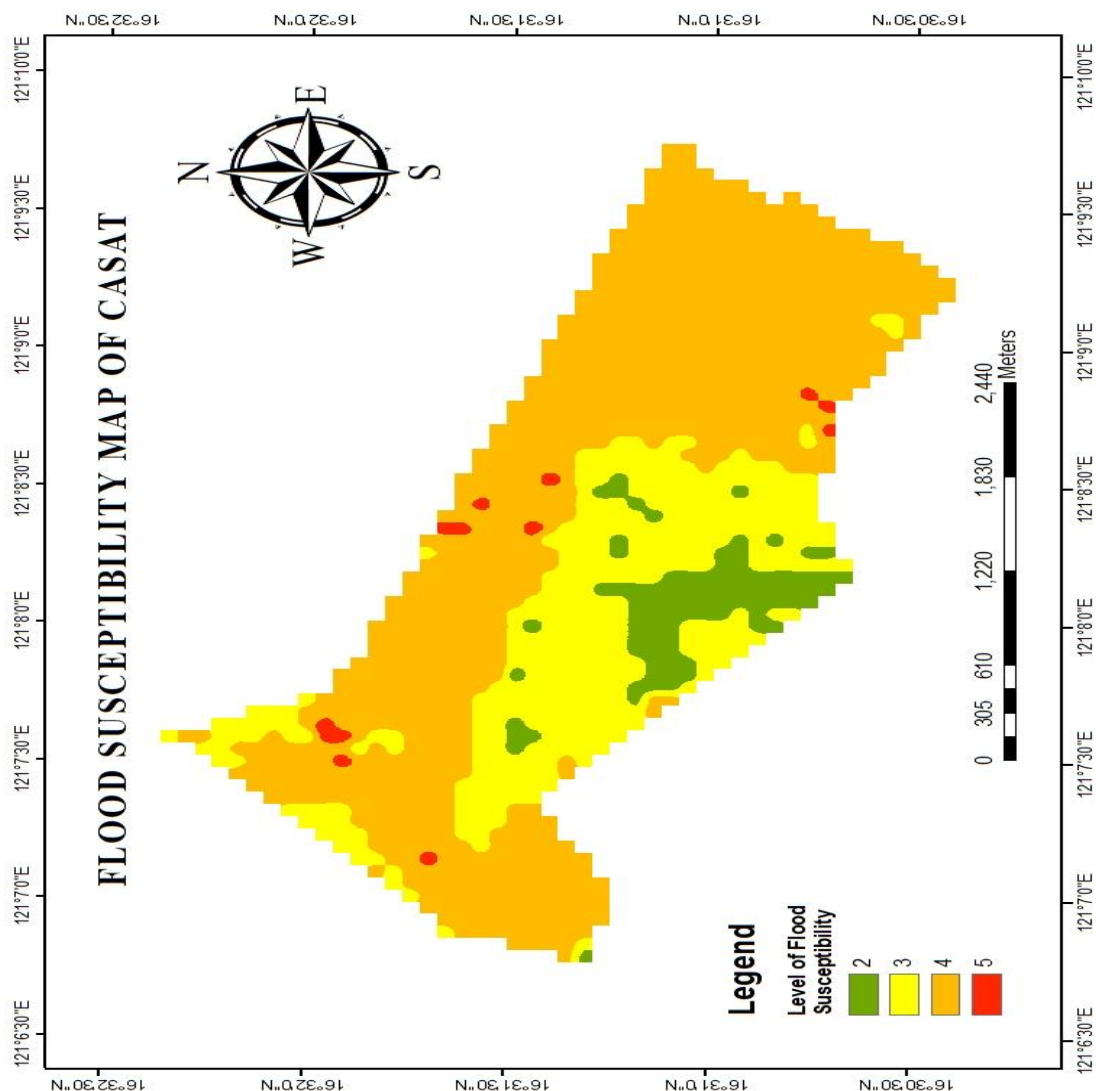


Figure 16: Flood Susceptibility Map of Casat

Barangay District IV

The table and figure below show the area in hectares of the level of flood susceptibility of a zone in District IV and the flood susceptibility map of the barangay, respectively. The large part of the barangay is high susceptible to flood, and it garnered an area of 76.50 hectares. Moreover, an approximate of 2 hectares and 8 hectares are considered to be moderate and very high susceptible to flood, respectively.

Table 19: Area coverage of each level based on the flood susceptibility map of District IV

DISTRICT IV		
RATE	LEVEL	AREA (Hectares)
3	Moderate	2.50
4	High	76.50
5	Very High	8.63

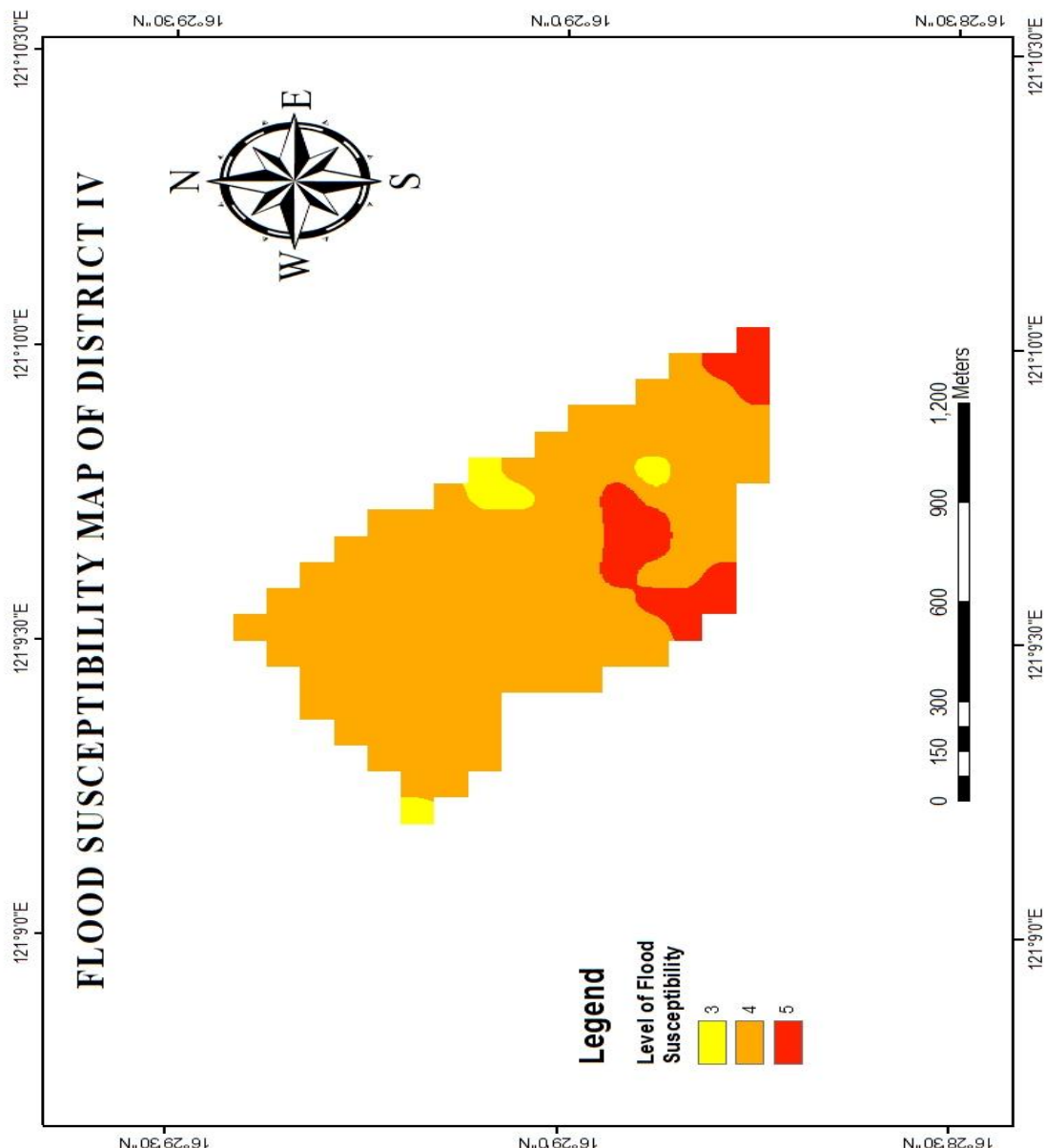


Figure 17: Flood Susceptibility Map of District IV

Barangay Don Domingo Maddela

The table and map below show data about barangay Don Domingo Maddela about its susceptibility to flood. The whole part of Barangay Don Domingo Maddela with an area 22.39 hectares, according to the map, is highly susceptible to flood. It is mostly composed of open/barren/built-up area. Also, its elevation is within 250-500 meters above datum and its slope is within 0-3 degrees.

Table 20: Area coverage of each level according to the flood susceptibility map of Don Domingo Maddela

DON DOMINGO MADDELA		
RATE	LEVEL	AREA (Hectares)
4	High	22.39

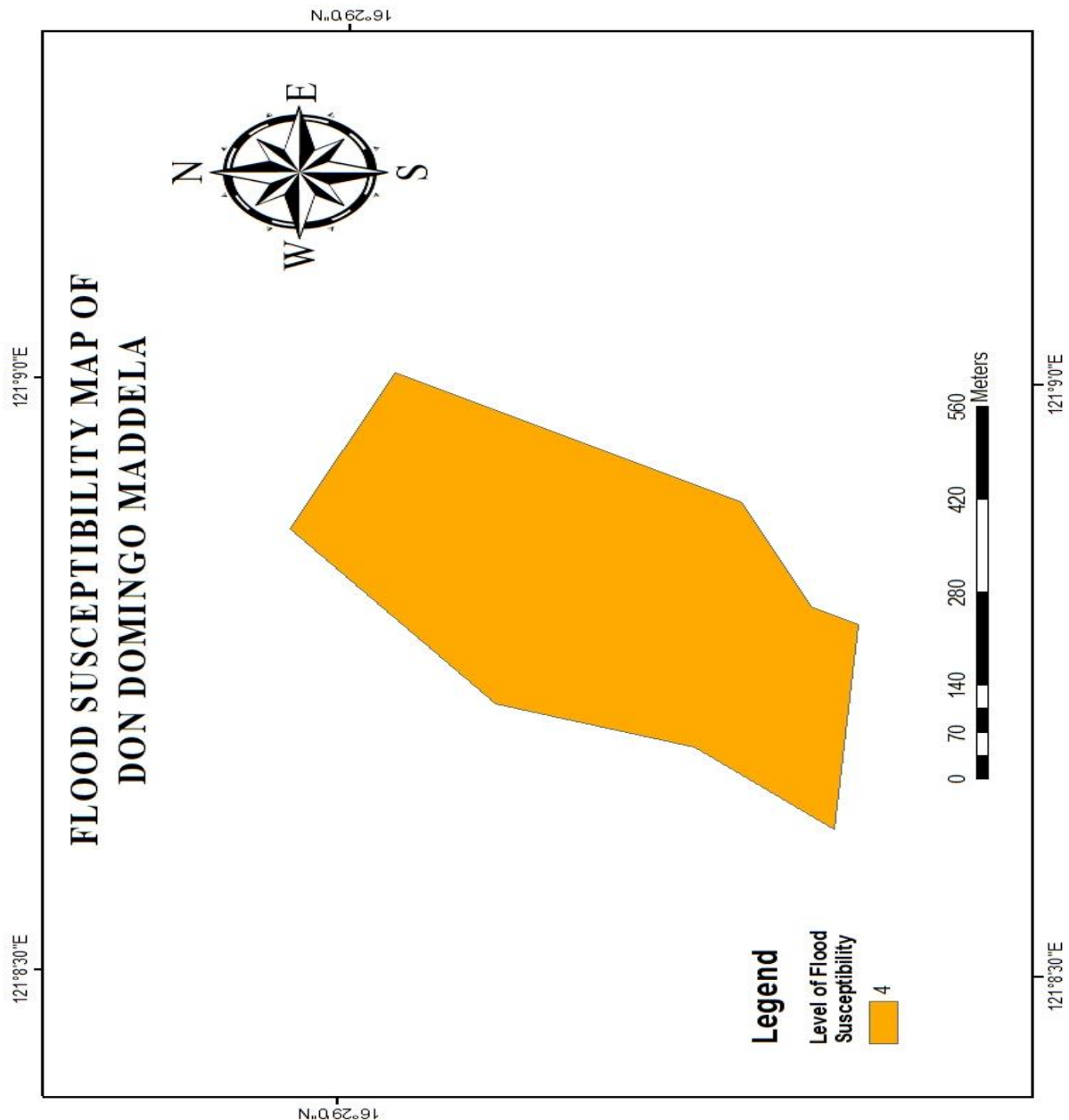


Figure 18: Flood Susceptibility Map of Don Domingo Maddela

Barangay Don Mariano Perez

Table 28 and figure 19, shows that Don Mariano Perez is highly susceptible to flood. Although, its distance from the river is above 300 meters and it has a low average total annual rainfall, it is located in an area where its elevation is between 250-500 meters above datum and its slope is 0-18 degrees. Moreover, its land cover is composed of mostly open/barren/built-up areas and grassland and annual crop. Therefore, a total of 58.59 hectares is highly susceptible to flood and 17.41 hectares is very highly susceptible to flood. Lastly, only 4.37 hectares is moderately susceptible to flood.

Table 21: Area coverage of each level based on the flood susceptibility map of Don Mariano Perez

DON MARIANO PEREZ		
RATE	LEVEL	AREA (Hectares)
3	Moderate	4.37
4	High	58.59
5	Very High	17.41

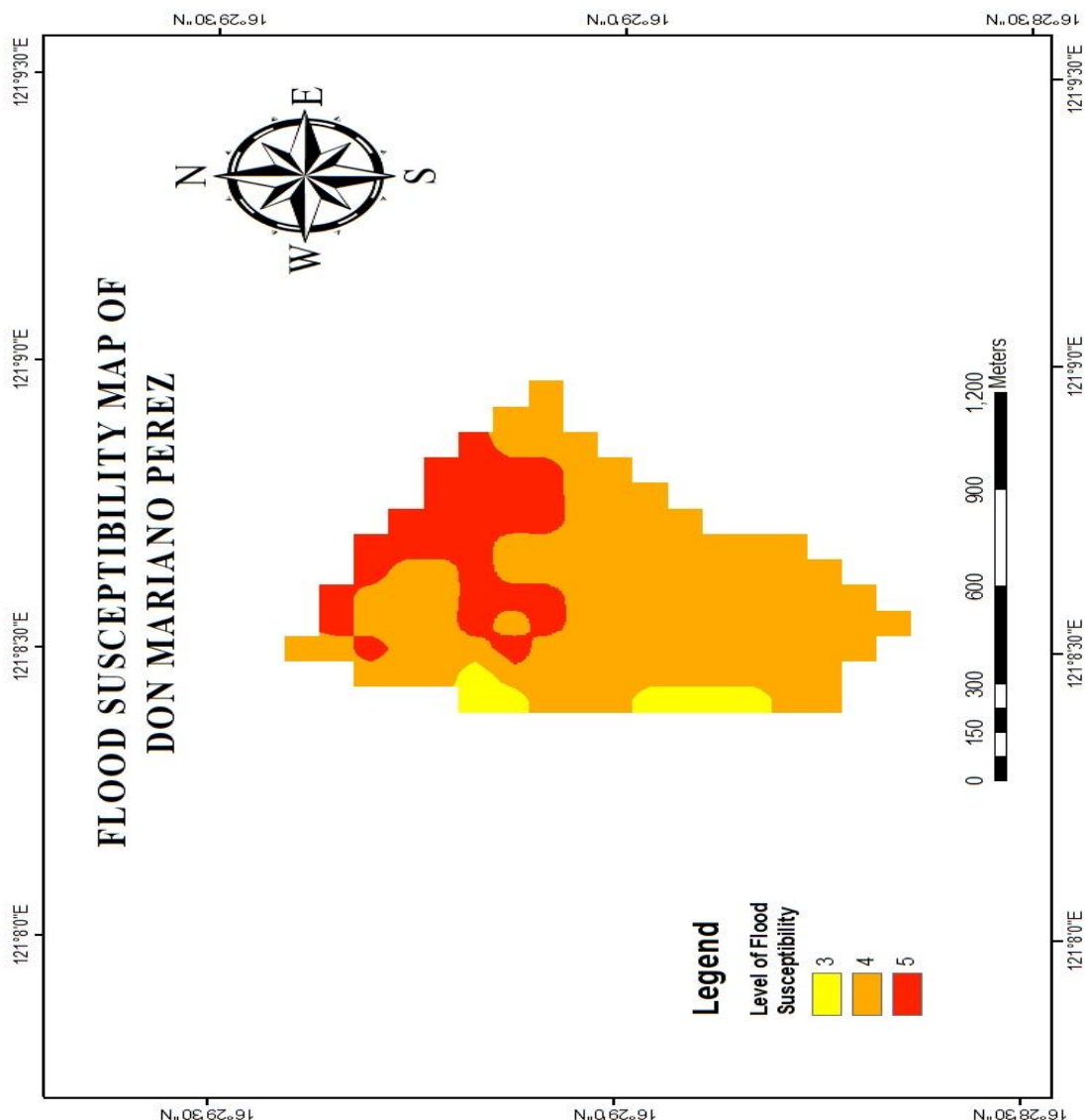


Figure 19: Flood Susceptibility Map of Don Mariano Perez

Barangay Don Mariano Marcos

The table and map below, represents that Don Mariano Marcos are among the barangays whose land cover is composed of open/barren/built-up area and is regarded as highly to very highly susceptible to flood based on the result of AHP and GIS weighted overlay tool although it receives a low amount of rainfall compared to other barangays. It is located at an elevation of 250-500 above datum and an area where its slope is between 0-18 degrees. Because of that an area of 29.41 hectares is highly susceptible to flood and the rest is very highly susceptible to flood with an area of 4.99 hectares.

Table 22: Area coverage of each level according to the flood susceptibility map of Don Mariano Marcos

DON MARIANO MARCOS		
RATE	LEVEL	AREA (Hectares)
4	High	29.41
5	Very High	4.99

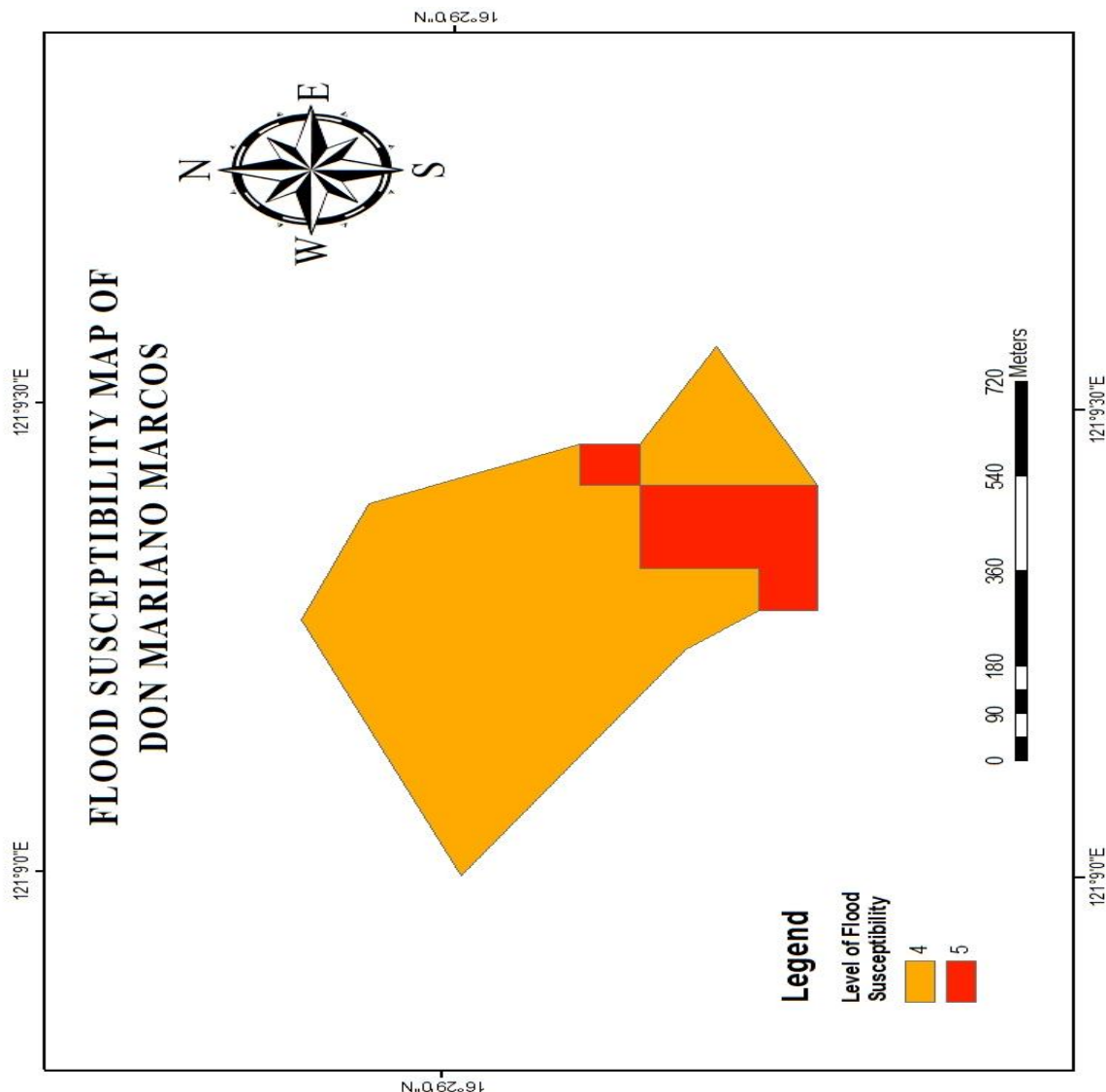


Figure 20: Flood Susceptibility Map of Don Mariano Marcos

Barangay Don Tomas Maddela

The table and map below show data about barangay Don Tomas Maddela about its susceptibility to flood. The whole part of Barangay Don Tomas Maddela with an area 10.60 hectares, according to the map, is highly susceptible to flood. It is mostly composed of open/barren/built-up area. Also, its elevation is within 250-500 meters above datum and its slope is within 0-3 degrees.

Table 23: Area coverage of each level according to the flood susceptibility map of Don Tomas Maddela

DON TOMAS MADDELA		
RATE	LEVEL	AREA (Hectares)
4	High	10.60

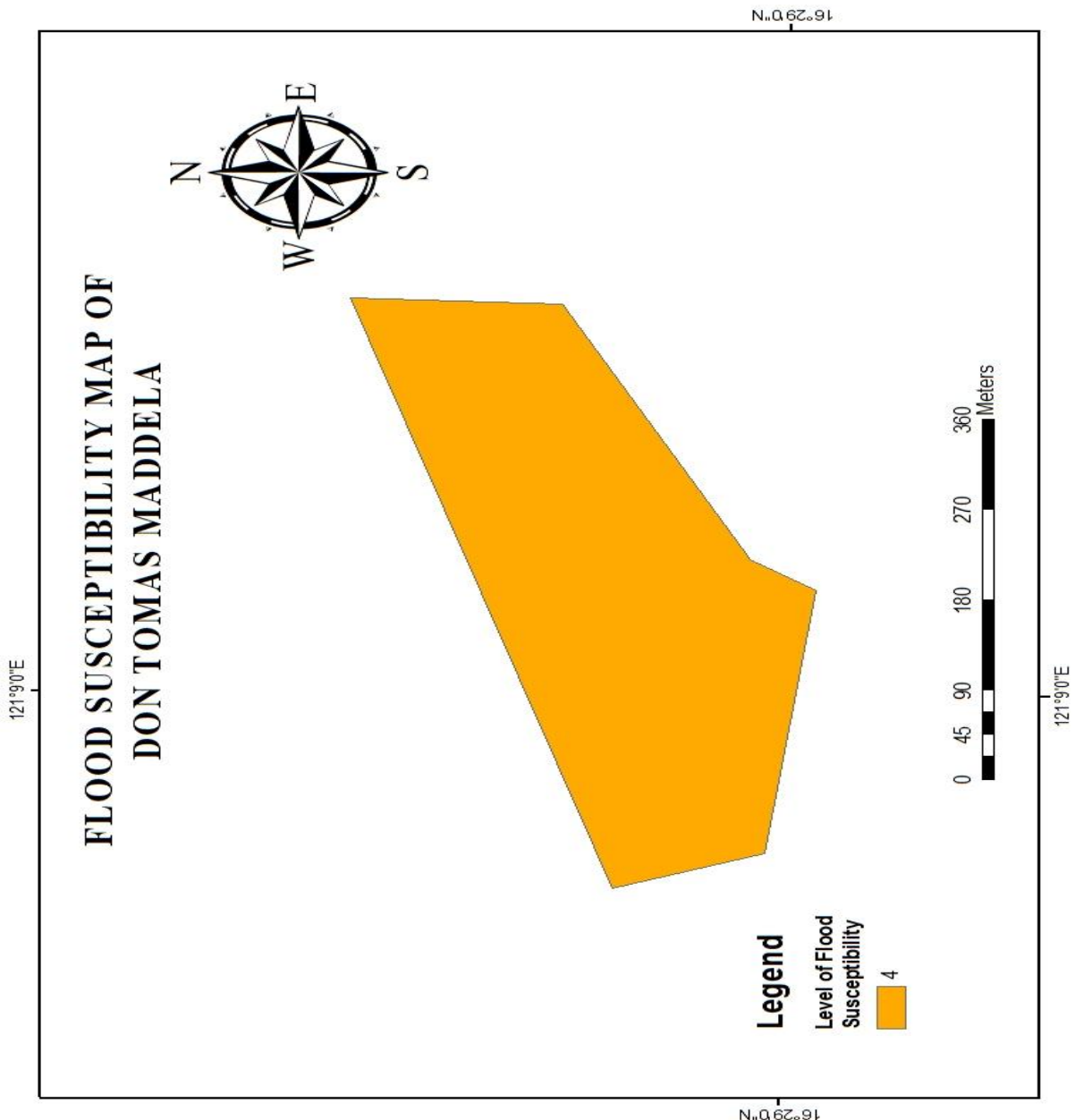


Figure 21: Flood Susceptibility Map of Don Tomas Maddela

Barangay Ipil Cuneg

Ipil Cuneg, from the table and figure below, has an area 169.66 hectares which is highly susceptible to flood. Moreover, an area 367.38 hectares is regarded as moderately susceptible to flood. Lastly, 203.28 hectares and 82.47 hectares is low and very low susceptible to flood, respectively. Ipil Cuneg receives a moderate amount of rainfall, but majority of its land cover is composed of forest, Brush/shrub, and grassland and annual crop. Its slope is between 3-18, 18-30 and 30-50 degrees. Moreover, half of its portion is above 500 meters above datum.

Table 24: Area coverage of each level according to the flood susceptibility map of Ipil Cuneg

IPIL CUNEG		
RATE	LEVEL	AREA (Hectares)
1	Very Low	82.47
2	Low	203.28
3	Moderate	367.38
4	High	169.66

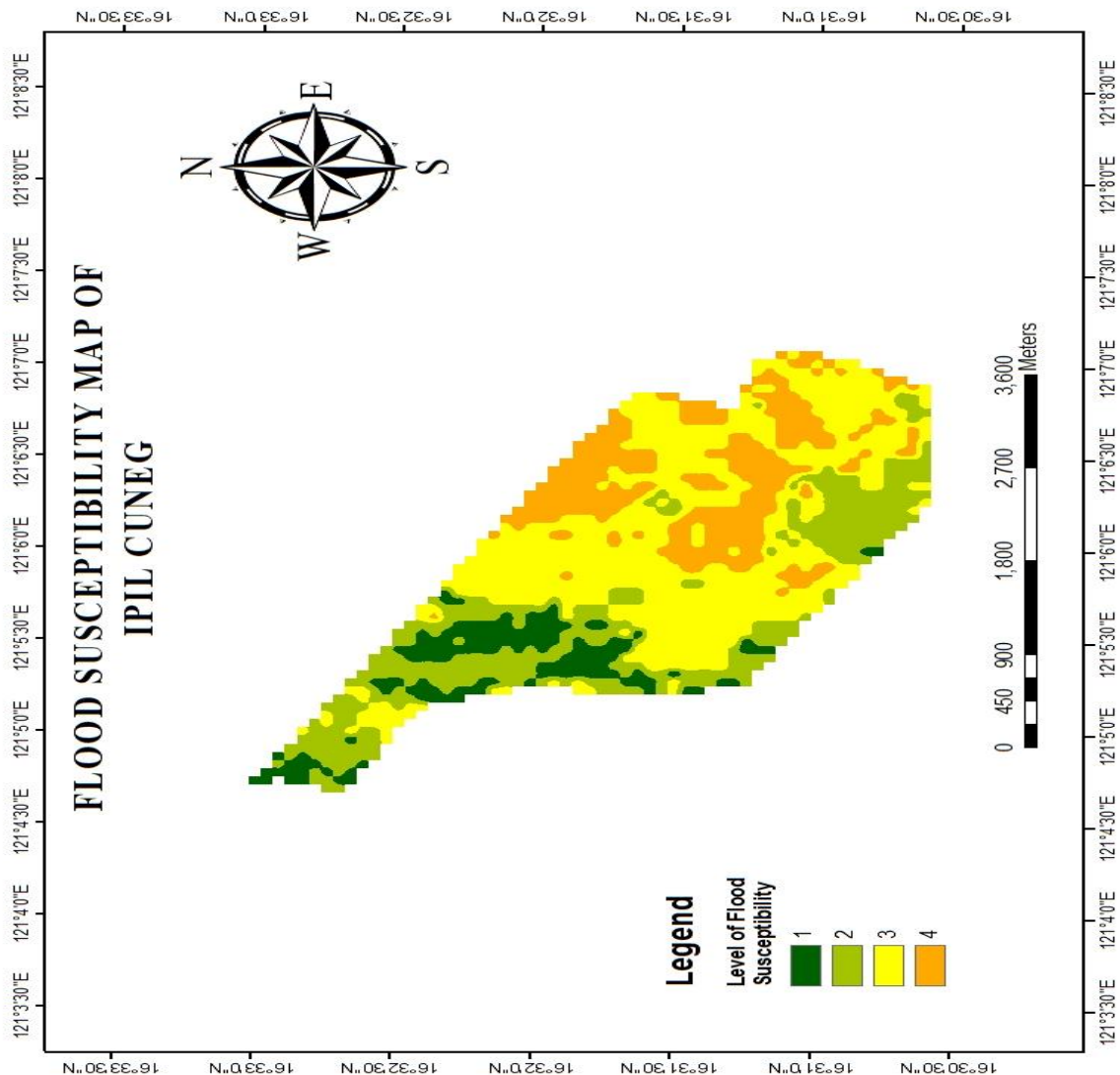


Figure 22: Flood Susceptibility Map of Ipil Cuneg

Barangay La Torre North

The table and figure below show that the largest portion with a total area of 153.24 hectares is highly susceptible to flood. Second largest area accumulating to 136.58 hectares is moderately susceptible to flood. And only an area of 69.04 hectares and 2.07 hectares is low and very high susceptible to flood. Its elevation is between 250-500 meters above datum and its slope is 0-18 degrees. Some portion of the barangay has a slope 18-50 degrees. Its land covers composed of forest, brush/shrub, grassland/annual crop, and open/barren/built-up areas. The barangay is more than 300 meters away from rivers and receives a low amount of rainfall.

Table 25: Area coverage of each level according to the flood susceptibility map of La Torre North

LA TORRE NORTH		
RATE	LEVEL	AREA (Hectares)
2	Low	69.04
3	Moderate	136.58
4	High	153.24
5	Very High	2.07

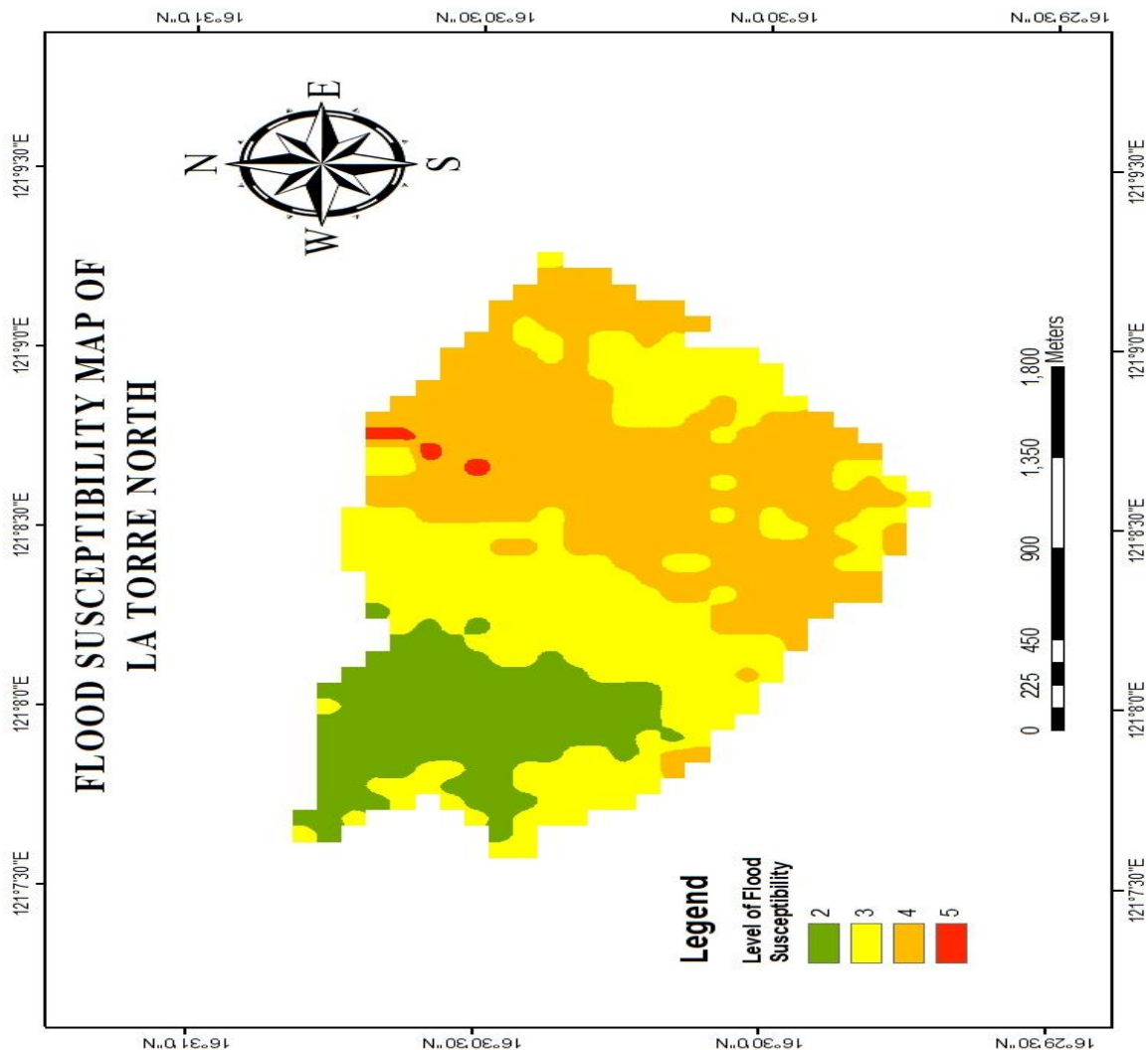


Figure 23: Flood Susceptibility Map of La Torre North

Barangay La Torre South

Based on the table and figure below, a large portion of La Torre South having an area of 261.06 hectares is highly susceptible to flood. Moreover, 68.90 hectares and 59.96 hectares is moderately and slightly susceptible to flood. Lastly, only a small portion of the barangay is very highly susceptible to flood with a total area of 20.72 hectares. Its elevation is between 250-500 meters above datum and its slope is 0-18 degrees. Its land covers composed of brush/shrub, grassland/annual crop, and open/barren/built-up areas. The barangay has a river crossing it, but other portion are 300 meters away from the river. Lastly, it receives only a small amount of rainfall compared to other barangays.

Table 26: Area coverage of each level according to the flood susceptibility map of La Torre South

LA TORRE SOUTH		
RATE	LEVEL	AREA (Hectares)
2	Low	59.96
3	Moderate	68.90
4	High	261.06
5	Very High	20.72

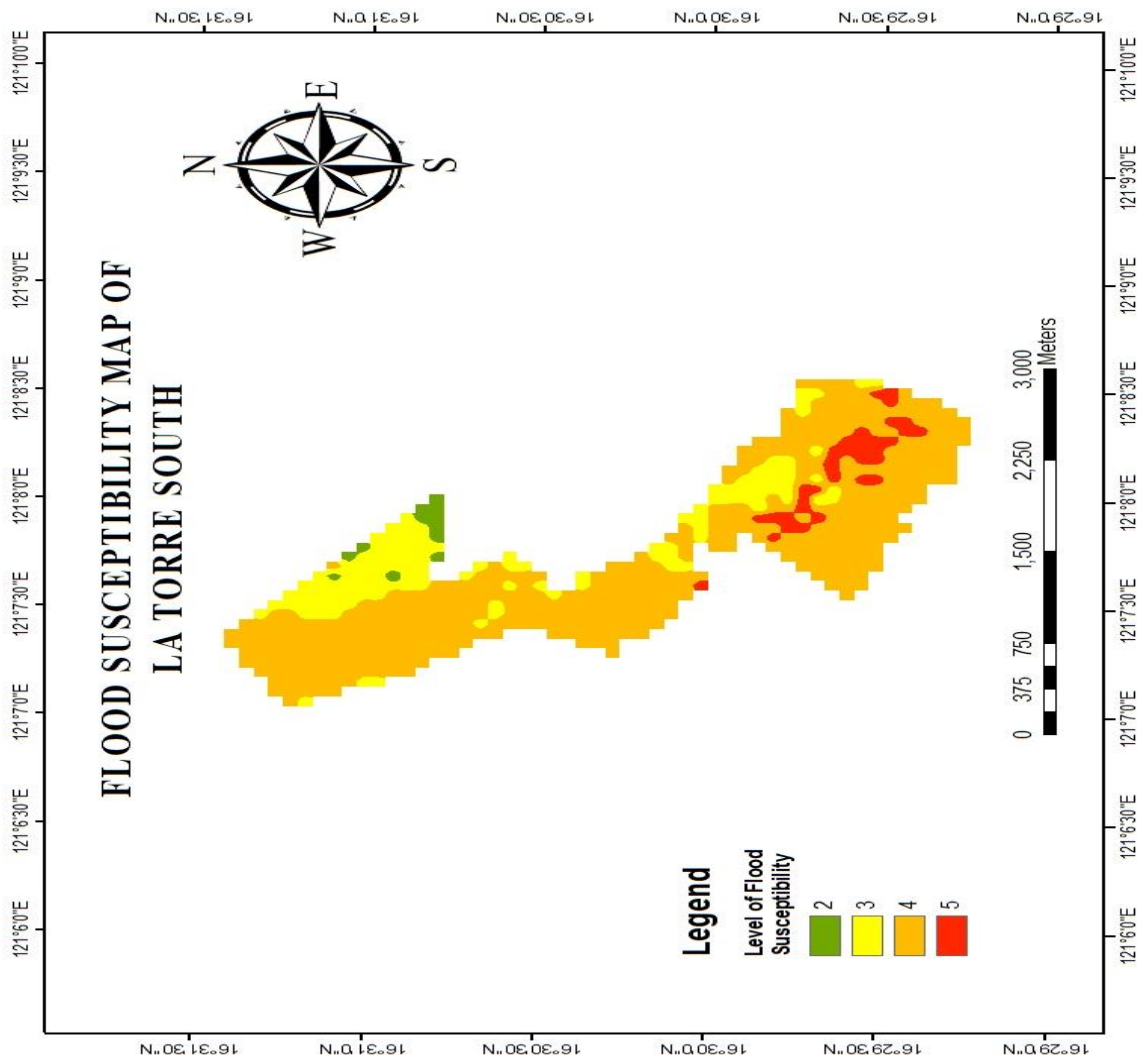


Figure 24: Flood Susceptibility Map of La Torre South

Barangay Luyang

From the table and figure below, barangay Luyang is mostly high susceptible to flood with an area of 137.28 hectares. The rest is very high and moderately susceptible to flood with a total area of 16.53 hectares and 21.62 hectares, respectively. A river also crosses barangay Luyang, but other portions are 300 meters away from the river. Luyang are among those barangays who receives low average total annual rainfall and has a slope between 0-18 degrees. Its elevation is between 250-500 meters above the datum. Luyang is only compose of Brushland, grassland/annual crop, and open/barren/built-up areas.

Table 27: Area coverage of each level according to the flood susceptibility map of Luyang

LUYANG		
RATE	LEVEL	AREA (Hectares)
3	Moderate	21.62
4	High	137.28
5	Very High	16.53

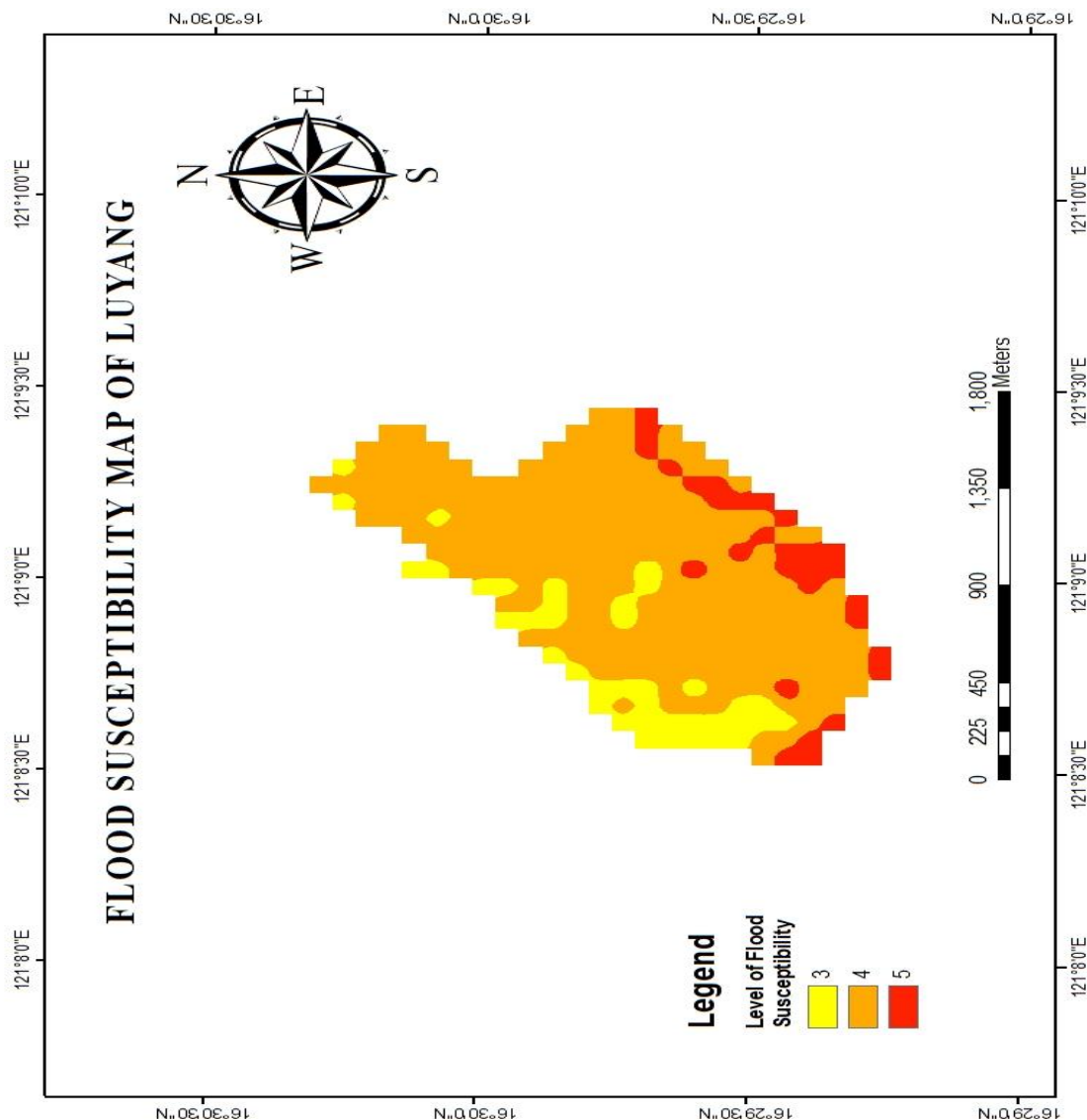


Figure 25: Flood Susceptibility Map of Luyang

Barangay Magapuy

Table 28 and figure 26 represents the Magapuy’s Land cover is varied as it has all the land cover classification. However, majority of the land cover is grassland/annual crop. Its elevation is 250-1000 meters above datum and a slope of 0-3 degrees on the river part and 3-18 degrees on the grassland areas. It also has above 30 degrees slope, and they are mostly in forest zones. Therefore, an area of 42.63 hectares is labeled to be very low to flood. 223.69 hectares and 544.49 hectares are very low and moderately susceptible to flood, respectively. Lastly, 334.07 and 24.70 hectares are high and very high susceptible to flood, respectively.

Table 28: Area coverage of each level according to the flood susceptibility map of Magapuy

MAGAPUY		
RATE	LEVEL	AREA (Hectares)
1	Very Low	42.63
2	Low	223.69
3	Moderate	544.49
4	High	334.07
5	Very High	24.70

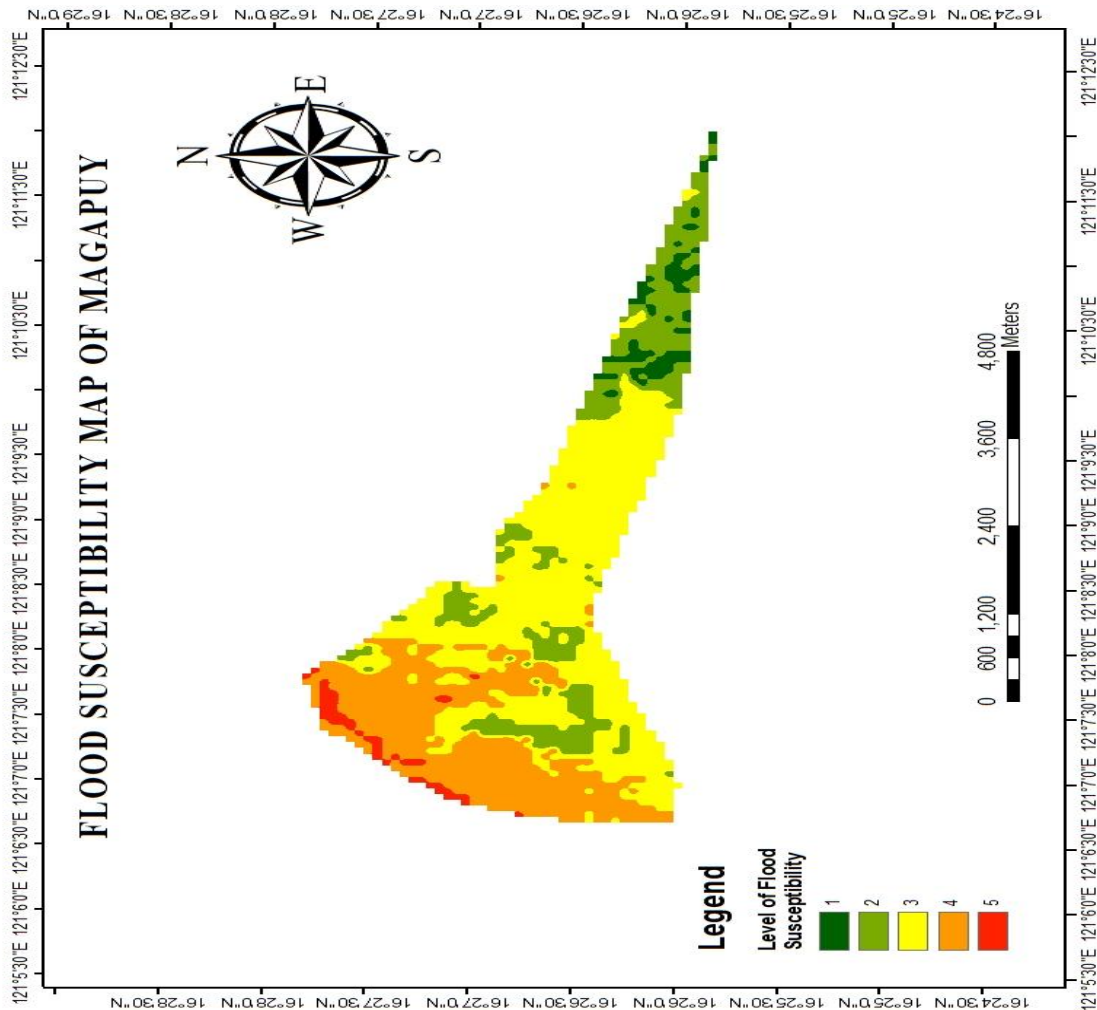


Figure 26: Flood Susceptibility Map of Magapuy

Barangay Magsaysay

The table and figure below shows that a total of 76.23 hectares is very highly susceptible to flood and majority is highly susceptible with a total area of 330.51 hectares. A portion of the barangay is moderately and slightly susceptible to flood with an area of 348.58 hectares and 170.35 hectares, respectively. Lastly, 37.91 hectares is regarded as very low susceptible to flood. Barangay Magsaysay has all the land cover classification and has a slope ranging from 0-50 degrees. It has an elevation of between 250-1000 meters above datum. Some portion of the barangay is within 0-200 meters away from the river. However, it receives a low average total annual rainfall.

Table 29: Area coverage of each level according to the flood susceptibility map of Magsaysay

MAGSAYSAY		
RATE	LEVEL	AREA (Hectares)
1	Very Low	37.91
2	Low	170.35
3	Moderate	348.58
4	High	330.51
5	Very High	76.23

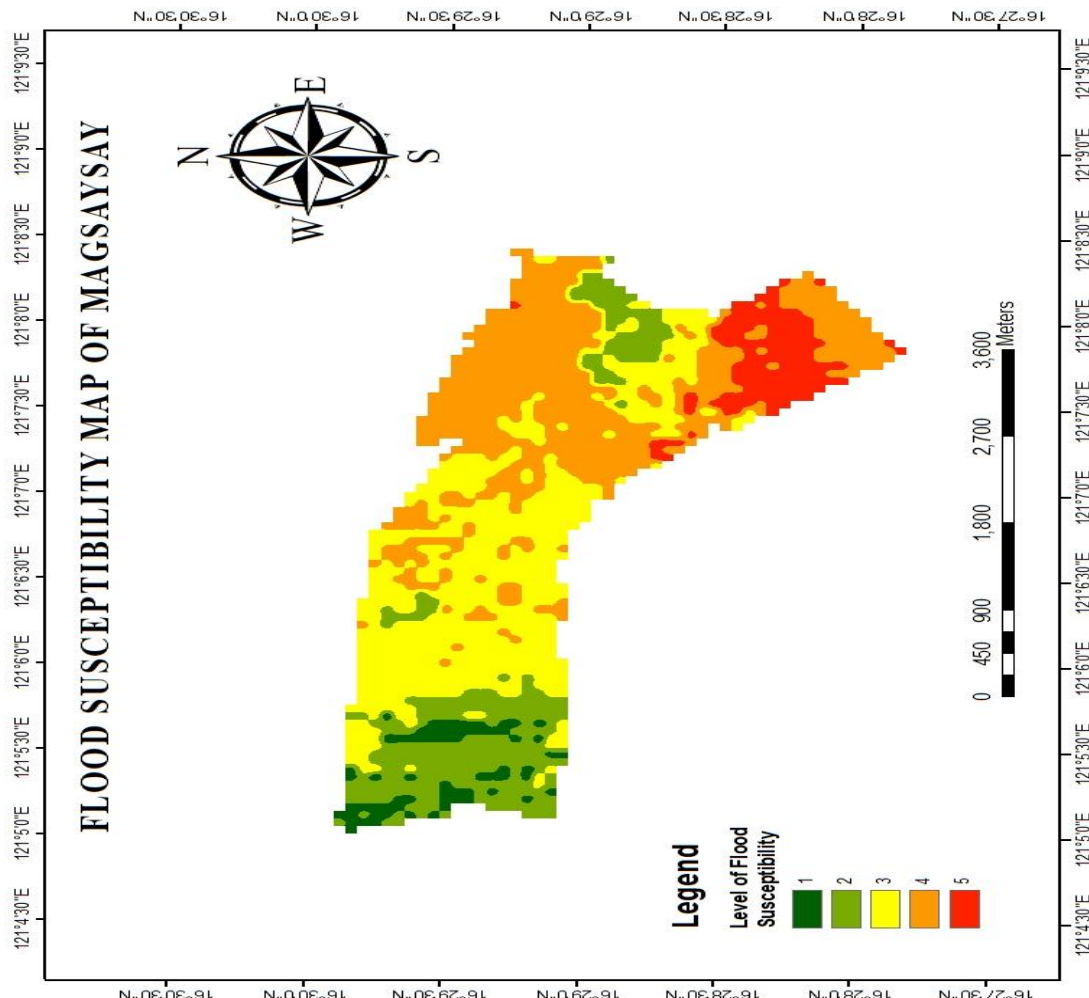


Figure 26: Flood Susceptibility Map of Magsaysay

Barangay Masoc

Masoc has all the land cover classification, but majority is forest and grassland/annual crop. It also has a river and built-up area. According to the result, majority of the barangay is moderately susceptible to flood with an area of 364.88 hectares. Followed by highly susceptible to flood with an area of 268.40 hectares. An area of 107.13 hectares and 13.99 hectares are regarded as low and very high susceptible to flood, respectively. The rest of the barangay which composed of an area 39.31 hectares is very low susceptible to flood as illustrated in figure 28.

Table 30: Area coverage of each level according to the flood susceptibility map of Masoc

MASOC		
RATE	LEVEL	AREA (Hectares)
1	Very Low	39.31
2	Low	107.13
3	Moderate	364.88
4	High	268.40
5	Very High	13.99

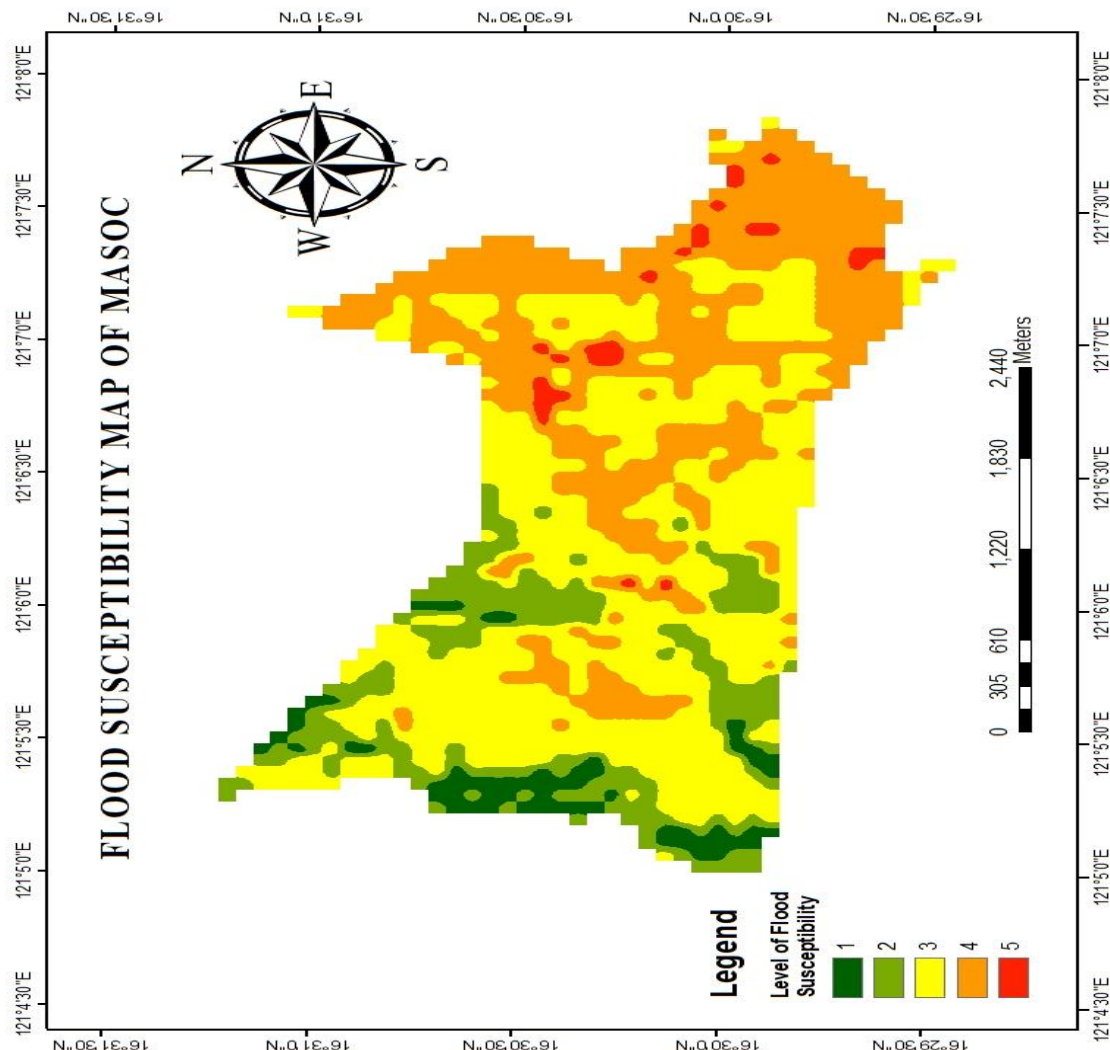


Figure 28: Flood Susceptibility Map of Masoc

Barangay Paitan

From the table and figure below, majority of barangay Paitan with an area of 867.70 hectares is highly susceptible to flood. Succeeded by an area 563.82 and 300.71 hectares which are moderately and slightly susceptible to flood. An area 196.92 hectare is very high susceptible to flood and only an area of 32.15 hectares is very low. Paitan has a lot of arterial river drainage, and a main river is also evident in the barangay. Although it receives low average of total annual rainfall, its land cover is majorly grassland/annual crop and built-up areas and inland waters. On the southeast portion of the barangay is a forest zone and brush land with an elevation of above 1000 meters above datum and a slope of 18-50 degrees.

Table 31: Area coverage of each level according to the flood susceptibility map of Paitan

PAITAN		
RATE	LEVEL	AREA (Hectares)
1	Very Low	32.15
2	Low	300.71
3	Moderate	563.82
4	High	867.70
5	Very High	196.92

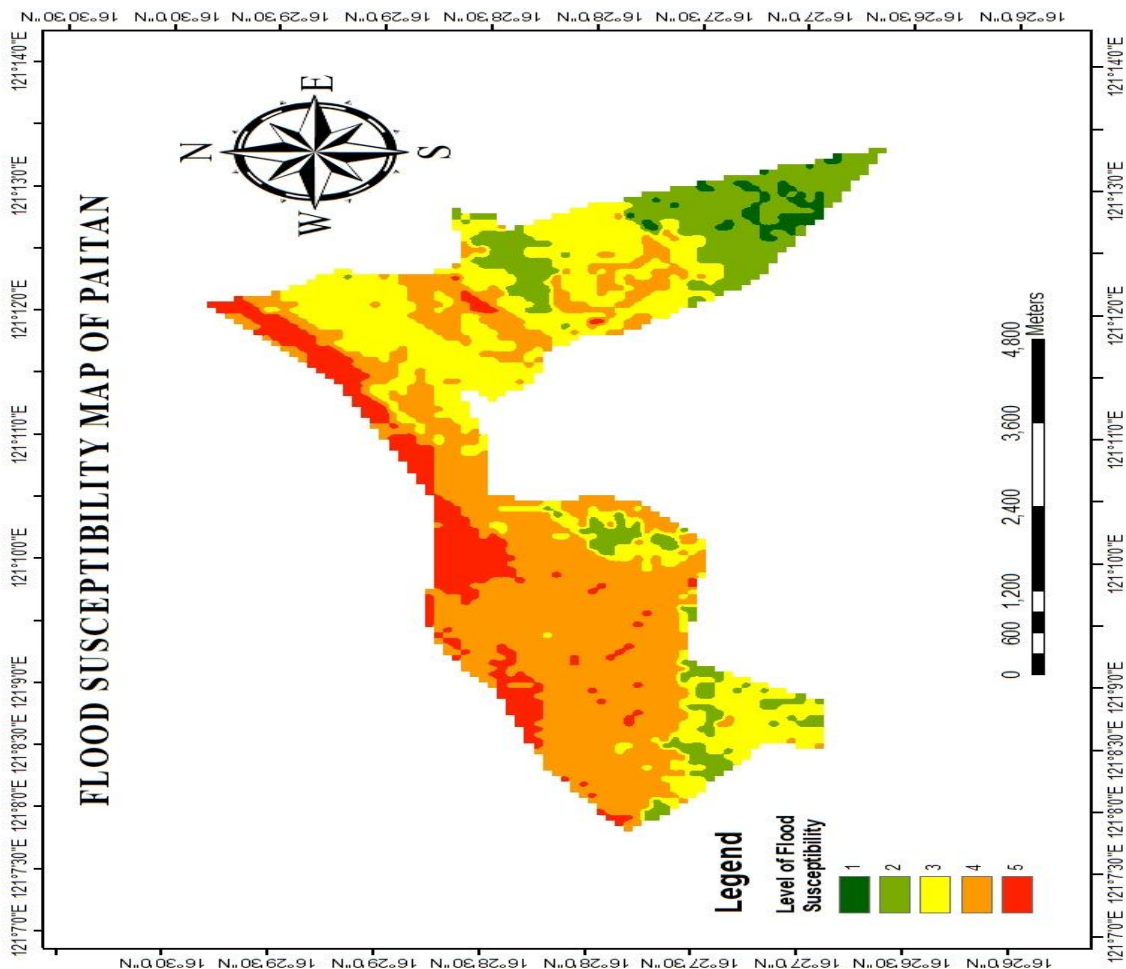


Figure 29: Flood Susceptibility Map of Paitan

Barangay Salvacion

As illustrated in figure 30, Salvacion is one of the nearest barangay from a main river. Some portion of it is within 0-300 meters from the river. It is also majorly a built-up area barangay like its neighboring barangays. Its elevation is between 250-500 meters above datum and a slope of 0-3 degrees. Therefore, majority of the barangay with an area of 34.98 hectares is highly susceptible to flood. Lastly, an area of 7.9 hectares and 0.62 hectares are very highly susceptible and moderately susceptible to flood, respectively.

Table 32: Area coverage of each level according to the flood susceptibility map of Salvacion

SALVACION		
RATE	LEVEL	AREA (Hectares)
3	Moderate	0.62
4	High	34.98
5	Very High	7.95

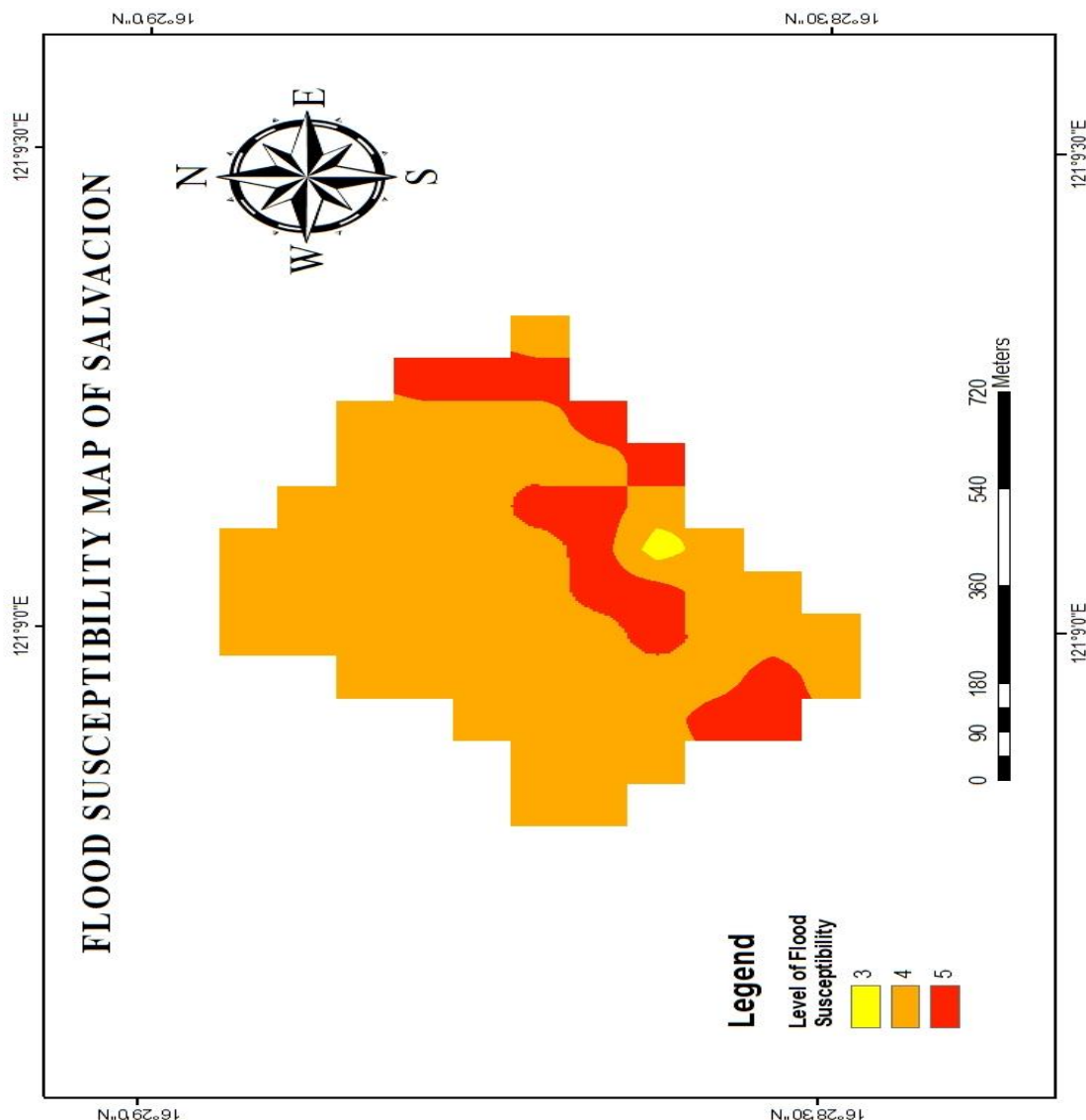


Figure 30: Flood Susceptibility Map of Salvacion

Barangay San Nicolas

San Nicolas’ elevation is between 250-500 meters above datum and a slope of 0-3 degrees. It is also majorly a built-up area and grassland and annual crop land barangay. Although it has a low annual rainfall, majority of the barangay with an area of 38.20 hectares is highly susceptible to flood. Lastly, an area of 6.07 hectares and 2.07 hectares are very highly susceptible and moderately susceptible to flood, respectively as shown in figure 31.

Table 33: Area coverage of each level according to the flood susceptibility map of San Nicolas

SAN NICOLAS		
RATE	LEVEL	AREA (Hectares)
3	Moderate	2.07
4	High	38.20
5	Very High	6.07

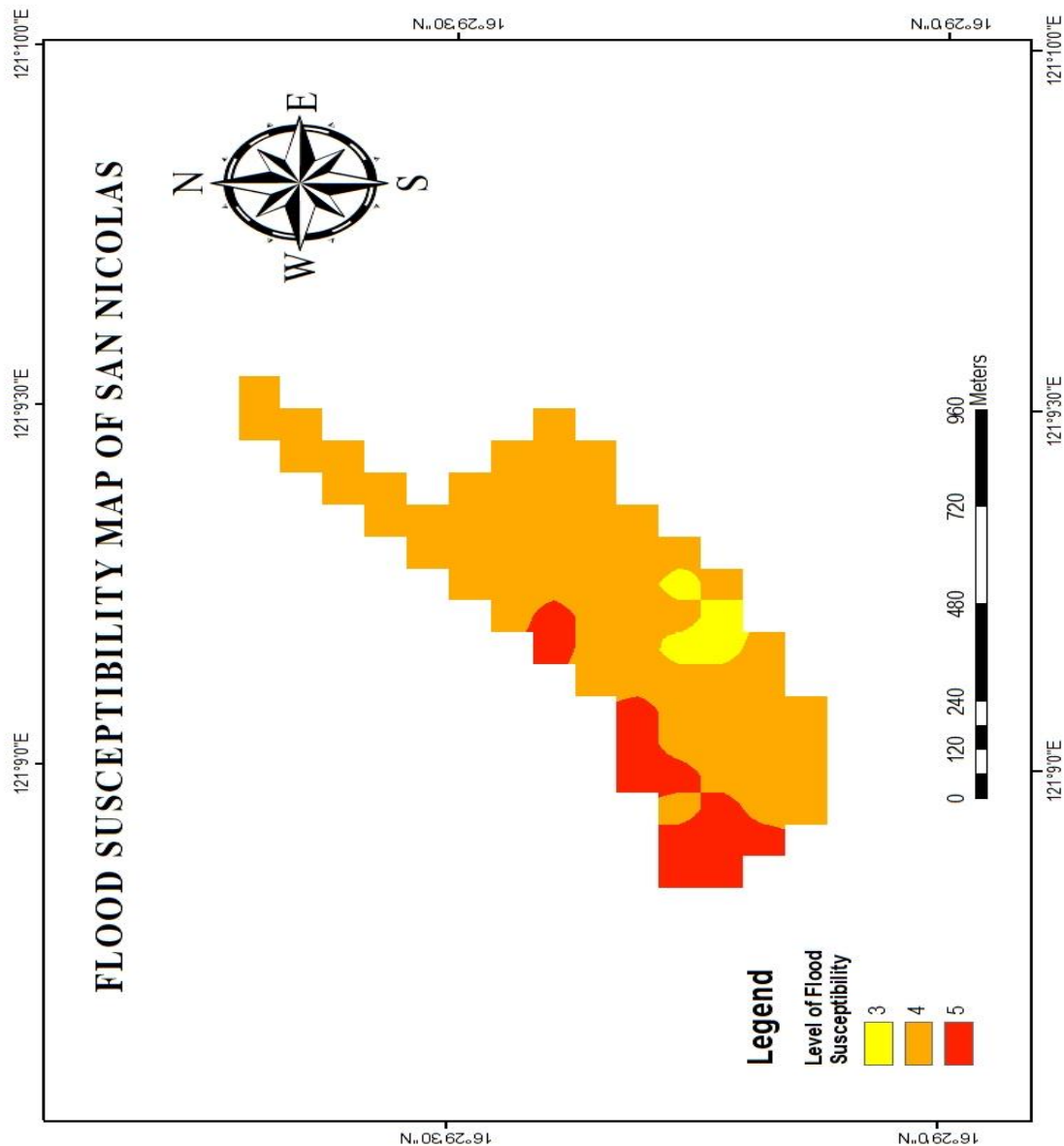


Figure 31: Flood Susceptibility Map of San Nicolas

Barangay Santa Rosa

Base from table 34 and figure 32, Santa Rosa’s elevation is between 250-500 meters above datum and a slope of 0-3 degrees. It is one of the nearest barangays from a main river. Some portion of it is within 0-300 meters from the river. It is also majorly a built-up area and grassland and annual crop land barangay. Although it has a low annual rainfall, majority of the barangay with an area of 89.03 hectares is highly susceptible to flood. Lastly, an area of 89.03 hectares and 7.78 hectares are very highly susceptible and moderately susceptible to flood, respectively.

Table 34: Area coverage of each level according to the flood susceptibility map of Santa Rosa

SANTA ROSA		
RATE	LEVEL	AREA (Hectares)
3	Moderate	7.78
4	High	89.03
5	Very High	89.03

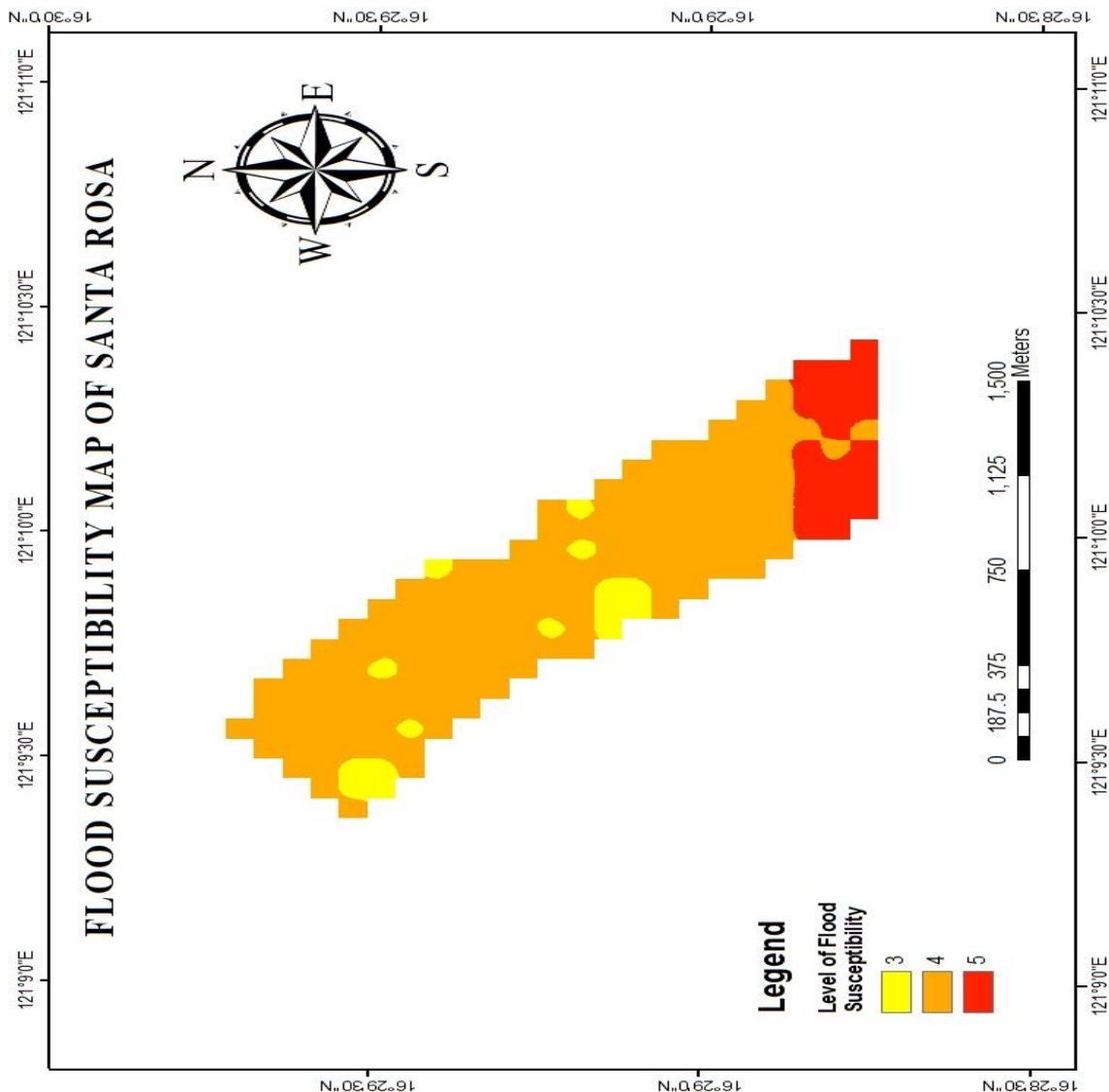


Figure 32: Flood Susceptibility Map of Santa Rosa

Barangay Vista Alegre

From the table and figure below, majority of barangay Vista Alegre with an area of 43.90 hectares is very highly susceptible to flood. Succeeded by an area 40.84 and 19.09 hectares which are highly and moderately susceptible to flood. An area 12.41 hectares is slightly susceptible to flood. Vista Alegre, just like Salvacion is one of the barangays that are near the river. Although it receives low average of total annual rainfall, its land cover is majorly open/barren/built-up areas and inland waters. A portion of it is forest and brush land. The barangay has an elevation between 250-500 meters above datum and a slope of 0-30 degrees.

Table 35: Area coverage of each level according to the flood susceptibility map of Vista Alegre

VISTA ALEGRE		
RATE	LEVEL	AREA (Hectares)
2	Low	12.42
3	Moderate	19.09
4	High	40.84
5	Very High	43.90

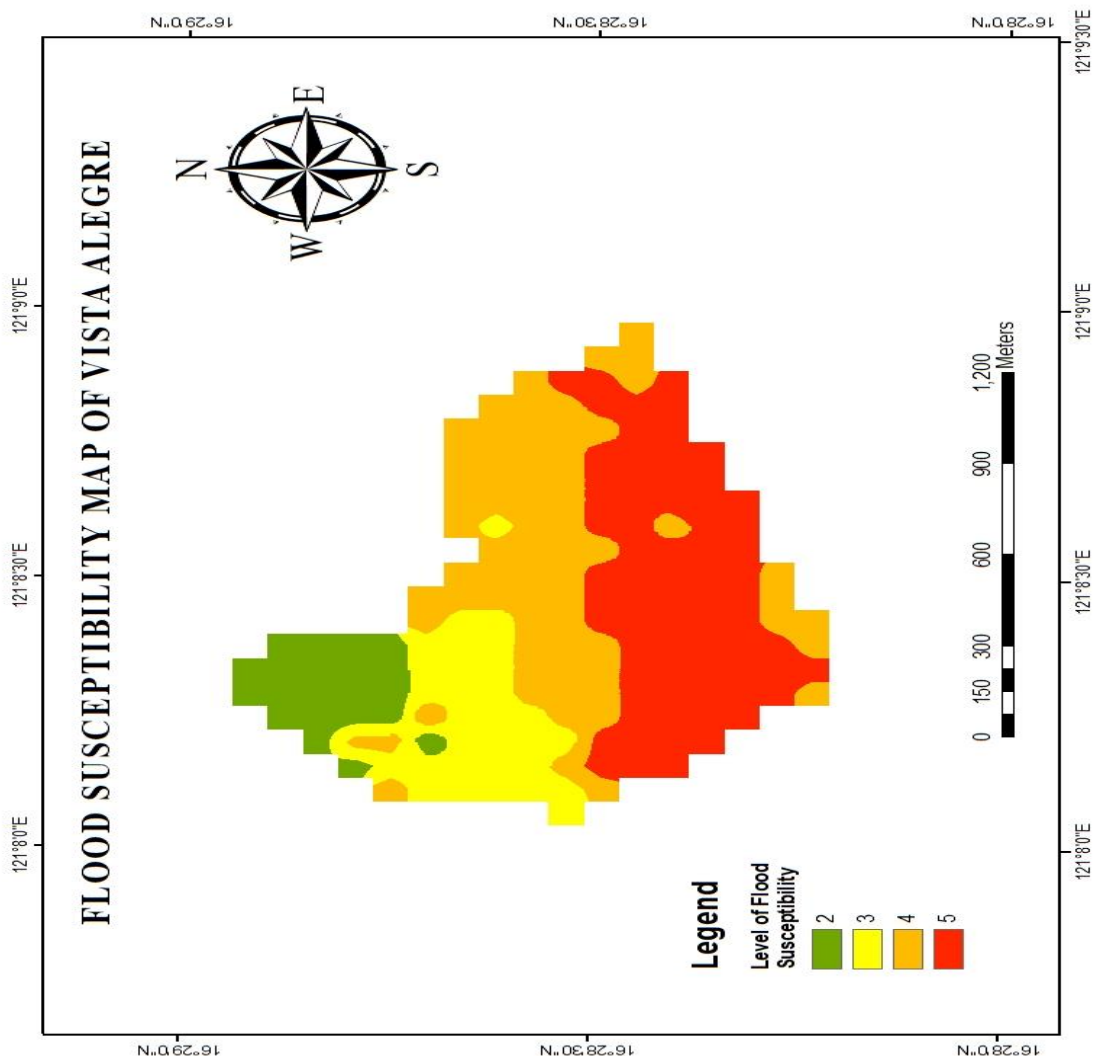


Figure 33: Flood Susceptibility Map of Vista Alegre

Validation

The validation of the produced flood susceptibility map was achieved by applying the aforementioned methodology. The aid of GPS-based field survey and geotagging was applied to validate the Flood susceptibility map. The researchers conducted a photo gathering with GPS cameras and geotagging. On the photo gathering, the researchers did an actual ground survey and took numerous georeferenced photographs. On the other hand, uploaded photos by the people in the community was also geotagged. The method employed in the generation of the flood susceptibility map of Bayombong, after validation, was identified to have a positive result. It was confirmed by the photos gathered and geotagged that floods do really occur on the places determined to be highly and very highly susceptible to flood. Figure 34 and 35 shows the validated points along with its corresponding captured and geotagged photos. The GPS-based field survey was conducted on the points 1, 2, 4, 5, and 7 which are located at barangay Buenavista (points 1 and 2), Vista Alegre (points 4 and 5) and District 4, respectively. From the flood susceptibility map generated, the first two points in Buenavista are highly susceptible to flood. It was validated through field survey and the result showed that these two points are really highly susceptible to flood as shown in the photos captured using GPS camera, because of the reason that although they receive low average total annual rainfall compared to other barangay, these are 0-100 meters away from nearby rivers and are in low elevated areas with an elevation of 250-500 meters above datum, they are in open/barren/built-up and inland waters, and has 0-3 degrees slope. Moreover, points 4 and 5 in Vista Alegre were identified to be very highly susceptible to flood. It was further validated, and the result is positive as it is really very highly susceptible to flood. These points are within 0-100 meters away from river as shown in the photograph. These points also have an elevation of 250-500 meters above datum, has a slope of 0-3 degrees and are in inland waters. Lastly, point 7 which is located at district 4, is regarded as very highly susceptible to flood. From the validation conducted, it was proved to be very highly susceptible to flood because flood warning signs are posted nearby. Furthermore, the point is validated to be within the range 100-200 meters away from river, it is in built-up areas, its elevation is 250-500 meters above datum, and its slope is 0-3 degrees. The geotagged photos in points 3 and 6 were gathered from social medias of the people in the community. In point 3 and 6, the flood susceptibility map shows that they are located in high flood susceptible areas and accordingly, from the geotagged photos they were validated to be in places which are really a high flood susceptible areas. Moreover, they are high flood susceptible areas because based on the elevation map, slope map, land cover map, their elevation are 250-500 meters above datum which were regarded as high susceptible to flood, their slope ranges from 0-3 degrees which were very highly susceptible to flood, and their land covers are open/barren/built-up/inland water which were very highly susceptible to flood.

Table 36: Validated points and its corresponding Flood Susceptibility Map Rating and Validation Rating

Points	Flood Susceptibility Map Rating	Validation Rating
1	High	High
2	High	High
3	High	High
4	Very high	Very high
5	Very high	Very high
6	High	High



7	Very high	Very high
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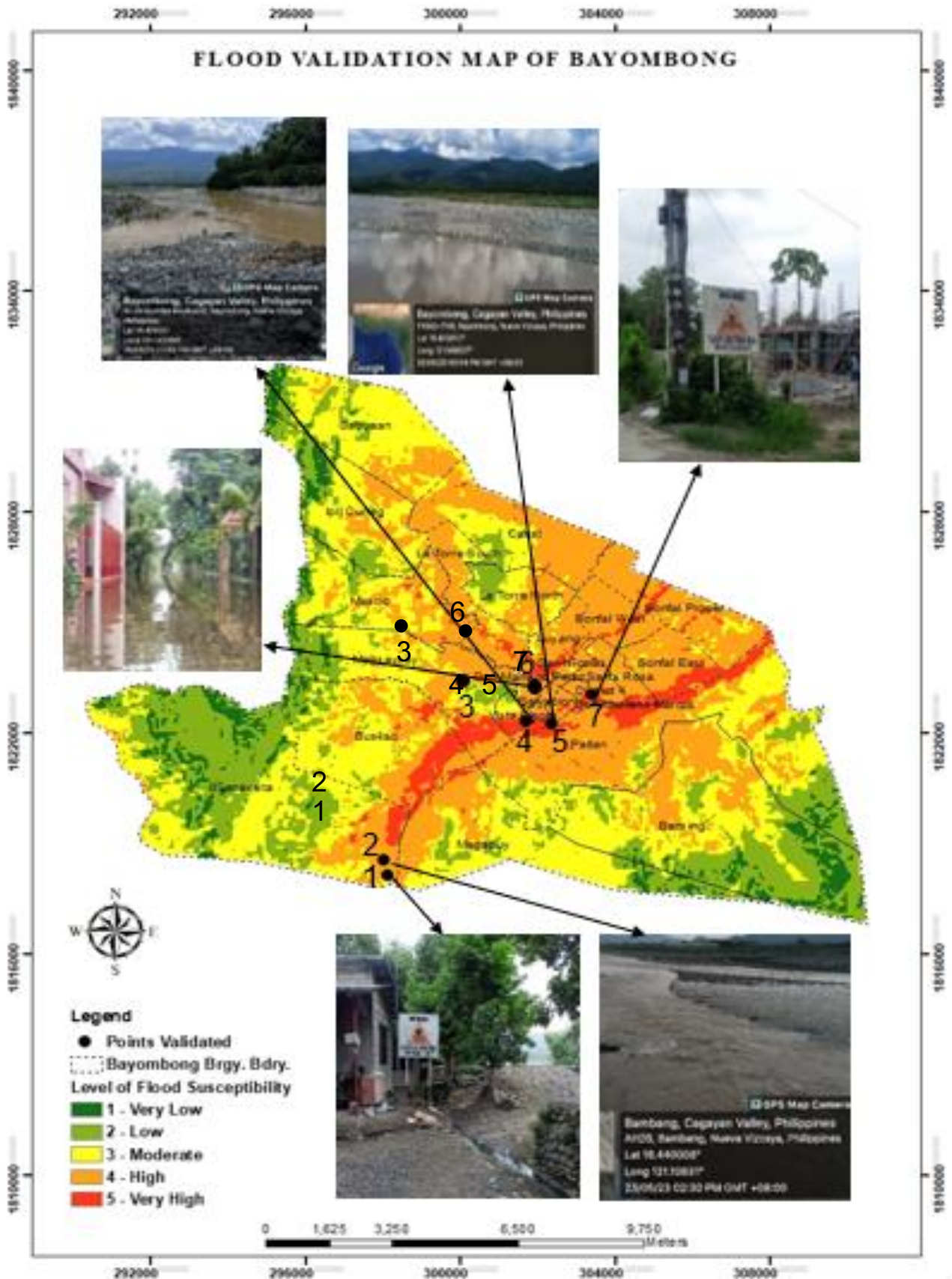


Figure 34: Flood Validation Map

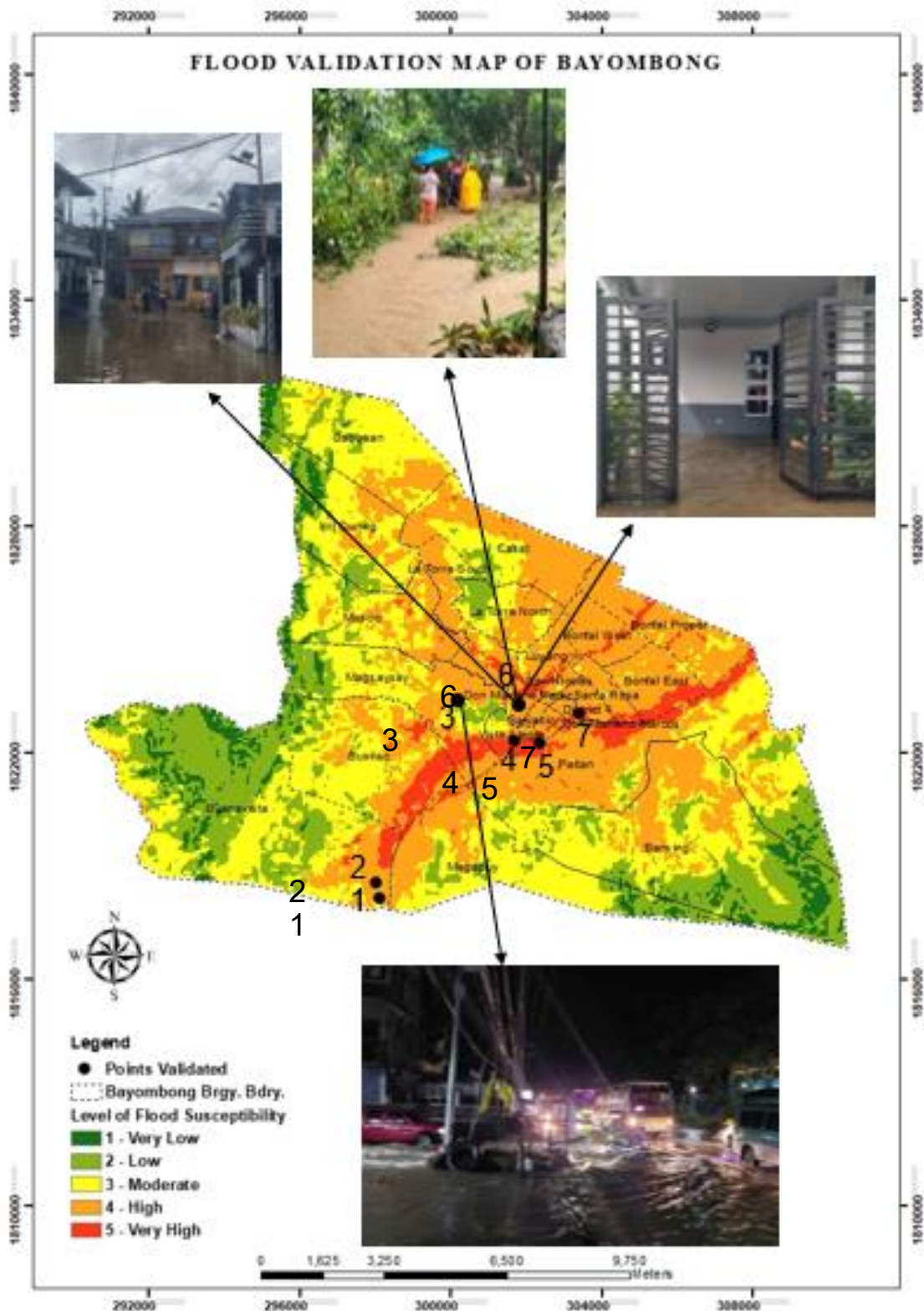


Figure 35: Flood Validation Map

Conclusion

Flood is a recurring natural hazard that adversely affects the lives and properties of many people around the world. It happens mostly because of typhoons and heavy rainfalls. The municipality of Bayombong has been one of the municipalities that suffers from flooding due to typhoons. A detailed analysis of remote sensed images using GIS alongside with GPS-based field validations was conducted by the researchers to determine the susceptibility of the municipality to flood. Moreover, to be able to assess flood susceptibility of the municipality, several flood-causing factors were selected like rainfall, elevation, slope, distance from river, and Land cover. Using the concept of AHP as an MCDA technique, each factor was given weight adapted from the study of Domanikis et al. (2020). The weights contribute to the determination of the susceptibility level of each barangay in the municipality. Elevation is the most flood-influencing factor in Bayombong with a percentage weight of 42%. Followed by slope (26%), Distance from river (16%), Land cover (10%) and Rainfall (6%). The factors were reclassified into 5 classes with a level of susceptibility ranging from very high, high, moderate, low and very low.

In general, based on the results of the study the whole municipality of Bayombong is susceptible to flood with a level of susceptibility ranging from very high to very low. The places with very high flood susceptibility covered an area of 768.31 hectares. Moreover, majority of the municipality is high susceptible to flood covering an area of 5,655.40 hectares. Comparing each barangay, Bonfal East, Bonfal West, Bonfal Proper, District 4, Don Domingo Maddela, Don Mariano Marcos, Don Tomas Maddela, Don Mariano Perez, La Torre South, Luyang, Salvacion, San Nicolas, Santa Rosa and Vista Alegre are the most critical from getting inundated. These barangays are in low lying areas composing of land cover of mostly open/barren/built-up and inland water. Their elevation is within 250-500 meters above the datum and their slope ranges from 0-3 degrees. On the other hand, barangay Buenavista is assessed to be the most very low flood susceptible barangay. As it composed of mostly, perennial crop, forest land, and brush land. There is only a small percentage of built-up areas in the municipality when compared to the portion of forest land and perennial crop and brush land. Moreover, although it has the most rainfall, it also has the highest elevation and steepest slope. Therefore, it has higher water run off than most barangays. In the validation of the flood susceptibility map, the AHP statistical tool shows a positive result in which points that were validated shows to have 100% conformity to the flood susceptibility map generated. Areas where the flood map shows to be very high susceptible to flood is indeed has a very high possibility of getting inundated.

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