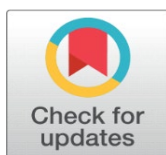


THEMATIC MAPPING OF LANDSLIDE SUSCEPTIBILITY IN NUEVA VIZCAYA: ENHANCING DISASTER RESILIENCE AND MANAGEMENT STRATEGIES

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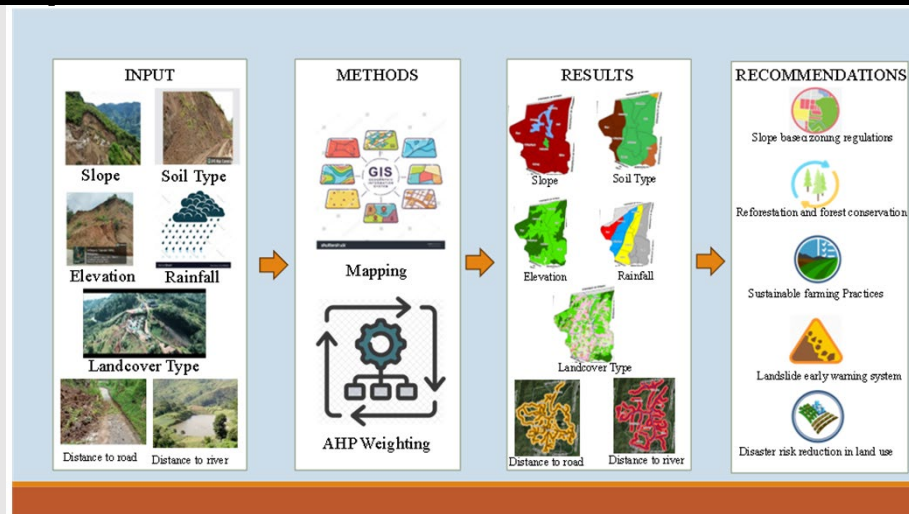
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ABSTRACT



Graphical Abstract

The province of Nueva Vizcaya had experienced landslide occurrences almost every year for the past decade, and last year, the municipality of Ambaguio had experienced landslides causing seven deaths, damages to properties, and degradation of environment. This study aimed to map the causative factors of landslide susceptibility in the municipality of Ambaguio, province of Nueva Vizcaya. The purpose of this study is to provide significant information to the Local Government Unit particularly the Municipal Disaster Risk Reduction and Planning Office, to mitigate disasters brought by landslides. The Geographic Information System and Analytical Hierarchy Process tools were utilized for the thematic mapping and weighting, respectively. The vulnerability of landslide was classified into four classes, namely low, moderate, high, and very high susceptibility. The total area of coverage in hectares in each susceptibility class was also determined to map the individual causative factors. The study reveals that slope, soil type, elevation, precipitation, and landcover with relative weights of 24.68%, 18.00%, 15.07%, 14.49%, and 10.89%, respectively, were the most influential factors of landslide susceptibility, whereas distance from roads and rivers with relative weights of 9.99% and 6.87%, respectively were identified as the least influential factors contributing to landslide susceptibility. To avoid reoccurrences of landsliding, reforestation and preservation of the ecosystem is highly recommended. Policies for land utilization and management for disaster risk reduction to be considered by the concerned authority are enforcement of slope-based zoning regulations, promotion of reforestation and forest conservation, adaptation of sustainable farming practices, development of a community-based landslide early warning system, and integration of disaster risk reduction in local land use and development planning.

Keywords: Analytical Hierarchy Process, Causative Factors, Geographic Information System, Landslide Susceptibility, Thematic Mapping

1. INTRODUCTION

Landslides are common and hazardous [15]. Each year, hydrological risks and related landslides result in millions of pesos in damage and hundreds of fatalities. In fact, the Philippines accounts for about 46% of all landslides caused by rainfall in Southeast Asia, with typhoons responsible for 42% of these landslides [27]. Even though landslides are common in the Philippines, there aren't many high-quality typhoon-triggered landslide susceptibility maps available, which is a significant resource gap in attempts to effectively manage and mitigate future landslide hazards nationwide.

Nueva Vizcaya has a significant risk of landslides, according to the information that is accessible at the moment. This indicates that there are rainfall trends, land cover, slope, geology, soil, and perhaps earthquakes in the area that constitute localized hazards. A common occurrence of hazards is landslides. In light of this data, planning choices such as project design, construction techniques, and project siting must consider the likelihood of landslides.

On November 15, 2020 (manilastandard.net), a retrieval operation for the landslide case was carried out in the municipality of Quezon. Two injured victims and ten dead bodies were found. Evasco, a police colonel, claimed that the heavy rains brought on by Typhoon "Ulysses" caused the steep mountain in Sitio Compound to collapse, resulting in a landslide that concealed the victims' homes below. Evasco also mentioned how a massive mudslide in the same location during the height of Typhoon "Ompong" in 2006 killed over a dozen people. FCF's open-pit mining activities have ruined the majority of the land, which the Mines and Geosciences Bureau have designated as hazardous and unsuitable for human habitation. In Kayapa, at least fifteen barangays in an upland town are isolated due to landslides from rains brought by the typhoon "Ompong". A family of four were also buried by landslide and a town's bridge was also damaged. The latest case of landslide was also happened in barangay Labang Ambaguio, Nueva Vizcaya on November 2024, causing seven confirmed dead and three were injured triggered by heavy rains brought by Super Typhoon Pepito and because of saturated soil. The typhoon wrecked houses and establishments, roads and bridges, rice, corn, vegetable gardens and people were trapped because of multiple landslides.

Even with the growing knowledge of landslides and the recent technological advancements in landslide forecasting and mitigation, landslide disasters continue to impact human activity. Slope stability is weakened by significant seismic activity and heavy rainfall, which both enhance the likelihood of landslides. Rapid population growth causes deforestation, increased urbanization, and unplanned land-use development, all of which increase the vulnerability of landslide-prone areas. Thus, this study aimed to determine the factors affecting landslides occurrences within the municipality of Ambaguio, Nueva Vizcaya through thematic mapping to provide useful information to the Municipal Disaster Risk Reduction Management Office for planning and implementation to prevent or lessen landslide occurrences.

2. METHODS

2.1. RESEARCH DESIGN

This research involves a mixed qualitative and quantitative research method with descriptive statistics approach. Qualitative research method was used to measure the characteristics of soil and landcover in the study area according to its classification or type. Moreover, qualitative with descriptive approach is used for the formulation of policies in land utilization and management for disaster risk reduction. While, Quantitative research method was used to measure the slope angle measure in degrees ($^{\circ}$), elevation in meters, precipitation in millimeters (mm), distance from roads and rivers in meters (m).

2.2. CONCEPTUAL FRAMEWORK

The Input-Process-Output (I-P-O) model is used to illustrate the scope of this study. The seven causative factors that include slope, precipitation, elevation, soil type, landcover, distance from roads and rivers were considered in this study to determine the most influential factor of landslide susceptibility in terms of area in hectares per class categorized as low, moderate, high, and very high susceptibility.

2.3. RESEARCH LOCALE

The study area is the entire municipality of Ambaguio, Nueva Vizcaya. Municipality of Ambaguio is composed of eight barangays is a conglomeration of mountains, forest, rivers and lakes with a total land area of 18, 560 hectares with an average elevation of 940 meters and considered as one of the coldest in weather temperature municipalities of Nueva Vizcaya. (Nueva Vizcaya Tourism website)

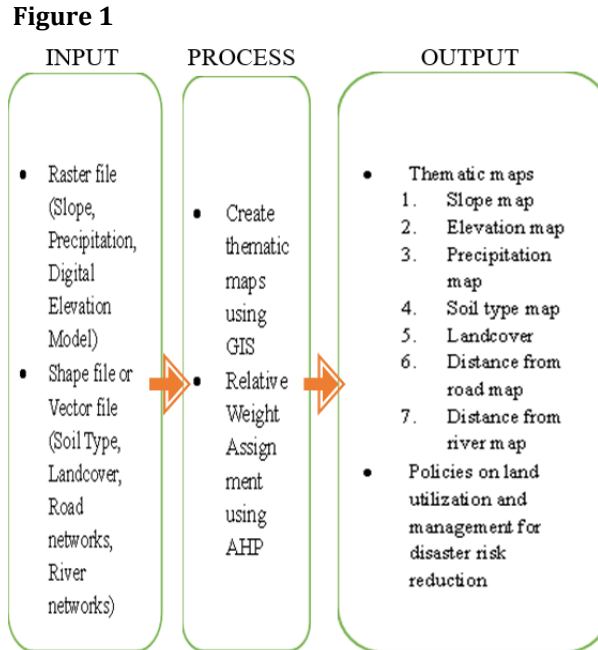


Figure 1 Conceptual Framework Representing the Variables Used (Input), The Methodology (Process) and Assumptions (Output)

2.4. RESEARCH INSTRUMENT

Geographic Information System (GIS) particularly the ArcGIS 10.8 (Developed by Esri) is the primary tool used for data processing, analysis, geospatial modeling and to create thematic maps. Individual maps for slope, elevation, precipitation, soil type, land cover, distance from river and distance from road are the thematic maps generated using that ArcGIS 10.8.

2.5. STATISTICAL TOOL

In this study, researcher applied the Analytical Hierarchy Process (AHP) as a suitable statistical tool to facilitate the decision-making and weighting process for accurately reflecting the influence of each causative factors in developing landslide susceptibility map through the application of Geographic Information System (GIS). The AHP developed by mathematician and operations researcher Thomas L. Saaty (1980) is a powerful multi-criteria decision analysis (MCDA) technique that enables the incorporation of multiple criteria in decision-making processes. Table 1 shows the Saaty's proposed numerical scale. In the context of this study, where various factors such as slope, aspect, landcover, soil type, elevation, rainfall and distance from roads and rivers contribute to landslide susceptibility, the AHP were aid in prioritizing and weighting these factors according to their significance.

A pairwise comparison of all components of the variables that contribute to landslides is conducted in order to create a scale of the relative significance of each element; the outcomes are presented as a numerical rating on a rating scale. Pairwise comparisons in matrix form, when combined, will provide a priority scale for the key variables contributing to landslides. The weight analysis evaluation of utilizing the Analytical Hierarchy Process (AHP) was used, as presented in Table 2.

2.6. STATISTICAL ANALYSIS AND PROCEDURES

The creation of thematic maps for each causative factor involved the application of spatial analysis and geoprocessing tools in ArcGIS 10.8. For the slope and soil map, it was extracted from Bureau of Soils and Water Management (BSWM) maps. On the other hand, for the rainfall map, Inverse Distance Weighting (IDW) interpolation was applied to create the rainfall map of the province of Nueva Vizcaya. Also, for the land cover map, data for each municipality were extracted from the Nueva Vizcaya Land Cover map from National Mapping and Resource Information Authority (NAMRIA). Meanwhile, the Global Digital Elevation Model acquired from the Provincial Planning and Development Office (PPDO) which was downloaded from the United States Geological Survey (USGS) was utilized in the study. Lastly, proximity to rivers and roads were calculated using GIS geoprocessing tools, and buffer zones were created employing the Euclidean distance.

All raster thematic maps were reclassified and assigned into four (4) values. Lower value means that the area is less likely to have landslide, vector data like soil, land cover and rainfall were converted to raster first using rasterize (polygon to raster) tool in GIS with spatial resolution of 30mx30m. Using the assigned four (4) values we used the following reclassification scheme:

- 1) Low Susceptibility to Landslide
- 2) Moderate Susceptibility to Landslide
- 3) High Susceptibility to Landslide
- 4) Very High Susceptibility to Landslide

After completing all the data preparation and pre-processing, we proceeded to computing the landslide susceptibility index (LSI). Relative weights were prepared using Analytical Hierarchy Process (AHP) for each factor and created factor layers with uniform values of 1 to 4, from lowest to highest susceptibility to landslide using reclassification method.

Table 1

Table 1 Saaty's Proposed Numerical Scale		
Scale	Definition	Explanation
1	Equal importance	Two factors contribute equally to the objective
3	Moderate importance	Experience and judgement slightly favor one over the other
5	Strong importance	Experience and judgement strongly favor one over the other
7	Very strong importance	Experience and judgement very strongly favor one over the other. Its importance is demonstrated in practice
9	Extreme importance	The evidence favoring one over the other is of the highest possible validity
2, 4, 6, 8	Intermediate values	When compromise is needed

Table 2

Table 2 Pairwise Comparison Matrix, Normalized Factor Weights and Consistency Ratio of Data Layers (Rahim et.al., 2018)								
Criteria	1	2	3	4	5	6	7	Weights (%)
Soil (1)	1	1	0.333	3.875	1.2	2.666	1.75	18
Rainfall (2)	1	1	0.875	0.75	0.833	1.75	2.25	14.49
Slope (3)	3.166	1.142	1	3	1.2	2.25	2.25	24.68
Landcover (4)	0.25	1.333	0.333	1	1.4	1.75	0.571	10.89
Elevation (5)	0.833	1.2	0.833	0.714	1	2.25	2.25	15.07
Distance to River (6)	0.375	0.571	0.444	0.571	0.444	1	0.571	6.87
Distance to Road (7)	0.571	0.444	0.444	1.75	0.444	1.75	1	9.99

CR (Consistency Ratio) = 0.068, < 0.1 acceptable

3. RESULT AND DISCUSSION

Generating of thematic maps of the seven causative factors that include slope, soil type, elevation, precipitation, landcover type, distance from roads and distance from rivers is the main objectives of this study. Tables represents the susceptibility class with its corresponding areas in hectares. Likewise, maps represent the boundaries or areas of coverage of each susceptibility classes.

Table 3

Table 3 Area Coverage in Hectares in Each Susceptibility Class Based on the Slope			
Slope (degrees)	High Susceptibility to Landslide	Moderate Susceptibility to Landslide	Total Area (Hectares)
0–3 Level to nearly level	1,264.52	—	1,264.52
3–8 Gently sloping to undulating	2.38	—	2.38
8–18 Undulating to rolling	184.37	—	184.37
50 and above Very Steep	14,175.85	301.22	14,477.07
Total Area (Hectares)	15,627.15	301.22	16,208.95

Table 3 shows the area coverage in hectares in high and moderate susceptibility classes in terms of slope which is one of the causative factors considered in this study. The slope measured in degrees ($^{\circ}$) categorized into 0° - 3° (nearly level), 3° - 8° (gently sloping to undulating), 8° - 18° (undulating to rolling) and 50° and above (very steep). It depicts that the municipality of Ambaguio covers 89.32% or approximately 14,175.85 hectares are within the 50° and above slope representing highly susceptible to landslide

In Figure 2 it illustrates that all the eight barangays of the study area are within the red color representing 50° and above slope. The green color representing 8° - 18° (undulating to rolling) is only 1.14% or 184.37 hectares and 0° - 3° (nearly level) has an area of 1,264.52 hectares or representing 7.81% out of the total area. Based on the slope, the municipality of Ambaguio is highly susceptible to landslide.

To support this study, Maksul Kamal et.al [16] concluded in their study titled “Assessing the effectiveness of landslide slope stability by analyzing structural mitigation measures and community risk perception” that the slopes are stable for lower slope angles from 0° - 18° but unstable for higher slope angles ranging from 50° and above.

Additionally, Yan Liu, Zhiyuan Deng and Xiekang Wang [19] on their study title “The Effects of Rainfall, Soil Type and Slope on the Processes and Mechanisms of Rainfall-Induced Shallow Landslides” concluded that no landslides occurred on a slope of 5° , and also to 15° of slope. Steeper slopes, stronger rainfall and coarser soils are influential to landslide occurrence.

Table 4

Table 4 Area Coverage in Hectares in Each Susceptibility Class Based on the Soil Type			
Soil Type	High Susceptibility to Landslide	Moderate Susceptibility to Landslide	Total Area (Hectares)
Annam Clay Loam	125.8	—	125.8
Guimbalaon Gravelly Clay Loam	10,786.20	—	10,786.20
Mountain Soils	3,973.84	—	3,973.84
Sibul Clay	741.27	301.22	1,042.48
Total Area (Hectares)	15,627.11	301.22	15,923.33

Table 4 shows the area of coverage in hectares in each susceptibility class based on the soil type. The municipality of Ambaguio is composed of Annam Clay Loam, Guimbalaon Gravelly Clay Loam, Mountain Soils, and Sibul Clay soil types. Among these soil types, the Guimbalaon Gravelly Clay Loam has the widest area of coverage containing 10786.20 hectares and classified as highly susceptible to landslides. Likewise, mountain soils contain an area of 3973.84 hectares or approximately 24.96% of the total area and also classified as highly susceptible to landslides.

Figure 3 shows the distribution of soil type across the eight barangays of the municipality of Ambaguio. The green color represents the Guimbalaon Gravelly Clay Loam soil type, also the red color represents the Mountain soil type, and the orange and yellow colors represents the Sibul Clay and Annam Clay Loam soil types respectively. the map revealed

that six of the eight barangays are composed of Guimbalaon Gravelly Clay Loam or that is approximately 67.74% of the total area are covered of this type of soil. Barangay Labang, the location of the latest landslide that claims seven lives last November 2024 during the onslaught of Typhoon Pepito is characterized of this type of soil.

According to the study of Dariagan et.al, [8]. Identified that soil texture like Guimbalaon Gravelly Clay Loam is with low permeability which has isolated pore spaces that trap waters within them. In connection, clay type of soil most pore spaces block water where it can't flow easily. With this theory, this type of soil has the highest possible probability of landslide because of its characteristics.

Moreover, based on the study of Donna Gabor [10] a clay soil type has a larger surface area, the larger the surface area, the easier it is for the soil to hold onto water leading to a higher water-holding capacity.

Table 5

Table 5 Area Coverage in Hectares in Each Susceptibility Class Based on the Elevation			
Elevation (m)	High Susceptibility to Landslide	Moderate Susceptibility to Landslide	Total Area (Hectares)
500 and below	94.29	—	94.29
500 to 1000	9,115.03	301.22	9,416.25
1000 and above	6,417.78	—	6,417.78
Total Area (Hectares)	15,627.10	301.22	16,208.32

Table 5 represent the are coverage in hectares in each susceptibility classes based on the average elevation of the study area. It is under the elevations measured in meters 500 and below, 500 to 1000 and 1000 and above from the mean sea level. Approximately 39.60% are within the average elevation of 1000 meters and above containing an area of 6,417.78 hectares. While 58.10% or 9,416.25 are within the average elevation of 500 to 1000 meters. Likewise, only 1.86% or approximately 301.22 hectares are moderately susceptible to landslide and 15627.10 hectares or 98.14% are within the high susceptibility class.

Figure 4 shows the elevation map of Ambaguio, the green color represents the average elevation ranging from 500 to 1000 meters, while the dark green represents the average elevation from 1000 meters and above. Among the eight barangays of the municipality of Ambaguio are located within these average elevations of 500 to 1000 meters and 1000 meters and above respectively.

According to B.R. Nakileza and S. Nedala [23] in their study titled "Topographic influence on landslides characteristics and implication for risk management in upper Manafwa catchment, Mt Elgon Uganda" most of the landslide's occurrences were in the mid altitude, at higher altitude (elevation) the thin colluvial materials limit slide occurrences. In relation to that, barangay Labang is located within the average elevations ranging from 500 meters to 1000 meters and above. The latest landslide occurrences last November 2024 were located within 500 meters to 1000 meters which was identified as the mid elevation in this study.

Table 6

Table 6 Area Coverage in Hectares in Each Susceptibility Class Based on the Precipitation (Rainfall)			
Precipitation (mm)	High Susceptibility to Landslide	Moderate Susceptibility to Landslide	Total Area (Hectares)
190.00–201.41	5,264.34	301.22	5,565.56
201.41–212.13	4,023.19	—	4,023.19
212.13–225.17	3,545.64	—	3,545.64
225.17–249.40	1,533.70	—	1,533.70
Total Area (Hectares)	14,336.87	301.22	14,688.09

Table 6 shows the area coverage in hectares in each susceptibility class based on the average Precipitation or rainfall every year. Precipitations were measured in millimeters (mm) ranging from 190 mm to 249.40 mm. Notably, the 190.00-201.41 mm precipitation range has the widest area of coverage with a total of 5264.34 hectares and it is within the high susceptibility classes. Followed by 201.41-212.13 mm precipitation range with a total area of 4023.19 hectares and also it is within the highly susceptible class.

Figure 5 shows the distribution of the average precipitations yearly received by the municipality of Ambaguio. Color gray on the eastern part of the map represent the precipitations ranges from 190-249.40mm were both received by

Figure 4

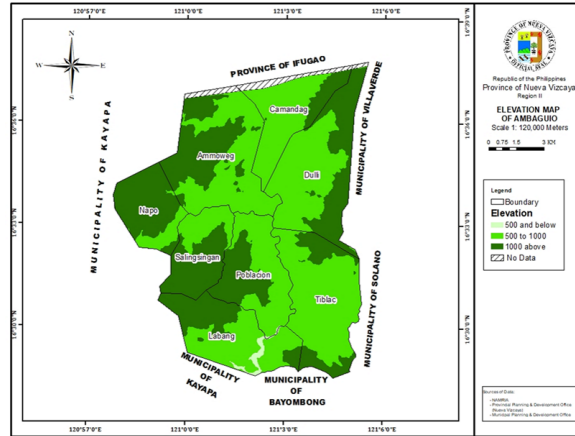


Figure 4 Elevation Map of Ambaguio, Nueva Vizcaya

Figure 5

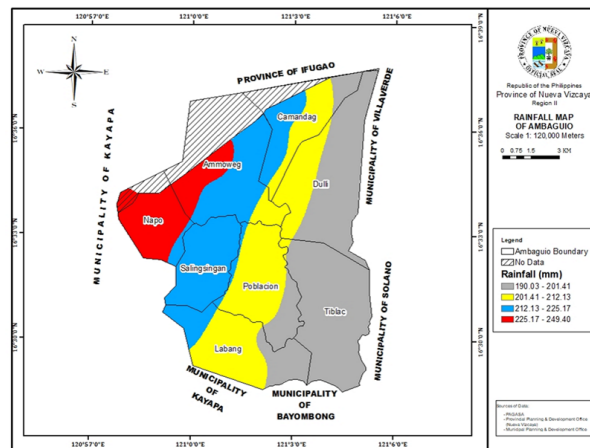


Figure 5 Rainfall Map of Ambaguio, Nueva Vizcaya

Figure 6

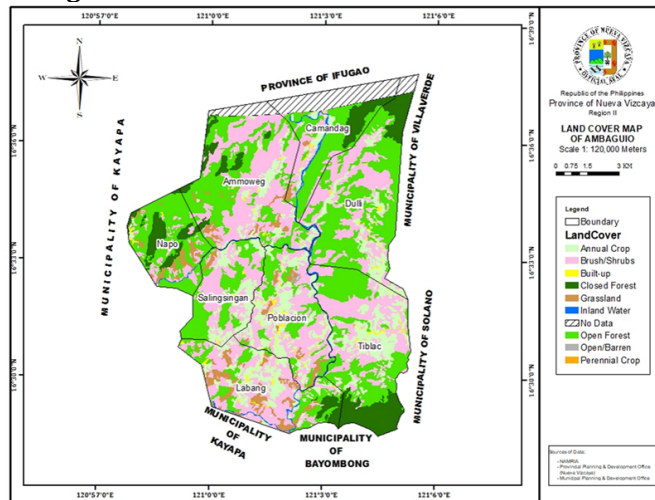


Figure 6 Land Cover Map of Ambaguio, Nueva Vizcaya

Figure 7

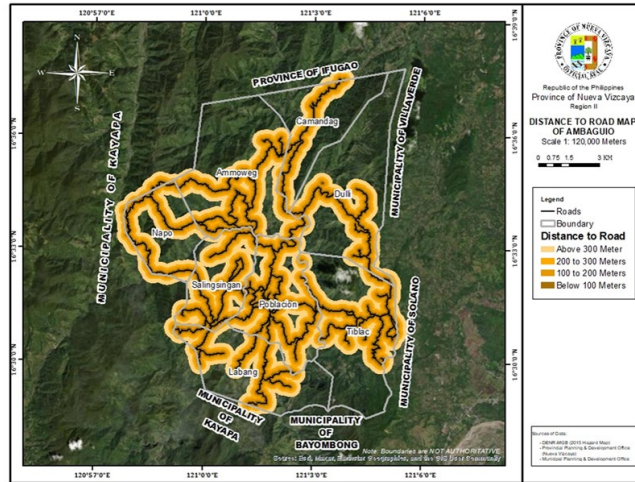


Figure 7 Distance to Road Map of Ambaguio, Nueva Vizcaya

Figure 8

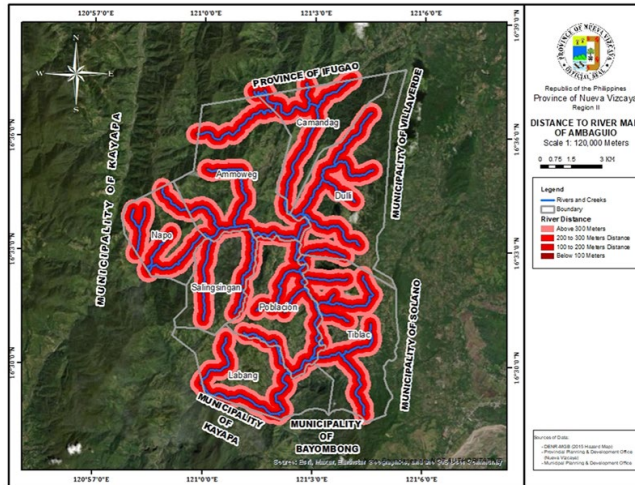


Figure 8 Distance to River Map of Ambaguio, Nueva Vizcaya

Table 7

Table 7 Area Coverage in Hectares in Each Susceptibility Class Based on the Landcover Type

Landcover Type	High Susceptibility to Landslide	Moderate Susceptibility to Landslide	Total Area (Hectares)
Annual Crop	2,243.81	83.25	2,327.06
Brush/Shrubs	5,264.55	73.08	5,337.62
Built-up	152.88	0.14	153.03
Closed Forest	1,288.24	3.22	1,291.47
Grassland	594.83	0.24	595.07
Inland Water	187.38	—	187.38
Open Forest	5,427.93	141.29	5,569.22
Open/Barren	29.64	—	29.64
Perennial Crop	0.79	—	0.79
Total Area (Hectares)	15,190.05	301.22	15,491.27

Table 7 shows the area coverage in hectares in each susceptibility class based on the landcover type. There are nine soil types identified in the study area, among these nine-soil type, it is notable that despite Ambaguio is a mountainous place, it is not covered with big trees as expected but mostly covered with brush/Shrubs and an open forest that contains an area of 10906.84 hectares or that is approximately 70.41% out of the total area. Likewise, the Annual crop that contains an area of 2327.06 hectares also prominent in this place, it implies that farming is one of the foremost activities in this place in spite of its terrains. On the other hand, approximately 98.04% or 15190.05 hectares are classified as highly susceptible to landslides.

Figure 6, depicts the distribution of landcover type across the eight barangays of the study area. Light green color represents the areas covered with an open forest. Pink color represents the areas covered with brush/shrubs. Likewise, dark green and yellow green colors represent closed forest and annual crop respectively. It reveals that barangay Labang are mostly covered with brush/shrubs, open forest, grass land, and annual crop landcover types. It is notable that this area is highly susceptible in landsliding based of its landcover type.

According to Renata Pacheco Quevedo et.al [28] on their study titled "Land use and land cover as a conditioning factor in landslide susceptibility: a literature review" they stated that landslide occurrences increasing due to human activities. Changing land use and landcover is a vital factor to avoid reoccurrences of landslides, according to their review, most of the studies conducted that land use and land cover classes that include road, soil, forest, or in short changing the land cover from its natural may cause landslide especially in deforestation for farming purposes.

Furthermore, Ilenia Murgia et.al [22] concluded that vegetation covers potentially amplified the slope stability of more than three time as compared to the unvegetated areas. Changing land cover in mountainous areas directly affect the soil stability.

Table 8

Table 8 Area Coverage in Hectares in Each Susceptibility Class Based on the Distance to Roads			
Distance to Roads (m)	High Susceptibility to Landslide	Moderate Susceptibility to Landslide	Total Area (Hectares)
Below 100	2,764.36	105.39	2,869.75
100 to 200	2,201.37	82.25	2,283.62
200 to 300	1,791.72	44.69	1,836.41
Above 300 meters	2,646.31	39.79	2,686.10
Total Area (Hectares)	9,403.76	272.12	9,675.88

Table 8 shows the area coverage in hectares in each susceptibility class based on the distance to roads. Distance to roads is divided from below 100m, 100m to 200 m, 200m to 300m and above 300 m. Below 100m has the widest area of coverage with a total of 2869.75 and approximately 96.33% of that area falls under high susceptibility to landslide. Also, above 300m distance to road has an area coverage of 2686.10 of which 2646.31 or 98.52% falls under the high susceptibility to landslide. Likewise, distances 100m-200m and 200m-300m have an area of 2283.62 hectares and 1836.41 hectares respectively, and both are mostly classified within the highly susceptible class. Based on the area of its distances, they are closed with each other, it implies that distance to roads is less significant to landslide susceptibility, as reflected in Table 10, that distance to river has a relative weight of 9.99% to landslide susceptibility.

Figure 7 shows the distribution of distance to roads from landslide susceptibility areas. Black color represents the road networks in the municipality of Ambaguio. Nearest to road is the dark brown color represents the distance to road of below 100 meters. Likewise, brown color represents the distance to roads of 100m to 200m. farthest from the road is the golden-brown color and gold color represents the distances ranging from 200m-300m and above 300m respectively. It is noticeable that most of the time landslides were occurred nearest to road particularly during rainy seasons causing road closures and damages to properties. The disruptions of mountains slope stability due to road construction and road widening are one of the factors of landslide adjacent to roads.

According to the study of Seda Celtek [6], in his literature review "The Effect of the Road Distance Parameter on Landslides,". Road construction changes vegetation or land cover, and during road works (vibration of equipment) directly affect the ground and influential to landslide occurrences because the distraction of soil from its original form nature makes the slope unbalanced particularly in mountainous places.

Table 9

Table 9 Area Coverage in Hectares in Each Susceptibility Class Based on the Distance to Rivers			
Distance from River (m)	High Susceptibility to Landslide	Moderate Susceptibility to Landslide	Total Area (Hectares)
Below 100	2,235.22	21.71	2,256.93
100 to 200	2,159.19	25.3	2,184.49
200 to 300	2,011.46	29.13	2,040.59
Above 300 meters	3,489.22	60.66	3,549.88
Total Area (Hectares)	9,895.09	136.8	10,031.89

Table 9 shows the area coverage in hectares in each susceptibility class based on the distance to rivers. Distances to rivers are divided into four groups ranging from below 100 meters, 100m to 200m, 200m to 300m, and above 300 meters. The distance to rivers for above 300 meters has the widest area of coverage with a total of 3549.88 hectares and approximately 98.29% of that are within the high susceptibility class to landslide. Also, distance to river from below 100m meters are more susceptible to landslide as compared to 100m to 200m and 200m to 300m.

Figure 8 depicts the distribution of distance to rivers ranging from below 100 meters to above meters. The blue color represents rivers and creeks networks found in the municipality of Ambaguio. It is visible that the whole municipality is surrounded by bodies of water. It also reveals that barangay Labang is surrounded by rivers, which one of the causes of landslide occurrence.

According to the study of Jikai Zhang et.al [40] stated that the distance relationship from landslide area to the river is less than 200 meters, because slopes are easily eroded by the river wash causing landslide. In the contrary, the river distance over 200 meters to landslide area is not totally significant to landslide susceptibility.

Table 10

Table 10 Synoptic Table Presenting the Causative Factors, Their Rating, Susceptibility Class, and the Weight Assigned to Each Factor Through AHP (Rahim et al., 2018)			
Causative Factors	Rating	Susceptibility Class	Weights (%)
Slope (degrees)			
0–3 Level to nearly level	3	High	24.68
3–8 Gently sloping	3	High	
8–18 Undulating to rolling	3	High	
50 and above Very Steep	2,3	Moderate, High	
Soil type			
Annam Clay Loam	3	High	18
Guimbalaon Gravelly Clay	3	High	
Mountain Soils	3	High	
Sibul Clay	2,3	Moderate, High	
Elevation (m)			
500 and below	3	High	15.07
500 to 1000	2,3	Moderate, High	
1000 and above	3	High	
Precipitation (mm)			
190.00–201.41	2,3	Moderate, High	14.49
201.41–212.13	3	High	
212.13–225.17	3	High	
225.17–249.40	3	High	

Landcover type			
Annual Crop	2,3	Moderate, High	10.89
Brush/Shrubs	2,3	Moderate, High	
Built-up	2,3	Moderate, High	
Closed Forest	3	High	
Grassland	3	High	
Inland Water	3	High	
Open Forest	3	High	
Open/Barren	2,3	Moderate, High	
Perennial Crop	3	High	
Distance to Road (m)			
Below 100	2,3	Moderate, High	9.99
100 to 200	2,3	Moderate, High	
200 to 300	2,3	Moderate, High	
Above 300 meters	2,3	Moderate, High	
Distance to River (m)			
Below 100	2,3	Moderate, High	6.87
100 to 200	2,3	Moderate, High	
200 to 300	2,3	Moderate, High	
Above 300 meters	2,3	Moderate, High	

Table 10 shows the corresponding rating, susceptibility classes and relative weights of each causative factors. Based on the table, the slope has obtained the highest weight, it means that it is the most influential factor of landslide susceptibility within the study area. Likewise, soil type, elevation, precipitation and landcover type placed a significant number of weights that contributes to landslide susceptibility of the municipality of Ambaguio, province of Nueva Vizcaya.

Policies for land utilization and management for disaster risk reduction to be implemented by the Municipal Local Government Unit of Ambaguio, Nueva Vizcaya

- 1) Enforcement of slope-based zoning regulations. Restrictions on residential or agricultural activities on areas with very steep slope. Moreover, the establishment of land classification zones based on slope gradient, soil type and precipitation levels to regulate land use is necessary to prevent landsliding, and requiring engineering studies and environmental impact assessment for any development for slope 50 degrees and above to concerned individual.
- 2) Promote reforestation and forest conservation. A reforestation program to open forest and brush/shrubs areas is deemed necessary to stabilize the soil.
- 3) Adaptation of sustainable farming practices. By promoting agroforestry system that integrate crops with tree cover to maintain soil stability, by providing training and support for slope-friendly farming practices, and by offering technical and financial support for farmers transitioning away from high-risk farming methods.
- 4) Develop a community-based landslide early warning system. By installing rainfall monitoring stations and early warning systems in high-risk areas, and by training the community on landslide signs and emergency evacuation plans.
- 5) Integrate disaster risk reduction in local land use and development planning. Hazard map should be included in the municipal comprehensive land use plan, by identifying the areas not suitable for building, farming, and other related activities particularly in highly landslide susceptible areas, and by ensuring all new infrastructure projects undergo hazard-resilient planning that include slope stabilization and drainage design.

4. CONCLUSION

Based on the conclusions derived from this study, the recommendations are:

- 1) To maintain the well balance ecosystem, the MDPO and MDRRMO should conduct continuous public awareness and environmental education. Implement education campaigns on the relationship between deforestation, slope instability, and landslides;
- 2) To the MPDO of Ambaguio, implement reforestation program using deep-rooted native species that are effective in attaching soil and promote sustainable agroforestry practices; and
- 3) To the MLGU of Ambaguio, it is necessary to provide alternative livelihood programs to reduce reliance on farming in marginal lands, offer a support for livelihood diversification, or introduce sustainable development on farming without altering the environment.

CONFLICT OF INTERESTS

None.

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