International Journal of Multiphysics
Volume 18, No. 4, 2024
ISSN: 1750-9548

Locating the Proper Sites for Sanitary Landfill of Wastewater and Wastes with a Land Use Planning Approach *(Case Study: Basra County, Iraq)*

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Abstract

In today's world, waste and wastewater management has become one of the fundamental challenges in large cities. Basra County, Iraq, is one of the industrial and densely populated areas facing serious issues. This study sought to determine the optimal sites for urban trash disposal in Basra County utilizing a land use planning methodology. The applied research method was descriptive-analytical, utilizing the Analytic Hierarchy Process (AHP) and Geographic Information Systems (GIS) techniques. Site selection was based on five primary criteria: human issues, hydrology, geology, geomorphology, and environmental considerations. The findings indicated that, among the evaluated factors, the distance from population centers (0.3679) and land use (0.2562) possessed the most significant weights. After layer integration and applying legal restrictions, suitable areas were categorized into three priorities, with areas of 15,225, 2,457, and 1,876 hectares, respectively. This study demonstrated that using a land use planning approach for waste disposal site selection could help mitigate negative environmental, social, and economic impacts, providing a suitable model for other similar regions.

Keywords: Site Selection, Sanitary Landfill of Waste, Land Use Planning, Basra, Iraq

1. Introduction

In today's world, environmental and health issues arising from improper waste and wastewater management have become one of the major challenges in many countries around the world (Jalilian, 2021). This problem becomes even more complex in countries experiencing rapid population growth, industrial and urban development, and infrastructure issues. Basra County in Iraq, one of the country's industrial and densely populated areas, faces fundamental waste and wastewater management crises. Therefore, the need for scientific and systematic methods for managing this waste and wastewater, particularly in sanitary landfilling, has become more urgent. This issue is important because improper waste disposal seriously threatens groundwater, soil, and air resources and can lead to irreversible health and environmental consequences (Behbahani-Nia, 2021). In this context, research on the site selection for sanitary landfills using a land-use planning approach, as an environmental and health necessity in Basra, can be a key solution to many problems. The selection of sites for waste and wastewater disposal must include the area's geological, ecological, and social attributes to avert environmental and health complications. In Basra, trash disposal has frequently occurred without adherence to scientific and environmental principles, polluting groundwater, soil, and air and causing significant health issues for the local population. Consequently, investigating site selection for sanitary landfills through a land-use planning framework, particularly by considering the unique attributes of Basra, can yield practical and scientifically grounded solutions to this problem (Bagherabadi, 2022). The need for research on the site selection for sanitary landfills and wastewater disposal in Basra, particularly from the land-use planning perspective, is evident due to the environmental and health status of the region. Due to its specific geographical location, high population density, and growth in industries and agriculture, Basra faces the challenge of generating large amounts of waste and wastewater. These conditions can lead to major environmental and health crises if not properly managed. Therefore, identifying suitable locations

for sanitary waste disposal using scientific land-use planning models and environmental principles can significantly help reduce these crises. Proper site selection for waste and wastewater disposal, in addition to preventing contamination of water and soil resources, can reduce economic costs and minimize negative environmental impacts (Shabani, 2018). On the other hand, selecting appropriate locations for waste disposal, based on the scientific principles of land-use planning, will ensure that areas with environmental sensitivities, such as agricultural lands or those near water resources, remain protected from such processes, thereby minimizing health risks. Therefore, research in this area for Basra and other similar regions facing comparable issues can be a practical and effective model (Ali Shai, 2023). Several key issues complicate addressing the challenges related to waste and wastewater disposal in Basra. One of the major challenges is the lack of advanced and integrated waste management systems. Currently, many waste materials in Basra are disposed of without proper processing, and the sites for their disposal are often selected without regard to environmental standards. The resulting soil, groundwater, and air pollution negatively affect public health, particularly in densely populated areas near disposal sites. Another significant challenge is the lack of coordination between the various entities responsible for waste and wastewater management (Amiri, 2022). In Basra, multiple institutions, including the municipality, environmental agencies, and the Ministry of Health, are responsible for this domain. Nonetheless, the absence of coordination among these groups has resulted in disjointed and ineffective decision-making. The fragmentation in decision-making has led to no comprehensive and coordinated efforts to identify waste and wastewater disposal sites. Additionally, land-use planning and environmental management gaps have led to land allocation for waste disposal without properly considering environmental and social characteristics (Keramat, 2023). The lack of accurate and up-to-date information on land mapping and the ecological status of various areas in Basra hinders the identification of suitable locations for waste disposal and may lead to incorrect decisions with potentially concerning environmental and health consequences. Additionally, the economic challenges and shortage of financial resources for establishing and developing the necessary infrastructure for sanitary landfill sites in Basra remain serious issues (Talebi, 2023). The high costs associated with establishing and maintaining sanitary landfill systems have resulted in many projects facing funding difficulties, leading to incomplete actions. Therefore, this study addresses the "Location Selection for Sanitary Wastewater and Waste Disposal with a Land Use Planning Approach: A Case Study of Basra, Iraq." This research uses hierarchical analysis techniques (AHP) and geographical information systems (GIS) to examine the appropriate location for municipal waste disposal in Basra, Iraq.

2. Literature Review

Talebi et al. (2023) conducted a study titled *"Location Selection for Sanitary Waste Disposal in Bam City Using Multi-Criteria Decision-Making Modeling in GIS Environment."* They emphasized that selecting appropriate landfill sites is an essential environmental issue in urban areas. If waste disposal sites are not adequately designed, they threaten human health. Their study aimed to locate appropriate waste disposal sites in Bam City using Geographic Information Systems (GIS). This research is applied in nature and employs a descriptive-analytical methodology. The study identified, prepared, and standardized the criteria for selecting landfill sites in Bam City. Subsequently, they digitized and weighted eight layers based on existing standards, including topography, geology, slope, fault lines, watercourses, transportation routes, and distance from the city. These layers were input into GIS software to create specialized databases for waste disposal, and various multi-criteria decision-making models were applied to analyze the layers. Based on the used layers and the final map generated, the study classified the region into four categories: very suitable, suitable, unsuitable, and very unsuitable. The results indicated that the southeastern part of the area provided the most suitable space for waste disposal, while the northwestern part of the city offered the least suitable area. Managing waste, or even more broadly, managing material cycles, has become one of the central and critical elements of sustainable development today. Therefore, it is necessary to establish the required infrastructure for better management of urban waste, which has not yet been implemented and requires proper management and the application of sound economic programs. Abedini et al. (2023), in their study titled "Environmental Impact Assessment of Waste Disposal in Saravan Forests Using the Analytical Network Process (ANP) Model for Site Selection," stated that waste disposal is the most common waste management method in many countries due to its low cost and the wide variety of waste types. In the site selection process for waste disposal, various parameters such as social needs, governmental regulations,

environmental laws, and qualitative and quantitative criteria are assessed. This study examined ten key factors for selecting waste disposal sites: land use, slope, elevation, geology, and distance from roads, rivers, springs, wells, villages, and faults. To create the final map, the ANP model was used, and the criteria were converted to GIS format and then to raster format. The results indicated that the distance from faults had the highest weight, while geology had the least impact on site selection. The final map was classified into five classes and showed that suitable waste disposal areas were far from rivers, springs, and residential areas. The best location for waste disposal in the westernmost part of the study area is along the Aqaa Seyed Sharif area. Saghai et al. (2023), in their study titled *"An Analytical Approach to Waste Disposal Site Selection in Ahvaz to Reduce Environmental Damages,"* stated that waste management refers to the set of activities aimed at reducing, transferring, converting, neutralizing, or disposing of waste, where the performance of each component of the system affects the other parts. This study examined the status of waste disposal in Ahvaz city. The Ahvaz waste disposal site, which has been operational since 2012, is located near the Safira village, and approximately 1,000 tons of waste are transported there daily. Due to the activities of waste pickers and their dry waste collection, the total amount of waste collected has decreased to 800 tons per day. The research method was descriptive-analytical, and GIS software was used to assess the current waste disposal situation. This study analyzed the geographical distribution of suitable waste disposal sites in Ahvaz using raster and point-based techniques. Additionally, by employing the FAHP method, the final maps, including the current waste disposal site and proposed alternative locations, were identified. The results showed that the Safira waste disposal site is spatially in a suitable location; however, the challenges present in waste management are primarily due to the lack of proper management.

3. Research Methodology

This multi-phase, descriptive-analytical research evaluates the feasibility of suitable areas for municipal waste disposal in Basra, Iraq, based on hydrogeomorphological, demographic, climatic, and industrial characteristics. The software programs SPSS and ArcGIS were utilized for spatial and statistical analyses. In the first phase, factors influencing waste disposal site selection in Basra, Iraq, were identified. These factors included distance from residential areas, land use types, regional instability, rainfall, and distance to water resources, rivers, lakes, fault lines, and roads. Subsequently, the Analytic Hierarchy Process (AHP) method was employed to assign weights to each layer. Then, the data were consolidated, and with the application of GIS, appropriate and inappropriate locations for garbage disposal were determined. In this model, numerical values ranging from 1 to 9 were used to compare two criteria in terms of priority. This method is highly efficient due to its simplicity, power, and flexibility in decision-making when choosing between similar criteria. This research is applied in nature, utilizing both library and field methods for data collection. Initially, a questionnaire was developed based on the standards for municipal waste management and under the Infrastructure, Industry, and Environment Commission regulations. The validity of the questionnaire was confirmed, and it was distributed to experts for analysis. The results obtained were reviewed for further investigation. The questionnaire and sampling aimed to achieve objectives such as identifying the available workforce in the waste management unit, evaluating the waste management process, and assessing the quality and methods of safe disposal of municipal and household waste.

3.1. Validity and Reliability of the Questionnaire

As a research tool, a questionnaire must be highly accurate to provide valid and reliable information for the researcher. This tool, along with other measurement instruments, is generally categorized into two groups: the first category includes tools that meet the necessary standards and are properly calibrated, ensuring they can be used confidently. The second category contains tools that, due to insufficient reliability, require evaluation and confirmation of their validity and reliability to ensure they possess the necessary credibility. Validity and reliability are key features for assessing the quality of a questionnaire. Validity refers to whether the questions in the questionnaire accurately assess the intended variables and issues. In other words, validity measures the extent to which the collected information is relevant to the research topic. Therefore, confirming the validity of the questionnaire is crucial in the decision-making process to ensure the results are both credible and applicable. To determine the validity and relevance of the questions in the questionnaire, experts and specialists in the relevant field typically evaluate them. This process helps to identify whether the questions have been correctly designed and how effectively they address the intended topics. If necessary, the experts' feedback is incorporated to refine

the questionnaire, ensuring it more accurately addresses the research objectives. Once these steps are completed, testing hypotheses and performing more detailed analyses becomes possible. In this study, the questionnaire consists of six sections, and each question was reviewed and completed by ten experts and managers. The evaluation results of each question will be analyzed separately in the subsequent stages of the study.

Table 1. Frequency and percentage of experts' opinions on separation, packaging, and collection questions

Comments	**Frequency**	**Percentage**
Strongly Disagree	0	0%
Disagree	0	0%
Neutral	0	0%
Agree	7	70%
Strongly Agree	3	30%
Total	10	100%

All experts have confirmed the accuracy and precision of the questions regarding separation, packaging, and collection, so these questions have been approved.

Table 2. Frequency and percentage of experts' opinions on waste transportation

Comments	**Frequency**	**Percentage**
Strongly Disagree	0	0%
Disagree	0	0%
No Opinion	0	0%
Agree	6	60%
Strongly Agree	4	40%
Total	10	100%

These questions were approved, given that all experts fully confirmed the accuracy and precision of the questions regarding waste transportation.

Table 3. Frequency and percentage of experts' opinions about temporary waste storage sites

Comments	**Frequency**	**Percentage**
Strongly Disagree	0	0%
Disagree	0	0%
No Opinion	0	0%
Agree	6	60%
Strongly Agree	4	40%
Total	10	100%

Given that all experts agreed on the accuracy and precision of the questions regarding the temporary storage location of waste, these questions were accepted.

Cronbach's alpha coefficient was used to determine the reliability of the questionnaire. This coefficient measures the internal consistency of instruments such as questionnaires. Cronbach's alpha is calculated using the variance

of the scores for each question and the variance of the total set of questions. This value is obtained through a specific formula calculated in SPSS software. The formula for calculating Cronbach's alpha is as follows:

$$a = \frac{kr}{1 + (k-1)r}$$

In this formula, α represents the reliability of the test, j is the number of questions in the test, S^2j is the variance of each question, and S^2 is the variance of the entire test. If the responses to the questions are unrelated, the value of α will approach zero. If all the questions function correctly and yield consistent results, α will be equal to one. When the questions are standardized to exhibit similar variance, the α coefficient is calculated more simply. In this study, approximately ten questionnaires were prepared and distributed during the initial stages to assess the collected data's reliability. After entering the data into SPSS software version 22, Cronbach's alpha coefficient was calculated for this variable. Given that the α\alphaα value for each question was more significant than 0.7, the reliability of the questionnaire was confirmed. Additionally, Cronbach's alpha coefficient for the pilot sample of the questionnaire was 0.993, well above the threshold of 0.7. Table 4 presents the reliability of the questionnaire based on Cronbach's alpha test.

Table 4. Statistical reliability

Number of questionnaire sections	**Cronbach's Alpha**
7	0.993

Table 5. Calculation of Cronbach's alpha for questionnaire sections

Cronbach's Alpha	**Correlation**	**Variance**	**Mean**	**Questionnaire Sections**
0.990	0.998	446.44	14.01	Segregation, Packaging, Collection
0.992	0.954	462.00	14.00	Waste Transport
0.992	0.954	462.00	14.00	Temporary Waste Storage

4. Findings

4.1. Results Related to the Classification of the 10 Layers

The first step is to present the classification map of the ten layers crucial for identifying areas suitable for creating and developing educational projects. The area of each layer class is then described in a table. The weights derived from each layer are introduced using the AHP method, and finally, a composite map is presented. The layers for identifying suitable locations for urban waste disposal in Basra, Iraq, are divided into five main criteria, each containing various sub-criteria, based on which the distance from settlements is considered a sub-criterion. The distance from surface water resources, such as streams and rivers, is assessed. The distance from faults is regarded as an essential factor. The slope is analyzed. Land use is treated as a determining parameter. Based on these criteria, seven spatial layers need to be classified. The results for each of these layers will be provided below.

4.1.1. Classification Map of Human Criteria

4.1.1.1. Distance from Settlements

Figure 1 and Table 6 display the classification map of the distance from settlements, which includes urban centers and villages within the Basra region of Iraq.

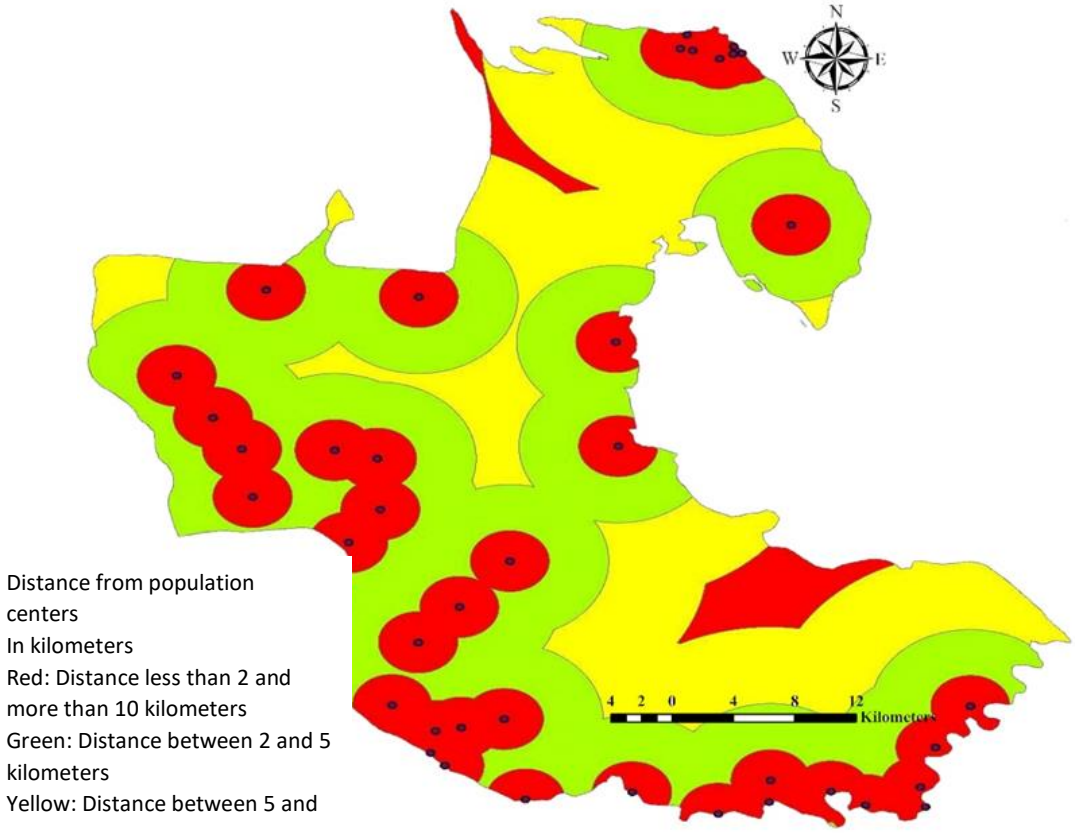


Figure 1. Distance to settlements classification map

Table 6. Characteristics related to distance to settlements classification

Class	Score	Status
Less than 2 km or more than 10 km	-	Inappropriate
Between 5 to 10 km	-	Moderately Suitable
Between 2 to 5 km	-	Suitable

4.1.2. Hydrology Criteria Classification Map

4.1.2.1. Distance from Surface Water Sources

Figure 2 and Table 7 present the classification map of the distance from surface water sources, including rivers and streams, in Basra County, Iraq.

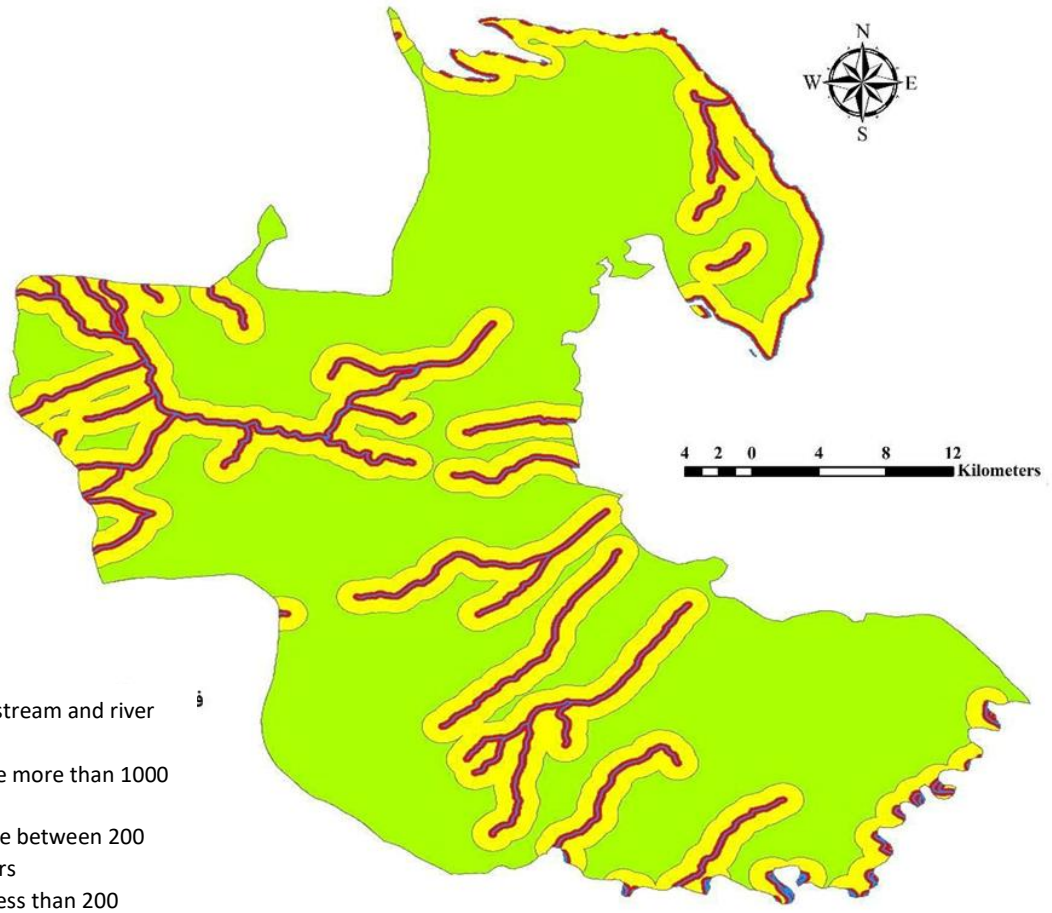


Figure 2. Distance to surface water resources classification map

Table 7. Distance to surface water resources classification specifications

Class	Score
Less than 200 meters	1
Between 200 and 1000 meters	2
More than 1000 meters	3

4.1.3. Geological Criteria Classification Map

4.1.3.1. Distance from Faults

Figure 3 and Table 8 present the classification map of the distance from faults, including primary and minor faults, in Basra County, Iraq.

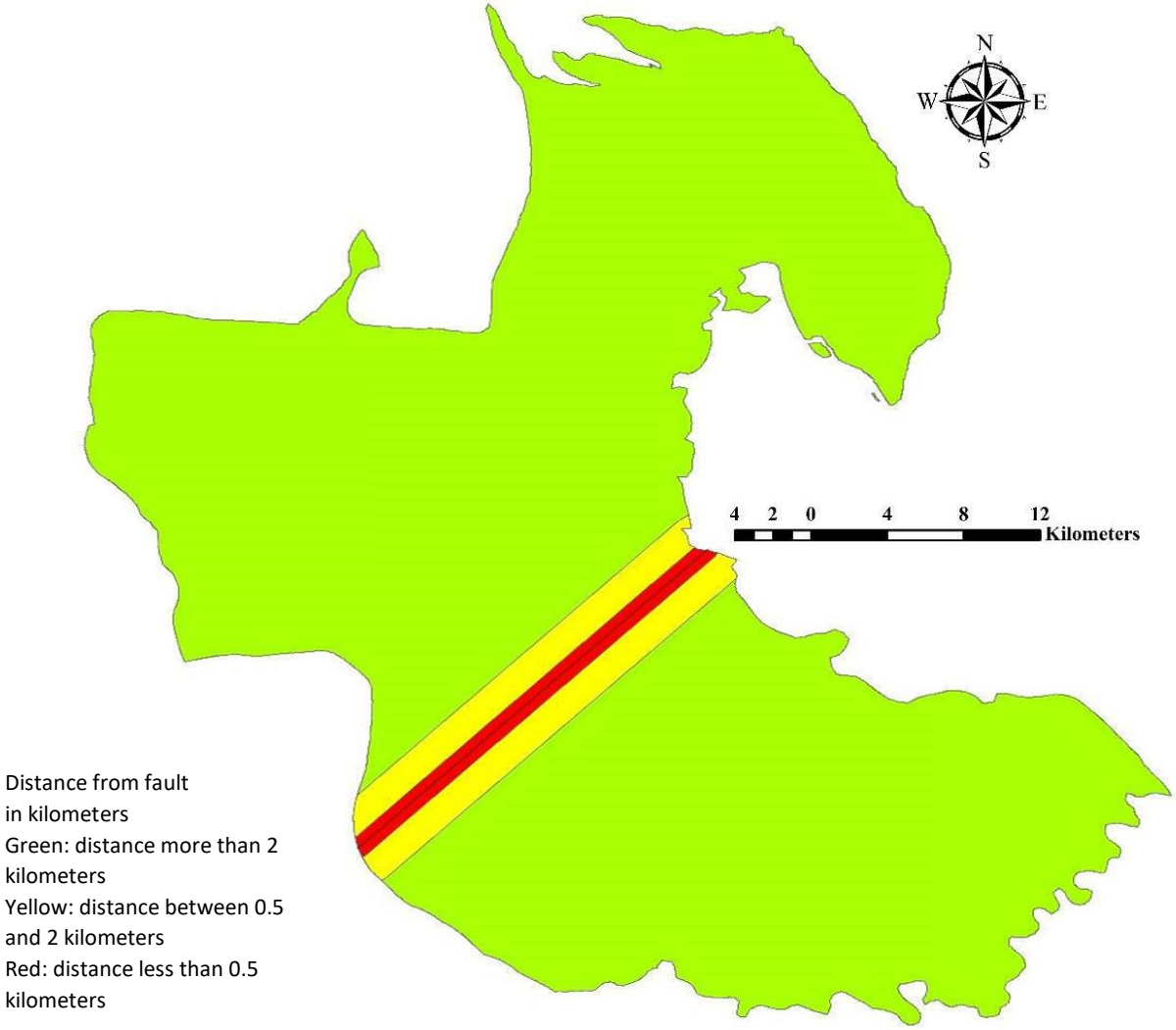


Figure 3. Distance to Fault Classification Map

Table 8. Distance to Fault Classification Specifications

Class	**Score**
Less than 500 meters	1
Between 500 and 2000 meters	2
More than 2000 meters	3

4.1.4. Geomorphological Criteria Classification Map

4.1.4.1. Slope

Figure 4 and Table 9 display the slope classification map for Basra County, Iraq.

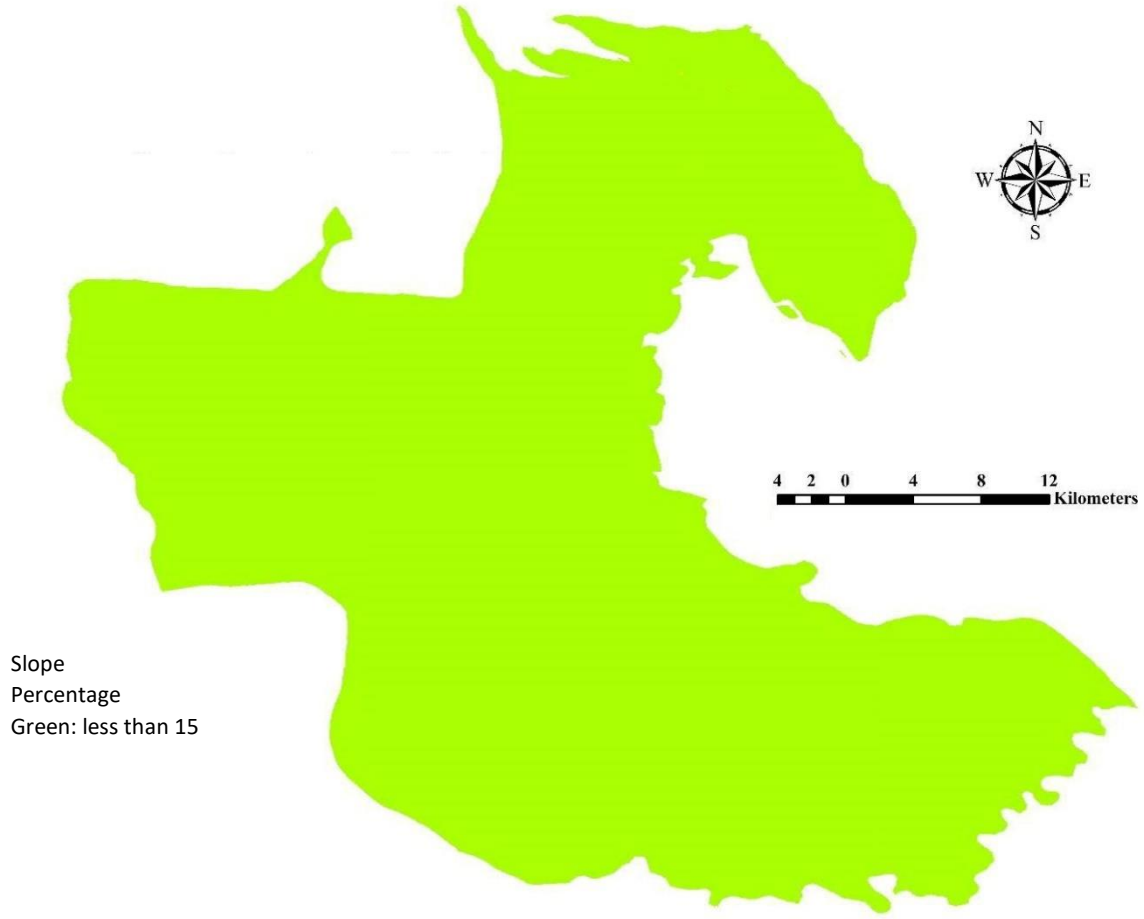


Figure 4. Slope Classification Map

Table 9. Slope Classification Specifications

Class	Score
More than 30%	1
Between 15% and 30%	2
Less than 15%	3

4.1.5. Environmental Criteria Classification Map

4.1.5.1. Land Use

Figure 5 and Table 10 show Basra County, Iraq's land use classification map.

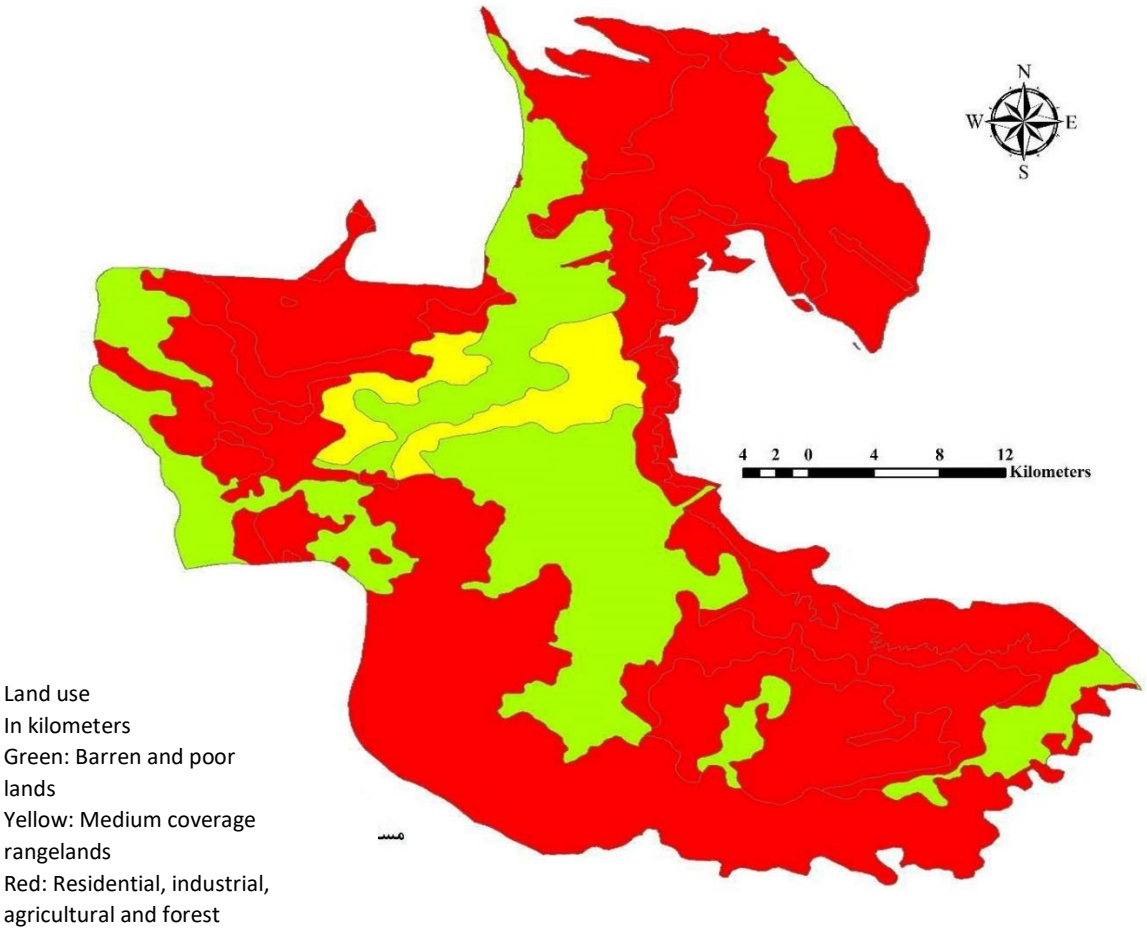


Figure 5. Land Use Classification Map

Table 10. Land Use Classification Specifications

Class	**Score**
Wetlands, agricultural and orchard land, forests, residential and industrial areas, wetlands, salt flats, and protected areas	1
Rainfed land and pastures with moderate cover	2
Poor rangeland and barren land	3

2.4. Results related to Layer Weights

In this phase, based on a pairwise comparison of criteria according to expert judgments, the layers' weights were determined using the AHP method. This process was carried out using the AHP extension in ArcGIS 10.3 software. Accordingly, Table 11 displays each layer's weight and the model's corresponding consistency ratio.

Table 11. Weight of each layer and the corresponding consistency ratio

Criterion	**Weight**	**Inconsistency Ratio**
Distance from Fault	0.0328	0.03679
Distance from Watercourses and Rivers	0.0932	

Distance from Road	0.1789	
Slope	0.0473	
Elevation	0.0237	
Land Use	0.2562	
Distance from Population Centers	0.3679	

3.4. Results of Layer Overlay

Initially, the weight of each criterion in the corresponding layer was multiplied, and the seven layers were overlayed (Figure 6). Then, the overlay layer was standardized, so the values fell from 0 to 1 (Figure 7).

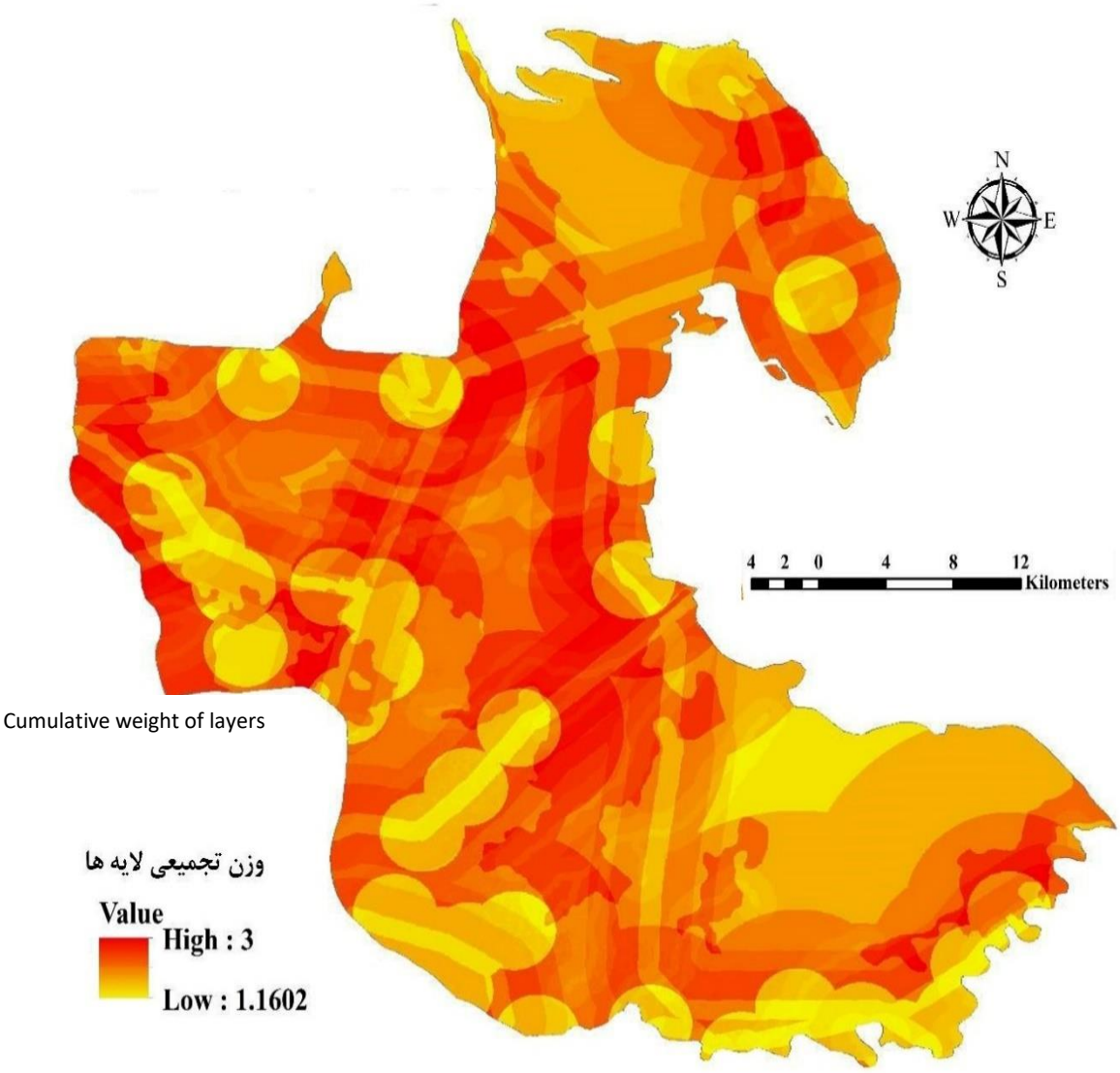


Figure 6. Layer overlap weighting map

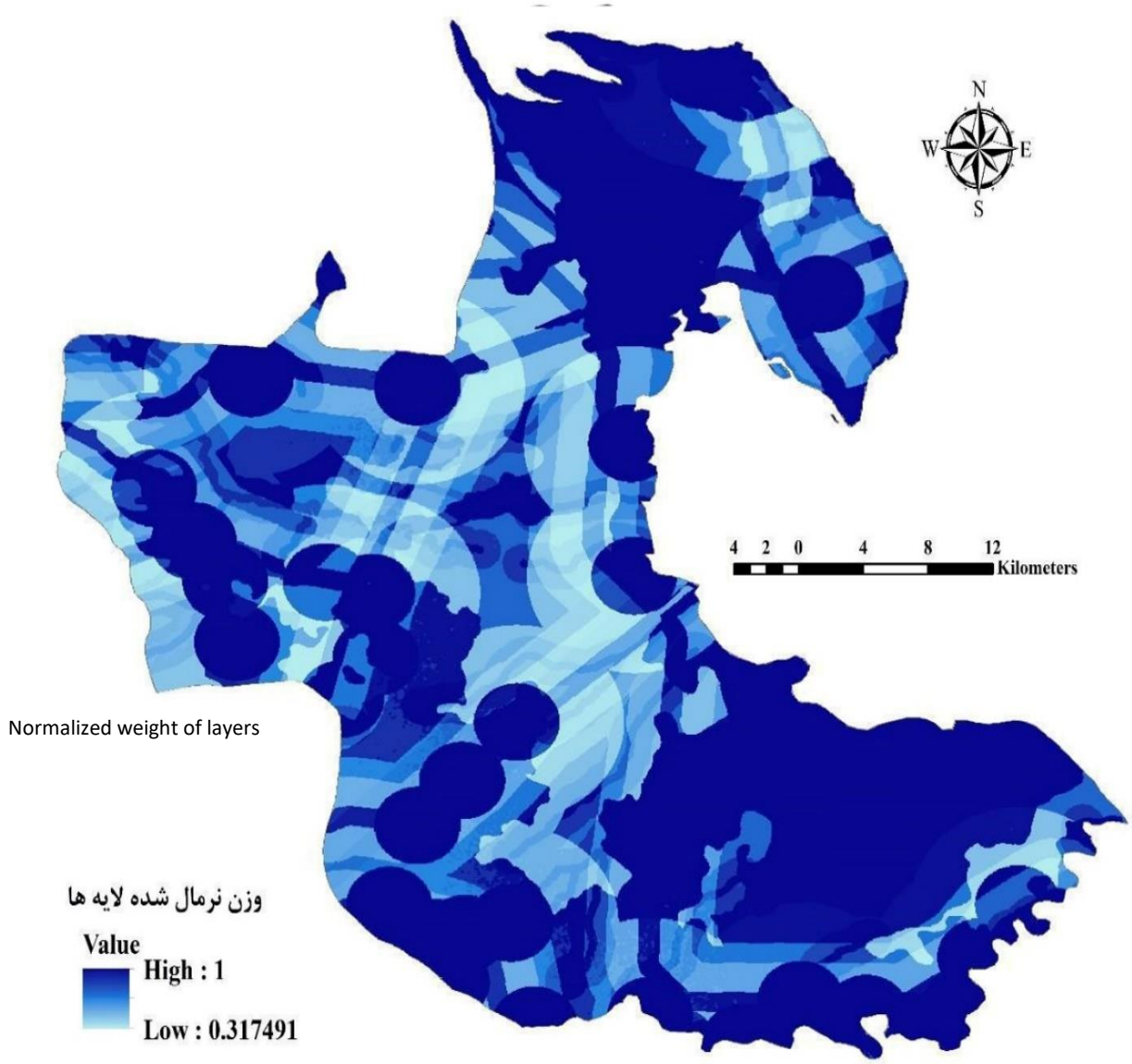
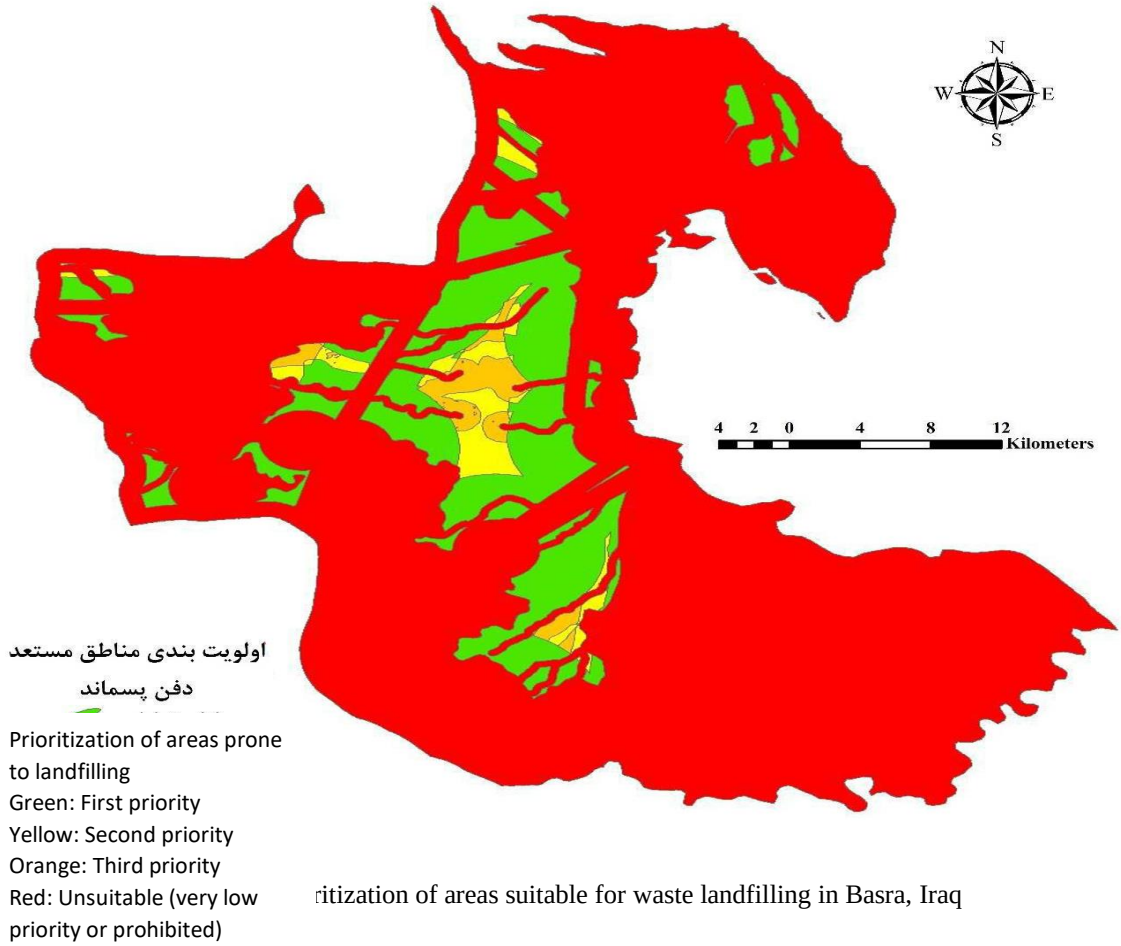


Figure 7. Standard layer overlap map

4.4. Extraction of Final Map

The final step involved applying the constraint layers. Based on this, the final map identifying the suitable areas for establishing and developing waste disposal sites in Basra County, Iraq, was prepared. The restricting regions, as stipulated by Article 12 of the Waste Management Law and Article 23 of its executive regulations, which are not suitable for waste disposal due to their potential environmental impact, include residential areas, industrial zones, afforested areas, mangroves, wetlands, protected environmental areas, floodplains, and a one-kilometer buffer zone along the coastline. Accordingly, the prioritization map for waste disposal areas in Basra County was prepared, as shown in Figure 8. Table 12 lists the areas of the prioritized regions.



ritization of areas suitable for waste landfilling in Basra, Iraq

Table 12. Area of priority areas suitable for waste landfilling in Basra, Iraq

Priority	Land Use Area (hectares)
First	15,225
Second	2,457
Third	1,876

4.5. Land Use Planning Approach in Identifying Suitable Locations for Sanitary Landfill of Waste

Land use planning is a comprehensive strategy in spatial planning designed to optimize the utilization of natural and human resources while systematically allocating land for many applications, including residential, agricultural, industrial, environmental, and service reasons. This methodology is essential in waste management, as appropriate site selection for waste disposal must satisfy both human and environmental requirements while mitigating the adverse effects of inappropriate disposal. In this context, land use planning is an analytical instrument to pinpoint locations suitable for waste disposal hygienically and securely, ensuring no detriment to water resources, soil, air, or adjacent ecosystems. This method functions by assessing and scrutinizing diverse land attributes, including slope, soil composition, proximity to water sources, and fault-related hazards, to identify the most suitable sites for garbage disposal. Moreover, land use planning in garbage disposal facilitates cost reduction, efficient use of natural resources, and environmental conservation. The land use planning strategy is essential as a management tool for planning sanitary landfill sites and can mitigate the environmental and social consequences of inappropriate waste disposal.

4.5.1. Importance of Spatial Planning in Waste Management

Spatial planning denotes a collection of techniques and methodologies designed for the optimal and sensible distribution of natural resources and land within a region, informed by environmental, social, economic, and technical attributes. Spatial planning is crucial in waste management as the placement of trash disposal facilities directly influences environmental and health outcomes. Inadequate selection of disposal sites may lead to water, soil, and air contamination, posing risks to human health and the environment. Thus, by implementing spatial planning concepts, one can pinpoint sites that inflict less ecological damage and optimize land usage effectively. This method guarantees that trash disposal facilities are located in environmentally sustainable and socially and economically viable regions, therefore enhancing the total welfare of the region. Spatial design enables considering elements such as proximity to residential areas, water bodies, and sensitive ecosystems, thereby mitigating the risks associated with trash disposal. Consequently, incorporating spatial planning into waste management methods is crucial for developing more resilient, sustainable, and eco-friendly systems.

4.5.2. The Role of Spatial Planning in Selecting Suitable Landfill Sites

Selecting appropriate locations for waste disposal requires a detailed analysis of various land characteristics, including environmental parameters such as proximity to water resources, land slope, soil type, fault lines, and environmental hazards resulting from waste disposal. Spatial planning assists decision-makers in identifying areas for landfill sites that cause minimal damage to surrounding ecosystems and do not threaten underground and surface water resources. This approach is also significant from social and economic perspectives. Choosing sites far from residential areas and agricultural activities reduces environmental risks and helps minimize social resistance and economic costs. Appropriate site selection grounded in spatial planning principles can improve public approval, minimize disputes with local people, and guarantee effective land utilization without compromising essential resources or public health. Furthermore, integrating land use planning with waste management guarantees that trash disposal practices are conducted sustainably, emphasizing long-term environmental stewardship and resource conservation.

4.5.3. Advantages of Using Spatial Planning Approach to Reduce Environmental Impacts

The use of spatial planning in waste disposal site selection offers multiple benefits. One of the primary advantages is preventing the contamination of water and soil resources. By choosing appropriate locations and precisely defining environmentally stable regions, it is feasible to avert underground and surface water pollution. Moreover, refraining from garbage dumping in ecologically sensitive regions, like forests, wetlands, and protected areas, might prevent biodiversity loss and the deterioration of natural habitats. This method also facilitates the sustainable management of land resources by optimizing land use for future agricultural and residential purposes. Spatial planning functions as a potent instrument in waste management, mitigating adverse environmental and social effects of trash disposal while enhancing the quality of life in urban populations. Aligning waste management activities with ecological principles fosters long-term sustainability and improves human and environmental health.

5. Discussion and Conclusion

Waste and wastewater management poses a significant difficulty for major urban areas. Basra, Iraq, a crucial industrial and demographic hub, encounters substantial challenges in waste management. Accelerated population increase, industrial and urban expansion, inadequate waste management systems, and improper dump site selection present a significant risk to human health and the environment. This issue is crucial as inappropriate garbage disposal jeopardizes groundwater, soil, and air quality, potentially resulting in permanent health and environmental repercussions. This research sought to determine appropriate sites for urban trash disposal in Basra through a land-use planning methodology. The Analytical Hierarchy Process (AHP) and Geographic Information System (GIS) methodologies were utilized to accomplish this objective, and the data were obtained from both library and field studies. Five primary variables were evaluated for site selection: human issues, hydrology, geology, geomorphology, and environmental factors. The results showed that among the criteria considered, "distance from population centers," with a weight of 0.3679, and "land use," with a weight of 0.2562, were the most important in site selection. After layer integration and applying legal restrictions, the suitable areas for waste

disposal were classified into three priorities: the first with an area of 15,225 hectares, the second with 2,457 hectares, and the third with 1,876 hectares. In this process, unsuitable areas such as residential zones, industrial areas, planted forests, mangroves, wetlands, protected environmental areas, flood zones, and the one-kilometer coastal buffer were excluded from the study. The study demonstrated that using a land-use planning approach in waste disposal site selection can significantly reduce environmental, social, and economic impacts. By considering multiple criteria simultaneously and prioritizing suitable areas, this approach facilitates better decision-making for urban managers. Moreover, it provides a practical model for similar regions facing waste management challenges. The land-use planning method, considering environmental, social, and economic issues, minimizes negative impacts and ensures sustainable and efficient waste management in Basra. It provides significant insights that may enhance waste management techniques and the overall quality of life in the city. This methodology can be valuable for other locations with analogous difficulties, enhancing resilient and sustainable urban planning.

6. Recommendations

- Analyze and Prioritize Environmental Criteria for Waste Disposal Site Selection**.**
- Utilize Geographic Information Systems (GIS) to evaluate suitable disposal sites**.**
- Forecast Long-Term Impacts of Waste Disposal Using Land-Use Planning Approaches**.**
- Develop Multi-Criteria Decision-Making Models for Optimizing Landfill Site Selection**.**

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