IDENTIFICATION OF POTENTIAL SITES OF LANDFILLS BY GEO-SPATIAL TECHNIQUES: A CASE STUDY AL-DAWAYA QADHAA, DHI QAR, IRAQ

Mukhalad N. Altai 1, a *,
Faisel G. Mohammed 2, b,
Mourtadha Sarhan Sachit 3, c
Ayaat K. Alzaidy 4, d
1 Department Surveying Engineering, University of Baghdad, Baghdad, Iraq.
2 Department Remote Sensing, Universityof Baghdad, Baghdad, Iraq.
3 Department Civil Engineering, University of Thi-Qar, Nasiriyah, Iraq.
4 Department Surveying Engineering, University of Baghdad, Baghdad, Iraq.
am.mohammed1012@coeng.uobaghdad.edu.iq, bfaisel.mohammed@sc.uobaghdad.edu.iq
c murtadha-s@utq.edu.iq, d a.thejel1412@coeng.uobaghdad.edu.iq
*Corresponding author email: m.mohammed1012@coeng.uobaghdad.edu.iq

Abstract

This study aims to use the geographic information system as an auxiliary technology to select and identify sites for sanitary landfills, in addition to selecting new future sites, determining the suitability of the lands of the city of Al-Dawaya to create sanitary landfill sites, and producing digital maps of the best sites through a set of main criteria such as (Groundwater depth, rivers, urban areas, roads, villages, schools, elevation, power plants, slop, water surfaces, land use, gas pipes, electricity lines, oil pipelines, and wells).Using the data available about the city of Al-Dawaya and assistive techniques such as tools such as geographic information systems and remote sensing, standards were derived for the study area and transformed into a set of maps that represent geological, social and economic standards and environmental considerations, which were processed through the use of tools for spatial analysis, In order to create a suitable indicator map, the weighted linear combination (WLC) approach and the Straight Rank Sum (SRS) method from multi-criteria decision-making were employed. The weights were then derived using the pair-wise comparison method. Two viable locations for the sanitary landfill were chosen after analyzing the data produced by integrating the two maps using geographic information systems to determine the percentage of pixels for compliance and non-conformity. When creating acceptable sites using geographic information systems, the act of confirming the results is a crucial and critical step. The study of fifteen identified criteria was used to accomplish the verification. The first site (A) has an area of (0.80) Km2, while the second site (B) has a total area of (0.99) Km2, and the third site (C) has an area of about (1.40) Km2 square kilometers, these sites are deemed proposed, and the selection procedure is for the decision-maker to select the most suited site. This study provides a method for determining the optimum sites as well as valuable assistance to decision makers in selecting viable sites for sanitary landfills.

Keywords: landfill sites, GIS, Analytic Hierarchy Process (AHP), Straight Rank Sum (SRS) Method.

Introduction

The quality and quantity of waste increased with the development of human settlement and the change in lifestyle, as it was simple waste and food leftovers, and he did not struggle with how to dispose of it because most of it was organic material that quickly decomposed [1].

The increase in the population of cities, economic, cultural and agricultural progress, rising standards of living, and lack of adherence to appropriate methods for collecting and treating waste - all of this has led to an increase in the volume of waste and thus pollution of the environment [2] Choosing a site for sanitary landfill is a complex task because it depends on many factors. It has become more complex due to ongoing environmental work. Also, the significant lack of government support, social and political opposition, increasing rates of population density, and lack of places to build sanitary landfill sites lead to more difficulties in these problems [3].

Suitable sites for landfilling are selected by evaluating geological characteristics using geographic information systems [4]. Geographic information systems are considered to be of great importance for choosing appropriate sites because they can manage and use large amounts of spatial data, and this data can be stored, retrieved, and analyzed with high efficiency [5]. Also, the use or integration of geographic information systems with decision analysis is multiple. The standards lead to processing spatial data in a short period of time and extracting it using the correct methods [6].

GIS (geographic information system) and multi-criteria decision-making processes are powerful, integrated technologies used to address the issue of choosing landfill locations. The selection of a dump location involves the use of GIS. It has a strong capability to manage big volumes of data from a range of sources and decreases time and expense associated with the landfill siting process. Decision-makers can manage a lot of complex information with the use of multi criteria decision techniques (MCDA), [7,8]. Such methods include the analytical hierarchy process (AHP) and the straight rank sum (SRS). [9]. first created AHP in 1980 to determine the weights of criteria using a pair wise comparison matrix. SRS is regarded as one of the multi-criteria making methods, and it was used to give criteria weights directly [10].

2. METHODOLOGY

2. 1. Stady area

The city of Al-Dawaya is located 70 kilometers north of Dhi Qar Governorate, and is 24 kilometers away from the city of Al-Shatra. It is administratively affiliated with Dhi Qar Governorate. Its area is about (113 km^2) [11]. The population of Al-Dawaya Its population is (91.224). It is divided into two parts, the large part and the small part, and is separated by the Al-Dawaya River, where it is located within geographical coordinates. Longitude (31° 29′ 43.1″N) and latitude (46° 22′ 47.59″E), (refer with: Figure 1).

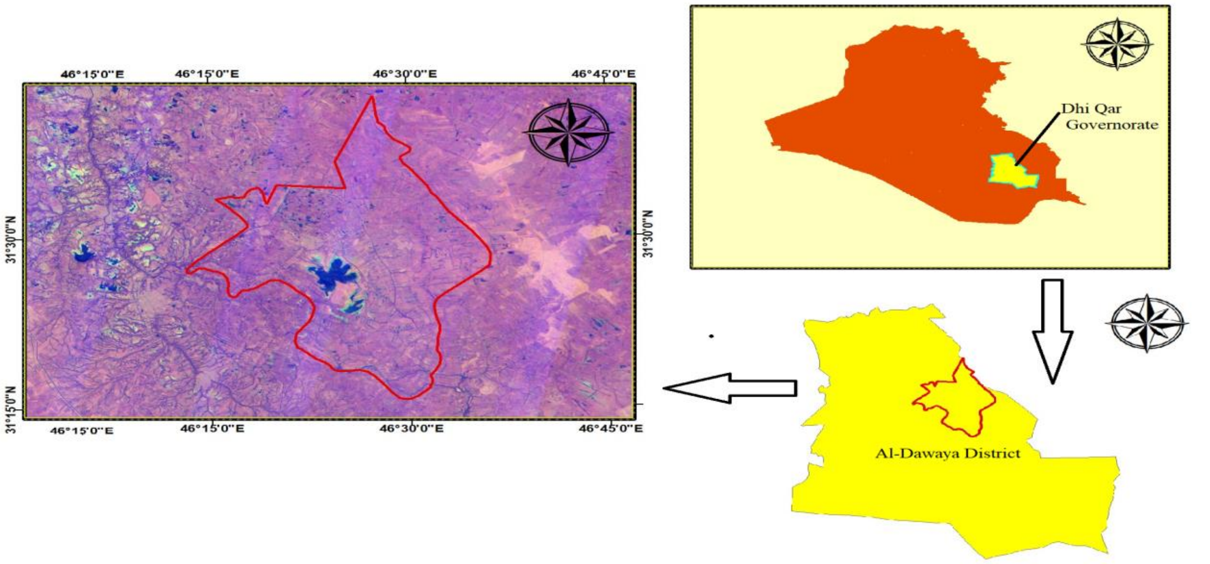

Figure 1: Map of Al-Dawaya Qadhaa.

2.2 Evaluation Criteria for Landfill Siting

Choosing the best suitable sanitary landfill site is the major goal of a multi-decision analysis (AHP, SRS). (refer with: Figure 2). the criteria in the first categorization were divided into two categories: Environmental Factorsand Artificial Factors, and the choice problem has multiple layers. On the other level, in addition to other criteria, there are six categories: hydrological, topographical, land uses, accessibility. The third level, which consists of fifteen digital map layers, provides the secondary and sub-criteria that were employed in the study. Groundwater depth, rivers, urban areas, roads,villages, schools, elevation, power plants, slop, water surfaces, land use, gas pipes, electricity lines, oil pipelines, and wells are some of these characteristics.

2.3 Data collection

There are several approaches to get the data needed to finish the study. From [12] the layer depicting land usage at a scale of 1:1000, 000 was derived. Seventeen wells located both inside and outside the city of Al Dawaya were used to measure the groundwater level. Geographic information systems are used to build a map of the depths of groundwater by interpolating between them using the (IDW) technique inside the spatial analysis capabilities of the GIS software [13]. For maps of schools and power plants at a scale of (1: 400,000), sources can be found in the form of shape files received from the Ministry of Water Resources, such as (Rivers, Villages, Urban area, Road). ALOS satellite-derived DEM with a 12-meter resolution According to the criteria established by the [14] the slope, elevation above sea level, and gas, oil, and power lines should be chosen [15]. "Global Geodetic System (WGS, 1984) using the projected coordinate system (UTM)" was used for the input of all data. Through the USGS website, the Landsat 8 OLI satellite picture for the year 2019 was utilized to define the research area.

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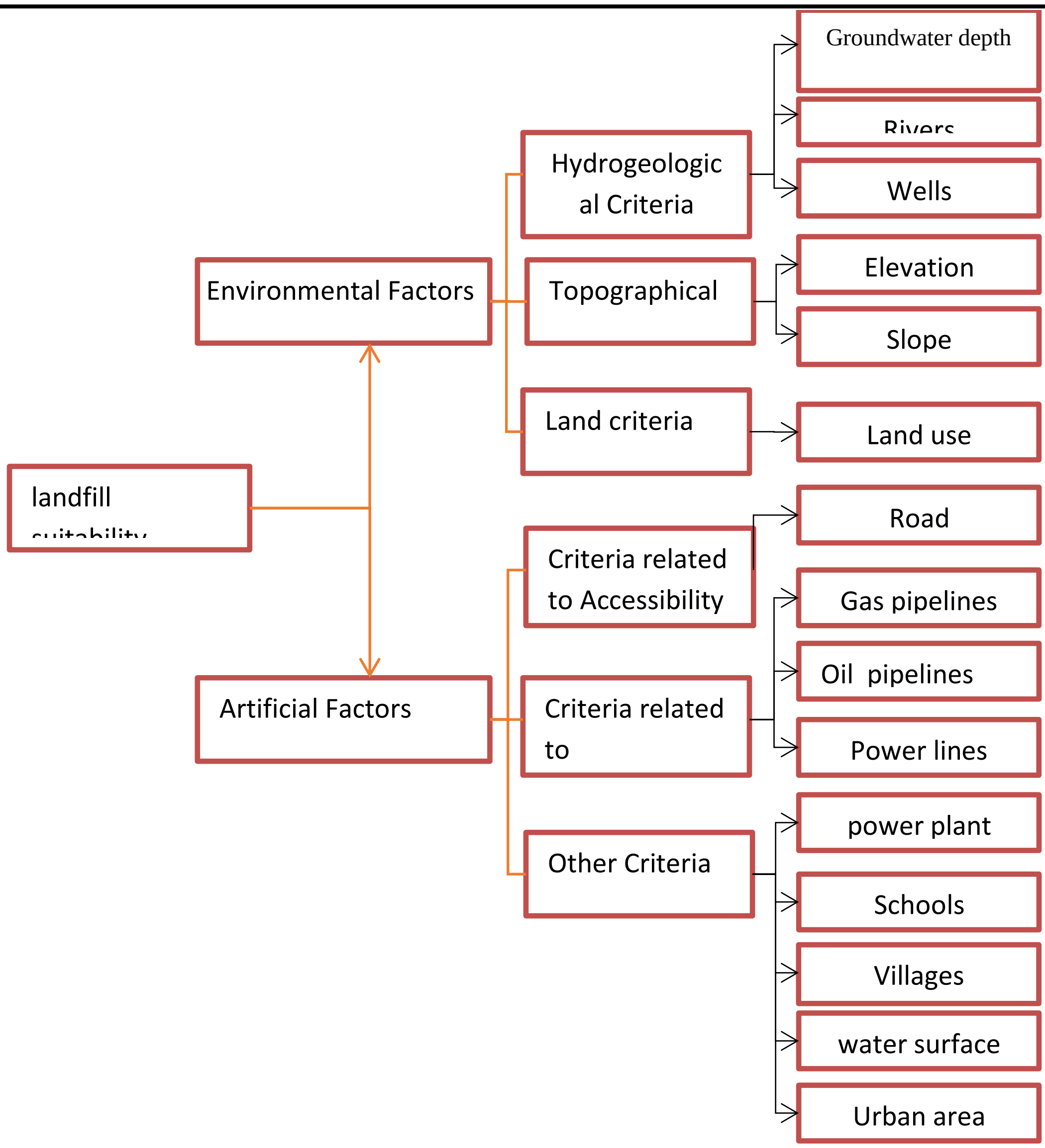

Figure 2: The decision tree developed for the landfill site selection problem

2.4 Buffer Zone

Identifying the best dump site necessitates a large-scale review process. Any chosen site should meet regulatory standards while also decreasing environmental, economic, and societal expenses [16]. Restricted sites are regions that do not permit the establishment of a landfill due to potential environmental, human health, or financial risks [17] Using the special extension tool " buffer ", buffer zones, or geographical limits, were employed around important places or specific geographic characteristics in each criterion in the GIS environment.

2.5 calculating the grading values for the sub-criteria

With the use of the Arc Gis 10.8 program, which was utilized in this study, GIS has the ability to implement some spatial analytic methodologies for data analysis in an objective manner. This methodology is used to identify and select the best locations for the sanitary landfill. Groundwater depth, rivers, urban areas, roads,villages, schools, elevation, power plants, slop, water surfaces, land use, gas pipes, electricity lines, oil pipelines, and wells are among the fifteen layers of input maps. The GIS environment prepares and assesses us for usage in the analytical process. Each criterion was divided into a number of categories (Sub-Criteria Value), and each category was given an appropriate value based on previous studies as well as the opinion of experts and a review of many literature in this field, as well as a number of regulations, requirements, and data available in the study area. Expert and prior judgment. We are ready and evaluated for use in the analysis process by the GIS environment in order to prepare and produce sub-standards. Before the final layers could be obtained, the GIS through a variety of stages, including (buffer, Extract, clip, Aries, proximity, converters, Reclassify, and map Algebra) (refer with: Table 1) and (refer with: Figure 3).

Table 1: Summary of the input layers used in the analysis

criteria	Sub-criteria Value	Sub-criteria scoring	Criteria weights (AHP)
Groundwater depth	0-11 11-12 12-13 >13	2 6 8 10	0.213
Urban area	0-5000 5000-10000 10000-15000 >15000	0 10 5 1	0.155
Rivers	0-1000 >1000	0 10	0.115
Villages	0-1000 >1000	0 10	0.110
Schools	0-2000 2000-4000 4000-6000 > 6000	2 10 4 0	0.104
Roads	0-500 500-1000 1000-2000 2000-3000 >3000	0 10 7 5 2	0.067
Elevation	0-2 2-4 4-10 >10	0 3 7 10	0.048
Slope	0-10 10-20	10 0	0.039
power plant	0-500 >500	0 10	0.033
water surface	0-250 250-500 500-750 750-1000 >1000	0 2 6 8 10	0.033
Land use	agricultural land unused land	0 10	0.021
gas pipelines	0-300 >300	0 10	0.021
Power lines	0-250 >250	0 10	0.016
Oil pipelines	0-400 >400	0 10	0.013
Wells	0-500 >500	0 10	0.010

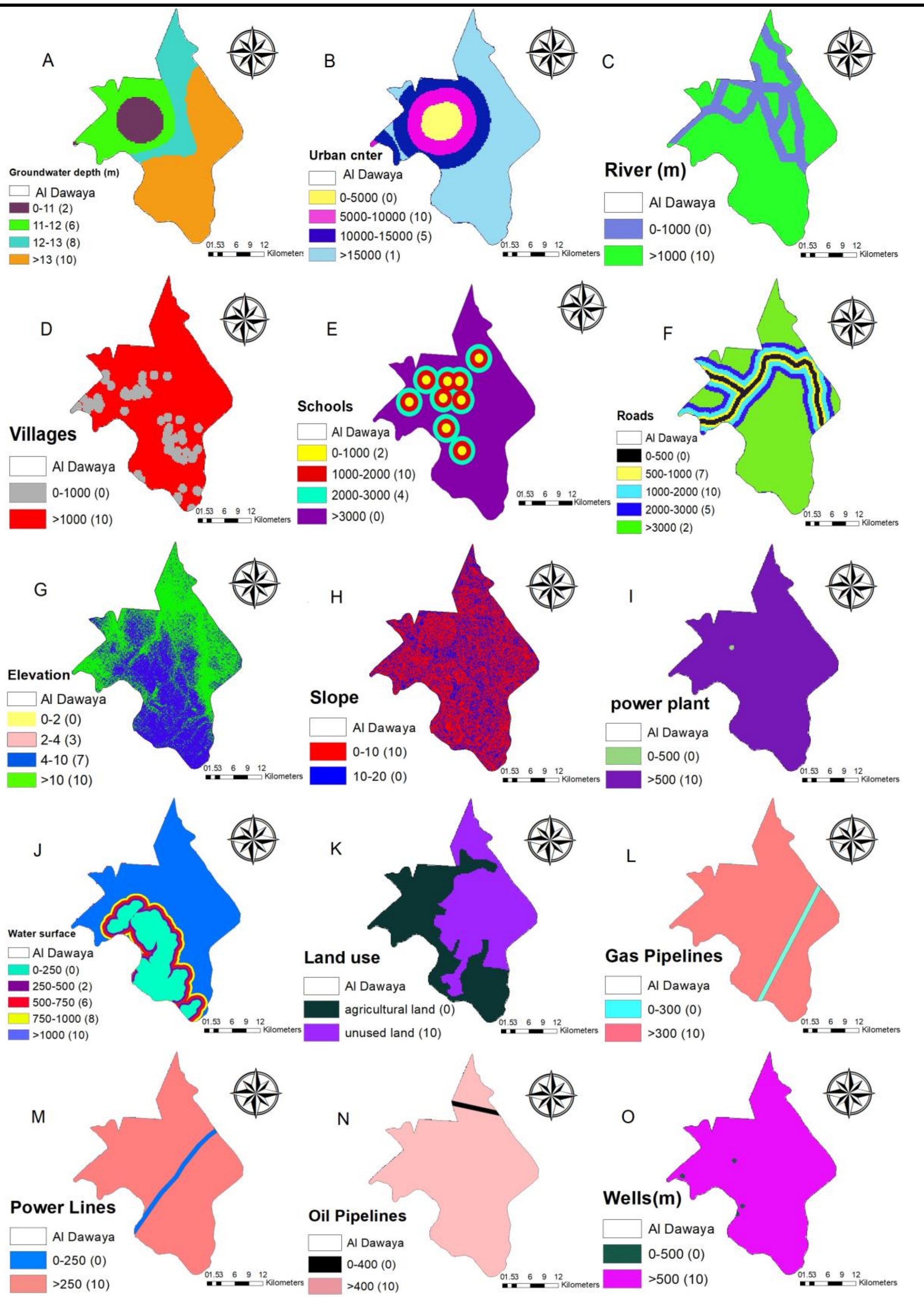

Figure 3: (A) Ground water Depth. (B) urban area. (C) Rivers. (D) Villages. (E) Schools. (F) Road. (G) Elevation. (H) Slope. (I) power plant. (J) water surface. (K) Land use. (L) gas pipelines. (M)Power lines. (N) Oil pipelines. (O) Wells

3. DECISION RULES

3.1 Analytical hierarchy process

According to [18], the Analytic Hierarchy Process (AHP) was created as a decision-making tool for situations with multiple objectives and options. The method involves breaking down the problem, comparing options, and synthesizing priorities based on three key principles.

The Analytic Hierarchy Process utilizes a numerical scale of 9 points to determine the relative importance between each pair of criteria. Each point represents an expression of this importance. Once all criteria (n) have been selected for comparison, the AHP method follows specific steps to derive the weight for each criterion,(Uyan, 2014).The matrix for pairwise comparison (B) of criteria (n x m) refer with: Eq. (1).

$$B=\begin{bmatrix} b11 & b12 & b13 & b14 & b15\cdots & b1n \\ b21 & b22 & b23 & b24 & b25\cdots & b2n \\ bm1 & bm2 & bm3 & bm4 & bm5\cdots & bmn \end{bmatrix} \quad (1)$$

The value of "bij" represents an element in a matrix's row (i = 1, 2,...,m) and column (j = 1, 2,...,n), indicating performance values in terms of the i-th and j-th. The comparison criteria values above the matrix's diagonal are used to fill the upper triangle of the matrix. Then, the reciprocal values of the upper diagonal fill the lower triangle of the matrix, refer with: Eq. (2).

$$b_{ij} = 1/b_{ij} \quad (2)$$

To ensure consistency in the pairwise comparison matrix (B_v), each value in column (j) was divided by the sum of values in that column. This results in a total sum of 1 for each column. The team created the new normalized matrix using the following method, refer with: Eq. (3).

$$B_v=\begin{bmatrix} \frac{b11}{\sum bi1} & \frac{b12}{\sum bi2} & \frac{b13}{\sum bi3} & \frac{b14}{\sum bi4} & \frac{b15}{\sum bi5}\cdots & \frac{b1n}{\sum bin} \\ \frac{b21}{\sum bi1} & \frac{b22}{\sum bi2} & \frac{b23}{\sum bi3} & \frac{b24}{\sum bi4} & \frac{b25}{\sum bi5}\cdots & \frac{b2n}{\sum bin} \\ \frac{bm1}{\sum bi1} & \frac{bm2}{\sum bi2} & \frac{bm3}{\sum bi3} & \frac{bm4}{\sum bi4} & \frac{bm5}{\sum bi5}\cdots & \frac{bmn}{\sum bin} \end{bmatrix} \quad (3)$$

The eigenvector was obtained by calculating the average values in each row (F_i) of the matrix (B_v). This resulted in the creation of the matrix (B_F), where (F_i) represents the weight or relative importance of the criterion, refer with: Eq. (4).

$$B_F=\begin{bmatrix} F1 \\ F2 \\ F3 \\ Fn \end{bmatrix} = \begin{bmatrix} \frac{\frac{b11}{\sum bi1}}{n} & \frac{\frac{b12}{\sum bi2}}{n} & \frac{\frac{b13}{\sum bi3}}{n} & \frac{\frac{b14}{\sum bi4}}{n} & \frac{\frac{b15}{\sum bi5}}{n}\cdots & \frac{\frac{b1n}{\sum bin}}{n} \\ \frac{\frac{b21}{\sum bi1}}{n} & \frac{\frac{b22}{\sum bi2}}{n} & \frac{\frac{b23}{\sum bi3}}{n} & \frac{\frac{b24}{\sum bi4}}{n} & \frac{\frac{b25}{\sum bi5}}{n}\cdots & \frac{\frac{b2n}{\sum bin}}{n} \\ \frac{\frac{bm1}{\sum bi1}}{n} & \frac{\frac{bm2}{\sum bi2}}{n} & \frac{\frac{bm3}{\sum bi3}}{n} & \frac{\frac{bm4}{\sum bi4}}{n} & \frac{\frac{bm5}{\sum bi5}}{n}\cdots & \frac{\frac{bmn}{\sum bin}}{n} \end{bmatrix} \quad (4)$$

In order to calculate the consistency vector of the weight values W, this is done by multiplying the matrix (B_v) with the matrix (B_F), which is considered the best estimation for the eigenvector, refer with: Eq. (5).

$$B_F \; x \; B_V \begin{bmatrix} F1 \\ F2 \\ F3 \\ Fn \end{bmatrix} x \begin{bmatrix} b11 & b12 & b13 & b14 & b15\cdots & b1n \\ b21 & b22 & b23 & b24 & b25\cdots & b2n \\ bm1 & bm2 & bm3 & bm4 & bm5\cdots & bmn \end{bmatrix} = \begin{bmatrix} W1 \\ W2 \\ W3 \\ Wn \end{bmatrix} \quad (5)$$

The eigenvalue of the pairwise comparison matrix(λmax) was calculated, refer with: Eq. (6).

$$\lambda max=\frac{1}{n}\sum_{i=1}^{n}\frac{Wi}{Fi} \quad (6)$$

In this study, it was found that the consistency index (CI) of a matrix can be determined, refer with: Eq. (7).

$$CI = \{(\lambda max - n) / (n - 1)\} \quad (7)$$

With a matrix size of n = 15 and a maximum value of λmax = 16.078, the CI was calculated to be 0.077. To calculate the consistency ratio (CR) depending on [19]., the CI value was divided by the random index (RI), which is 1.59 for a matrix with 15 criteria [20]. A CR value less than 0.1 suggests a reasonable level of consistency in pairwise comparison. The CR in this study was 0.048, which is below the critical limit of 0.1, Table 2 presents the pairwise comparison matrix and criteria weights.

Table 2: The comparison matrix developed for the landfill site selection problem

Criteria	Groundwater depth	Urban area	Rivers	Villages	Schools	Road	Elevation	Slope	power plant	Water surface	Land use	Gas pipeline	Power lines	Oil pipelines	Wells	Eigenvalue	Priority vector
Ground water	1	3	3	3	5	5	4	5	7	4	7	8	8	9	9	4.740	0.213
Urban area	0.3	1	2	3	3	4	4	5	6	3	6	6	6	8	8	3.455	0.155
Rivers	0.3	0.5	1	2	2	3	3	3	4	2	5	5	6	8	8	2.567	0.115
Villages	0.3	0.3	0.5	1	1	3	3	4	4	5	5	7	8	8	8	2.457	0.110
Schools	0.2	0.3	0.5	1.0	1	3	3	4	5	5	6	6	6	7	7	2.327	0.104
Road	0.2	0.2	0.3	0.3	0.3	1	2	2	2	4	5	6	6	6	6	1.487	0.067
Elevation	0.2	0.2	0.3	0.3	0.3	0.5	1	2	1	2	3	3	4	4	4	1.068	0.048
Slope	0.2	0.2	0.3	0.2	0.2	0.5	0.5	1	1	2	2	2	4	4	5	0.874	0.039
Power plant	0.1	0.1	0.2	0.2	0.2	0.5	1.0	1.0	1	1	1	2	3	3	4	0.739	0.033
Water surface	0.2	0.3	0.5	0.2	0.2	0.2	0.5	0.5	1.0	1	2	2	2	3	4	0.736	0.033
Land use	0.1	0.1	0.2	0.2	0.1	0.2	0.3	0.5	1.0	0.5	1	1	1	2	3	0.479	0.021
Gas pipeline	0.1	0.1	0.2	0.1	0.1	0.1	0.3	0.5	0.5	0.5	1.0	1	2	3	3	0.471	0.021
Power lines	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.3	0.5	1.0	0.5	1	2	2	0.363	0.016
Oil pipelines	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.5	0.3	0.5	1	3	0.291	0.013
Wells	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.5	0.3	1	0.232	0.010
SUM																22.285	1.000

3.2 Straight Rank Sum Method

Based on the data, the SRS method ranks criteria to determine their relative significance. This is achieved by organizing the criteria in descending order, with the most important criteria receiving the highest ranking according to the decision makers' opinions. To normalize the weights of criteria, (refer with: Table 3) each weight is divided by the sum of all weights, refer with: Eq. (8).

$$Wi = \{(n - ri + 1) / \sum(n - rj + 1)\} \quad (8)$$

Wi; represent relative important of NW for i criteria, n; number of criteria, (1,2,3…n), ri; represent rating position of criteria.

Table 3:The criterion weightings defined for the SRS method and normalized weights

NO.	Criteria	Criteria Weight (n-ri+1)	Normalized Weight
1	Groundwater	15	0.125
2	Urban area	14	0.117
3	Rivers	13	0.108
4	Villages	12	0.100
5	Schools	11	0.092
6	Road	10	0.083
7	Elevation	9	0.075
8	Slope	8	0.067
9	power plant	7	0.058
10	water surface	6	0.050
11	Land use	5	0.042
12	gas pipelines	4	0.033
13	Power lines	3	0.025
14	Oil pipelines	2	0.017
15	Wells	1	0.008
Sum		120	1.000

4. RESULTS AND DISCUSSION

4.1 Final Output Maps

After all layers were prepared for the input data, fifteen layers were entered into the GIS environment. After that, the (WLC) method was used, refer with: Eq. (9).

$$Y=\sum_{j=1}^{n} Wj \text{ x } Lij \tag{9}$$

Y; "represent the suitability index for area I", W j; represent relative importance weight of criteria, Lij; "grading value" of area I", n; "represent total number of criteria".

The appropriateness index was calculated by adding the results of multiplying the values of the criteria scores with the relative weight of each criterion, and two methods of multi-resolution analysis—AHP and SRS—were used in detail for data analysis and selection of the best location for the healthy landfill by geographic information systems. The equation was used for all criteria by extension tools, map algebra, in geographic information systems (refer with: Figure 4).

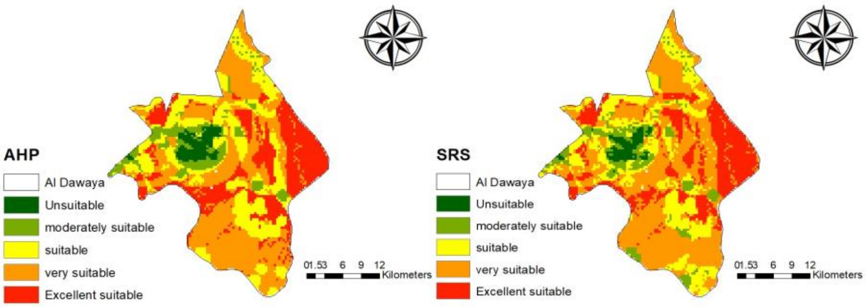

Figure 4:The procedure for both MCDA methods

4.2 Comparison of the results from multi-criteria decision-making methods

Comparing the maps created by the different multi-resolution analysis techniques (AHP, SRS), each map was classified into one of five categories: "unsuitable," "moderately suiting," "suitable," "most suiting," and "excellent suiting." Regarding the Pixel Count and Suitability Index for Multi-Resolution Analysis Techniques (refer with: Figure 5).

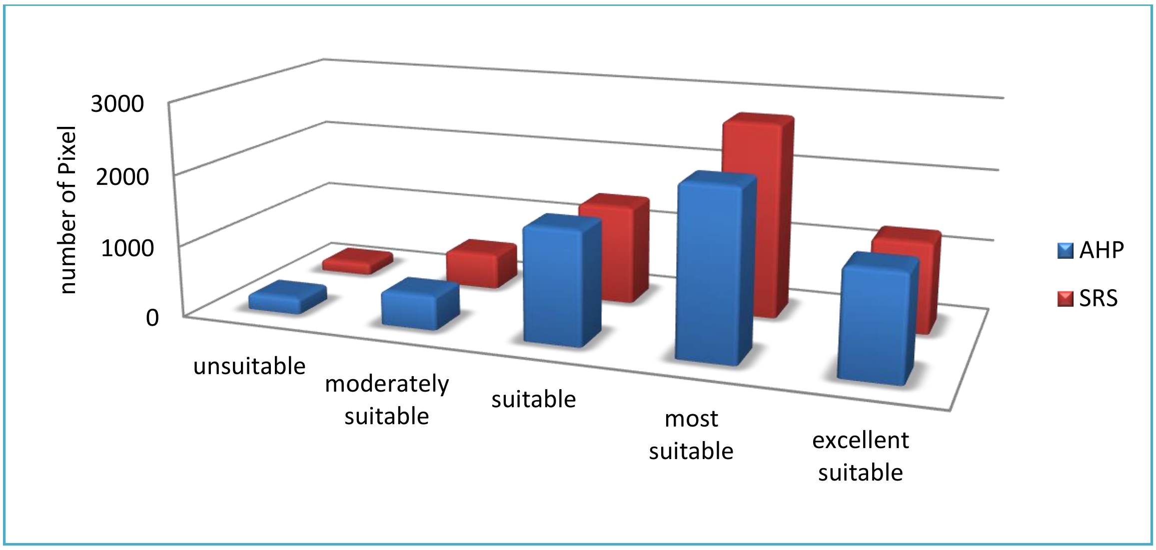

Figure 5: Suitability Index and number of Pixels Resulting from the two maps

Maps are entered into GIS 10.8 via the Spatial Analysis tool (Local) using the Combination formulation (Analytic Hierarchy Process raster map, Straight Rank Sum raster map) to compare these two techniques. The maps were combined into a single map termed the final comparison map, which includes the amount of pixels for each of the AHP and RSW categories. It also contains the compatibility ratios for each category that will be used in matching , (refer with: Table 4). "the similar combine number of raster categories" for AHP and SRS [1,1];[2,2];[3,3];[4,4];[5,5] considered corresponding or matching to Their number of pixel result from-methods-the-dissimilar-Combine-number-of-raster Categories for AHP and SRS [1,2];[2,3];[3,4];[4,5];[5,4] It took non-matching.

Table 4: The results of combining Two maps result from (AHP) and (RSW) methods

NO	Count	Categories (AHP)	Categories (SRS)	Pixels ratios	Classification
1	2143	(most suitable)$_4$	(most suitable)$_4$	35.33	Matching
2	1146	(suitable)$_3$	(suitable)$_3$	18.89	Matching
3	356	(moderately suitable)$_2$	(moderately suitable)$_2$	5.87	Matching
4	341	(suitable)$_3$	(most suitable)$_4$	5.62	Non-matching
5	1210	(excellent suitable)$_5$	(excellent suitable)$_5$	19.95	Matching
6	123	(moderately suitable)$_2$	(suitable)$_3$	2.03	Non-matching
7	59	(most suitable)$_4$	(excellent suitable)$_5$	0.97	Non-matching
8	95	(suitable)$_3$	(moderately suitable)$_2$	1.57	Non-matching
9	56	(unsuitable)$_1$	(moderately suitable)$_2$	0.92	Non-matching
10	173	(unsuitable)$_1$	(unsuitable)$_1$	2.85	Matching
11	2	(moderately suitable)$_2$	(unsuitable)$_1$	0.03	Non-matching
12	237	(excellent suitable)$_5$	(most suitable)$_4$	3.90	Non-matching
13	125	(most suitable)$_4$	(suitable)$_3$	2.06	Non-matching

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The final Comparison map was eventually acquired, along with the "combined number" for the AHP and SRS raster categories and the number of pixels for each suitability category. with the required percentages for each of the relevant groups (refer with: Figure 6.) displays the relevance index's fraction of matching and non-matching categories of pixel values.

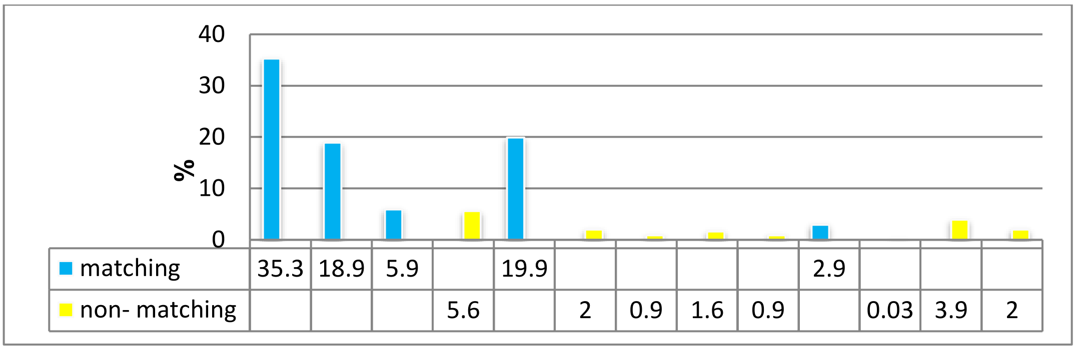

Figure 6: the Percentages of raster Values of comparison map Classes

For purposes of comparison, the output map has been categorized, displaying the corresponding output number categories from the raster data categories. Whereas the other classes were combined to create non-conforming regions (acceptance regions), we combined the pixel categories to create matching regions (refer with: Figure 7). where the non-conforming pixels account for (17.11%) and the matching region's area (82.89%). The matching and non-conforming pixels can be added up to determine that they are (100%) identical.

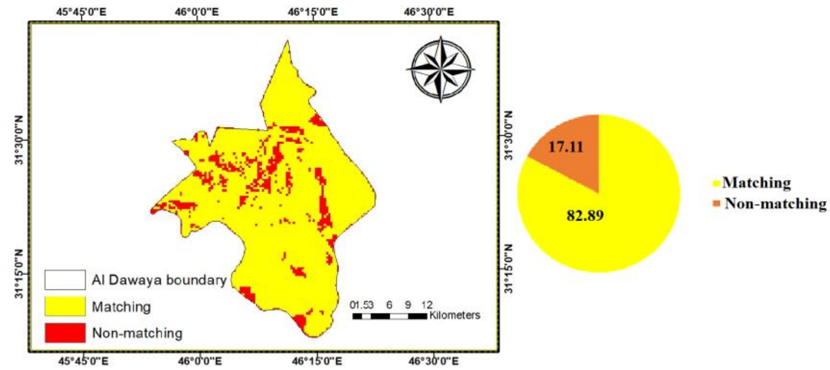

Figure 7:The comparison map of SRS and AHP methods

4.3 Obtaining of suitability of candidate sites

Three candidate sites were obtained to establish a sanitary landfill site within the excellent area. The symbol (A,B,C) was assigned to them and the area of each of them is () respectively. The site (A) is located at latitude (31°32'55''N) and longitude (46°17'30''E), while site (B) is located at latitude (31°15'44''N)and longitude (46°15'30''E) The location(C) is within latitude (31°17'50''N) and longitude (46°14'52''E). These locations were chosen and their authenticity was verified through satellite images of Al-Gharraf district in Dhi Qar Governorate (refer with: Figure 8.)

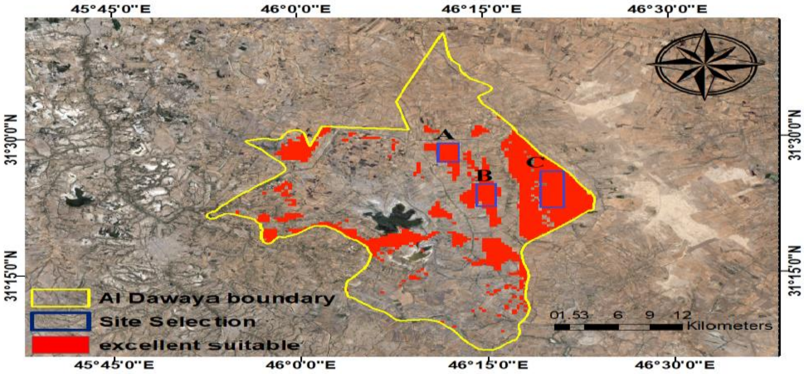

Figure 8: Location of candidate sites

5. CONCLUSION

Determining a site for sanitary landfill is considered one of the important and complex procedures, as it includes a number of factors such as social, organizational, environmental, engineering, cultural, and economic factors. The use of geographic information systems to choose sanitary landfill sites is considered an important and economic matter, as it has the potential to produce important and high-quality maps to determine a suitable place for landfilling. Sanitary landfill, as well as multi-criteria decision analysis, is considered an effective tool, and the process of making an appropriate decision to choose a sanitary landfill site is appropriate by providing weights for potential areas. The necessary data was reviewed during the review of previous studies and literature, as well as relying on the opinion of experts. Fifteen criteria were provided for selecting The appropriate location for sanitary landfill. Both GIS and MCDM were integrated. To compare the results and ensure their accuracy, there are two methods (AHP, SRS).The output maps are divided into five categories, starting from unsuitable to excellent suitability, Where the percentage of excellent areas was represented by (23.85%) , (20.92%) respectively for AHP and SRS and after the spatial analysis was done and the final map was produced, Field visits must be conducted to select the candidate sites, where three suitable sites were chosen.

The study identified a number of environmental gaps in the city of Al Dawaya ability to locate appropriate sites for hazardous waste disposal and landfilling, and a number of recommendations were made, including the following:

- It is advised to utilize the AHP approach to balance factors while choosing a suitable location or any other process that is founded on accuracy and fundamental theory.
- The importance of utilizing geographic information systems, which have been employed as a technology to successfully achieve proper management in waste management operations, which results in environmental protection.

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