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Original Article

Environmental Monitoring and Assessment for Landfill Site Selection Using GIS-Based SWARA and Rapid Impact Assessment Matrix

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Abstract
Landfill site selection is a complex decision-making process which requires the evaluation of various environmental, social, and economic criteria. The present research aims to propose a GIS-based Stepwise Weight Assessment Ratio Analysis (SWARA) method for landfill site selection in the east of Lorestan province, Iran. The study used 11 criteria including land use, distance from protected areas, slope, elevation, distance from the water resource, distance from the road, geology, distance from the fault, soil texture, distance from the city, and distance from the village. The results show that the proposed method can be used as a reliable tool for landfill site selection. The method provides decision-makers with a systematic approach to evaluate and rank potential sites based on their suitability. The study found that distance from water resources and soil texture were the most important criteria for landfill site selection in the study area. The proposed method can help decision-makers to identify suitable sites for landfill development considering potential environmental impacts. The study highlights the importance of using the GIS-based SWARA technique for landfill site selection, as it provides a comprehensive and efficient approach to decision-making. The proposed GIS-based SWARA method can be used as a valuable tool for landfill site selection in other regions and can help in achieving sustainable development goals.
Keywords: Landfill site selection, SWARA, GIS, RIAM, EIA

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1. Introduction

Solid waste management is one of the most significant environmental challenges faced by modern societies (1). Improper waste disposal practices result in significant health and environmental risks (2). In this context, the proper selection of landfill sites plays a crucial role in mitigating the negative effects of solid waste disposal (3). Landfill site selection involves a complex process of identifying suitable locations that requires consideration of environmental and socio-economic factors (4). Landfill site selection is a critical and complex process that requires careful consideration of various factors such as environmental impact, social acceptability, economic feasibility, and technical feasibility (5). The strategic selection of landfill sites is an imperative facet of contemporary waste management practices (3). With the exponential growth of urban populations and industrialization, the need for effective waste disposal strategies has become paramount. The necessity of meticulous landfill site selection lies in its direct impact on public health, environmental integrity, and sustainable urban development (2, 5). As urban centers burgeon, the generation of waste materials increases. Ensuring the proper disposal of waste is not only a legal obligation but also a moral and ethical responsibility (6). Inadequate waste management poses risks of pollution, disease transmission, and ecological degradation (2). Thus, the location of landfill sites demands prudent consideration to minimize potential negative consequences on both the environment and human well-being. Moreover, the selection of landfill sites significantly influences land use planning and urban growth. Ill-advised site choices can impede the expansion of residential, commercial, or recreational areas in the future. Conversely, thoughtfully chosen sites can synergize waste management objectives with sustainable urban development goals, optimizing land utilization while safeguarding environmental health. The traditional site selection process can be time-consuming, costly, and prone to errors, leading to potentially negative consequences for both the environment and the community (6). Geographic Information System (GIS) and Multi-criteria Decision Making (MCDM) techniques have been proven to be useful tools for site selection processes, providing a more comprehensive and efficient approach to decision-making (7, 8). Several studies have employed different methodologies to select suitable landfill sites (9, 10). The use of GIS-based MCDM techniques has been found to be a promising approach for landfill site selection (11). In this study, we will explore the use of GIS-based Stepwise Weight Assessment Ratio Analysis (SWARA) as an MCDM technique for landfill site selection. This approach aims to help decision-makers identify the most suitable location for landfill sites, considering a range of criteria and environmental constraints. The use of GIS-based SWARA allows the integration and analysis of various data sources, providing a more accurate and informed decision-making process (12). Several studies have been conducted using GIS-based SWARA to determine suitable landfill site locations (13-15). Ulutaş et al (16) employed SWARA in conjunction with GIS to identify appropriate landfill sites, with the results of their study potentially applicable to waste landfill locations through SWARA. Jafarzadeh Ghoushchi et al (13) employed the SWARA technique to select landfill sites, with their research indicating that it is a powerful and high-performance tool for identifying waste landfill locations. Majeed and Breesam (17) used a hybrid SWARA technique to select landfill sites in Baghdad, and their findings suggested that the use of MCDM algorithms, such as the SWARA technique, improved the accuracy of weighting criteria for site selection. Jalilian et al (15) evaluated landfill sites in Kermanshah province, Iran, using SWARA and MCDM methods, with their research revealing that these algorithms were effective in assessing landfill site suitability for solid waste disposal. Şimşek and Alp (14) employed GIS-based SWARA to identify potential areas suitable for municipal solid waste disposal, finding it to be a useful tool for landfill site selection. Tripathi et al (12) used the SWARA algorithm to identify landfill sites and their sensitivity analysis indicated a high performance of 91% for selecting suitable landfill sites. The SWARA method is a structured approach that involves breaking down complex decision-making problems into simpler parts and assigning weights to each criterion to determine their relative importance (18). GIS-based SWARA can be particularly useful for landfill site selection because it allows decision-makers to evaluate multiple criteria simultaneously (14). This can help ensure that the selected site is not only suitable for waste disposal but also takes into consideration the impact on the environment and surrounding communities (15). By using GIS-based SWARA, decision-makers can generate a composite score for each potential landfill site and rank them based on their suitability for the purpose (16). This approach can provide a more objective and systematic way of making decisions compared to traditional approaches based on intuition or subjective opinions. The main objective of this study was landfill site selection using GIS-based SWARA modeling in the east of Lorestan province, Iran. The present study also aimed to discuss the benefits and limitations of using GIS-based SWARA for landfill site selection, as well as potential areas for future research and development.

2. Materials and Methods

2.1. Case Study

The region under study is an area located in the east of Lorestan (Fig. 1), Iran, with an estimated population of approximately 386 978 people. It is situated at an elevation of around 1480 meters above sea level. The province is known for its mountainous terrain, scenic landscapes, and diverse climate. The part of Lorestan province is characterized by a semi-arid climate with hot summers and cold winters. The average temperature in the province ranges from 5 °C in winter to 30 °C in summer. The region also experiences precipitation throughout the year, with the highest rainfall occurring during the winter months. This part of Lorestan province is divided into 3 counties, including Dorood, Azna, and Aligoodarz, each with its unique neighborhood and population.

2.2. Methodology

The process of selecting a landfill site using GIS-based SWARA involves identifying and prioritizing criteria, collecting and analyzing data, applying the SWARA method to evaluate potential sites, and selecting a suitable site based on various factors (13). It requires expert judgment and the use of GIS and other tools to make informed decisions. This study utilizes GIS software version 10.8. Fig. 2 shows the research process. To model the selection of a landfill site, the research was carried out in 4 steps as follows:

Step 1: Criteria identification and prioritization

- Identify and prioritize the criteria that must be considered in landfill site selection (Table 1)
- Develop a hierarchical structure to represent the criteria and sub-criteria that must be considered
- Use expert judgment to assign weights to each

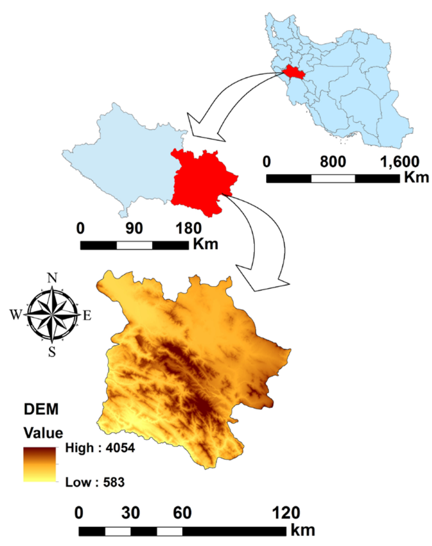

Fig. 1. Location of the Case Study

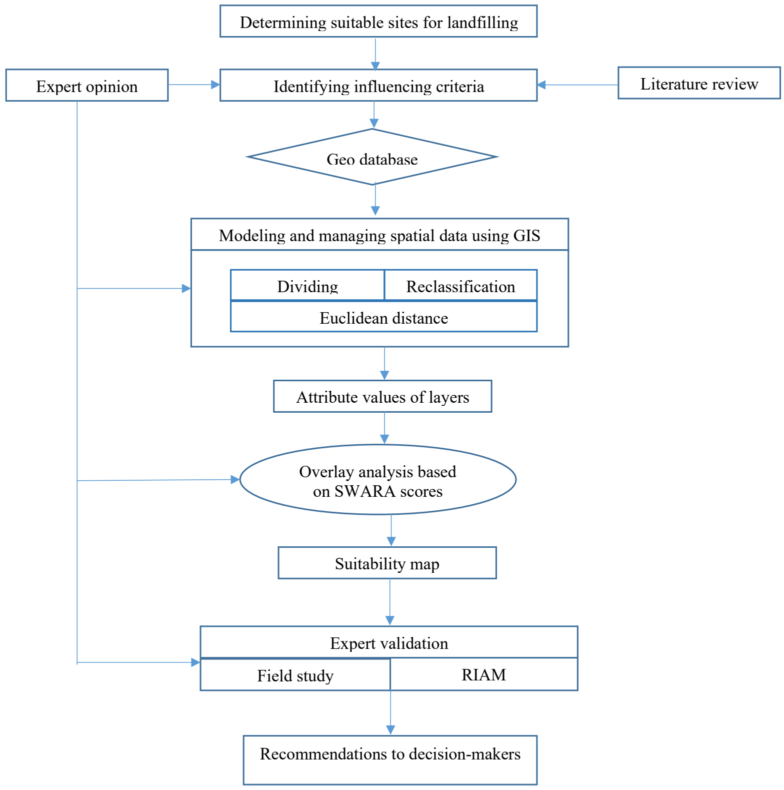

Fig. 2. Diagram of the Research Process

Table 1. Classification of Criteria

Criteria		Suitability				
		Very high	**High**	**Moderate**	**Low**	**Very low**
C1	Land use	Barren lands	Poor rangelands	Mainly dry lands	Agricultural lands	Forest lands
C2	Distance from protected areas (km)	>20	15-20	10-15	5-10	<5
C3	Slope (%)	0-5	5-15	15-30	30-45	>45
C4	Elevation (m)	<800	800-1000	1000-1200	1200-1500	>1500
C5	Distance from water resource (km)	>2	1.5-2	1-1.5	0.5-1	<0.5
C6	Distance from road (km)	1-5	5-10	10-15	15-20	<1 and >20
C7	Geology	Very low permeability	Low permeability	Moderate permeability	High permeability	Very high permeability
C8	Distance from fault (km)	>3	2-3	1.5-2	1-1.5	<1
C9	Soil (%)	Very high clay content	High clay content	Moderate clay content	Low clay content	Very low clay content
C10	Distance from city (km)	3-10	10-15	15-20	20-25	<3 and >25
C11	Distance from village (km)	1-2	2-5	5-10	10-15	<1 and >15

criterion and sub-criterion based on their relative importance

Step 2: Data collection and preparation

- Collect and prepare relevant data for each criterion, such as land use (C1), distance from protected areas (C2), slope (C3), elevation (C4), distance from the water resource (C5), distance from the road (C6), geology (C7), distance from the fault (C8), soil texture (C9), distance from the city (C10), and distance from the village (C11)
- Use GIS to store, visualize, and analyze the spatial data

Step 3: SWARA analysis

- Apply the SWARA methodology to evaluate each potential landfill site based on the identified criteria and sub-criteria
- Calculate the weighted scores for each criterion and sub-criterion based on their importance and the data collected in step 2
- Summarize the scores for each potential site to identify the most suitable locations for a landfill

Step 4: Site selection and rapid impact assessment matrix (RIAM) analysis

- Select the best landfill site based on the SWARA analysis and input layers
- Validate the selected site using field surveys and

RIAM analysis to ensure that it meets all legal and environmental requirements
- Monitor and evaluate the site regularly to ensure that it continues to meet the criteria for a safe and sustainable landfill

2.3. The Process of the SWARA Method

The SWARA method is a multi-criteria decision-making technique that can be used for landfill site selection (17). The SWARA method is a useful tool for landfill site selection as it allows decision-makers to consider multiple criteria and evaluate potential sites based on their suitability (12). The mathematical equation for the SWARA method provides a systematic approach to the decision-making process, ensuring that all criteria are considered and weighted appropriately. The SWARA method involves the following steps:

Step 1: Identify the problem and determine the criteria
- The first step is to clearly define the problem and determine the criteria that will be used to evaluate the alternatives. These criteria should be measurable and relevant to the problem at hand.

Step 2: Construct a decision matrix
- Create a decision matrix that lists the alternatives in the rows and the criteria in the columns. Assign scores to each alternative for each criterion based on their relative performance.

Step 3: Normalize the decision matrix
- Normalize the decision matrix by dividing each score in each column by the sum of all scores in that column. This ensures that all criteria have equal importance.

Step 4: Calculate the relative weights of the effective criteria
- Assign weights to each criterion based on their relative importance

$$W_j = \frac{Q_j}{\sum_{j=1}^{n} Q_j} \quad (1)$$

The SWARA method is a comprehensive and systematic approach that can be used in a variety of decision-making contexts. It provides a way to objectively evaluate alternatives based on multiple criteria and helps to ensure that the best option is selected.

2.4. The Process of RIAM Method

RIAM is a method used to assess the potential environmental impacts of a proposed project or activity (19). The method involves identifying the potential impacts, assessing the magnitude and probability of each impact, and then evaluating the overall significance of the impact (20). In the context of landfill site selection, the RIAM method could be used to assess the potential environmental impacts of the proposed landfill site on the surrounding area. In this study, the RIAM method involves the following steps:

Step 1: Identify the criteria
- Identify the criteria that will be used to assess the potential impacts of the landfill site

Step 2: Assign scores to the criteria
- Assign scores to each criterion based on its potential impact. The scores can be assigned based on expert opinions.

Step 3: Calculate the weighted decision matrix
- Multiply the normalized matrix by the corresponding weight of each criterion to obtain the weighted decision matrix

Step 4: Calculate the total impact score
- Calculate the total impact score of the landfill site by adding the weighted decision matrix for each criterion

Step 5: Determine the level of impact
- Determine the level of impact of the landfill site based on the total impact score. The level of impact can be categorized.

This method was introduced for the first time by Pastaccia (21). Evaluation criteria in this method were divided into two groups including a and b. The scoring method is as follows:

$$(a1)*(a2) = aT$$
$$(b1) + (b2) + (b3) = bT$$
$$(aT)*(bT) = ES$$

Where a1 and a2 represent the importance of the condition and magnitude of change, respectively. In this method, b1, b2, and b3 present permanence, reversibility, and cumulative, respectively. Table 1 shows the environmental score (ES) of the RIAM method.

The effects of selected places were investigated on four environmental parts including economic/operational (EO), socio-cultural (SC), biological/ecological (BE), and physical/chemical (PC).

3. Results and Discussion

The use of SWARA in this study has provided valuable insights into the relative importance of different criteria in assessing the suitability of land for landfilling. The results indicate that the distance from water sources is the most significant factor in determining landfill suitability, with a weight of 0.213 (Table 2). This finding is consistent with previous research that has highlighted the importance of distance from water resources in landfill site selection (22, 23). The second and third most important criteria identified in this study were soil and land use, with weights of 0.154 and 0.124, respectively. Soil is a critical factor in determining landfill sites, and it is essential to ensure that the soil is suitable for the landfill sites (24). The land use criteria also play a significant role in determining the suitability of land for landfilling, as different wastes have different requirements and preferences for land use type (22). The classification maps displayed in Fig. 3 offer a visual depiction of the diverse criteria and their spatial distribution in the study area. These maps serve as valuable tools for decision-makers and stakeholders, aiding them in recognizing optimal locations for landfill

Table 2. Final Weights of the Criteria Using SWARA

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
Weight	0.124	0.085	0.039	0.027	0.213	0.053	0.112	0.103	0.154	0.048	0.042

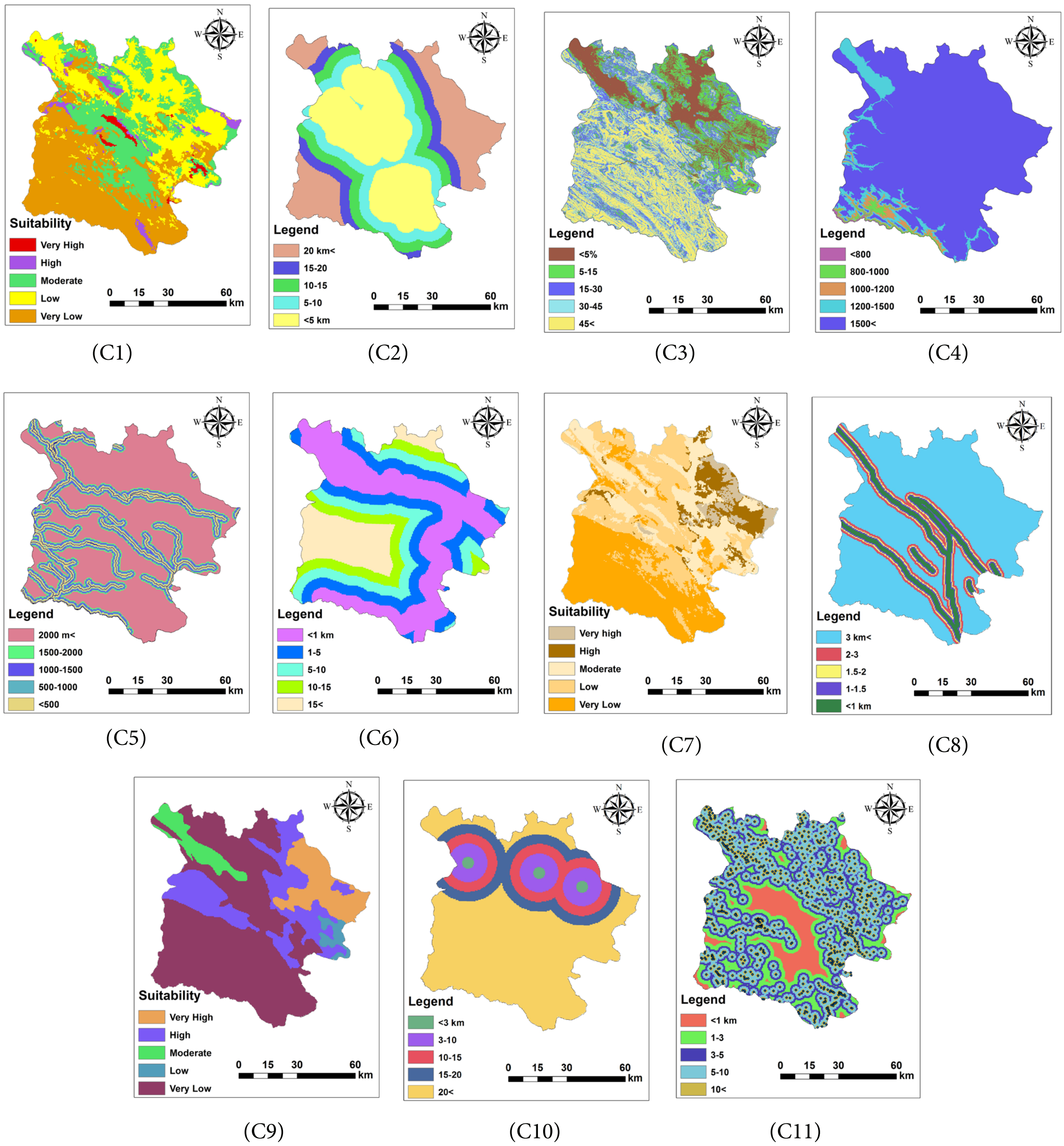

Fig. 3. Classification Maps of Effective Criteria for Landfill Site Selection

establishment and facilitating the formulation of strategies for sustainable landfill expansion. Additionally, these maps have the capacity to pinpoint regions unsuitable for landfilling, enabling more informed and judicious decision-making processes. As a result, these classification maps play a pivotal role in promoting environmentally sound landfill site selection and overall effective land use management in the study region.

The present study was conducted using GIS-based SWARA which provided a comprehensive analysis of the suitability of the area for waste landfill. The overlaying of different layers helped in identifying the most suitable areas for the establishment of a waste landfill. The results obtained from the analysis showed that about 10.6% (898.65 km^2) of the study area was considered to be very highly suitable for waste landfill, whereas about 20.03 % (1684.8 km^2) of the area was found to be completely unsuitable. After finalizing the zones for the waste landfill, a field survey was conducted to verify the results of the analysis. The field survey focused on investigating the presence or absence of nearby roads, the approximate costs of building-related structures, and other obstacles to the construction of the selected sites. The information gathered from the field survey helped in determining the final zones for establishing the waste landfill. Based on the findings of the field survey, 3 zones were selected for the establishment of the waste landfill. The final suitability map generated by the GIS-based SWARA analysis and the field survey helped in identifying the most suitable zones for establishing the waste landfill, which would aid in effectively managing the waste generated in the study area (Fig. 4).

Landfills are of crucial importance in waste management, but their potential environmental impacts must be thoroughly evaluated before they are implemented (21). This study aimed to compare the environmental effects of selected landfill options using the RIAM. Fig. 5 presents the results of the RIAM method for the selected options. The evaluation results of the three zones showed that zone 2 had the least impact on different parts of the environment, followed by zone 1 and zone 3. This finding suggests that zone 2 could be the most suitable option for the proposed landfill site, as it would have the least environmental impact. The RIAM method is a useful tool for decision-makers who need to understand the potential impacts of a proposed landfill site. By evaluating different options using the RIAM matrix, decision-makers can make informed decisions about whether a site is suitable for use. The method can also help identify potential mitigation measures that could be implemented to minimize negative impacts on the environment. It is worth noting that the RIAM method is not a perfect tool, and it has some limitations. For instance, the method relies on expert judgment to evaluate the potential impacts of a proposed landfill site, which could be subjective. Additionally, the method may not consider all possible environmental impacts of a site, and some impacts may be overlooked.

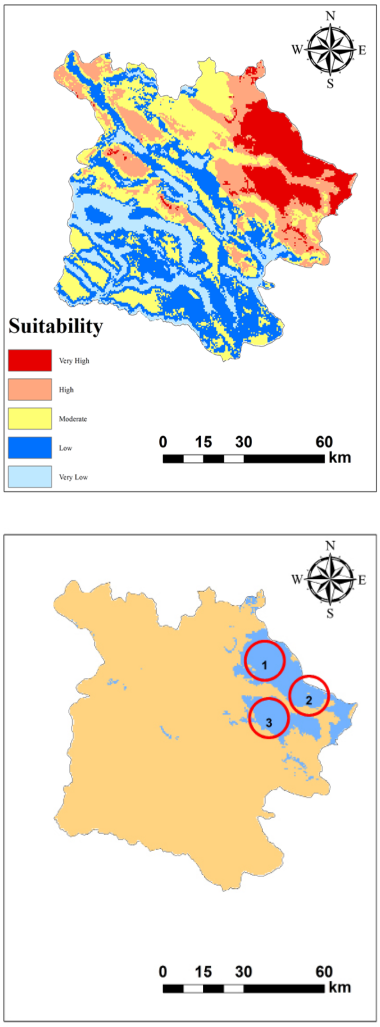

Fig. 4. a) Final Map of Landfill Suitability b) Location of Selected Sites

The use of GIS-based SWARA for landfill site selection is a significant advancement in solid waste management. This approach employs a multicriteria decision-making method that helps decision-makers to select the best location for a landfill site based on various criteria. GIS is a powerful tool for spatial data analysis, and it enables the integration of multiple criteria into a decision-making process. SWARA, on the other hand, is a multicriteria decision-making method that helps to identify the most suitable option based on a set of criteria. The use of this approach in landfill site selection can help to address the growing concern of waste disposal. The selection of a suitable site can minimize the negative impact of waste disposal on the environment, as well as the potential health risks to the surrounding communities (11, 25). However, the success of this approach depends on the accuracy and completeness of the data used in the analysis (12, 13, 16, 26). Therefore, it is crucial to ensure that the data used for the analysis is up-to-date, relevant, and reliable. Additionally, it is essential to involve all stakeholders, including the local community, in the decision-making process. The input of the expert opinion can provide valuable insights into the potential social and environmental impacts of the proposed landfill site (15, 27). In conclusion, the use of GIS-based SWARA for landfill site selection is a valuable tool that can help to ensure that waste disposal is managed in an environmentally and socially responsible manner. However, it is important to ensure that the data used in the analysis is accurate and reliable and that all stakeholders are involved in the decision-making process. The study provides a valuable contribution to the field of environmental engineering by demonstrating how GIS-based SWARA can be used for landfill site selection. The study highlights the importance of considering both technical and non-technical factors in the site selection process and the use of MCDM as a decision-making tool. The findings can be of great use to urban planners, policymakers, and environmentalists seeking to develop sustainable waste management solutions. The study on the application of the RIAM method for environmental

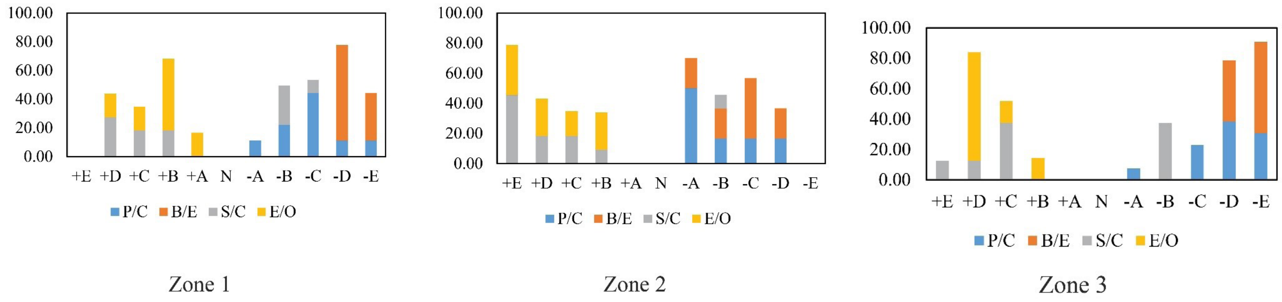

Fig. 5. Results of Environmental Impact Assessment of Selected Sites Using RIAM Matrix

impact assessment (EIA) of landfill site selection provides valuable insights into the use of this method for assessing the potential environmental impacts of landfill projects. The study demonstrates the importance of conducting an EIA before selecting a site for a landfill and highlights the strengths of the RIAM method in conducting such assessments. In many studies, the RIAM method is a useful tool for conducting a rapid assessment of the potential environmental impacts of a project (19, 21, 28). It involves identifying and assessing the significance of environmental impacts based on a set of predetermined criteria (29). The authors have effectively applied this method to assess the potential impacts of a landfill project on the environment. The study provides valuable insights into the use of the RIAM method for EIA of landfill site selection. The study highlights the importance of conducting an EIA before selecting a site for a landfill and the importance of stakeholder engagement in the EIA process. One of the strengths of the study is its comprehensive approach to identifying the criteria that should be considered when selecting a landfill site. The authors have identified a range of factors. This holistic approach is important for ensuring that the selected site is compatible with its surroundings and that it meets the needs of all stakeholders (30-32). One limitation of the study is the lack of detailed information on the specific site being assessed. The study has provided a broad overview of the criteria used to assess the potential impacts of a landfill project but has not provided detailed information on the site-specific factors that could impact the project. Future studies could benefit from including more site-specific information to provide a more accurate assessment of the potential impacts of a landfill project.

4. Conclusion

The article evaluated the use of GIS-based SWARA for landfill site selection. This approach employs a multicriteria decision-making method that integrates various criteria and helps decision-makers to select the best location for a landfill site. Landfill site selection is a complex process that requires the consideration of various environmental, socio-economic, and regulatory factors. The use of GIS-based MCDM techniques, particularly the SWARA method, has been found to be effective in selecting suitable landfill sites. The use of GIS-based SWARA for landfill site selection is a valuable tool that can help to ensure that waste disposal is managed in an environmentally and socially responsible manner. However, it is important to ensure that the data used in the analysis is accurate and reliable and that all stakeholders are involved in the decision-making process. With the use of this approach, decision-makers can make informed and responsible decisions that benefit the environment, the local community, and society as a whole.

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Competing Interests

None declared.

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