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Optimizing Landfill Site Selection and Solid Waste Management in Urbanizing Regions: A Geospatial Analysis of Rewari City, Haryana, India

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ABSTRACT

Improper disposal of solid waste obstructs drainage systems and pollutes surface water. Additionally, the dumping of unsorted garbage generates emissions and leachate, which harm local ecosystems and contribute to climate change. With Rewari City's growing population, effective municipal solid waste management, including landfill site selection, is crucial. This study employs Geographic Information System (GIS), Analytical Hierarchical Process (AHP), and Weighted Linear Combination (WLC) methodologies to determine appropriate sites for landfills. The FAO, ALOS PALSAR DEM, Sentinel 2B images, Google Earth Pro, and interviews were employed to gather data. The results of the Analytic Hierarchy Process (AHP) indicate that 35.4% of the parameters under consideration are associated with Land Use Land Cover (LULC), whereas roads rank as the second most significant criterion, accounting for 24.0%. The WLC technique determined that 4.65 square kilometers were inappropriate for dump sites, while 0.11 square kilometers were extremely favorable. These findings can assist decision-makers in determining the order of importance for variables when selecting a landfill location.

INTRODUCTION

Solid waste refers to the range of garbage materials arising from human activities that are discarded as unwanted and useless. It encompasses various items, including discarded food, paper, plastics, metals, glass, and other industrial substances that pose significant environmental and health risks if not managed effectively (Al Arni & Elwaheidi 2020, Chandrappa & Das 2012, Cheremisinoff 2003). Annually, around 11.2 billion tonnes of solid trash is gathered globally, and the decomposition of the organic element of this waste is responsible for roughly 5 percent of total greenhouse gas emissions worldwide (UNEP, 2017). Individuals in metropolitan cities in India generate an average of 0.8 kilograms of waste per person every day. The annual municipal solid waste (MSW) generated in metropolitan India is projected to be 68.8 million tonnes (0.573 million metric tonnes per day) in 2008 (Hasan & Ghosal 2023, Karmakar et al. 2023). The composition of MSW generally consists of 51% organic waste, 17% recyclables, 11% hazardous waste, and 21% inert waste. Approximately 40% of all MSW remains uncollected, accumulating in urban areas and contaminating neighboring drains and water bodies. MSW not only causes blockages but also pollutes surface water. Failure to separate waste during collection and transportation results in the disposal of waste in open areas, which produces leachate and gaseous emissions while also generating disturbances in the nearby ecosystem. The leachate pollutes both the groundwater and surface water nearby, while the gaseous emissions add to the phenomenon of global warming. Thus, effective solid waste management is crucial to mitigate these risks and safeguard human health and the environment. Municipal solid waste, originating from households and commercial establishments, requires systematic collection, transportation, treatment, and disposal to prevent pollution and public health hazards (Hong et al. 2017, Narayana 2009, Singh 2019). Proper solid waste management is paramount, emphasizing the need for appropriate landfill site selection and waste disposal practices. This study explores the various aspects of solid waste management and the importance of landfill site selection in promoting sustainable waste management practices and protecting the environment.

Landfill site selection is critical in municipal solid waste management, which aims to mitigate environmental pollution, protect human health, and ensure urban development. Proper site selection for landfills is essential to minimize the negative impacts of waste disposal on the environment and local communities, including the prevention of water contamination, disease transmission, and other health hazards (Ampofo et al. 2022, Rawal 2019). The selection process involves evaluating multiple criteria, such as environmental, social, technical, and economic factors, to identify locations that are both environmentally sound, economically feasible, and socially acceptable. The complexity of this decision-making problem is compounded by the need to comply with regulations and to consider the long-term implications of landfill operations (Unal et al. 2020).

The Analytical Hierarchy Process (AHP) method and Weighted Linear Combination (WLC) technique are valuable tools in the identification of solid waste disposal sites, offering structured approaches to decision-making (Rahmat et al. 2017, Shahabi et al. 2014). AHP involves breaking down the decision criteria into a hierarchical structure, comparing them pairwise to determine their relative importance, and synthesizing these comparisons to obtain the final ranking of alternatives. This method helps decision-makers consider various factors such as environmental impact, proximity to residential areas, and cost-effectiveness. On the other hand, the WLC technique assigns weights to different criteria based on their importance and combines these weighted criteria to create a composite score for each potential site (Zarin et al. 2021). By integrating these two methods, decision-makers can comprehensively evaluate potential waste disposal sites, leading to more informed and sustainable decisions in solid waste management.

Geographic Information System (GIS) is critical in the landfill site selection process to enable a methodical and scientific approach (Isalou et al. 2013, Jamshidi-Zanjani & Rezaei 2017, Sekulovic & Jakovljevic 2016). GIS facilitates the visualization of spatial data through maps, aiding in interpreting complex relationships and patterns. Multicriteria decision analysis techniques, such as the Analytical Hierarchical Process (AHP) and Weighted Linear Combination (WLC), improve decision-making by taking into account multiple criteria and stakeholder input (Islam et al. 2018, Mousavi et al. 2022, Rezaeisabzevar et al. 2020). Contemporary techniques emphasize the importance of merging indigenous knowledge with advanced spatial data to improve the analysis of site appropriateness (Mussa & Suryabhagavan 2021, Yildirim et al. 2018, Yousefi et al. 2018). The importance of this selection process is underscored by the need for sustainable waste management practices that align with environmental protection goals, urban life quality, and economic considerations (Hussien & Meaza 2019, Unal et al. 2020, Wayessa et al. 2021).

MATERIALS AND METHODS

The Study Area

Rewari is a municipal city located in the state of Haryana. It is situated between 28°10’25.48’’ to 28°13’33.99’’ North latitudes and 76°34’23.45’’ to 76°39’30.29’’ East longitudes (Fig. 1). The city has a total land area of 25.49 square kilometers. The climate of Rewari is predominantly tropical steppe, semi-arid, and hot. Dry conditions, with scorching summers and chilly winters, characterize it. Four distinct seasons occur in a single year. The hot weather season commences in mid-March and extends until the last week of June, after which it is succeeded by the southwest monsoon, which persists until September. The onset of the southwest monsoon occurs in the final week of June and concludes at the end of September, accounting for around 88% of the total annual precipitation. Due to the city’s fast industrialization, the number of emigrants has been rising, causing the population to undergo an inflow at various times. The requirement to process household garbage has increased and will continue to increase with the population. To make the city a better place to live, the current waste collection system needs to be updated or replaced with something more modern.

Data Sets

The current study focuses on the identification of landfill sites using Geographic Information System (GIS) techniques. The study utilizes several datasets from various sources to analyze and identify suitable locations for landfill sites. The Land Use Land Cover (LULC) data is sourced from Sentinel 2B satellite imagery having a resolution of 10 meters, which provides detailed information on land cover types. Data on roads, water bodies, canals, and sensitive places are digitized from Google Earth Pro images, aiding in understanding the environmental and social context of the area. Soil data is sourced from the Food and Agriculture Organization of the United Nations (FAO), providing information on soil types and characteristics. The slope data, crucial for identifying suitable landfill sites, is derived from the ALOS PALSAR Digital Elevation Model (DEM) with a resolution of 12.5 meters. The outer boundary of the city, a key reference for the study area, is obtained from the Department of Town and Country Planning, Haryana. Additional information was collected through interviews with environmental protection officers and citizens near current dumps. The input datasets were georeferenced to the UTM Zone 43N coordinate system and classed with assigned weights. These classed datasets were used to build new maps within the GIS environment. The shapefiles were transferred to the respective feature datasets, and the raster files were transferred as separate raster datasets within the geodatabase. Integrating these datasets, the study aims to identify suitable locations for landfill sites, considering environmental, social, and infrastructural factors. All the data sets are summarized in Table 1.

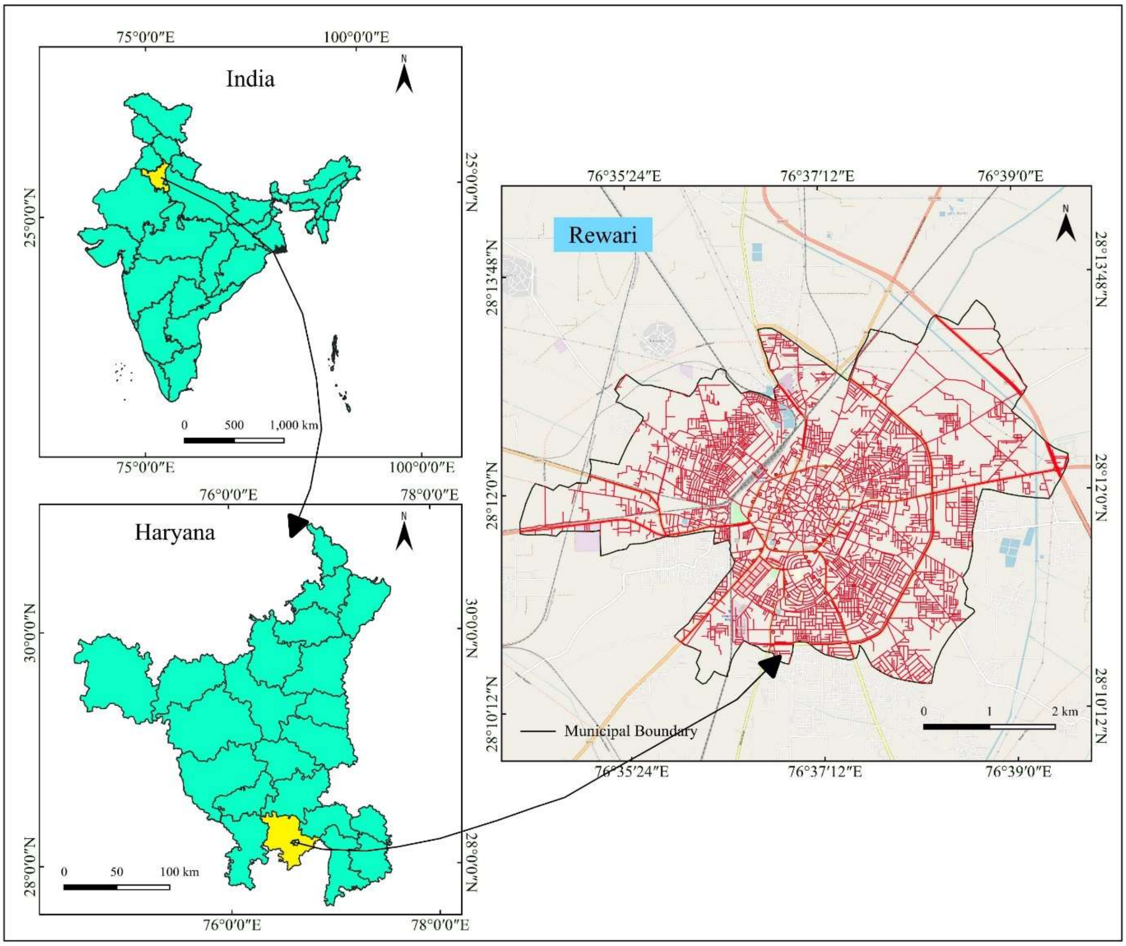

Fig. 1: Study area map.

Table 1: Details of the dataset used to identify landfill sites.

Data	Data Source	Year	Web Access
LULC	Sentinel 2B	2024	https://scihub.copernicus.eu/
Roads	Google Earth Pro	2024	https://earth.google.com/
Water Bodies	Google Earth Pro	2024	https://earth.google.com/
Canal	Google Earth Pro	2024	https://earth.google.com/
Sensitive Places	Google Earth Pro	2024	https://earth.google.com/
Soil	Food and Agriculture Organization UN	1961	https://www.fao.org/soils-portal/
Slope	ALOS PALSAR DEM	2007	https://search.asf.alaska.edu/

Selection of Criteria

Seven criteria, namely LULC, roads, water bodies, canals, sensitive places, soil, and slope were selected to identify suitable landfill sites. The Land Use Land Cover (LULC) data provides insights into the current land cover types, which are essential for understanding the existing landscape and its compatibility with landfill operations. Road networks are vital in determining accessibility to potential landfill sites, ensuring efficient waste transportation and management. Water bodies' data is important to avoid contamination and ensure compliance with environmental regulations. Similarly, canal data helps assess potential impacts on water resources and the surrounding environment. Information on sensitive places such as schools, hospitals, and parks is critical to avoid adverse impacts on human health. Soil data provides insights into the soil characteristics, which influence the suitability of a site for landfill operations. Lastly, slope data is essential for identifying suitable areas with minimal slope, as steep slopes can lead to erosion and instability.

Selection of Buffers for Each Criterion

According to the "Solid Waste Management Rules, 2016", issued by the Ministry of Environment, Forest and Climate Change, India, certain buffer zones are mandated for landfill site construction to protect sensitive areas. Roads require a buffer zone of 500 meters, while water bodies necessitate a 200-meter buffer, and canals require a 30-meter buffer zone. Similarly, sensitive places such as schools, hospitals, and residential areas should have a buffer zone of 500 meters to prevent adverse impacts from landfill operations. In addition to these buffer zones, land suitability for landfill construction is determined by the Land Use Land Cover (LULC) classification, where barren land is considered most suitable due to minimal environmental impact. Low slope gradients are preferred for landfill sites, as they reduce the risk of erosion and instability. Sandy soil is also considered ideal for landfill construction, as it allows for better drainage and reduces the risk of groundwater contamination. By adhering to these guidelines and considering these factors, the construction of landfill sites can be planned to minimize environmental and social impacts, ensuring sustainable waste management practices.

Methods

The methodology for identifying suitable landfill sites begins with the acquisition of data from various sources, including satellite imagery, government records, and field surveys. This data is essential for understanding the environmental and socio-economic context of the study area. Once obtained, the data is processed and projected to the UTM 43N coordinate system using QGIS to ensure consistency in analysis across different datasets. Digitization is carried out where necessary, such as for roads, canals, and other features, to create digital

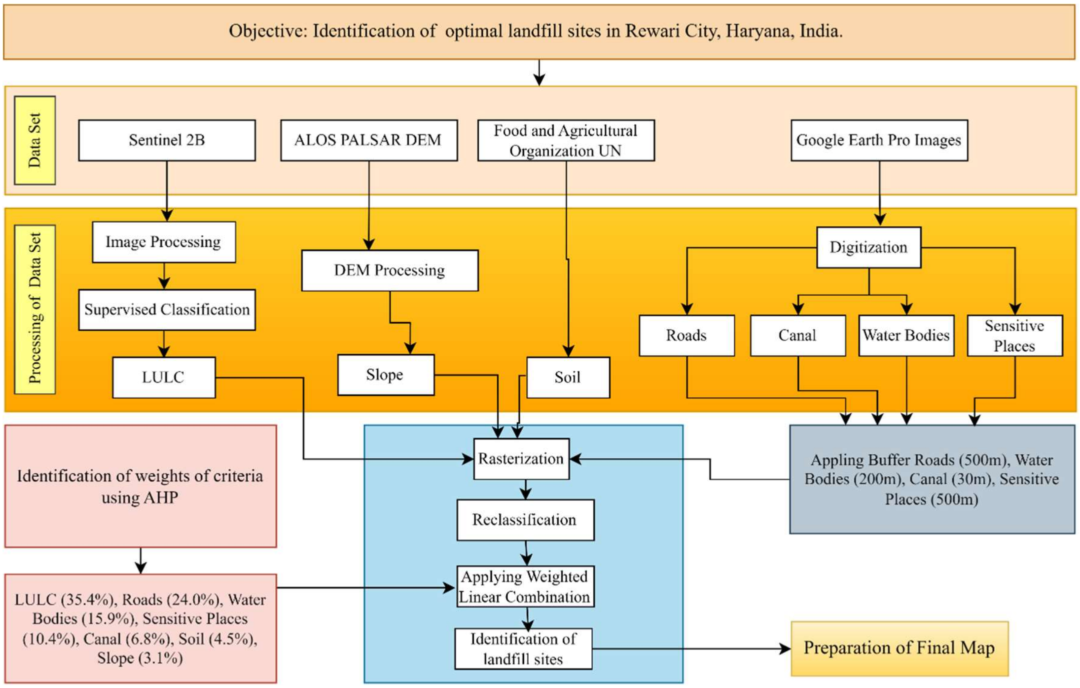

Fig. 2: Flow chart of the methodology used in this study.

representations of these elements. Thematic maps are then prepared for seven Criteria viz. Land Use Land Cover (LULC), Roads, Water Bodies, Canal, Sensitive Places, Soil, and Slope. These maps provide detailed information on the characteristics of the study area, helping to identify suitable locations for landfill sites. Boolean Constraints are applied using different buffer values specified earlier to determine areas where landfill construction is prohibited. For example, a buffer of 500 meters is applied to roads and sensitive places, while a buffer of 200 meters is applied to water bodies. These buffers help to delineate areas where construction should be avoided due to potential environmental or social impacts. Each thematic layer is then rasterized to convert them into raster datasets, which can be more easily analyzed and manipulated. For the purpose of landfill site selection, the AHP method is used to give each thematic layer a weight according to its relative value. Lastly, a comprehensive landfill site suitability map is generated by combining all the criteria using the Weighted Linear Combination technique. The methodology is depicted in Fig. 2.

Analytic Hierarchy Process (AHP)

The AHP is a method for making decisions based on several criteria. It involves defining important criteria for prioritization, such as land-suitability variables, morphometric characteristics, and flood susceptibility factors (Arulbalaji et al. 2019, Hembram & Saha 2020). These criteria are subsequently compared in pairs to determine their relative significance, using a scale ranging from 1 to 9 based on Saaty's fundamental scale. The comparisons' reliability is assessed by evaluating the consistency of these judgments using consistency ratios. The criteria weights are determined by combining the pairwise comparison matrices using the eigenvector approach. These weights are utilized to compute the comprehensive scores of the criteria, hence establishing their priority levels for Landfill Suitable Sites (Ali et al. 2023, Beskese et al. 2015, Mahammad & Islam 2021).

Dividing the consistency index (RI) by the random index yields the consistency ratio (Eq. 1 & Eq. 2). The random index depends on the size of the matrix being compared and is used to determine the acceptable level of inconsistency based on the number of criteria or alternatives. The consistency ratio should ideally be less than 0.1 (10%) for the judgments to be considered consistent. If the consistency ratio exceeds 0.1, it indicates that the judgments are not sufficiently consistent.

$$\text{Consistency Ratio (CR)} = \frac{\text{Consistency Index (CI)}}{\text{Random Index (RI)}} \quad \ldots(1)$$

where the Consistency Index (CI) is calculated as:

$$\text{Consistency Index (CI)} = \frac{\lambda\text{max} - \text{n}}{\text{n} - 1} \quad \ldots(2)$$

Here, λ_{max} is the maximum eigenvalue of the pairwise comparison matrix, and n is the number of criteria or alternatives being compared.

Weighted Linear Combination

The weighted linear combination (WLC) model is a highly prevalent decision-making approach in Geographic Information Systems (GIS) (Mahini & Gholamalifard 2006, Salman 2006). The technique is commonly utilized in the investigation of land use suitability, site selection, and resource appraisal problems (Al-Hanbali et al. 2011, He et al. 2014, Malczewski 2000, Moeinaddini et al. 2010, Yin et al. 2020). The main factor contributing to its widespread use is the method's simplicity in implementation inside the GIS environment through the utilization of map algebra operations and cartographic modeling (Dhakal & Sharma 2024, Ghosh & Lepcha 2019). The WLC technique for identifying landfill sites involves several key steps. Firstly, the objectives of the analysis are defined, and attribute map layers representing different study area characteristics, such as land use and slope, are identified. Feasible alternatives representing different locations within the study area are then identified. The commensurate attribute maps are created by transforming the original attribute values into a common scale, i.e., from 1 to 5. This transformation ensures that all criteria are comparable and can be combined effectively. After this, the combination of attribute maps and weights is done using a weighted sum approach, where each normalized attribute map is multiplied by its corresponding weight and then added together to obtain the overall suitability score for each alternative cell Eq. 3.

$$S = \sum_{i=1}^{n} W_i \, X \, f_i \quad \ldots(3)$$

S = overall suitability score, Wi = weight of the i^{th} evaluation factor, fi = suitability score of the i^{th} evaluation factor.

According to Eastman et al. (1993, 1995), the WLC model can be adjusted for GIS applications by including constraint maps using Eq. 4. In this equation, r_{jk} represents the value assigned to the j^{th} cell on the k^{th} constraint map layer. A value of 1 is given to feasible cells, while a value of 0 is assigned to cells that are not feasible.

$$S = \sum_{i=1}^{n} (W_i f_i) \prod_{j=1}^{m} r_{jk} \quad \ldots(4)$$

Finally, the alternatives are ranked based on their suitability scores, with higher scores indicating greater suitability for landfill site selection. The WLC method provides a systematic and transparent approach to decision-making, allowing for a more informed and defensible selection of landfill sites.

RESULTS AND DISCUSSION

Criteria

Land Use Land Cover (LULC): Land Use Land Cover (LULC) is the classification of the earth's surface based on human activities and natural features. It is a critical Criteria in landfill site selection as it helps in identifying areas that are already in use or have a certain cover, such as agricultural, residential, or industrial zones, which may not be suitable for landfilling due to potential conflicts with existing land uses (Rahmat et al. 2017a, Sekulovic & Jakovljevic 2016). The study area's suitable landfill sites were identified using a land use land cover (LULC) map prepared from Sentinel 2 satellite imagery. The map was generated using supervised classification in GIS software, categorizing the land cover into agricultural land, vegetation, built-up area, water bodies, and barren land (Fig. 3a). Barren land was identified as suitable for landfill sites. Because barren land typically has low ecological value, it is often flat and devoid of vegetation, and placing landfills on barren land can minimize conflicts with other land uses and reduce the risk of contamination of nearby water bodies or agricultural areas.

Roads: Roads are considered in landfill site selection due to the need for accessible transportation routes for waste collection vehicles. Proximity to roads can reduce transportation costs and environmental impacts but must be balanced against the potential for traffic congestion and accidents (MAlanbari et al. 2014a, 2014b). The road network map was created using Open Street Maps as the base data source. To assess the suitability of different areas for landfill sites based on their proximity to roads, buffers were applied at intervals of 200, 300, 400, 500, and greater than 500 meters around the road network (Fig. 4). These buffer zones were then reclassified into distance zones, ranked from 1 to 5, to indicate their suitability for landfill sites. In the reclassification scheme, distance zone 1 represents areas within 0 to 200 meters of roads, which are considered less suitable for landfill sites due to potential proximity to roads (Table 2). Conversely, distance zone 5 represents areas located more than 500 meters away from roads, indicating higher suitability for landfill sites.

Water Bodies: Water Bodies, including lakes, rivers, and streams, are important to consider because landfills must be situated at a safe distance to prevent contamination of these water sources through leachate migration (Rahmat et al. 2017, Şener et al. 2011). The water bodies in the study area were demarcated using images from Google Earth Pro in order to evaluate their proximity to prospective landfill locations. Buffers were implemented at regular intervals of 50, 100, 150, 200, and beyond 200 meters surrounding the water bodies (Fig. 4). These buffer zones were then categorized into distance zones ranging from 1 to 5 (Table 2). The suitability of zone 1, which encompasses locations within a 0 to 50-meter radius of water bodies, is lower due to the heightened probabilities of water contamination, adverse effects on aquatic ecosystems, and environmental effects. In contrast, distance zone 5, which encompasses lands situated over 200 meters distant from water bodies, was deemed extremely appropriate for dump sites due to the diminished likelihood of water contamination and ecological damage.

Canals: Canals, like other water bodies, must be protected from potential landfill pollution. They are also part of the infrastructure that may need to be considered for the management of stormwater and leachate from the landfill site (Sk et al. 2020). The study area's canal network was mapped using Google Earth Pro images (Fig 3c). Buffer zones were established at 30-meter intervals and beyond 30 meters from the canals (Fig. 4). The reclassed distance zone 1 denotes areas within 0 to 30 meters from the canals, which are deemed less suitable for landfill sites due to heightened risks of water contamination and environmental impact (Table 2). Conversely, distance zone 5 signifies areas located more than 30 meters away from the canals, which are considered highly suitable for landfill sites due to reduced risks of water pollution and environmental harm.

Sensitive Places: Sensitive Places refer to areas such as schools, hospitals, and protected natural habitats. Landfills should not be located near these places to avoid adverse effects on human health and the environment (Mohsin et al. 2021, Sekulovic & Jakovljevic 2016). The map of sensitive places, which includes schools, hospitals, and parks, was created using Google Earth Pro image (Fig. 3e). Buffers were applied at intervals of 200, 300, 400, 500, and greater than 500 meters around these sensitive locations and then reclassified into distance zones, ranging from 1 to 5, where distance zone 1 represents areas within 0 to 200 meters from sensitive places (Fig. 4) (Table 2), which are considered less suitable for landfill sites due to potential impacts on public health, safety, and quality of life. On the other hand, distance zone 5 represents areas located more than 500 meters away from sensitive places, which are deemed highly suitable for landfill sites due to minimized disturbance to these areas, enhanced public health and safety by reducing environmental hazards, and improved community relations.

Soil: Soil is a key factor in landfill site selection due to its role in the natural attenuation of contaminants and support for the landfill structure. Soil type affects the permeability and stability of the site, which are crucial for preventing leachate migration and ensuring structural Ramu integrity (Ramu et al. 2023).

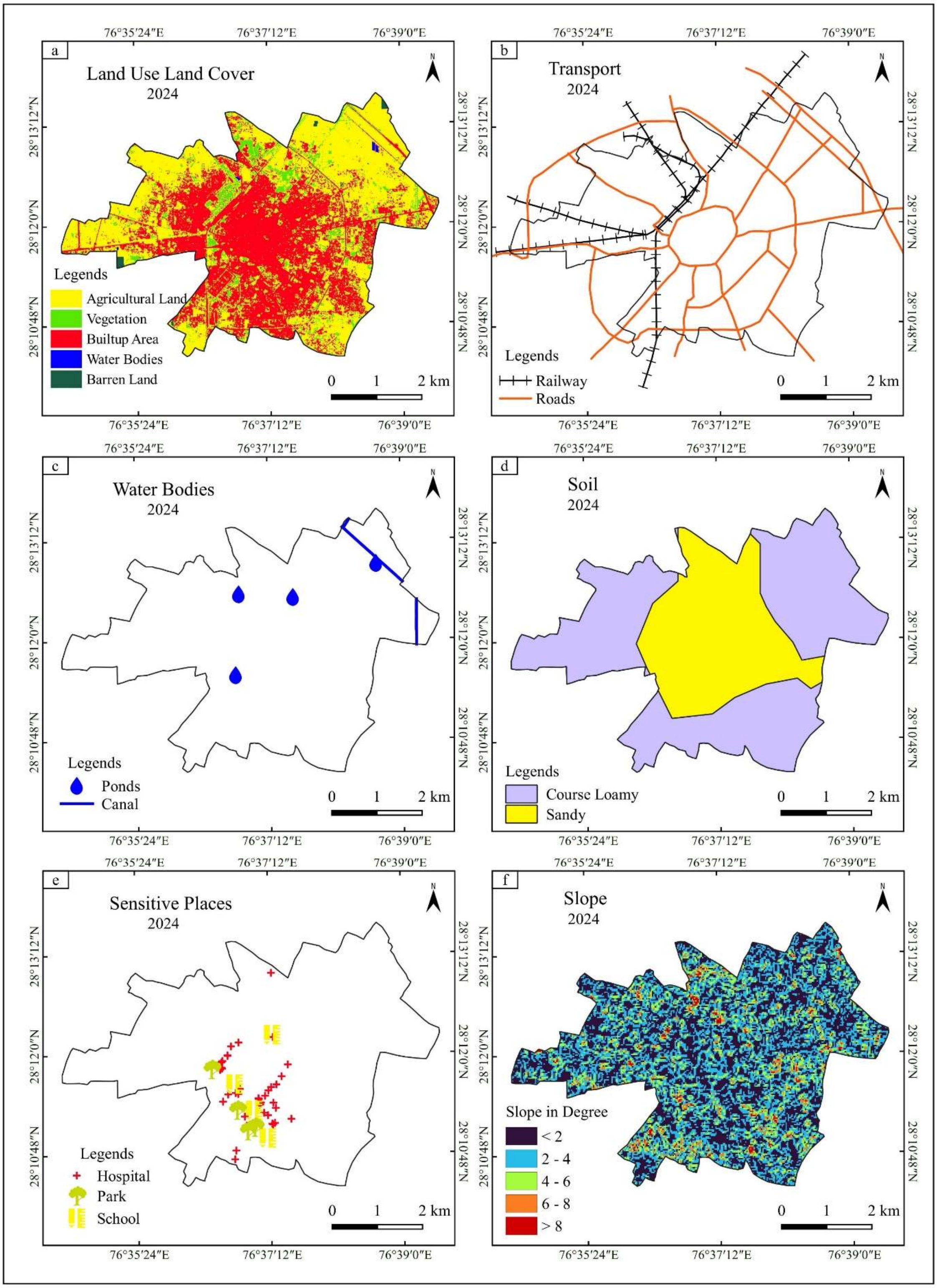

Fig. 3: Map showing the distribution of criteria in the Rewari City, namely LULC (a), roads (b), water bodies (c), canals (c), soil (d), sensitive places (e), and slope (f).

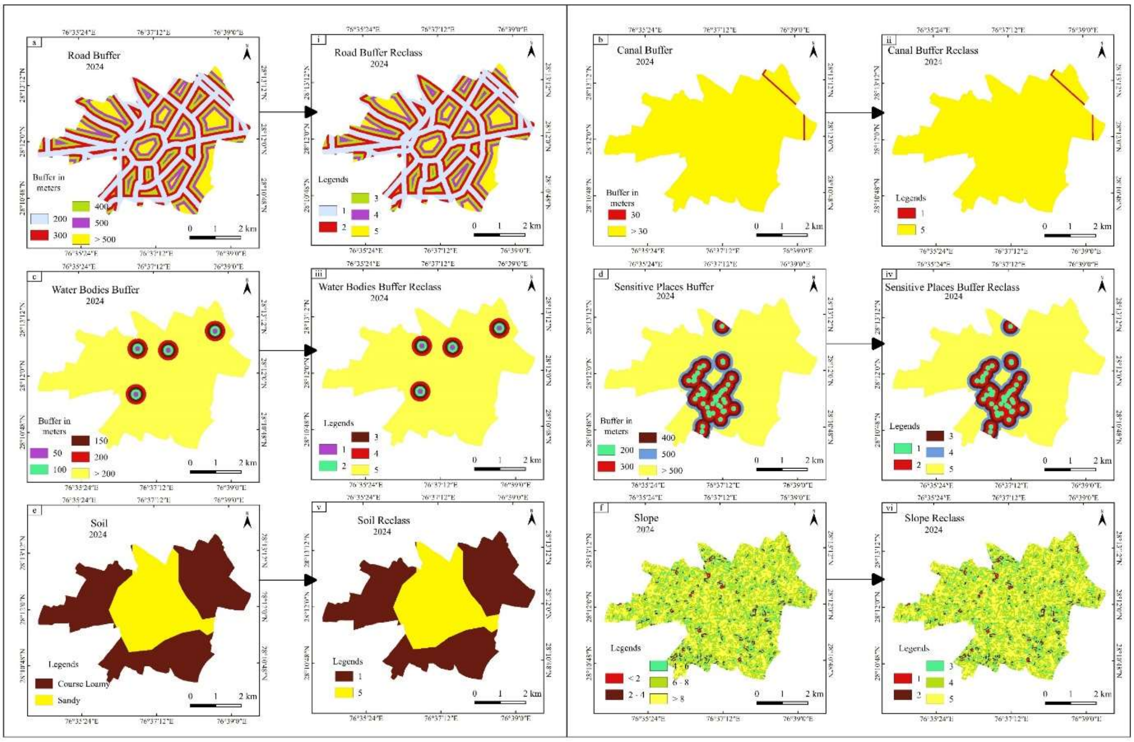

Fig. 4: Map showing the buffer applied on each criterion and their respective ranking from 1 to 5.

The soil map was developed using data from the FAO to assess its suitability for landfill sites based on soil types. The soil was classified into two main categories, Course Loamy and Sandy (Fig. 3d). These classifications were further reclassified into Zone 1, representing Course Loamy soil, considered less suitable, and Zone 5, representing Sandy soil, considered highly suitable for landfill sites (Fig. 4) (Table 2). Advantages of locating landfill sites in sandy soil include enhanced drainage, lower environmental impact due to reduced contaminant spread, and easier construction. However, disadvantages include the risk of leachate migration, the potential for subsidence, and limited soil stability, which can pose challenges for landfill infrastructure.

Slope: The slope is relevant because steep slopes can complicate landfill construction and operation, increase erosion risks, and affect the stability of the landfill. Flatter areas are generally preferred to minimize these issues (Ramu et al. 2023, Şener et al. 2011). The slope map was generated using the ALOS PALSAR Digital Elevation Model to evaluate its suitability for landfill sites based on the degree of slope. The slope was classified into five categories: slopes less than 2 degrees, slopes between 2-4 degrees, slopes between 4-6 degrees, slopes between 6-8 degrees, and slopes greater than 8 degrees (Fig. 3f). These categories were reclassified into distance zones ranging from 1 to 5, with zone 1 representing slopes greater than 8 degrees, considered less suitable, and zone 5 representing slopes less than 2 degrees, considered highly suitable for landfill sites (Fig. 4) (Table 2).

Identification of Suitable Sites

The identification of landfill sites is a multifaceted process that incorporates various criteria, and both the AHP and WLC are prominent methods used in this context. AHP is advantageous for its ability to handle multiple criteria and its simplicity in dealing with both qualitative and quantitative data, which is crucial for prioritizing landfill siting alternatives (Moeinaddini et al. 2010). The results of AHP indicate that Land Use Land Cover (LULC) was assigned the highest weightage, comprising 35.4% of the decision-making process (Table 2, Table 3 and Table 4). This suggests that the composition and characteristics of the land, including its current use and cover types, are deemed crucial in site selection. Roads were deemed the second most important criterion, with a weightage of 24.0%, highlighting the significance of accessibility and transportation infrastructure in landfill site planning. Water Bodies followed closely behind, with a weightage of 15.9%, emphasizing the need to consider environmental factors and potential impacts on water resources. Sensitive Places,

Table 2: Criteria for Landfill site selection suitability and their rank.

Sr. No.	Factor	Sub-criteria/alternatives	Suitability index (ranking)	Area in sq. km	Area (%)
1	LULC	Agricultural Land	3	12.6	49.41
		Vegetation	4	1.96	7.69
		Builtup	1	10.78	42.27
		Water Bodies	2	0.08	0.31
		Barren Land	5	0.08	0.31
2	Roads	200	1	9.87	38.71
		300	2	6.62	25.96
		400	3	4.31	16.90
		500	4	2.55	10.00
		> 500	5	2.16	8.47
3	Canal	30	1	0.19	0.75
		> 30	5	25.31	99.25
4	Water Bodies	50	1	0.12	0.47
		100	2	0.37	1.45
		150	3	0.62	2.43
		200	4	0.87	3.41
		> 200	5	23.49	92.12
5	Soil	Course Loamy	1	16	62.75
		Sandy	5	9.5	37.25
6	Sensitive Places	200	1	1.1	4.31
		300	2	1.75	6.86
		400	3	1.53	6.00
		500	4	1.45	5.69
		> 500	5	19.67	77.14
7	Slope	< 2	5	0.25	0.98
		2 to 4	4	0.81	3.18
		4 to 6	3	3.34	13.10
		6 to 8	2	10.67	41.84
		> 8	1	10.42	40.86

Table 3: Pairwise comparison matrix for Criteria for solid waste management.

	LULC	Roads	Water Bodies	Sensitive Places	Canal	Soil	Slope
LULC	1	2	3	4	5	6	7
Roads	1/2	1	2	3	4	5	6
Water Bodies	1/3	1/2	1	2	3	4	5
Sensitive Places	1/4	1/3	1/2	1	2	3	4
Canal	1/5	1/4	1/3	½	1	2	3
Soil	1/6	1/5	1/4	1/3	1/2	1	2
Slope	1/7	1/6	1/5	¼	1/3	1/2	1

including schools, hospitals, and parks, were assigned a weightage of 10.4%, indicating the importance of minimizing the impact on these areas. Canals and Soil were assigned weightage of 6.8% and 4.5%, respectively, suggesting that

Table 4: Principal eigenvector of the pairwise comparison matrix.

Sr. No.	Criterion	Weights	Error (+/-)
1	LULC	35.4%	9.7%
2	Roads	24.0%	5.4%
3	Water Bodies	15.9%	3.5%
4	Sensitive Places	10.4%	2.4%
5	Canal	6.8%	1.6%
6	Soil	4.5%	1.1%
7	Slope	3.1%	1.0%

λ_{max} = 7.19, CI = 0.09, RI = 1.32, CR = 2.4% i.e. less than 10%.

while they are considered in site selection, their influence is relatively lower compared to other factors (Table 4). The slope was assigned the lowest weightage of 3.1%, indicating that while terrain characteristics are considered, they are of lesser importance compared.

WLC, on the other hand, is frequently employed for the initial identification of suitable sites by integrating multiple criteria into a composite index (Rezaeisabzevar et al. 2020). It is a multicriteria decision-making approach used to derive composite maps in Geographic Information Systems (GIS) and to evaluate based on multiple criteria in various fields. The fundamental formula for WLC is given by the sum of the products of the criteria values and their corresponding {(LULC × 35.4) + (Roads × 24) + (Water Bodies × 15.9) + (Sensitive Places 10.4) + (Canal × 6.8) + (Soil × 4.5) + (Slope × 3.1)} (Malczewski 2000, Mateo 2012, Sivaji et al. 2022). The results indicate that out of the total study area, the largest proportion was classified as "Less Suitable," covering an area of 12.58 square kilometers (Fig. 5, Fig. 6). This suggests that a significant portion of the study area meets the criteria set for less suitability for landfill sites. The second-largest category was "Unsuitable," with an area of 4.65 square kilometers, indicating areas that do not meet the criteria for landfill site suitability. "Moderately suitable" sites covered an area of 3.46 square kilometers, suggesting areas that may require further evaluation or mitigation

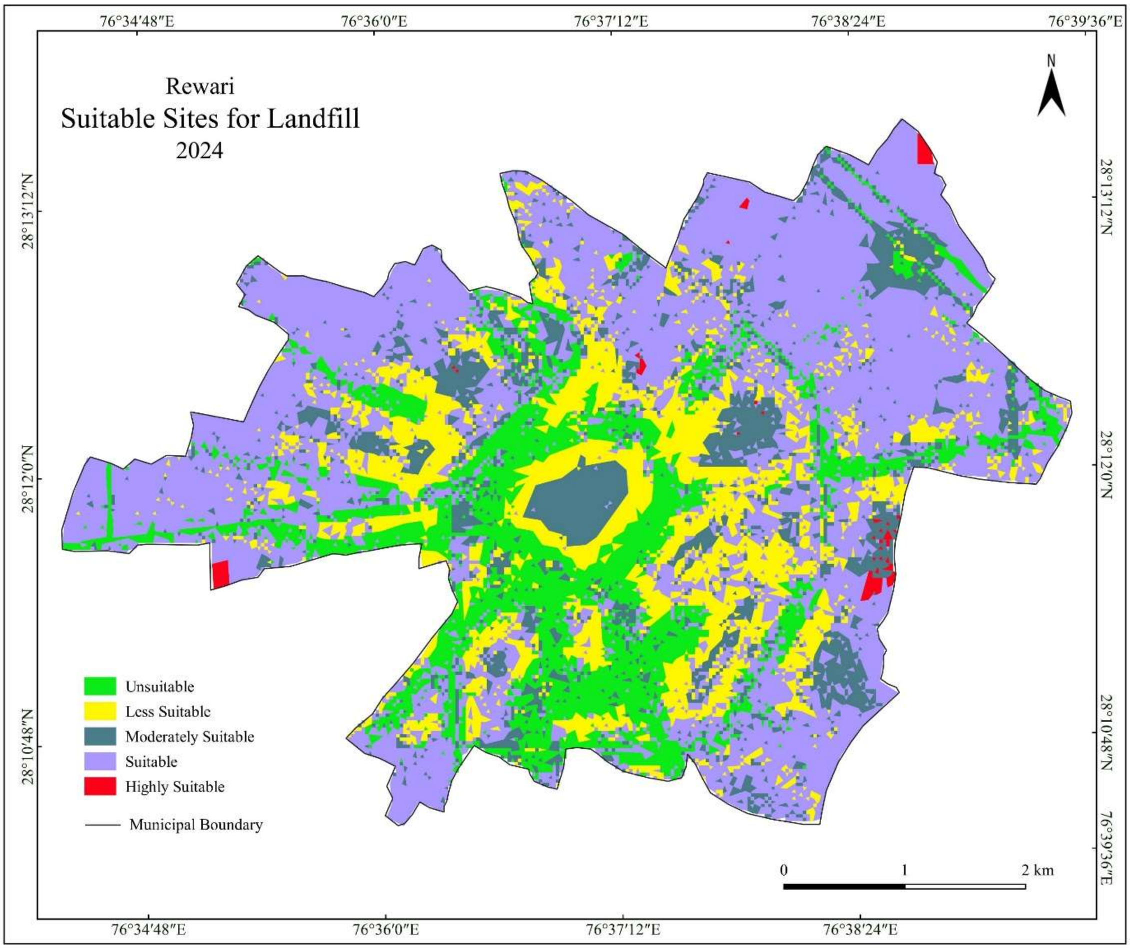

Fig. 5: Final map of landfill site suitability.

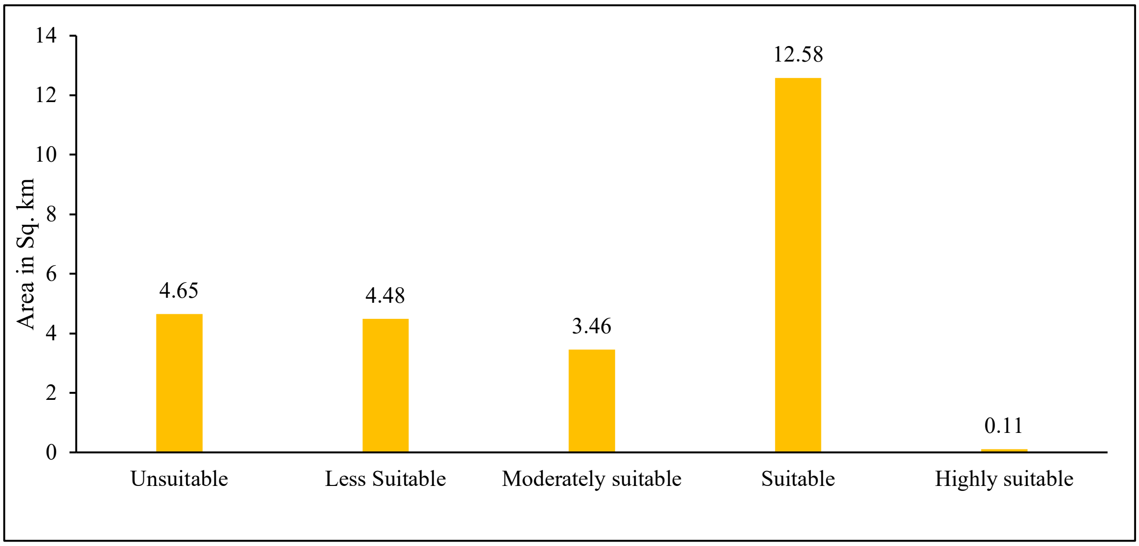

Fig. 6: Area under landfill site suitability classes.

measures before being considered suitable. Interestingly, a small area of 0.11 square kilometers was classified as “Highly suitable,” indicating a small but potentially ideal location for landfill development (Fig. 5, Fig. 6).

Both the AHP and WLC are valuable in the landfill site selection process. Their integration within a GIS environment is particularly effective. The combination of AHP and WLC within a GIS framework is also recommended for its ability to minimize public health risks and environmental degradation (Saleh et al. 2020). The findings of this work provide valuable insights for decision-makers and planners in identifying appropriate sites for landfill development while considering various environmental and socio-economic factors.

CONCLUSIONS

The study focuses on identifying landfill sites using Geographic Information Systems (GIS) techniques. It uses various datasets from various sources, including Sentinel 2B satellite imagery, Google Earth Pro images, water bodies, canals, and sensitive places data, soil data from the FAO, slope data from ALOS PALSAR Digital Elevation Model (DEM), and interviews with environmental protection officers and citizens. Each of these criteria plays a significant role in landfill site selection. LULC ensures compatibility with existing land uses, roads provide necessary access, water bodies and canals must be protected from contamination, sensitive places require a buffer from landfill impacts, soil properties are crucial for containment and stability, and slope affects the feasibility of construction and operation. The AHP and WLC are prominent methods used in this context. AHP is advantageous for its ability to handle multiple criteria and its simplicity in dealing with both qualitative and quantitative data. The results indicate that Land Use Land Cover (LULC) is the highest weightage, comprising 35.4% of the decision-making process. Roads are the second most important criterion, with 24.0% emphasizing the significance of accessibility and transportation infrastructure in landfill site planning. Water Bodies follow closely behind, with 15.9%, emphasizing the need to consider environmental factors and potential impacts on water resources. Sensitive Places, including schools, hospitals, and parks, are assigned 10.4%, emphasizing the importance of minimizing their impact. Canals and Soil are assigned 6.8% and 4.5%, respectively, suggesting that while they are considered in site selection, their influence is relatively lower compared to other factors. Notably, a compact region measuring 0.11 square kilometers was designated as “Highly suitable,” suggesting a modest yet possibly optimal site for landfill expansion. The findings provide valuable insights for decision-makers and planners in identifying appropriate sites for landfill development while considering various environmental and socio-economic factors. The combination of AHP and WLC within a GIS framework is recommended for its ability to minimize public health risks and environmental degradation.

REFERENCES

Al Arni, S.S. and Elwaheidi, M.M., 2020. Solid Waste Management. In: *Concise Handbook of Waste Treatment Technologies*, pp.29–37. https://doi.org/10.1201/9781003112266-6

Alanbari, M.A., Al-Ansari, N. and Jasim, H.K., 2014a. GIS and multicriteria decision analysis for landfill site selection in AL-HashimyahQadaa. *Natural Science*, 6(5), pp.282–304.

Alanbari, M., Al-Ansari, N., Jasim, H. and Knutsson, S., 2014b. Al-Mseiab

Qadaa landfill site selection using GIS and multicriteria decision analysis. *Engineering*, 6(9), pp.526–549.

Al-Hanbali, A., Alsaaideh, B. and Kondoh, A., 2011. Using GIS-based weighted linear combination analysis and remote sensing techniques to select optimum solid waste disposal sites within Mafraq City, Jordan. *Journal of Geographic Information System*, 3(04), pp.267.

Ali, I., Islam, A., Ali, S.M. and Adnan, S., 2023. Identification and selection of suitable landfill sites using GIS-based multi-criteria decision analysis in the Peshawar District, Pakistan. *Waste Management & Research*, 41(3), pp.608–619.

Ampofo, S., Sackeyb, I., Danaaa, L. and Kusibua, M.M., 2022. Multi-criteria assessment (Mca) and selection of a solid waste disposal site within Wa Municipality, Upper West Region, Ghana. *Journal of Wastes and Biomass Management (JWBM)*, 4(2), pp.83–91.

Arulbalaji, P., Padmalal, D. and Sreelash, K., 2019. GIS and AHP techniques based delineation of groundwater potential zones: A case study from southern Western Ghats, India. *Scientific Reports*, 9(1), pp.2082.

Beskese, A., Demir, H.H., Ozcan, H.K. and Okten, H.E., 2015. Landfill site selection using fuzzy AHP and fuzzy TOPSIS: a case study for Istanbul. *Environmental Earth Sciences*, 73(7), pp.3513–3521. https://doi.org/10.1007/S12665-014-3635-5

Chandrappa, R. and Das, D.B., 2012. *Solid Waste Management*. Springer, p.681. https://doi.org/10.1007/978-3-642-28681-0

Cheremisinoff, N.P., 2003. *Handbook of Solid Waste Management and Waste Minimization Technologies*. Oxford Publications, pp.34–95. https://doi.org/10.1016/B978-075067507-9/50004-8

Dhakal, D. and Sharma, K., 2024. QWLCPM: A Method for QoS-Aware Forwarding and Caching Using Simple Weighted Linear Combination and Proximity for Named Data Vehicular Sensor Network. *Electronics*, 13(7), p.1183.

Ghosh, P. and Lepcha, K., 2019. Weighted linear combination method versus grid-based overlay operation method–A study for potential soil erosion susceptibility analysis of Malda district (West Bengal) in India. *The Egyptian Journal of Remote Sensing and Space Science*, 22(1), pp.95–115.

Hasan, M.S. and Ghosal, S., 2023. Informal plastic waste recycling firms in rural eastern India: Implications for livelihood and health. *Clinical Epidemiology and Global Health*, 21, p.1286. https://doi.org/10.1016/J.CEGH.2023.101286

He, X., Hong, Y., Yu, X., Cerato, A.B., Zhang, X. and Komac, M., 2014. *Landslide Science for a Safer Geoenvironment: Methods of Landslide Studies*. Springer, pp.371–377.

Hembram, T.K. and Saha, S., 2020. Prioritization of sub-watersheds for soil erosion based on morphometric attributes using fuzzy AHP and compound factor in Jainti River basin, Jharkhand, Eastern India. *Environment, Development and Sustainability*, 22(2), pp.1241–1268. https://doi.org/10.1007/S10668-018-0247-3

Hong, J., Chen, Y., Wang, M., Ye, L., Qi, C., Yuan, H., Zheng, T. and Li, X., 2017. Intensification of municipal solid waste disposal in China. *Renewable and Sustainable Energy Reviews*, 69, pp.168–176.

Hussien, K. and Meaza, H., 2019. A GIS-based multi-criteria evaluation approach location suitability modeling for solid waste disposal: Dire Dawa City, East Hararghe, Ethiopia. *Papers in Applied Geography*, 5(3–4), pp.272–293.

Isalou, A.A., Zamani, V., Shahmoradi, B. and Alizadeh, H., 2013. Landfill site selection using integrated fuzzy logic and analytic network process (F-ANP). *Environmental Earth Sciences*, 68(6), pp.1745–1755. https://doi.org/10.1007/S12665-012-1865-Y

Islam, A., Ali, S.M., Afzaal, M., Iqbal, S. and Zaidi, S.N.F., 2018. Landfill site selection through analytical hierarchy process for twin cities of Islamabad and Rawalpindi, Pakistan. *Environmental Earth Sciences*, 77(3), p.314. https://doi.org/10.1007/S12665-018-7239-3

Jamshidi-Zanjani, A. and Rezaei, M., 2017. Landfill site selection using a combination of fuzzy logic and a multi-attribute decision-making approach. *Environmental Earth Sciences*, 76(13), pp.16-28. https://doi.org/10.1007/S12665-017-6774-7

Karmakar, A., Daftari, T., Sivagami, K., Chandan, M.R., Shaik, A.H., Kiran, B. and Chakraborty, S., 2023. A comprehensive insight into Waste to Energy conversion strategies in India and its associated air pollution hazard. *Environmental Technology and Innovation*, 29, p.301. https://doi.org/10.1016/j.eti.2023.103017

Mahammad, S. and Islam, A., 2021. Evaluating the groundwater quality of Damodar Fan Delta (India) using fuzzy-AHP MCDM technique. *Applied Water Science*, 11(7). https://doi.org/10.1007/S13201-021-01408-2

Mahini, A.S. and Gholamalifard, M., 2006. Siting MSW landfills with a weighted linear combination methodology in a GIS environment. *International Journal of Environmental Science & Technology*, 3, pp.435–445.

Malczewski, J., 2000. On the use of weighted linear combination method in GIS: common and best practice approaches. *Transactions in GIS*, 4(1), pp.5–22.

Moeinaddini, M., Khorasani, N., Danehkar, A. and Darvishsefat, A.A., 2010. Siting MSW landfill using weighted linear combination and analytical hierarchy process (AHP) methodology in GIS environment (case study: Karaj). *Waste Management*, 30(5), pp.912–920.

Mohsin, M., Ali, S.A., Shamim, S.K. and Ahmad, A., 2021. A GIS-based novel approach for sustainable sanitary landfill site selection using integrated fuzzy AHP and machine learning algorithms. *Research Square,* 71, p. 64

Mousavi, S.M., Darvishi, G., Mobarghaee Dinan, N. and Naghibi, S.A., 2022. Optimal landfill site selection for solid waste of three municipalities based on boolean and fuzzy methods: A case study in Kermanshah Province, Iran. *Land*, 11(10), pp.1779. https://doi.org/10.3390/land11101779

Mussa, A. and Suryabhagavan, K.V., 2021. Solid waste dumping site selection using GIS-based multi-criteria spatial modeling: A case study in Logia town, Afar region, Ethiopia. *Geology, Ecology, and Landscapes*, 5(3), pp.186-198. https://doi.org/10.1080/24749508.2021.1950535

Narayana, T., 2009. Municipal solid waste management in India: From waste disposal to recovery of resources? *Waste Management*, 29(3), pp.1163-1166. https://doi.org/10.1016/j.wasman.2008.11.020

Rahmat, Z.G., Niri, M.V., Alavi, N., Goudarzi, G., Babaei, A.A., Baboli, Z. and Hosseinzadeh, M., 2017. Landfill site selection using GIS and AHP: A case study: Behbahan, Iran. *KSCE Journal of Civil Engineering*, 21(1), pp.111-118. https://doi.org/10.1007/S12205-016-0296-9

Ramu, P., Santosh, B.S. and Praveen, S., 2023. An Integrated GIS-AHP Approach for Municipal Solid Waste Landfill Siting in Srikakulam District, Andhra Pradesh. *Nature Environment & Pollution Technology*, 22(1), pp.163-180.

Rawal, N., 2019. An approach for selection of solid waste disposal sites by rapid impact assessment matrix and environmental performance index analysis. *International Journal of Environment and Pollution*, 66(1–3), pp.127-142. https://doi.org/10.1504/IJEP.2019.100282

Rezaeisabzevar, Y., Bazargan, A. and Zohourian, B., 2020. Landfill site selection using multi-criteria decision making: Influential factors for comparing locations. *Journal of Environmental Sciences*, 93, pp.170-184. https://doi.org/10.1016/j.jes.2020.01.001

Saleh, S.K., Aliani, H. and Amoushahi, S., 2020. Application of modeling based on fuzzy logic with multi-criteria method in determining appropriate municipal landfill sites (case study: Kerman City). *Arabian Journal of Geosciences*, 13(22). https://doi.org/10.1007/S12517-020-06213-W

Salman, S.M., 2006. Siting MSW landfills with a weighted linear combination methodology in a GIS environment. *International Journal of Environment Science and Technology,* 3(4), p.53

Sekulovic, D. and Jakovljevic, G., 2016. Landfill site selection using GIS technology and the analytic hierarchy process. *Vojnotehnicki Glasnik*, 64(3), pp.769-783. https://doi.org/10.5937/VOJTEHG64-9578

Şener, Ş., Sener, E. and Karagüzel, R., 2011. Solid waste disposal site selection with GIS and AHP methodology: A case study in Senirkent-Uluborlu (Isparta) Basin, Turkey. *Environmental Monitoring and Assessment*, 173(1–4), pp.533-554. https://doi.org/10.1007/S10661-010-1403-X

Shahabi, H., Keihanfard, S., Ahmad, B. Bin and Amiri, M.J.T., 2014. Evaluating Boolean, AHP, and WLC methods for the selection of waste landfill sites using GIS and satellite images. *Environmental Earth Sciences*, 71, pp.4221-4233. https://doi.org/10.1007/s12665-013-2864-2

Singh, A., 2019. Managing the uncertainty problems of municipal solid waste disposal. *Journal of Environmental Management*, 240, pp.259-265. https://doi.org/10.1016/j.jenvman.2019.02.022

Sk, M.M., Ali, S.A. and Ahmad, A., 2020. Optimal sanitary landfill site selection for solid waste disposal in Durgapur city using geographic information system and multi-criteria evaluation technique. *KN-Journal of Cartography and Geographic Information*, 70, pp.163-180. https://doi.org/10.1007/s42419-020-00039-0

Unal, M., Cilek, A. and Guner, E.D., 2020. Implementation of fuzzy, Simos and strengths, weaknesses, opportunities and threats analysis for municipal solid waste landfill site selection: Adana City case study. *Waste Management & Research*, 38(1_suppl), pp.45-64. https://doi.org/10.1177/0734242X20908159

UNEP, 2017. Solid waste management | UNEP - UN Environment Programme. Available at https://www.unep.org/explore-topics/resource-efficiency/what-we-do/cities/solid-waste-management. Accessed on May 13, 2024.

Wayessa, S.G., Duresa, J.N., Beyene, A.A. and Regasa, M.S., 2021. Suitable Site Selection and Location Allocation of Solid Waste Collection Bin by Using Geographic Information Systems: A Case of Nekemte Town. *Journal of Building Material Science*, 3(1), pp.22-30.

Yildirim, V., Memisoglu, T., Bediroglu, S. and Colak, H.E., 2018. Municipal solid waste landfill site selection using multi-criteria decision making and GIS: case study of Bursa province. *Journal of Environmental Engineering and Landscape Management*, 26(2), pp.107-119. https://doi.org/10.3846/16486897.2018.1493137

Yin, S., Li, J., Liang, J., Jia, K., Yang, Z. and Wang, Y., 2020. Optimization of the weighted linear combination method for agricultural land suitability evaluation considering current land use and regional differences. *Sustainability*, 12(23), pp.10134-10145. https://doi.org/10.3390/su122310134

Yousefi, H., Javadzadeh, Z., Noorollahi, Y. and Yousefi-Sahzabi, A., 2018. Landfill site selection using a multi-criteria decision-making method: A case study of the salafcheghan special economic zone, Iran. *Sustainability (Switzerland)*, 10(4), pp.1107-1120. https://doi.org/10.3390/SU10041107

Zarin, R., Azmat, M., Naqvi, S.R., Saddique, Q. and Ullah, S., 2021. Landfill site selection by integrating fuzzy logic, AHP, and WLC method based on multi-criteria decision analysis. *Environmental Science and Pollution Research*, 28(16), pp.19726-19741. https://doi.org/10.1007/S11356-020-11975-7