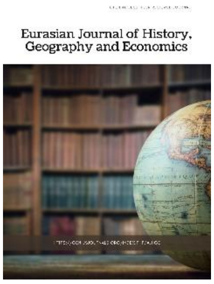

Using Multi Criteria Decision-Making techniques to identify landfill sites: A Case study Al-Garraf Qadhaa, Dhi Qar, Iraq

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ABSTRACT

Located in the northern region of the Dhi Qar Governorate in southern Iraq, Al-Gharraf city boasts a population of approximately 117,549 inhabitants and encompasses an area spanning 623 square kilometers. The primary predicament afflicting residential areas within Al-Gharraf city is the absence of designated spaces for waste disposal. To mitigate this issue, a suitable waste disposal site was carefully chosen through the amalgamation of Geographic Information Systems (GIS) and a Multi-Criteria Decision-Making (MCDM) mechanism. A total of fifteen distinct criteria were considered, encompassing factors such as groundwater depth, urban centers, rivers, villages, schools, roads, elevation, slope, power plants, water surface, land use, gas pipelines, power lines, oil pipelines, and wells., were considered to ensure that the chosen site met all environmental, health, and economic requirements. Two decision-making methods "Analytic Hierarchy Process (AHP) and simple Additive Weighting (SAW)", The "weighted linear combination" (WLC) method was used to obtain a suitable spatial fit map, where this method was used for the process of deriving "weights using pairwise comparisons. Two suitable sites have been proposed for landfilling, and these sites meet all environmental, health and economic requirements and standards, according to the opinion of experts.

Keywords: Geographic information system; landfill sites; Analytic Hierarchy Process (AHP); Simple Additive Weighting (SAW).

استخدام تقنيات اتخاذ القرار متعدد المعايير لتحديد مواقع دفن النفايات: دراسة حالة الغراف قضاء، ذي قار، العراق

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الخلاصة

تقع مدينة الغراف في المنطقة الشمالية من محافظة ذي قار جنوب العراق، ويبلغ عدد سكانها حوالي 117,549 نسمة، وتمتد على مساحة 623 كيلومتر مربع. المشكله الأساسية التي تعاني منها المناطق السكنية داخل مدينة الغراف هي عدم وجود مساحات مخصصة للتخلص من النفايات. وللتخفيف من هذه المشكلة، تم اختيار مواقع مناسبه للتخلص من النفايات بعناية من خلال دمج نظم المعلومات الجغرافية (GIS) وآلية اتخاذ القرار متعدد المعايير (MCDM). من خلال استخدام خمسة عشر معيارًا متميزًا، تشمل المعايير التاليه مثل عمق المياه الجوفية، والمراكز الحضرية، والأنهار، والقرى، والمدارس، والطرق، والارتفاع، والانحدار، ومحطات الطاقة، وسطح المياه، واستخدام الأراضي، وخطوط أنابيب الغاز، وخطوط الكهرباء، وخطوط أنابيب النفط، و تم الأخذ في الاعتبار التأكد من أن الموقع المختار يلبي جميع المتطلبات البيئية والصحية والاقتصادية. طريقتان لاتخاذ القرار عملية التسلسل الهرمي التحليلي (AHP) والوزن الإضافي البسيط (SAW)، وتم استخدام طريقة الخطية الموزونة (WLC) للحصول على خريطة ملائمة مكانية مناسبة، حيث تم استخدام هذه الطريقة لعملية استخلاص الأوزان باستخدام المقارنات الزوجية. وقد تم اقتراح موقعين مناسبين لدفن النفايات، ويلبي هذان الموقعان جميع المتطلبات والمعايير البيئية والصحية والاقتصادية، حسب رأي الخبراء

1. Introduction

Choosing the appropriate site for sanitary landfill for waste disposal is considered a more cost-effectives System in most built-up areas. Such a decision requires a major process to evaluate places in order to determine the most appropriate site. All environmental conditions must be met at this site, and we must reduce the impacts Economic, health, environmental and social costs when choosing a sanitary landfill site [1]. In the last period, choosing the most appropriate landfill site has become a necessity due to the increase in environmental difficulties in built-up areas. For this reason, there are a tendency to choose a suitable sites that contains all the environmental conditions [2]. When selecting the ideal location for a sanitary landfill, several factors need to be considered. These include economic, social, and environmental factors. Economic factors include the expenses involved in identifying and developing the site, which is a critical aspect of the decision-making process. [3, 4]. Environmental criteria must also be taken into account, as the landfill process may have a negative impact on the environment in area [5, 1, 6]. The largest and most difficult issue in front of determining the optimal location for a sanitary landfill is the social issue, political opposition and citizens, which has caused pressures on decisions-makers in the Process of choosing the appropriate site [7 , 5, 8]. In this study, powerful and coherent tools such as geographic information systems and the hierarchy process are utilized to select the most suitable site for landfills. Geographic information systems play a crucial role in identifying the best location for sanitary landfills by efficiently displaying, analyzing and managing geographical data. This results in reduced cost and time for selecting the appropriate site.[3 9]. Where several potentials landfill site has been recognized by (GIS, AHP) [10]. This study employs various multiple criteria decision-making methods to determine the optimal landfill site. The criteria weights are obtained from selected criteria and applied to criteria maps using geographic information systems. The study utilizes AHP and RSW methods, which are part of Integrated Geographic Information Systems (GIS) and Multi-criteria decision-making methods (MCDM). These methods are widely used by decision makers to select the most suitable landfill sites because of their ability to handle complex information. Pair-wise, ranking, and ratio techniques are used to obtain standard weights through MCDM. Geographic information systems (GIS) and MCDM methods are applied to identify the best location for the landfill. Furthermore, GIS software enables efficient display of data from various sources, making it easier and more cost-effective to select the optimal landfill site and waste transportation routes..[3, 11].

Numerous prior research studies have focused on identifying the most suitable location for constructing sanitary landfills. A research endeavor concentrated on the identification of optimal sites for waste disposal facilities within the Babylon Governorate through the application of Multi-Criteria Decision Making (MCDM) methodologies. Fifteen criteria were merged into layers, and a final map was extracted using the WLC method. two appropriate landfill sites were identified. In a study [12], GIS and the Analytic Hierarchy Process (AHP) were employed as integral tools to ascertain appropriate locations for sanitary landfill sites, resulting in a final map of locations up to 2040 in Al-Diwaniyah Governorate. and, the geographic information systems (GIS) have been utilized along with MCDM to resolve the issue of selecting a suitable sanitary landfill site in the vicinity of "Ankara". Sixteen different criteria have been analyzed and created a map that identified the ideal location for the sanitary landfill site.

2. Study area.

This city is situated in Dhi Qar Governorate, located 25 km north of the city of Nasiriyah, which is the center of Dhi Qar Governorate. Additionally, it is 18 km south of the city of Shatrah, which is the district center that the city belongs to. The city is positioned between longitude (46°14'30"E) and latitude (31°17'55"N), Figure 1. Al-Gharraf city is considered the fifth largest city in Dhi Qar Governorate in terms of population, as the city's population reached more than 117 thousand people and the area of Al-Gharraf city is 623 km^2[13].

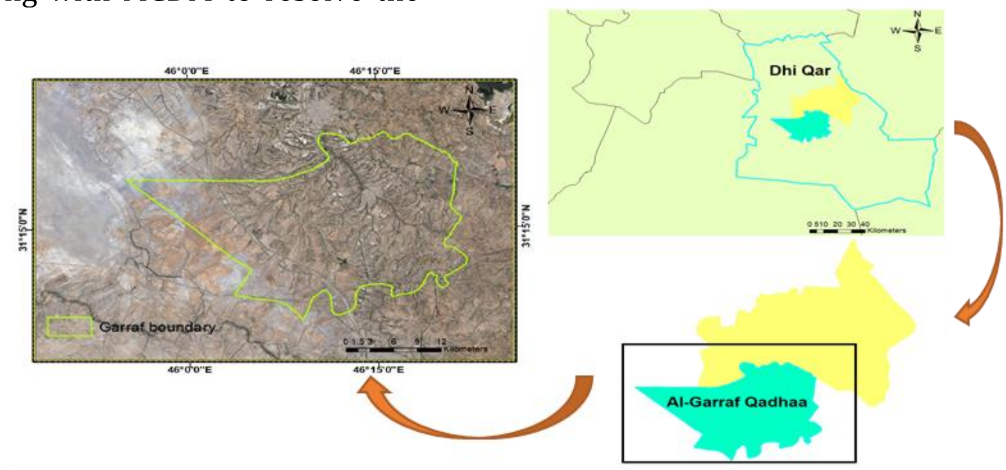

Figure -1 Location of study

3. Methodology.

In this study, geographic information systems and Analytic Hierarchy Process were chosen to choose the optimal location. To determine the optimal location of the sanitary landfill, spatial analysis tools were used in geographic information systems to prepare fifteen different standards in the form of layers covering the study area Depth of groundwater, rivers, urban and rural areas, roads, schools, elevation, slope, water surface, power plants, land use, gas/oil pipelines, power/water wells. Each criterion includes a digital map database used in geographic information systems. The processed data is then entered into the AHP form for the landfill site using basic steps.

- Using a geographic information system, create a digital map for each standard and eliminate inappropriate places by sorting them into categories..
- Buffer zones should be created around areas based on past studies and expert opinions to fit specific map standards.
- To determine the most suitable site based on study goals, use Analytic Hierarchy

Process and Simple Additive Weighting to assign weights.

- A comparison was made between the maps produced by WLC to obtain a digital map showing the locations of sanitary landfills.

4. Sub-Criteria Weights

For this study, a total of fifteen input maps were created and evaluated for use in the GIS analysis process. These maps included data on Depth of groundwater, rivers, urban and rural areas, roads, schools, elevation, slope, water surface, power plants, land use, gas/oil pipelines, power/water wells. Various GIS techniques such as buffer, extract, clip, erase, convert, proximity, Reclassify, and (map Al gebra) were used to obtain the final layers.

4.1. Groundwater depth

The groundwater aquifer for the city of Garraf was prepared using the IDW interpolation method as part of GIS spatial analysis. The measurements were taken between 2006 and 2014 by the Iraqi Ministry of Water Resources from 6 wells in the city. finally, a layers was extracted to the depths of the aquifer by using extract using mask tools, using GIS to clip all layer of the Raster map to the depth of the aquifer in the area. Finally, the layer is categorized into four categories, (Fig. 2a). In general, in the areas of the city of Al-Garraf, there is a difference in the depths of the groundwater, ranging from 11.5 meters to 14 meters below the surface to the level of the groundwater.

4.2 Urban centres

During our research, we analyzed "buffer zones" with a size of less than 5000m and concluded that they did not have any effect, resulting in a score of zero. However, buffer zones ranging from 5000m to 10000m were identified as having the most significant impact and were given a score of 10. Areas that were between 10000m and 15000m were considered moderately appropriate and given a score of 5. If the distance was greater than, (Fig. 2b).

4.3 River

The goal of protecting the water in the city of Garraf from pollution and waste leachate is established by the standard for the river. This standard includes creating a buffer zone of at least 1000 meters from the river border to prevent pollution. Areas within 1000 meters of the river are deemed unsuitable and given a division of zero. Any distance greater than 1000 meters is assigned a value of 10, (Fig. 2c). This information was found in a study by [14].

4.4 Villages

Buffer zones with a width below 1000m were assigned a value of zero, while those with a width greater than or equal to 1000m were given a value of 10,(Fig. 2d).

4.5 Schools

In Al-Garraf city, there are six schools located in various areas. A buffer zone has been designated for each school site, and their suitability is determined based on the distance of the buffer zone. If the buffer distance is 2000 meters or less, the school is given a rating of 2, indicating that it is unsuitable. If the buffer distance is 4000 meters, the school is rated 10, indicating that it is highly suitable. However, if the distance is 6000 meters, the school is still considered suitable but with a lower rating of 4. If the distance exceeds 6000 meters, the school is rated 0, (Fig. 2e).

4.6 Roads

This standard pertains to main roads or highways. If the buffer zone distance from the road to the land site is less than 500m, the area is deemed unsuitable and given a value of zero in the classification of criteria. For buffer zones ranging from 500m to 1000m, a value of 7 is assigned, indicating that the area is slightly suitable. Buffer zones from 1000m to 2000m are given a value of 10, which is considered very suitable. For buffer zones ranging from 2000m to 3000m, a value of 5 is assigned, indicating that the area is moderately suitable. Areas greater than 3000m are given a value of 2, indicating that they are unsuitable and considered bad, (Fig. 2f).

4.7 Elevation

The Iraqi Ministry of Education conducted research to address waste leachate leakage and flooding using a digital elevation model (DEM). The criteria used were topography and elevation, with the highest point located in the south-eastern part of Garraf city, Iraq, at 10 meters above sea level (a.m.s.l). (Fig. 2g) shows that the lowest point was 2 meters above sea level (a.m.s.l).

4.8 Slop (Degree)

When selecting the ideal location for a sanitary landfill, the slope of the land is a crucial consideration. Steep slopes can increase the release of harmful toxins to nearby areas, making it easier for leachate to leak. According to the city's digital elevation map (DEM), the slope ranges from zero to 20 degrees above sea level. Therefore, slopes ranging from 0 to 10 degrees were deemed highly suitable and assigned a value of 10. Any slope greater than 10 degrees was deemed unsuitable and given a value of zero, (Fig. 2h).

4.9 power plant

In Al-Garraf city, there is a single station located at the city center. The distance between the power plant and the landfill sites is over 1000 meters, which was assigned a value of 10 since it adheres to the classification criteria. However, any distance less than 1000 meters was assigned a rate of zero, indicating its inappropriateness, (Fig. 3i).

4.10 Water surface

To ensure safety and prevent environmental pollution, a buffer zone of at least 1000 meters was established around marshes, water bodies, and streams in the study area. Ratings were assigned based on the distance from the designated area: 0 for 250 meters, 2 for 500 meters (unsuitable), 8 for 750 meters (suitable but less so), and 10 for over 1000 meters (very suitable), (Fig. 3j).

4.11 Land use

In the city of Garraf, there are three categories used to create "the land use layer": agricultural land, sandy lands, and unused land (Iraqi Ministry of Education, 2015). These layers are collected and merged into one layer called "land use", see (Fig. 3k). The unused land category is given a rating of 10 and considered very suitable, while sandy lands are given a rating of 5 as moderately suitable. The value of agricultural land is zero due to its unsuitability for use.

4.12 Gas Pipelines

(Buffer Zones) from Gas Pipeline to landfill sites is take in this study 300m on Together sides. Therefore, the distance Not more than 300 meters was given a rate of zero. While the distance more than 300 meters was given a rate of 10 and it is considered very suitable, (Fig. 3l).

4.13 Power Lines

In this study, a buffer zone of zero is assigned for power lines less than 250m on both sides, while a buffer zone of 10 is assigned for power lines more than 250m, (Fig. 3m).

4.14 Oil Pipelines

There is an oil pipeline that runs through the study area. The Iraqi Ministry of Oil (Iraqi Determinants, Ministry of Oil, 2015) recommends a distance of over 400 meters on both sides of the pipeline from the sanitary landfill site as suitable, (Fig. 3n) also indicates that distances less than 400 meters are considered unsafe and were given a gradual rate of zero. Distances greater than 400 meters were rated at 10.

4.15 Wells

There is a (7) well located in the city of Garraf. A buffer distance of over 500 meters is deemed suitable and has been assigned a value of 10. Anything less than 500 meters is considered unsuitable and given a value of zero, (Fig. 3o).

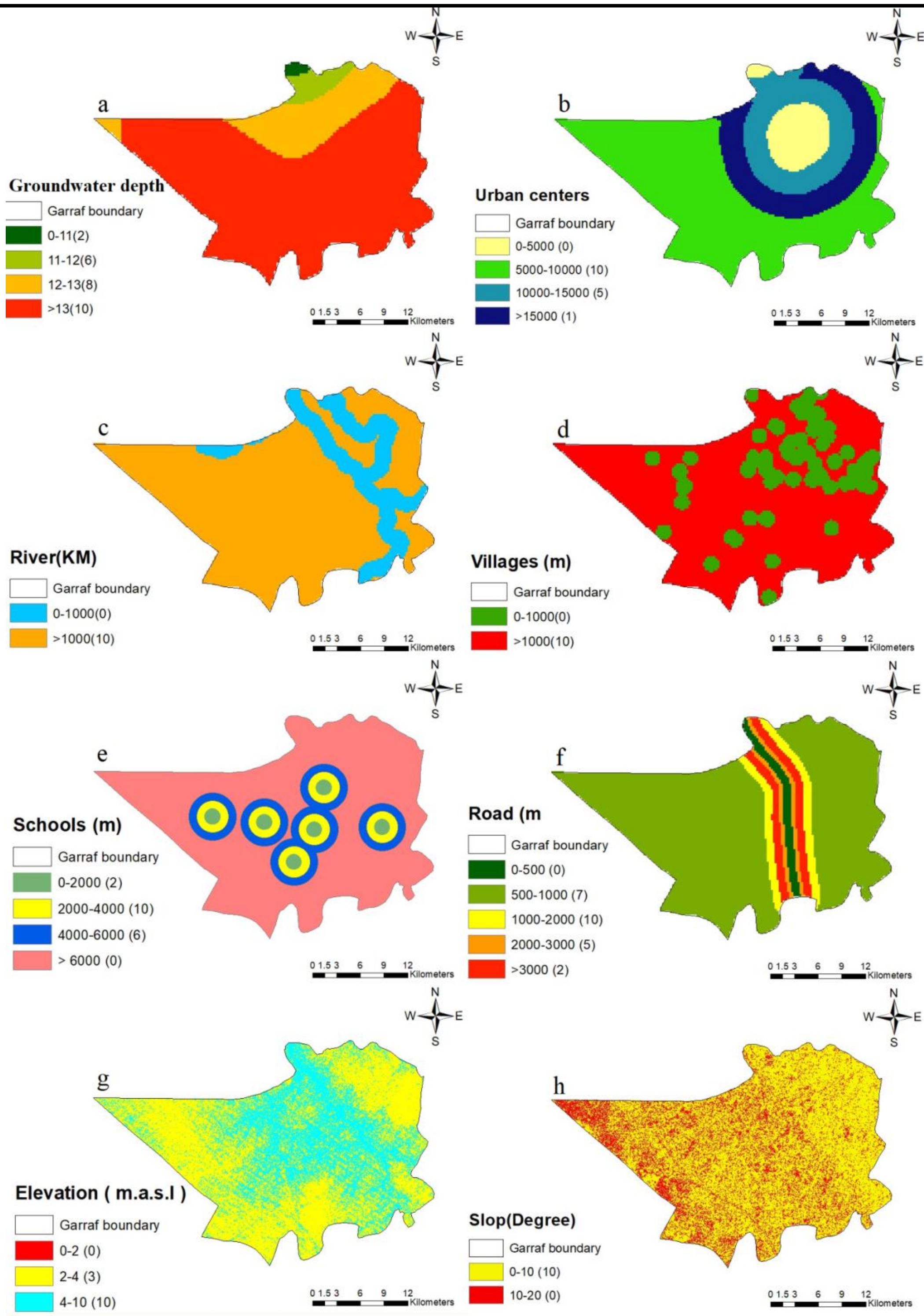

Figure -2 (a) Ground water Depth. (b) urban area. (c) Rivers. (d) Villages. (e) Schools. (f) Road. (g) Elevation. (h) Slope.

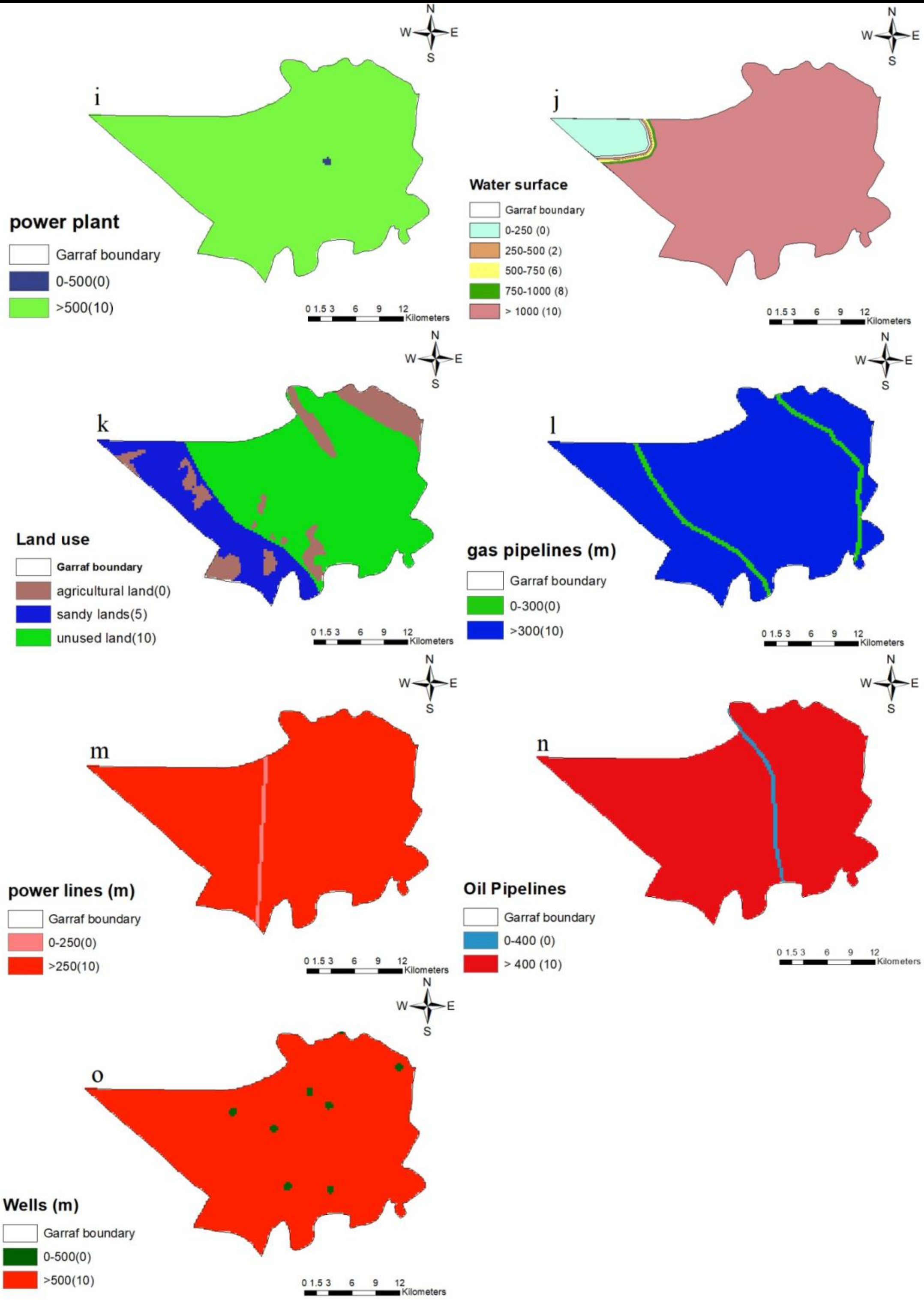

Figure -3 (i) power plant. (j) water surface. (k) Land use. (l) gas pipelines. (m)Power lines. (n) Oil pipelines. (o) Wells.

5. Selection of suitable sites by using two methods.

5.1 Analytical Hierarchy Process (AHP) method

The (AHP) methodology serves as a valuable tool for the selection and evaluation of study criteria, as well as the analysis of data to streamline the decision-making process. The hierarchical structure is delineated into two matrices: one designated for conducting pair-wise comparisons, facilitating the determination of the relative significance of each alternative concerning the established criteria

The hierarchy process is applied in the study area to determine the locations of the sanitary landfill because it has firm theoretical foundations. During the process of applying the hierarchy. Nine points were used refer with Table 1. where each point expresses the relative importance, which contributes to helping the decision maker to the goal independently and correctly through Pair-wise comparisons. Thus to facilitate and Simplify the decision-making.

Table 1- Scale of relative importance for pairwise comparison [15].

Intensity of importance	Definition
1	equal Importance
2	Equal to Moderately Importance
3	Moderate Importance
4	Moderate to Strong Importance
5	Strong Importance
6	Strong to Very strong Importance
7	Very strong importance
8	Very to extremely strong Importance
9	extreme Importance

In this study, a model organization is formed for "the decision problem" using symbols (m) and (n).

the value of (j=1;2;3;4;5.....n) and (i=1;2;3;4;5.....m) aij are used to denote the values of the commands In Terms of (i_Th ,and j_ Th) in the matrix

The upper triangle of the matrix is populated with comparison criterion values positioned above the matrix diagonal. To complete the lower triangle of the matrix, reciprocal values from the upper diagonal are employed, refer to Eq. (1).

$$aij=1/aij, \quad (1)$$

Represents the elements of row I and column j where aij is the representation of the typical comparison matrix and the relative importance of criteria in the decision matrix.

$$\begin{bmatrix} a11 & a12 & a13 & a14 & a15 & a1n \\ a21 & a22 & a23 & a24 & a25 & a2n \\ am1 & am2 & am3 & am4 & am5 & amn \end{bmatrix} . \begin{bmatrix} W1 \\ W2 \\ Wn \end{bmatrix}$$

In this case, the overall criteria weights are calculated by multiplying each criterion's value in each row and column, as shown in Table 2.

Eg. Each line can be calculated using geometric principles. Multiply the value of each parameter in each column and apply to each line refer to Eq. (2).

$$\text{Egi} = \sqrt[n]{a11 * a12 * a13 \ldots\ldots * a1n} \quad (2)$$

Egi = Eigen Value for row I; n = number of Element in the Row I,

Pri or AHP weight is selected by normalizing the Ei values to 1, dividing each by the sum of all values refer to Eq. (3).

$$\text{Pri}=\text{Egi}/(\textstyle\sum_{k=1}^{n} Egk) \quad (3)$$

The upper bound "λmax" is calculated by Multiplying Each Element of the Pri with the sum of the corresponding column of the reciprocal matrix refer to Eq. (4).

$$\lambda\text{max}=\textstyle\sum_{k=j}^{n}\{Wj \sum_{i=1}^{m} aij\} \quad (4)$$

aij; (the Total of the Criteria listed in each Column of the Matrix).

Wi; This represents the weight value of each factor.

The term refers to the Pri in the decision matrix.

Where the value {i=1,2,3,4,5....m} and {j=1,2,3,4,5.....n} he calculation for the Consistency Index (CI) refer to Eq. (5).

$$\text{CI} = \frac{(\lambda\text{max} - \text{n})}{(\text{n} - 1)} \quad (5)$$

(Saaty,1980) determined the Consistency Ratio {CR} refer to Eq. (6).

$$\text{CR}=(\text{CI}/\text{RI}) \quad (6)$$

Where-RI15 is represent Random-index (R.I = 1.59) for n=15 refer with Table 3.
where n represent the size of the matrix. In this study, To Check results CR=CI/RI <0.1;" Consistency OK"

If the consistency ratio (CR) is below 0.1, it is acceptable; if it is above 0.1, it is not acceptable (Musingwini et al., 2008).

Table 2- a matrix for pairwise comparisons to help select an appropriate landfill location

Criteria	Groundwater	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	2	4	5	4	5	7	4	6	8	8	9	9	4.499	0.204
Urban area	0.3	1	2	2	3	4	4	5	6	3	6	6	6	7	8	3.333	0.151
Rivers	0.3	0.5	1	2	2	3	3	3	4	2	5	5	6	7	8	2.544	0.115
Villages	0.5	0.5	0.5	1	1	3	3	4	4	5	6	7	8	8	8	2.625	0.119
Schools	0.2	0.3	0.5	1.0	1	3	3	5	5	5	6	6	7	7	7	2.422	0.110
Road	0.2	0.2	0.3	0.3	0.3	1	2	2	2	4	5	5	5	6	6	1.451	0.066
Elevation	0.2	0.2	0.3	0.3	0.3	0.5	1	2	1	2	3	3	3	4	4	1.047	0.047
Slope	0.2	0.2	0.3	0.2	0.2	0.5	0.5	1	1	2	2	2	4	4	5	0.861	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	3	0.725	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	0.1	0.1	0.2	0.3	0.5	1.0	0.5	1	1	1	2	2	0.465	0.021
Gas pipeline	0.1	0.1	0.2	0.1	0.1	0.2	0.3	0.5	0.5	0.5	1.0	1	2	2	3	0.464	0.021
Power lines	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.2	0.3	0.5	1.0	0.5	1	2	2	0.371	0.017
Oil pipelines	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.5	0.5	0.5	1	2	0.296	0.013
Wells	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.3	0.2	0.5	0.3	0.5	0.5	1	0.249	0.011

Table 3- random inconsistency indices for different values of (n)

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.5	0.9	1.1	1.2	1.3	1.4	1.4	1.4	1.5	1.4	1.5	1.5	1.5

5.2. Simple Additive weighting (SAW) Method

This method may be characterized as a "balanced linear formula" or a scoring technique, representing a straightforward approach employed within the framework of multi-criteria decision analysis. Its foundation lies in expert judgment to derive the weights associated with each of the available criteria. There are two types of assumptions when using the SAW method of addition and linearity. It is difficult to apply these assumptions to solve real problems. In the linear assumption, any additional units remain constant, but in the addition assumptions there is no effect between classes [16]. In this research, we attempted to integrate different standards more effectively. The SAW method offers the advantage of keeping standard sizes equal through a linear proportional transformation of raw data. This method relies on a weighted average to calculate scores for different alternatives. The relative importance of each criterion is determined by the decision maker and normalized using the standard classification value of the sub-criterion. Finally, the GIS system can be used to select the evaluation criteria (including layers of maps and alternatives) based on the SAW method [16].

During this study, we analyzed fifteen essential factors to identify the optimal spot for a sanitary landfill. We assigned weights to each criterion and compiled the results in a table.

Then, we utilized GIS's spatial extension tools, including map algebra, to convert the weights into map models. After completing this process, we created a final map showing the appropriate locations using SAW, which is referenced in Table 4. Additionally, we used the following equation refer to Eq. (7).to evaluate each alternative using the SAW method.

$$\text{Wi}=\frac{Ai}{\sum_{j=1}^{n} Aj} j = 1,2,3,4,5..n \qquad (7)$$

To determine the normalized weight of each criterion, divide its weight by the sum of all criteria weights. In row i, Ai represents the weight assigned to each criterion, while Aj represents the weight of each criterion in column (j). N is the total number of criteria.

Table 4-The criterion weightings defined for the SAW method and normalized weights.

NO.	Criteria	weight of SAW	Normalized Weight
1	Groundwater	10	0.104
2	Urban area	9	0.093
3	Rivers	9	0.093
4	Villages	8	0.083
5	Schools	8	0.083
6	Road	7	0.072
7	Elevation	7	0.072
8	Slope	7	0.072
9	power plant	6	0.062
10	water surface	6	0.062
11	Land use	5	0.052
12	gas pipelines	4	0.041
13	Power lines	4	0.041
14	Oil Pipeline	4	0.041
15	Wells	2	0.020
Sum		96	1.000

6. Results and Discussion

After conducting a thorough analysis using a comparison matrix, it have been determined that the upper limit, also known as {λ max}, is 15.924, and the {CI} is 0.066. To calculate the weights, multi-criteria it have been utilized decision-making methods such as the Analytic Hierarchy Process (AHP) and Simple Additive Weighting (SAW). Table 5 displays the results. Additionally, I have used the Linear Combination (LWC) method to adapt the "Suitability Index Sites Map" for land fill sites in Garraf City, incorporating both AHP and SAW. (Fig. 4) displays the outcome, with the AHP method assigning the highest weight to the most critical criteria, In accordance with the amalgamation of prior research findings and expert assessments, the resultant maps have been stratified into a classification system encompassing the following five categories: "unsuitable," "moderately suitable," "suitable," "very suitable," and "excellent."

Table 5- Criteria weighting based on MCDM methods (AHP, SAW)

NO.	Criteria	AHP Weight	SAW Weight
1	Ground water depth	0.204	0.104
2	Urban Area	0.151	0.093
3	Rivers	0.115	0.093
4	Villages	0.119	0.083

5	Schools	0.110	0.083
6	Road	0.066	0.072
7	Elevation	0.047	0.072
8	Slope	0.039	0.072
9	power plant	0.033	0.062
10	water surface	0.033	0.062
11	Land use	0.021	0.052
12	gas pipelines	0.021	0.041
13	Power lines	0.017	0.041
14	Oil pipelines	0.013	0.041
15	Wells	0.011	0.020
Sum		1.000	1.000

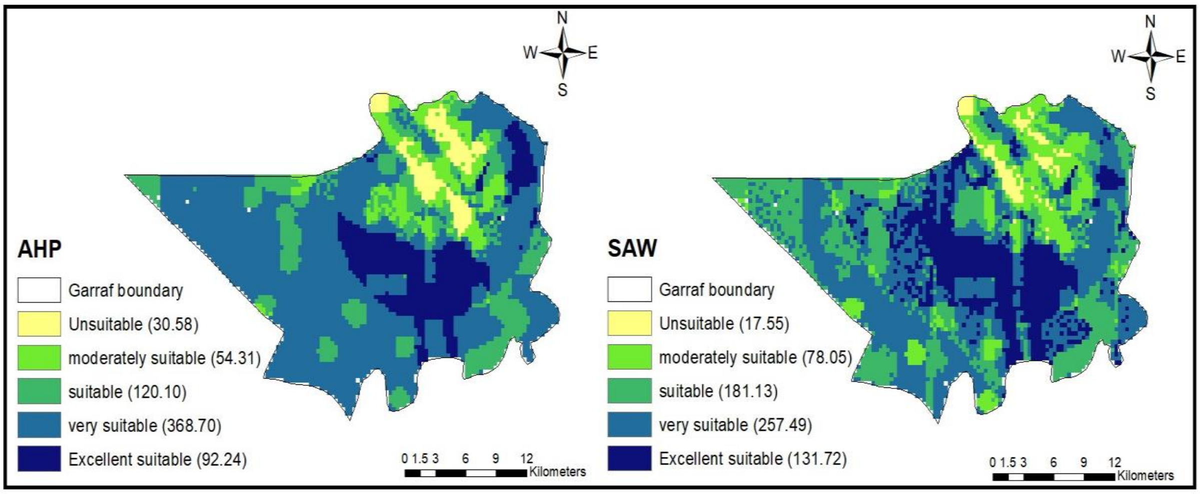

Figure -4
final map of suitability landfill using AHP and SAW methods

7. Finalizing the map for landfill sites.

In order to evaluate sites for a landfill, a geographic information system was used to input 15 layers. The Weighted Linear Combination (WLC) method was applied refer to Eq. (8). [17].

$$\text{Ai}=\text{A}_\text{i}\sum_{\text{J}=1}^{\text{n}}\text{WJ}*\text{Cij} \quad (8)$$

$Ai =$ "suitability index" for area (i); $WJ =$ the "relative importance" weight of criteria; $Cij =$ the grading value for area (i); and $n =$ the total number of criteria.

The equation, which is consistent across extension tools, map algebra, and Geographic Information Systems (GIS), was systematically applied to all pertinent criteria. It involved the estimation of an appropriateness index, calculated by summing the products of the criterion scores and their respective relative weights. The resulting output map was subsequently classified into five distinct categories denoting suitability levels, spanning from unsuitable to highly suitable. The final cartographic representation, illustrated in (Fig. 5), presents the percentage distribution of areas within each of these categories, constituting 5.0%, 10.6%, 17.6%, 46.2%, and 20.3% of the total area, respectively.

8. Assessment of suitability of candidate sites

A comparison process has been conducted using multi-decision analysis to determine suitable landfill sites in Garraf. Two sites were identified, labelled as A and B, and both meet all the necessary requirements. Site A covers an area of 3.802 km2, while site B covers 8.321 km2. These sites are located in different parts of the city refer with(Fig. 6).

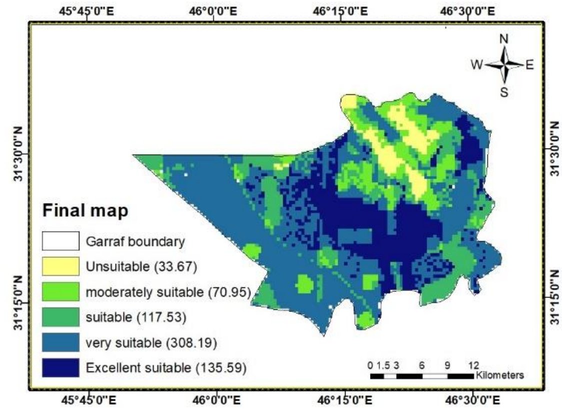

Figure -5 landfill map suitability of al Garraf city

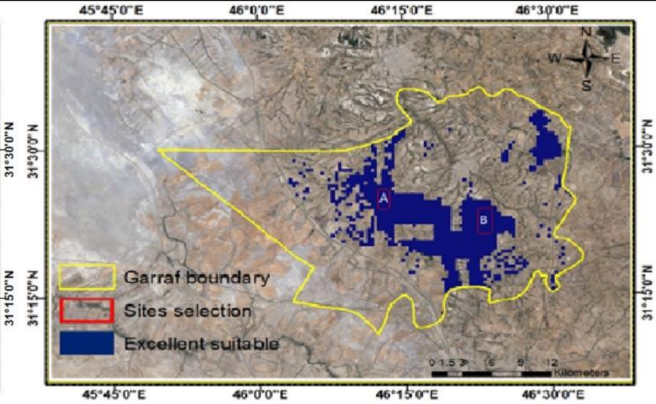

Figure -6 Location of candidate sites.

9. Conclusion

Determining the location of a landfill is a multifaceted process that involves evaluating numerous environmental, social, and economic factors. The use of geographic information system to locate landfill sites is a necessary and important economic factor because it has the ability to produce high-resolution and useful maps for selecting the optimal site in a short period of time. A multi-criteria decision is an important decision-making tool in determining an appropriate site for a sanitary landfill by providing a consistent weighting arrangement for the selected areas. In this study, the necessary criteria were collected and arranged from the most important to the least important through previous studies and expert opinion. Through the use of MCDM and GIS methods, we determined the best location. The team utilized two multi-criteria decision-making methods: analytical hierarchy process and Simple Additive Weighting. To ensure precision, a comparative analysis of the results was conducted, leading to the classification of the areas into five distinct categories: "unsuitable," "moderately suitable," "suitable," "most suitable," and "excellently suitable." Geographic Information System (GIS) was employed to calculate these areas based on pixel-based assessments. Ultimately, the optimal location exhibited an excellent suitability level of 13.9% when evaluated using the Analytical Hierarchy Process (AHP) and 19.78% when assessed through the Simple Additive Weighting (SAW) method.

Presently, there are two landfill sites in Gharraf that do not meet health and environmental standards. Spatial analysis was used to identify two new sites, with Site A being the best and most accessible. The process demonstrated that geographic information system is a powerful tool for managing large volumes of data and determining appropriate locations.

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