Criteria on Sanitary Landfill Suitability Analysis in the Ifugao Province, Philippines

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ABSTRACT

The Philippines is facing an alarming contemporary environment issue on solid wastes generation, which primarily caused by the increase of population, improvement of living standards, rapid economic growth, and industrialization, especially in urban areas. The establishment of a sanitary landfill is highly needed as a mechanism to manage generated solid wastes. However, it requires thorough suitability analysis to foresee and prevent irreversible adverse impacts on society and the ecological environment. This study determined criteria and sub-criterion in the suitability analysis on the establishment of a sanitary landfill in Ifugao Province. This study utilized secondary analysis GIS analysis of required maps based on landfill siting area requirement using ArcMap GIS software licensed to UPLB. Results show that criteria in the suitability analysis classified into economic, environmental, and physical criteria as well as the identified policy consideration, exclusionary zones, and sub-criterion zones. The implementation of suitability analysis through GIS analysis is highly recommended.

Keywords: *Criteria and Suitability Analysis*

I. Introduction

The Philippines is currently encountering alarming environmental issues, particularly on the generation of solid wastes in which the trend is increasing that caused by the increase of population, improvement of living standards, rapid economic growth, and industrialization especially in urban and dense areas (Senate Economic Planning Office, 2017). In 2012, the computed solid waste generation in the country is 37,427.46 tons per day and steadily increase until 2016, with 40,087.45 tons per day (NSWMC, 2015). Most of the generated solid wastes were from residential (57%) then commercial (27%) followed by institutional (12%) and industrial (4%) (NSWMC, 2017).

The formulated mechanism of the national government is mainly stated in RA 9003, otherwise known as the Ecological Solid Wastes Management Act of 2001, in which the establishment of sanitary landfills by the local government units (LGU) is required. In the country, there 86 existing sanitary landfills that cater the increasing generated solid wastes and these existing sanitary landfills has its own capacity (NSWMC, 2015). In this case, the organization of sanitary landfills and growth or development of existing sanitary landfills in local government units is needed and mandate in RA 9003 to run the solid wastes generate by dissimilar sources correctly.

The absence of proper wastes management may cause human health problems such as diarrhea, helminthiasis, typhoid/paratyphoid, cholera and hepatitis A that may cause complications and death. In addition, flora and fauna in both terrestrial and aquatic ecosystems can be negatively affected by mismanaged wastes. These diseases can be mitigated through waste management like the establishment of a sanitary landfill.

The establishment of a sanitary landfill is one of the strategies to manage solid wastes to mitigate health-related problems and impacts on wildlife and marine organism. However, there are some criteria in identifying suitable sites for the establishment of sanitary landfill based on the guidelines of DENR through DAO 1998-50. These criteria include land use, road, slope, river, groundwater, key biodiversity/protected areas, land cover, groundwater, soil, erosion susceptibility, cultural sites, settlements/built-up areas and faults.

Ifugao is one of the provinces in the Cordillera Administrative Region (CAR) and can be found in a mountainous area. This province needs a sanitary landfill that will cater to the wastes generated by households, tourists and other institutions in the entire province. So, this study determined criteria in the suitability analysis of the establishment of the sanitary landfill.

II. Research Method

Study Area

This study mainly focused on the province of Ifugao, Philippines, in determining the suitable sanitary landfill sites covering its all municipalities. Ifugao is situated at the foot of the Cordillera Mountain range. It is surrounded on the west by Benguet, on the south by Nueva Vizcaya, on the east by Isabela and on the north by Mt. region. It is generally located at 1650'0" N and 12110'0" E. It has a land area total of 2,517.78 sq. Km. spread over its 11 municipalities. The biggest municipality in terms of the land area is Aguineldo, with 454.51 sq. Km. or 18.05% of the total local land area, while the smallest number of is Hingyon with 114.56 sq. km. or 4.55%.

The research area showed in figure 1. This covered all municipalities of Ifugao province.

Figure 1. Provincial Map of Ifugao

In this study, guidelines from the Department of Environment and Natural Resources (DENR) and Housing and Land Use Regulatory Board (HLURB) was utilized as criteria for landfill site selection.

Available secondary data in shapefile format requested from DENR was utilized in this study for spatial analysis. DEM data was downloaded from the USGS Earth Explorer portal to generate a slope map of the study area. This study utilized GIS analysis to assess each criterion under economic, physical, and environmental criteria.

III. Results and Discussions

Minimum Dataset Requirements

Table 1. List of all the Data Requirements for Landfill Suitability Mapping

Criteria	Dataset Requirement*	Feature class
<i>Economic</i>		
Land use	Existing land use	Polygon
Distance from roads	Road Network	Line
Slope	ASTER DEM (30m resolution) (source: USGS Earth Explorer)	Polygon
<i>Environmental</i>		
Distance from surface waters/rivers	Surface water/River Network	Line
Groundwaters	Groundwater map	Polygon
Distance from Key Biodiversity /Protected Areas	Biodiversity /Protected Areas Map	Polygon
Land Cover	Land cover map	Polygon
Soil Erosion	Erosion Map	Polygon
Soil permeability	Soil map	Polygon
<i>Physical</i>		
Distance from Built-up areas/settlements	Built-up/settlement sites	Polygon
Distance from cultural heritage	POIs of cultural sites	Points
Distance to Faults (Seismic Conditions)	Active Faults	Line

*Data Source: DENR, except Slope map- generated from DEM data downloaded from USGS Earth Explorer portal

Table 2. Identified Landfill Site Selection Criteria with Policies/Considerations, Exclusionary Zones and Sub-criterion Zones

Criteria	Policies / Considerations	Exclusionary Zones	Sub-criterion zones
<i>Economic</i>			
Land Use	The site shall avoid converting land with high productivity	Built-up areas, Closed canopy, mature trees covering > 50 percent, Open canopy, mature trees covering < 50 percent, Mangrove vegetation, Pine forest, Mossy Forest, lake, marshy area and swamp, and riverbeds	Quarry/other plantations; Grassland, grass covering > 70 percent; Cultivated area mixed with brushland/ grassland; Arable land; Crops mainly cereals and sugar; Cropland mixed with coconut/other plantation/open canopy
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 main roads	101–250 m 251–500 m 501–750 m > 750 m
Slope	Ideally, the site has a gently sloped topography. Areas with above 20% slope should be avoided.	Avoid hilly area with ground slopes nominally greater than 20 % (DAO 98-50). As consideration for hilly areas, landfilling in hilly areas is feasible but with an increase in cost associated with engineering and access arrangement.	0-18% 18-35% 35-55% 55-65% >65%
<i>Environmental</i>			
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 (DAO 98-50)	301-1000 m 1001–1500 m 1501–2000 m 2001–2500 m > 2500 m
Groundwaters	Avoid areas within significant groundwater reservoir or water supply intakes used for private or public drinking irrigation or livestock shall also be excluded.		Impermeable Rocks Generally without Significant Groundwater; Dominantly through Fracture and Solution Opening Flow; Dominantly Intergranular Flow

Distance from environmentally sensitive areas (Distance from Key Biodiversity /Protected 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, or by any related issuances.	500 m from environmentally sensitive areas (DAO 98-50)	501–1000 m 1001–1500 m 1501–2000 m > 2000 m
Land cover	Avoid areas with closed forest and natural marshland.	Built-up areas, natural marshland, closed forest	Natural barren/grassland; Cultivated annual/perennial; Wooded land: Fallow, shrubs and wooded grass/forest plantation; Open forest, broadleaved; Open forest, coniferous
Soil erosion Susceptibility	Avoid locating site in areas that may be subject to inundation during highly severe erosion	Areas with highly severe susceptibility (DAO 98-50)	No Apparent Erosion/Unclassified Erosion; Slight Erosion; Moderate Erosion; Severe Erosion; River/Reservoir
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 and slumping.	Areas with highly permeable soils (DAO 98-50)	Clay (loam, clay); Mountain soil; Rock land; Silt (silty clay, silty loam)/ complex; Loam

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 (DAO 98-50)	251-1000 m 1001–1500 m 1501–2000 m 2001–2500 m > 2500 m
Distance from cultural heritage	The sites shall not be located in or within 1000 meters of areas with historical, archaeological, cultural geological, or scientific interests that are more than 100 years old and declared by traditional Commission for Culture and the Arts National Historical Institute or National Museum.	1000 m from cultural heritage sites (DAO 98-50)	1001-1500 m 1501-2000 m 2001-2500 m 2501-3000 m > 3000 m
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 (World Bank Guidelines), (DAO 98-50)	501–1500 m 1501–2500 m 2501–3500 m > 3500 m

Polygon to Raster Output Maps

The following maps are output maps after converting vector to raster data. These maps/layer will be input to spatial overlay analysis.

Figure 2. Land use map of Ifugao

Figure 2 shows the land use map of Ifugao. Land use is under the criterion Economic and comprises a weight of 54%. The majority of the area appears to be grassland and cultivated areas in terms of land use.

Figure 3. Erosion susceptibility map of Ifugao

Figure 3 shows the erosion susceptibility map of Ifugao. Erosion susceptibility is under the criterion Environmental, which comprises a weight of 12%. The majority of the area appears to be susceptible to slight

erosion. The municipality of Mayayao and some parts of Aguineldo located at the center of Ifugao appears to be susceptible to severe erosion.

Figure 4. Land cover map of Ifugao

Figure 4 shows the land cover map of Ifugao. Land cover is under the criterion Environmental and comprises a weight of 5%. The majority of the area appears to be an open forest with broadleaved trees and is located at the eastern part of the province. The center part is mostly wooded land, and the southwestern part is built-up areas. The western part of the province is cultivated areas with annual crops.

Figure 5. Groundwater map of Ifugao

Figure 5 shows the groundwater map of Ifugao. Distance from groundwater is under the criterion Environmental and comprises a weight of 31%. The majority of the area appears to be impermeable rocks without significant groundwater.

Figure 6. Soil type map of Ifugao

Figure 6 shows the soil type map of Ifugao. Soil type is under the criterion Environmental and comprises a weight of 16%. Since Ifugao is a mountainous region, the majority of the soil type is undifferentiated mountain soil. Looking at the municipal level, Alfonso Lista, Mayaoyao, and Hingyon are represented by clay soil.

Euclidean

The figures below show the result maps after executing **Euclidean Distance** the following layers: distance from the road, distance from surface waters/rivers, distance from environmentally sensitive areas, distance from settlements, distance from cultural sites, and distance from faults. These showed the created zones and calculated Euclidean distance to the closest source. This zone represents the degree of influence of a specific criterion in a particular zone or distance from center to the determination of sanitary landfill site.

Figure 7. Result maps of Euclidian distance

Reclassification

The figures below show the result maps after executing Reclassification the following layers: distance from the road, distance from surface waters/rivers, distance from environmentally sensitive areas, distance from settlements, distance from cultural sites, distance from faults and slope. These maps showed the reclassified zones created in Euclidean distance analysis based on the sub-criterion zones provided by both literatures and laws. These were reclassified into: restricted, very low suitability, low suitability, moderate suitability, high suitability and very high suitability.

Figure 8. Output map for road network

Figure 8 shows the resulting map of road layer after executing reclassification. Road layer is under the criterion of Economic and comprises a weight of 30%. Based on the map, the majority of the areas in Ifugao province fall on very high suitability for sanitary landfill site using a road layer.

Figure 9. Output map for slope layer

Figure 9 shows the resulting map of the slope layer after executing reclassification. The slope layer is under the criterion of Economic and comprises a weight of 16%. Based on the map, large areas of Alfonso and Lamot fall on very high suitability, but the majority of the areas in Ifugao province fall on moderate to low suitability for sanitary landfill site using a slope layer.

Figure 10. Output map for river network layer

Figure 10 shows the resulting map of river layer after executing reclassification. The river layer is under the criterion of Environment and comprises a weight of 31%. Based on the map, Alfonso has the largest area that falls on very high suitability but the majority of the areas in Ifugao province fall on from low to restricted in terms of suitability for sanitary landfill site using a river layer.

Figure 11. Output map for KBA layer

Figure 11 shows the resulting map of key biodiversity/protected areas layer after executing reclassification. Key biodiversity/protected areas layer is under the criterion of Environment and comprises a weight of 5%. Based on the map, majority of the areas in Ifugao province fall on very high suitability for sanitary landfill sites using a key biodiversity/protected area layer.

Figure 12. Output map for built-up area layer

Figure 12 shows the resulting map of the built-up layer after executing reclassification. The built-up layer is under the criterion of Physical and comprises a weight of 68%. Based on the map, large areas in Ifugao province fall on very high suitability for sanitary landfill site using a built-up layer. Still, there are large areas that fall on moderate to very low suitability in most of its municipalities.

Figure 13. Output map for cultural site layer

Figure 13 shows the resulting map of the cultural sites layer after executing reclassification. The cultural sites layer is under the criterion of Physical and comprises a weight of 22%. Based on the map, a large area in Ifugao province fall on very high suitability for sanitary landfill site using a cultural sites layer.

Figure 14. Output map for

Figure 14 shows the resulting map of the faults layer after executing reclassification. Faults layer is under the criterion of Physical and comprises a weight of 10%. Based on the map, a large area in Ifugao province fall on very high suitability for sanitary landfill site using a faults layer.

IV. Conclusion

The main criteria for the suitability analysis of sanitary landfill sites classified into economic, environmental, and physical. Economic criterion focuses on land use, distance from road, and slope. The environmental criterion determines the suitability of landfill establishment by the assessment of distance from the water surface, groundwaters, distance from environmentally sensitive areas (e.g., distance from key biodiversity areas and protected areas), land cover, soil erosion susceptibility, and soil permeability. Physical criterion uses the distance from settlements, distance from the cultural heritage, and distance from faults (seismic conditions) in the suitability analysis of sanitary landfill establishment. Each criterion and sub-criterion have policy considerations and identified exclusionary zones as needed in the quantification of suitability analysis.

V. Recommendations

- 1) Conduct actual sanitary landfill suitability assessment using the criterion provided in this study. This will identify areas with very highly suitable site/s for the establishment of a sanitary landfill in Ifugao province;
- 2) Conduct full Environmental Impact Assessment to identify, quantify and predict socio-economic and environmental Impacts. With this, negative impacts can be mitigated, and positive impacts can be enhanced;
- 3) Comply the requirements and guideline provided by RA 9003 otherwise known as Ecological Solid Wastes Management Act of 2001 in establishing sanitary landfill particularly on: liners, leachate collection and treatment system, gas control recovery system, groundwater monitoring well system, cover, closure procedure and post-closure care procedure
- 4) Conduct wastes characterization or assessment. Based on wastes characterization/assessment, create policies, incentive-based approach, market other appropriate approach.

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