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REVIEW ARTICLE Open Access

Landfill Site Selection Techniques in the Kurdistan Region of Iraq: A Comprehensive Study

Kaifi Chomani [1]*

[1] Civil Engineering Department, University of Raparin, Ranya, Sulaymaniyah, Kurdistan Region 46012, Iraq.

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*Email address:
kaifi.chomani@uor.edu.krd
*Corresponding Author

Abstract:
This thorough analysis focuses on methods for choosing landfill sites in Iraq's Kurdistan Region, with a focus on the cities of Halabja and Koya in particular. The research investigates the concrete effects of present landfilling procedures by integrating Geospatial Information Systems (GIS) to illustrate the condition of garbage disposal and the corresponding environmental implications. This review aims to provide a thorough analysis and promote debate on the creation of sustainable waste management plans, the significance of using GIS in decision-making, and the requirement for creative solutions to enhance public health, environmental sustainability, and resource recovery in the Kurdistan Region of Iraq. The research underscores the importance of increased cooperation between relevant groups and institutions to enhance efficient waste handling. It also proposes potential directions for future exploration, such as more comprehensive inquiries into the effects of various weight allocation methods in AHP, SAW, and WLC procedures, as well as the possibility of advanced GIS technologies and alternative decision-making techniques to enhance the decision-making process.

Keywords: *AHP, GIS, Solid Waste Management, KRI.*

1. Introduction

Selecting an appropriate disposal location represents a critical aspect of effectively managing solid waste. This process involves considering various factors, including environmental, societal, economic, and regulatory constraints, along with a significant demand for public services [1-3]. The importance of this decision-making process stems from its far-reaching implications, encompassing issues such as aesthetics, odor, and public health concerns on the societal front, and pollution of soil, water, and air on the environmental front [1]. Given the increasing urban and semi-urban population densities and the growth in solid waste generation rates, these considerations have gained even more prominence [4, 5]. Consequently, the approach to selecting disposal sites has evolved to incorporate more sophisticated and diverse decision-making methodologies, including the utilization of Geographical Information Systems (GIS) and Multi-Criteria Decision-Making (MCDM) techniques [1, 3, 6, 7].

As cities expand and solid waste generation rates increase, the demand for suitable landfill locations has grown significantly. This has led to the adoption of more advanced selection methods that consider a wide range of factors [1]. These methods encompass AHP (Analytic Hierarchical Process), SAW (Simple Additive Weighting), and various other MCDM techniques [1, 8], alongside models based on GIS technology. GIS has emerged as a powerful tool for site selection due to its capacity to gather and analyze extensive and diverse data [9]. It is often employed in conjunction with MCDM approaches to facilitate the assessment of multiple criteria and choices [1].

Similar to numerous other developing regions, the Kurdistan area within Iraq has experienced a rapid urban expansion, leading to a notable surge in municipal solid waste generation. This underscores the pressing requirement for meticulous landfill site selection procedures that encompass economic, societal, and environmental considerations. Earlier research conducted in this locale has showcased the effective application of various models, including GIS, AHP, and SAW, among others, in pinpointing suitable landfill locations [10, 11]. However, comprehensive studies that amalgamate the diverse approaches implemented across the region remain limited.

The overarching objective of this review is to provide a unified and cohesive overview of the prevailing best practices in landfill site selection for the Kurdish region of Iraq by amalgamating these diverse studies and methodologies. This compilation is intended to serve as a valuable resource for policymakers, researchers, and professionals in the field of solid waste management.

The challenge of handling solid waste, including the selection of disposal sites, is a common concern for both developing and industrialized nations [12]. The literature under consideration underscores a variety of efforts aimed at tackling this problem, with a specific focus on the Iraqi Kurdistan region. These studies hold relevance for the ongoing research as they integrate the use of GIS alongside Multi-Criteria Decision-Making (MCDM) techniques.

In a research study conducted within the Sulaimaniyah Governorate of Iraq by Alkaradaghi et al. [10], Geospatial Information Systems were employed by the authors to pinpoint landfill locations. They utilized two Multi-Criteria Decision-Making (MCDM) methods, namely AHP and SAW. The primary aim of this investigation was to underscore the critical importance of carefully selecting landfill sites to protect the environment and preserve urban aesthetics. The study did, however, acknowledge a limitation related to insufficient data on specific criteria, suggesting potential avenues for further research. In a separate study, Aziz and Khodakarami [13] delved into the application of Multi-Criteria Decision-Making (MCDM) techniques and GIS models for the selection of waste disposal sites, with a particular emphasis on urban areas. The study underscored the need for an improved waste disposal site in Koya city, driven by resident complaints and environmental considerations. The authors advocated for the significance of GIS models and emphasized the importance of collaborative efforts among relevant organizations to effectively address this issue.

Manguri and Hamza [11] integrated the AHP method with GIS technology to enhance the accuracy and comprehensiveness of landfill site selection in the Pshdar region, Sulaymaniyah, Kurdistan Region/Iraq. This study underscored the efficacy of the Spatial-AHP method in identifying suitable landfill sites and suggested its potential applicability to similar regions. In alignment with this trend, Khdir and Saeed [14] provided a thorough examination of Ranya City, utilizing AHP and GIS methodologies to identify suitable landfill locations. The study successfully identified three viable landfill sites meeting the required criteria, showcasing the practical utility of these methods in real-world scenarios.

However, Manguri et al. [15] placed its focus on the environmental challenges stemming from the escalating generation of municipal solid waste (MSW) in the Kurdistan Region-Iraq. The paper explored the components and generation rates of MSW in seven distinct cities while emphasizing the consequences of MSW disposal sites on their surrounding areas. Othman et al. [16] comprehensively evaluated the Analytic Hierarchy Process (AHP) and the Method for Order Performance by Similarity to an Ideal Solution as Multi-Criteria Decision-Analysis (MCDA) approaches in the Tanjero River Basin, Kurdistan Region, Iraq (TOPSIS). Of particular note, this research marked a pioneering utilization of the Topographic Position Index (TPI) in the field for the selection of municipal solid waste (MSW) disposal sites. Lastly, employing an array of geospatial tools and the weighted linear combination (WLC) method in the context of TaqTaq in the Kurdistan region of Iraq, Aziz [17] explored the process of selecting suitable solid waste disposal sites. The research underscored the

importance of considering political, economic, and environmental factors when formulating site-appropriate policies.

The application of GIS and MCDM techniques has advanced the domain of landfill site selection significantly. Nevertheless, there remain unexplored avenues worth investigating. One such aspect pertains to the absence of comprehensive comparisons among the diverse MCDM methodologies utilized within these studies [10]. Subsequent research endeavors could aim at discerning the most efficacious MCDM approach for landfill site selection or conceiving a novel method that amalgamates the merits of existing techniques [1]. The literature underscores the pivotal importance of selecting suitable landfill sites. Nonetheless, there is a conspicuous absence of attention directed towards the pragmatic execution of these solutions. Future inquiries could delve into the feasibility of putting the chosen sites into practical operation, encompassing potential challenges and devised strategies for surmounting them [1].

Table 1: The summary of landfill site selection articles.

Authors	Method	Factors	Study area
Karwan [10]	SAW Methods With AHP and GIS	Power lines, Settlement area, rivers, villages, water depth, soil, geology, roads, oil and gas field, LULC, slope, and archaeology.	Sulaimaniyah Governorate, Iraq
Sarkar [14]	Analytical Hierarchy Process (AHP)	Surface water, land use, elevation, Groundwater depth, Geological formations, archeological sites, residential areas, soil, slope, and roads.	Ranya City, Sulaimaniyah Governorate, Iraq
Shwana [11]	Integration of (AHP) with (GIS)	Elevation, the stream power index , the sediment transport index, lithology, rainfall, land use land cover, soil, distance from the river, topographic roughness index aspect, slope, and , topographic wetness index.	Pshdar Area, Sulaymaniyah, Kurdistan Region/Iraq
Aziz [13]	GIS, multi criteria evaluation techniques and Boolean Logic Overlay Model	Distance from rivers, Distance from farmlands, Slope, Distance from springs, Distance from urban areas, Distance from city center, Depth of water table, Distance from roads, Land use, and Distance from Ttopco.	Koya city, Erbil, Kurdistan Region, Iraq
Othman [16]	WSM, Boolean Overlay (BO), WPM, TOPSIS and AHP	Soil, distance to water body surfaces, Distance to road, Slope, distance to agricultural lands, elevation, LULC, groundwater level, distance to city center, distance to village, distance to active fault, Lithology, distance to powerline, TPI, distance to springs.	Tanjero, Kurdistan Region, Iraq
Rostam [17]	Weighted linear combination (WLC) and GIS	Slope, river, water bodies, land use, road, residential, boundary of town.	TaqTaq Sub-district in Iraqi Kurdistan Region

Although the utility of these techniques has demonstrated effectiveness within the Kurdistan region of Iraq, their broader suitability in diverse locales awaits substantiation. Hence, forthcoming investigations could center on implementing these methodologies in disparate geographic and socio-economic settings to ascertain their generalizability [10].

While numerous studies have acknowledged constraints stemming from information deficiencies concerning specific criteria, none have undertaken endeavors to rectify these gaps. Prospective research initiatives could delve into methodologies for acquiring and amalgamating data, thereby furnishing a more comprehensive and precise evaluation of potential landfill locations [1].

The review paper identifies gaps in the current literature on landfill site selection using multi-criteria decision-making (MCDM) approaches. To address these gaps, the following research inquiries are proposed: Which MCDM approach is most effective for selecting landfill sites, and why? What are the practical challenges of implementing the selected landfill locations, and how can these be overcome? How can the effectiveness of different MCDM methodologies be evaluated in different geographical and socio-economic contexts? What strategies can be used to improve data availability for specific criteria, in order to provide a more comprehensive assessment of potential landfill sites?

The primary objective of this review article is to conduct an in-depth examination of the various methods employed for selecting landfill sites within the Kurdistan region of Iraq. This comprehensive analysis will draw insights from case studies conducted in cities within the region, specifically Sulaimaniyah, Ranya, and Koya [10, 16]. The central focus of this review will revolve around the utilization of GIS and other Multi-Criteria Decision-Making (MCDM) techniques, including AHP and SAW. Furthermore, this evaluation will assess their effectiveness while also outlining their respective advantages and disadvantages.

2. Methodology

The detailed review piece offered an extensive examination of techniques for selecting landfill sites within the Kurdistan Region of Iraq, with a special emphasis on recognizing frequently used methods, appraising their advantages and limitations, and delving into their pertinence to the distinct conditions prevalent in this region. In the process of conducting the systematic literature review, the study area exclusively encompassed the Kurdistan Region of Iraq, as only papers focusing on this specific locale were incorporated in this exhaustive article. Rigorous searches were performed across various databases, including Scopus, Web of Science, PubMed, and Google Scholar, utilizing specific keywords like landfill site selection, Kurdistan Region of Iraq, MCDM, GIS, sustainability, and the environment, with a particular focus on all English language publications. Data extraction from these selected papers involved an in-depth analysis of the employed landfill site selection techniques, evaluation criteria, criterion weighting, decision-making methodologies, and the resultant outcomes of the selection process. These extracted insights were subsequently amalgamated to pinpoint the prevailing techniques and critically assess their suitability. Furthermore, this comprehensive review article took into account various considerations, including the distinct necessities of the Kurdistan Region, recent strides in landfill site selection technology, and the perspectives of diverse stakeholders, encompassing the public, private sector, and government.

3. Discussions

Determining landfill locations stands as a pivotal task with profound ramifications for the environment, public health, and overall community welfare. The assortment of scrutinized documents unequivocally demonstrates the evolutionary trajectory of procedures and models embraced for the selection of landfill sites within the Iraqi Kurdistan region. These advancements encompass the incorporation of cutting-edge technologies like Geographic Information System (GIS) and the employment of Multi-Criteria Decision-Making (MCDM) techniques such as the Analytic Hierarchy Process (AHP) and

Simple Additive Weighting (SAW). For instance, Alkaradaghi et al. [10] harnessed MCDM methodologies and GIS tools to designate a landfill site within the Sulaimaniyah Governorate, Iraq (refer to Table 1).

3.1 Strengths and Limitations of Diverse Approaches

In the context of landfill site selection within Iraq's Kurdistan region, investigations consistently reveal the prevalent adoption of GIS integration with MCDM methods [10, 16]. GIS emerges as a valuable instrument adept at handling spatial data efficiently, offering visualization capabilities that facilitate decision-makers in comprehending and analyzing findings [10]. In parallel, MCDM methods furnish a structured and unbiased framework for the inclusion and equilibrium of a multitude of societal, environmental, and economic criteria in the decision-making process [10]. The amalgamation of AHP and GIS, as evidenced in the studies concerning the Sulaimaniyah Governorate and the Tanjero River Basin [16], has proven to be efficacious. AHP contributes a mathematical approach to prioritize criteria through pairwise comparisons. When coupled with the spatial analytical capabilities of GIS, it assists in identifying the most fitting landfill site locations [10].

The utilization of the Simple Additive Weighting (SAW) method, as observed in the context of Sulaimaniyah Governorate, marks a progression beyond the fundamental pairwise comparison approach. It presents a more comprehensive strategy for assigning weight to diverse decision criteria. Nevertheless, it's imperative to note that this method demands that all criteria possess quantifiable attributes, a feasibility that may not always align with practicality. A shared limitation of both the Analytic Hierarchy Process (AHP) and SAW is their reliance on expert judgment, which introduces the potential for subjective biases [10]. Furthermore, these methods presuppose the independence of criteria, a presumption that may not accurately reflect real-world scenarios, as certain criteria might indeed exhibit interdependencies.

The studies conducted in Koya City and the Tanjero River Basin introduced more intricate Multi-Criteria Decision-Making (MCDM) techniques, including Boolean Overlay and the Technique for Order Performance by Similarity to an Ideal Solution (TOPSIS). These methodologies offer a more sophisticated approach to managing decision-making processes, accommodating both quantitative and qualitative data while acknowledging the intricate interplay of decision criteria. Nevertheless, it's worth noting that their implementation demands a higher degree of technical expertise and resource allocation, which can present challenges in a developing region like Kurdistan [16].

3.2 Considerations in Method Selection

When contemplating the choice of a methodology for landfill site selection, a host of factors merit careful deliberation. First and foremost, the accessibility of data is pivotal. It's imperative to recognize that techniques such as the Analytic Hierarchy Process (AHP) and the Simple Additive Weighting (SAW) method necessitate data with quantifiable attributes for all decision criteria [12, 18, 19]. Secondly, the intricacy of the decision conundrum must be weighed. While uncomplicated Multi-Criteria Decision-Making (MCDM) approaches may suffice for less intricate determinations, the terrain shifts when grappling with more elaborate quandaries, particularly those featuring an extensive array of criteria and alternatives. In such scenarios, harnessing advanced methodologies like the Technique for Order Performance by Similarity to an Ideal Solution (TOPSIS) can yield benefits. Additionally, the depth of technical expertise and the availability of resources constitute crucial considerations. More sophisticated methods demand a heightened level of technical proficiency and computational resources. Last but not least, the necessity for transparency and the extent of stakeholder involvement come into play. Certain techniques, such as AHP, inherently offer a higher degree of transparency and lend themselves more readily to effective communication with stakeholders. This

facet carries particular significance in scenarios characterized by public decision-making processes, as exemplified in the context of landfill site selection [20].

3.3 Future Directions

As the intricacies of landfill site selection continue to evolve, demanding the harmonious equilibrium of an ever-expanding array of social, environmental, and economic variables [16], forthcoming investigations might chart courses that revolve around the innovation and application of more advanced decision-making frameworks adept at managing such intricate landscapes [10]. Moreover, the infusion of machine learning techniques into this domain holds the potential to augment the precision and efficiency of site selection processes. Prospective research endeavors may also embark on voyages that explore the integration of community involvement within the decision-making milieu. Such integration bears the promise of amplifying the acceptability and sustainability of the designated landfill locations [1]. Furthermore, the advent of pioneering technologies, exemplified by remote sensing, could further enrich the corpus of data harnessed within these models, thereby enabling the assimilation of more precise and contemporaneous information into the decision-making continuum [16]. Lastly, in light of the escalating significance of sustainability concerns, upcoming research initiatives could undertake quests to mitigate waste generation and unearth alternatives to conventional landfills, such as recycling mechanisms and waste-to-energy technologies. In summation, while extant methodologies for landfill site selection in Kurdistan have proven their mettle [10], there remains ample space for the exploration of fresh frontiers in research and development to refine the decision-making procedures and their attendant outcomes.

Which MCDM methodology proves most efficacious for landfill site selection, and what attributes underlie its superiority?

This reviewed papers for landfill site selection has featured an array of Multi-Criteria Decision-Making (MCDM) techniques, encompassing Analytic Hierarchy Process (AHP), Simple Additive Weighting (SAW), Spatial-AHP, Weighted Linear Combination (WLC), Boolean Overlay, Weighted Sum Model (WSM), Weighted Product Model (WPM), and Technique for Order Performance by Similarity to an Ideal Solution (TOPSIS) [10, 21]. However, it is evident that the Analytic Hierarchy Process (AHP) reigns as the prevailing and efficacious choice. Particularly when coupled with Geographic Information System (GIS), AHP exhibits noteworthy utility. This methodology furnishes a structured and methodical platform for evaluating criteria, endowing the decision-making process with a discernible hierarchy of importance. Notably, AHP possesses the capacity to accommodate both qualitative and quantitative data, facilitating the incorporation of multiple criteria while remaining accessible and comprehensible [10, 21].

What are the practical challenges entailed in the execution of designated landfill sites, and how can they be surmounted?

One of the paramount challenges inherent in the operationalization of designated landfill sites revolves around the paucity of comprehensive data pertinent to specific criteria. This deficit can result in an incomplete evaluation of potential landfill locations. Addressing this challenge mandates concerted efforts in future research and data collection endeavors, aiming to fill these data gaps [7, 12, 22, 23]. Another formidable challenge lies in mitigating potential social and environmental ramifications, ranging from proximity to residential enclaves and water sources to the preservation of archaeological sites. Resolving social opposition necessitates comprehensive public education and engagement initiatives, while adherence to stringent environmental regulations serves as a pivotal mechanism for the amelioration of environmental impacts [23-25].

How can the efficacy of acknowledged Multi-Criteria Decision-Making (MCDM) methods be assessed?

The efficacy of MCDM methods can be gauged through the deployment of case studies and the comparative analysis of outcomes across diverse contexts. Variables such as population density, socioeconomic development, and local regulations can exert influence on the effectiveness of these methodologies [26]. Furthermore, these methods can undergo rigorous testing through their application across various scenarios, accompanied by a scrutiny of result validity and reliability [27]. Additionally, active involvement of local communities and stakeholders in the decision-making process can serve as a mechanism to ascertain that the chosen sites align with the local context [26].

What strategies are available for bridging data gaps on specific criteria, thereby enhancing the comprehensiveness of landfill site assessments?

To tackle data gaps, a multidisciplinary approach featuring collaboration among researchers, local communities, and governmental entities can be employed [18]. Surveys and participatory methodologies can be harnessed to amass localized knowledge and data. Furthermore, technological advancements, including remote sensing and Geographic Information Systems (GIS), offer avenues for augmenting data reservoirs. Moreover, prioritizing long-term monitoring and data collection stands as a crucial facet to cultivate a more comprehensive grasp of the variables under consideration in the landfill site selection process [12].

4. Conclusion

The examination of landfill site selection methods in Iraq's Kurdistan region reveals a consistent utilization of Geographic Information System (GIS) technology and Multi-Criteria Decision-Making (MCDM) techniques, specifically Analytic Hierarchy Process (AHP), Simple Additive Weighting (SAW), Weighted Linear Combination (WLC), and Boolean approaches. Case studies encompassing various cities and regions within Kurdistan, including Sulaimaniyah Governorate, Koya city, Pshdar area, Ranya City, and Tanjero River Basin, underscore the importance of this approach in addressing waste disposal challenges in both urban and suburban settings, exacerbated by population growth and escalating waste generation rates. Throughout the reviewed research, the imperative of meticulous consideration of criteria during landfill site selection remains a recurring theme, often encompassing a blend of environmental, social, and economic factors. Additionally, the spatial comprehension of these factors facilitated by GIS emerges as an indispensable tool. Weight assignment to criteria surfaces as a pivotal aspect in the decision-making process, underscoring the fundamental role of criterion relevance in the successful application of MCDM methodologies.

Despite variations in geographic scope and specific criteria employed, all studies underscore the value of amalgamating MCDM techniques with GIS for the purpose of landfill site selection. This synergy yields the identification of suitable landfill sites, mitigation of environmental impacts, and enhancement of urban aesthetic and health conditions. Furthermore, the combination of these methods, particularly when intertwined, yields precise and dependable outcomes, indicating the potential for their widespread adoption to substantially enhance landfill site selection practices. Nevertheless, the reviewed research also spotlights certain limitations and hurdles. The scarcity of comprehensive data pertaining to several criteria, the complexity arising from the overlap and interconnectedness of factors, and the challenges in accurately assigning weights to these factors persist as ongoing obstacles. Certain studies also underscore the necessity for heightened collaboration among pertinent entities and organizations to bolster effective waste management. This review underscores several avenues for future research. There exists a clear need for more extensive investigations delving into the impact of diverse weight assignment methodologies within the AHP, SAW, and WLC processes. Additionally, the potential for advanced GIS technologies and alternative decision-making methods to augment the selection process warrants further exploration. A more thorough examination of the sociopolitical dimensions of landfill site selection, encompassing residents' perceptions and the repercussions on local communities, could yield valuable insights. Lastly, inquiries into the long-term ramifications of

selected landfill sites on environmental health and sustainability in the Kurdistan region stand as a valuable contribution to this field of research.

5. Conflict of Interest

The author declared that they have no conflict of interest.

6. Author Contribution

The author is contributed to the study conception and analysis were performed by [Kaifi Chomani]. The first draft of the manuscript was written and revised by [Kaifi Chomani]. The author read and approved the final manuscript.

References:

[1] Özkan B, Özceylan E, Sarıçiçek İ. GIS-based MCDM modeling for landfill site suitability analysis: a comprehensive review of the literature. Environmental Science and Pollution Research. 2019;26:30711-30 https://doi.org/10.1007/s11356-019-06298-1.

[2] Cobos-Mora SL, Guamán-Aucapiña J, Zúñiga-Ruiz J. Suitable site selection for transfer stations in a solid waste management system using analytical hierarchy process as a multi-criteria decision analysis: a case study in Azuay-Ecuador. Environment, Development and Sustainability. 2023;25(2):1944-77 https://doi.org/10.1007/s10668-022-02134-8.

[3] Abubakar IR, Maniruzzaman KM, Dano UL, AlShihri FS, AlShammari MS, Ahmed SMS, et al. Environmental Sustainability Impacts of Solid Waste Management Practices in the Global South. International Journal of Environmental Research and Public Health. 2022;19(19):12717 https://doi.org/10.3390/ijerph191912717.

[4] Makonyo M, Msabi MM. Potential landfill sites selection using GIS-based multi-criteria decision analysis in Dodoma capital city, central Tanzania. GeoJournal. 2022;87(4):2903-33 https://doi.org/10.1007/s10708-021-10414-5.

[5] Voukkali I, Papamichael I, Loizia P, Zorpas AA. Urbanization and solid waste production: prospects and challenges. Environmental Science and Pollution Research. 2023 https://doi.org/10.1007/s11356-023-27670-2.

[6] Mancini SD, de Medeiros GA, Paes MX, de Oliveira BOS, Antunes MLP, de Souza RG, et al. Circular Economy and Solid Waste Management: Challenges and Opportunities in Brazil. Circular Economy and Sustainability. 2021;1(1):261-82 https://doi.org/10.1007/s43615-021-00031-2.

[7] Nanda S, Berruti F. Municipal solid waste management and landfilling technologies: a review. Environmental Chemistry Letters. 2021;19(2):1433-56 https://doi.org/10.1007/s10311-020-01100-y.

[8] Mozaffari M, Bemani A, Erfani M, Yarami N, Siyahati G. Integration of LCSA and GIS-based MCDM for sustainable landfill site selection: a case study. Environmental monitoring and assessment. 2023;195(4):510 https://doi.org/10.1007/s10661-023-11112-0.

[9] Boyacı AÇ, Şişman A. Pandemic hospital site selection: a GIS-based MCDM approach employing Pythagorean fuzzy sets. Environmental Science and Pollution Research. 2022;29(2):1985-97 https://doi.org/10.1007/s11356-021-15703-7.

[10] Alkaradaghi K, Ali SS, Al-Ansari N, Laue J, editors. Landfill site selection using GIS and multi-criteria decision-making AHP and SAW methods: a case study in Sulaimaniyah Governorate, Iraq. Conference of the Arabian Journal of Geosciences; 2019: Springer https://doi.org/10.4236/eng.2020.124021.

[11] Manguri SBH, Hamza AA. Sanitary landfill site selection using spatial-AHP for Pshdar area, Sulaymaniyah, Kurdistan region/Iraq. Iranian Journal of Science and Technology, Transactions of Civil Engineering. 2021:1-14 https://doi.org/10.1007/s40996-021-00605-y.

[12] Donevska K, Jovanovski J, Gligorova L. Comprehensive review of the landfill site selection methodologies and criteria. Journal of the Indian Institute of Science. 2021;101(4):509-21 https://doi.org/10.1007/s41745-021-00228-2.

[13] Aziz R, Khodakarami L. Application of GIS models in site selection of waste disposal in an urban area. WIT Transactions on State-of-the-art in Science and Engineering. 2013;77(9):27-35 https://doi.org/10.2495/ISUD130041.

[14] Khdir SH, Saeed KT. Landfill Site Selection Using GIS and (AHP): Case Study of Ranya City. Academic Journal of Nawroz University. 2021;10(4):39-49 https://doi.org/10.25007/ajnu.v10n4a1289.

[15] Manguri S, Hamza A, Mizzouri N, Aziz SQ, Hawez D, Braim S, et al. GIS Visualization of Solid Waste Disposal Sites and Environmental Impacts In Kurdistan Region-Iraq. Eurasian Journal of Science and Engineering. 2022;8:169-87 https://doi.org/10.23918/eajse.v8i3p169.

[16] Othman AA, Obaid AK, Al-Manmi DAM, Pirouei M, Salar SG, Liesenberg V, et al. Insights for landfill site selection using GIS: A case study in the Tanjero River Basin, Kurdistan Region, Iraq. Sustainability. 2021;13(22):12602 https://doi.org/10.3390/su132212602.

[17] Aziz RS. Landfill Site Selection for Solid Waste Using GIS-based Multi-Criteria Spatial Modeling: TaqTaq Sub-district in Iraqi Kurdistan Region as a Case. ARO-THE SCIENTIFIC JOURNAL OF KOYA UNIVERSITY. 2022;10(2):99-105 https://doi.org/10.14500/aro.11017.

[18] Carević I, Sibinović M, Manojlović S, Batoćanin N, Petrović AS, Srejić T. Geological Approach for landfill site selection: a case study of Vršac Municipality, Serbia. Sustainability. 2021;13(14):7810 https://doi.org/10.3390/su13147810.

[19] Mousavi SM, Darvishi G, Mobarghaee Dinan N, Naghibi SA. Optimal Landfill Site Selection for Solid Waste of Three Municipalities Based on Boolean and Fuzzy Methods: A Case Study in Kermanshah Province, Iran. Land. 2022;11(10):1779 https://doi.org/10.3390/land11101779.

[20] Karakuş CB, Demiroğlu D, Çoban A, Ulutaş A. 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. 2020:1-19 https://doi.org/10.1007/s10163-019-00935-0.

[21] Zarin R, Azmat M, Naqvi SR, Saddique Q, Ullah S. Landfill site selection by integrating fuzzy logic, AHP, and WLC method based on multi-criteria decision analysis. Environmental Science and Pollution Research. 2021;28:19726-41 https://doi.org/10.1007/s11356-020-11975-7.

[22] Ali SA, Ahmad A. Suitability analysis for municipal landfill site selection using fuzzy analytic hierarchy process and geospatial technique. Environmental Earth Sciences. 2020;79(10):227 https://doi.org/10.1007/s12665-020-08970-z.

[23] Amoah RA, Kursah MB. Geospatial analysis of landfill site selection perspectives using geographic information systems in Bongo district, Ghana. SN Applied Sciences. 2019;1(10):1237 https://doi.org/10.1007/s42452-019-1273-y.

[24] Koda E, Rybak-Niedziółka K, Winkler J, Černý M, Osiński P, Podlasek A, et al. Space Redevelopment of Old Landfill Located in the Zone between Urban and Protected Areas: Case Study. Energies. 2022;15(1):146 https://doi.org/10.3390/en15010146.

[25] Townsend TG, Powell J, Jain P, Xu Q, Tolaymat T, Reinhart D. The Landfill's Role in Sustainable Waste Management. In: Townsend TG, Powell J, Jain P, Xu Q, Tolaymat T,

Reinhart D, editors. Sustainable Practices for Landfill Design and Operation. New York, NY: Springer New York; 2015. p. 1-12 https://doi.org/10.1007/978-1-4939-2662-6_1.

[26] De Azevedo Reis G, de Souza Filho FA, Nelson DR, Rocha RV, da Silva SMO. Development of a drought vulnerability index using MCDM and GIS: study case in São Paulo and Ceará, Brazil. Natural Hazards. 2020;104:1781-99 https://doi.org/10.1007/s11069-020-04247-7.

[27] Taherdoost H, Madanchian M. Multi-criteria decision making (MCDM) methods and concepts. Encyclopedia. 2023; 3(1): 77-87 https://doi.org/10.3390/encyclopedia3010006.