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Research article

Nabaoy River Watershed potential impact to flooding using Geographic Information System remote sensing

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Abstract: Watersheds are naturally prone to environmental disasters such as flooding. The purpose of the study was to analyze the potential impact of flooding on the Nabaoy River Watershed using Geographic Information System (GIS) remote sensing. Secondary data for flood factors such as slope, elevation, land cover, surface run-off, rainfall, and soil were used and reclassified using the critical scale of factors of flood vulnerability ratings and weighting overlay using the GIS environment to create geospatial data on the potential impact to flooding. Data revealed the following percentages of the susceptibility of the watershed to flooding: very low (8.06%), very highly (19.79%), moderate (22.15%), high (22.84%), and low (27.16%). The main result showed that the upstream area of the Nabaoy river watershed such as Nabaoy, Napaan, Pawa, and Tag-osip was within low to very low flood vulnerability. Meanwhile, the inundation vulnerability intimidation on the downstream side of the Nabaoy river watershed such Cubay Sur, Motag, and low-lying areas of Nabaoy, Napaan, and Tag-osip have moderate to very highly susceptibility to flooding. The results obtained can help the concerned agencies and stakeholders to craft policy and water management plans, adaptive capacity, conservation measures, and resilience programs in response to severe flooding.

Keywords: flooding; Geographic Information System; hazard; Nabaoy Watershed; vulnerability

1. Introduction

The Nabaoy Watershed, with an approximate land area of 2,469 hectares, is situated in the Municipality of Malay and covers Barangays of Cubay Sur, Motag, Napaan, Pawa, Nabaoy, Malay, and a portion of Tag-osip, Buruanga. The Nabaoy watershed is the main source of potable water in the community, neighboring barangays, and municipalities as well as the source of water to the famous Island of Boracay. This small watershed is being drained by its river system and tributaries with a common outlet that discharges downstream of Nabaoy River flowing its water out into the Sibuyan Sea. People live in a naturally formed hydrological unit called a watershed and about 70% of the total area of the Philippines is considered to be a major watershed. However, watersheds are naturally prone to environmental disasters due to several active faults, steep topography, poor vegetation cover, and socio-economic pressures that contribute to environmental disasters. If only development plans were able to identify vulnerable areas and were able to include measures to reduce hazards, human suffering and economic losses would have been avoided or reduced [1].

Most farmers, fishermen, small-businesses holders, and other communities living in low-lying waterlogged areas experience a wide range of climate variability because of global warming and flooding, especially flash floods, which were found to be more pronounced in such areas [2]. Flash flooding is caused by a set of preliminary and triggering factors which determine their locations, frequency, and magnitude. Excessive rainfall with high intensity was the main source of flash floods in the hilly area, particularly resultant landslides in the area composed of unconsolidated rocks [3]. Flash floods are typically associated with short, high-intensity rainstorms. As such, they are characterized by short response time and have the potential to severely impact and damage communities in different climatic settings all over the world. Despite their scientific and social importance, the fundamental processes triggering a flash-flood response are poorly understood [4].

When water or intensive rainfall enters the watershed too quickly for the land to absorb, flooding can occur. Flooding causes billions of pesos in damages to agricultural lands and takes dozens of lives every year. Accurate flooding forecasts are dependent on an understanding of an area's land use, land cover, geology, and hydrology, as well as weather predictions. Flood forecasting allows LGUs, Provincial Governments, and Disaster Risk Management Offices to predict, with a high degree of accuracy, when local flooding is likely to take place. Thus, they are able to provide disaster risk resilience programs and craft adaptive capacity management.

Spatial planning is increasingly being considered as an important mechanism in coping with flood risk [5–8]. Given that flood hazard is a spatial phenomenon, the application of GIS and Remote Sensing techniques are essential to the flood hazard/risk management process. For instance, Geographical Information Systems (GIS) with their ability to handle spatial data are an appropriate tool for processing spatial data on flood risk [9–11]. Moreover, flood hazard maps and flood risk maps have long been important tools in flood management [12–15].

Tracking the impact of floods is complex because they come in many forms and for myriad reasons. Flash floods are often caused by extreme rain on mountain slopes and sudden water discharges from reservoirs, or other causes. This can happen in all small watersheds at any time of the day and are dangerous due to its velocity and destructive power [16]. As of now, there is no existing study or research on the potential impact of flooding on the area covered by the Nabaoy Watershed. In addition, the peak flow that occurs when there is heavy rainfall in the area that causes immediate flash flood downstream of Nabaoy down to Cubay Sur eventually put the community, the people, and property at risk. By initiating to provide geospatial data on the areas of concern, policy decision-makers will have adequate information as input during crafting the risk reduction management and resiliency plan in response to flooding and natural calamities that will occur. The prediction of the potential impact to flooding of the Nabaoy Watershed in terms of slope, elevation, surface run-off, land cover and soil using Geographic Information System (GIS) remote sensing had not been explored yet, hence, this study was conceptualized.

2. Scope and limitations

The study focuses on the flooding vulnerability of the boundaries and communities covered by the Nabaoy Watershed. The processing of the potential impact to flooding of the Nabaoy watershed was conducted using the ARC GIS 10.5 Software. Hence, some data generated are secondary data that came from various reliable sources and were used in generating the geospatial map. All the references gathered were validated and verified on the ground. Moreover, it is still highly encouraged to take into consideration the observation and ground data in assessing the accuracy of the model generated. The researcher's access to other related reviews that are relevant to the study is limited, thus some important procedures and results of the study may not have been explained further or with comparison to other related studies which may have possibly been conducted already.

3. Data collection and methodology

Biophysical factors which are Exposure (Rainfall) and Sensitivity (soil, elevation, slope, and land cover), are collectively known as Potential Impact. The Digital Elevation Model (DEM) and other important parameters for potential impact to flooding were investigated with ArcGIS 10.5 software. The secondary data was used in the study and obtained through various agencies/bureaus/academies such as the Department of Environment and Natural Resources (DENR), Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), Bureau of Soils and Water Management (BSWM), National Mapping and Resource Information Authority (NAMRIA), Local Government Units (LGUs), and respective Barangays.

3.1. Study area

The study area was Nabaoy Watershed, which is situated in the Municipality of Malay, Aklan and covers six (6) Barangays namely: Cubay Sur, Motag, Napaan, Pawa, Nabaoy, Malay and a portion of Tag-osip, Buruanga. Geographically, the Nabaoy Watershed is at Latitude 11.9069° or 11° 54' 24.7" north and Longitude 121.9279° or 121° 55' 40.5" east (Figure 1). The watershed is also part of the Northwest Panay Peninsula Natural Park in which 891.0 hectares or 36% of it is classified as a protected area under RA 7586 (NIPAS act of 1992). This watershed was selected because it is one of the lone sources of potable water to nearby Boracay Island and the residents of Malay. The natural park is also home to a community of Indigenous Malay Ati people, who fish in the Nabaoy River and rely on the forests for sustenance [17]. This watershed was elected as the area of study because of the influence of driving factors for the flash flood occurrence that were: climatology, geomorphology, and hydrology conditions.

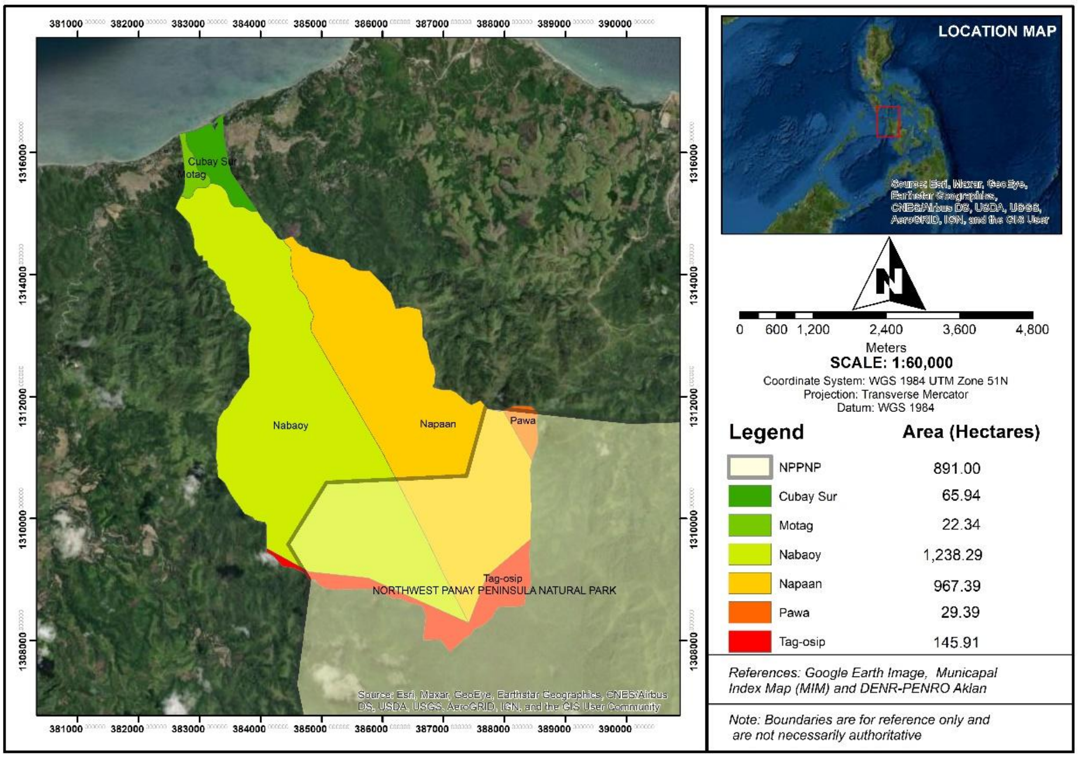

Figure 1. Location map of Nabaoy Watershed.

3.2. Potential impact to flooding assessment

Potential Impact is a function of Exposure and Sensitivity. For the flooding assessment, benchmark and projected rainfall amounts, topographic map/Digital Elevation Model (DEM), Soil Type, Landover, and watershed boundary are the required data and have been rasterized, categorized within raster format, and are aligned with the Vulnerability Assessment Manual and DENR Technical Bulletin 16-A [1,18]. The thematic maps for sensitivity to flooding are generated using the critical factor analysis of each parameter (Table 2), in which the required thematic maps are land cover, slope, elevation, soil, and drainage. The exposure to flooding, is derived from PAGASA Climatic projections in 2050. The thematic map that must be generated is the rainfall map using the critical factor analysis. All the generated data are weighted and overlaid with ArcGIS to make a potential impact map to flooding. A digital elevation model of a 3-D illustration for the terrain surface was made from terrain elevation data. DEM was used in symbolizing a raster or as a vector-based triangular irregular network [19]. Figure 2 depicts the overall methodology of this study.

For the simulation of the flood vulnerability map, the Rational Equation was used. Table 1 shows the breakdown of the Rational Equation in relation to the Flood Hazard Vulnerability including the Maps involved per data needed, data sources, and part in vulnerability equation [18].

PI=Q=CIA

Where:

Q=Discharge

C=Runoff Coefficient (slope, elevation, land cover, soils)

I=Rainfall Intensity (monthly rainfall)
A=Watershed Area (flow accumulation or flow length – upstream or downstream)

Table 1. Breakdown of factors included in the formula for the flood model [18].

Variable	Factor/Meaning	Map/s Involved	Data Needed	Sources
C	Runoff Coefficient	Slope, Elevation, Land cover, Soil	Field Data, Soil Map, DEM	BSWM, DENR-PENRO Aklan, Soil Analysis and NAMRIA
I	Rainfall Intensity	Rainfall	Rainfall Frequency, Intensity	DENR-PENRO Aklan, PAGASA
A	Watershed Area	Flow Length	Generated in GIS from DEM	DENR-PENRO Aklan, NAMRIA

All thematic maps were prepared in raster format and reclassified through the GIS feature Reclassify (Spatial Analysis). Then, using the raster calculator feature of the ArcGIS software, all the layers were combined using the formula below:

Potential Impact=[(reclassified slope × reclassified soil × reclassified land cover × reclassified elevation) × (reclassified rainfall × reclassified flow length)]

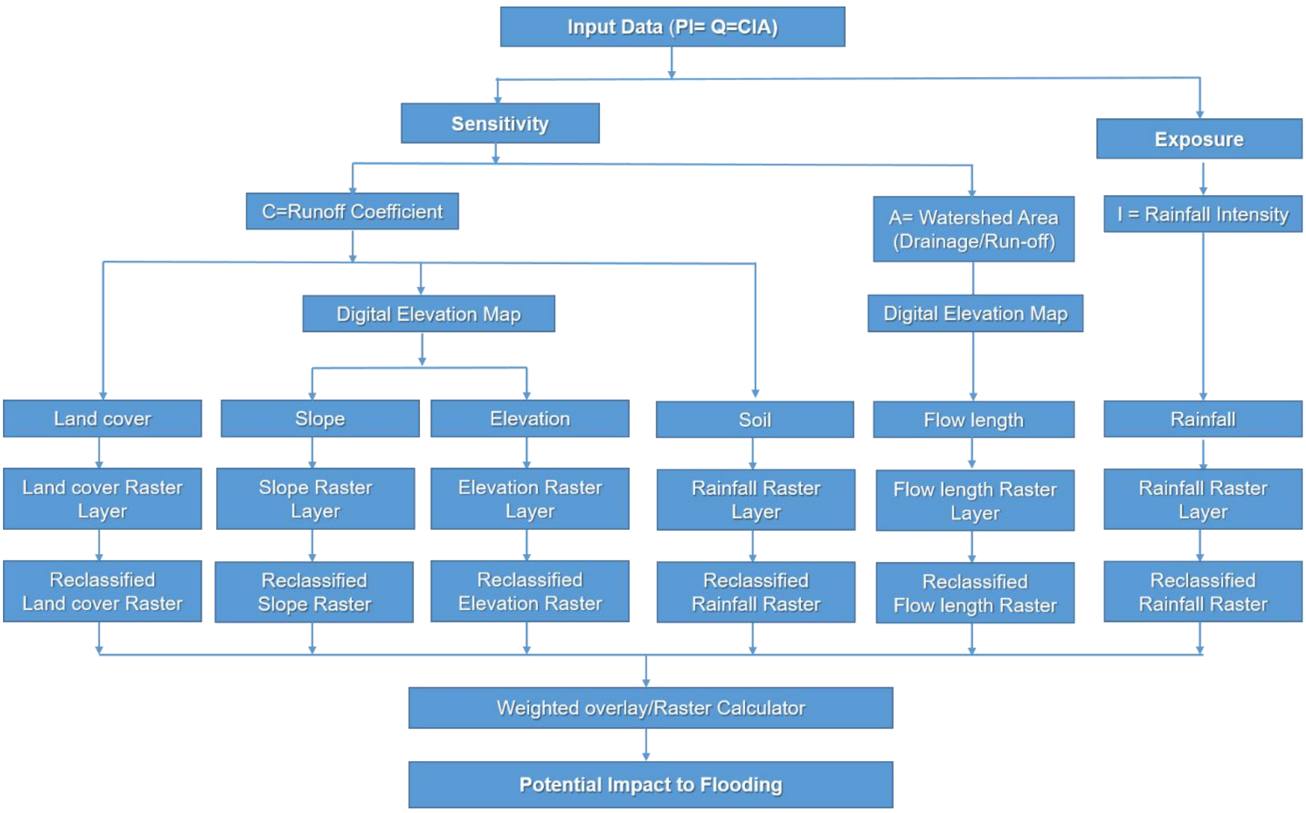

Figure 2. Flow chart of the overall activities and processing for potential impact to flooding.

3.3. *General scale factors*

All the different factors were reclassified in the ARCGIS Software to their corresponding vulnerability and rating. Table 2 shows the interpretation of each potential impact rating and the analysis how a factor plays a role in the potential impact of flooding to the watershed. The resulting potential impact maps of Nabaoy River Watershed for flooding were rated 1 to 5 with their corresponding color and vulnerability from very low to very high.

Table 2. Critical scale of factors of Flood Vulnerability ratings according to DMC 2008-05, Soils of the Philippines, and expert opinions [18].

Land Cover	Slope (%)		Soil Texture	Maximum Monthly Rainfall (mm)	Elevation	Vulnerability	Rating	Color
Closed Forest, Inland Water	≥50	Severely Steep	Sand	<100	>50	Very Low	1	Green
Open Forest, Mangrove Forest	30–50	Very Steep	Sandy Loam	100.1–200	30.1–50.0	Low	2	Light Blue
Shrubs, Natural Grasslands, Marshland, Swamp	18–30	Steep	Loam, Silt, Silt Loam	200.1–300	18.1–30.0	Moderate	3	Blue
Agricultural (Perennial and Annual Crop), Pastureland, Built Up, Fallow, Fishponds	8–18	Moderate	Clay Loam, Silty Clay, Sandy Clay	300.1–500	8.1–18.0	High	4	Yellow
Open/Bare/Barren Land	0–8	Level to gently sloping	Clay	>500	0–8.0	Very High	5	Red

3.4. *Thematic modeling*

Thematic maps for sensitivity and exposure to flooding were generated using the critical factor analysis of each parameter (Table 1). GIS Modeling of the different parameters was carried out using ArcGIS 10.5 software to finalize the thematic maps. Calculated flooding factors were incorporated into the thematic maps by integrating the data in a model/ map representation. It was further processed and analyzed using spatial analyst tools and raster calculations on ArcGIS software-ready for final modeling.

3.5. *Data analysis*

All the factors contributing to the flooding were calculated and reclassified using raster calculator in ARC GIS Software and other spatial analyses tool based on the classification and rating scale of flooding rate as shown on Table 2. After the integration and reclassification of the critical factors to their corresponding thematic models, land cover susceptibility map, soil susceptibility map, elevation susceptibility map, slope susceptibility map and rainfall intensity map were overlaid one by one. The potential impact to flooding was carried out by multiplying these five factors using the raster calculator of the ARCGIS software on the attribute table. The results show the susceptibility of the watershed to flooding.

4. Results and discussions

The main flood causing factors such as slope, elevation, average rainfall, drainage density, land cover, and soil texture were used for inundation of vulnerability valuation [20]. The raster layers were classified according to critical scale of factors of Flood Vulnerability ratings as shown in Table 2.

4.1. Watershed boundary and surface run-off

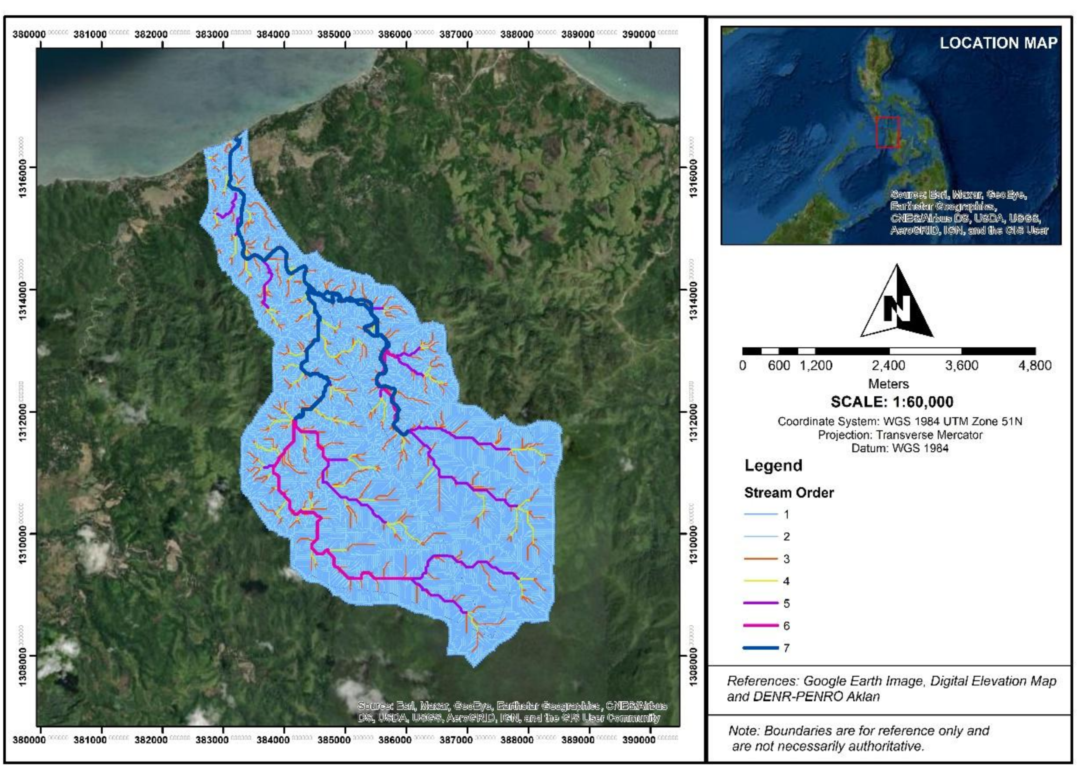

Figure 3. Nabaoy River Watershed stream order tributaries.

Digital Elevation Model (DEM) raster data in GeoTIFF format of Nabaoy River Watershed was requested and was obtained from DENR PENRO Aklan. A 10×10 cell size digital elevation model (DEM) was manipulated in ArcGIS 10.5 to delineate first the streams of watersheds, which was used to easily characterize the watershed boundaries of the sites. Drainage density is one of the most important flooding hazard factors and it is an inverse function of infiltration [15,21,22]. In generating the surface run-off, the Nabaoy River Watershed boundary was clipped to DEM using a conversion tool to produce a raster layer. It was further converted using the following conversion tool: fill, flow direction, flow length, con, stream order and dissolve to generate all the stream order of the watershed as shown in Figure 3. The stream order shows the total number of stream tributaries detected. Hence, the stream order is reversed when it comes to the watershed, the higher the number of stream order the larger the stream, and the lower the number of the stream order, the smaller the stream tributaries. Thus, the first three small stream order tributaries were removed, and the last four highest stream order tributaries have remained as they are the most important streams in the watershed (Figure 4) and serve as the flow length of the study.

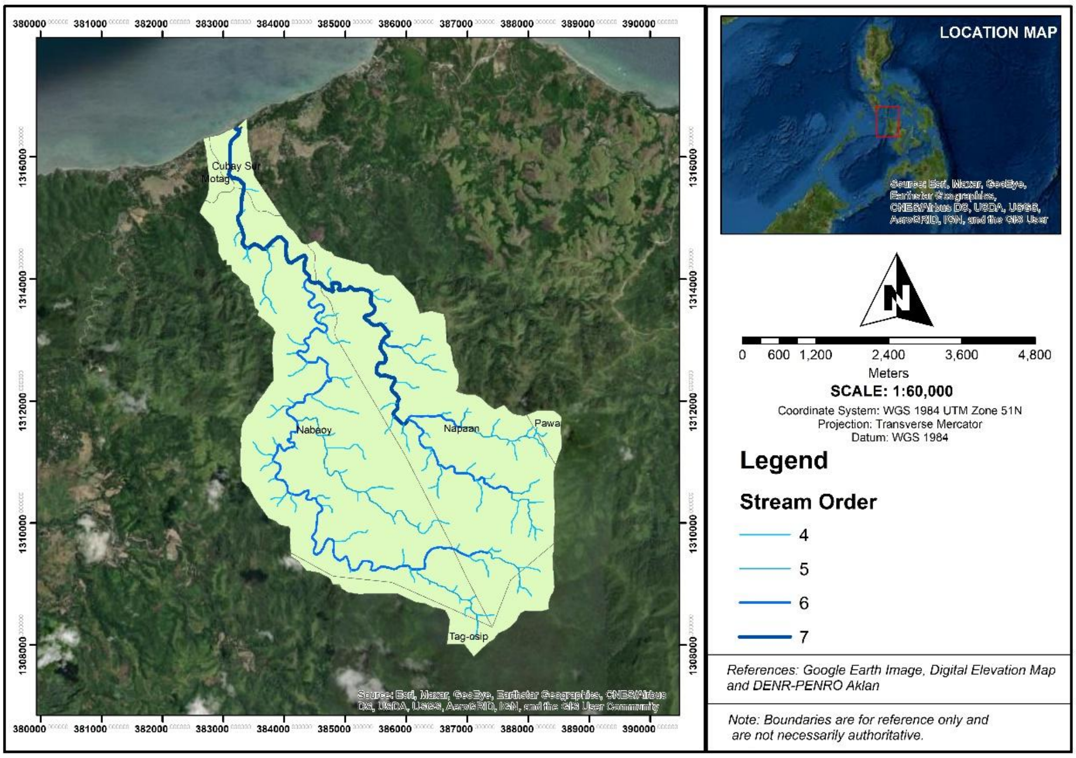

Figure 4. Nabaoy River Watershed surface run-off/flow length.

4.2. Slope factor

The vector data of the Nabaoy River Watershed boundary was clipped to DEM creating a raster version of the Nabaoy River Watershed. The raster version of the Nabaoy River Watershed was then converted using the slope spatial analyst tool creating several slope categories as shown in Figure 5. The slope raster layers were further reclassified according to the critical scale of factors of flood vulnerability ratings for slope (Figure 6). As presented in Figure 6, the reclassified slopes have been given significance one to five through the upper value, five showing high effect in resulting very high flood rate, while the lower value, one, indicating very low influence showing very low flood rate. Consequently, an area with a very low slope was ranked as five, and an area with a very high slope was ranked as one. This categorization method segregates a variety of features worth to the same sized sub-ranges which allow specifying the number of intervals [23].

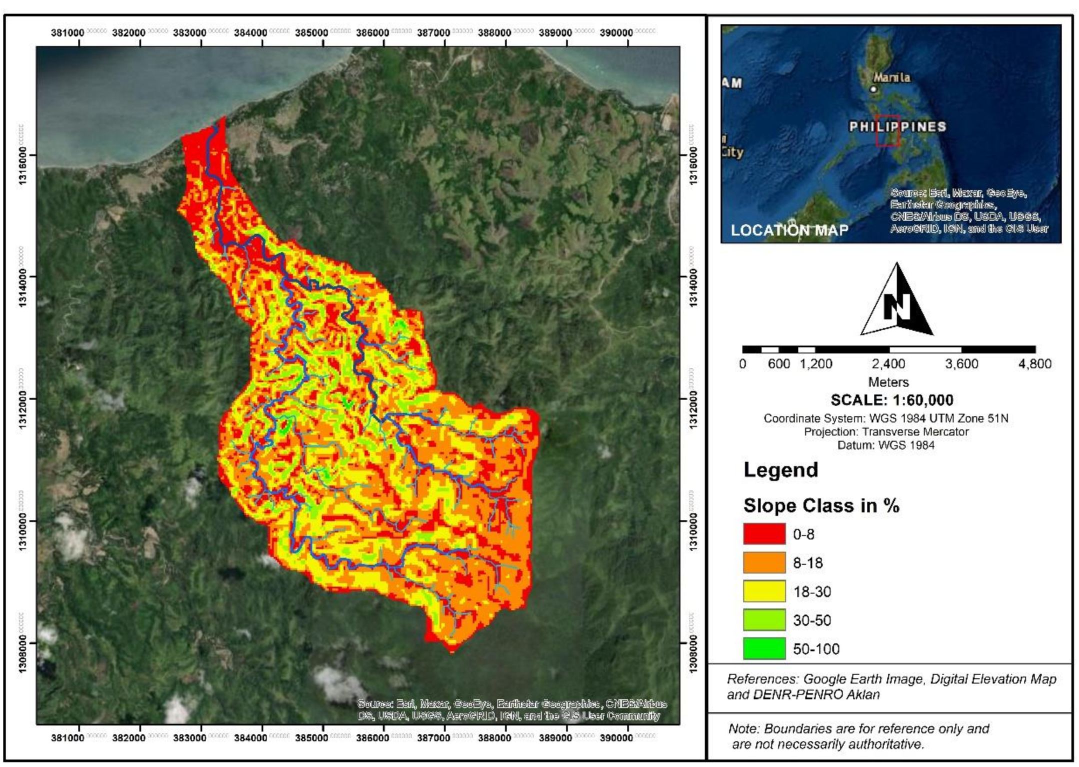

Figure 5. Nabaoy River Watershed slope raster map.

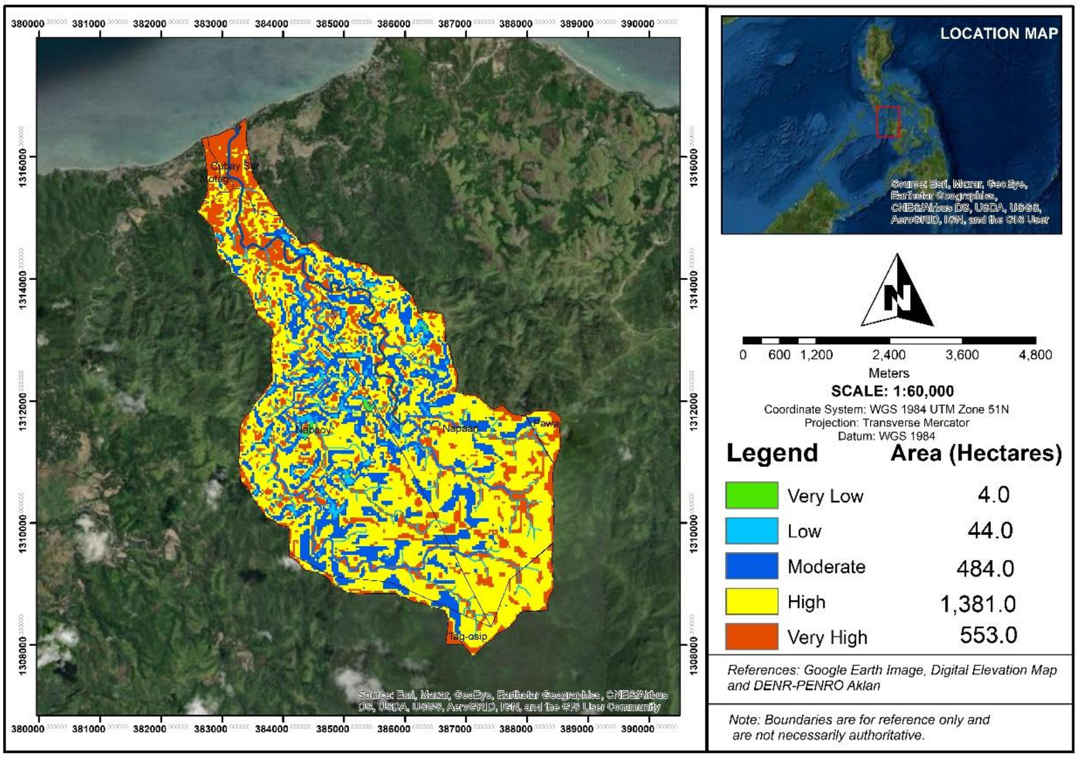

Figure 6. Nabaoy River Watershed slope susceptibility map to flooding.

The lower the slope value and the flatter the topography are, the more susceptible it is to flooding. Likewise, the higher the slope values and the steeper the topography are, the less susceptible it is to flooding. Depending on their vulnerability to inundating, slopes were reclassified into five categories according to their rating [23]. As presented in Table 2, areas with gentle slopes were rated to class five (0–8%) and can greatly be affected by flood. Similarly, a high vulnerability with moderate slope ranked to class four (8%–18%), moderate with steep slope ranked to class three (18%–30%), low with very steep slope ranked to class two (30%–50%), and very low with severe slope ranked to class one (>50%) which is not significantly affected by flooding. All the values were verified and were checked on the ground. Data shows that the majority of the slope of the Nabaoy River Watershed has a high rating for flooding (1,381 hectares), followed by very high (553 hectares), moderate (484 hectares), low (44 hectares), and very low (4 hectares).

Steep slopes tend to reduce the amount of infiltration of water into the ground, this water can then flow quickly down to rivers as the overland flows. Additionally, steep slopes also cause more floods that flow within the soil. Both can raise river levels. Gentle slopes or flat land allow water to penetrate the soil and increase lag times [24]. Most areas near the watershed have gentle slopes and moderate slopes, therefore, when rain falls, the surface runoff can move very quickly from mountainous or hilly areas to low lying areas making these low-lying areas more prone to flooding [25]. Most of the low-lying barangays along the Nabaoy River such as Nabaoy, Napaan, Cubay Sur and Motag, are prone to severe flooding since these areas have very low topography and are very susceptible to flooding when intensive rainfall occurs.

4.3. Elevation factor

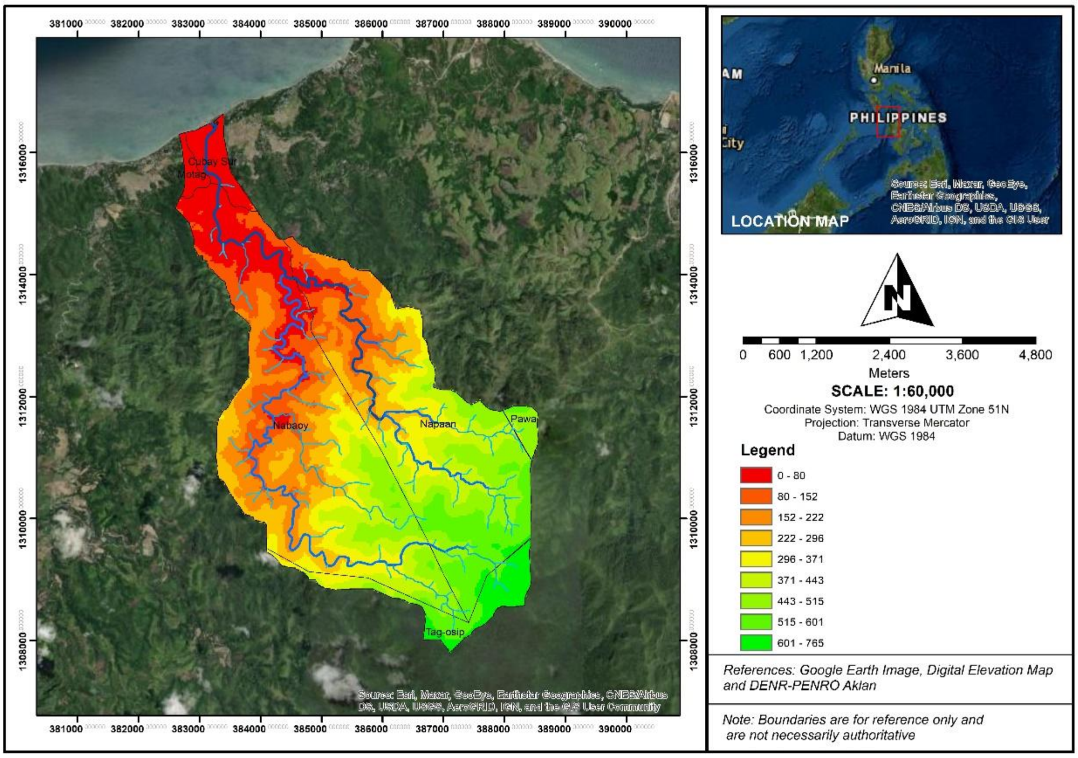

Figure 7. Nabaoy River Watershed elevation raster map.

The vector data of the Nabaoy river watershed boundary was clipped to DEM creating a raster version of the Nabaoy river watershed. DEMs were further changed to elevation raster layers with the ArcGIS conversion tool (Figure 7). The latest value was reclassified to flood vulnerability rating. Hence, the reclassification procedure to the lowest elevation was greatly affected by flooding the same as with the slope. Thus, rating five upper elevations have been affected by floods more than rating one. The latest value was reclassified to flood vulnerability rating. Hence, the reclassification procedure to the lowest elevation was greatly affected by floods the same as with the slope. Thus, rating five upper elevations have been affected by floods more than rating one.

Elevation has a key role in controlling the movement of the overflow direction and in the depth of the water level [26]. The elevation factor has the same concept with the slope in terms of flooding, the lower the elevation value and the flatter the topography are, the more susceptible an area is to flooding, likewise, the higher the elevation values and the steeper the topography are, the less susceptible an area is to flooding. Depending on their vulnerability to flooding, elevation was further reclassified into five categories according to its rating. As presented in Table 2, areas with the elevation of 0–8.0 are rated to class five and are greatly affected by floods. Similarly, a high vulnerability ranked to class four with an elevation of 8.1–18.0. moderate ranked with class three with an elevation of 18.1–30.0, low ranked to class two with an elevation of 30.1–50 and very low ranked with class one with an elevation of >50 which is not significantly affected by flooding. All the values were verified and were checked on the ground.

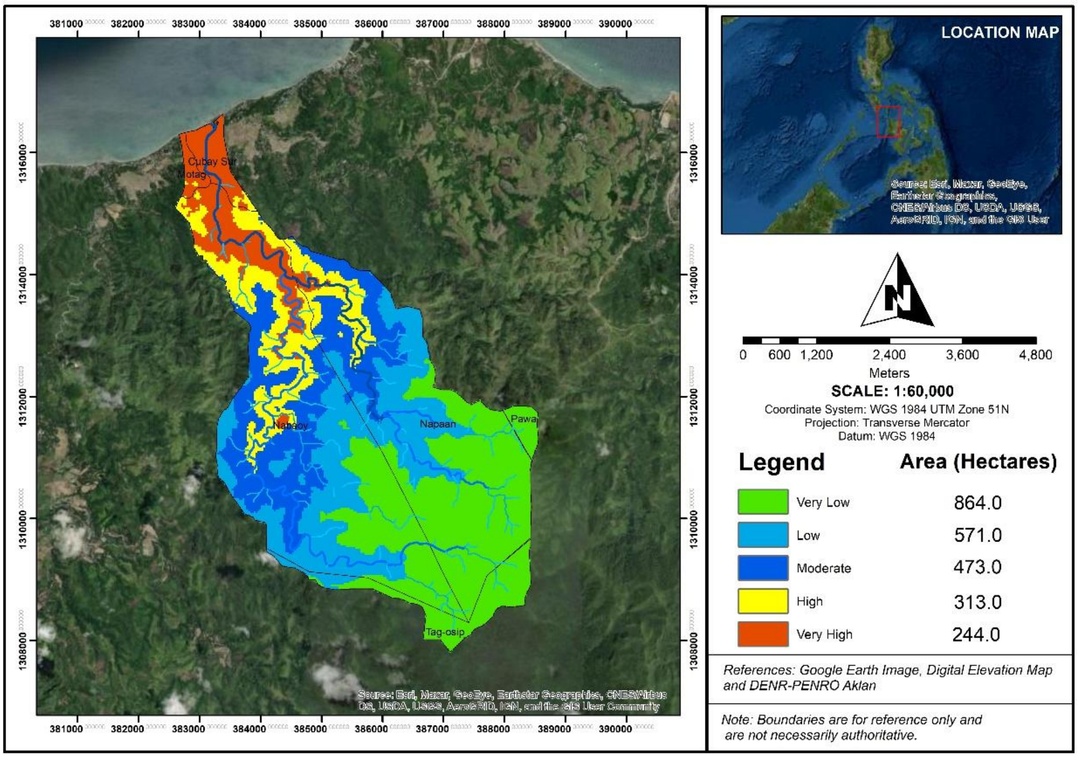

Figure 8. Nabaoy River Watershed elevation susceptibility map to flooding.

As Figure 8 shows, the majority of the elevation of the Nabaoy River Watershed has a very low vulnerability to flooding (864 hectares), followed by low, (571 hectares), moderate (473 hectares), high rating (313 hectares), and very high (244 hectares). Water always flows downhill. As a result, low elevated areas are more likely to experience significant flooding than higher elevated areas. The towns near the Nabaoy River Watershed with low elevations are highly flood-prone areas. The data presented emphasized that the barangays of Nabaoy, Napaan, Cubay Sur, and Motag are considered flood-prone areas while high elevated portions of Nabaoy, Napaan, Pawa and Tag-osip are less susceptible to flooding in terms of elevation.

4.4. Rainfall factor

Rainfall data for the maximum monthly rainfall were obtained from DENR PENRO Aklan, Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA) Climatic projections in 2050 and clipped with the Nabaoy River Watershed boundary as a vector file. Further, the vector data of the Nabaoy River Watershed with rainfall projection were clipped to DEM and was converted to the raster layer of the rainfall amount within the Nabaoy River Watershed (Figure 9). The converted raster layer is ultimately reclassified into five according to its vulnerability rating (Table 2).

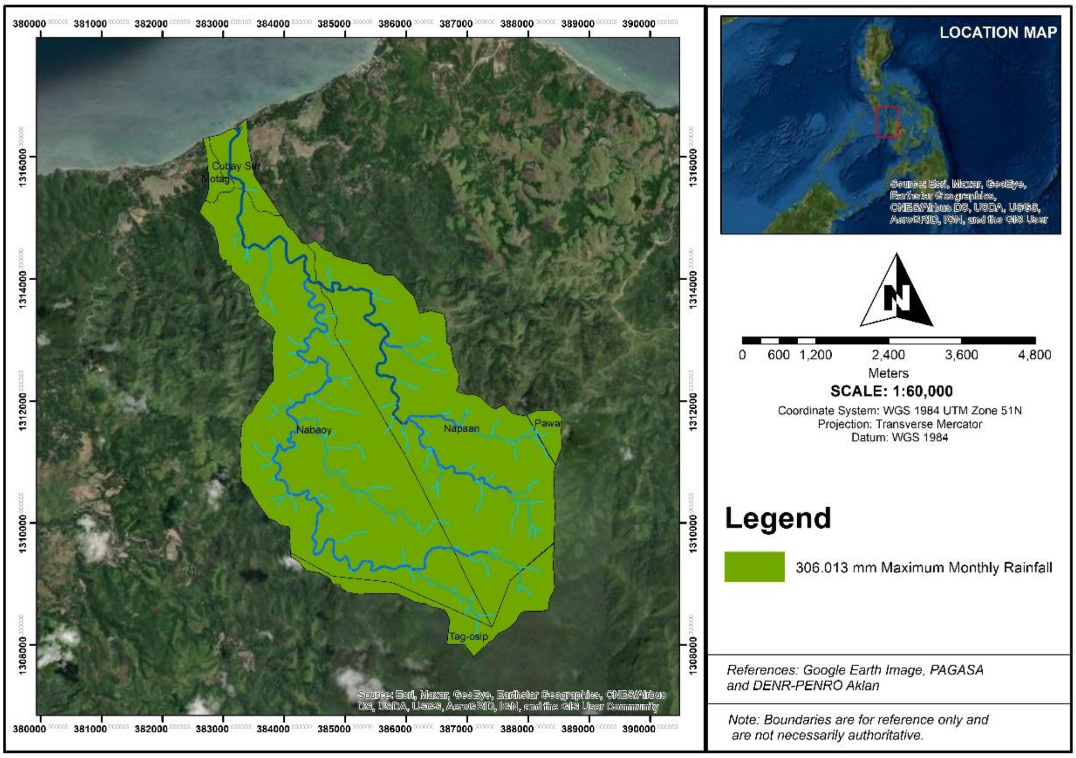

Figure 9. Nabaoy River Watershed raster map of rainfall layer.

The reclassified rainfall data were provided with one to five rating through the upper value, five indicating high influence in ensuing very high flood rate, whereas the smallest value, one, viewing incredibly low impact inconsequential very low flood rate. Therefore, the area with very low rainfall has a rating of one whereas the area that was classified with very high rainfall has a rating of five. Figure 10 shows that higher rainfall value is significantly affected with extreme exposure to overflow and was rated as five (>500mm), highly rated as four (300.1–500 mm), moderately rated as three (200.1–300 mm), low rated as two (30.1–50.0 mm) and very low rated as one (<100 mm). Data revealed that the whole watershed is highly susceptible to flooding having a total area of 2,469 hectares.

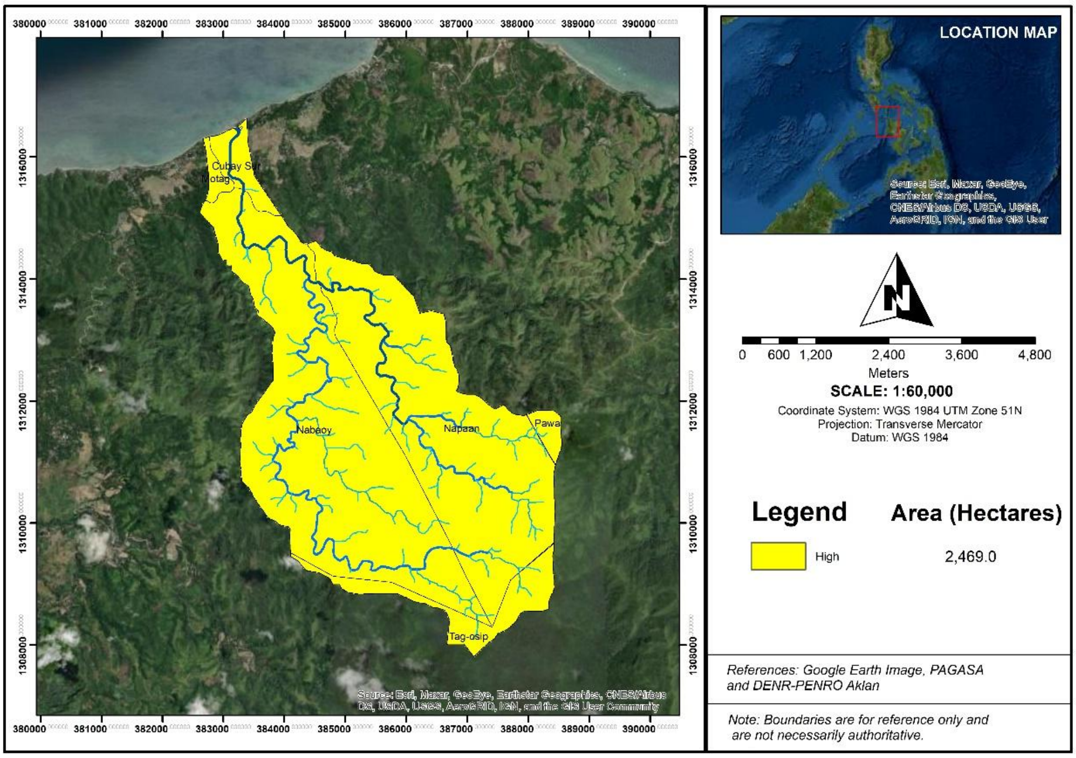

Figure 10. Nabaoy River Watershed rainfall susceptibility map to flooding.

Generally, a warmer atmosphere can hold more water vapour, which may increase heavy precipitation and therefore floods [27,28]. More extreme rainfall means more likelihood of floods, particularly flash floods [29,30]. Moreover, flooding is one of the most widespread of climatic hazards and poses multiple risks to human health [29,31]. A flash flood occurs when water overflows on or inundates normally dry land. Rivers can overflow their banks to cause flooding, and sea waters can be pushed towards land by massive winds, which then causes flooding. Rainfalls over an extended period can cause major rivers to overflow their banks. Rivers can overflow their banks, causing flooding during heavy rains, severe storms, and dam breaks. Huge amounts of water flowing in rivers are due to incessant heavy rains and the melting of snow, resulting in severe flooding [32].

4.5. Land cover factor

The land cover 2015 data of the Nabaoy River Watershed was requested and obtained from National Mapping and Resource Information Authority (NAMRIA). As shown in Figure 11, the land cover types within the watershed were identified. Hence, the identified land cover of the watershed area was reclassified according to five ranks and was improved into the raster layer. Further, the land cover type was re-categorized into five ratings (Table 2), depending on their capacity to raise or reduce the rate of flooding. As presented in Table 2, areas with the land cover type of open, bare, and barren land are rated as five and are very high to flooding. Similarly, a high vulnerability ranked to class four with a land cover type of agricultural (perennial and annual crop), pastureland, built up, fallow, and fishponds. Moderate ranked with class three with a land cover type of shrubs, natural grasslands, marshland, and swamp. Low ranked to class two with a land cover type of open forest and mangrove forest. Lastly, very low ranked with class one with a land cover type of closed forest and inland water is not significantly affected by flooding. Land cover of the watershed was verified through site visits, interviews, geotagging using android software, and Google Earth image.

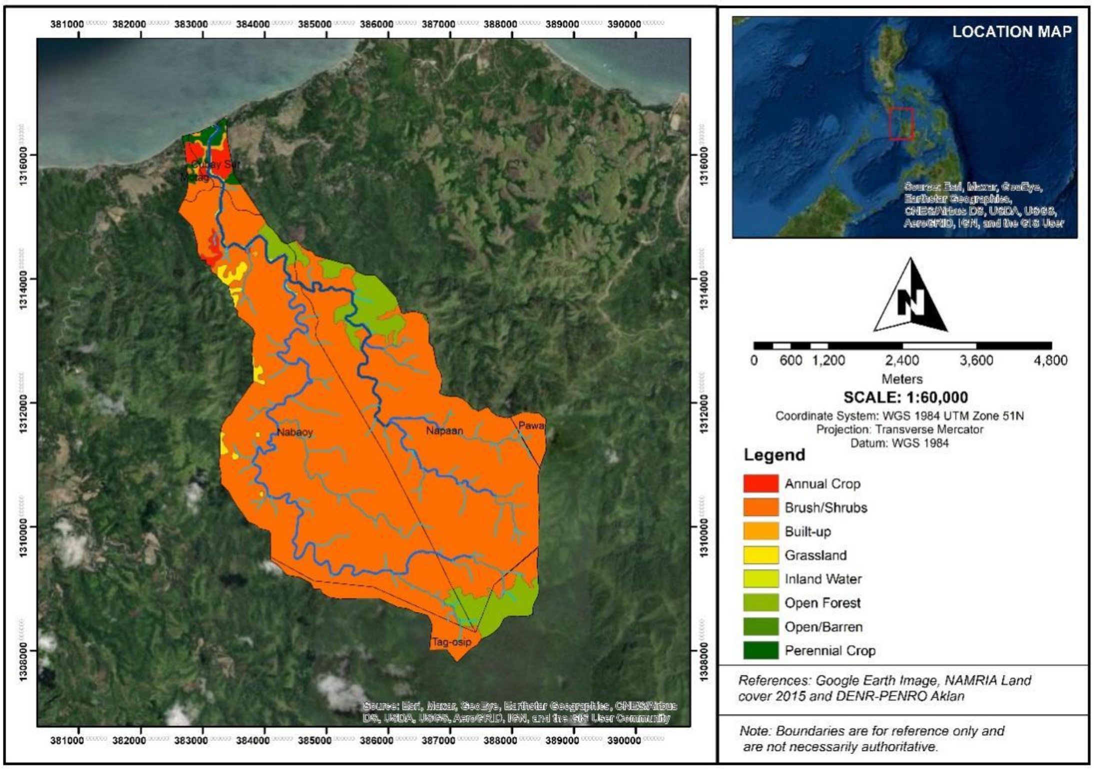

Figure 11. Nabaoy River Watershed land cover raster map.

Many scholars in the field of flooding risk management attest that land use/land cover change is one of the major contributors of flooding as urban expansion increases, impervious cover increases, and forest cover decreases in urban areas contributing to increase in run-off [27,33–36]. As shown in Figure 12, the majority of the area of the Nabaoy River Watershed according to its land cover type is moderately (2,198 hectares) susceptible to flooding, followed by low (184 hectares), high (68 hectares), and very high (19.0 hectares) susceptibility to flooding. Land-use change has, potentially, a very strong effect on floods as humans have heavily modified natural landscapes. Large areas have been deforested or drained, thus either increasing or decreasing antecedent soil moisture and triggering erosion [37]. Hillslopes were modified for agricultural production, thus changing flow paths, flow velocities, water storage, and consequently flow connectivity and concentration times. It is likely that hydrologically significant changes will continue in the next decades due to the loss of agricultural land and forests [38–40]. Climate and unpredictable weather conditions are the main drivers of flooding, however, changes in land cover can also influence the occurrence and frequency of floods by changing the responsiveness of river flows to rainfall.

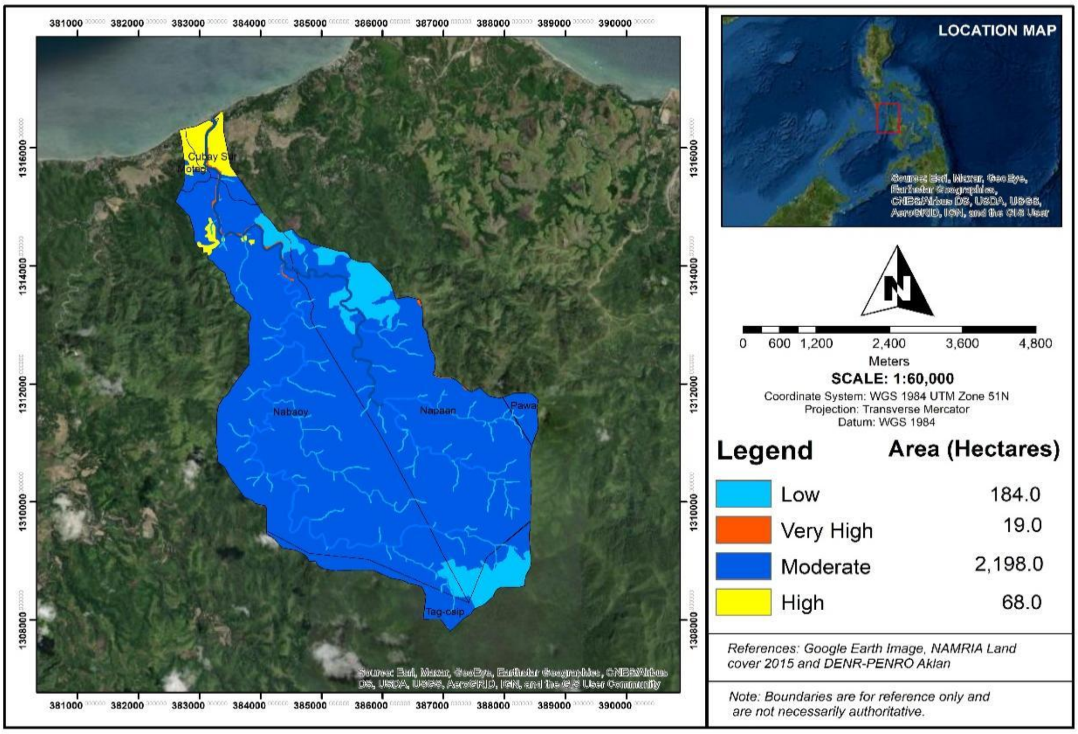

Figure 12. Nabaoy River Watershed land cover susceptibility map to flooding.

4.6. *Soil factor*

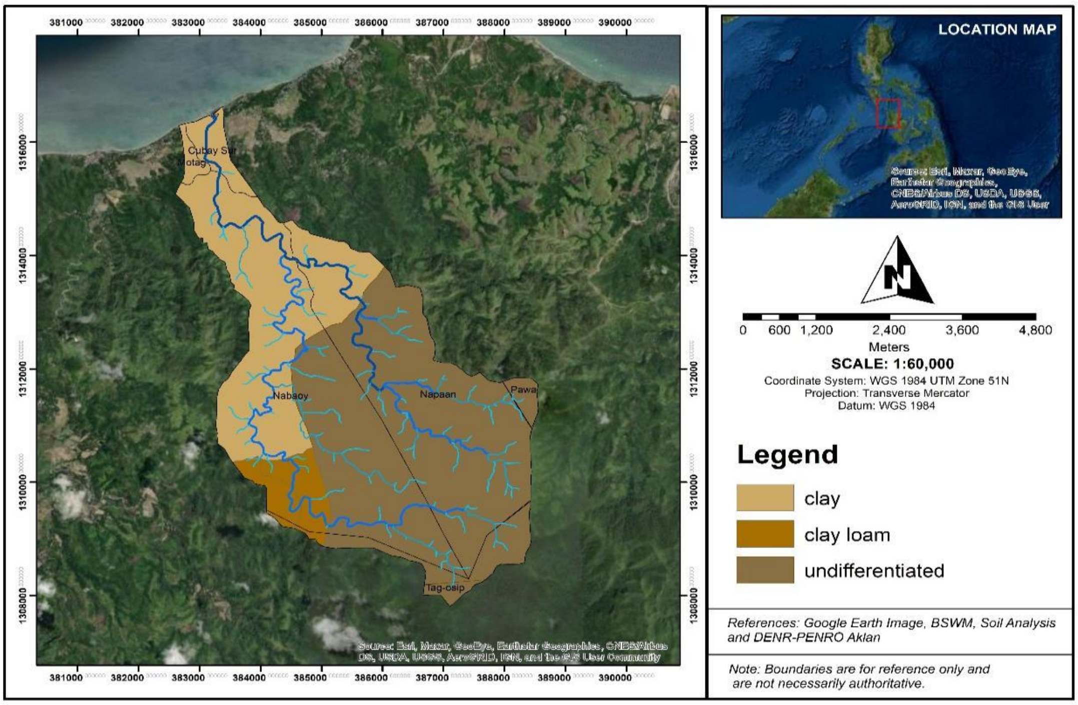

Figure 13. Nabaoy River Watershed soil raster map.

The Soil map data of the Nabaoy River Watershed was requested and obtained from the Bureau of Soils and Water Management and DENR PENRO Aklan. As shown in Figure 13, the different soil textures within the watershed were identified. Hence, the undifferentiated soils identified were subjected to soil analysis to determine their soil texture and were further reclassified according to five ranks and were improved into the raster layer. Moreover, the soil texture was re-categorized into five ratings (Table 2), depending on their capacity to raise or reduce the rate of flooding.

As presented in Table 2, areas with the soil texture of clay are rated as five and are very high to flooding. Similarly, a high vulnerability ranked to class four with a soil texture of clay loam, silty clay, and sandy clay. Moderate ranked with class three with a texture of loam, silt, and silt loam. Low ranked to class two with a soil texture of sandy loam. Lastly, very low ranked with class one with a soil texture of sandy is not significantly affected by flooding. Figure 14 shows that the soil texture of most areas in the Nabaoy River Watershed is moderately (1,484 hectares) susceptible to flooding, followed by very high (840 hectares), and high (145 hectares) susceptibility to flooding respectively.

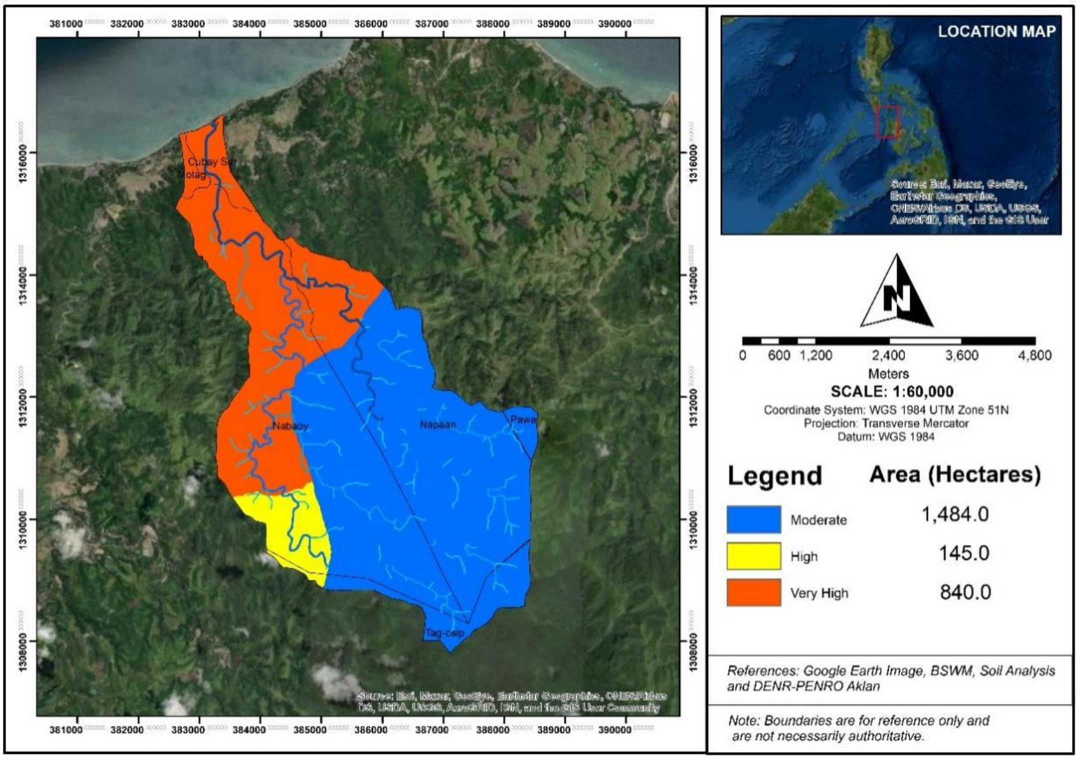

Figure 14. Nabaoy River Watershed soil susceptibility map to flooding.

The structure and infiltration capacity of soils also have an important impact on the efficiency of the soil to act as a sponge and soak up water. Different types of soils have differing capacities. The chance of flood hazard increases with decrease in soil infiltration capacity, which causes increase in surface runoff. When water is supplied at a rate that exceeds the soil's infiltration capacity, it moves down slope as runoff on sloping land, and can lead to flooding [28]. The soil texture is an important soil characteristic that determines the rate of storm water infiltration. The key components that determine soil water holding capacity are soil texture and organic matter. In terms of soil texture, those made up of smaller particle sizes, such as in the case of silt and clay, have a larger surface area. The larger the surface area the easier it is for the soil to hold onto water so it has a higher water holding capacity. Sand in contrast has large particle sizes which result in a smaller surface area. The water holding capacity for sand is low [41].

Clay soil is soil that is comprised of very fine mineral particles and not much organic material. The resulting soil is quite sticky since there is not much space between the mineral particles, and it does not drain well at all [42]. Soil texture determines the rate at which water drains through saturated soil; water moves more freely through sandy soils than it does through clayey soils. Hence, the majority of the watershed is classified as loam, silt, and clay which result in moderate and high susceptibility to flooding.

4.7. Potential impact to flooding

The slope, elevation, rainfall, land use/land cover, drainage density, and soil types have been used to develop a flood vulnerability map by using Arc GIS software 10.5 and Critical scale of factors of flood vulnerability ratings according to DMC 2008-05, Soils of the Philippines, and expert opinions. The flood vulnerability caused by the excessive discharges of the main rivers is predictable to increase due to climate change [43]. The potential impact map shows high to extremely high potential impact intimidations downstream parts of the river, which was the lowland flat area of the Nabaoy River Watershed (Figure 15). According to this study, most areas near the Nabaoy River Watershed have low potential impact to flooding with an area of 667 hectares (27.16%). However, a huge percentage also detected that potential susceptibility to flooding is moderate, high to very high with an area of 544 (22.15%), 561 (22.84%), and 486 (19.79%) hectares respectively. While potential impact to flooding in some portions of the watershed are classified as very low with an area of 198 hectares (8.06%).

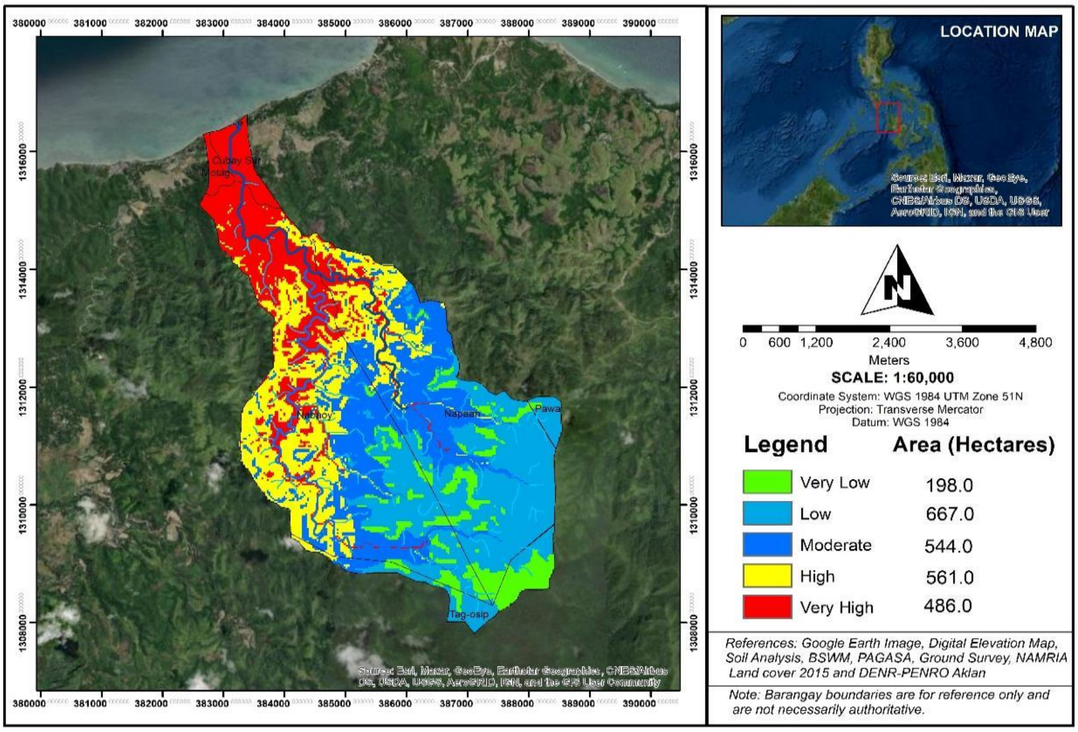

Figure 15. Nabaoy River Watershed potential impact to flooding.

Table 3 shows that the Barangays Motag, Cubay Sur, Napaan, Nabaoy and Tag-osip are classified as moderate to highly susceptible to flooding due to their low slope, elevation, land cover and rainfall intensity. Meanwhile, some portions of the barangays of Pawa, Nabaoy, Napaan and Tag-osip are classified as very low to low susceptible to flooding. These Barangays are in high elevated areas, however some of these are in low lying areas near the watershed and still have a huge chance of experiencing severe flooding since these areas are along the river where the water drains from the Tag-osip, Napaan and Nabaoy flowing down to the Sibuyan Sea. If the rainfall water overflows the aforementioned low-lying areas will be greatly affected by severe flooding. These kinds of geologic hazards are naturally occurring geological phenomena which pose a danger to people's lives, communities, infrastructure, and properties. Hence the identification of towns highly vulnerable to flooding provides data to the community, Government Agencies, and stakeholders to lessen the impacts of geologic hazards. Without flood risk maps it is not easy to identify the areas at risk, and without a systematic way of making development decisions there will be no consistency in deciding how and where to reduce urban encroachment into at-risk areas. The availability of the land use plan gives readily available guidance to developers, planners and others on which areas may be developed for which uses, and allows the incorporation of flood risk information into their decisions and judgements [12,14]. Consequently, this paper explores the use of risk modelling as a tool that can support local government to better understand, manage, and communicate natural hazard risk [44].

Table 3. Breakdown of Potential Impact to flooding of affected barangays near the Nabaoy River Watershed.

Municipality	Barangay	Flood Vulnerability (Hectares)					TOTAL
		Very Low	Low	Moderate	High	Very High	
Malay							
	Pawa	2	26				28
	Cubay Sur					65	65
	Motag					23	23
	Nabaoy	61	177	261	394	341	1234
	Napaan	79	397	270	160	57	963
Buruanga							
	Tag-Osip	56	67	13	7		143
TOTAL		198	667	544	561	486	2456

5. Conclusions

The flooding-producing factors were computed to generate the overflow threat of barangays within the watershed through the critical scale of factors of flood vulnerability ratings and weighting overlay using the GIS environment. The influences to very high, high, moderate, low, and very low vulnerability towns were formulated and reclassified depending on various factors contributing to inundation. The data showed that Motag, Cubay Sur, Napaan, Nabaoy and Tag-osip were the areas that have moderate to very high potential impact to flooding. Whereas, high elevated areas of Pawa, Nabaoy, Napaan and Tag-osip were classified as areas with very low to low potential impact to flooding. People living in high-risk barangays and towns are advised to follow extra precautionary measures and be aware of their respective evacuation centers in case torrential rains caused by intensive rainfalls and typhoons would flood their areas. This study provides the basis for another set of development and conservation strategies in the updating of the Integrated Watershed Management Plan, providing disaster risk resilience programs and crafting adaptive capacity management.

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Conflict of interest

The author declares no conflict of interest.

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