

P-ISSN: 2706-7483

E-ISSN: 2706-7491

NAAS Rating (2026): 4.5

IJGGE 2026; 8(5): 47-48

www.geojournal.net

Received: 27-02-2026

Accepted: 29-03-2026

Prem

Research Scholar, Mohanlal
Sukhadia University (MLSU),
Udaipur, Rajasthan, India

Dr. Sabiha Khan

Assistant Professor, Mohanlal
Sukhadia University (MLSU),
Udaipur, Rajasthan, India

Integrating GIS and AHP for optimal landfill site selection: A case study of Sikar city, India

Prem and Sabiha Khan

DOI: <https://www.doi.org/10.22271/27067483.2026.v8.i5a.753>

Abstract

Municipal solid waste management (MSWM) has emerged as a major concern both globally and locally, with landfill site selection being a crucial aspect. In many Indian cities, including Sikar, existing dumping sites were chosen based on land availability rather than actual suitability. This study applied Geographic Information Systems (GIS) and multi-criteria decision analysis (MCDA) through the Analytical Hierarchy Process (AHP) to categorize city areas into three suitability classes most suitable, suitable, and unsuitable for landfill development. Results showed that 87.23 percentage were unsuitable, while 10.98 percentage were suitable, and only 1.75 percentage fell into the most suitable category. Out of 12 potential locations identified, only 6 met the minimum requirement of 20 hectares and complied with the Sikar City Master Plan 2031. The analysis also found that the current landfill sites in a moderately suitable zone. This research contributes to the body of knowledge on scientifically and socially acceptable landfill site selection in developing countries by integrating MCDA, AHP, and GIS methods to enhance environmental and socioeconomic sustainability, aligning with Sustainable Development Goals (SDGs) 3, 6, and 11.

Keywords: Municipal solid waste management, landfill site selection, geographic information systems (GIS), analytical hierarchy process (AHP), sustainable urban development

Introduction

The management of municipal solid waste (MSW) has become increasingly important due to the numerous obstacles that MSW presents, as well as the identification and allocation of suitable disposal sites (Gbanie *et al.*, 2013). Consequently, it is imperative to conduct a comprehensive assessment and make well-informed decisions regarding the selection of a disposal site in order to achieve environmentally responsible and sustainable solid waste management. The optimal landfill sites can be determined by incorporating a variety of disciplines, including environmental science, hydrogeology, sociology, economics, and engineering, as demonstrated by numerous studies. In order to identify an appropriate landfill site for solid waste disposal, Kontos and Komin integrated socioeconomic and environmental variables. Kharat and colleagues (Kharat 2016) ^[34] identified sensitive areas and intra-municipal factors as the most significant influences. It necessitates an understanding of numerous criteria, parameters, regulations, and simultaneous evaluations (Djokanovic 2016) ^[21]. The issue of solid waste management in Indian cities has become increasingly intricate over the past two decades, akin to that of rapidly expanding industrial cities (Gupta, 2015) ^[27]. The rapid increase in municipal solid waste in Sikar City can be attributed to a variety of factors, including inadequate urban planning, insufficient capital investment in this sector, and a rapid surge in population over the past decade, particularly in the education industry that has grown in anticipation of competitive exams. The impetus for this research is the imperative need to evaluate the appropriateness of a landfill location in Sikar City by integrating MCDA and GIS, and to offer evidence-based insights for sustainable landfill site management.

The generation of municipal solid waste (MSW) is increasingly recognized as a global environmental issue, significantly affecting public health, environmental deterioration, and climate change (Joshi & Ahmed, 2016) ^[30]. According to World Bank report "Waste 2.0" highlights that municipal solid waste generation is projected to rise from 2.1 billion tonnes annually in 2023 to 3.8 billion tonnes by 2050 (Beede & Bloom, 1995) ^[12]. India produces over 160,038.9 tonnes of solid trash daily, with approximately 152,749.5 tonnes collected, reflecting a collection efficiency of 95.4% (CPCB Annual Report, 2022) ^[17].

Corresponding Author:

Prem

Research Scholar, Mohanlal
Sukhadia University (MLSU),
Udaipur, Rajasthan, India

The 79,956.3 TPD (50%) of the collected waste was treated, while 29,427.2 TPD (18.4%) was sent to landfills (CPCB Annual Report, 2022) ^[17]. Nevertheless, 31.7% of the total waste generated, or 50,655.4 TPD, remains unaccounted for (CPCB Annual Report, 2022) ^[17]. Various factors, including GDP development, rapid urbanisation, population growth, tourist traffic, and industrial expansion, influence the massive amount of MSW generation (Srivastava 2015) ^[46]. Waste management systems, particularly those in developing nations worldwide, are confronted with significant challenges as a result of the substantial rise in municipal solid waste generation (Pal & Bhatia, 2022) ^[41]. Consequently, in order to surmount the obstacles presented by MSW, it is imperative to adhere to the principle of integrated solid waste management (ISWM).

The Sikar Nagar Parishad operates a landfill facility in the city. Nevertheless, the selection of this disposal site is primarily determined by administrative convenience and land availability, rather than scientific parameters that consider environmental, social, and infrastructural factors. In the western region of the city, the landfill site is situated in a densely populated location adjacent to an aquatic body. This location is in opposition to the city's geography, as it is subject to wind for the majority of the year. The current landfill site is located in the western region of the city, in close proximity to an aquatic body. The area is densely populated. The city's geography presents a challenge in this location, as the prevailing winds from the west or southwest frequently transport odours. The site's proximity to residential neighbourhoods and aquatic bodies also poses substantial hazards to public health and environmental

safety. It emits an unpleasant odour throughout the city as it flows from the west or southwest. The proximity to residential areas and water bodies also poses a significant hazard to the welfare of the public and the environment.

Description of study area

Sikar City, located in the north-eastern part of Rajasthan, India, is an important urban center and administrative headquarters of Sikar district. Geographically, it lies between 27°36' to 27°57' N latitude and 75°02' to 75°25' E longitude, covering an area of around 17 square kilometers within the municipal limits. The city is part of the semi-arid region of the Shekhawati area, known for its distinctive culture, painted havelis, and historical heritage. Sikar serves as a key educational hub in Rajasthan, often referred to as the "Education City," hosting numerous schools, colleges, and coaching institutes that attract students from across the state and beyond. Economically, the city's livelihood is supported by trade, agriculture from surrounding rural areas, and service-based industries. The climate is characterized by extreme summers, mild winters, and low to moderate annual rainfall, influenced by the arid and semi-arid conditions of the region. The city is well-connected by road and rail, linking it to major cities like Jaipur, Delhi, and Bikaner. Culturally rich, Sikar reflects a blend of traditional Rajasthani lifestyle and modern urban growth. Rapid urbanization in recent decades has led to expansion beyond its historical core, bringing challenges related to infrastructure, waste management, and sustainable development.

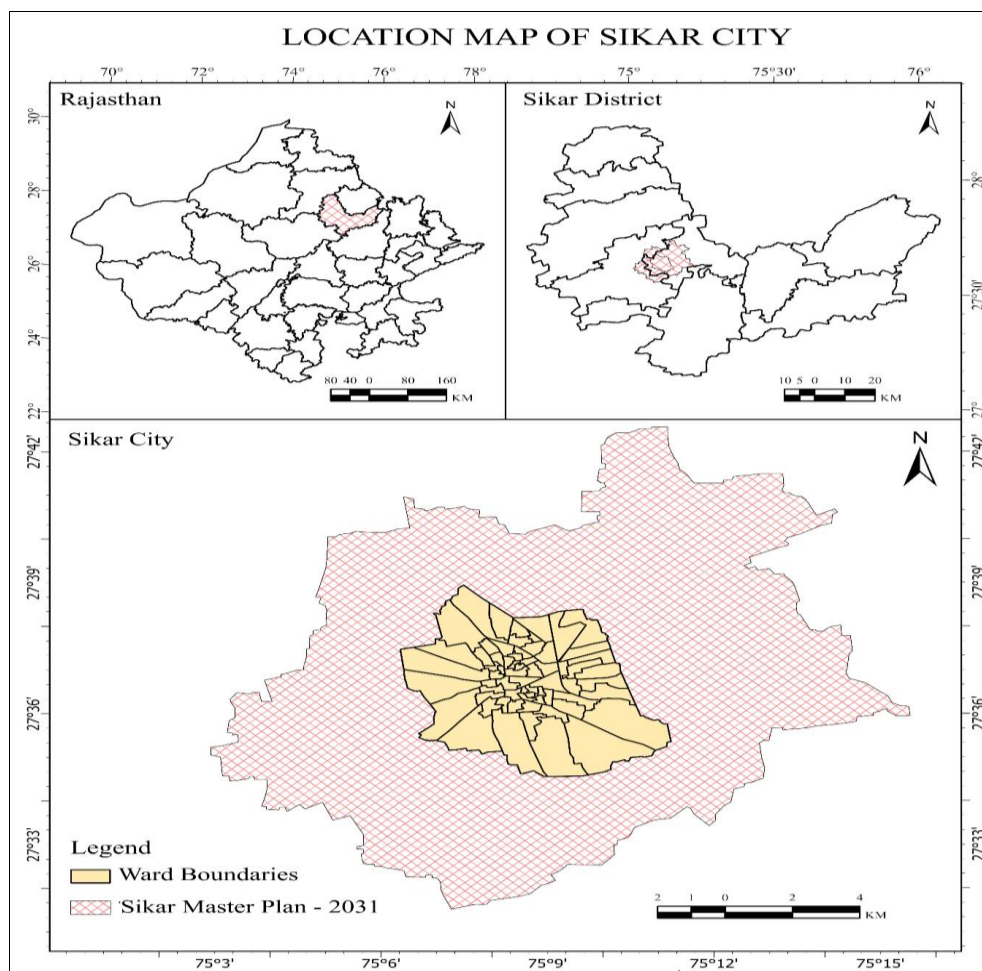


Fig 1: Location Map of Sikar City

Material and Methods

Data Collection

The analysis encompasses ten unique input map layers: elevation, slope, residential zones, local roads, highways, railway lines, land use and land cover, significant commercial areas, groundwater, and water bodies (refer to Table 1). The criteria for constraints were established in accordance with the regulations set forth by the Central Pollution Control Board (CPCB), the Rajasthan State Pollution Control Board (RSPCB), and the Municipal Solid Waste Management Rules of 2016, alongside contributions from academic specialists in pertinent areas. The criteria are designed to protect the environment, ensure public health, and address various aesthetic considerations. The criteria for constraints encompass water bodies along with a 200-meter buffer zone surrounding them, residential areas accompanied by a 200-meter buffer zone, and a 200-meter zone encircling significant commercial spaces. In the analysis of land use and land cover, residential areas and water bodies are identified as constraint criteria. Elements like water bodies, residential zones, and commercial areas function as both criteria for consideration and limitations, thus acting as dual criteria.

The LULC and water body layers were derived from Sentinel 2A imagery for 2024, featuring a resolution of 10 meters, acquired from the European Space Agency. Data pertaining to highways, railway lines, and local roads were sourced from the OpenStreetMap platform. Additional datasets, including digital elevation data, were obtained from the Shuttle Radar Topography Mission (SRTM) at a resolution of 30 meters through USGS Earth Explorer. Data on groundwater levels were sourced from the district groundwater authority. All map layers were developed with ArcGIS software, and the statistical analysis of the Multi-Criteria Decision Analysis (MCDA) employing the Analytic Hierarchy Process (AHP) was performed using Microsoft Excel 2021. Every map layer adheres to a consistent reference framework that aligns with national mapping standards, namely WGS 84 and UTM 43N. A raster data model was chosen, and all input map layers, regardless of their original format as raster or vector, were either resampled or converted to a raster with a uniform grid size of 30 meters. Table 1 presents the layers, buffer zones, and rankings.

Methods

Setting of Factor Criteria

The criteria are divided into three main categories: environmental factors (such as water bodies, LULC and groundwater), socio-economic factors (including highways, local roads, railway lines, residential areas, and commercial spaces), and topographic factors (slope, and elevation). Each factor is ranked on a scale from 1 to 3, where one indicates that the factor is unsuitable, two means suitable, and three denotes the most appropriate (see Table 1).

Water Body

Water bodies play a crucial role in determining landfill site suitability, as they are considered one of the most important factors in the selection process. This study, water bodies are critical factors in landfill site suitability analysis due to their potential vulnerability to contamination. In this study, the criteria for proximity to water body were defined as follows: 0-300 m is deemed unsuitable, 300 - 400 m is considered suitable, and more than 400 m is most suitable.

Groundwater

Groundwater depth plays a crucial role in landfill site selection, as it is considered one of the most important criteria in the process. In this study, the criteria for depth of groundwater were defined as follows: 72-82 m is deemed unsuitable, 82-94 m is considered suitable, and more than 94 m is most suitable.

Land Use and Land Cover (LULC).

Land use and land cover are crucial in determining landfill site suitability. This study utilized the 2024 Sentinel 2A Satellite Imagery, which was processed through a supervised classification method using ArcGIS software, applying the maximum likelihood parametric decision rule (Saini *et al.*, 2024) ^[43-44]. The classification was based on a predefined LULC classification scheme provided by ESRI, along with a field survey conducted in the study area. The framework included six distinct categories: water bodies, vegetation, built-up areas, agriculture, rangeland, and bare land. The comparative appropriateness of various land uses indicates that waterbodies and built-up areas are deemed unsuitable, whereas agricultural and vegetative land is considered suitable. Additionally, bare land and rangeland are identified as the most suitable options, as illustrated in the table.

Highways

The role of highways in selecting landfill sites is considered an important economic factor in the site selection process. Thus, highways play a significant role in landfill site selection, primarily as an economic factor influencing transportation costs and accessibility. However, their environmental impact is also considered in some studies, highlighting the complex nature of landfill site selection processes that must balance various factors to find optimal locations. In this study, the criteria for proximity to Highways were defined as follows: 0-200 m is deemed unsuitable, 200 - 300 m is considered suitable, and more than 300 m is most suitable.

Local Roads

The accessibility and consistent usability of the road are essential considerations for determining the suitability of landfill sites. In this study, the criteria for proximity to local roads were established based on the feasibility of local conditions and transport costs as follows: Depths of 0-50 m are regarded as unsuitable, while those between 50 and 150 m are viewed as suitable, and depths exceeding 150 m are classified as most suitable.

Residential Area

The distance from residential areas plays a crucial role in selecting suitable landfill sites, as highlighted by multiple studies: Residential areas are consistently considered a key criterion in landfill site selection processes. Based on these considerations, the buffer distance from the residential area is as follows: <300 m is unsuitable, 200 - 400 m is suitable and >400 m is most suitable.

Commercial Space

Commercial space plays a significant role in landfill site suitability assessment, as it is an important factor to consider when selecting appropriate locations for waste disposal. Commercial space is a critical factor in the suitability assessment of landfill sites. In this study the

buffer distance from the commercial space is as follows: <300 m is unsuitable, 200 - 400 m is suitable and >400 m is most suitable.

Railway line

Proximity to transportation routes like railway lines or highways plays a significant role in environmental impact assessments for landfill sites, influencing both economic and environmental factors. In this study, the criteria for proximity to Railway line were defined as follows: 0-300 m is deemed unsuitable, 300 - 400 m is considered suitable, and more than 400 m is most suitable.

Elevation: Elevation plays a significant role in determining landfill site suitability, as highlighted in several studies: Elevation is considered an important criterion in landfill site selection due to its impact on environmental and operational factors. Lower elevations are generally preferred for landfill sites to minimize the risk of contamination to surrounding areas and water sources (Mallick, 2021; Zandi *et al.*, 2024).

The study area is situated in flat plain area eastern most part have some undulating hills. The elevation in this region varies from 401-573 meters. Based on literature the higher elevation area above 475m is deemed unsuitable, and low laying area below 425 m is suitable and area between 425-475m is most suitable.

Slope

Slope plays a crucial role in determining landfill site suitability across multiple studies: Slope is consistently identified as one of the key criteria for landfill site selection (Elkhrachy 2023) ^[61]. It is considered an important factor due to its influence on various landfill construction and operation aspects. Steeper slopes are generally less suitable for landfills as they can lead to increased runoff, soil erosion, and potential instability of the landfill structure (Karimi *et al.*, 2018) ^[57]. Interestingly, in the study area, slope values range from 0.01° to 34°. Areas with slopes between 0° and 3° are considered most suitable. Slopes from 3° to 6° are suitable, >9° are not suitable.

Table 1: Summary, of input data used in this study

Sr. No.	Layer Name	Source map	Buffer Zones	Ranking	Suitability
1	Residential Area (in meter)	Sentinal 2A 2023 imagery. Supervised classification of LULC.	0-300	1	Not Suitable
			300-400	2	Suitable
			>400	3	Most Suitable
2	Water Body	Hydrological data India WRIS	0-300	1	Not Suitable
			300-400	2	Suitable
			>400	3	Most Suitable
3	Commercial Space	OSM Portal	0-300	1	Not Suitable
			300-400	2	Suitable
			>400	3	Most Suitable
4	Distance from Highways	OSM Portal	0-200	1	Not Suitable
			200-300	2	Suitable
			>300	3	Most Suitable
5	Distance from Local Roads	OSM Portal	0-50	1	Not Suitable
			50-150	2	Suitable
			>150	3	Most Suitable
6	Distance from Railway line	OSM Portal	0-300	1	Not Suitable
			300-400	2	Suitable
			>400	3	Most Suitable
7	Groundwater Depth	District Goundwater Authority	77-82	1	Not Suitable
			82-94	2	Suitable
			>94	3	Most Suitable
8	LULC	Sentinal 2A 2023 imagery. Supervised classification of LULC.	Waterbody, Builtup Area	1	Not Suitable
			Vegetation, Agriculture Land	2	Suitable
			Barren and Rangeland	3	Most Suitable
9	Elevation	USGS Earth Explorer, SRTM 30M	>425	1	Not Suitable
			401-425	2	Suitable
			425-475	3	Most Suitable
10	Slope	USGS Earth Explorer, SRTM 30M	>9	1	Not Suitable
			03-Sep	2	Suitable
			0-3	3	Most Suitable

Multi-criteria decision analysis: Multicriteria decision analysis (MCDA) integrated with Geographic Information Systems (GIS) has emerged as a powerful tool for landfill site suitability analysis. Multiple MCDA techniques are utilized for decision-making tasks, including the assessment of landfill site suitability. This study employs the Analytical Hierarchy Process (AHP) and Weighted Linear Combination (WLC) methods of Multi-Criteria Decision Analysis (MCDA). The pairwise comparison matrix is constructed using Microsoft Excel 2021.

Analytic Hierarchy Process: AHP, introduced by Satty in 1980, utilizes pairwise comparison to assess the relative significance of the criteria (Saaty, 1980) ^[58]. This approach enables the prioritization of criteria and aids in intricate decision-making by breaking down criteria into hierarchical structures that incorporate both quantitative and qualitative elements (McIntyre & Parfitt, 1998) ^[37].

AHP is frequently applied in studies assessing the suitability of landfill sites, typically alongside Geographic Information Systems (GIS) and various multi-criteria decision-making

approaches. The AHP methodology facilitates the allocation of weights to different criteria involved in the selection of landfill sites, enabling a structured and impartial assessment of prospective locations.

According to Saaty and Vargas in (Saaty & Vargas, 2012) [42], the consistency ratio (CR) for pairwise comparisons should be below 10%. The Consistency Index (CI) was calculated using the following formula:

$$CI = \frac{\lambda_{max} - n}{(n-1)} \quad (1)$$

In this context, n represents the total number of criteria, while λ_{max} signifies the average eigenvalue of the judgment matrix. A lower Consistency Index (CI) signifies enhanced consistency within the pairwise comparison matrix. The Consistency Ratio (CR) is calculated by dividing the Consistency Index (CI) by the Random Consistency Index (RI) corresponding to the specified value of n, as demonstrated in Table 3.

$$CR = \frac{CI}{RI} < 0.1 \quad (2)$$

Table 2: Random Index Value

Order Matrix (n)	1	2	3	4	5	6	7	8	9	10
Random Index (RI)	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.51

Source: Satty (1980)

Weighted Linear Combination (WLC): This approach is widely recognized as the primary technique for decision-making in GIS when it comes to developing composites. This approach facilitates the incorporation of multiple elements, assigning specific weights according to their significance, to produce a conclusive suitability or vulnerability map (Malczewski, 2000; Mvula *et al.*, 2023; Vavatsikos *et al.*, 2020) [54, 59]. This study integrated the results from AHP with WLC to produce the final suitability map (Mvula *et al.*, 2023) [62]. The Weighted Linear Combination (WLC) method is employed to consolidate criteria weights and calculate the suitability index value for potential areas through the following formula:

$$s_i = \sum_{j=1}^n w_i * x_{ij} * \Pi c_j \quad (3)$$

In this context, S_i represents the suitability index for area i, while w_i indicates the weight of the criterion. x_{ij} represents the value of the criterion, where n denotes the total number of criteria and C_j reflects the constraint score, which can take on values of either 0 or 1 (Gorsevski *et al.*, 2012; Rezaeisabzevar *et al.*, 2020) [25, 60]. All ten map layers underwent standardization using ArcGIS, with each layer being "reclassified" via the spatial analyst tool. Classes were categorized with ranks ranging from 1 to 3, where 1 denotes not suitable, 2 indicates suitable, and 3 represents the most suitable option.

Calculation of weightage using AHP

Pairwise Comparison Matrix Calculation

Table 3: Pairwise Comparison Matrix

Factor Criteria	Residential Area	Distance from Highways	Distance from Local Roads	Distance from Railway line	Ground water Depth	Water Body	LULC	Slope	Elevation	Commercial Establishment
Residential Area	1	1	2	1	1	1	3	5	3	5
Distance from Highways	1	1	1	1	1	1/2	1	3	3	1
Distance from Local Roads	1/2	1	1	1/3	1	1/3	1	3	3	1
Distance from Railwayline	1	1	3	1	1	1	1	3	5	3
Groundwater Depth	1	1	1	1	1	1/3	1	1	3	1/3
Water Body	1	2	3	1	3	1	2	3	3	3
LULC	1/3	1	1	1	1	1/2	1	3	5	1
Slope	1/5	1/3	1/3	1/3	1	1/3	1/3	1	2	1
Elevation	1/3	1/3	1/3	1/5	1/3	1/3	1/5	1/2	1	1
Commercial Establishment	1/5	1	1	1/3	3	1/3	1	1	1	1
Total	6.56666667	9.66666667	13.6666667	7.2	13.3333333	5.66666667	11.5333333	23.5	29	17.3333333

Result and Discussion

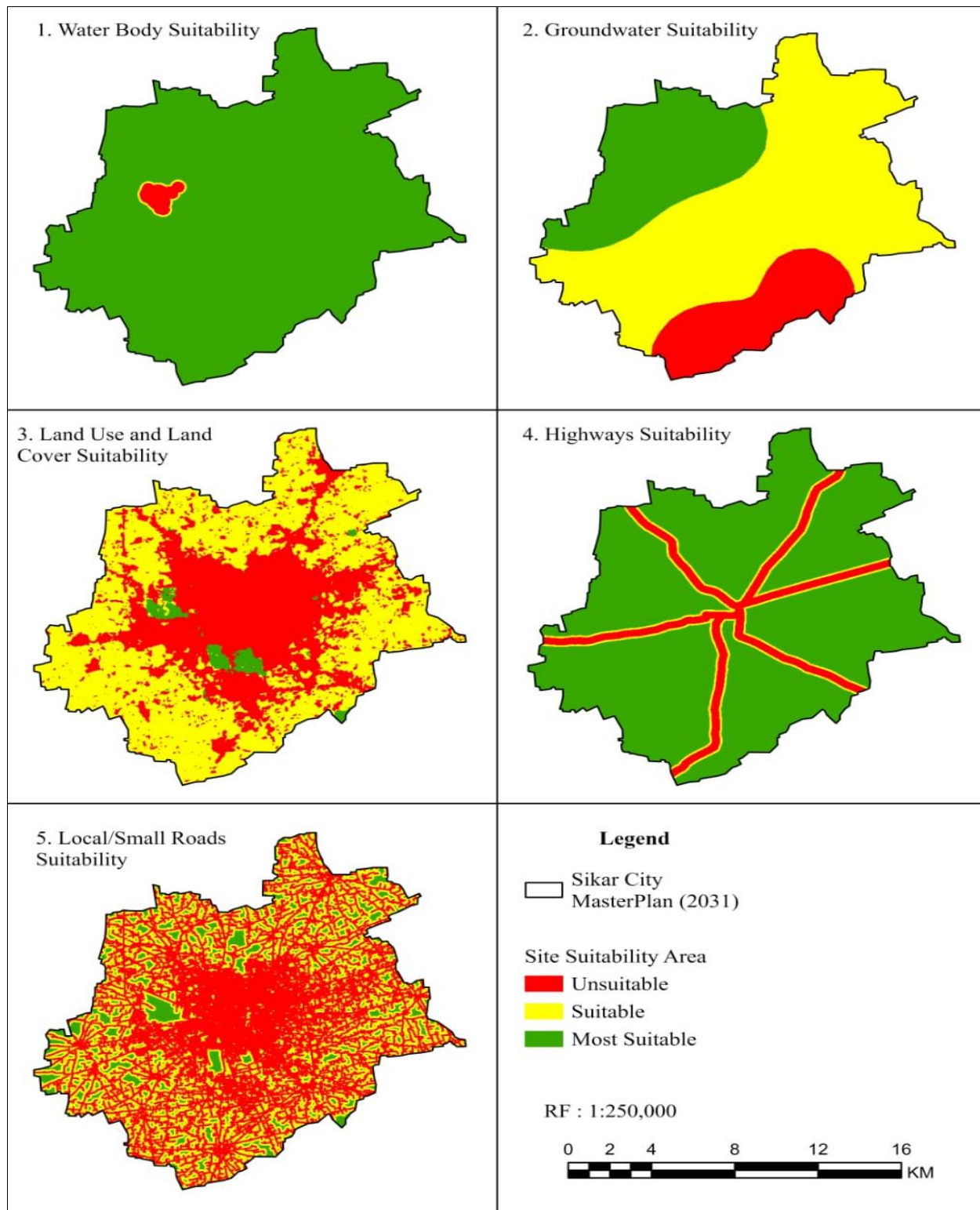
Suitability condition of criteria

The total area for landfill suitability is categorized into three ranks: 1 signifies the least suitability or unsuitable, 3

denotes the highest suitability or most suitable, and 2 is classified as suitable. Table (7) and Figures 1 to 10 depict the spatial distribution of suitability classifications according to the established factor criteria.

Table 4: Suitability Condition of Criteria

Sr. No.	Factor Criteria	Not Suitable (%)	Suitable (%)	Most Suitable (%)	Total (%)
1	Residential Area	10.98	87.53	1.49	100
2	Distance from Highways	9.3	4.5	86.2	100
3	Distance from Local Roads	57.12	36.04	6.84	100
4	Distance from Railway line	4.57	4.18	91.25	100
5	Groundwater Depth	14.55	58.74	26.71	100
6	Water Body	1	0.3	98.7	100
7	LULC	39.8	57.87	2.33	100
8	Slope	0.004	10.24	89.756	100
9	Elevation	45.72	3.3	50.98	100
10	Commercial Establishment	4.7	5.92	89.38	100

**Fig 2:** Factor criteria maps

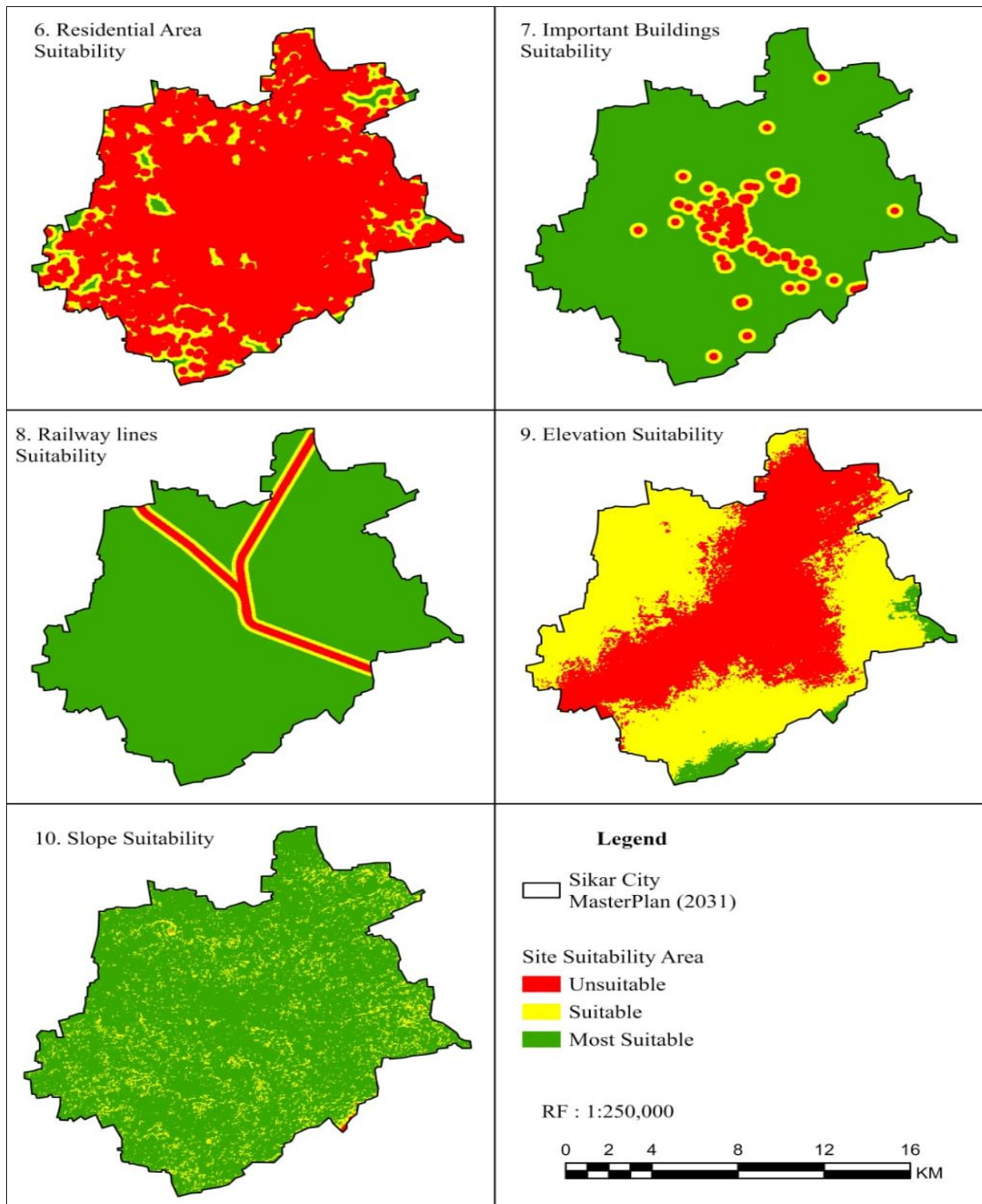


Fig 3: Factor criteria maps

The analysis of the Residential Area reveals that a substantial portion of land 87.23% is classified as not suitable for landfill placement. Conversely, only 10.98% is considered Suitable, with a minimal 1.75% designated as Most Suitable. These findings indicate that areas adjacent to residential zones are largely inappropriate for landfill sites, primarily due to potential health and environmental risks to the community.

The distance from Highways reveals that 86.2% of the region is classified as Most Suitable, highlighting that most prospective sites are situated at an optimal distance from

highways, reducing the likelihood of adverse effects on primary transport routes. A minor percentage (9.3%) is categorized as Not Suitable. In contrast, Distance from Local Roads exhibits a comparatively adverse distribution, with 57.12% categorized as Not Suitable. Merely 6.84% of the region is classified as Most Suitable, indicating that closeness to local roadways presents issues and necessitates meticulous site selection to mitigate traffic congestion and associated disruptions.

The distance from the Railway Line factor demonstrates exceptional compatibility, with 91.25% of the area

designated as Most Suitable. This demonstrates efficient separation from railway infrastructure, minimizing groundwater protection. The existence of 14.55% in the Not Suitable category necessitates careful selection to prevent groundwater contamination.

Water bodies have a remarkably high appropriateness, with 98.7% categorized as Most Suitable. This signifies that most regions uphold a suitable distance from surface water sources, mitigating water pollution hazards. The Land Use Land Cover (LULC) research indicates that 57.87% is classified as Suitable, 2.33% as Most Suitable, and 39.8% as Not Suitable. This indicates that a considerable fraction of land uses may impede landfill growth, underscoring the necessity for comprehensive land use planning. Potential risks and disturbances. Groundwater depth is a vital environmental factor. In this location, 26.71% is designated as Most Suitable, while a predominant 58.74% is deemed Suitable.

The slope is another essential physical requirement. The findings indicate that 89.756% of the region is classified as Most Suitable, signifying predominantly level terrain, which is optimal for landfill development regarding operational stability and cost efficiency. Elevation exhibits a

dichotomous distribution, with 50.98% categorized as Most Suitable, while a significant 45.72% is deemed Not Suitable. This variability indicates that elevation differences must be meticulously evaluated during site selection to guarantee environmental safety and accessibility. Ultimately, Commercial Establishments are adequately removed from possible sites, with 89.38% categorized as Most Suitable. Only 4.7% is Not Suitable, indicating negligible conflict with economic zones.

The suitability assessment indicates that features, including proximity to roads, railway lines, water bodies, topography, and commercial establishments, significantly facilitate the identification of suitable dump sites in Sikar city. Challenges related to proximity to residential zones, local roadways, land use classifications, and elevation necessitate meticulous site selection and design. Special emphasis must be placed on groundwater depth to mitigate any environmental hazards. The significant proportion of Most Suitable sites for crucial elements highlights a promising opportunity for establishing an environmentally sustainable landfill, contingent upon the cautious mitigation of less favourable factors.

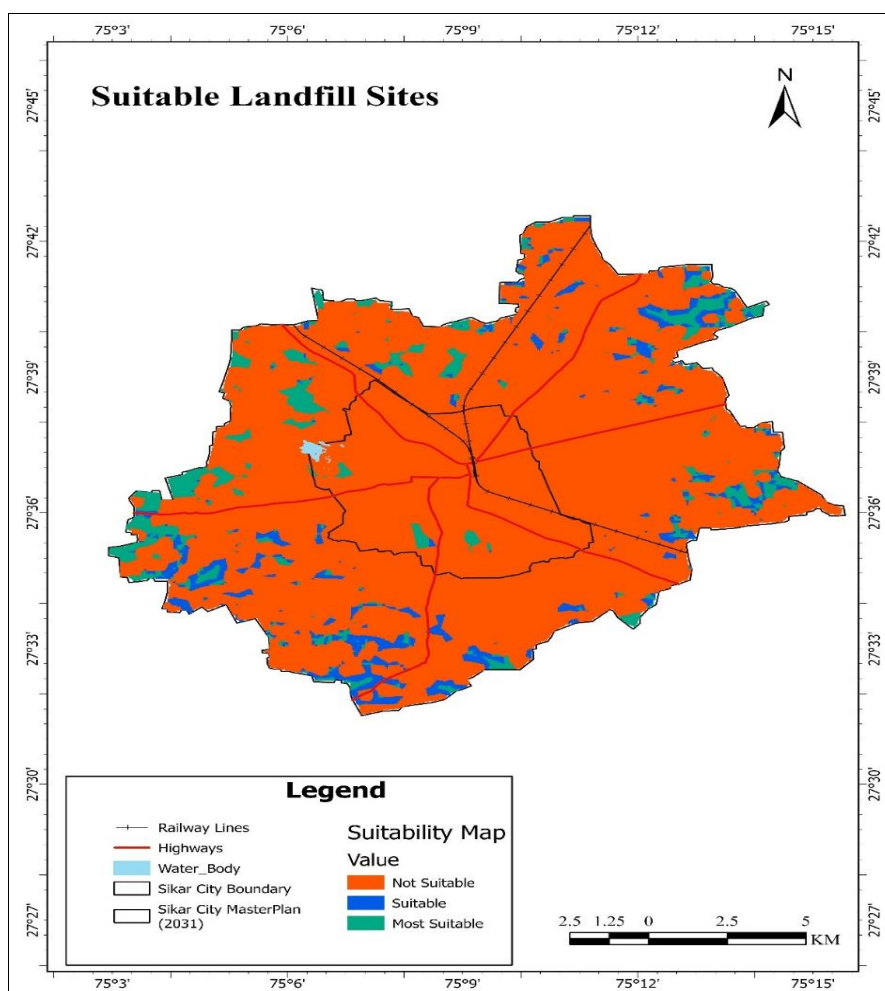


Fig 4: Overall Suitable sites

Landfill Suitability

The final landfill suitability map was developed utilizing Eq. (3), which integrates the results from the MCDA and AHP pairwise comparison matrix as presented in Table 3.

The results show that approximately 5.05% of the area is appropriate for landfill use, whereas 6.21% is classified as highly suitable, and 88.73% is considered unsuitable.

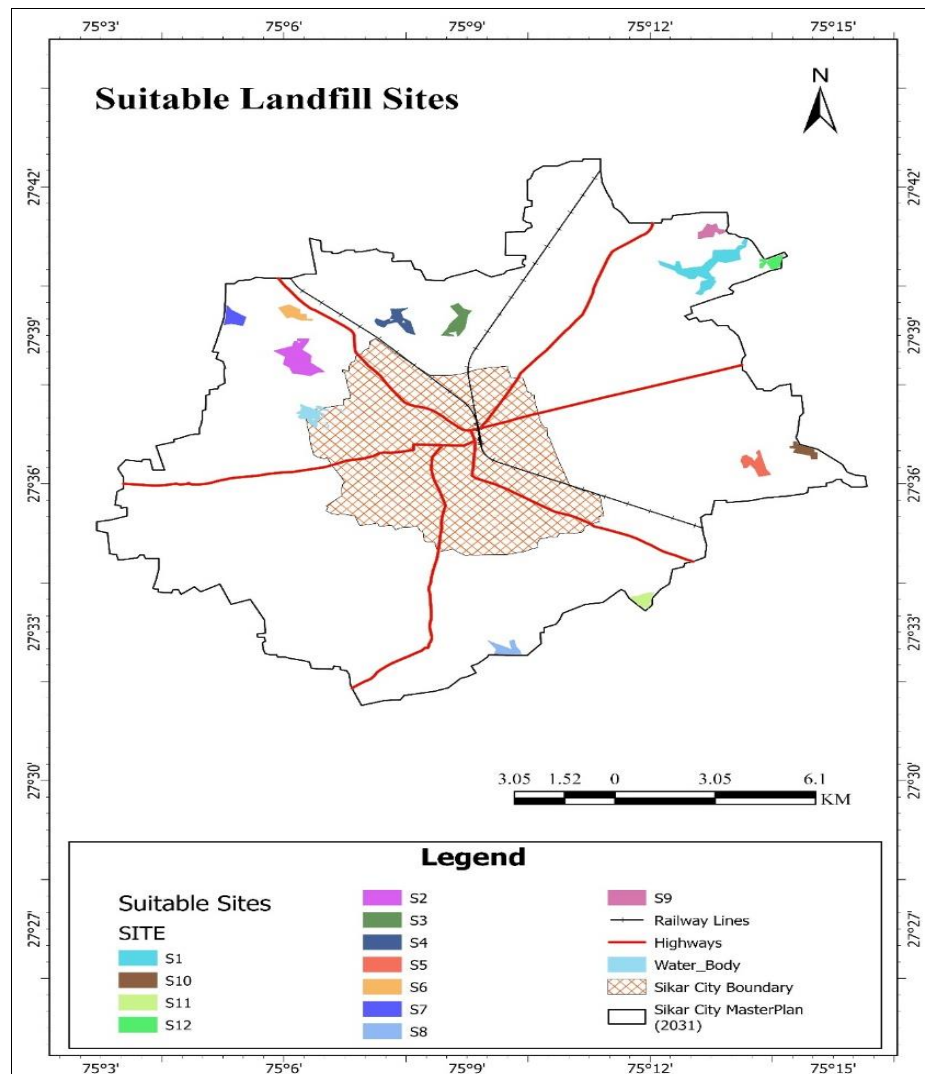


Fig 5: Final landfill Suitability map

Simultaneously, the city is producing approximately 160 tons of waste each day, with an annual population growth rate of 2.1-2.2%. This growth necessitates a minimum of 20 hectares of land, although ideally, more than 50 hectares would be preferable to accommodate future requirements. Upon applying the necessary criteria and considering the wind direction (westerly and southwest), 12 appropriate sites have been identified: S1, S2, S3, S4, S5, S6, S7, S8, S9, S10, S11, and S12, as illustrated in Figure 5. These sites fulfill the minimum requirements, with S1, S9, S12, S5, S10, and S11 being the most suitable due to their area exceeding 20 hectares. The landfill site was chosen ten years ago, and the area has since evolved into a bustling industrial center with a high population density. This study advances the establishment of clean and sustainable waste disposal sites while also addressing future implications for waste management.

Conclusion and Recommendation: The suitability map for the landfill site in Sikar City has been developed through the application of Geographic Information System (GIS), Multi-Criteria Decision Analysis (MCDA), and the Analytical Hierarchy Process (AHP). The analysis utilized GIS, MCDA, and AHP to evaluate a range of environmental factors, including water bodies, land use and land cover, and groundwater. It also took into account socio-economic factors such as highways, local roads, railway lines,

residential areas, and commercial spaces, as well as topographic factors like slope and elevation, to identify the most appropriate landfill sites. The optimal locations are found in the eastern and north-eastern regions of the study area, including S1, S12, S9, S5, S10, S3, among others, and are deemed most suitable for the year 2031. The two locations can be evaluated from the northern sections S3 and S4, as well as the eastern sections S12 and S5, to minimize transportation expenses. This study illustrates the effectiveness of combining a multi-disciplinary approach with scientific techniques. This integration leads to negligible environmental, economic, and public health issues, which is a vital concern in developing countries such as India. The methodology employed is in harmony with the fundamental aims of Sustainable Development Goals 11 and 6. This underscores the critical need to safeguard our environment and public health in order to foster sustainable urban areas and ensure access to clean water and sanitation. This study holds considerable importance as it deepens the existing knowledge regarding the selection of suitable landfill sites in developing nations. Landfill locations must be chosen based on scientific criteria and should gain community approval. It is advisable for local governments to improve their capabilities and infrastructure facilities while incorporating GIS and MCDA methods for effective waste management. This method contributes to landfill selection and utilization that is more environmentally sustainable, economically viable, and socially acceptable.

References

1. Afzali A, Sabri S, Rashid M, Mohammad Vali Samani J, Ludin ANM. Inter-municipal landfill site selection using analytic network process. *Water Resources Management*. 2014;28(8):2179-2194.
2. Aksoy E, San BT. Geographical information systems and multi-criteria decision analysis integration for sustainable landfill site selection considering dynamic data source. *Bulletin of Engineering Geology and the Environment*. 2019;78(2):779-791.
3. Alanbari MA, Al-Ansari N, Jasim HK. GIS and multicriteria decision analysis for landfill site selection in Al-Hashimiyah Qadaa. *Natural Science*. 2014;6(5):282-304.
4. Alavi N, Goudarzi G, Babaei AA, Jaafarzadeh N, Hosseinzadeh M. Municipal solid waste landfill site selection with geographic information systems and analytical hierarchy process: a case study in Mahshahr County, Iran. *Waste Management and Research: The Journal for a Sustainable Circular Economy*. 2013;31(1):98-105.
5. Ali SA, Parvin F, Al-Ansari N, Pham QB, Ahmad A, Raj MS, *et al.* Sanitary landfill site selection by integrating AHP and FTOPSIS with GIS: a case study of Memari Municipality, India. *Environmental Science and Pollution Research*. 2021;28(6):7528-7550.
6. Alkaradaghi K, Ali SS, Al-Ansari N, Laue J, Chabuk A. Landfill site selection using MCDM methods and GIS in the Sulaimaniyah Governorate, Iraq. *Sustainability*. 2019;11(17):4530.
7. Almansi KY, Shariff ARM, Kalantar B, Abdullah AF, Ismail SNS, Ueda N. Performance evaluation of hospital site suitability using multilayer perceptron and analytical hierarchy process models in Malacca, Malaysia. *Sustainability*. 2022;14(7):3731.
8. Ashraf MA, Yusoff I, Yusof M, Alias Y. Study of contaminant transport at an open-tipping waste disposal site. *Environmental Science and Pollution Research*. 2013;20(7):4689-4710.
9. Azadeh A, Saberi M, Chang E, Pazhoheshfar P, Atashbar NZ. Z-AHP: a Z-number extension of fuzzy analytical hierarchy process. 7th International Conference on Digital Enterprise Technology. 2013:141-147.
10. Barakat A, Hilali A, Baghdadi ME, Touhami F. Landfill site selection with GIS-based multi-criteria evaluation technique: a case study in Béni Mellal-Khouribga Region, Morocco. *Environmental Earth Sciences*. 2017;76(12):413.
11. Barton DN, Sundt H, Bustos AA, Fjeldstad HP, Hedger R, Forseth T, *et al.* Multi-criteria decision analysis in Bayesian networks diagnosing ecosystem service trade-offs in a hydropower regulated river. *Environmental Modelling and Software*. 2019;124:104604.
12. Beede DN, Bloom DE. The economics of municipal solid waste. *World Bank Research Observer*. 1995;10(2):113-150.
13. Bilgilioglu SS, Gezgin C, Orhan O, Karakus P. A GIS-based multi-criteria decision-making method for the selection of potential municipal solid waste disposal sites in Mersin, Turkey. *Environmental Science and Pollution Research*. 2022;29(4):5313-5329.
14. Chabok M, Asakereh A, Bahrami H, Jaafarzadeh NO. Selection of MSW landfill site by fuzzy-AHP approach combined with GIS: case study in Ahvaz, Iran. *Environmental Monitoring and Assessment*. 2020;192(7):433.
15. Chang NB, Parvathinathan G, Breeden JB. Combining GIS with fuzzy multicriteria decision-making for landfill siting in a fast-growing urban region. *Journal of Environmental Management*. 2008;87(1):139-153.
16. Chen X, Yi W, Yuan H, Wu W. Construction and demolition waste disposal charging scheme design. *Computer-Aided Civil and Infrastructure Engineering*. 2024;39(2):222-241.
17. Central Pollution Control Board. Annual report. New Delhi: Central Pollution Control Board; 2022.
18. Csató L. Characterization of an inconsistency ranking for pairwise comparison matrices. *Annals of Operations Research*. 2017;261(1-2):155-165.
19. Davies AL, Redpath SM, Bryce R. Use of multicriteria decision analysis to address conservation conflicts. *Conservation Biology*. 2013;27(5):936-944.
20. Demesouka O, Vavatsikos A, Anagnostopoulos K. GIS-based multicriteria municipal solid waste landfill suitability analysis: a review of the methodologies performed and criteria implemented. *Waste Management and Research: The Journal for a Sustainable Circular Economy*. 2014;32(4):270-296.
21. Djokanović S, Abolmasov B, Jevremović D. GIS application for landfill site selection: a case study in Pančevo, Serbia. *Bulletin of Engineering Geology and the Environment*. 2016;75(3):1273-1299.
22. El Baba M, Kayastha P, De Smedt F. Landfill site selection using multi-criteria evaluation in the GIS interface: a case study from the Gaza Strip, Palestine. *Arabian Journal of Geosciences*. 2015;8(9):7499-7513.
23. Feizizadeh B, Ghorbanzadeh O. GIS-based interval pairwise comparison matrices as a novel approach for optimizing an analytical hierarchy process and multiple criteria weighting. *GI Forum*. 2017;1:27-35.
24. Gallagher L, Ferreira S, Convery F. Host community attitudes towards solid waste landfill infrastructure: comprehension before compensation. *Journal of Environmental Planning and Management*. 2008;51(2):233-257.
25. Gorsevski PV, Donevska KR, Mitrovski CD, Frizado JP. Integrating multi-criteria evaluation techniques with geographic information systems for landfill site selection: a case study using ordered weighted average. *Waste Management*. 2012;32(2):287-296.
26. Güler D, Yomralıoğlu T. Alternative suitable landfill site selection using analytic hierarchy process and geographic information systems: a case study in Istanbul. *Environmental Earth Sciences*. 2017;76(20):678.
27. Gupta N, Gupta R. Solid waste management and sustainable cities in India: the case of Chandigarh. *Environment and Urbanization*. 2015;27(2):573-588.
28. Hazarika R, Saikia A. Landfill site suitability analysis using AHP for solid waste management in the Guwahati Metropolitan Area, India. *Arabian Journal of Geosciences*. 2020;13(21):1148.
29. Jain K, Subbaiah YVS. Site suitability analysis for urban development using GIS. *Journal of Applied Sciences*. 2007;7(18):2576-2583.

30. Joshi R, Ahmed S. Status and challenges of municipal solid waste management in India: a review. *Cogent Environmental Science*. 2016;2(1):1139434.
31. Kapilan S, Elangovan K. Potential landfill site selection for solid waste disposal using GIS and multi-criteria decision analysis. *Journal of Central South University*. 2018;25(3):570-585.
32. Kara C, Doratli N. Application of GIS and analytical hierarchy process in siting sanitary landfill: a case study in Northern Cyprus. *Waste Management and Research: The Journal for a Sustainable Circular Economy*. 2012;30(9):966-980.
33. Kazuva E, Zhang J, Tong Z, Liu XP, Memon S, Mhache E. GIS- and MCD-based suitability assessment for optimized location of solid waste landfills in Dar es Salaam, Tanzania. *Environmental Science and Pollution Research*. 2021;28(9):11259-11278.
34. Kharat MG. Identification and evaluation of landfill site selection criteria using a hybrid fuzzy Delphi, fuzzy AHP and DEMATEL based approach. *Modeling Earth Systems and Environment*. 2016;2(2):98.
35. Kim J, Jeong S. Economic and environmental cost analysis of incineration and recovery alternatives for flammable industrial waste: the case of South Korea. *Sustainability*. 2017;9(9):1638.
36. Kontos TD, Komilis DP, Halvadakis CP. Siting MSW landfills with a spatial multiple criteria analysis methodology. *Waste Manag*. 2005;25(8):818-832. DOI:10.1016/j.wasman.2005.04.002
37. McIntyre C, Parfitt MK. Decision support system for residential land development site selection process. *J Archit Eng*. 1998;4(4):125-131. DOI:10.1061/(asce)1076-0431(1998)4:4(125)
38. Mohsin M, Ali SA, Shamim SK, Ahmad A. A GIS-based novel approach for suitable sanitary landfill site selection using integrated fuzzy analytic hierarchy process and machine learning algorithms. *Environ Sci Pollut Res*. 2022;29(21):31511-31540. DOI:10.1007/s11356-021-17961-x
39. Mushtaq J, Dar AQ, Ahsan N. Spatial-temporal variations and forecasting analysis of municipal solid waste in the mountainous city of north-western Himalayas. *SN Appl Sci*. 2020;2(7):1161. DOI:10.1007/s42452-020-2975-x
40. Özkan B, Özceylan E, Sarıççek İ. GIS-based MCDM modeling for landfill site suitability analysis: A comprehensive review of the literature. *Environ Sci Pollut Res*. 2019;26(30):30711-30730. DOI:10.1007/s11356-019-06298-1
41. Pal MS, Bhatia M. Current status, topographical constraints, and implementation strategy of municipal solid waste in India: A review. *Arab J Geosci*. 2022;15(12):1176. DOI:10.1007/s12517-022-10414-w
42. Saaty TL, Vargas LG. *Models, methods, concepts & applications of the analytic hierarchy process*. New York: Springer; 2012.
43. Saini M, Mohd S. Integrating GIS and AHP for optimal landfill site selection: A case study of Alwar City, India. *Rev Electron Vet*. 2024;3850-3863. DOI:10.69980/redvet.v25i1.1857
44. Saini M, Mohd S, Kalia S. Analysing land use/land cover (LULC) changes and its dynamics using remote sensing and GIS: A case study of Bansur Tehsil in Rajasthan. *Int J Geogr Geol Environ*. 2024;6(2 Pt B):97-105.
45. Şener Ş, Sener E, Karagüzel R. Solid waste disposal site selection with GIS and AHP methodology: A case study in Senirkent-Uluborlu Basin, Turkey. *Environ Monit Assess*. 2011;173(1-4):533-554. DOI:10.1007/s10661-010-1403-x
46. Srivastava V, Ismail SA, Singh P, Singh RP. Urban solid waste management in the developing world with emphasis on India: Challenges and opportunities. *Rev Environ Sci Biotechnol*. 2015;14(2):317-337. DOI:10.1007/s11157-014-9352-4
47. Suleman HA, Baffoe PE. Selecting suitable sites for mine waste dumps using GIS techniques at Goldfields, Damang Mine. *Ghana Min J*. 2017;17(1):9-17. DOI:10.4314/gm.v17i1.2
48. Sumathi VR, Natesan U, Sarkar C. GIS-based approach for optimized siting of municipal solid waste landfill. *Waste Manag*. 2008;28(11):2146-2160. DOI:10.1016/j.wasman.2007.09.032
49. Tercan E, Dereci MA, Tapkın S. A GIS-based multi-criteria evaluation for MSW landfill site selection in Antalya, Burdur, Isparta planning zone in Turkey. *Environ Earth Sci*. 2020;79(10):246. DOI:10.1007/s12665-020-08974-9
50. United Nations. The sustainable development goals report 2024. Available from: <https://unstats.un.org/sdgs/report/2024/The-Sustainable-Development-Goals-Report-2024.pdf>
51. Torabi-Kaveh M, Babazadeh R, Mohammadi S, Zaresefat M. Landfill site selection using combination of GIS and fuzzy AHP: A case study of Iranshahr, Iran. *Waste Manag Res*. 2016;34(5):438-448. DOI:10.1177/0734242X16633777
52. Unal M, Cilek A, Guner ED. Implementation of fuzzy, Simos and SWOT analysis for municipal solid waste landfill site selection: Adana City case study. *Waste Manag Res*. 2020;38(1 Suppl):45-64. DOI:10.1177/0734242X19893111
53. Vasanthi P, Kaliappan S, Srinivasaraghavan R. Impact of poor solid waste management on groundwater. *Environ Monit Assess*. 2008;143(1-3):227-238. DOI:10.1007/s10661-007-9971-0
54. Vavatsikos AP, Demesouka OE, Anagnostopoulos KP. GIS-based suitability analysis using fuzzy PROMETHEE. *J Environ Plan Manag*. 2020;63(4):604-628. DOI:10.1080/09640568.2019.1599830
55. Wilson DC, Velis CA, Rodic L. Integrated sustainable waste management in developing countries. *Proc Inst Civ Eng Waste Resour Manag*. 2013;166(2):52-68. DOI:10.1680/warm.12.00005
56. Zambrano-Monserrate MA, Ruano MA, Ormeño-Candelario V. Determinants of municipal solid waste: A global analysis by countries' income level. *Environ Sci Pollut Res*. 2021;28(44):62421-62430. DOI:10.1007/s11356-021-15167-9
57. Karimi H, Amiri S, Huang J, Karimi A. Integrating GIS and multi-criteria decision analysis for landfill site selection: case study Javanrood County in Iran. *Int J Environ Sci Technol*. 2019;16(4):1885-1898. DOI:10.1007/s13762-018-2151-2157.

58. Saaty TL. The analytic hierarchy process: planning, priority setting, resource allocation. New York: McGraw-Hill; 1980.
59. Malczewski J. On the use of weighted linear combination method in GIS: common and best practice approaches. Trans GIS. 2000;4(1):5-22.
60. Rezaeisabzevar Y, Bazargan A, Zohourian B. Landfill site selection using multi criteria decision making: influential factors for comparing locations. J Environ Sci. 2020;93:170-184.
61. Elkharchy I. Solid waste assessment and management using remote sensing data and GIS tools: a case study of Najran City, KSA. IOP Conf Ser Earth Environ Sci. 2023.
62. Mvula PM, *et al.* GIS and AHP-based landfill site suitability analysis using multi-criteria decision-making approach. 2023.