OPTIMAL SITE SELECTION FOR SANITARY LANDFILLS IN MATALE CITY USING A MULTI-CRITERION EVALUATION FOR SOLID WASTE MANAGEMENT

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ABSTRACT

The management of municipal solid waste (MSW) represents a critical environmental challenge globally, with improper disposal practices continuing to threaten both ecological integrity and public health. This study integrates Geographic Information Systems (GIS) and the Analytical Hierarchy Process (AHP) within a Multi-Criteria Decision Analysis (MCDA) framework to identify optimal sites for sanitary landfills in Matale City, located in Sri Lanka's Central Province. The methodology involved the selection and evaluation of five key criteria: slope, land use/land cover (LULC), distance to surface water, proximity to roads, and distance from settlements. Each criterion was weighted using the AHP method, revealing slope as the most influential factor (43.7%), followed by distance to surface water (28.3%) and LULC (15%), due to the region's predominantly hilly terrain. A weighted overlay analysis was conducted in the GIS environment to synthesize the spatial data and generate suitability maps. The study identified two highly suitable sites for landfill development, measuring 36.86 ha (S1) and 21.95 ha (S2), respectively. These locations were prioritized due to their bare land cover, minimal environmental sensitivity, low population density, and adequate access to transportation networks. Three other potential sites were excluded due to unfavorable characteristics such as proximity to water bodies, dense vegetation, urbanized zones, and permeable sandy soils with high infiltration potential. The study demonstrates the effectiveness of combining GIS and AHP in spatial decision-making for sustainable solid waste management. The proposed methodology offers a replicable model for urban planners and environmental managers in Matale and other rapidly urbanizing regions, aiding in the development of scientifically grounded, environmentally sound landfill siting strategies that support long-term urban sustainability.

KEYWORDS: Municipal solid waste, multiple criteria decision analysis, Landfill, Site Selection GIS techniques, Matale City

1. INTRODUCTION

In recent years, for the first time in history, more than half of the world's land area has been converted into urban areas. Today, more than 4.3 billion people live in urban settings, or 55% of the world's population. It is expected that by 2050, two-thirds (66%) of the world's people are expected to live in Megacities (Valavanidis, 2024). The rapidly growing pattern of urban growth has presented a significant challenge for Sri Lankan urban areas. Even while carefully planned urbanization will raise living standards and enhance socioeconomic conditions, there may be several difficulties along the way, particularly in the planning and development phase. Many complicated concerns and interconnected policies have been made possible by the current trends and patterns of urban growth in Sri Lanka.

Urban planners, engineers, and other professionals should correctly plan a city or other highly populated region. The public perceives that local authorities are solely responsible for solid waste management (Nuzrath & Ruzaik, 2023). The primary product from a city or the people who live nearby is solid waste. There should be a designated location for disposing of waste from town or city regions, and planners should have a good understanding of how to handle solid waste management problems. They also create an alternate location for the specific garbage disposal in case the dumpsite fills up. This is the outcome of issues brought on by Matale City's present planning flaws. For example, the Matale Municipality's primary problem is managing its daily solid waste because there isn't a suitable place to dispose of it; therefore, action must be taken to address this problem. In addition to being the capital of the Matale district, it has been a municipality for over 50 years. Despite this, the district has two municipal councils: the Matale Municipal Council (MMC) and the Dambulla Municipal Council. Solid waste management, which is the primary duty of the Matale Municipal Council, presents several difficulties for the city of Matale. The city produces between 30 and 32 tonnes of garbage per day. Despite the Municipal Council's efforts, the rate of rubbish output continues to increase by 1-2 percent annually. Waste collection is usually poor, even though solid waste management makes up 20% of municipal spending. The cost of collecting one tonne of rubbish could be around $30. Municipal rubbish collectors serve 60 percent of the city. Open dumping at a municipal dumpsite is the most popular way to dispose of waste. The city is searching for a new location because the dumpsite is nearly full. With 2.5 tonnes of recyclable inorganic garbage collected daily, the unorganized sector plays a significant part in Matale's waste management (Jayathilake et al., 2020)

Municipal Solid Waste (MSW) is a rising problem in Sri Lanka's urban areas, which is aggravated due to the absence of proper solid waste management systems in the country (Nuskiya and Sahana, 2021). Residents who live close to landfill sites see an increase in health issues (Jafar et al., 2023). The environment is negatively impacted both locally and globally by improper solid waste management and hot climate conditions. The MMC currently uses a landfill site to dispose of its solid waste. It is located outside of the city boundary and characterized as small, which has been almost filled recently. The authorities have made multiple attempts to enhance the efficacy and efficiency of the solid waste management system, but they have not been successful. The primary issues noted are inadequate technology use, a lack of basic infrastructure, a lack of community awareness and involvement, a focus on end-of-pipe disposal, and a lack of economic value placed on trash. To maintain environmental sustainability and lessen detrimental effects on the environment and public health, Matale's current solid waste management (SWM) system needs to be improved. Enough collection, the application of smart transfer strategies, and safe disposal practices should all be part of this progress. Given this, the current study uses GIS and the analytic hierarchy process (AHP) to determine the best sanitary landfill location for the disposal of solid waste in Matale City. The generation of solid waste is closely linked to contamination of the air, soil, and water. The continuous release of metals and other toxic materials from MSW causes leachate to significantly contaminate soil, groundwater, and surface water. The visual components of Matale City may be impacted by this issue overall. For example, a major source of the Mahaweli Ganga and a stream that flows through Matale town, the Sudu Ganga, has been turned into a sizable rubbish disposal site. On Dole Road, Wariayapola Watte, home to more than 300 households, is quickly becoming uninhabitable due to pollution that causes odours and unsanitary conditions. Groundwater supplies in the city are also impacted. Furthermore, improper MSW disposal exacerbates the problem by contaminating roadways, waterways, and other places. This enables us to comprehend the problem's efficacy and the importance of taking prompt action to address this issue.

However, simply gathering the debris from different locations throughout the city won't address the issue; it also needs to be disposed of in a way that is both economically and environmentally sound. An effective solid waste management (SWM) system is crucial for enhancing public health and environmental safety. Key components of such a system include waste collection and transportation, resource recovery through waste processing, treatment without resource recovery, and environmentally safe disposal in landfills. Efficient waste collection and transportation are essential to prevent environmental contamination and protect public health (Awino et al., 2024). Resource recovery methods, such as recycling and composting, reduce the volume of waste requiring final disposal and conserve natural resources (Awasthi et al., 2025). When resource recovery is not feasible, waste treatment processes aim to reduce the volume or toxicity of waste, making it safer for final disposal (Awino et al., 2024). Finally, environmentally safe and sustainable disposal in landfills minimizes the impact on soil, water, and air quality (Kumar et al., 2025).

1.1. Study Area

A significant city in Sri Lanka's Central Province is Matale (Fig. 1). In the Matale District, it is the largest urbanized city and the administrative center. It is situated in the center of the island's Central Highlands, between latitudes 7°28'7" N and longitudes 80°37'22" E. It is situated at an elevation of 364 meters (1,194 feet) above sea level in a wide, verdant, agricultural valley. Matale is located 46.9 kilometres south of Dambulla, 26 km north of Kandy, and 153.7 km northeast of Colombo. Dambulla, Ukuwela, Laggala Pallegama, Naula, Wilgamuwa, Rattota, Pallepola, Ambangange Korale, Yatawatta, and Matale are the eleven Divisional Secretariat Divisions (DSD) within the district. The Knuckles Mountain Range makes up the city's surroundings. The Municipalities Ordinance Act of 1865 allowed for the creation of the Matale Municipal Council in 1963. Matale has an urban density of 4,051 km³ and a total area of 70.0 km³. Two Municipal Councils (MC) and eleven Pradeshiya Sabhas (PS) are among the thirteen local government bodies that oversee these divisions. With 63 km^2 of Matale Pradeshiya Sabha and 8 km^2 of the Municipal Council Area, the Matale Divisional Secretariat Division has a total area of 71 km^2 (Divisional Report, 2018). Matale experiences an average annual temperature of 31°C. During the year, the average annual temperature of 31°C. During the year, the average monthly temperature can fluctuate between 29°C and 32°C, and about 2759 mm of rain falls there each year.

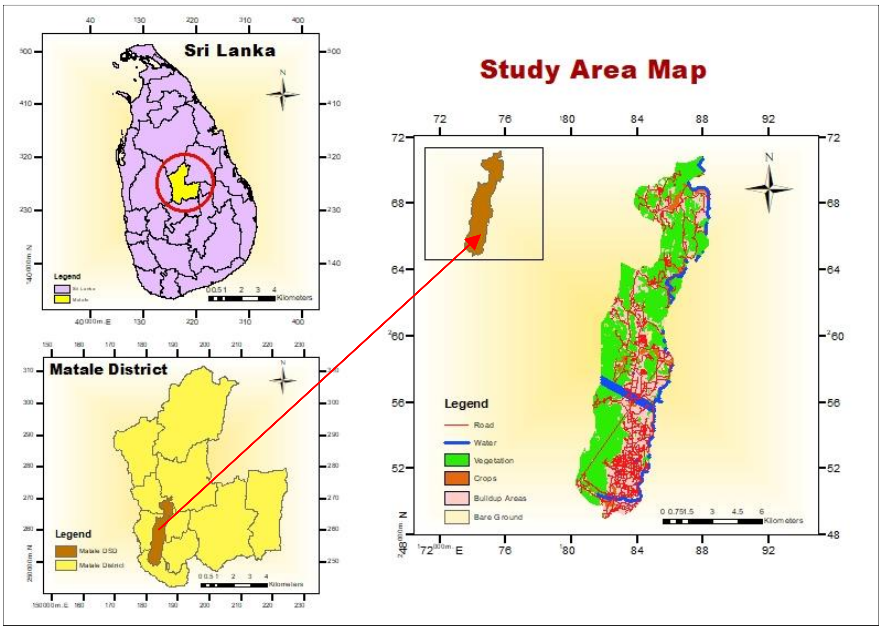


Fig. 1: Study Area

Given that there are about 42500 residents in the MMC, 0.91 kg of MSW is generated daily per person. The MMC waste management system is used to dispose of waste in about 70% of residential units and most commercial, small-scale industrial, and other establishments. According to the survey, the MMC landfill site disposes of 19.021 tons of rubbish per day.

2. MATERIAL AND METHODS

Most of the data needed for the study came from secondary sources, such as satellite data and open-source spatial information. However, there was also room for primary data gathering techniques, including speaking with the key informants over the phone.

This study focused heavily on integrating GIS with the AHP to identify potential sanitary landfill locations for solid waste disposal in Matale, Sri Lanka. The research area's GIS data sets, including highways, surface water bodies, land use, and digital elevation models (DEMs), were gathered for Matale city from a variety of sources, including the USGS's Sentinel 2 satellite, Esri, and Open Street Map (OSM). Maps of roads, water features, and land cover at specific scales were gathered and later converted to digital format. Slope maps and DEMs were created using data from the Shuttle Radar Topography Mission (SRTM) with a resolution of 10 m. Table 1 provides a summary of them.

Table 1: Data and Source

Data	Data source
Slope	SRTM
Surface water bodies	Open Street Map
Land use/land cover	Sentinel-2
Roads	Open Street Map
Settlement area	Sentinel-2

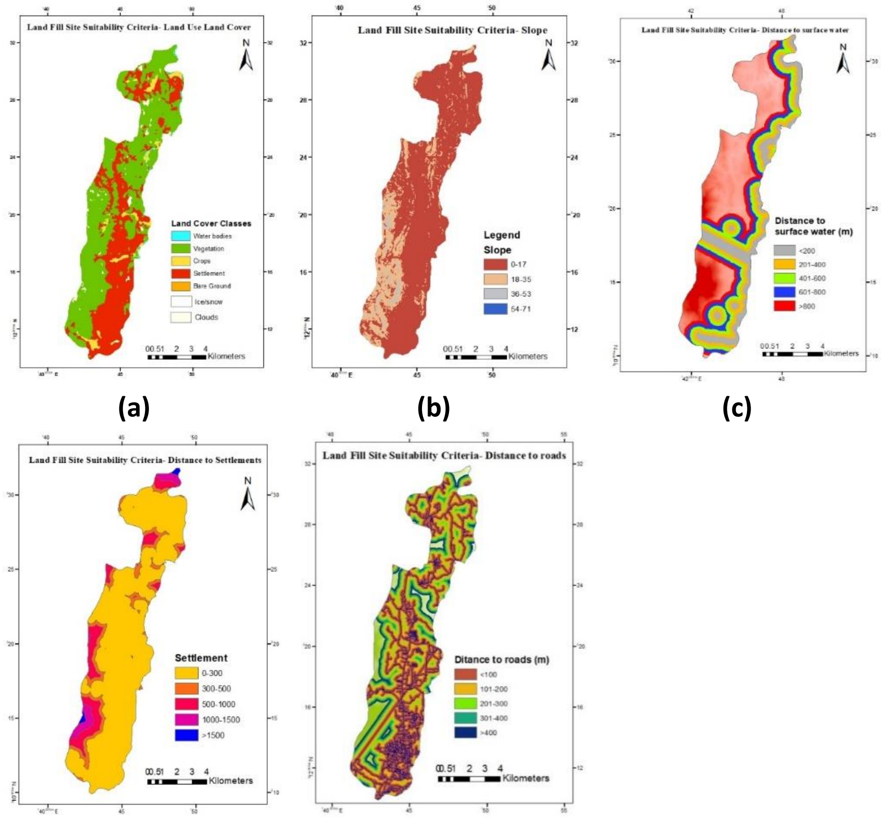
The analysis, digitization, and mapping were done using the ArcGIS 10.8 environment. Using the AHP, the selection problems are systematically broken down into manageable components, each of which is assessed separately and then logically merged. The MSWM Rules (2016) and the body of existing literature were used to determine the five site selection criteria. The rank technique was used to analyse each criterion. This analysis used five input map layers: highways, settlement area, slope, surface water bodies, and land-use/land-cover (Table 2).

Table 2: Selected criteria and ranking values

Criterion	Sub-criteria/alternatives	Suitability index (ranking)	Other studies on landfill site selection used the same criteria
Slope (`)	0-17	1	Ali & Ahmad (2020), Aziz & Khodakarami (2013), Ebistu & Minale (2013), Guiqin et al. (2009)
	18-35	2	
	36-53	3	
	54-71	4	
	72-89	5	
Distance to surface water (m)	< 200	5	Ali & Ahmad (2020), Chang et al. (2008), Gorsevski et al. (2012), Ebistu & Minale (2013), Jaybhaye et al. (2014)
	201-400	4	
	401-600	3	
	601-800	2	
	>800	1	
Distance to road (m)	<100	1	Ali & Ahmad (2020), Donevska et al. (2012), Guiqin et al. (2009), Guler & Yomralioglu (2017)
	101-200	2	
	201-300	3	
	301-400	4	
	>400	5	
Distance to settlement	0-300	5	Ali & Ahmad (2020), Guler & Yomralioglu (2017), Kontos et al. (2005)
	300-500	4	
	500-1000	3	
	1000-1500	2	
	1500-2000	1	
LULC	Water bodies	4	Ali & Ahmad (2020), Aziz & Khodakarami (2013), Gorsevski et al. (2012), Serwan & Flannagan (1998)
	Vegetation	2	
	Crops	4	
	Built up areas	5	
	Bareground	1	

3. RESULTS AND DISCUSSION

The location and construction of a landfill must be appropriate to check for pollution and groundwater and surface water contamination. In addition, the selection of landfill sites must consider built-up and settlement factors to safeguard public health. To save money on transportation and collection, the dump site should also be close to the current roadways. Khodakarami and Aziz (2013). For the landfill suitability assessment in this study, five parameters have been selected. All of these criteria were selected based on published literature that took case study scenarios into consideration, as well as norms and regulations for landfills located in Sri Lanka. Ultimately, a final composite map and individual maps for each suitability criterion were created using WAO. The integration of WOA methodologies has significantly enhanced traditional map overlay approaches for land-use suitability assessments. The following maps show the study of a few chosen landfill site selection criteria.



(a) **(b)** **(c)**

(d) **(e)**

Fig. 2: Selected criterion maps

The LULC map (Fig. 2a) used in this study shows the areas of bare ground, vegetation, crops, water bodies, built-up, and settlement. Sentinel-2 provided high-quality images (10 m resolution) for land use classification. Built-up and settlement areas were deemed unsuitable because the landfill site's odour, dust, and noise could negatively impact residential areas, while barren land was ranked as a highly suitable area for the establishment of a candidate landfill site in the study area. Since leachate migration is believed to contribute to soil and water contamination in certain places, higher degree slopes are technically unsuitable for landfill construction. According to Ebistu and Minale (2013) and Ali and Ahmad (2020), they are likewise not economically viable for landfill building. Guiqin et al. (2009) based on the SRTM DEM data of the study area, a slope layer map was produced using a GIS. The slope of the study area varies from >0° to 89°. Based on its slope, it was separated into four groups: areas with a little slope (18°–35°), places with a sharp slope (54°–71°), intermediate areas (35°–53°), extremely steep areas (72°–89°), and plane areas (0°–17°). According to Table 2, these categories were given ranks of 5, 4, 3, 2, 1, and so on. The plane areas with a rank of 1 (Fig. 2b) were deemed to be the most appropriate because areas with a slope of less than 17° are regarded as highly suitable for sanitary landfill sites, while areas with a slope of more than 17° are deemed unsuitable.

Because it is the primary cause of disease outbreaks and surface water contamination, surface water is an essential criterion for landfill construction to avoid environmental and financial issues. Motlagh and Sayadi (2015), Gorsevski et al. (2012). The USGS was used to extract the input layers of specific hydrology-related criteria. The vector layer for each criterion was initially constructed and exported in a GIS program for proximal analysis. Five buffer zones of 200 meters each were considered surrounding surface water bodies, such as ponds, canals, rivers, and other water sources in the research region, but MSWM, Sri Lanka's landfill siting laws, rejected any less than 200 meters. These vector layers were classed using a scale value of 1–5 after being transformed into a raster layer (V2R) (Fig. 2c). The LULC classification of Sentinel-2 imagery is used to determine the settlement areas for this study. Barren land received a ranking of 1 in this study, indicating that it is a highly suitable area for the establishment of a candidate landfill site in the study area. Built-up and settlement (Fig. 2d) areas were deemed unsuitable because the landfill site's noise, dust, and odour could negatively impact residential areas (Uyan, 2013).

Since the costs of constructing additional road infrastructure and transportation rise with the distance between waste generation points and potential disposal sites, this analysis considered appropriate dump sites that were close to roadways. However, other research programs carefully considered placing the dump far from the road network due to aesthetic and environmental issues. Jaybhaye et al. (2014), Rafiee (2011). The input layers for the selected road-related criteria were extracted using an open street map. These vector layers were converted into raster layers (V2R) after being classified using a scale value ranging from 1 to 5 (Fig. 2e).

3.1. Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP), created by Saaty (1980), is one of the most extensively used approaches in the multi-criteria decision-making (MCDM) paradigm. It helps make logical decisions by organizing complex situations into a hierarchy of criteria and alternatives, allowing decision-makers to choose the best option among multiple options (Jankowski, 1995; Eastman et al., 1995; Uyan, 2013; Maletič et al., 2016). AHP is extremely effective when combined with Geographic Information Systems (GIS), which enables spatially informed decisions that are notably useful in environmental planning and land use applications.

The logical structure and clarity of AHP have made it a popular MCDM technique for dump site selection (Şener et al., 2011; Guiqin et al., 2009; Gbanie et al., 2013; Khan & Samadder, 2015; Guler & Yomralioglu, 2017; Chabuk et al., 2017). The subjectivity that human judgment may incorporate into paired comparisons is a significant drawback of AHP, though, and can result in inconsistent decision matrices (Ali & Ahmad, 2020). AHP is still a strong and flexible approach, nevertheless, able to incorporate public, environmental, socioeconomic, and biophysical factors into a thorough framework for decision-making (Zahir, 2021).

AHP was used in this study to determine the best landfill locations in Matale City, Sri Lanka. To support the objective of sustainable site selection, a hierarchical structure of choice criteria was developed. Slope (SL), Land Use/Land Cover (LULC), Distance to Surface Water (DSW), Distance to Roads (DR), and Distance from Settlement Areas (DS) were the five criteria used for investigation. Using Saaty's 1–9 scale, these factors were compared pairwise to determine their relative relevance.

Table 3: Pairwise comparison matrix

	SL	DSW	DR	DS	LULC
SL	1	0.56	0.47	0.38	0.30
DSW	3	1	0.23	0.23	0.30
DR	2	2	1	0.15	0.15
DS	2	3	2	1	0.07
LULC	4	3	3	2	1

The relative importance of each criterion was determined through expert input, where six specialists provided pairwise judgments using the Saaty scale, shown in Table 4.

Table 4: Pair-wise comparison scale

Verbal judgment	Numeric value
Extremely important	9
	8
Very strongly more important	7
	6
Strongly more important	5
	4
Moderately more important	3
	2
Equally important	1

To assess the consistency of expert evaluations, the Random Index (RI) values were used (see Table 5), enabling calculation of the Consistency Ratio (CR) to ensure the reliability of the PCM.

Table 5: Random index

Numeric value	RI
1	0
2	0
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49

3.2. Weighed Overlay Analysis (WOA)

GIS users can mix many spatial layers to create the desired outcome by using the weighted overlay tool. The compensatory combination rules are followed by this multi-parametric model, which is one of the core components of the multi-criteria decision-making approach. The WOA helps to identify the potential zone by combining multiple spatial factors to create a composite raster map (Jayapathma, 2024). This method has proven effective in a variety of investigations and evaluations. The WOA was used in this study to identify the best and most suitable landfill selection locations based on the weights established by AHP.

A landfill suitability map was then produced by combining the criteria maps using the Land Suitability Index. Two solid waste disposal candidate sites were chosen based on their maximum landfill suitability as assessed by GIS and AHP analyses, considering the five factors that were chosen: slope, land-use land cover, surface water bodies, and roads. Three GIS methods are employed: buffer zoning, interpolation, and overlay analysis. Two sites that suited the data the best were selected at the first level of examination. The weighting of the criteria and the importance of each selected criterion were ascertained using the AHP technique to get the result. The slope requirement has the largest weightage value (43.7%), according to the AHP result shown in Table 7. Considering that most of the terrain surrounding Matale is on a hill and as a result, it may be crucial to take this into account while selecting a potential location for trash disposal. After slope, LULC (15%) and distance to surface water (28.3%) were ranked second and third, respectively. Road and distance to settlement areas are the other considerations, which are listed in decreasing order of significance. The relative weights assigned to each factor in the Matale District's landfill site suitability analysis decision-making process are shown by these percentages.

Table 6: Selected Suitable Landfill Sites in Matale City

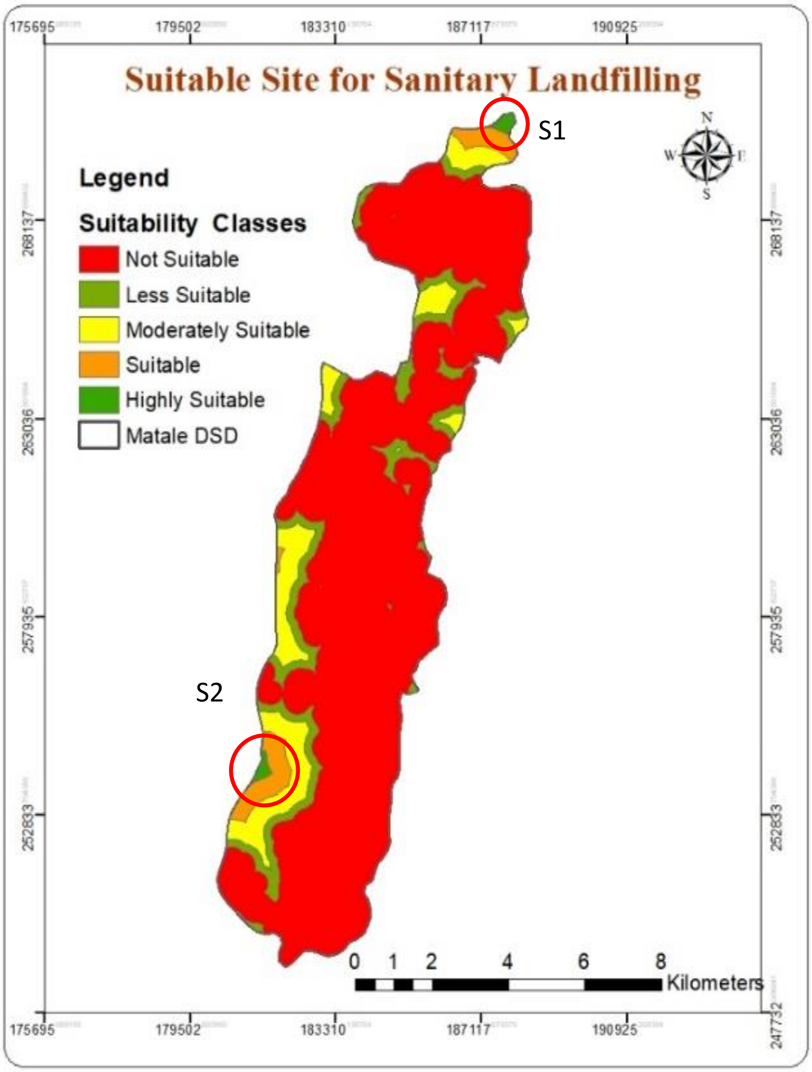
Site No.	Description of the site	Area (ha)
S 1	Located on barren land with minimal vegetation cover, this site is situated at a safe distance from residential areas, sensitive receptors, and surface water bodies. It features low land acquisition costs, accessible roadway connectivity, and relatively low elevation and slope, making it favourable for landfill development.	36.85774
S 2	This site is also situated on undeveloped land, distant from settlements, sensitive areas, industrial zones, built-up regions, and water bodies. It demonstrates suitable topographic characteristics, including optimal slope and elevation, alongside low land value, supporting its potential as a landfill site.	21.95142

***SL slope, DSW distance to surface water, DR instance to Roads, DS distance to settlement, LULC land use land cover.*

Five criteria for the best and most sustainable placement of municipal landfills in Matale City were used to create a landfill site suitability map at the conclusion of the investigation. According to the site suitability map, there are two very suitable sites spread across arid terrain and sparse vegetation in the city's north and west. The two possible sites, S1 and S2

(Fig. 3), were chosen based on several parameters, including surface water bodies, roads, land value, land use, settlement, and transportation costs.

Fig. 3: Suitable site for sanitary landfill



The sites S1, S2 cover the areas of 36.85774 and 21.95142 ha, respectively (Table 7). According to the map (Fig. 3), S1, which has an area of 36.85774 ha, is situated close to the northernmost boundary of the city. This location is ideal for disposing of MSW since it has all the necessary features, including low land value, lack of vegetation, water bodies, and good road connectivity. The second site was smaller than the other, encompassing 21.95142 hectares. This position can also be considered the best fit due to its proximity to the main neighbourhood and easy access to the roads. These two sites were inherited because they are low-cost, bare ground, far from populated areas and bodies of water, and have adequate transportation connections. Due to their locations near water bodies, dense vegetation, main highways, built-up regions, sandy soil with a high infiltration rate, and substantial settlement, the remaining three of the five selected sites were eliminated. Green indicates locations with high potential and ideal sanitary landfill sites, while red highlights areas with the least amount of suitability (Fig. 3).

Table 7: The weights of the criteria (%)

SL	DSW	DR	DS	LULC
43.7	28.3	12.7	7.4	15

The result showed that the slope criteria have the highest weightage value (43.7%). Given that the land around the Matale city is mostly surrounded by slope areas. Therefore, it can be important to consider this while choosing a prospective site for waste disposal. Distance to surface water (28.3%) and LULC (15%) came in second and third place, respectively, after slope (Table 7).

4. CONCLUSION

This article highlights the necessity for creative urban planning strategies to address Matale City's solid waste problems. Solid waste management is a key element of a city's urban planning. By integrating sustainable waste management techniques into urban planning, Matale City can improve sustainability, environmental quality, and public health. The MMC waste management agencies should use strategic SWM planning as part of an integrated approach. Even though many studies have examined sustainable MSW procedures, this one provides a comprehensive overview of contemporary MSW approaches, with the main objectives and creates a GIS-based landfill site suitability analysis for the research area. This would preserve the sustainability of waste management while safeguarding the public's health from air pollution, water contamination, disagreeable odours, and hazardous gases released during waste burning. In terms of the final disposal of MSW for better environmental sustainability and public health, the current study has been seen as a rapid and rational decision-making process.

The application of GIS and AHP in identifying possible landfill locations is highlighted in this study. A more advanced method of geographical analysis is provided by GIS, which also clearly displays locations that may be troublesome or suitable based on predetermined criteria. The weight and overlay analysis for the optimal site selection were determined using the analytical hierarchy approach (AHP). Additionally, the method highlighted regions that were deemed unsuitable for site selection due to their vulnerability to environmental threats. Two possible locations for a sanitary landfill were identified in Matale City. Given that most of the land around Matale is on hills, the slope criterion has the highest weight (43.7%), according to the data. Therefore, it can be important to consider this when choosing a possible waste disposal place. Distance to surface water (28.3%) and LULC (15%) were ranked second and third, respectively, after slope.

Reliable solutions for a new landfill siting process require considering the expertise of experts in a variety of related fields, including engineers, geographers, soil scientists, geologists, and economists. Economic and environmental factors were the primary criteria used during the selection of alternatives. Since the distance between waste-producing locales and possible disposal sites grows with the installation of new road infrastructure and transportation costs, the best landfill locations from an economic standpoint were those that were near roads. Because of environmental concerns, surface water bodies have not been selected as dump locations. To address the landfill site selection issue for Matale City and other rapidly growing metropolitan regions that encounter comparable problems worldwide, the study ends by suggesting the usage and application of such scientific work. However, to get precise information regarding Matale City's solid waste issues, local studies and reports could be required. Matale City's urban planners can use these findings to develop comprehensive plans that tackle waste-related issues and promote sustainable urban growth across the city.

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