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A comprehensive geospatial analysis for optimal waste disposal site selection: integrating environmental, social and economic factors

Jenish Chauhan* and Subash Ghimire

Department of Geomatics Engineering, Kathmandu University, Dhulikhel, Kavre, Nepal.

Abstract

Uncontrolled city growth and quick development have made solid waste management a global challenge. Choosing the wrong disposal site leads to economic, physical, and environmental losses, impacting the human environment deeply. The aim of this paper is to discuss on geospatial analysis for optimal waste disposal site selection integrating environmental, social and economic factors. Among various methods, the combination of Geographic Information System (GIS) and Analytical Hierarchy Process (AHP) based on Multi Criteria Decision Analysis (MCDA) has proven to be a good way to find suitable landfill sites. This paper also presents the selection of the best and most scientific landfill sites within Kavrepalanchowk District of Nepal. In this study, seven criteria are taken into account: distance to water bodies, distance to road, and distance to settlement area, slope percentage, soil type, geology, and forests. Each rating map is created using GIS environment and the weight is obtained from the AHP pairwise comparison matrix. The map showing suitable sites for waste disposal is obtained by using the weightage overlay tool and assigning the weightage to each criterion.

Keywords: Geospatial Analysis; Waste disposal; Site selection

1. Introduction

Solid waste has become a global environmental concern due to factors such as population growth, rapid economic expansion, and improved living standards in developing cities, all contributing to increased solid waste generation. In urban areas, solid waste is often dumped on land near water bodies, crop fields, residential areas, and roads. However, unplanned and unmanaged disposal poses a serious threat to the environment and human health. Addressing this issue is essential to the well-being of our environment and communities. Waste disposal site selection is considered one of the most challenging tasks as it is subject to government regulation, funding from the government, rising population densities, growing environmental awareness, public health concerns, limited land availability for landfills, and political and social resistance to establishing such sites.

Most of the waste generated in the Kavrepalanchowk district goes directly to the Sisdol landfill site, located in Sisdol, Nuwakot District in Nepal is overseen by Kakani Rural Municipality, Nepal which is barely 51 km away [1]. The wastes are collected rarely due to the huge distance to the disposal site. Also, there has been dispute and opposition from local people many times regarding the waste disposal at Sisdol. As a result, the hills of garbage and waste are seen on the streets sometimes. The local government also tried to dump the waste in the area, but local people opposed this decision because the disposal option was not properly studied and was close to residential areas. There are ongoing conflicts between local organizations and the public over the waste problem. So, the local government has been trying to find the best site within the district to solve the problem of land pollution.

*Corresponding author. Email: jenishchauhan785@gmail.com

This study deals with the selection of landfill sites within the Kavrepalanchwok district in Nepal. Our study has incorporated different criteria that are necessary for the selection of waste disposal sites.

2. Materials and methods

2.1. Study area

This study focuses on the Kavrepalanchowk district, located in the Bagmati Province of Nepal as shown in Fig. 1. Spanning elevations from 300 to 3000 meters, it covers an area of 1396 square kilometers and is home to a population of 366,879 [2].

2.2. Data, software and methods

In this study, ArcGIS software is used for data processing and analysis. Different criteria are considered while performing suitability analysis for waste disposal site [3]. After the criteria selection, Data are retrieved from different sources as mentioned in Table 1.

The methods used for this study is portrayed by Fig. 2.

2.3. GIS analysis

After acquiring the required data, GIS tool is used for Euclidean distance for data of each selected criteria. The tool also automatically converted the vector form of the data into raster form. Reclassification is done to obtain rating map. After reclassification, the weightage is calculated using AHP method and weighted overlay is done using GIS. Similarly, pair wise comparison method is carried out among the criteria to obtain the weightage as tabulated in

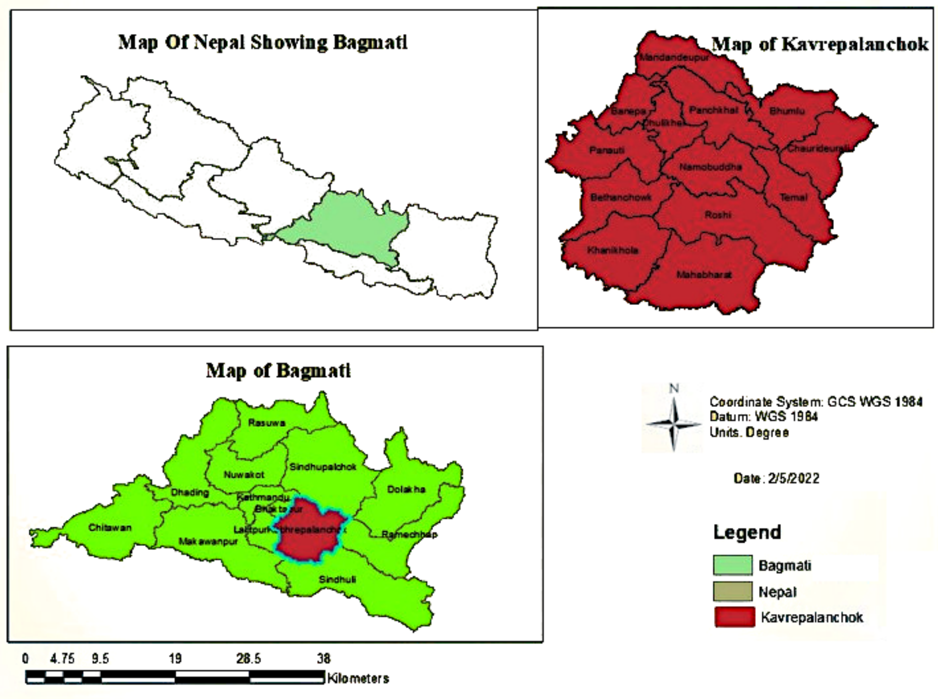

Figure 1: Study area.

Table 1: Criteria and data sources.

Criteria	Data sources
Road	ICIMOD
Water Bodies	Humanitarian Data Exchange
Settlement	Open Street Map
Slope	Humanitarian Data Exchange
Soil	SOTER
Forest	Open Street Map
Geology	ICIMOD

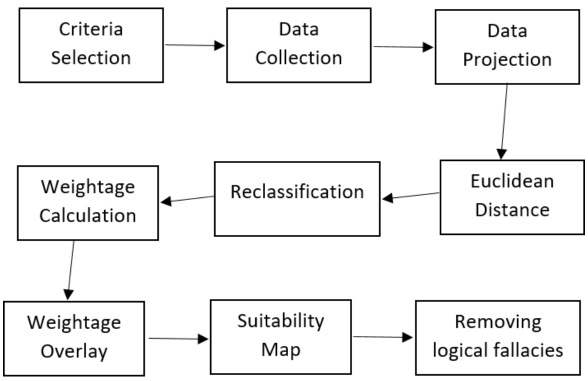

Figure 2: Workflow in GIS.

Table 2: Comparison scale.

Importance level	Remarks
1	Restricted
2	Unsuitable
3	Least Suitable
4	Highly Suitable

Table 2.

The data is reclassified into different classes as mentioned in Table 3 [4].

AHP is one of the widely used MCDA tools to address multi-objective and weighted evaluation models. It allows various options to be distributed in advance and multiple measures to be integrated into a single priority. The pair-wise comparison is carried out with a nine-point scale value which includes values 9, 8, 7, 6...., 1/7, 1/8, 1/9 as shown in Table 4. Nine indicates as extreme preferences while 7 as very strong preferences, 5 as strong preference, and so on down to 1 which represents no preference [5].

The weight is then derived from the comparison matrix as portrayed in Table 4; where these comparisons are analyzed to create a weight that sums to 100 % as given in Table 5.

3. Discussion

Different criteria are considered while performing a suitability analysis for the waste disposal site. The waste disposal site should be as much as away from water resources, residential areas, forest areas, cultural heritage sites, and other aspects. But it would be better if the waste disposal site has access to the road. These are the criteria for suitable site selection.

3.1. Slope

Slope is one of a crucial factor for selecting the waste disposal site because very steep slopes will result in high excavation costs

Table 3: Reclassification.

Criteria	Category	Class
Distance from road (m)	>2250	1
	1500-2250	2
	750-1500	3
	0-750	4
Distance from a water body (m)	<1000	1
	1000-1500	2
	1500-2000	3
	>2000	4
Distance from the settlement area (m)	<1000	1
	1000-2000	2
	2000-3000	3
	>3000	4
Slope (%)	>20%	1
	15-20%	2
	10-15%	3
	0-10%	4
Geology	Highly Permeability	1
	Moderate Permeability	2
	Low Permeability	3
	Least Permeability	4
Soil Type	Eutric REGOSOLS/CAMBISOLS	1
	Chromic LUVISOLS	
	Humic/Chromic/Ferralic CAMBISOLS	2
	Gleyic CAMBISOLS	3
	Dystric REGOSOLS	4

Table 4: Comparison matrix.

Road	Water Body	Settle-ment	Slope	Geology	Soil Type	Forest
1	1/5	1/7	1/2	1/4	1/3	1/4
5	1	1/3	4	2	3	3
7	3	1	5	4	3	5
2	1/4	1/5	1	1/3	1/3	1/3
4	1/2	1/4	3	1	2	1/2
3	1/3	1/3	3	1/2	1	1/3
4	1/3	1/5	3	2	3	1
2	1/2	1/4	4	3	4	2

Table 5: Weights derived.

Factors	Influence %
Road	5.2
Water Body	20.3
Settlement	35.5
Slope	6
Geology	11
Soil Type	9.1
Forest	12.9
Total	100

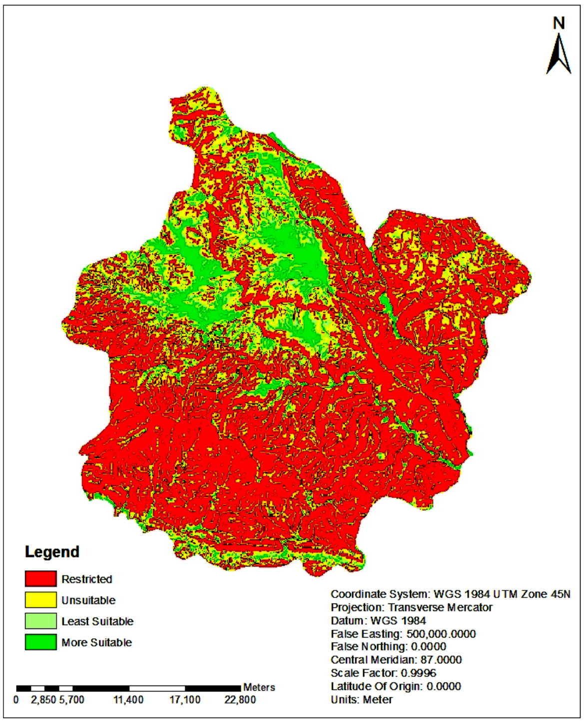

Figure 3: Soil rating map.

[6]. The study utilized a Digital Elevation Model (DEM) to calculate the slope percentage across the study area at a pixel level. A slope of less than 10% is assigned to be highly suitable as indicated in Fig. 3.

3.2. Water body

The waste disposal should not be mixed with water resources. In terms of human health and water quality, landfills should be away from water. Considering the environmental health, the place that is more than 2000 m away from the water body is considered as a suitable place as shown in Fig. 4.

3.3. Road

The waste disposal area should not be too far away, otherwise the transportation cost will be too high. The suitability map according to proximity to road is displayed in Fig. 5.

3.4. Geology

It is classified according to permeability to identify areas where groundwater is more affected by seepage. The suitability according to geology is shown in Fig. 6. Geological features with low per-

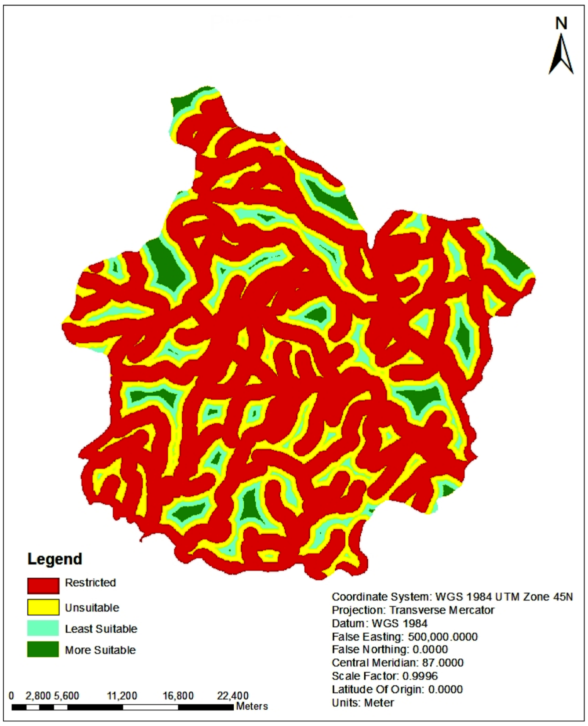

Figure 4: River rating map.

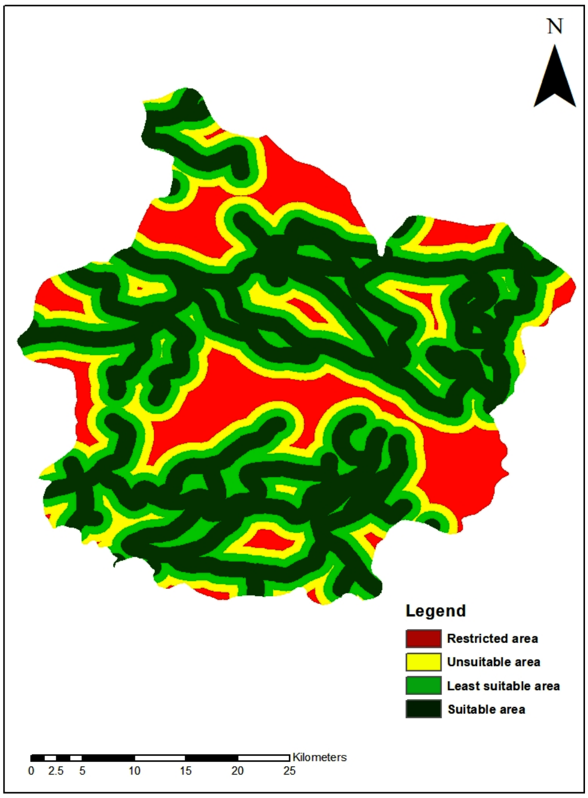

Figure 5: Road rating map.

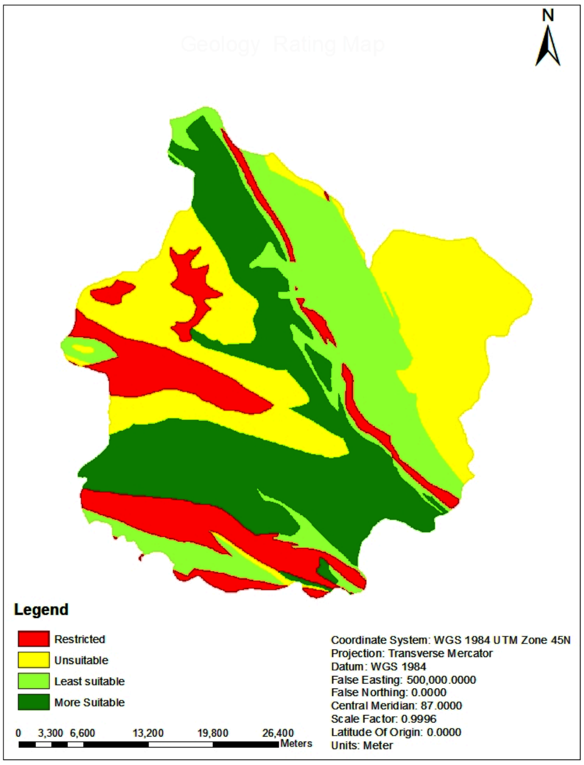

Figure 6: Geology rating map.

meability are considered to be very suitable.

3.5. Soil

The disposal site should not be nearer to fertile lands [7]. For this reason, soils are classified according to their productivity as portrayed in Fig. 7, and highly productive soils are selected as less suitable.

3.6. Settlement

When the waste storage area is close to a residential area, it causes many problems in terms of human health or at least a bad smell. Hence, distance less than 3000 m is assigned to be unsuitable as shown in Fig. 8.

3.7. Forest

The disposal site should not be in forest areas. Therefore, the area containing forest areas are directly classified as unsuitable while other area rather than forest areas is classified as suitable.

4. Results

After an analysis, a suitable site for waste disposal is found as shown in Fig. 9.

Fig. 9 shows all areas that are suitable, least suitable, unsuitable and restricted for waste disposal while Fig. 10 shows the area covered by each category.

About 75% of the total area is found to be restricted and unsuitable. These areas generally include densely populated areas and commercial areas. For this reason, these areas should be separated from garbage dumps as they may cause serious problems for the environment and health. The least suitable area constitutes 24.32% of the total area, and the suitable area constitutes 0.68% of the total area which is located in north western side as displayed in Fig. 11.

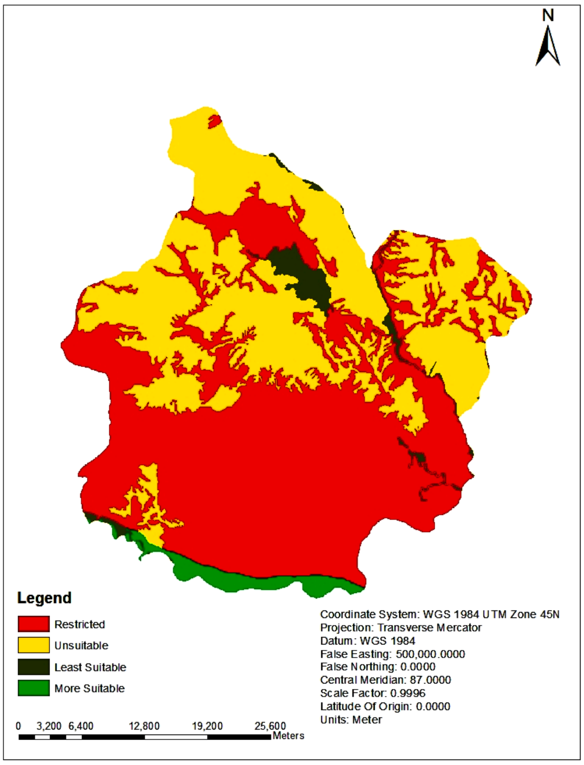

Figure 7: Soil rating map.

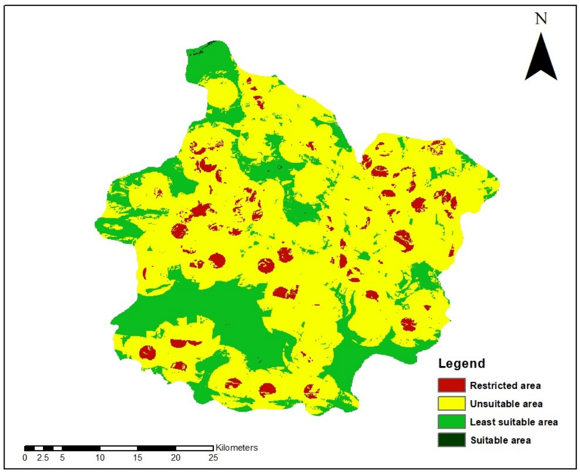

Figure 9: Suitability map for waste disposal.

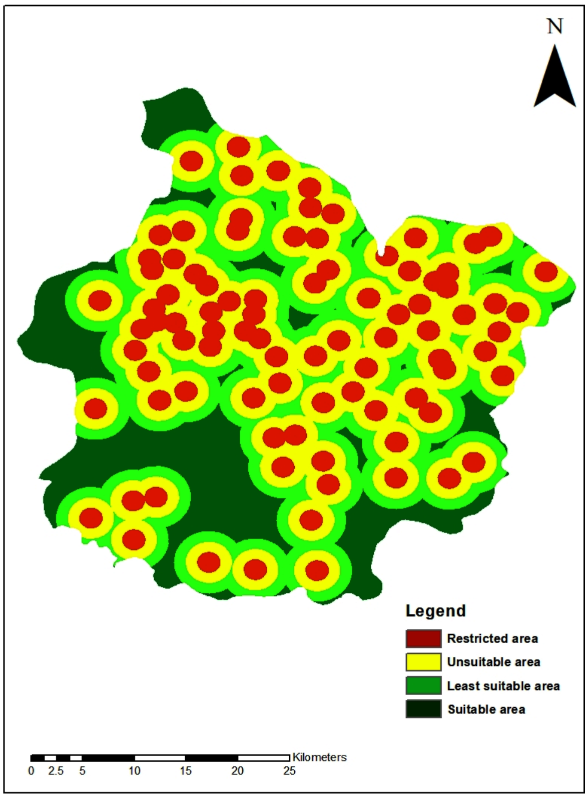

Figure 8: Settlement rating map.

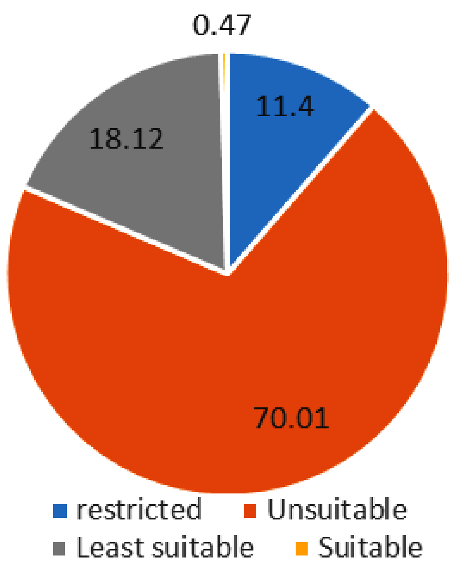

Figure 10: Area covered.

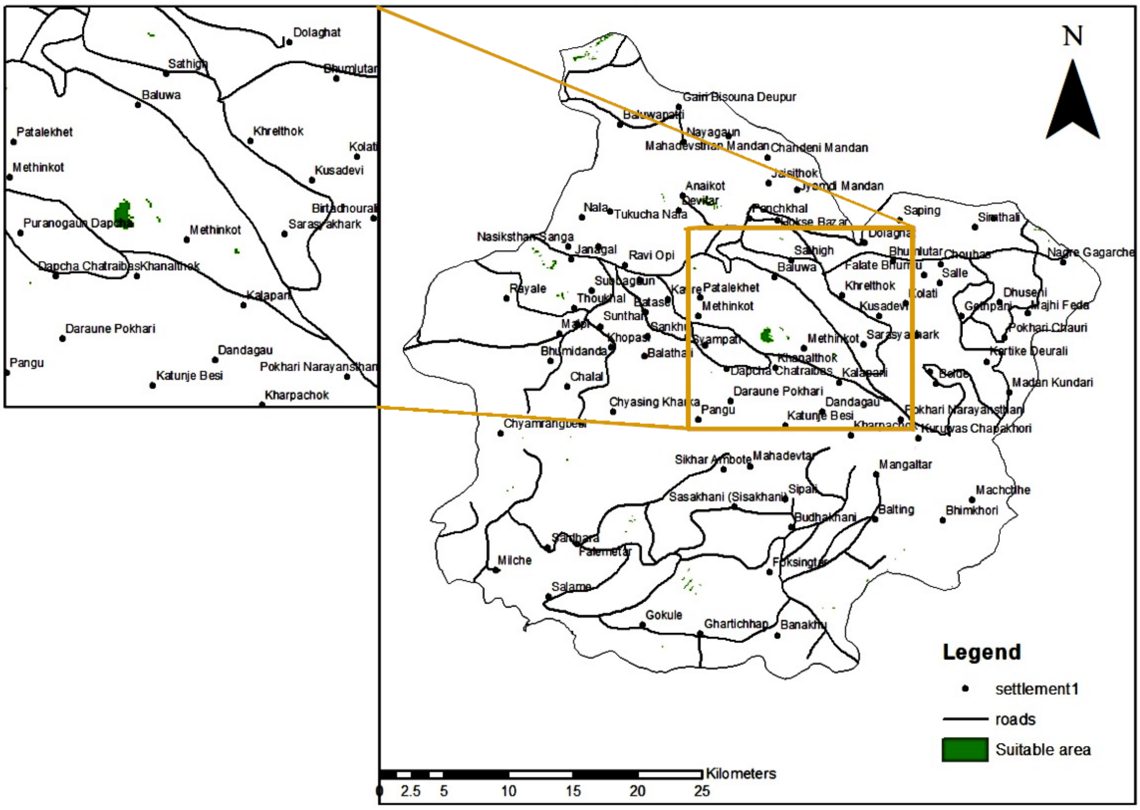

Figure 11: Location map of a suitable site.

5. Conclusion

The main result of this research is the map within Kavrepalachwok district in Nepal that shows restricted, unsuitable, least suitable, suitable, and highly suitable sites for waste disposal. This analysis is helpful to the concerned authorities to decide on future dumping sites. It is also useful for facility site planners to locate the site. Various socio-economic and natural factors have to be analyzed for selecting waste disposal sites but the study has considered only seven criteria for the analysis. More criteria can be added for better results like proximity to features such as airports, schools, hospitals, etc. Also, the AHP method can be used in other multi-criteria decision analysis.

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