GEOGRAPHIC INFORMATION SYSTEM-BASED LAND SUITABILITY ANALYSIS AND MULTI-HAZARD MAPPING FOR POTENTIAL URBAN DEVELOPMENT SITES IN A STATE UNIVERSITY IN ROMBLON, PHILIPPINES

Sarah Joy A. Acepcion, MSc., [1] Marjohn E. Lucidos, ME, [2] and Juniel G. Lucidos, MSc.[3]
[1]Planning and Development Office, Romblon State University, Odiongan, Romblon, Philippines
Email: sjacepcion@rsu.edu.ph
[2] Planning and Development Office, Romblon State University, Odiongan, Romblon, Philippines
Email: marjohnlucidos@rsu.edu.ph
[3] Planning and Development Office, Romblon State University, Odiongan, Romblon,
Email: juniel.lucidos@gmail.com

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ABSTRACT
In urban development, land suitability assessment (LSA) is very critical to be considered by urban planners and policymakers for designing urban development in areas prone to natural hazards. One of the campuses of Romblon State University (RSU), located in the municipality of San Agustin, is situated on a coastline and a fault line, which makes it susceptible to the effects of climate change, such as floods, earthquakes, and landslides. This study aimed to synthesize a multi-hazard map as the basis for the identification of suitable areas for urban development on the RSU San Agustin campus using the Geographic Information System (GIS) and Analytical Hierarchy Process (AHP) method. After performing GIS-based AHP, this study found out that 1% of the land area of the RSU San Agustin campus is least suitable, while 89% is considered moderately suitable for potential urban development sites where resilient infrastructure designs must be prioritized.

1. INTRODUCTION

Natural hazards are a complex phenomenon, and there can be more than one natural hazard in an area. Hazard maps provide urban planners and policymakers to determine the feasibility of zoning an area for urban development. Urban planners and policymakers use multi-hazard maps for hazard mitigation and urban disaster management by assessing the potential and risk of natural hazards for making urban land suitability analyses (Anastasia et al., 2021). Apud and team (2020) stated that an "unplanned urban expansion exerts pressure on natural resources, resulting in environmental conflicts, contamination of water resources, loss of biodiversity, deterioration of fragile ecosystems, degradation of productive soils, and land use conflicts" (Apud et al., 2020). In line with this, the United Nation's 13th Sustainable Development Goal (SDG) focuses on urgent climate action to somehow eradicate the adverse effects of climate change and integrate climate change measures into national policies, the improvement of education, awareness-raising, and institutional capacity on climate change mitigation, adaptation, impact reduction, and early warnings.

Being considered a developing country whose climate change status may bear further unprecedented and adverse effects, the Committee on Higher Education (CHED) of the Philippines imposed on State Universities and Campuses (SUCs) nationwide the Republic Act No. 11396, also known as the "SUCs Land Use Development and Infrastructure Plan (LUDIP)" to craft a campus land use plan for allocating, utilizing, developing, and managing their land resources. Since one of the RSU campuses is situated on a coastline and a fault line, the Planning and Development Office (PDO) of Romblon State University (RSU) was tasked to identify priority areas in need of resilient infrastructures within its most vulnerable campus.

Numerous studies have demonstrated the ability of Geographic Information System (GIS) and, specifically, its weighted overlay approach, being flexible enough to perform various kinds of spatial analysis (Anastasia et al., 2021; Apud et al., 2020; El Jazouli et al., 2019; Everest et al., 2021; Jiang et al., 2008, Pokhrel, 2019, Sia et al., 2021; and Swain et al.,2020). The weighted overlay approach used by these studies reflects the spatial relationships with the use of weights by surveying urban planners, reviewing previous related literature and research, and the Analytical Hierarchy Process (AHP) method. AHP was first introduced by Thomas Saaty in 1980, which is based on expert knowledge, and it is used in Land Suitability Analysis (LSA) to determine weighting scores. AHP is a multi-criteria decision-making approach, which is suitable for dealing with complex decisions by breaking down the problem into different factors or components and organizing them into a hierarchy (Saaty et al., 2017). In this study, the aim was to synthesize a multi-hazard map as a basis for the identification of suitable areas for urban development on RSU campus situated on a coastline and fault line using the GIS and AHP method.

2. MATERIALS AND METHODS

2.1 Study Area

The study area, which is the San Agustin campus (as shown in Figure 1), is one of the nine (9) existing campuses of Romblon State University. RSU San Agustin is located on Tablas Island, and it lies at 12º 36'13'' North latitude and 122º 7'55'' East longitude with a GIS-generated total land area of 84,679 square meters. It ranks second to the RSU main campus in terms of total land area. It has an average of 796 enrollees per semester. And it is situated on a coastline and active fault line, which makes it susceptible to the effects of climate change, such as floods, earthquakes, and landslides.

Figure 1. (a) Existing campus of Romblon State University San Agustin and (b) its location in an island province of Romblon, Philippines

2.2 Spatial Data

The spatial data used in the analysis of this study were collected from the Mines and Geoscience Bureau of the Department of Environment and Natural Resources (MGB, DENR) and the Philippine Institute of Volcanology and Seismology of the Department of Science and Technology (PHIVOLCS, DOST). The summary of all spatial data gathered before preprocessing is shown in Table 1.

Table 1. List of gathered data and their original sources.

Data	File Format	Source
Flood Susceptibility	Raster (JPG)	MGB, DENR
Landslide Susceptibility	Raster (JPG)	MGB, DENR
Active Fault	Raster (JPG)	PHIVOLCS, DOST

2.3 Methods

Even nature has provided a wide range of resources, and some natural resources, are limited by the environmental potential for anthropogenic use; thus, spatial planning by assessing the land suitability vital. Lands having no significant limitations to the sustained application of a given use or having no significant reductions of benefits to an acceptable level are considered as highly suitable land, while lands with severe restrictions preventing any possibilities of successful sustained use of land are considered as not suitable land (Pokhrel, 2019).

Identification of the best criteria is the key to land suitability analysis. Criteria selection depends on factors that can influence the land. The most significant criteria used for suitability evaluation are environmental criteria such as natural hazards. Natural hazards, such as floods, earthquakes, and landslides, were considered as criteria or factors.

In processing hazard maps into multi-hazard maps and making land suitability maps, integration between GIS and AHP was used. This study utilized the GIS method, weighted overlay, in determining urban land suitability. Using

GIS software, ArcGIS Pro 2.8 (Environmental Systems Research Institute (ESRI), Redlands, CA, USA), the gathered spatial data were preprocessed and spatially analyzed. A pairwise matrix was created using Microsoft Excel (2019) to calculate the weights needed for the weighted overlay method. The steps for determining the urban land suitability of RSU San Agustin are shown in Figure 2.

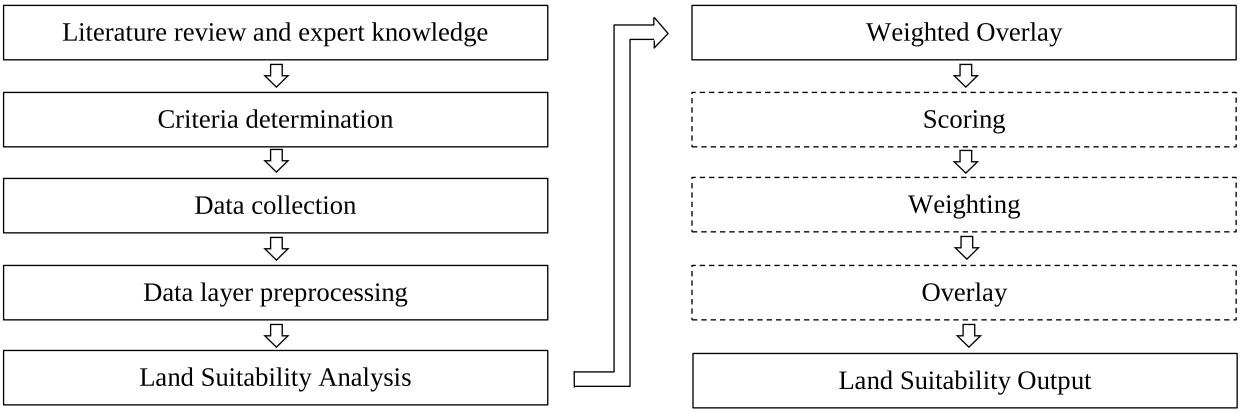
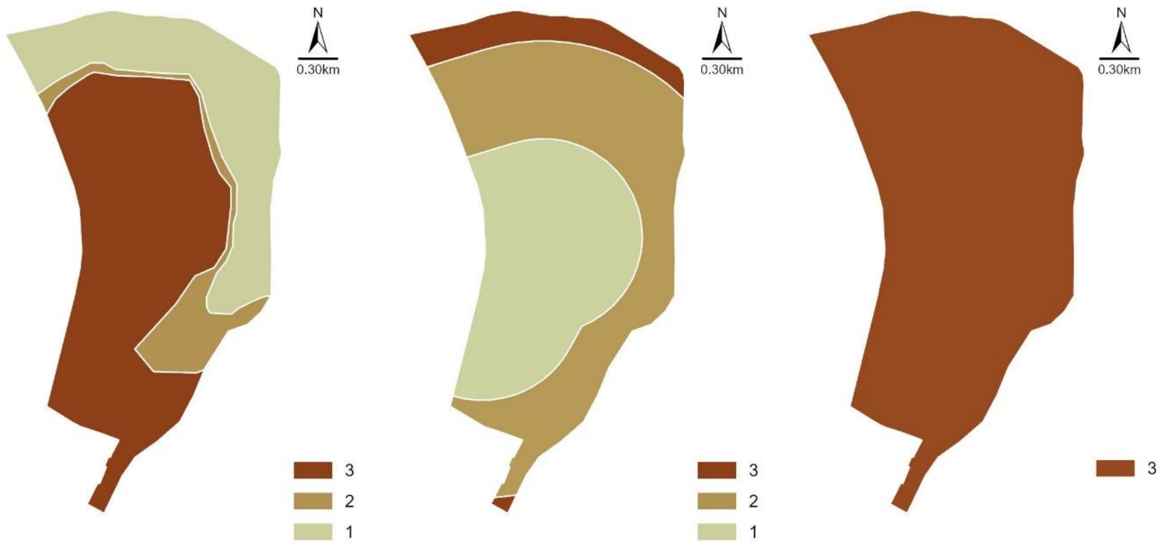


Figure 2. The workflow of this study

2.4 Weighted Overlay

Weighted Linear Combination (WLC) is commonly used as a straightforward approach to weighted overlay. It involves standardization of criteria scores and weighting of factors. Scores 1, 2, and 3 were used to standardize the input values and represent 1 as least suitable and 3 as most suitable. Spatial data of selected factors were reclassified based on Food and Agriculture Organization (FAO) standard land suitability classification such as (S1) highly suitable, (S2) moderately suitable, and (S3) less suitable using the reclassify tool of ArcGIS Pro 2.8 software. The reclassify tool was used to assign new values to the input data to generate new layers.

Scoring was based on the related studies and literatures conducted by researchers, availability of the data, and site observations (Anastasia et al., 2021; El Jazouli et al., 2019; Everest et al., 2021; and Swain et al.,2020). Favorable conditions such as average elevation, loam soil texture, low canopy cover, warm temperature, less precipitation or rainfall, low susceptibility to natural hazards were considered to determine if an area is suitable for development. The reclassified maps of selected factors for weighted overlay analysis are shown in Figure 3.



(a) Flood (b) Earthquake (c) Landslide

Figure 3. Individual factors or criteria maps used in the weighted overlay

Weighting was based to the existing condition of the study area, the vision of RSU, and related literatures since the study investigators were not able to establish proper communication to disseminate questionnaires from urban planners. A pairwise comparison matrix, derived from Analytical Hierarchy Process (AHP), with Saaty's comparison scale (as shown in Table 2), is commonly used as a popular method in multi-criteria decision-making (MCMD) scenarios (Saaty, 1977). The adapted pairwise comparison matrices (as shown in Table 3) by Anastasia and team (2021) were used in computing the weights for each selected factor (Anastasia et al., 2021).

Table 2. The comparison scale used in AHP method.

Preference weights/ Level of importance	Definition	Explanation
1	Equally preferred	Two activities contribute equally to the objective
3	Moderately preferred	Experience and judgment slightly favor one activity over another
5	Strongly preferred	Experience and judgment strongly or essentially favor one activity over another
7	Very strongly preferred	An activity is strongly favored over another and is affirmed to the highest degree possible
9	Extremely preferred	The evidence favoring one activity over another is affirmed to the highest degree possible
2,4,6,8	Intermediate values	Used to represent compromise between the preferences listed above

Source: (Saaty, 1977)

Table 3. Pairwise comparison matrices of computing the suitability weights (Anastasia et al., 2021).

Criteria	Flood	Earthquake	Landslide	Weight
Pairwise Comparison Matrix				
Flood	1	1/2	1/5	-
Landslide	5	3	1	-
Earthquake	2	1	1/3	-
Normalized Pairwise Comparison Matrix				
Flood	0.13	0.11	0.13	0.12
Earthquake	0.63	0.67	0.65	0.65
Landslide	0.25	0.22	0.22	0.23

The computed weights were integrated into the weighted overlay tool of ArcGIS Pro 2.8. The weighted overlay tool was utilized to determine spatial priorities for the location of proposed green infrastructures.

3. RESULTS AND DISCUSSION

LSA focuses on developing resilient built-up areas while preserving the natural environment. In this study, GIS-based AHP, as a multi-criteria evaluation approach, was used to create a multi-hazard map and identify the potential urban development sites in the study area.

3.1 Potential for Natural Hazards

The study area is situated on a coastline and active fault line, which makes the study area susceptible to flood, earthquake, and landslide. The potential area for least and most susceptibility to flood occupies around 59% and 31% of the total land area of the study area, respectively. The study area has a 324-meter coastline, creek, and bioclimatic variables of annual precipitation and temperature of 2,115% and 27.4%, respectively, which makes the study area susceptible to flood. Moreover, the potential area for least and most susceptibility to earthquake occupies around 10% and 41% of the total land area of the study area, respectively. A 104-meter active fault line lies at the center of the study area, which make majority of the area within the 200-meter earthquake zone. Furthermore, the study area has a 100% potential area for least susceptibility to landslide. Majority of the high elevated areas consist of vegetation cover of 35% and sandy clay loam soil of the total land area of the study area.

3.2 Land suitability assessment

Distinct levels of suitability from least suitable, moderately suitable, to most suitable areas were determined using the weighted overlay approach. The areas in light yellow represent the least suitability values, while the dark brown ones represent the areas with most suitability for potential urban development sites. According to the final urban suitability map (as shown in Figure 5 and Table 4), only 1% (≈778 sq. m.) of the study area is deemed least suitable. These areas are mostly located in eastern part of the campus towards the coast line and creek. The majority of the study are moderately suitable for potential urban development sites, making up 89% (≈75,571 sq. m.) of its total land area. And most suitable for potential urban development sites take up 10% (≈8,330 sq. m.) of the total land area, which are located at the northern and southern part of the study area.

Figure 5. Final urban suitability map

Table 4. Percent area covered by each suitability level in final urban suitability map

Suitability Level	Approximate Area (sq. m.)	Percent Area (%)
Most Suitable	8,330	10
Moderately Suitable	75,571	89
Least Suitable	778	1

The study investigators recognize that this study findings should not be the sole basis for planning as the dynamics of development is much more complex. The use of the data produced by this study will contribute to the formulation of LUDIP of the PDO and Physical Plant and Facilities Office (PPFO) for the transition of the study area, RSU San Agustin, into a resilient, green, and smart university.

4. CONCLUSION AND RECOMMENDATION

Without land suitability analyses and multi-hazard mapping, land use plans and policies may be detrimental to the development of an area, thus, unsustainable. After performing GIS-based AHP, this study found out that 1% of the land area of the RSU San Agustin campus is least suitable, 89% is considered moderately suitable, and 10% is considered most suitable for potential urban development sites. It is necessary to develop campus infrastructure with resilient features such as floodproofing, reinforced concrete, and other flood or earthquake resistive designs to reduce the risk of disasters in the identified least and moderately suitable areas and establish evacuation centers in the identified most suitable areas in the final urban suitability map.

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