FLOOD HAZARD MAP GENERATION OF BUED-ANGALACAN RIVER WATERSHED USING GIS ASSISTED TECHNIQUE

Annie Melinda Paz-Alberto[1], Armando N. Espino Jr.[2], Nicasio C. Salvador[1], Eleazar V. Raneses Jr.[1], Jose T. Gavino Jr.[1], Bennidict P. Pueyo[1] and Cristopher R. Genaro[1]
[1] Institute for Climate Change and Environmental Management, Central Luzon State University, Science City of Muñoz, Nueva Ecija 3120, Philippines
Email: melindapaz@gmail.com, nick_asio80@yahoo.com, eleazarjr.raneses@yahoo.com, josegavino1983@gmail.com, venpueyo@gmail.com, christopher_reyes_genaro@yahoo.com
[2] Land and Water Resources Management Center, College of Engineering, Central Luzon State University, Science City of Muñoz, Nueva Ecija 3120, Philippines
Email: anespinoj@yahoo.com.ph

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ABSTRACT: The aim of the study was the generation of Bued-Angalacan River Watershed (BARW) flood hazard map and identification of flood susceptible areas within the watershed using the spatial analyst tool integrated in Geographic Information System (GIS). This study was conducted in the provinces of La Union, Benguet and Pangasinan, Philippines. Thematic maps such as elevation map, slope map, distance to river map and land cover map were used as factors to generate the flood hazard map. Using the Analytic Hierarchal Process (AHP), the factors were weighted according to their relative importance to each other and to their expected importance in causing floods. Final flood hazard map was obtained by adding the weighted flood hazard ranking of all the factors and it was generated using the spatial analyst tool of ArcGIS. Based on the generated flood hazard map of BARW, 37.07 percent of the total watershed area which include 9 municipalities and 2 cities were susceptible to flooding.

1. INTRODUCTION

Philippines is a tropical country which often experiences tropical typhoons mostly during rainy season. Approximately 80 typhoons develop above tropical waters, of which 19 enter the Philippine area and 6 to 9 make landfall annually (Wingard and Brandlin, 2013).

The province of Pangasinan in Philippines is one of the highly prone areas to flooding. Most of its municipalities are situated within downstream area of the Bued-Angalacan Watershed. During heavy rain, waters from mountain part of watershed find its way down through streams and rivers and passes to the low lying municipalities which resulted into extreme flooding. Yearly, the Provincial Disaster Risk Reduction and Management Council (PDRRMC) reported that hundreds of thousands of individuals were affected due to flooding. Also, severe damage to property, livelihood, agricultural productivity, industrial production, communication networks and infrastructure are caused by extreme flooding.

The flood hazard maps display flood hazard information in a given area. These maps provide information to assist local governments and land-use managers in the development and implementation of land-use plans and in decision-making. The GIS assisted hazard mapping is fast and reliable technique that can give information with just a click of your fingertips. With this modern technology, it can reduce the potential loss of life and property, enhance government operations and management, and create possible plans to mitigate the hazard.

The aim of the study was the generation of Bued-Angalacan River Watershed (BARW) flood hazard map and identification of flood susceptible areas in the watershed using the spatial analyst integrated in Geographic Information System (GIS).

2. METHODS

This study was conducted in the provinces of La Union, Benguet and Pangasinan, Philippines as illustrated in Figure 1. Watershed boundary of Bued-Angalacan river was delineated using the Spatial Analyst Tools of ArcGIS.

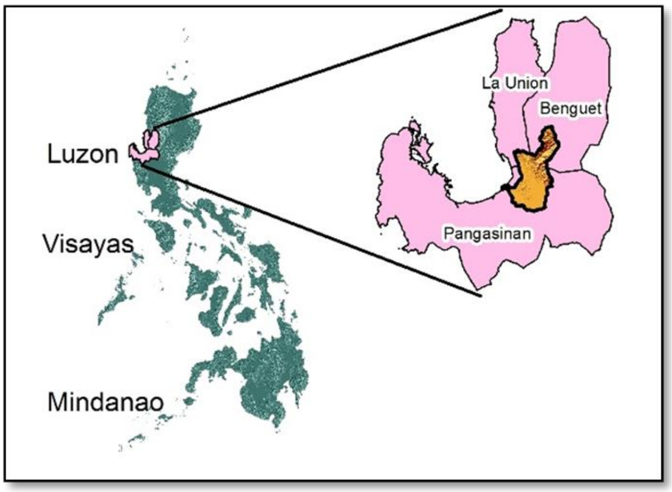

Figure 1. Bued-Angalacan River Watershed study site map.

Using GIS software (ArcMap) the flood hazard map was developed. Thematic maps such as elevation, slope, distance to river and land cover were used to generate the flood hazard map within the watershed. The flood hazard map was created by weighting and ranking technique. This technique is a numerical system based on biophysical factors which are directly or indirectly correlated with the occurrence of floods. The factors were weighted according to their relative importance to each other and to their expected importance in causing floods.

Using the Analytic Hierarchal Process (AHP) technique the weighting factors were computed. Among the four factors, elevation weighted the highest with 56.38 percent, followed by slope with 26.34 percent, then by distance to river and land cover with 11.78 and 5.50 percent, respectively. For each factor, the weighted hazard ranking was obtained by multiplying its weight by the ranking value for the corresponding subfactor. The generated flood hazard map was obtained by adding the weighted flood rankings of all the factors and the formula is as follows:

$$\mathrm{FH}=\frac{(\mathrm{E}\times 56.38)+(S\times 26.34)+(D\times 11.78)+(L\times 5.50)}{5} \quad (1)$$

in which: FH is flood hazard, E is elevation, S is slope, D is distance to river and L is land use, respectively.

Estimated areas susceptible to flood were calculated using GIS and were classified at different hazard levels. As presented in Table 1, five flood hazard classifications were created: values greater than 87 percent was categorized as very high, 74-87 percent as high, 61-73 percent as moderate, 47-60 percent as low, and less than 47 percent as very low.

Table 1. Flood hazard classification (Tanavud et al., 2004).

Classification	Percentage Range (%)
Very Low	< 47
Low	47 – 60
Moderate	60 – 73
High	73 – 87
Very High	> 87

3. RESULTS AND DISCUSSION

The Bued-Angalacan River Watershed (BARW) is located at the municipalities of Sison, Dagupan City, San Fabian, Pozzorubio, San Jacinto, Mangaldan, Mapandan, Manaoag, Laoac, Urdaneta City, Binalonan, Rosario, Santo Tomas, Pugo, Tuba, Itogon and Baguio City in the provinces of Pangasinan, La Union and Benguet. It has a catch basin area of 612.62 km^2.

3.1. Elevation

The elevation of an area within the watershed is very significant factor in relation to the occurrence of flood. Normally, water flows from higher elevation (high areas) to lower elevation (low lying areas). Low lying areas were commonly become a catchment basin of running waters. Therefore, low lying areas may flood quickly before it reaches to the higher areas and more susceptible to flooding. Using the DEM (Digital Elevation Model) and the classification tool of ArcGIS, the elevation and elevation factor maps were generated. Elevation classes within the watershed are <50, 50-100, 100-150, 150-200, 200-250 and >250 masl (meters above sea level). Each elevation classes were reclassified into six weighted ranks. Reclassification are based to the relative importance of each classes in causing floods. The generated elevation map is shown in Figure 2.

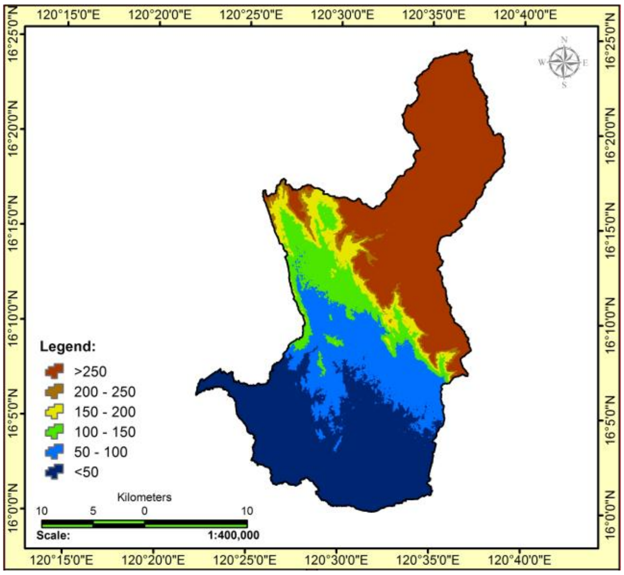

Figure 2. The generated elevation map (masl) of BARW.

3.2. Slope

Slope is another factor to consider to the occurrence of flood within the watershed. Slope influences the effect of rainfall to surface streamflow. A smooth/flat slope surface that allows the water to flow quickly is not desirable and causes flooding, whereas a higher surface roughness can slow down the flood response and is desirable. Steeper slopes are more susceptible to surface runoff, while flat terrains are susceptible to flooding (Ajin et al., 2013). The slope map was generated using the analyzed surface DEM and the spatial analysts' tool of ArcGIS software. Slope classes in angle (degree) within the watershed are 0-3, 3-8, 8-18, 18-30 and >30. Each slope classes were reclassified into five weighted ranks. The generated slope map is shown in Figure 3.

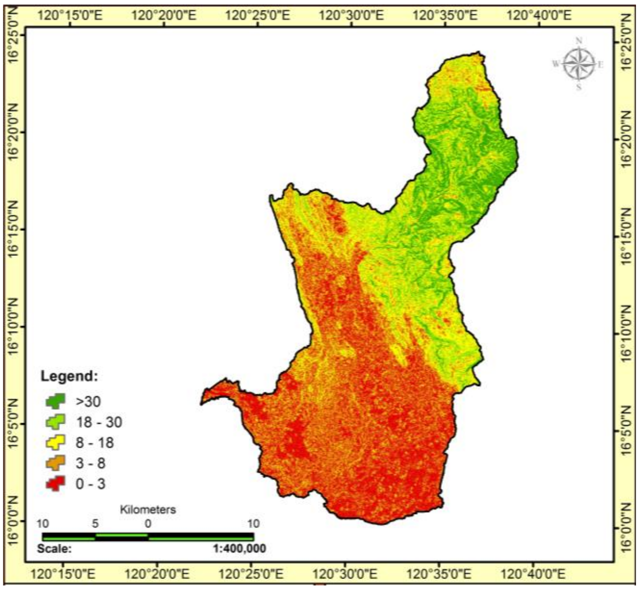

Figure 3. The generated slope map (degree) of BARW.

3.3. Distance to river

One common type of flooding which occur is during a heavy rainfall and the water level rises and overflow from the river banks. Depending on its distances from the river, low lying areas adjacent to the river are usually susceptible to flooding. Distances were buffered to 0 – 500, 500 – 1,000, 1,100 – 1,500, 1,500 – 2,500 and >2,500 meters from digitized major river using the ArcGIS tools. Buffered distances were considered distance to river classes. Each distance to river classes were reclassified into six weighted ranks. The generated distance to river map is shown in Figure 4.

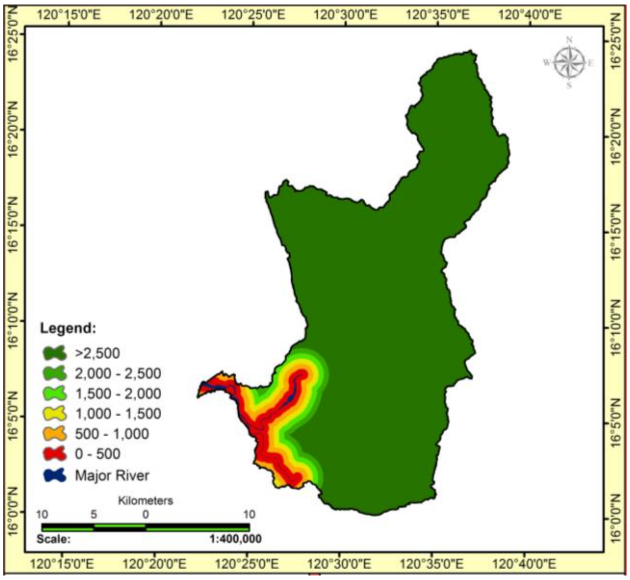

Figure 4.The generated distance to river map (meter) of BARW.

3.4. Land cover

Since land cover factor weighted lowest from the four flood rankings, its impact is significant on the occurrence of flood within the watershed. Primarily, land cover affects the infiltration and storage capacity of soil, thus, it influences the surface runoff. A land cover with thick canopy has the ability to decrease the volume of runoff whereas land cover with impermeable surface such as built-ups has low water absorption capacity which could result into surface flooding. Chow et al., 2016 cited that changes in land-use, such as conversion of forest land into cropland or grazing land, and urbanization, can increase surface runoff and flooding.

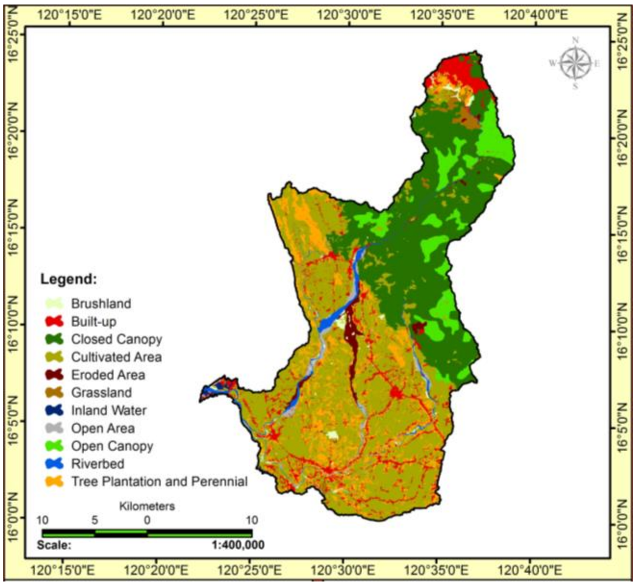

Figure 5. The generated land cover map of BARW.

Watershed land cover were classified through analyzed digitization process using the latest downloaded google satellite images loaded to the ArcGIS program. Land cover classes within the watershed are brushland, built-up, closed canopy, cultivated area, eroded area, grassland, inland water, open area, tree plantation and perennial, open canopy and riverbed. Each land cover classes were reclassified into five weighted ranks. The generated land cover map is shown in Figure 5.

3.5. Flood hazard

Using the Analytic Hierarchal Process (AHP) technique, weighting and ranking values for factors and subfactors of elevation, slope, distance to major rivers and land cover maps were computed. The generated flood hazard map of BARW is shown in Figure 6.

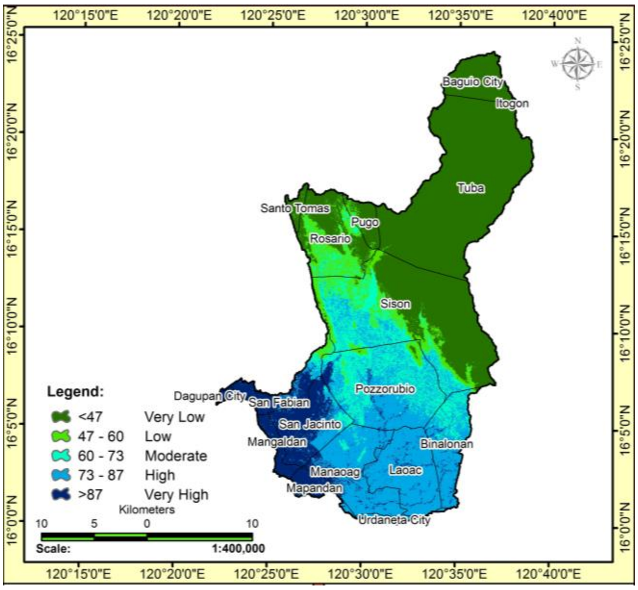

Figure 6. The generated flood hazard map of Bued-Angalacan River Watershed.

Based on the output of the derived flood hazard map of BARW, 37.07 percent of the total area is susceptible to flooding, which are categorized as high and very high (Table 2). The areas that were identified susceptible to flooding within BARW are the municipalities of Mangaldan, Mapandan, San Jacinto, Manoag, Laoac and Cities of Dagupan and Urdaneta. Also, 8.97 percent of Sison, 83.84 percent of San Fabian, 55.46 percent of Pozzorubio and 76.01 percent of Binalonan are susceptible to flooding.

Table 2. Flood hazard affected area within Bued-Angalacan River Watershed.

Category	Area (km^2)	Percent (%)
Very Low	265.11	43.28
Low	42.45	6.93
Moderate	77.96	12.72
High	160.95	26.27
Very High	66.15	10.80
Total	612.62	100.00

Municipalities within the watershed that falls in areas susceptible to flooding based on a high and very high flood hazard category were validated. Actual interview and actual flood experience (Figure 7) to the local community within the flood hazard municipalities were done. Also, other related articles and news literatures were used as reference of validation.

Based on the validation, almost of the municipalities which are susceptible to flood can often experience flooding during rainy season and when there is an intense or torrential rainfall bolstered by tropical storm and monsoon rain. Also, these municipalities are low lying areas, urban situated places and near from the riverbank.

Figure 7. Actual flood validation in the municipality of San Fabian, Pangasinan.

4. CONCLUSION

The GIS assisted flood hazard mapping technique which used an Analytical Hierarchical Process (AHP) provides a systematic approach for assessing and integrating all factors necessary for generation of Bued-Angalacan flood hazard map. The resulted map provides reliable information on the areas susceptible to flood within the watershed based on the validation.

This flood hazard mapping technique can create an easily readable and rapidly accessible maps which facilitate the decision makers to identify the flood susceptible areas for managing resources efficiently and sustainability as well as in disaster risk management. Also, this method can be adopted to other watershed areas for fast and reliable flood hazard map generation.

5. ACKNOWLEDGMENT

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