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ARTICLE

Landfill Site Suitability Assessment Using Geographic Information System (GIS) and Analytic Hierarchy Process (AHP) in Butuan City, Philippines

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ABSTRACT

Landfilling is one of the most effective and responsible ways to dispose of municipal solid waste (MSW). Identifying landfill sites, however, is a challenging and complex undertaking because it depends on social, environmental, technical, economic, and legal issues. This study aims to map the optimal sites that were environmentally suitable for locating a landfill site in Butuan City, Philippines. With reference to the policy requirements from DENR Section I, Landfill Site Identification Criteria and Screening Guidelines of National Solid Waste Management Commission, the integration of a Geographic Information System (GIS) model builder and Analytical Hierarchy Process (AHP) has been used in this study to address the aforementioned challenges related to the landfill site suitability analysis. Based on the generated sanitary landfill suitability map, results showed that Barangay Tungao (1131.42967 ha) and Florida (518.48 ha) were able to meet and consider the three (3) main components, namely economic, environmental, and physical criteria, and are highly suitable as landfill site locations in Butuan City. It is recommended that there will conduct a geotechnical evaluation, involving rigorous geological and hydrogeological assessment employing a combination of site investigation and laboratory techniques. In addition, additional specific social, ecological, climatic, and economic factors need to be considered (i.e. including impact on humans, flora, fauna, soil, water, air, climate, and landscape).

Keywords: Geographic information system; Sanitary landfill; Analytic hierarchy process; Butuan City; Site suitability

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1. Introduction

Landfill site suitability assessment is a crucial task in solid waste management, as it involves identifying the most suitable location for a landfill site. The process involves considering various factors such as topography, geology, hydrology, and land use, among others. The use of Geographic Information Systems (GIS) and the Analytic Hierarchy Process (AHP) has gained significant popularity in recent years in the assessment of landfill site suitability. GIS is a powerful tool that allows for the visualization, analysis, and interpretation of spatial data, while AHP is a decision-making technique that facilitates the prioritization of different factors based on their relative importance.

Several studies have been conducted on landfill site suitability assessment using GIS and AHP. For instance, in a study by Li et al. [1], the authors used GIS and AHP to assess landfill site suitability in a rural area of China. The study identified various factors that were crucial in the selection of a suitable landfill site, including topography, distance to settlements, and distance to water sources. The results of the study indicated that GIS and AHP are effective tools for landfill site suitability assessment. In another study by Mohammadi et al. [2], the authors used GIS and AHP to assess landfill site suitability in Iran. The study identified various factors that were crucial in the selection of a suitable landfill site, including distance to transportation routes, distance to settlements, and soil type. The study concluded that the use of GIS and AHP is an effective approach to landfill site suitability assessment.

Numerous studies have demonstrated the efficacy of using GIS and AHP for landfill site suitability assessment. For example, Abbas and Ahamad [3] used GIS and AHP to assess landfill site suitability in India. The study identified several factors that played a significant role in the selection of a suitable landfill site, including land use, distance to settlements, and slope. The authors concluded that GIS and AHP are effective tools for landfill site suitability assessment.

In a study by Villanueva et al. [4], they used multi-criteria decision-making (MCDM) approach to evaluate and rank potential landfill sites in the municipality of San Nicolas, Pangasinan, Philippines. The study identified suitable landfill sites based on several criteria, including distance from residential areas, distance from water bodies, and accessibility to transportation routes. The results of the study can assist local decision-makers in identifying suitable landfill sites in accordance with the guidelines set forth by Republic Act 9003: Ecological Solid Waste Management Act of 2000 [5]. The study highlights the importance of proper waste management in ensuring environmental sustainability and public health.

As Butuan City in the Philippines has become one of the most heavily populated cities in the country, there is a need for the consequent wastes generated to be properly disposed of and catered to that will prevent its possible negative impacts on the people and the environment. This leads to an area meeting certain criteria for it to be the proposed area for building a sanitary landfill. Because of this, the city will benefit from this research by achieving sustainable landfill standards that are acceptable to the surrounding community and environmentally responsive.

Generally, the study aims to map the optimal sites that were environmentally suitable for locating a landfill site in Butuan City, Philippines. Specifically, it aims to identify a set of criteria for siting sanitary landfill and utilize the analytic hierarchy process (AHP) in providing weights for the identified criteria by generating a landfill suitability map based on the identified criteria and its corresponding weights using a Geographic Information System (GIS) in Butuan City, Philippines.

2. Methodology

2.1 Study area

Butuan City (8°57'N 125°32'E) is the 1st District of Agusan del Norte (**Figure 1**). Its total population according to the 2015 census is 337,063 with a density of 410/km^2. It is considered to be a 1st city income class and was declared as a highly urbanized city on February 7, 1995. It has a land area of 816.62

km^2 (315.30 sq mi) approximately considered to be 4.1% of the total area of the Caraga region covering 86 barangays which are categorized into 27 Urban and 59 Rural. Its land use involves agriculture area (397.23 km^2), forestland (268 km^2), grass/shrub/pasture land (61.14 km^2), and other uses (90.242 km^2). Production forest and protection forest areas cover 105 km^2 and 167.5 km^2 of the total forestland. Butuan City has a tropical rainforest climate, which is characterized by high temperatures and abundant rainfall throughout the year. The city experiences two distinct seasons: The wet season, which usually lasts from May to November, and the dry season, which usually lasts from December to April. During the wet season, Butuan City receives an average of 300 to 400 millimeters of rainfall per month. The heaviest rainfall usually occurs in October and November. The high humidity and rainfall during this season can sometimes lead to flooding in low-lying areas. During the dry season, the city experiences warm and dry weather, with temperatures averaging around 28 to 32 degrees Celsius during the day and around 22 to 24 degrees Celsius at night. The dry season is also characterized by occasional thunderstorms and occasional brief rainfall. Overall, Butuan City has a warm and humid climate throughout the year, with temperatures averaging around 26 to 28 degrees Celsius.

2.2 Data collection

A total of twelve (12) data sets were gathered and processed from various sources in the conduct of the study. **Table 1** lists the inventory of the data requirements with their corresponding sources. First, distance from urban areas was generated using the population per barangay data from Philippine Statistics Authority (PSA) census in 2010 [6] by identifying the urban areas following the condition set by the aforementioned agency. According to PSA, a barangay is considered urban if its population reaches 500 and above per square kilometer. Second, the slope was generated from a 30-meter resolution ASTER DEM data downloaded from the USGS Earth Explorer [7]. Third, road network distance from settlements data was generated from the OpenStreetMap [8] to identify the distance between the road and settlement areas. Fourth, the surface water or stream network data were digitized from the 1:250,000 topographic

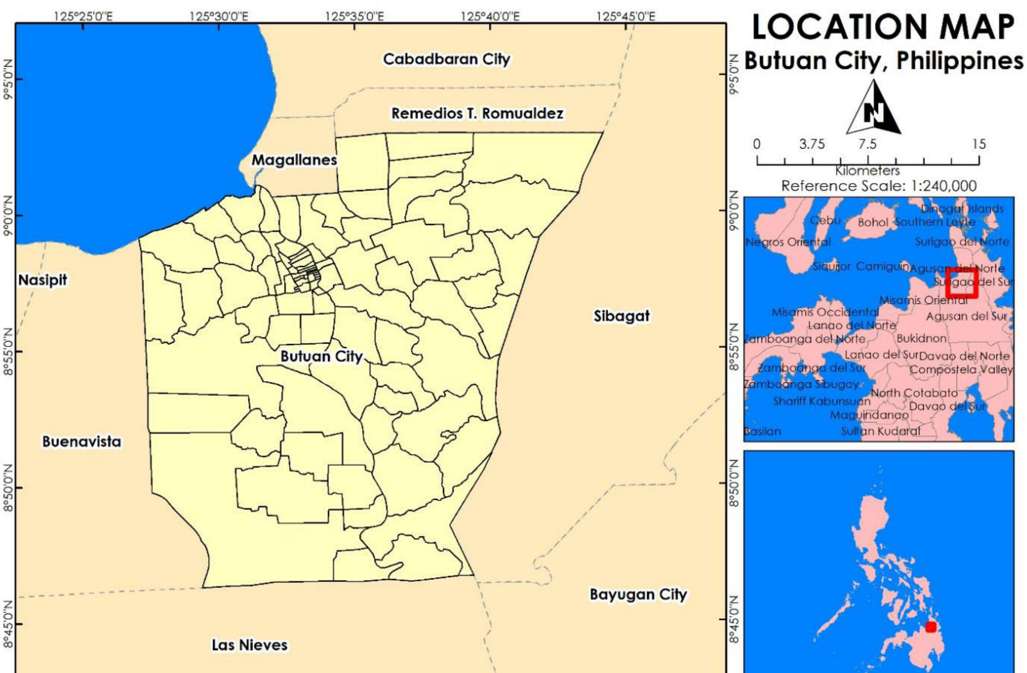

Figure 1. Location map of Butuan City, Philippines.

maps of NAMRIA [9] and land cover maps. Fifth, groundwater point source coordinates were gathered from the Philippine Groundwater Data Bank [10] and were then converted into shapefile. Identification of cultural sites using Google Earth [11] to locate sites in those areas with cultural importance. Other data were just downloaded, projected, and then clipped to the administrative boundary of Butuan City in the Geoportal PH [12], LiPAD Portal [13], DA-BSWM [14], and DOST-PHIVOLCS [15].

2.3 Landfill site selection criteria

After conducting a review of relevant literature, establishing a hierarchy of criteria and sub-criteria is a crucial step in any land suitability analysis. The selection of criteria and sub-criteria depends on the study's objectives and scope based on the study by Ali et al. [15]. Moreover, **Table 2** shows the hierarchy of criteria and sub-criteria consisting of three primary criteria, namely economic, environmental, and physical, along with twelve sub-criteria described in a study by Kara and Doratli [16].

This broad classification will each include various criteria that are necessary for the determination of the optimal site for a landfill. A detailed list of factors with their scale classification is provided in **Table 2**. The classification was revised for it to be tailor-fitted to local conditions, especially with the policies. The policy guidelines were taken from Section I. Landfill Site Identification Criteria and Screening Guidelines of NSWMC Resolution No. 64, Series of 2013.

2.4 Analytic hierarchy process

The Analytical Hierarchy Process (AHP) is a powerful tool that helps decision-makers tackle complex decision-making challenges by assisting them in prioritizing options to arrive at the best decision. On the other hand, the Multi-Criteria Decision Analysis (MCDA) method supports the framework, design, evaluation, and prioritization of alternatives in decision problems. Among the different decision-making techniques used by both decision-makers and researchers, the Analytical Hierarchy Process is one of the most frequently utilized techniques by Sari et al. [18]

Moreover, it generates a weight for each criterion according to the decision maker's pairwise comparison of the criteria. For a fixed criterion, the AHP as-

Table 1. List of all the data requirements and their sources for landfill suitability mapping.

Main Criteria	Criteria	Dataset Requirement	Data Source
Economic	Distance from urban areas	Population Density per barangay	PSA (Census 2010) [6]
	Slope	ASTER DEM (30 m resolution)	USGS Earth Explorer [7]
	Distance from roads	Road Network	OpenStreetMap (as of June 2020) [8]
Environmental	Distance from surface waters	Digitized stream network from NAMRIA topographic maps	NAMRIA [9]
	Distance from groundwaters	Groundwater point sources	Philippine Groundwater Data Bank [10]
	Distance from environmentally sensitive areas	Taguibo watershed (listed in critical watersheds in the Philippines)	Geoportal PH [12]
	Land Cover	Land cover map	NAMRIA (2010) [8]
	Flood Susceptibility	Flood Susceptibility map (25-year return period)	LiPAD Portal [13]
	Soil permeability	Soil types	DA-BSWM [14]
Physical	Distance from settlements	Building dataset	OpenStreetMap (as of June 2020) [8]
	Distance from cultural heritage	POIs of cultural sites	Google Earth [11]
	Distance to Faults (Seismic Conditions)	Active Faults	DOST PHIVOLCS [15]

Source: [16].

Table 2. Identified landfill site selection criteria with policies/considerations, exclusionary zones and sub-criterion zones for Butuan City, Philippines.

Main Criteria	Criteria	Policies / Considerations	Exclusionary Zones	Sub-criterion zones	Suitability Classification
Economic	Distance from urban areas	Urban Areas are those areas with at least 500 persons per square kilometer (PSA)	-	0-10 km 10-25 km 25-50 km > 50 km	Low Moderate High Very High
	Distance from roads	The site shall be accessible from major roadways and thoroughfares provided that if it is not accessible the project design shall include means of access.	100 m from the main roads	100-250 m 250-500 m 500-750 m > 750 m	Low Moderate High Very High
	Slope	Ideally, the site has a gently sloped topography. Areas above 18% slope should be avoided. The slope is classified according to the DENR-LMB classification.	Areas with above 18%	0-8% 8-18% 18-30% 30-50%	Very High High Moderate Low
Environmental	Distance from surface waters	The site shall not be located within 300 meters of watershed areas or upgradient (point of intake) of any surface waters used for public or private drinking water supply irrigation or livestock.	300 m from surface waters	300-1000 m 1000-1500 m 1500-2000 m 2000-2500 m > 2500 m	Low Moderate High Very High Very High
	Distance from groundwaters	The site shall not be located on shallow unconfined aquifers. Areas in or within 500 meters up a gradient of groundwater reservoir or water supply intakes used for private or public drinking irrigation or livestock shall also be excluded.	500 m from aquifers	500-1000 m 1000-1500 m 1500-2000 m 2000-2500 m > 2500 m	Low Moderate High Very High Very High
	Distance from environmentally sensitive areas	The site shall not be located within 500 meters of the boundaries of ecologically sensitive areas proclaimed as protected areas under the National Integrated Protected Areas System (NIPAS) Act.	500 m from environmentally sensitive areas	500-1000 m 1000-1500 m 1500-2000 m > 2000 m	Low Moderate High Very High
	Land cover	Avoid areas with valuable mineral and energy resources, tourist destinations or across major transportation routes, water gas, electrical power or communication transmission infrastructures.	Inland Water, Fishponds Open Forest, Broadleaf Mangrove Forest	Grassland Bare/pasture Bare/sand/rock Forest scrub/	Low Moderate High Very High
	Flood Susceptibility	Avoid locating sites in areas that may be subject to washout or inundation during a major flood	Areas with moderate and high susceptibility	Not flood prone Low susceptibility	Very high
	Soil permeability	The site shall not be located in unstable, very soft, and settling soils (sand, coarse sand, or fine sand) with high potential for liquefaction, slumping or erosion.	-	Nearly impermeable Low impermeable Conditionally Permeable Permeable	Very high High Moderate Low
Physical	Distance from settlements	The sites shall not be located in or within 250 meters of existing or proposed residential, commercial or urban development areas among other land use classes	250 m from settlements	250-1000 m 1000-1500 m 1500-2000 m 2000-2500 m > 2500 m	Low Moderate High Very High Very High

Table 2 continued

Main Criteria	Criteria	Policies / Considerations	Exclusionary Zones	Sub-criterion zones	Suitability Classification
	Distance from cultural heritage	The sites shall not be located in or within 250 meters of areas with historical, archaeological, cultural geological, or scientific interests which are more than 100 years old and declared by the traditional Commission for Culture and the Arts National Historical Institute or National Museum.	250 m from cultural heritage sites	250-500 m 500-1000 m 1000-1500 m 1500-2000 m > 2000 m	Low Moderate High Very High Very High
	Distance to Faults (Seismic Conditions)	Avoid areas within 500 meters of active faults or in areas with an average return period between 50 to 100 years for an earthquake of magnitude 6 and above	500 m from active faults	500-1500 m 1500-2500 m 2500-3500 m > 3500 m	Low Moderate High Very High

signs a score to each option according to the decision maker's pairwise comparisons of the options based on the criterion. The AHP also combines the criteria weights and the options scores that determine a global score for each option and a consequent ranking.

Table 3 shows the weights assigned for each main criterion with its corresponding consistency ratio (CR). However, this study assumed an equal weight for the sub-criterion zones since some of its categories are not applicable to local conditions. The calculation of the consistency ratio (CR) is an important step because it checks if the estimated weights were already acceptable or needed to be changed. The acceptable value of CR is less than 0.10, otherwise, the judgments were considered inconsistent and had to be checked and revised. Consistency Ratio (CR) and Consistency Index (CI) were calculated based on the following equations:

$$CR = CI/RI \quad (1)$$

$$\text{CI} = ((\lambda max - n))/((n-1)) \quad (2)$$

where, CI = Consistency Index; RI = Random Index.

2.5 Stepwise spatial analysis

First, eight of the twelve criteria were subjected to the Euclidean distance (ArcGIS toolbox > Spatial Analysis > Distance > Euclidean distance). This tool calculates, for each cell, the Euclidean distance to

Table 3. Assigned weights of main criteria and criteria.

Main Criteria	Weight	CR	Criteria	Weight	CR
Economic	0.21	0.016	Distance from urban areas	0.54	0.008
			Distance from roads	0.30	
			Slope	0.16	
Environmental	0.55		Distance from surface waters	0.31	0.007
			Distance from ground waters	0.31	
			Distance from environmentally sensitive areas	0.05	
			Land cover	0.05	
			Flood Susceptibility	0.12	
			Soil permeability	0.16	
Physical	0.24		Distance from settlements	0.68	0.002
			Distance from cultural heritage	0.22	
			Distance to Faults (Seismic Conditions)	0.10	

Source: [17].

the closest source (ArcGIS Help). This tool can be visualized using the illustration provided by ArcGIS Help. For this study, this tool was utilized for creating zones. This zone represents the degree of influence of a specific criterion in a particular zone or distance from the center to the determination of the landfill site. For this step, the software automatically creates the zones. Urban centers, road networks, groundwater point sources, stream networks, critical areas, cultural sites, built-up areas, and active faults are the criteria wherein this tool was executed for.

2.6 Model development

The study utilized ArcGIS^{TM}, a licensed model builder to develop the landfill suitability model for landfill site selection in Butuan City, Philippines. The schematic diagram generated from the model builder detailed the general stepwise method implemented to determine the optimized landfill site (**Figure 2**).

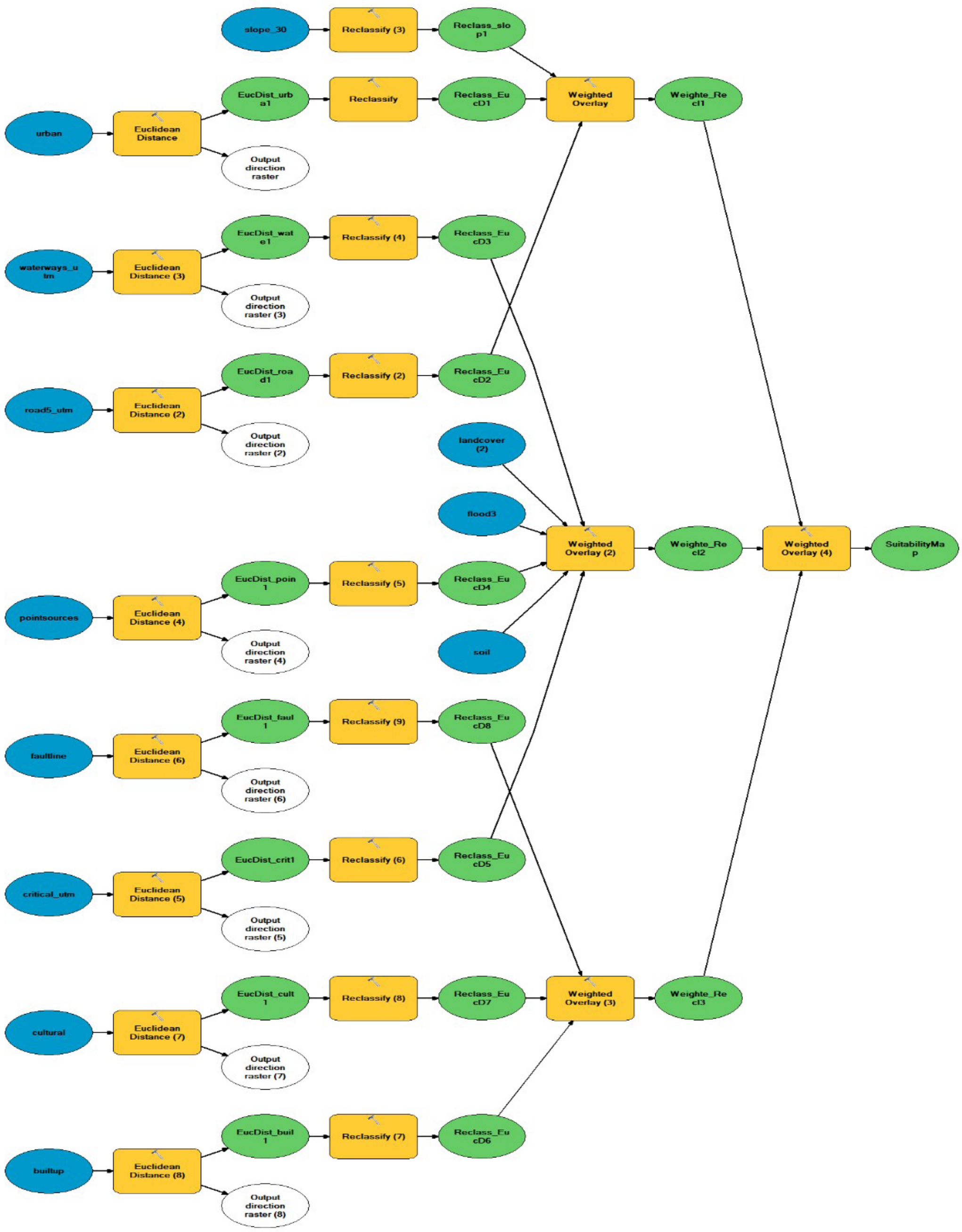

Figure 2. General workflow of the landfill suitability mapping using ArcGIS model builder.

3. Results and discussion

To minimize negative long-term environmental impacts, such as groundwater contamination, air and noise pollution, and public health risks, it is crucial to conduct a thorough evaluation of various criteria when siting a landfill. However, economic factors must also be considered, and sometimes it may not be feasible to locate the landfill far from the main roads due to increased transportation and collection costs. In a study conducted by Habiba et al. [19], thirteen criteria maps were developed based on a literature review and Malaysian guidelines for landfill siting to gain a comprehensive understanding of suitable landfill site criteria. A similar approach was taken in Butuan City, Philippines, using the Philippine Guidelines for landfill sitting.

After developing a landfill suitability model using ArcGIS model builder, an additional requirement and process were conducted to compute the area needed for landfill site selection in accordance with the Solid Waste Management Guidelines of CLUP Guidebook Volume 2 [20]. The landfill suitability map for Butuan City was produced, and **Tables 4, 5, and 6** discuss the specific areas for low, moderate, high, and very high suitability. **Figure 3** below illustrates the landfill site suitability of Butuan City.

3.1 Very highly suitable areas

Table 4 and **Figure 3** show the areas (in hectares) of 4 barangays in Butuan City that have very highly suitable sites in Butuan City for building a sanitary landfill. Results show that Barangay Bugsukan has the highest number of areas for building a sanitary landfill with 26.74 hectares of very highly suitable areas. Barangay Nong-Nong has the lowest number of areas for building a sanitary landfill with 0.0956 hectares of a very highly suitable site. However, none of the barangays have met the total land area for building a sanitary landfill.

Land availability is one of the critical factors to consider when selecting a site for a sanitary landfill. According to Ali et al. [16], the size of the site is one of the most important criteria that influence the suitability of a site for landfilling. It is essential to select a site with sufficient land area to accommodate the waste generation of the community for several years to come. However, if the land area is insufficient, the landfill may reach its capacity faster than anticipated, requiring the need to establish additional landfills or expand the existing ones, which can be costly and time-consuming.

Furthermore, the selection of a sanitary landfill site should also consider the distance from residential areas, water bodies, and transportation routes,

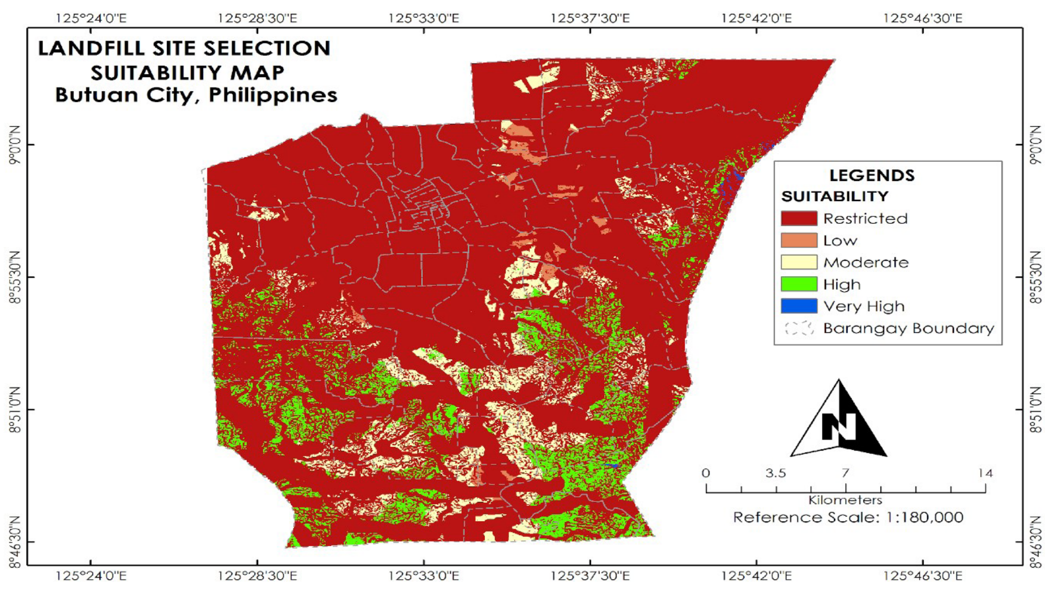

Figure 3. Landfill site selection suitability map of Butuan City, Philippines.

among other factors, to prevent adverse environmental and public health impacts. The results of the study by Kara and Doratli [17] show that the physical, economic, and environmental criteria are critical in selecting an appropriate site for a sanitary landfill.

In conclusion, while the barangays mentioned in **Table 4** may have very highly suitable sites for building a sanitary landfill, the total land area available in each barangay must also be considered. It is crucial to identify a site with enough land area to accommodate the waste generated by the community for an extended period while considering the necessary criteria to prevent adverse environmental and public health impacts.

Table 4. Very highly suitable areas for landfill site selection in Butuan City, Philippines.

BARANGAY	AREA (hectares)
Bugsukan	26.7413283
Florida	10.4310974
Nong-Nong	0.0955391
Pianing	6.9079892
Total Land Area	**44.175954**

3.2 Highly suitable area

The identification of highly suitable areas for constructing a sanitary landfill is an important aspect of solid waste management planning. The results presented in **Table 5** indicate that some barangays in Butuan City have significant areas that are highly suitable for landfill construction. Barangay Florida is one of the barangays that have met the total land area requirement for building a sanitary landfill with 518.48 hectares of the area considered to be highly suitable. Barangay Tungao, having 1131.43 hectares of the area highly suitable for building a sanitary landfill has the highest number of areas as compared to Barangay Tagabaca. It has the lowest number of areas with only 2.73 hectares highly suitable for building a sanitary landfill. This can help decision-makers to identify potential sites for building a landfill that would meet the criteria for proper waste disposal while minimizing negative environmental and public health impacts.

Furthermore, this finding is consistent with a study conducted by Ali et al. [16] which emphasizes the importance of identifying appropriate criteria for landfill suitability analysis. They highlight that the criteria used should vary depending on the scope and objectives of the study and that a review of relevant literature can aid in establishing a hierarchy of criteria and sub-criteria. The use of such criteria can assist in identifying highly suitable areas for landfill construction while minimizing potential negative impacts.

Table 5. Highly suitable areas for landfill site selection in Butuan City, Philippines.

BARANGAY	AREA (hectares)
Amparo	72.0874578
Anticala	37.2093499
Aupagan	19.4932393
Basag	3.9174409
Bilay	3.5055031
Bitan-Agan	214.537154
Bit-Os	204.32094
Bugabus	35.1679778
Bugsukan	68.9205218
Camayahan	200.730793
Dankias	34.3457281
De Oro	48.8555106
Don Francisco	105.495956
Dulag	177.908904
Florida	518.478423
Maguinda	291.998449
Maibu	216.915679
Mandamo	378.757613
Manila de Bugabus	166.081443
Nong-Nong	170.753381
Pianing	36.615961
Pigdaulan	25.6876102
Salvacion	161.070872
San Mateo	25.4985378
Sumile	186.126838
Tagabaca	2.7285528
Taligaman	71.5297566
Tungao	1131.42967
TOTAL LAND AREA	**4610.16926**

3.3 Moderately suitable sites

Table 6 presents the results of the land suitability analysis for potential landfill sites in the study area. It indicates that three barangays, namely Amparo, Tungao, and Manila de Bugabus, have a relatively larger area of land that is moderately suitable for constructing a sanitary landfill, making them potential locations for landfill development. However, it is important to note that the criteria used in the analysis are not the only factors that should be considered when deciding on a landfill site. Other social and economic factors, such as the proximity to population centers and the cost of transportation, should also be considered.

On the other hand, Barangay Basag has the smallest area of moderately suitable land for landfill construction, indicating that it may not be a viable option for landfill development. However, it is important to consider other factors that may impact the suitability of the site, such as its proximity to water bodies, population density, and land use restrictions.

Overall, the results of the land suitability analysis can serve as a useful tool in identifying potential locations for landfill development, but they should be considered in conjunction with other relevant factors and careful consideration of potential environmental and social impacts.

3.4 Suitable sites with areas greater than the landfill area requirement of Butuan City

With the addition of landfill area requirements as a factor, no area in the municipality is categorized as a very highly suitable site. Barangay Tungao (1131.42967) and Florida with 518.48 hectares are highly suitable as the landfill site location. Moreover, Barangays Amparo (433.7004 ha), Manila de Bugabus (406.5156 ha), and Tungao (413.0025 ha) are moderately suitable sites. Furthermore, in a study conducted by Zulu et al. [21], an overlay analysis revealed that the current dumpsite in Banket Town Board, Zimbabwe is unsuitable due to various critical parameters, such as roads, hydrological network, and land use. The presence of a power line that runs

Table 6. Moderately suitable areas for landfill site selection in Butuan City, Philippines.

BARANGAY	AREA (hectares)
Amparo	433.7004
Ampayon	32.9984
Anticala	19.2062
Antongalon	60.05356
Aupagan	103.6259
Baan Km3	2.192468
Bancasi	59.80117
Baobaoan	80.76925
Basag	1.569937
Bilay	175.169
Bitan-Agan	37.82903
Bit-Os	157.1715
Bobon	0.654652
Bugabus	208.7171
Bugsukan	27.2267
Cabcabon	33.46424
Camayahan	65.06163
Dankias	157.0967
Don Francisco	25.48383
Dulag	48.54295
Dumalagan	121.5627
Florida	53.04027
Los Angeles	57.74676
Maguinda	248.7865
Mahay	35.58821
Maibu	147.8911
Mandamo	20.44589
Manila de Bugabus	406.5156
Nong-Nong	0.147941
Pianing	0.937307
Pigdaulan	183.5733
Pinamanculan	9.355365
Salvacion	6.839699
San Mateo	80.09127
Santo Nino	132.1781
Sumile	44.67656
Sumilihon	18.6711
Tagabaca	129.4023
Taguibo	1.325041
Taligaman	70.08011
Tiniwisan	10.39523
Tungao	413.0025
TOTAL LAND AREA	**3922.587**

through the dumpsite further complicates the issue. Utilizing key environmental parameters, a map was created, highlighting several alternative sites that are potentially suitable for establishing a well-engineered landfill or dumpsite. This result corresponds with the findings of other studies that have found the existing dumpsites as unsuitable possible suitable sites for establishing a landfill in their respective study areas [21-23].

4. Conclusions and recommendations

After conducting a spatial determination of an optimal landfill location that ensures proper environmental and social acceptability of the proposed landfill site, several conclusions were reached. First, the researcher identified a set of criteria for Butuan City as per guidelines provided by DENR National Solid Waste Management Commission (NSWMC) on-site identification and suitability assessment procedure for sanitary landfills. These criteria are considered economic, environmental, and physical criteria. The utilization of the Analytical Hierarchy Process (AHP) helped in the identification process of potential sites by considering the most relevant criteria. The relative importance weights for the various criteria were calculated using a pair-wise comparison method that enabled the proper integration of various screening criteria.

Geographical Information System (GIS) was used as a decision-support system to help in finding suitable sites for potential landfill sites. Based on the site area requirement provided by DENR National Solid Waste Management Commission (NSWMC), Barangay Tungao (1131.42967) and Florida with 518.48 hectares were identified as highly suitable for the landfill site location. However, constraints were identified in the proper integration of GIS due to the lack of funds, limited availability of detailed data, and the availability of a technical workforce with adequate knowledge and training in GIS.

Limitations were also identified in terms of evaluation and analysis. The analysis was limited to the availability and accuracy of data, and a careful field research and evaluation process was required to assess the impact on local communities, the environment, the and ecology of the area. Further geotechnical and hydrogeological analyses were also necessary for the protection of groundwater as well as surface water.

At the end of the analyses, suitable areas for appropriate solid waste landfill sites were identified that generally satisfied the minimum requirements for new landfill site selection and fulfilled the legislative and environmental obligations associated with site selection. The study showed that it provides a tool and methodology for landfill site selection to local authorities.

To ensure proper landfill site selection, several steps must be taken. First, a geotechnical evaluation stage must be conducted, involving rigorous geological and hydrogeological assessment using a combination of site investigation and laboratory techniques. Additionally, more detailed social, ecological, climatic, and economic parameters should be considered, including the impact on humans, flora, fauna, soil, water, air, climate, and landscape. Objective ranking of potential sites in order of suitability and social acceptance is also important. This can be achieved through the use of household surveys or public consultations. The general public must be involved in the selection process from the start, through the dissemination of information, consultation, and public meetings. Moreover, an Advisory Committee on Landfill Site Selection should be in place consisting of various fields of expertise and technical consultants who will oversee the findings and recommendations. They will ensure that the most suitable site is selected, considering all relevant factors.

Lastly, future research should focus on the possibility of GIS with Environmental Impact Assessment in the location of landfills. This will help to further refine the site selection process and ensure that the environmental impact is minimized. By following these steps, the proper selection of landfill sites can be achieved, ensuring the safety and health of both humans and the environment.

Conflict of Interest

There is no conflict of interest.

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