International Journal of Sustainable Development Goals

www.ijsdg.org
eISSN: 3080-5023

Integrating Multi-Criteria Decision-Making and Geographic Information Systems in Landfill Site Selection: A Comprehensive Review

Zakaria Maafa[1], Ibrahim Badi [2,*]

[1,2] Department of Mechanical Engineering, Libyan Academy-Misrata, Misrata, Libya

ARTICLE INFO

Article history:
Received 21 June 2025
Received in revised form 10 August 2025
Accepted 9 September 2025
Available online 13 September 2025

Keywords:
Municipal Solid Waste (MSW); Multi-Criteria Decision-Making (MCDM); Geographic Information System (GIS); Analytical Hierarchy Process (AHP); Weighted Linear Combination (WLC); fuzzy logic; landfill site selection

ABSTRACT

Landfilling is one of the most affordable and appropriate ways to dispose of Municipal Solid Waste (MSW). However, because it depends on social, environmental, technical, economic, and legal aspects, deciding where to put landfills is a challenging and complex undertaking. Over the years, professionals have investigated and used the Geographic Information System (GIS) and Multi-Criteria Decision-Making (MCDM) combinations to address the aforementioned landfill site appropriateness study difficulties. The high quantity of scholarly papers that have been announced for the foreseeable future makes this fact clear. A state-of-the-art of current studies is essential for guiding colleagues and providing a context of the available literature. Reviewing all scholarly publications on GIS-based MCDM modelling for landfill site suitability evaluations is the aim of this project. We have compiled and surveyed 115 studies that were published between 2014 and 2024. A developed taxonomy that includes the following categories—GIS software, application area, uncertainty, MCDM approaches, cell sizes in GIS, and criteria—is then used to examine and categorize the studies. The most popular MCDM techniques for weighting the criteria and ranking the alternatives are the Analytical Hierarchy Process (AHP) and Fuzzy Logic. In contrast, the Environmental dimension is the most frequently favoured primary criterion, and criteria analysis reveals that surface and ground water, geology, among other criteria groups, the most often utilized ones include land use, distance to a fault zone, distance to an urban region, and distance to a road and slope. In addition to offering insights for upcoming modelling and research initiatives in the subject, these classifications and observations are useful for locating study gaps in the existing literature.

1. Introduction

The problem of landfill placement in developing countries is a serious one that has an immediate effect on public health and environmental sustainability. A combination of community opposition, commonly known as the "Not in My Backyard" (NIMBY) mindset, plus the scarcity of suitable property in many areas impede the process. These elements may influence the choice of improper dumping

* *Corresponding author.*
E-mail address: i.badi@lam.edu.ly

https://doi.org/10.59543/ijsdg.v1i.15325

locations, which not only disregard legal requirements but also seriously endanger nearby ecosystems and water supplies. Furthermore, the siting process is labor-intensive and manual due to its complexity, which necessitates a careful evaluation of numerous environmental, socioeconomic, and regulatory considerations. These problems may be made worse by neglecting geological and topographical factors when choosing a location, which could lead to landfills that are more susceptible to contamination and environmental damage. Therefore, resolving the landfill siting issue is crucial to guaranteeing efficient waste management procedures that safeguard the environment and public health.In many developing nations, landfilling has been the most popular way to dispose of solid waste. Landfills continue to be an essential component of solid waste management programs, even in the face of numerous advancements in the reduction and recycling of solid waste.

The process of landfill siting is difficult and time-consuming. It necessitates the assessment of numerous factors pertaining to the environment, socioeconomics, and statutory rules and regulations. The "not in my backyard" mentality of communities and the availability of land are the main factors influencing Libya's manual, expensive, and time-consuming landfill selection procedure. Inappropriate garbage disposal sites are chosen as a result, which eventually has an impact on the environment and public health. The placement of landfills must shield surface waters, groundwater, and the local ecosystem from the waste stream's effects. For sustainable management, geology, topography, and other natural resources should all be taken into account while choosing a landfill location. When choosing a landfill location, a Geographic Information System (GIS) is a useful tool for analyzing vast amounts of geographical data as a first screening step. The relative importance weighting of each criterion is measured using Multiple-Criteria Decision Analysis (MCDM). Every criterion map is subjected to overlay analysis. The study area's high and low appropriate zones can be identified based on the findings. Finding appropriate landfill locations can be aided by a variety of GIS programs and MCDM techniques. With an emphasis on the application of GIS and MCDM methodologies, this study attempts to present a thorough analysis of landfill site selection. It sets itself apart by analyzing the variables affecting site selection in various nations and showcasing important discoveries made by scholars in this area. This method makes it easier to make sustainable decisions that promote environmental and public health preservation. Enhancing landfill site selection requires integrating MCDM with GIS, which enables the evaluation of environmental, social, and economic factors through spatial analyses such as overlay and sensitivity evaluations [1]. Fuzzy sets play a crucial role in MCDM by addressing uncertainty and imprecision, with approaches like Parsimonious Fuzzy AHP, Z-number Fuzzy AHP, and fuzzy TOPSIS improving decision-making in resource management and sustainable development [1]. Recent studies emphasize Intuitionistic Fuzzy Sets (IFS), Z-Numbers, and their combination in Intuitionistic Fuzzy Z-Numbers (IFZNs), enhancing reliability in complex assessments [2,3]. Models such as Fuzzy P-BWM and IFRS further strengthen decision frameworks by integrating ambiguous data from multiple sources [3,4].

The framework of the applied methodology is illustrated in Figure (1).

Fig. 1. framework for the applied model

2.Methodology for Selecting research Papers

The research papers in this review were chosen through a systematic process that focused on the selection of landfill sites between 2014 and 2024 utilizing GIS and MCDM. Determining the primary study goals and formulating targeted inquiries about the standards utilized in dump site selection as well as the difficulties in utilizing GIS and MCDM techniques are the first steps in the procedure. Using scholarly resources like Google Scholar and Scopus, terms following "landfill site selection," "Geographic Information Systems," and "Multi-Criteria Decision Making" are highlighted. Peer-reviewed research that explicitly address the topic are included in the inclusion criteria; however, articles published prior to 2014 are not. Following an initial screening of abstracts and titles, each chosen work is critically assessed with an emphasis on the use of MCDM and GIS. Important information is retrieved and arranged into themes that support the goals of the study, including the criteria and analytical techniques.

3. Statistical Analyses

This section provides a thorough statistical analysis of all scientific publications published since 2014 that deal with landfill site selection. In order to better comprehend the development of studies and

approaches employed in the area, this analysis attempts to present a clear picture of the temporal trends in research. The temporal distribution of these papers is shown in Figure (2), which also highlights times when research effort significantly increased.
These studies are crucial for highlighting the different strategies put forth in the literature and for determining the degree of interest among academics in this field. We may learn more about how landfill siting techniques have changed over time and how case studies are used to provide practical and long-lasting solutions by reading these publications.

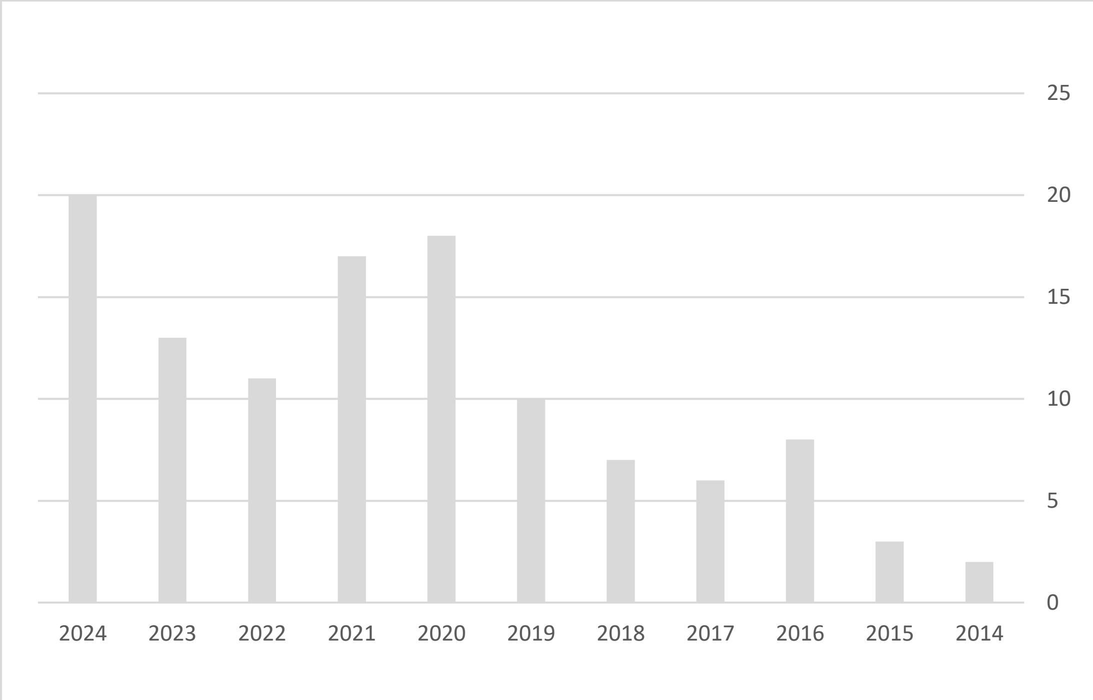

Fig. 2. *Temporal distributions of scientific articles*

The chronological distribution of the 115 scientific publications published since 2014 is displayed in table (1). Because of the date of the database search, the sample of articles for the current year (2024) is not representative. According to the frequency of appearance, there was a notable rise in research papers between 2018 and 2024. All reviewed paper's authors perform their research using a case study and suggest a landfill siting methodology.

Table 1
Temporal distributions of scientific articles

year	Frequency	Authors
2014	2	[35] [121]
2015	3	[81] [82] [97]
2016	8	[63] [71] [32] [20] [27] [28] [103] [41]
2017	6	[53] [74] [77] [101] [12] [115]
2018	7	[30] [59] [16] [31] [6] [93] [111]
2019	10	[56] [75] [10] [94] [43] [104] [112] [119] [122] [9]
2020	18	[48] [22] [61] [62] [73] [83] [26] [89] [91] [92] [95] [34] [11] [96] [42] [106] [116] [120]
2021	17	[21] [57] [23] [66] [38] [24] [76] [19] [78] [33] [84] [39] [40] [98] [113] [8] [124]
2022	11	[36] [60] [69] [70] [25] [87] [107] [108] [110] [29] [44]
2023	13	[5] [51] [54] [55] [37] [65] [67] [17] [79] [85] [88] [90][68]
2024	20	[49] [15] [50] [52] [58] [64] [72] [18] [7] [86] [99] [100] [102] [105] [109] [114] [117] [118] [123][80]

The country in which the case study was conducted is shown in table (2), along with the frequency and total number of publications for each of the 32 case study countries that were identified. The top five nations ranked by the number of case studies per nation—which account for 51.3% of all articles—are Iran, Turkey, India, Iraq, and Ethiopia.

Table 2
The country in which the case study was conducted

Country	Frequency	Authors	Country	Frequency	Authors
Zambia	1	[5]	Australia	2	[62] [89]
Bangladesh	1	[48]	Pakistan	4	[37] [69] [40] [118]
Congo	1	[49]	Canada	2	[68] [73]
Jordan	1	[15]	China	2	[6] [24]
Saudi Arabia	5	[50] [19] [85] [88] [113]	Bengal	2	[72] [105]
Ethiopia	7	[51] [66] [67] [17] [86] [92] [102]	Kenya	1	[74]
India	14	[21] [36] [22] [65] [38] [11] [96] [101] [28] [103] [106] [107] [115] [117]	Malaysia	3	[32] [81] [109]
Turkey	11	[52] [30] [23] [10] [91] [34] [35] [42] [99] [44] [116]	Greece	1	[18]
Nigeria	5	[53] [70] [20] [100] [104]	Mozambique	1	[78]
Iraq	10	[54] [56] [80] [83] [84] [94] [98] [12] [112] [8]	Kuwait	1	[7]
Algeria	1	[55]	Egypt	2	[90] [97]
Poland	1	[57]	Tanzania	1	[39]
Vietnam	3	[58] [87] [29]	Morocco	2	[27] [108]
Iran	17	[59] [61] [63] [31] [64] [71] [75] [76] [33] [25] [82] [26] [93] [95] [41] [43] [111]	Sultanate of Oman	1	[110]
Bosnia and Herzegovina	1	[60]	Malawi	1	[114]
Brazil	3	[16] [77] [79]	LIBYA	7	[119] [120] [121] [122] [123] [124] [9]

Numerous approaches have been developed in the field of decision-making to help practitioners and researchers make sense of complex data and make informed decisions. With 106 research using this method, GIS is the most popular among them, underscoring its importance in spatial analysis and decision support. Given that GIS offers vital insights into geographical elements and environmental implications, this is especially relevant for choosing appropriate locations for garbage disposal sites. Next in line is MCDM, which is employed in 94 articles and is very useful for assessing possible sites in light of different environmental, social, and economic issues because it makes it easier to prioritize based on many criteria. With 73 studies using its organized framework to simplify complex site selection decisions, the Analytic Hierarchy Process (AHP) is also well-known. The variety of methods available to address the complex problems of waste management is further demonstrated by other strategies like fuzzy logic and spatial decision support systems. This variation emphasizes how crucial it is to use the right approach in order to guarantee efficient and long-lasting waste disposal solutions. The Methods Used distribution of the 115 scientific publications in Figure (3) and Table (3).

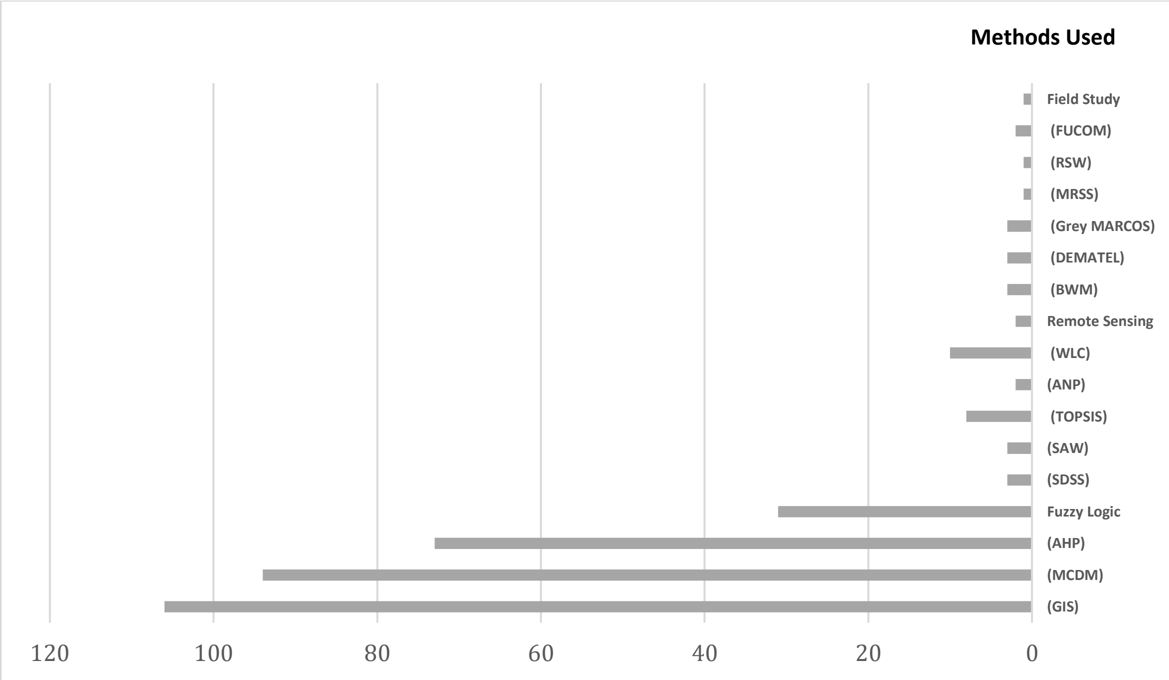

Fig. 3. *Methods Used of scientific articles*

Table 3
The Methods Used which the case study was conducted

no	Methods Used	Total articles
1	Geographic Information Systems (GIS)	106
2	Multi-Criteria Decision-Making (MCDM)	94
3	Analytic Hierarchy Process (AHP)	73
4	Fuzzy Logic	31
5	Spatial Decision Support System (SDSS)	3
6	Simple Additive Weighting (SAW)	3
7	Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)	8
8	Analytic Network Process (ANP)	2
9	Weighted Linear Combination (WLC)	10
10	Remote Sensing	2
11	Best-Worst Method (BWM)	3
12	Decision-Making Trial and Evaluation Laboratory (DEMATEL)	3
13	Multi-Attribute Decision Making with Grey Numbers (Grey MARCOS)	3
14	Multi-Resolution Spatial Strategy (MRSS)	1
15	Ranked Sum Weighting (RSW)	1
16	Full Consistency Method (FUCOM)	2
17	Field Study, Questionnaire	1

4. Methodology

Calculating landfill acreage, examining local conditions, reviewing federal, state, and local regulations, creating maps and putting them into practice, identifying possible landfill locations, and conducting a preliminary site investigation are all part of the suggested methodology for MSW landfill site selection. The transdisciplinary nature of GIS methods and approaches has led to their increasing application in planning and management procedures.

Many scholars are using GIS in the landfill site selection process because of its benefits, which include advanced spatial analytics and modeling. In the landfill siting procedure, GIS techniques are used in combination with other solution strategies in 102 out of 115 reviewed research papers (88.7%). Furthermore, the landfill suitability analysis solely employed GIS as a problem-solving method. The scientific publications examine the patterns and benefits of using MCDM and GIS techniques in alternative selection research. An outstanding analytical tool is created when GIS and MCDM are combined. Either by meeting target requirements on all alternatives or by applying exclusive constraints/criteria (Boolean constraints), the feasible alternatives that satisfy all constraints are found. The exclusionary criteria/restrictions stem from either physical impracticability (surface water bodies, national parks, etc.) or legal limitations on landfill siting (the distance between the site and residential and recreational areas, airports, water bodies, public drinking water sources, flood risk areas, cultural heritage, etc.). Boolean logic algebra and GIS overlay procedures are used to implement Boolean constraints. The intersection (logical AND), if all criteria are satisfied, or the union (logical OR), where only one requirement is satisfied, are typically viable options.

5. Landfill Site Selection Criteria

Selection Criteria for Landfill Sites The site evaluation process for choosing a landfill location frequently uses a wide variety of criteria. Exclusionary and non-exclusionary criteria are typically used in accordance with their function in the decision-making process. Considered essential, the exclusionary criteria or limitations are used in an initial screening procedure to weed out regions that aren't appropriate for further examination. Landfill siting is prohibited in areas that do not meet legal requirements for landfill siting, such as the distance between the site and sanitary protection zones surrounding public water supplies, waterways and water bodies, cultural heritage, airports, national parks and other protected natural zones, the boundary of residential and recreational areas, flood risk areas, etc. Additionally, some areas are not physically feasible for landfill placement, such as surface water bodies, national parks and protected areas, faults, land with urban and rural settlements, and transportation infrastructure. The possible landfill location candidate is selected by ranking the remaining viable locations using the non-exclusionary criteria. After combining non-exclusionary criteria that are weighed, some researchers choose the best option. Non-exclusionary criteria that may be difficult to measure or incommensurable criteria that are measured on various scales must be taken into account when ranking appropriate areas. The following Table (4) shows the criteria used by researchers to select the landfill site.

Table 4
The criteria used by researchers to select the landfill site

Category	Criteria	Frequency (%)
Environmental	Environmental impacts, public acceptance, sensitive areas	58%
Land Use	Land use compatibility, land cover, proximity to agricultural land	46%
Geological	Geology, soil type, lithology, groundwater depth	13%
Social and Economic	Population density, land value, economic considerations	21%
Hydrological	Proximity to water bodies, surface water proximity, drainage density	4%
Accessibility	Distance to roads and transportation networks	7%
Technical	Infrastructure availability, site accessibility	3%
Topographical	Elevation, aspect	3%

6. Detailed analyses of the literature

There are a number of important themes that show the complexity of solid waste management and landfill site selection in the literature, especially in urban areas like Libya. Integration of GIS with MCDM methodologies is a major focus, since it facilitates spatial analysis and improves the accuracy and effectiveness of site selection. The social, environmental, and accessibility effects of possible landfill locations can therefore be evaluated by decision-makers. Economic and social concerns, such as proximity to residential areas and public approval, environmental variables, such as soil qualities and groundwater levels, and geomorphological norms to reduce the danger of leachate pollution are all common reasons for site selection. assessing these various factors, assisting in the process of making wise decisions. Effective decision-making is facilitated by MCDM techniques, such as fuzzy logic and the AHP, which offer a formal framework for methodically assessing these many factors.
We have studied and analyzed a selection of research focusing on landfill site selection, utilizing a variety of methods and models. I can provide additional details about the specific studies evaluated, including their main objectives, findings, and the criteria employed in each study:

6.1 Used GIS software

One of the most important tools for assessing the feasibility of dump sites is spatial analysis using GIS. Numerous studies use sophisticated methods to pinpoint a range of factors, including geological features, environmental effects, and proximity to transportation networks, that affect the choice of suitable locations. Through the use of techniques such as overlay analysis, weighted sum models, and buffer analysis, researchers are able to produce comprehensive geographic maps that show each location's suitability according to a number of criteria. ArcGIS and QGIS are two examples of software applications that offer thorough insights to help decision-makers make decisions that are in line with national and international laws, thereby advancing sustainable waste management techniques. Some research that has addressed the program: In numerous studies, researchers have using GIS to locate landfills in various parts of the world, underscoring the variety of criteria employed and the importance of contemporary technologies in waste management.
According to a GIS analysis, 41.69% of Kitwe, Zambia, is considered unsuitable, while 40.74% is considered most suitable. Seven potential locations were found to handle the trash that is expected to accumulate over the next 20 years. [5] Only 0.38% of the land in Shenzhen, China, is deemed very

ideal for landfills, according to an assessment of the sites' suitability based on factors like their closeness to residential areas, roadways, and water sources. [6] Using GIS and geotechnical studies, the study found seven sites in Kuwait that could manage municipal solid garbage for more than ten years.[7] In the meantime, researchers in Iraq identified eight ideal sites in the Tanjero River Basin using Multi-Criteria Decision Analysis (MCDA) techniques, such as AHP.[8] In Libya, the focus was on the importance of selecting landfill sites based on environmental and economic criteria.[9] A study in Turkey found that 39.23 km² of land was suitable after evaluating seven criteria. [10] Seven possible locations were identified in India using an approach that combined AHP and FTOPSIS to find sanitary dump sites. These places were chosen based on socioeconomic and environmental variables. [11] Finally, the study mapped 15 distinct site evaluation criteria in Al-Hashimiyah Qadhaa, Iraq, highlighting the significance of data analysis in improving waste management tactics [12]. MCDM models, such as the BWM and AHP, are vital for ranking key factors behind inflation in Libya and guiding effective economic strategies [13, 14]. All things considered, these studies show how GIS helps with the landfill site selection process by offering thorough evaluations of numerous elements, enhancing the efficacy of waste management and environmental preservation.

6.2 Multi-Criteria Decision-Making (MCDM)

A methodical technique for assessing and ranking several competing criteria during the decision-making process is called MCDM. This approach is especially useful in complicated situations when a number of variables, including social, economic, and environmental ones, must be taken into account. By quantifying qualitative and quantitative data, MCDM techniques make it easier to compare options and help decision-makers evaluate trade-offs. The Fuzzy Logic, the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), and the AHP are examples of popular approaches, Weighted Linear Combination (WLC). MCDM improves decision quality and facilitates strategic planning in a variety of domains, such as resource allocation, urban planning, and environmental management, by offering an organized framework for analysis. Some research that has addressed MCDM:

6.2.1 Analytic Hierarchy Process (AHP)

By arranging data in a hierarchical manner, the AHP is a systematic decision-making method for handling complicated issues. There are three primary levels involved: the overarching goal is represented at the top, decision-influencing criteria are at the center, and the various options are at the bottom. By enabling pairwise comparisons of criteria, AHP enables decision-makers to rank alternatives according to their significance and give relative weights. With its capacity to assess landfill site appropriateness by taking into account a variety of environmental, social, and economic aspects, this technique is very useful in domains like waste management. AHP improves decision accuracy and reduces biases by offering a methodical approach, which produces more lasting and efficient results.

The AHP has been used by researchers in a number of studies to improve the selection of dump sites in various geographical areas. Omar S. Arabeyyat et al., for example, concentrated on the Al-Balqa Governorate in Jordan, finding appropriate locations based on criteria such as proximity to metropolitan centers and water. They found that around 6% of the region is extremely favorable [15]. After identifying 10 crucial elements, Mulusew Minuyelet Zewdie and Simachew Miniykis Yeshanew discovered that 7.9% of the terrain in Dejen, Ethiopia, was ideal for disposing of trash [6].

In São Paulo, Brazil, Luciana MG Spigolon and her colleagues used AHP in conjunction with MCDA to assess economic, social, and environmental factors. They came to the conclusion that 64% of the land was appropriate in some situations [16]. Similarly, Mulumebet Demeke Desta et al. created a suitability index map in Debre Birhan, Ethiopia, by evaluating twelve factors [17]. AHP analysis was presented on Lemnos Island, Greece, by Themistoklis D. Kontos and Yiannis G. Zevgolis, who found that it was 9.7% appropriate [18]. Nora Al Khaldi et al. combined AHP and GIS in Dammam, Saudi Arabia, to assess suitability, pointing out that the existing landfill failed to meet important requirements [19]. While Farah Abdelouhed et al. concentrated on Ouarzazate, Morocco, and discovered two extremely favorable locations, Fagbohun and Aladejana in Ado-Ekiti, Nigeria, determined 39.23 km^2 to be appropriate based on seven parameters [20]. Collectively, these studies demonstrate AHP's effectiveness in systematically addressing landfill site selection across various contexts.

6.2.2 fuzzy logic

A potent computer paradigm called fuzzy logic expands on classical logic to address the ambiguity and imprecision present in real-world issues. Fuzzy logic includes the idea of degrees of truth, enabling a more nuanced representation of information than classic binary logic, which works with clear values (true or false). This method works especially well when there is unclear or imprecise data, which makes it useful in a variety of domains, including artificial intelligence, control systems, and decision-making. Fuzzy logic allows systems to analyze and reason with uncertain data by using fuzzy sets and rules, producing resilient and adaptable solutions that are more like to human thinking. Sanu Dolui and Sumana Sarkar employed MCDM and GIS techniques to find appropriate landfill sites in Kharagpur, West Bengal, India. The research identified five possible landfill sites by evaluating fourteen factors, such as distance from water bodies and settlements. It concluded that 10.69% of the region is extremely acceptable and 20.17% is unsuitable [21]. Sk Ajim Ali and Ateeque Ahmad: In Kolkata, India, they chose appropriate disposal locations for municipal solid trash using a GIS-based decision support technique. They employed the Fuzzy Analytic Hierarchy Process (FAHP) to determine the relative weights of 20 pertinent criteria that were divided into five categories. After taking environmental issues and public acceptability into account, they finally identified three appropriate locations [22]. Colleagues and Esra Çakır: They presented a brand-new circular intuitionistic fuzzy multi-criteria decision-making (MCDM) method for assessing landfill locations. Four landfill options in Turkey were evaluated using this approach, which used intuitionistic fuzzy numbers to evaluate a variety of parameters [23]. Jiamin Liu and Associates: By combining fuzzy MCDM approaches with clustering algorithms, they investigated a unique method for choosing municipal solid waste (MSW) dump sites in Lanzhou, China. The study determined the weights of 21 criteria and clarified interdependencies between them using the DEMATEL-ANP approach [24]. Mohsen Mousavi, Seyed, and Associates: They looked at the best dump site option for managing solid waste in Iranian municipalities located in Kermanshah Province. They proposed two ideal landfill locations based on their appropriateness after identifying 10 crucial parameters impacting site selection using a mix of Boolean and fuzzy approaches, GIS, and the AHP [25]. Majid Chabok and Associates: To choose the best municipal solid waste (MSW) dump locations in Ahvaz, Iran, they used a fuzzy multi-criteria decision-making process combined with GIS. Eleven locations were categorized as satisfying the established standards after the investigation discovered important variables, such as transportation networks and geological structure [26]. Hanine Mohamed and Associates: By combining OLAP/GIS technology with Fuzzy-AHP and TOPSIS, they presented a unique approach for choosing landfill locations for industrial waste (LIW). The efficiency of this strategy in locating appropriate waste sites was illustrated by a case study conducted in Casablanca, Morocco [27]. In order to choose landfill locations for the management of MSW in Mumbai, India, Manoj Govind Kharat and associates investigated an integrated fuzzy MCDM technique. The study tackled important environmental issues associated with trash creation by using fuzzy AHP and TOPSIS [28]. Nguyen Van Thanh: Using a fuzzy MCDM model, he created the best waste-to-energy plan in Vietnam. Through sensitivity analysis, the study demonstrated the robustness of the model and determined that Hai Phong was the best location for solid waste-to-energy facilities [29]. With adaptable methods that handle uncertainties and confusing data, these studies highlight the value of applying fuzzy logic to landfill site selection procedures.

6.2.3 Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

One popular multi-criteria decision-making technique that assists in choosing the best choice from a group of options based on how close they are to an ideal solution is called the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). Choosing a suitable landfill location is a difficult process in waste management that calls for taking into account a number of social, economic, and environmental aspects. By identifying which sites are closest to the ideal situation (such as low cost or minimum environmental damage) and farthest from the worst-case scenario, TOPSIS offers an organized method for evaluating possible landfill locations, assisting decision-makers in choosing the best site.

Volkan Yıldırım and His Coworkers This study employs the TOPSIS approach in conjunction with Geographic Information Systems (GIS) to locate appropriate municipal solid waste dump sites in Bursa Province, Turkey. After analyzing 23 geographical data layers, which included variables like population density and distance from bodies of water, researchers identified six potential locations. Kayapa District was chosen as the best one because of its accessibility [30]. Kandlousy, Ali Moghimi, and Coworkers The writers discuss the crucial problem of choosing a landfill location in Iran's Langroud County, emphasizing the detrimental effects of poor garbage management. They assessed twenty criteria based on environmental norms using TOPSIS in the ArcGIS software environment. The study determined five ideal locations in the southern and southwestern regions of Langroud by classifying possible dump sites into five suitability categories [31]. M. Aghajani Mir and Associate Members A hybrid decision-making method for improving Malaysian municipal solid waste management is presented in this study. In order to assess scenarios according to social, economic, and environmental standards, it integrates GIS techniques with TOPSIS and VIKOR procedures. According to the study's findings, the most environmentally friendly waste management options include sanitary landfilling, anaerobic digestion, and recycling [32]. Mahdi Zarrini and Ameneh Rezaei The authors use both TOPSIS and the AHP to evaluate landfill sites in Rasht, Iran. They used GIS to examine factors including land use and geological features in order to address the problems caused by rising trash creation. According to their research, alternative site number four is a better fit for disposing of garbage, whereas the existing dump site is the least suited [33]. Özkan Barış and Coworkers In order to assess landfill sites in Samsun, Turkey, this study presents a GIS-based multi-criteria decision analysis approach that makes use of hesitant fuzzy linguistic term sets (HFLTS). The study uses TOPSIS to assess possible landfill sites according to socioeconomic and environmental factors, and the results show that the Atakum and Canik districts are the best places to build landfills [34]. Coworkers with Hanine Mohamed The researchers combine OLAP/GIS technology with TOPSIS and Fuzzy-AHP to present a unique approach for choosing landfill locations for industrial waste (LIW).

A case study in Casablanca, Morocco, shows how this method successfully handles the difficulties involved in choosing a landfill site, finding appropriate locations and improving waste management decision-making [27]. Ahmet Beskese and His Coworkers This study employs fuzzy AHP and fuzzy TOPSIS to choose landfill sites in Istanbul. Three possible locations are identified by the research using a hierarchical model that evaluates factors including land acreage and soil conditions. It demonstrates that although these sites are comparable in terms of overall appropriateness, they differ in some characteristics [35]. Kharat and Manoj Govind and Associates For the purpose of choosing dump locations in Mumbai, India, the authors investigate an integrated fuzzy MCDM technique. In order to solve major environmental problems associated to the city's high municipal solid waste output and current landfill closures, they evaluate possible locations based on environmental, economic, and social variables by integrating fuzzy AHP and TOPSIS [28]. Othman, Arsalan Ahmed, and Associates This study uses a variety of MCDA techniques, such as TOPSIS, to examine landfill site selection in the Tanjero River Basin in the Kurdistan Region, Iraq. The study determines eight ideal landfill locations in the western portion of the river basin by evaluating 15 theme layers; AHP offers the maximum accuracy in site evaluation [8].

6.2.4 Weighted Linear Combination (WLC)

By giving several criterion weights according to their relative relevance and combining them into a single score for each choice, the Weighted Linear Combination (WLC), a well-liked multi-criteria decision analysis approach, makes evaluating alternatives easier. This approach is especially helpful when choosing a landfill location, as decision-makers need to take into account a number of variables including the influence on the environment, the distance from residential areas, and the expense of transportation. Stakeholders may efficiently rate possible dump locations by using WLC, guaranteeing that the site selected satisfies community demands and environmental sustainability.
Sasanka Ghosh and Swapan Paul The problems with solid waste management in India's Kolkata Metropolitan Area are the subject of this study. The researchers use four primary criteria—topographical, lithological, socioeconomic, and hydrogeological factors—to choose appropriate landfill sites using the Fuzzy Analytic Hierarchy Process (F-AHP) and Weighted Linear Combination (WLC) methodologies. According to the findings, just 9.64% of the land is deemed extremely acceptable for landfill development, while 40.59% of the land is unfit. 15 possible locations for trash disposal are recommended by the research. [36] Iftikhar Ali and His Employees The management of municipal solid waste (MSW) in Peshawar, Pakistan, is the main topic of this study, with a particular emphasis on finding appropriate landfill locations. The study assesses a number of environmental, social, and economic factors using Geographic Information Systems (GIS) and Multi-Criteria Decision Analysis (MCDA), particularly the Analytical Hierarchy Process (AHP) and WLC. The results show that about 11.4% of the research region is extremely highly suited for disposal sites, while 20.8% is considered unsuitable. This highlights the significance of methodical site selection to reduce environmental degradation and public health hazards [37]. Multaniya, Amit P., and Associates The authors use the WLC approach and GIS tools within an MCDA framework to evaluate appropriate landfill sites in the Raipur metropolitan area of Chhattisgarh, India. The study provides twelve criteria, such as accessibility to drainage networks and transportation routes, to address the solid waste management issues in quickly expanding metropolitan regions. Only 1.03% of the land is deemed extremely acceptable for landfill site, according to the studies, which show that 74.79% of the region is unsuitable [38]. Michael M. Msabi and Michael Makonyo This study employs GIS-based multi-criteria decision analysis (MCDA) to choose possible landfill locations in Dodoma, Tanzania.

There are now major waste management issues as a result of the area's fast urbanization. Using AHP and WLC techniques, the study takes into account fifteen variables, such as proximity to surface water and populated regions. Eleven potential areas have been selected for additional assessment, and the results show that 14.7% of the research area is extremely appropriate for disposal sites [39]. Riaz Zarin and His Coworkers This study uses GIS in conjunction with fuzzy logic, AHP, and WLC to examine the best landfill site selection in Islamabad, Pakistan. Thirteen criteria are identified by the study and divided into socioeconomic and environmental components. The significance of these criteria is evaluated using AHP, and then fuzzy logic is used for standardization. The results demonstrate that the fuzzy-WLC approach successfully identifies a number of potential landfills sites and generates a more detailed suitability map than AHP alone. [40] Sara Bahrani and Her Coworkers The article uses fuzzy functions in GIS and multi-criteria decision-making to examine the selection of landfill sites in Shabestar, Iran. According to Iranian legislation, the study assesses a number of criteria, such as ecological, technological, socioeconomic, and physical aspects. The researchers use fuzzy functions to standardize, AHP to weight, and WLC to establish that around 6.2% of the study region is eligible for landfill development. [41] Coworkers with Emre Tercan This study employs GIS-based multi-criteria evaluation methodologies to choose municipal solid waste (MSW) landfill locations in Turkey's Antalya, Burdur, and Isparta planning zones. The research establishes fourteen exclusion criteria to weed out regions that aren't appropriate and finds appropriate sites based on a variety of legislative, technological, social, and environmental factors. The WLC evaluates these criteria to create a landfill suitability map, and the AHP is used to establish the weights of the criterion. According to the findings, 3.75% of the land is extremely appropriate for landfills, while just 4.03% is somewhat suitable. [42] Mojtaba Barzehkar together with coworkers Using a GIS-based multi-criteria assessment methodology that contrasts fuzzy logic with Boolean logic methodologies, this study focuses on landfill site selection in the SaharKhiz Region of Gilan Province, Iran. First, possible and excluded zones are identified using Boolean logic, then information layers are standardized using fuzzy logic using WLC, with weights assigned using AHP. About 14.72% of the area is acceptable for dump sites, according to the data, which show that fuzzy logic is more flexible and accurate than Boolean logic in resolving disputes in human judgment. [43] Alp Selçuk and Kasım Şimşek This study uses a mix of fuzzy techniques and GIS-based Multi-Criteria Decision Analysis (MCDM) to assess landfill site selection in Diyarbakır, Turkey. In order to meet the increasing solid waste management difficulties brought on by urban population growth, 14 criteria including sociocultural, economic, and environmental aspects are identified. Only 3.44% of the overall area is appropriate for landfill sites, according to the results of the site evaluation using WLC and the SWARA technique for generating criteria weights. [44].

7. Future Studies

Machine learning (ML) offers significant potential to enhance landfill site selection by predicting stress distributions, environmental impacts, and site suitability through analysis of soil, environmental, and layout data [45]. Deep reinforcement learning can enable multiple agents to evaluate sites from diverse stakeholder perspectives, refining criteria with real-time feedback [46]. Deep learning models can classify geographic and environmental features affecting site suitability, improving accuracy [47]. ML can also automate environmental impact assessments, forecast ecological risks, and simulate landfill layouts to support informed decisions. While advanced AHP and BWM extensions like Z-Numbers and Spherical Fuzzy AHP exist, their high data demands, complexity, and limited accessibility in developing countries make conventional AHP and BWM preferable for clarity, transparency, and stakeholder acceptance.

8. Conclusions

The methods and standards for choosing MSW dump sites used in research publications published from 2014 to 2024 are thoroughly reviewed in this study. The study offers an overview of all landfill siting techniques and selection criteria in chronological order. According to statistical analysis of the evaluated papers, the number of published papers increased significantly between 2020 and 2024. Taking into account the nation where the case study is being applied, the top five nations ranked by the quantity of case studies per nation are Iran, Turkey, India, Iraq, and Ethiopia. The review that was undertaken indicates that the vast majority of researchers (88.7%) have utilized GIS either alone or in conjunction with other methods. nine percent of authors utilize the WLC approach extensively to rank alternatives in MCDM. Common techniques for eliciting criteria weights include equal weighting, ratio scale weighing, and the AHP. Sixty-four

percent of the researchers employed the AHP, which is the most used multi-criteria decision procedure for weighting the criteria. While numerous authors use fuzzy logic research (27%) and other methods (37%), many studies use multiple methods in decision-making to improve outcomes. Four primary criteria groups are the most widely used when choosing a landfill site out of all the main criteria or groups of criteria: Environmental: 58 %, Land Use: 46 %, Geological: 13 %, and Social and Economic: 21 %. Since public and political opinion, along with engineering and technical procedures, play a major role in landfill site selection, the evaluated papers were searched for factors pertaining to local community approval. In conclusion, the researchers and engineers can benefit from the current overview of landfill placement approaches and criteria since it offers guidance for further study and modeling. The review supports the intricacy and difficulty of decision-making in actual landfill site selection problems and helps readers gain a better grasp of landfill site selection techniques.

Author Contributions

Conceptualization, Z.M. and I.B.; methodology, Z.M.; writing—original draft preparation, Z.M.; writing—review and editing, I.B.; supervision, I.B. All authors have read and agreed to the published version of the manuscript.

Funding

This research was not funded by any grant.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] Badi, I., Bouraima, M. B., Qiu, Y., & Wang, Q. (2025). Advancing sustainable logistics and transport systems in free trade zones: A multi-criteria decision-making approach for strategic sustainable development. *International Journal of Sustainable Development Goals, 1*, 45-55. https://doi.org/10.59543/ijsdg.v1i.13519

[2] Hussain, A., & Ali, M. (2025). A critical estimation of ideological and political education for sustainable development goals using an advanced decision-making model based on intuitionistic fuzzy Z-numbers. *International Journal of Sustainable Development Goals, 1*, 23-44. https://doi.org/10.31181/comdemxxxxx

[3] Moslem, S., & Ali, M. (2025). Evaluating commuters' travel mode choice using the Z-number extension of Parsimonious Best Worst Method. *Applied Soft Computing Journal, 173*, 112918. https://doi.org/10.1016/j.asoc.2025.112918

[4] Khan, M. R., Ullah, K., Raza, A., Ali, Z., Senapati, T., Esztergar-Kiss, D., & Moslem, S. (2025). Evaluating safety in Dublin's bike-sharing system using the concept of intuitionistic fuzzy rough power aggregation operators. *Measurement, 253*, 117553. https://doi.org/10.1016/j.measurement.2025.117553

[5] Mvula, R. L. S., Mundike, J., & Nguvulu, A. (2023). Spatial suitability analysis for site selection of municipal solid waste landfill using hybrid GIS and MCDA approach: The case of Kitwe, Zambia. *Scientific African*, 21, e01885. https://doi.org/10.1016/j.sciaf.2023.e01885

[6] Ding, Z., Zhu, M., Wu, Z., Fu, Y., & Liu, X. (2018). Combining AHP-entropy approach with GIS for construction waste landfill selection—A case study of Shenzhen. *International Journal of Environmental Research and Public Health, 15*(10), 2254. https://doi.org/10.3390/ijerph15102254

[7] Al-Fares, R. A. (2024). Optimal landfill site selection through the application of GIS analysis & geotechnical investigation. *Annals of GIS, 30*(3), 383–409. https://doi.org/10.1080/19475683.2024.2390409

[8] Othman, A. A., Obaid, A. K., Al-Mamni, D. A. M., Pirouei, M., Salar, S. G., Liesenberg, V., Al-Maamar, A. F., Shihab, A. T., Al-Saady, Y. I., & Al-Attar, Z. T. (2021). Insights for landfill site selection using GIS: A case study in the Tanjero River Basin, Kurdistan Region, Iraq. *Sustainability, 13*(22), 12602. https://doi.org/10.3390/su132212602

[9] Al-Zarroumi, R. A. H. (2019). Using geographic information systems to determine the optimal location for solid waste landfills in Benghazi. *Journal of Research, *13*, 350-378.*

[10] Karakus, C. B., Demiroğlu, D., Çoban, A., & Ulutaş, A. (2019). Evaluation of GIS-based multi-criteria decision-making methods for sanitary landfill site selection: The case of Sivas city, Turkey. *Journal of Material Cycles and Waste Management*, *21*(6), 1379–1398. https://doi.org/10.1007/s10163-019-00935-0

[11] Ali, S. A., Parvin, F., Al-Ansari, N., Pham, Q. B., Ahmad, A., Raj, M. S., Anh, D. T., Ba, L. H., & Thai, V. N. (2020). Sanitary landfill site selection by integrating AHP and FTOPSIS with GIS: A case study of Memari Municipality, India. *Environmental Science and Pollution Research*, *27*(1), 1–23. https://doi.org/10.1007/s11356-020-11004-7

[12] Chabuk, A., Al-Ansari, N., Hussain, H. M., Knutsson, S., Pusch, R., & Laue, J. (2017). Combining GIS applications and method of multi-criteria decision-making (AHP) for landfill siting in Al-Hashimiyah Qadhaa, Babylon, Iraq. *Sustainability, 9*(11), 1932. https://doi.org/10.3390/su9111932

[13] Badi, I., Bouraima, M. B., & Zunon, B. I. P. (2025). A multi-criteria decision-making model for prioritizing the causes of inflation in Libya using the best-worst method and analytic hierarchy process. *Knowledge and Decision Systems with Applications, 1*, 165-176. http://doi.org/10.59543/kadsa.v1i.14259

[14] Kayıran, H. F. (2025). Stress field characterization in rotating anisotropic polypropylene cylinders: Analytical modeling and SVR validation. *International Journal of Sustainable Development Goals, 1*, 70-81. https://doi.org/10.59543/ijsdg.v1i.13519

[15] Arabeyyat, O. S., Shatnawi, N., Shbool, M. A., & Al Shraah, A. (2024). Landfill site selection for sustainable solid waste management using multiple-criteria decision-making: Case study of Al-Balqa governorate in Jordan. MethodsX, 12, 102591. https://doi.org/10.1016/j.mex.2024.102591

[16] Spigolon, L. M. G., Giannotti, M., Larocca, A. P., Russo, M. A. T., & Souza, N. da C. (2018). Landfill siting based on optimisation, multiple decision analysis, and geographic information system analyses. *Waste Management & Research, 36*(10), 1-10. https://doi.org/10.1177/0734242X18773540

[17] Desta, M. D., Tesseme, T., Yigezu, T. T., & Nigussie, A. B. (2023). Evaluation of landfill site suitability using GIS, remote sensing, and the multi-criteria decision-making (AHP) approach, Ethiopia. *Preprint*. https://doi.org/10.21203/rs.3.rs-2723584/v1

[18] Kontos, T. D., & Zevgolis, Y. G. (2024). A fuzzy spatial multiple criteria analysis methodology for solid waste landfill siting. *J*, 7, 502–528. https://doi.org/10.3390/j7040031

[19] Al Khaldi, N., Almadani, F., & Ouerghi, S. (2021). Landfill siting evaluation using GIS and multi-criteria decision-making method: A case study: Dammam municipal solid waste landfill. *Journal of Geographic Information System, 13*, 508–522. https://doi.org/10.4236/jgis.2021.134028

[20] Fagbohun, B.J., & Aladejana, O.O. (2016). Integrating knowledge-based multi-criteria evaluation techniques with GIS for landfill site selection: A case study using AHP. *RMZ – Materials and Geosciences*, 63, 169–182. https://doi.org/10.1515/rmzmag-2016-0016

[21] Dolui, S., & Sarkar, S. (2021). Identifying potential landfill sites using multicriteria evaluation modeling and GIS techniques for Kharagpur city of West Bengal, India. *Environmental Challenges*, 5, 100243. https://doi.org/10.1016/j.envc.2021.100243

[22] Ali, S. P., & Ahmad, A. (2020). Suitability analysis for municipal landfill site selection using fuzzy analytic hierarchy process and geospatial technique. *Environmental Earth Sciences*, 79, 227. https://doi.org/10.1007/s12665-020-08970-z

[23] Çakir, E., Tas, M. A., & Ulukan, Z. (2021). A new circular intuitionistic fuzzy MCDM: A case of Covid-19 medical waste landfill site evaluation. *2021 IEEE 21st International Symposium on Computational Intelligence and Informatics (CINTI)*, 143-148. https://doi.org/10.1109/CINTI53070.2021.00034

[24] Liu, J., Li, Y., Xiao, B., & Jiao, J. (2021). Coupling fuzzy multi-criteria decision-making and clustering algorithm for MSW landfill site selection (Case study: Lanzhou, China). *ISPRS International Journal of Geo-Information, 10*(6), 403. https://doi.org/10.3390/ijgi10060403

[25] Mousavi, S. M., Darvishi, G., Mobarghaee Dinan, N., & 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), 1779. https://doi.org/10.3390/land11101779

[26] Chabok, M., Asakereh, A., Bahrami, H., & Jaafarzadeh, N. O. (2020). Selection of MSW landfill site by fuzzy-AHP approach combined with GIS: Case study in Ahvaz, Iran. *Environmental Monitoring and Assessment*, *192*(6), 433. https://doi.org/10.1007/s10661-020-08395-y

[27] Mohamed, H., Omar, B., Abdessadek, T., & Tarik, A. (2016). An application of OLAP/GIS-fuzzy AHP-TOPSIS methodology for decision making: Location selection for landfill of industrial wastes as a case study. *KSCE Journal of Civil Engineering, 00*(0), 1-11. https://doi.org/10.1007/s12205-016-0114-4

[28] Kharat, M. G., Kamble, S. J., Raut, R. D., Kamble, S. S., & Dhume, S. M. (2016). Modeling landfill site selection using an integrated fuzzy MCDM approach. *Modeling Earth Systems and Environment, 2*(1), 53. https://doi.org/10.1007/s40808-016-0106-x

[29] Van Thanh, N. (2022). Optimal waste-to-energy strategy assisted by fuzzy MCDM model for sustainable solid waste management. *Sustainability, 14*(11), 6565. https://doi.org/10.3390/su14116565

[30] Yildirim, V., Memisoglu, T., Bediroglu, S., & 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), 107–119. https://doi.org/10.3846/16486897.2017.1364646

[31] Moghimi Kandlousy, A., Mohebbi Tafreshi, A., & Mohebbi Tafreshi, G. (2018). Locating appropriate areas of municipal waste landfill using TOPSIS method (Case study: Langroud County). *Journal of Research in Environmental Health, 4*(2), 112-128.

[32] Mir, M. A., Ghazvinei, P. T., Sulaiman, N. M. N., Basri, N. E. A., Saheri, S., Mahmood, N. Z., Jahan, A., Begum, R. A., & Aghamohammadi, N. (2016). Application of TOPSIS and VIKOR improved versions in a multi criteria decision analysis to develop an optimized municipal solid waste management model. *Journal of Environmental Management, 166*, 109–115. https://doi.org/10.1016/j.jenvman.2015.09.028

[33] Rezaei, A., & Zarrini, M. (2021). The analysis and ranking of spatial distribution of waste landfill potential, using AHP model and TOPSIS technique (Case study: Rasht). *Journal of Radar and Optical Remote Sensing, 4*(1), 7–29. https://www.jrors.ir

[34] Özkan, B., Sarıçiçek, İ., & Özceylan, E. (2020). Evaluation of landfill sites using GIS-based MCDA with hesitant fuzzy linguistic term sets. *Environmental Science and Pollution Research*, *27*, 1–25. https://doi.org/10.1007/s11356-020-10128-0

[35] Beskese, A., Demir, H. H., Ozcan, H. K., & Okten, H. E. (2014). Landfill site selection using fuzzy AHP and fuzzy TOPSIS: A case study for Istanbul. *Environmental Earth Sciences*, *72*(4), 3635–3647. https://doi.org/10.1007/s12665-014-3635-5

[36] Paul, S., & Ghosh, S. (2022). Identifying potential landfill sites using multicriteria evaluation modeling and GIS techniques for Kharagpur city of West Bengal, India. *Cleaner Logistics and Supply Chain*, 3, 100030. https://doi.org/10.1016/j.clscn.2022.100030

[37] Ali, I., Islam, A., Ali, S. M., & 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), 608–618. https://doi.org/10.1177/0734242X221145432

[38] Multaniya, A. P., Verma, S., & Beg, M. K. (2021). Assessment of suitable landfill site using geospatial techniques: A case study of Raipur urban region, Chhattisgarh, India. *International Journal of Research - GRANTHAALAYAH*, *9*(3), 132–148. https://doi.org/10.29121/granthaalayah.v9.i3.2021.3778

[39] Makonyo, M., & Msabi, M. M. (2021). Potential landfill sites selection using GIS-based multi-criteria decision analysis in Dodoma capital city, central Tanzania. *GeoJournal*. https://doi.org/10.1007/s10708-021-10414-5

[40] Zarin, R., Azmat, M., Naqvi, S. R., Saddique, Q., & 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*(1), 19726–19741. https://doi.org/10.1007/s11356-020-11975-7

[41] Bahrani, S., Ebadi, T., Ehsani, H., Yousefi, H., & Maknoon, R. (2016). Modeling landfill site selection by multi-criteria decision making and fuzzy functions in GIS, case study: Shabestar, Iran. *Environmental Earth Sciences*, *75*(1), 337. https://doi.org/10.1007/s12665-015-5146-4

[42] Tercan, E., Dereli, M. A., & Tapkin, S. (2020). A GIS-based multi-criteria evaluation for MSW landfill site selection in Antalya, Burdur, Isparta planning zone in Turkey. *Environmental Earth Sciences*, *79*(1), 246. https://doi.org/10.1007/s12665-020-08974-9

[43] Barzehkar, M., Dinan, N. M., Mazaheri, S., Tayebi, R. M., & Brodie, G. I. (2019). Landfill site selection using GIS-based multi-criteria evaluation (case study: SaharKhiz Region located in Gilan Province in Iran). *SN Applied Sciences, 1*(8), 1082. https://doi.org/10.1007/s42452-019-1109-9

[44] Şimşek, K., & Alp, S. (2022). Evaluation of landfill site selection by combining fuzzy tools in GIS-based multi-criteria decision analysis: A case study in Diyarbakır, Turkey. *Sustainability, 14*(16), 9810. https://doi.org/10.3390/su14169810

[45] Kayıra, H. F. (2025). Machine learning-based investigation of stress in carbon fiber rotating cylinders. *Knowledge and Decision Systems with Applications, 1*, 1-10.

[46] Ullah, R., Saeed, M., Ali, W., Nazar, J., & Nazar, F. (2025). A cooperative heterogeneous multi-agent system leveraging deep reinforcement learning. *Knowledge and Decision Systems with Applications, 1*, 112-124. https://www.doi.org/10.59543/kadsa.v1i.13931

[47] Mushtaq, Y., Ali, W., Ghani, U., Ullah Khan, R., & Adak, A. K. (2025). Advancing aviation safety and sustainable infrastructure: High-accuracy detection and classification of foreign object debris using deep learning models. *International Journal of Sustainable Development Goals, 1*, 82-98. https://doi.org/10.59543/ijsdg.v1i.14279

[48] Islam, M., Kashem, S., & Morshed, S. (2020). Integrating spatial information technologies and fuzzy analytic hierarchy process (F-AHP) approach for landfill siting. *City and Environment Interactions*, 7, 100045. https://doi.org/10.1016/j.cacint.2020.100045

[49] Kang, Y. O., Yabar, H., Mizunoya, T., & Higano, Y. (2024). Optimal landfill site selection using ArcGIS Multi-Criteria Decision-Making (MCDM) and Analytic Hierarchy Process (AHP) for Kinshasa City. *Environmental Challenges, 14*, 100826. https://doi.org/10.1016/j.envc.2023.100826

[50] Al Awadh, M., & Mallick, J. (2024). A decision-making framework for landfill site selection in Saudi Arabia using explainable artificial intelligence and multi-criteria analysis. *Environmental Technology & Innovation*, 33, 103464. https://doi.org/10.1016/j.eti.2023.103464

[51] Zewdie, M. M., & Yeshanew, S. M. (2023). GIS based MCDM for waste disposal site selection in Dejen town, Ethiopia. *Environmental and Sustainability Indicators*, 18, 100228. https://doi.org/10.1016/j.indic.2023.100228

[52] Günay, E. E., & Dere, S. (2024). Hazardous solid waste landfill site selection for İstanbul, Türkiye using multi-criteria decision-making methods and GIS data. *Journal of Advanced Research in Natural and Applied Sciences*, 10(2), 446-463. https://doi.org/10.28979/jarnas.1416814

[53] Otun, O. W. (2017). Spatial decision support systems for locating waste landfills. *Malaysian Journal of Applied Sciences*, 2(1), 19-34. https://doi.org/10.28979/jarnas.1416814

[54] Chomani, K. (2023). Landfill site selection techniques in the Kurdistan Region of Iraq: A comprehensive study. *Eurasian Journal of Science and Engineering, 9*(3), 28–37. https://doi.org/10.23918/eajse.v9i30d3

[55] Magoura, A., Dehimi, S., & Redjem, A. (2023). A GIS-based multi-criteria evaluation of landfill site selection in the region of Hodna, Algeria. *Journal of Degraded and Mining Lands Management, 10*(4), 4709-4720. https://doi.org/10.15243/jdmlm.2023.104.4709

[56] Abdulhasan, M. J., Hanafiah, M. M., Sachit, M. S., Abdulaali, H. S., Torman, M. E., & Al-Raad, A. A. (2019). Combining GIS, fuzzy logic, and AHP models for solid waste disposal site selection in Nasiriyah, Iraq. *Applied Ecology and Environmental Research, 17*(3), 6701-6722. https://doi.org/10.15666/aeer/1703_67016722

[57] Malinowski, M., Guzdek, S., Petryk, A., & Tomaszek, K. (2021). A GIS and AHP-based approach to determine potential locations of municipal solid waste collection points in rural areas. *Journal of Water and Land Development, 51*, 94–101. https://doi.org/10.24425/jwld.2021.139019

[58] Oanh, N. T., Thanh, P. T., Long, N. B., Chien, L. H., Dinh, N. T., Thom, T. T., Bich, N. T., & Elshewy, M. A. (2024). Optimal solid waste landfill site identification employing GIS-based multi-criteria decision analysis within the Thach That District, Hanoi, Vietnam. *International Journal of Geoinformatics, 20*(1). https://doi.org/10.52939/ijg.v20i1.3021

[59] Soroudi, M., Omrani, G., Moataar, F., & Jozi, S. A. (2018). Modelling an integrated fuzzy logic and multi-criteria approach for land capability assessment for optimized municipal solid waste landfill siting yeast. *Polish Journal of Environmental Studies, 27*(1), 313–323. https://doi.org/10.15244/pjoes/69576

[60] Šušnjar, S., Golijanin, J., Pečelj, M., Lukić Tanović, M., & Valjarević, A. (2022). Environmental suitability of the city of East Sarajevo for the location of municipal solid waste disposal site using a GIS-based multi-criteria analysis. *Polish Journal of Environmental Studies, 31*(1), 857-870. https://doi.org/10.15244/pjoes/139382

[61] Karimi, H., Herki, B. M. A., Gardi, S. Q., Galali, S., Hossini, H., Mirzaei, K., & Pirsaheb, M. (2020). Site selection and environmental risks assessment of medical solid waste landfill for the City of Kermanshah-Iran. *International Journal of Environmental Health Research*. Advance online publication. https://doi.org/10.1080/09603123.2020.1742876

[62] Asefi, H., Zhang, Y., Lim, S., & Maghrebi, M. (2020). An integrated approach to suitability assessment of municipal solid waste landfills in New South Wales, Australia. *Australasian Journal of Environmental Management*, *27*(1), 63–83. https://doi.org/10.1080/14486563.2020.1719438

[63] Abediniangerabi, B., & Kamalirad, S. (2016). Landfill siting using MCDM in Tehran metropolitan. *Journal of Urban and Environmental Engineering*, *10*(1), 11–24. https://www.jstor.org/stable/10.2307/26240807

[64] Ghobadi, M. (2024). Environmental capability assessment for MSW landfill site using geographic information system and multi-criteria evaluation. *Advances in Environmental Technology, 10*(1), 29-40. https://doi.org/10.22104/AET.2023.6210.1712

[65] Ramu, P., Santosh, B. S., & Praveen, S. (2023). An integrated GIS-AHP approach for municipal solid waste landfill siting in Srikakulam District, Andhra Pradesh. *Nature Environment and Pollution Technology, 22*(1), 139–148. https://doi.org/10.46488/NEPT.2023.v22i01.012

[66] Asefa, E. M., Damtew, Y. T., & Barasa, K. B. (2021). Landfill site selection using GIS-based multicriteria evaluation technique in Harar City, Eastern Ethiopia. *Environmental Health Insights, 15*, 1–14. https://doi.org/10.1177/11786302211053174

[67] Desta, M. D., Tesseme, T., Yigezu, T. T., & Nigussie, A. B. (2023). Assessment of landfill site suitability using GIS, remote sensing, and the multi-criteria decision-making (AHP) approach, Ethiopia. *Geology, Ecology, and Landscapes*. Advance online publication. https://doi.org/10.1080/24749508.2023.2256549

[68] Islam, M. S., Sebastian, R. M., Kurian, V., Billal, M. M., & Kumar, A. (2023). The development of a framework for the selection of optimal sites for the location of municipal solid waste to value-added facilities through the integration of a geographical information system and a fuzzy analytic hierarchy process. *Biofuels, Bioproducts and Biorefining*, *17*(6), 1622–1638. https://doi.org/10.1002/bbb.2530

[69] Aslam, B., Magsoom, A., Tahir, M. D., Ullah, F., Rehman, M. S. U., & Albattah, M. (2022). Identifying and Ranking Landfill Sites for Municipal Solid Waste Management: An Integrated Remote Sensing and GIS Approach. *Buildings, 12*(5), 605. https://doi.org/10.3390/buildings12050605

[70] Oyedele, A. A., Omosekeji, A. E., Ayeni, O. O., Ewumi, T. O., & Ogunlana, F. O. (2022). Delineation of landfill sites for municipal solid waste management using GIS. *Journal of Human, Earth, and Future, 3*(3), 321–332.

[71] Ghazifard, A., Nikoubakht, S., & Azarafza, M. (2016). Municipal waste landfill site selection based on environmental, geological and geotechnical multi-criteria: A case study. *Iranian Journal of Environmental Technology, 2*(3), 49-67.

[72] Mondal, S., Parveen, M. T., Alam, A., Rukhsana, Islam, N., Calka, B., Bashir, B., & Zhran, M. (2024). Future site suitability for urban waste management in English Bazar and Old Malda Municipalities, West Bengal: A geospatial and machine learning approach. *ISPRS International Journal of Geo-Information, 13*(11), 388. https://doi.org/10.3390/ijgi13110388

[73] Islam, M. S. (2020). *Determination of optimal sites for municipal solid waste-to-value-added facilities for Canada through geographical information system modelling* [Master's thesis, University of Alberta].

[74] Hariz, H. A., Dönmez, C. Ç., & Sennaroglu, B. (2017). Siting of a central healthcare waste incinerator using GIS-Based Multi-Criteria Decision analysis. *Journal of Cleaner Production*, *10349*. https://doi.org/10.1016/j.jclepro.2017.08.091

[75] Rahimi, S., Hafezalkotob, A., Monavari, S. M., Hafezalkotob, A., & Rahimi, R. (2019). Sustainable landfill site selection for municipal solid waste based on a hybrid decision-making approach: Fuzzy group BWM-MULTIMOORA-GIS. *Journal of Cleaner Production*, *119186*. https://doi.org/10.1016/j.jclepro.2019.119186

[76] Torkayesh, A. E., Hashemkhani Zolfani, S., Kahvand, M., & Khazaelpour, P. (2021). Landfill location selection for healthcare waste of urban areas using hybrid BWM-grey MARCOS model based on GIS. *Sustainable Cities and Society, 67*, 102712. https://doi.org/10.1016/j.scs.2021.102712

[77] Nascimento, V. F., Sobral, A. C., Andrade, P. R., Ometto, J. P. H. B., & Yesiller, N. (2017). Modeling environmental susceptibility of municipal solid waste disposal sites: A case study in São Paulo State, Brazil. *Journal of Geographic Information System, 9*, 8–33. https://doi.org/10.4236/jgis.2017.91002

[78] Langa, C., Hara, J., Wang, J., Nakamura, K., Watanabe, N., & Komai, T. (2021). Dynamic evaluation method for planning sustainable landfills using GIS and multi-criteria in areas of urban sprawl with land-use conflicts. *PLOS ONE, 16*(8), e0254441. https://doi.org/10.1371/journal.pone.0254441.

[79] Loureiro, A. I. S., Bressane, A., Nascimento, V. F., Simões, J. V. O., & Negri, R. G. (2023). Enhancing landfill monitoring and assessment: A proposal combining GIS-based analytic hierarchy processes and fuzzy artificial intelligence. *Knowledge, 3*(4), 610–625. https://doi.org/10.3390/knowledge3040038

[80] Salman, Q. M. K., & Hamdan, A. N. A. (2024). Landfill site selection using analytical hierarchy process and GIS: A case study in Al-Zubair district, Basrah, Iraq. *Muthanna Journal of Engineering and Technology, 12*(2), 50–61. https://doi.org/10.52113/3/eng/mjet/2024-12-02/50-61

[81] Younes, M. K., Basri, N. E. A., Nopiah, Z. M., Basri, H., & Abushammala, M. F. M. (2015). Use of a combination of MRSS-ANP for making an innovative landfill siting decision model. *Mathematical Problems in Engineering*, *2015*, Article ID 381926. https://doi.org/10.1155/2015/381926

[82] Safavian, S. T. S., Fataei, E., Ebadi, T., & Mohamadian, A. (2015). Site selection of Sarein's municipal solid waste landfill using the GIS technique and SAW method. *International Journal of Environmental Science and Development, 6*(12), 934–937. https://doi.org/10.7763/IJESD.2015.V6.725

[83] Omar, N. Q., Shawkat, I. A., Ali, S. H., & Abujayyab, S. K. M. (2020). Selection of suitable site for solid waste landfill: A case study in Kirkuk City, Iraq. *IOP Conference Series: Materials Science and Engineering*, *737*(1), 012216. https://doi.org/10.1088/1757-899X/737/1/012216

[84] Kareem, S. L., Al-Mamoori, S. K., Al-Maliki, L. A., Al-Dulaimi, M. Q., & Al-Ansari, N. (2021). Optimum location for landfills landfill site selection using GIS technique: Al-Najaf city as a case study. *Cogent Engineering, 8*(1), 1863171. https://doi.org/10.1080/23311916.2020.1863171

[85] Arshad, M., Hasan, M. A., Al Mesfer, M. K., Al Alwan, B. A., Qureshi, M. N., & Eldirderi, M. (2023). Sustainable landfill sites selection using geospatial information and AHP-GDM approach: A case study of Abha-Khamis in Saudi Arabia. *Heliyon, 9*, e16432. https://doi.org/10.1016/j.heliyon.2023.e16432.

[86] Molla, M. B. (2024). Potential landfill site selection for solid waste disposal using GIS-based multi-criteria decision analysis (MCDA) in Yirgalem Town, Ethiopia. *Cogent Engineering, 11*(1), 2297486. https://doi.org/10.1080/23311916.2023.2297486

[87] Nguyen, D.-T., Truong, M.-H., Ngo, T.-P.-U., Le, A.-M., & Yamato, Y. (2022). GIS-based simulation for landfill site selection in Mekong Delta: A specific application in Ben Tre Province. *Remote Sensing, 14*(22), 5704. https://doi.org/10.3390/rs14225704.

[88] Elkhrachy, I., Alhamami, A., & Alyami, S. H. (2023). Landfill site selection using multi-criteria decision analysis, remote sensing data, and geographic information system tools in Najran City, Saudi Arabia. *Remote Sensing, 15*(15), 3754. https://doi.org/10.3390/rs15153754

[89] Asefi, H., Zhang, Y., Lim, S., Maghrebi, M., & Shahparvari, S. (2020). A multi-criteria decision support framework for municipal solid waste landfill siting: A case study of New South Wales (Australia). *Environmental Monitoring and Assessment, 192*(682), 1–15. https://doi.org/10.1007/s10661-020-08565-y

[90] Armanuos, A. M., Elgaafary, K. A., & Gado, T. A. (2023). Landfill site selection using MCDM methods and GIS in the central part of the Nile Delta, Egypt. *Environmental Monitoring and Assessment, 195*(1407), 1–27. https://doi.org/10.1007/s10661-023-11946-8

[91] Dereli, M. A., & Tercan, E. (2020). Comparison of GIS-based surrogate weighting methods for multi-directional landfill site selection in West Mediterranean Planning Region in Turkey. *Environment, Development and Sustainability*, 22(5), 4627–4651. https://doi.org/10.1007/s10668-020-00725-x

[92] Balew, A., Alemu, M., Leul, Y., & Feye, T. (2020). Suitable landfill site selection using GIS-based multi-criteria decision analysis and evaluation in Robe town, Ethiopia. *GeoJournal*, 86, 1431–1461. https://doi.org/10.1007/s10708-020-10284-3

[93] Khoshand, A., Bafrani, A. H., Zahedipour, M., Mirbagheri, S. A., & Ehtehsami, M. (2018). Prevention of landfill pollution by multicriteria spatial decision support systems (MC-SDSS): Development, implementation, and case study. *Environmental Science and Pollution Research, 25*(1), 1–17. https://doi.org/10.1007/s11356-017-1099-3

[94] Chabuk, A., Al-Ansari, N., Hussain, H. M., Laue, J., Hazim, A., Knutsson, S., & Pusch, R. (2019). Landfill sites selection using MCDM and comparing method of change detection for Babylon Governorate, Iraq. *Environmental Science and Pollution Research, 26*(33), 35325–35339. https://doi.org/10.1007/s11356-019-05064-7

[95] Davoudi Moghaddam, D., Haghizadeh, A., Tahmasebipour, N., & Zeinivand, H. (2020). Introducing the coupled stepwise areal constraining and Mahalanobis distance: A promising MCDM-based probabilistic model for landfill site selection. *Environmental Science and Pollution Research*, *27*, 1–13. https://doi.org/10.1007/s11356-020-08746-9

[96] Hazarika, R., & Saikia, A. (2020). Landfill site suitability analysis using AHP for solid waste management in the Guwahati Metropolitan Area, India. *Arabian Journal of Geosciences, 13*(1148). https://doi.org/10.1007/s12517-020-06156-2

[97] Abd-El Monsef, H. (2015). Optimization of municipal landfill siting in the Red Sea coastal desert using geographic information system, remote sensing and an analytical hierarchy process. *Environmental Earth Sciences*, *73*(7), 4220–4234. https://doi.org/10.1007/s12665-015-4220-2

[98] Mahmood, K. W., Khzr, B. O., Othman, R. M., Rasul, A., Ali, S. A., & Ibrahim, G. R. F. (2021). Optimal site selection for landfill using the boolean-analytical hierarchy process. *Environmental Earth Sciences, 80*(173), 1–13. https://doi.org/10.1007/s12665-021-09501-0

[99] Mete, M. O., & Biyik, M. Y. (2024). Disaster management with cloud-based geographic information systems: Site selection of landfill areas after Kahramanmaras, Türkiye earthquake sequence. *Environmental Earth Sciences, 83*(358), 1–16. https://doi.org/10.1007/s12665-024-11674-3

[100] Tella, A., Mustafa, M. R. U., Animashaun, G., Adebisi, N., Okolie, C. J., Balogun, A.-L., Pham, Q. B., & Alani, R. (2024). Data-driven landfill suitability mapping in Lagos State using GIS-based multi-criteria decision making. *International Journal of Environmental Science and Technology*. https://doi.org/10.1007/s13762-024-05803-5

[101] Majumdar, A., Hazra, T., & Dutta, A. (2017). Landfill site selection by AHP based multi-criteria decision making tool: A case study in Kolkata, India. *Journal of The Institution of Engineers (India): Series A, 98*(3), 361–369. https://doi.org/10.1007/s40030-017-0211-5

[102] Degefu, M. A., & Asefa, W. (2024). Municipal solid waste management practices and sanitary landfill site selection using the AHP approach for emerging industrial zones. *Environmental Systems Research, 13*(1), 58. https://doi.org/10.1186/s40068-024-00387-y

[103] Kharat, M. G., Kamble, S. J., Raut, R. D., & Kamble, S. S. (2016). Identification and evaluation of landfill site selection criteria using a hybrid Fuzzy Delphi, Fuzzy AHP and DEMATEL based approach. *Modeling Earth Systems and Environment, 2*(2), 98. https://doi.org/10.1007/s40808-016-0171-1

[104] Adewumi, J. R., Ejeh, O. J., Lasisi, K. H., & Ajibade, F. O. (2019). A GIS–AHP-based approach in siting MSW landfills in Lokoja, Nigeria. *SN Applied Sciences, 1*(11), 1528. https://doi.org/10.1007/s42452-019-1500-6

[105] Malo, S. K., Mandal, D., Chakraborty, K., & Saha, S. (2024). Identification of potential landfill site suitability for urban solid waste disposal of Balurghat Municipality of Dakshin Dinajpur District using GIS and multi-criteria decision-making approach. *Discover Applied Sciences, 6*(260), 1–24. https://doi.org/10.1007/s42452-024-05877-3

[106] SK, M. M., Ali, S. A., & 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*(1), 163–180. https://doi.org/10.1007/s42489-020-00052-1

[107] Roy, D., Das, S., Paul, S., & Paul, S. (2022). An assessment of suitable landfill site selection for municipal solid waste management by GIS-based MCDA technique in Siliguri municipal corporation planning area, West Bengal, India. *Computational Urban Science, 2*(18), 1-18. https://doi.org/10.1007/s43762-022-00038-x

[108] Abdelouhed, F., Ahmed, A., Abdellah, A., Yassine, B., & Mohammed, I. (2022). GIS and remote sensing coupled with analytical hierarchy process (AHP) for the selection of appropriate sites for landfills: A case study in the province of Ouarzazate, Morocco. *Journal of Engineering and Applied Science*, *69*(19), 1–23. https://doi.org/10.1186/s44147-021-00063-3

[109] Shukor, A. A. H. M., Ishak, N. M., Salleh, S. A., & Othman, F. (2024). Waste management: Landfill selection using GIS and analytical hierarchy process. *IOP Conference Series: Earth and Environmental Science, 1316*(1), 012003. https://doi.org/10.1088/1755-1315/1316/1/012003

[110] Abushammala, M. F. M., Qazi, W. A., Errag, S., Alazaiza, M. Y. D., & Younes, M. K. (2022). Site selection of municipal solid waste incineration plant using GIS and multicriteria decision analysis. *Journal of the Air & Waste Management Association, 72*(9), 1027–1039. https://doi.org/10.1080/10962247.2022.2064002

[111] Yousefi, H., Javadzadeh, Z., Noorollahi, Y., & 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, 10*(4), 1107. https://doi.org/10.3390/su10041107

[112] Alkaradaghi, K., Ali, S. S., Al-Ansari, N., Laue, J., & Chabuk, A. (2019). Landfill site selection using MCDM methods and GIS in the Sulaimaniyah Governorate, Iraq. *Sustainability, 11*(17), 4530. https://doi.org/10.3390/su11174530

[113] Mallick, J. (2021). Municipal solid waste landfill site selection based on fuzzy-AHP and geoinformation techniques in Asir region, Saudi Arabia. Sustainability, 13(3), 1538. https://doi.org/10.3390/su13031538

[114] Kalisha, S. M., & Munthali, K. G. (2024). Multi-factor GIS modeling for solid waste dumpsite selection in Lilongwe, Malawi. *Sustainability, 16*(3), 1202. https://doi.org/10.3390/su16031202

[115] Singh, C. K., Kumar, A., & Roy, S. S. (2017). Estimating potential methane emission from municipal solid waste and a site suitability analysis of existing landfills in Delhi, India. *Technologies, 5*(4), 62. https://doi.org/10.3390/technologies5040062

[116] Unal, M., Cilek, A., & 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 Supplement), 45-63. https://doi.org/10.1177/0734242X19893132

[117] Patel, R. K., Soni, P., & Singh, P. (2024). *A GIS-based multi-criteria decision framework for landfill site selection in Bilaspur and Gaurela-Pendra-Marwahi districts, Chhattisgarh: Integrating AHP and MIF*. Research Square. https://doi.org/10.21203/rs.3.rs-4329339/v1

[118] Talat, J., Naqvi, S. A. A., Shahzad, M., Khalid, S., Riaz, A., Gill, M. I., & Salma, U. (2024). Comprehensive multi-criteria evaluation for landfill site selection in Faisalabad, Pakistan. *International Journal of Innovations in Science & Technology, Special Issue*, 600-614

[119] Badi, I., Shetwan, A., & Hemeda, A. (2019). A grey-based assessment model to evaluate health-care waste treatment alternatives in Libya. *Operational Research in Engineering Sciences: Theory and Applications, 2*(3), 92-106.

[120] Badi, I. A., & Krebish, M. A. (2020). Evaluating the importance of criteria for decision-making in selecting municipal solid waste landfill sites: A case study in Libya. *Academic Research Journal (Applied Sciences), 16*, 1-5.

[121] Hamad, T. A., Agil, A. A., Hamad, Y. M., & Sheffield, J. W. (2014). Solid waste as renewable source of energy: Current and future possibility in Libya. *Case Studies in Thermal Engineering, 4*, 144-152. https://doi.org/10.1016/j.csite.2014.09.004

[122] Badi, I., Shetwan, A., Abdulshahed, A., & Eltayeb, W. (2019). Evaluation of solid waste treatment methods in Libya by using the analytic hierarchy process. *Decision Making: Applications in Management and Engineering, 2*(2), 19-35. https://doi.org/10.31181/dmame1902038b

[123] Aldeeb, W. A. (2024). The current status of solid waste handling in western region of Libya. *University of Zawia Journal of Engineering Sciences and Technology (UZJEST)*, *2*(1), 24–31.

[124] Badi, I., Abdulshahed, A., & Aljamel, S. (2021). Selecting a landfill site for municipal solid waste in Misrata, Libya using multi-criteria decision-making methods. *Journal of Academic Research (Applied Sciences)*, *17*, 1–7.