Landfill Site Selection Using GIS and Multi-criteria Decision-making AHP and SAW Methods: A Case Study in Sulaimaniyah Governorate, Iraq

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Abstract

Lack of land for waste disposal is one of the main problems facing urban areas in developing countries. The Sulaimaniyah Governorate, located in Northern Iraq, is one of the main cities of the country in the Kurdistan Region, covering an area of 2400 km^2. Currently, there is no landfill site in the study region that meets the scientific and environmental requirements, and the inappropriate dumping of solid waste causes adverse effects to the environment, economic and urban aesthetic. To overcome this phenomenon, it is crucial to suggest a landfill site, even in countries that recycle or burn their waste to protect the environment. Landfill sites should be carefully selected taking into account all regulations and other restrictions. The integration of geographic information systems and the multi-criteria decision analysis were used in this study to select suitable landfill locations in the region. To this end, thirteen layers prepared according to their importance including slope, geology, land use, urban area, villages, rivers, groundwater, slope, elevation, soil, geology, road, oil and gas, land use, archaeology and power lines. Two different methods (simple additive weighting and analytic hierarchy process) were implemented in a geographical information system to obtain the suitability index map for candidate landfill sites, where all these conditions satisfied the scientific and environmental criteria adopted in this study. The comparison of the maps resulting from these two different methods demonstrates that both methods produced consistent results.

Keywords

Criteria weights • GIS software • Simple additive weighting (SAW) method • Analytic hierarchy process (AHP) • Landfill site

1 Introduction

Solid waste management is considered to be a significant issue in developing nations. Despite the use of many efficient processes such as reuse and recycling, appropriate landfill disposal is still the most prevalent method of minimizing adverse effects on the environment and waste management (Moeinaddini et al. 2010). The process of selecting a landfill site is still considered complicated task. Currently, there is no landfill site in the study area that fulfils the scientific and environmental requirements to resolve the waste dump site issue. Two techniques have been used in this multi-criteria decision-making (MCDM) research; these are the analytic hierarchy process (AHP) and the simple additive weighting (SAW) methods for selecting landfill sites (Teknomo 2006; Şener et al. 2011; Uyan 2014). The geographic information system (GIS) with AHP and SAW methods are the most common techniques in MCDM exhibiting a high capacity to manage complicated problems with large data during the decision-making process (Office of UN Resident Co-Ordinator 2002). This study aimed to compare both methods to find the best candidate for landfill sites that complies with the environmental and scientific criteria.

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2 Materials and Methods

Sulaimaniyah is among the major cities in the region of Kurdistan and Iraq. The city is situated northwest of Iraq between latitude 35° 45′ 0″ N, 36° 0′ 0″ N and longitude 44° 45′ 0″ E, 45° 45′ 0″ E covering an area of around 2400 km^2. The administrative boundary unit of the Sulaimaniyah Governorate is shown in Fig. 1 (Office of UN Resident Co-Ordinator 2002). All types of waste are dumped without any treatment in an open area overlooking the Tanjaro River.

To proceed suitable landfill site, thirteen criteria as layer maps were prepared using GIS spatial analysis tools as an input for the AHP and SAW models. Each criterion was classified into sub-criteria and assigned a suitability rating value from zero to ten (Saaty 1980). Criteria rating and importance of their priority were specified on the basis of restrictions, literature and scientific experts. A pairwise comparison was implemented in the matrix for all criteria through the priority of the importance intensity of one activity over another using a numerical scale of nine points (Saaty 1980). The upper triangular matrix is filled with the comparative criteria values, and the lower triangular matrix is completed with the upper reciprocal values (Teknomo 2006; Şener et al. 2011). The eigenvalue was calculated by multiplying the value for each criterion in each column in the same row in the matrix of the pairwise comparison. The priority vector (Pr_i) was determined by normalizing the eigenvalue to one (Saaty 1980), as follows:

$$\mathrm{Pr}_i = (\mathrm{Eg}_i)/\left(\sum_{i=1}^{n} \mathrm{Eg}_i\right) \tag{1}$$

where Eg_i = eigenvalue for the row (i) $\left(\mathrm{Eg}_i = \left(a_{11} \times a_{12} \times a_{13} \times \cdots \times a_{1n}\right)^{1/n}\right)$; n = number of elements in row (i).

The consistency index was calculated according to Saaty (1980).

$$\mathrm{CI} = (\lambda \max - n)/(n-1) \tag{2}$$

where CI is consistency index and n is size or order of the matrix and (λmax) is equivalent to the priority vector in the decision matrix (Saaty 1980).

The consistency ratio (CR) depends on the size of the matrix (n = 13); thus, the random index value (RI = 1.56) (Saaty 1980).

$$\mathrm{CR} = (\mathrm{CI})/(\mathrm{RI}) \tag{3}$$

The simple additive weighting (SAW) is a ranking method defined as a weighted linear combination or scoring method (Saaty 1980).

$$W_i = \frac{A_i}{\sum_{j=1}^{n} A_j} j = 1, 2, \ldots, n \tag{4}$$

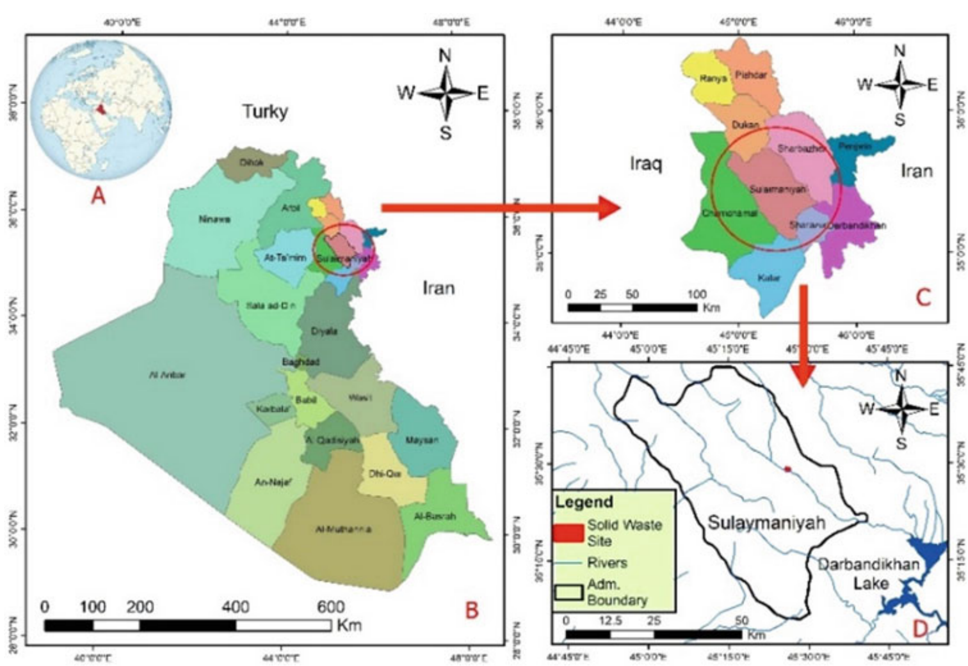

Fig. 1 Location map of the study area

	A	B	C	D	E	F	G	H	I	J	K	L	M	NW	AHP	SAW
A	1	2	2	3	4	4	5	5	6	6	7	8	9	0.211	0.21	0.124
B	0.50	1	1	2	3	3	4	4	5	5	6	7	8	0.149	0.15	0.111
C	0.50	1.00	1	2	3	3	4	4	5	5	6	7	8	0.149	0.158	0.111
D	0.33	0.50	0.5	1	2	2	3	3	4	4	5	6	7	0.029	0.10	0.099
E	0.25	0.33	0.33	0.50	1	1	2	2	3	3	4	5	6	0.099	0.074	0.086
F	0.25	0.33	0.33	0.50	1	1	2	2	3	3	4	5	6	0.099	0.074	0.086
G	0.20	0.25	0.25	0.33	0.50	0.50	1	1	2	2	3	4	5	0.065	0.048	0.074
H	0.20	0.25	0.25	0.33	0.50	0.50	1.00	1	2	2	3	4	5	0.065	0.048	0.074
I	0.17	0.20	0.20	0.25	0.33	0.33	0.50	0.50	1	1	2	3	4	0.015	0.032	0.062
J	0.17	0.20	0.20	0.25	0.33	0.33	0.50	0.50	1	1	2	3	4	0.043	0.032	0.062
K	0.14	0.17	0.17	0.20	0.25	0.25	0.33	0.33	0.50	0.50	1	2	3	0.043	0.022	0.049
L	0.13	0.14	0.14	0.17	0.20	0.20	0.25	0.25	0.33	0.33	0.50	1	2	0.021	0.016	0.037
M	0.11	0.13	0.13	0.14	0.17	0.17	0.20	0.20	0.25	0.25	0.33	0.5	1	0.012	0.012	0.025

Fig. 2 Pairwise comparison matrix (A): Urban area; (B): Villages; (C): Rivers; (D): Groundwater depth; (E): Slope; (F): Elevation; (G): Soil types; (H): Geological formations; (I): Roads; (J): Oil and gas field; (K): Land use classification (L): Archaeological site; (M): Power lines. NW = normalized weight

where W_i is the normalized weight of each criterion; A_i is the weight of each criterion of area (i) under criterion (j) n is the criteria number.

3 Results and Discussion

The matrix of pairwise comparisons with SAW and AHP weighs are presented in Fig. 2. The maximum lambda (λmax) = 13.51, CI = 0.04 and CR = 0.027, if CR is less than 0.1.The ratio indicates a reasonable consistency level in the pairwise comparison (Sólnes 2003). The final map shows the suitability index for landfill sites in Sulaimaniyah Governorate, which was divided into four categories of suitable areas, including: unsuitable, moderately suitable, suitable and the most suitable areas (Uyan 2014). The suitability index with areas for all categories of the SAW and AHP methods is shown in Fig. 3.

4 Conclusion

This research used the MCDM techniques with the GIS method to evaluate the suitable selection of landfill sites in the study region. The results show the index values that have been categorized into four areas calculated using the pixel calculation in GIS. The results indicate that the most suitable site covered the area of 16.37 and 24.35% or 392.92 and

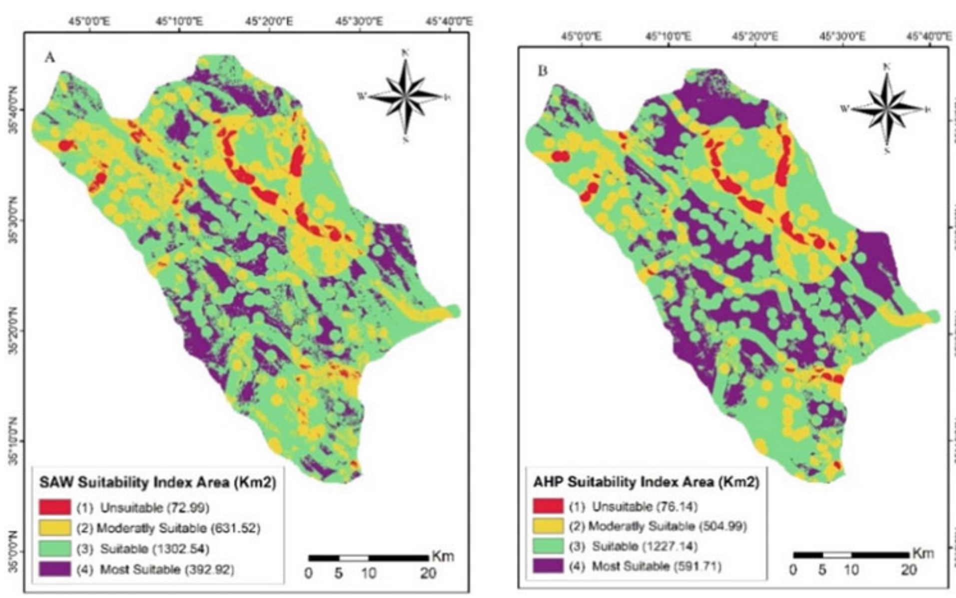

Fig. 3 Suitability index area for landfill site using SAW and AHP methods

591.71 km^2, respectively, in SAW and AHP methods. The compatibility of the most suitable area in both methods is 91.71%, while the compatibility of all zone areas in both methods is 99.8, 94.7 and 96.85%, respectively, for unsuitable, moderately suitable and suitable, respectively.

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