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Landfill Site Suitability Analysis in Puduserry region, Palakkad, Kerala: An Integrated Approach Using Geospatial Techniques and Analytical Hierarchy Process

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Abstract: The primary goal of the current study was to identify and discover a suitable site at Pudussery Panchayat in Kerala's Palakkad district for a landfill site in a way that was financially viable, environmentally beneficial, and acceptable to society. The landfill location was chosen based on nine critical criteria transportation network, water bodies, drainage, slope, public assets, settlements, geomorphology, land use/land cover, and depth to groundwater. Analytical Hierarchy Process (AHP) concept and geospatial technology were applied to the analysis. According to the study, of the total 65.14 km^2, 0.14 km^2 (0.21%) was highly suitable, 0.18 km^2 (0.28%) was moderately acceptable, 25.85 km2 (39.68%) was less suitable, and 38.97 km2 (59.83%) were unsuitable for garbage disposal. The study demonstrated the effectiveness of using GIS technologies in conjunction with AHP to make decisions and locate appropriate disposal sites.

Keywords: Solid waste management, Geographical information system, Remote sensing, Landfill, Analytical hierarchy process

The solid waste management (SWM) system is a serious environmental issue that will soon get considerably worse due to the current rising industrialization and urbanization (Ajay 2019, Kamdar et al 2019). To achieve a better sustainable development society, SWM has emerged as a significant challenge for both developing and developed countries (Khan et al 2018). Sustainable approaches to dealing with this waste are thus urgently needed (Abdel-Shafy and Mansour 2018). It is essential to develop a management system that is efficient and enables the resolution of solid waste disposal-related complexity, uncertainty, multi-objectivity, and subjectivity with the least amount of detrimental environmental effects. A symbolic SWM system in both developed and developing countries brought to the forefront several issues including low and inconsistent waste collection, unlawful dumping and burning, the emergence of fly and vermin breeding grounds informal garbing activities that cause major constraints.

In emerging countries like India, SWM has emerged to be one of the major development challenges (Kumar et al 2017). Over the last six years, from 2015 to 2020, India's per capita waste generation increased from 118.68 gm/day to 119.07 gm/day (CPCB 2020). An estimated 80% to 90% of solid waste in India is burned in open areas or dumped in landfills without proper management practices, which pollutes the air, water, and soil. There are different methods of disposal of solid wastes practiced in and around the globe such as thermal treatment or incineration, burial, biological treatment or composting, landfills, etc. (Makarichi et al 2018). Among those, landfills are the most widely used method in low and medium-income countries because of their simple and cost-effective (Kamdar et al 2019). In this context, reliable waste management systems must plan for the selection of new landfills and manage huge volumes of solid waste (Sukholthaman and Shirahada 2015).

Emerging technologies like geographic information systems (GIS) and Remote Sensing (RS) can be integrated to ensure the best potential results in effective and efficient strategies for SWM (Hazarika and Saikia 2020). GIS is a tool that allows users to store, retrieve and analyze spatial data and visualize the results of any spatial and non-spatial-based analysis (Mohammedshum et al 2014), and RS technology can provide up-to-date spatial information on land-cover patterns useful as input data in the task. Decision-making is a kind of data mining process that helps to solve day-to-day problems using standard optimization techniques. GIS and multi-criteria decision analysis (MCDA) offers tools to assist in resolving this problem and suggest suitable sites for landfilling, waste segregation, and recycling process (Chamchali et al 2019, Aderoju et al 2020, Eghtesadifard et al

2020). The analytic hierarchy process (AHP) (Saaty 1980) is one of the most widely accepted MCDA approaches and has been widely used in identifying potential landfill sites (Chabuk et al 2017, Rana et al 2017, Sharma et al 2018). The integration of GIS with the AHP is used to assist in the selection process as a decision-making tool (Ramya and Devadas 2019). The studies are lacking, despite the reality that the use of MCDM for thoroughly determining the suitability of potential landfill sites is recognized. Moreover, no studies have used the GIS and AHP techniques to identify potential landfill sites using locally available variables related to socioeconomic conditions, natural resources, land use, etc. In the end, it might be a reliable approach to selecting a landfill site, according to various technological, ecological, financial, sociocultural, and other factors with rigorous national and international rules (Chabok et al 2020). . This study is attempt to identify a suitable site for landfills by comprehending the factors that should be taken into account when determining whether a site is suitable, and how the AHP functions as a strong decision-making tool when ranking the factors and identifying suitable sites in Pudussery Panchayat of Palakkad district, Kerala.

MATERIAL AND METHODS

Study area: The study area which is located in the Palakkad district is known as the land of palmyras and agriculture and is often known as the Gateway of Kerala which is composed of 23 wards stretches between 10º 45' 50.14" N to 10º 50' 55.17" N latitudes and 76º 42' 55.13" E to 76º 50' 56.14" E longitudes of an elevation of 105 meters above mean sea level with an area of 65.14 sq. km (Fig. 1). The gap in the Western Ghats itself makes the area different from other places in the district. The study area has a tropical wet and dry climate and the temperatures remain moderate throughout the year except during the summer months which are extremely hot. The study area is bounded by Pudussery East, Pudussery West, and Pudussery Central, and the majority of the industries are concentrated in Kanjikode, known as the second-largest industrial region in Kerala state. Kanjikode is the industrial belt in Palakkad linking Kochi with Bengaluru through Palakkad and Coimbatore. The Walayar river, one of the tributaries of Bharathapuzha flows through the study area The major part of the study area is practicing agriculture and allied activities and the rest consists of open forests, natural vegetation, and plantations. The high-altitude wind direction is mainly from the west, east, and southwest direction in all seasons which is also a reason for the concentration of industries within the study area.

Selection criteria: Site selection for waste disposal in this study was an important step based on ten major parameters: groundwater level, drainage, slope, geomorphology, public assets, waterbodies, settlements, land use/land cover (LULC), and transportation system. The continuous granulite terrain disqualified geology. The significance of the study, regional traits, and long-term goals were taken into consideration when choosing the criteria. Proposed landfill sites were assessed using secondary data, including literature studies. Priority was given to factors like groundwater depth, distance from drainage, and proximity to water bodies to prevent water contamination. Settlements and public property were considered to protect public health, and distance from transportation networks helped avoid traffic congestion. Terrain slopes and bare land in the geomorphology were crucial for efficient and safe waste disposal sites, minimizing the risk of contamination and public disturbance.

Data acquisition and preparation of thematic layers: The details of data acquired from different sources for thematic layer preparation using GIS and RS are summarized in Table 1. Criteria layers for the evaluation of nine parameters were prepared for landfill site suitability analysis in the QGIS

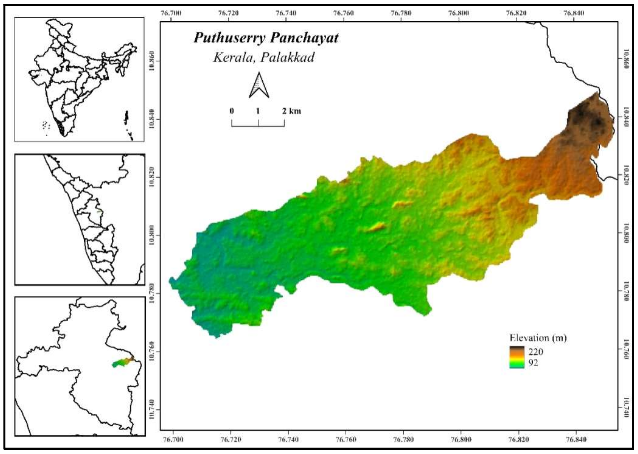

Fig. 1. Location map of the study area

Table 1. Data sets used in the study

	Data type	Data sources
Transport network	Vector	Open street map
Waterbodies	Vector	Open street map
Settlements	Vector	Open street map
Public assets	Vector	Open street map
Drainage	Vector	Bhuvan, Indian geo-platform of ISRO
Geomorphology	Vector	Bhukosh, Geological Survey of India
Land use/land cover	Raster	Sentinel 2A, 10m resolution (February 28, 2020)
Slope	Raster	ASTER DEM, 30m resolution
Depth to groundwater	Vector	Well inventory data

Platform. Separate buffer maps were created for each criterion using the proximity buffer ring tool in the GIS environment. Buffer maps were created under the guidelines specified in the Municipal Solid Waste Management Manual (May 2000) of the Central Public Health and Environmental Engineering Organization (CPHEEO), Government of India (Table 2) and the final suitability map obtained from hierarchical analysis of the input layers.

The input data layers for the study were generated from related maps by scanning, registering, and digitizing the relevant information in open-source QGIS software. Layers were projected in Universal Transverse Mercator (UTM) projection system, WGS 84/UTM Zone 43N. The transport network layer included both railway and road networks, Waterbodies included dams and rivers, which were extracted from Open Street Map (OSM). Settlements were mainly considered as the human-populated areas which were extracted as a point feature from OSM. Geomorphologic and Drainage datasets were acquired from the Bhukosh portal (https://bhukosh.gsi.gov.in/) of the Geological Survey of India and the Bhuvan Geo-portal (https://bhuvan.nrsc.gov.in/) of the National Remote Sensing Centre (NRSC) respectively. The slope was generated from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Digital Elevation Model (DEM) with a resolution of 30m. The LU/LC map of the study area was generated from Landsat 8 OLI (Operational Land Imager) satellite data acquired from USGS Earth Explorer (https://earthexplorer.usgs.gov/) by using the maximum likelihood classification technique of supervised learning algorithms. The depth of the well, well parapet height, and groundwater level were measured from 15 wells in the study area and locations were marked with the help of the handheld Global Positioning System (GPS) to prepare the well inventory dataset. Subsequently, the same dataset was interpolated by using Inverse Distance Weighted (IDW) technique and developed raster surface data.

Assign the weights and normalization with AHP: In the present study, a pairwise comparison matrix was created and each parameter was compared with one another by using Saaty's 9-scale table (Table 3). It has a value between 1 and 9. Priority reduces with a decrease in rank i.e., 1 for less preferable and 9 for highly preferable. To establish a pair-wise comparison matrix (A) for parameters, factors of each level and their weights are given as A1, A2… An. The relative importance between parameters A1 and A2 is expressed as A2/A1.

$$A = \begin{bmatrix} 1 & \frac{A1}{A2} & \cdots & \frac{A1}{An} \\ \frac{A2}{A1} & 1 & \cdots & \frac{A2}{An} \\ \frac{An}{A1} & \frac{An}{A2} & \cdots & 1 \end{bmatrix} \quad (1)$$

Table 2. Evaluating criteria specified in municipal solid waste management manual, Government of India (May 2000)

Criteria	Distances
Distance to the transport network	No landfill should be constructed within 200 m
Distance to waterbodies	No landfill should be constructed within 100 m of a navigable river or stream
Distance to drainage	No landfill should construct within 200 m
Distance to settlements	A landfill should be at least 500 m from a notified settlement area
Distance to assets	No landfill should be constructed within 300 m for both restricted and sensitive places
Groundwater	A landfill should not be constructed in areas where water is less than 2m below the ground surface

Table 3. Pairwise comparison scale for AHP

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one over another	Experience and judgment strongly favor one activity over another
5	Essential or strong importance	Experience and judgment strongly favor one activity over another
7	Very strong importance	Activity is strongly favored and its dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values between the two adjacent judgments	When compromise is needed
Reciprocals	If activity i has one of the above numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i	
Rationals	Ratios arising from the scale	If consistency were to be forced by obtaining n numerical values to span the matrix

In the study, nine individual parameters have been selected that influence the landfill site suitability. Since each parameter has a different level of influence on the landfill site selection process, it is mandatory to determine the influence quantitatively. To achieve that, the AHP method was used in this study. The significance of each criterion on landfill site suitability was analysed to determine the weight. The results of the pairwise comparison matrix and the parameter weights are given in Table 5. The same procedure was followed to get the weight of each sub-category of the main parameters and the weights are given in Table 6. It is important to get the consistency of the answer because otherwise, inconsistency of results regarding the judgment may occur (Saaty 2001). The Consistency Ratio (CR) is a comparison between the Consistency Index (CI) of the matrix and the Random Index (RI), which are already provided by Saaty who developed the AHP (Eq. 2). RI has been compiled based on several random samples (Saaty 1980) that are given in Table 4. CR is formulated as:

$$CR = CI/RI \quad (2)$$

CI can be calculated using the following equation:

$$CI = (\lambda max - n) / (n - 1) \quad (3)$$

where λ_{max} is the largest matrix eigenvalue and n is the number of elements present in the pairwise comparison matrix.

If CR is < 0.1, the consistency value can be considered

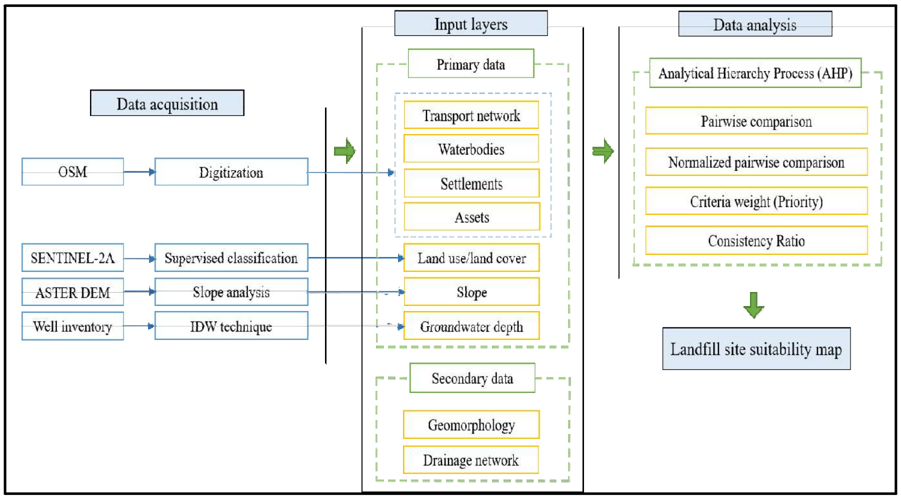

Fig. 2. Methodology followed in the study

Table 4. Random consistency values

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Source: Saaty (1980)

Table 5. Pairwise comparison matrix of nine thematic layers

Layers	LULC	SL	DT	AS	GM	SE	DW	DD	GW	Priority	Weighted sum	λ	λ_{max}	CI	CR
LULC	1	3	4	4	5	7	9	9	9	0.33	3.36	10.17	9.66	(9.66-9) / (9-1) = 0.08	0.08/1.45 = 0.06 < 0.10
SL	1/3	1	3	5	3	8	7	7	7	0.23	2.38	10.54			
DT	1/4	1/3	1	3	3	6	5	6	6	0.15	1.52	10.15			
AS	1/4	1/5	1/3	1	2	5	4	5	4	0.10	0.97	9.69			
GM	1/5	1/3	1/3	1/2	1	3	4	4	4	0.08	0.74	9.39			
SE	1/7	1/8	1/6	1/5	1/3	1	2	3	3	0.04	0.38	8.88			
DW	1/9	1/7	1/5	1/4	1/4	1/2	1	1	1	0.03	0.24	9.47			
DD	1/9	1/7	1/6	1/5	1/4	1/3	1	1	1	0.02	0.22	9.30			
GW	1/9	1/7	1/6	1/4	1/4	1/3	1	1	1	0.02	0.23	9.36			

LULC – Land use/land cover, SL - slope, DT – Distance from transport network, AS - Asset, GM – geomorphology, SE - settlement, DW – Distance from waterbodies, DD – Drainage density, GW - Groundwater, CI - Consistency Index, CR - Consistency Ratio realistic, whereas CR > 0.1 recommends a revised judgment. The CR values of each parameter are also given in Table 6.

RESULTS AND DISCUSSION

Assignment of weights: According to the impact of each variable on the choice of landfill location, weights were allocated, with the LULC receiving the largest weight (0.33) and the groundwater having the lowest weight (0.02). Table 6 shows the area covered in each class, and Figure 3 shows the criteria map.

Distance from public assets: Based on Distance from public assets, 23.55 km2 falls under the "unacceptable" zone (within 300 meters of public assets). 300-600 meters covers 21.43 km^2, 600-900 meters comprises 10.36 km^2, 900-1200 meters extend over 5.17 km^2, 1200-1800 meters encompass 2.80 km^2, 1800-2100 meters includes 1.22 km^2, 2100-2400 meters covers 0.46 km^2, and beyond 2400 meters spans 0.14 km^2.

Distance from drainage: The drainage buffer zones were categorized into seven classes. Within a distance of less than 200 meters, there is an extensive area of approximately 46.29 km^2, rendering it highly unsuitable for a landfill site. In the 200–300-meter range, there's an area of 11.80 km^2. 300-400 meters cover 5.02 km^2, 400-500 meters encompass 1.55 km^2, 500-600 meters comprise 0.31 km^2, 600-700 meters occupy 0.13 km^2, and finally, 700-800 meters cover 0.04 km^2.

Geomorphology: The geomorphology layer reveals several distinct landforms in the studied area, including pediplains, floodplains, active quarries, water bodies, and moderately to highly dissected hills and valleys. Predominantly, pediplains, resulting from denudation processes, cover the largest area at 58.75 km^2. A working quarry takes up 0.07 km^2, while floodplains take up 1.89 km^2, water bodies 1.76 km^2, moderately and badly dissected hills and valleys, and dams and reservoirs together take up 0.61 km^2.

Depth to groundwater: The landfill site is legally forbidden from having depth of groundwater within two meters. Within the surveyed area, 4.58 km^2 falls under the category of a less suitable intermediate zone (2-4 m), with an additional 0.01 km^2 falling within the narrower buffer zone (2 m). The land can be categorized into three depth ranges: 4 to 6 meters, which covers 27.60 km^2, 6 to 8 meters, encompass 28.90 km^2 and 8 to 10 meters, which constitutes 4.05 km2 of the area.

Distance from settlements: Regarding proximity to settlements, a significant portion of approximately 61.97 km2 lies within the buffer zone (500 m), making it strongly unsuitable for the landfill site. The rest of the categorized intervals 500-600 m spans around 1.81 km^2, 600-700 m encompasses about 0.82 km^2, 700-800 m includes 0.38 km^2, 800-900 m comprises 0.13 km^2, and 900-1000 m makes up 0.03 km^2.

Land use Land Cover: In the study area, the dominant land use and land cover categories include water bodies, paddy fields, plantations, natural vegetation, human settlements, and barren terrain. Specifically, water bodies occupy 1.73 km^2, while paddy fields cover 8.65 km^2. Natural vegetation spans an area of 16.33 km^2, followed by plantations at 10.25 km^2 and human settlements at 3.68 km^2. There is a substantial 24.50 km^2 of open, undeveloped land in the research region, which is being considered as a more suitable option for the establishment of a waste disposal site.

Slope: This study region has a slope (inclination) that ranges from 6° to 32°. About 49.61 km^2 of the region had a slope of 7°, making it ideal for dump sites. The area that fell under the intermediate zone was 14.71 km^2. The 0.82 km^2 of the site to be unfit.

Distance from transportation network: One of the evaluating factors for landfill suitability was the distance from the transportation network. With buffer distances, seven courses were dispersed around the research area. The vast majority of the region (55.12 km^2) is in the buffer zone, which is not suitable for landfills. The remaining classes, 200 - 300m, span an area of approximately 6.36 km^2, 2.30 km^2 by 300 to 400 meters, 0.74 km^2 by 500 to 600 meters, 0.41 km^2 by 600 to 700 meters, and 0.03 km^2 by 700 to 800 meters.

Distance from waterbodies: Eight classes were constructed with a set distance from water bodies as a buffer. 7.91 km^2 of the total area, which is not appropriate for a dump site, falls inside the buffer zone (less than 100 m). The remaining classes have a 21.40 km^2 area, which is less suited, The total of 13.50 km^2 is covered by the 600 to 1100 m range, 9.40 km^2 by the 1100 to 1600 m range, 6.89 km^2 by the 1600 to 2100 m range, 1.78 km^2 by the 2600 to 3100 m range, and 0.19 km^2 by the 3100 to 3600 m range. Regarding proximity to waterbodies, 55% of the research area was found to be suitable for the landfill.

Landfill site suitability: Based on the site characteristics, the final landfill suitability map was divided into four categories: highly appropriate sites, moderately suitable sites, less suitable sites, and unsuitable sites. An area of 0.14 km^2 (0.21%) is covered by a highly suitable site, 0.18 km^2 by moderately suitable site, 25.85 km^2 by a less suitable site, and 38.97 km^2 (59.83%) by an unsuitable site (Fig. 4 and Table 7) Sites 1 and 2 in represent the chosen suitable locations (Fig. 4). Due to their location on arid territory, 300–500 meters from the transportation network, 1600-2100 meters from water bodies, and far from drainage, these appropriate sites have very little potential for environmental difficulties. The location's groundwater depth ranges from 6 to 8 meters. The location is 500 to 800 meters away from any populated areas, and there are no resources nearby (900-

Table 6. Thematic layers with their area, weight, consistency index, and consistency ratio

Parameter	T	Features	Area (km^2)	Area (%)	S	T*S	CI	RI	CR
Land use/land cover	0.33	Paddy	8.65	13.28	0.05	0.015	0.08	1.24	0.07
		Plantation	10.25	15.73	0.06	0.019			
		Natural vegetation	16.33	25.07	0.21	0.070			
		Settlements	3.68	5.65	0.13	0.044			
		Waterbodies	1.73	2.66	0.03	0.011			
		Barren land	24.50	37.61	0.52	0.171			
Groundwater	0.02	≤ 2	0.01	0.02	0.05	0.001	0.05	1.12	0.04
		2-4	4.58	7.03	0.08	0.002			
		4-6	27.60	42.37	0.12	0.003			
		6-8	28.90	44.37	0.28	0.007			
		8-10	4.05	6.21	0.48	0.012			
Distance from Settlements	0.04	< 500	61.97	95.13	0.03	0.001	0.08	1.24	0.07
		500-600	1.81	2.78	0.05	0.002			
		600-700	0.82	1.26	0.08	0.003			
		700-800	0.38	0.58	0.14	0.006			
		800-900	0.13	0.20	0.25	0.011			
		900-1000	0.03	0.05	0.45	0.020			
Distance from waterbodies	0.03	< 100	7.91	12.14	0.37	0.009	0.11	1.41	0.08
		100-600	21.40	32.85	0.24	0.006			
		600-1100	13.50	20.73	0.15	0.004			
		1100-1600	9.40	14.43	0.09	0.002			
		1600-2100	6.89	10.58	0.06	0.002			
		2100-2600	4.07	6.25	0.04	0.001			
		2600-3100	1.78	2.73	0.03	0.001			
		3100-3600	0.19	0.29	0.02	0.001			
Distance from transport network	0.15	< 200	55.12	84.62	0.02	0.004	0.10	1.32	0.07
		200-300	6.36	9.76	0.03	0.005			
		300-400	2.30	3.53	0.05	0.008			
		400-500	0.74	1.14	0.09	0.013			
		500-600	0.41	0.63	0.15	0.022			
		600-700	0.18	0.28	0.25	0.037			
		700-800	0.03	0.04	0.41	0.061			
Distance from drainage	0.02	< 200	46.29	71.06	0.03	0.001	0.08	1.32	0.06
		200-300	11.80	18.12	0.03	0.001			
		300-400	5.02	7.70	0.06	0.001			
		400-500	1.55	2.38	0.08	0.002			
		500-600	0.31	0.48	0.14	0.003			
		600-700	0.13	0.20	0.23	0.006			
		700-800	0.04	0.06	0.42	0.010			
Slope	0.23	< 7	49.61	76.16	0.51	0.115	0.04	1.12	0.04
		7-14	14.71	22.58	0.26	0.058			
		14-21	0.77	1.18	0.13	0.029			
		21-28	0.04	0.06	0.06	0.014			
		> 28	0.01	0.02	0.04	0.009			
Geomorphology	0.08	Dam & reservoir	0.61	0.94	0.03	0.002	0.07	1.32	0.05
		Flood plains	1.89	2.90	0.10	0.008			
		Highly dissected hills & valleys	0.69	1.06	0.15	0.012			
		Moderately dissected hills & valleys	1.37	2.10	0.24	0.019			
		Pediplain complex	58.75	90.19	0.08	0.006			
		Quarry & Mine	0.07	0.11	0.37	0.030			
		Waterbodies	1.76	2.70	0.04	0.003			
Distance from assets	0.10	< 300	23.56	36.17	0.02	0.002	0.11	1.41	0.08
		300-600	21.43	32.90	0.03	0.003			
		600-900	10.36	15.90	0.04	0.004			
		900-1200	5.17	7.94	0.06	0.006			
		1200-1800	2.80	4.30	0.10	0.009			
		1800-2100	1.22	1.87	0.15	0.015			
		2100-2400	0.46	0.71	0.23	0.023			
		> 2400	0.14	0.21	0.37	0.037			

T - Theme weights, S - Feature weight, T*S - Final weight, CI - Consistency Index, RI - Random Index, CR - Consistency Ratio

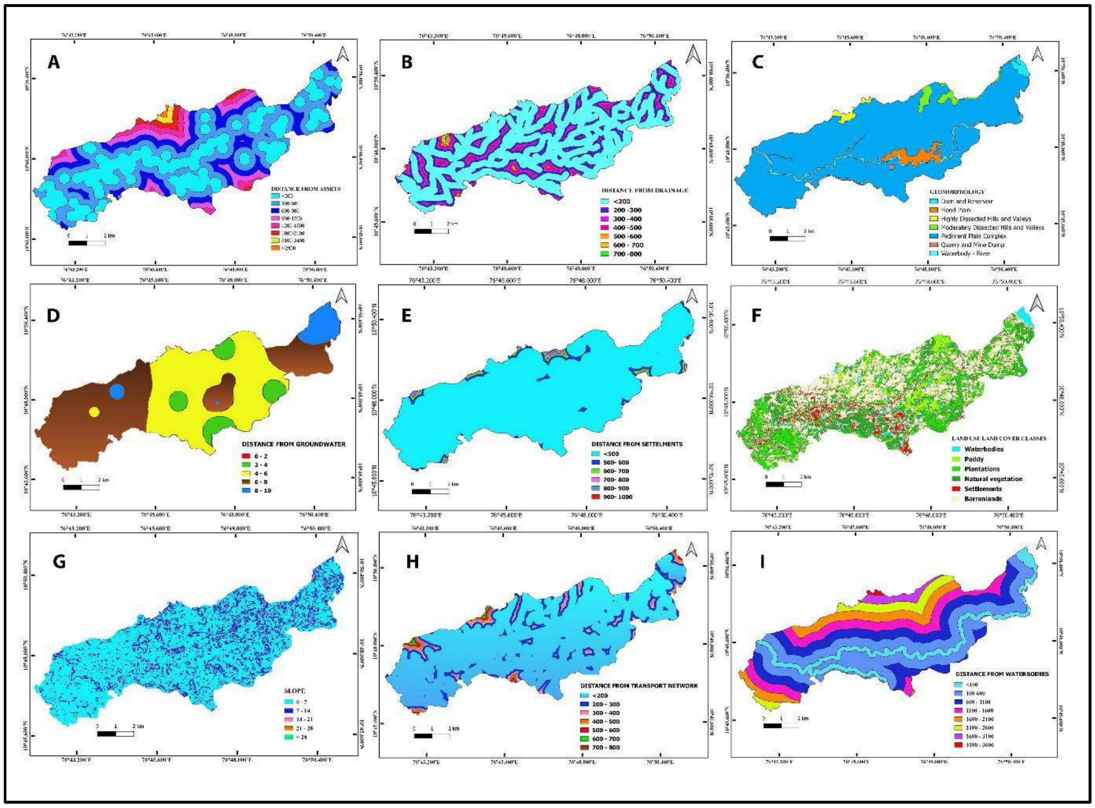

Fig. 3. Contributing criteria in landfill site suitability analysis: (A) Distance from assets, (B) Distance from drainage, (C) Geomorphology, (D) Distance from groundwater, (E) Distance from settlements, (F)Land use Land Cover, (G) Slope, (H) Distance from transport network, (I) Distance from water bodies

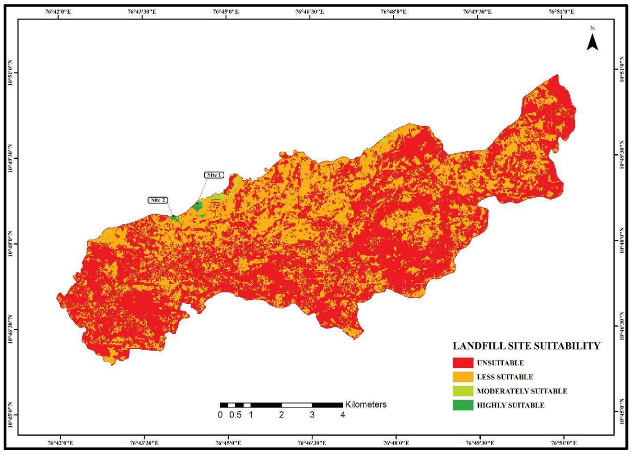

Fig. 4. Final landfill suitability sites derived from analytical hierarchy process

Table 7. Area distribution of final suitability classes

Landfill suitability classes	Area covered (km^2)	Area in %
Unsuitable site	38.97	59.83
Less suitable site	25.85	39.68
Moderately suitable site	0.18	0.28
Highly suitable site	0.14	0.21
Total area	65.14 km^2	100%

1800 m). The location has a flattened slope (< 7°), which is a significant feature that lowers construction costs in the area.

CONCLUSION

In this study, an effort was made to use GIS and Remote Sensing combined with AHP to locate a suitable waste disposal site over the Pudussery Panchayat in the Palakkad region of Kerala. According to the findings in relation to the CPHEEO requirements, there aren't many eligible sites for landfill sites inside the Panchayat. The fastest, cheapest, and most time-effective ways to determine if a landfill site is suitable for disposing of solid waste are through the use of spatial technologies like GIS and Remote Sensing. AHP provides the ideal outcome for this investigation when spatial technologies are combined with powerful decision-making techniques. The study demonstrated how geospatial technologies are more practical for suitability evaluation in a variety of disciplines in the modern, technologically advanced world.

REFERENCES

Abdel-Shafy HI and Mansour MS 2018. Solid Waste issue: Sources, composition, disposal, recycling, and valorization. *Egyptian Journal of Petroleum* **27**(4): 1275-1290.

Aderoju OM, Dias GA and Gonçalves AJ 2020. A GIS-based analysis for sanitary landfill sites in Abuja, Nigeria. *Environment Development and Sustainability* **22**: 551-574.

Ajay S 2019. Remote sensing and GIS applications for municipal waste management. *Journal of Environmental Management* **243**: 22-29.

Chabok M, Asakereh A, Bahrami H and Jaafarzadeh NO 2020. Selection of MSW landfill site by fuzzy-AHP approach combined with GIS: case study in Ahvaz, Iran. *Environmental Monitoring and Assessment* **192**(7): 1-15.

Chabuk AJ, Al-Ansari N, Hussain HM, Knutsson S and Pusch R 2017. GIS-based assessment of combined AHP and SAW methods for selecting suitable sites for landfill in Al-Musayiab Qadhaa, Babylon, Iraq. *Environmental Earth Sciences* **76**: 1-2.

Chamchali MM, Tafreshi AM and Tafreshi GM 2019. Utilizing GIS linked to AHP for landfill site selection in Rudbar County of Iran. *GeoJournal*. https://doi.org/10.1007/s10708-019-10064-8

CPCB India 2020. *Annual Report on Solid Waste Management (2020-21),* CPCB, Delhi.

CPHEEO 2000. *Manual on Municipal Solid Waste Management* (First Edition), Central Public Health and Environmental Engineering Organisation, New Delhi, India.

Eghtesadifard M, Afkhami P and Bazyar A 2020. An integrated approach to the selection of municipal solid waste landfills through GIS, K-Means, and multi-criteria decision analysis. *Environmental Research* **185**: 109348.

Hazarika R and Saikia A 2020. Landfill site suitability analysis using AHP for solid waste management in the Guwahati Metropolitan Area, India. *Arabian Journal of Geosciences* **13**(21): 1-14.

Kamdar I, Ali A, Bennui A and Techato K 2019. Municipal solid waste landfill siting using an integrated GIS-AHP approach: A case study from Songkhla, Thailand. *Resources, Conservation and Recycling* **149**: 220-235.

Khan, Md Mohib-Ul-Haque, Vaezi M and Kumar A 2018. Optimal siting of solid waste-to-value-added facilities through a GIS-based assessment. *Science of the Total Environment* **610-611:** 1065-1075.

Kumar S, Smith SR, Fowler G, Velis C, Kumar SJ, Arya S, Rena, Kumar R and Cheeseman C 2017. Challenges and opportunities associated with waste management in India. *Royal Society Open Science* **4**(3): 160764. https://doi.org/10.1098/rsos.160764

Makarichi L, Techato K and Jutidamrongphan W 2018. Resources, conservation & recycling material flow analysis as a support tool for multi-criteria analysis in solid waste management decision-making. *Resource Conservation and Recycling* **139**: 351-365.

Mohammedshum AA, Gebresilassiea MA, Rulindaa CM, Kahsaya GH and Tesfay MS 2014. Application of Geographic Information System and Remote Sensing ineffective solid waste disposal sites selection in Wukro Town, Tigray, Ethiopia. Int Arch Photogramm *Remote Sensing and Spatial Information Sciences* **2:** 115-119.

Ramya S and Devadas V 2019. Integration of GIS, AHP, and TOPSIS in evaluating suitable locations for industrial development: A case of Tehri Garhwal District, Uttarakhand, India. *Journal of Cleaner Production* **238:** 117872. https://doi.org/10.1016/j.jclepro.2019.117872.

Rana R, Ganguly R and Gupta AK 2017. Evaluation of solid waste management in satellite towns of Mohali and Panchkula. *The Journal of Solid Waste Technology and Management* **43:** 280-294.

Saaty TL 1980. *The analytic hierarchy process: Planning, priority setting, resource allocation*. McGraw-Hill International Book Company.

Saaty TL 2001. Fundamentals of the analytic hierarchy process. In *The analytic hierarchy process in natural resource and environmental decision-making* pp. 15-35. Springer, Dordrecht.

Sharma A, Ganguly R and Gupta AK 2018. Matrix method for evaluation of existing solid waste management system in Himachal Pradesh, India. *Journal of Material Cycles and Waste Management* **20:** 1813-1831.

Sukholthaman P and Shirahada K 2015. Technological challenges for effective development towards sustainable waste management in developing countries: Case study of Bangkok, Thailand. *Technology in Society* **43:** 231-239.

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