LANDFILL SITES SELECTION USING MCDM AND COMPARING METHOD OF CHANGE DETECTION FOR BABYLON GOVERNORATE, IRAQ

Ali Chabuk[1,2], Nadhir Al-Ansari[1], Anwer Hazim[3], Hussain Musa Hussain[4], Jan Laue[1], Sven Knutsson[1] and Roland Pusch[1]

[1] Department of Civil Environmental and Natural Resources Engineering, Lulea University of Technology, Lulea 971 87, Sweden. ali.chabuk@ltu.se, nadhir.alansari@ltu.se, jan.laue@ltu.se, Sven.Knutsson@ltu.se, drawrite.se@gmail.com.

[2] Department of Environment Engineering, college of Engineering, University of Babylon, Babylon, Iraq. ali_chabuk1975@yahoo.com

[3]Koya university, Koya, 46017, Iraq anwer.hazim@koyauniversity.org

[4] Remote Sensing Center, University of Kufa, Kufa, Iraq. humhudhy02@gmail.com

Abstract

Site selection process for a landfill is a complicated process due to the large number of variables involved. The study area was Babylon Governorate located in the middle parts of Iraq. There is no systematic landfill site that fulfil the environmental and scientific criteria in the Governorate. Fifteen of the most important criteria that fulfil the international requirements were selected for this purpose. These criteria are: groundwater depth, urban centers, rivers, villages, soil types, elevation, roads agricultural land use, slope, land use, archaeological sites, power lines, gas pipelines, oil pipelines and railways. Two methods of multi criteria decision making (MCDM) were used. The first is hierarchy process (AHP) and the second is Ratio Scale Weighting (RSW), were applied to find the criteria weights in different styles. In the GIS software, the raster map of each selected criterion was prepared and analysed. To compare the two output raster maps resulted from AHP and RSW methods, the change detection method was implemented. The results showed there were ten suitable candidate sites for landfill in the Babylon Governorate (two for each District), where all these sites fulfil the scientific and environmental criteria which were implemented in this study. The areas of the selected sites were suitable to receive the cumulative quantity of solid waste from 2020 until 2030.

Keywords: MCDM, Change Detection, RSW, AHP, Landfill siting

Introduction

Selecting an adequate site for landfill is necessary to protect human and environment. To determine the proper site for disposal of solid waste optimally, the decision makers need wide expert to evaluate the lands within the study area that conforms to environmental and scientific requirements and governmental regulations in any country. In addition, the selection site for a landfill should meet the following factors like rapid economic growth, social, population growth rate, improvements in living standards, growing environmental awareness, government and municipality funding, so on (Siddiqui et al. 1996, Lin and Kao, 1999; Javaheri et al, 2006).

Different effective techniques were used for disposition of the municipal solid waste in the term of solid Waste Management. Examples of these techniques are landfills, recycling, biological treatment and thermal treatment (Kontos et al., 2003; Moeinaddini et al., 2010). The landfill is considered the most common technique that is adopted in various countries because this process is a relatively cheap and simple method to be used. In developed countries, after recycling large parts of their waste, the remaining materials still need a suitable site for dumping (Yesilnacar and Cetin, 2008; Kim and Owens, 2010).

There is no landfill site in Babylon Governorate that follows the scientific and environmental criteria similar to that adopted in developed countries. The generated quantity of solid waste in Babylon Governorate in 2013 was 483,221 tonnes of solid waste with generation rate of 0.67 (kg/capita. day). For the waste collection in Babylon Governorate, the budget that was spent on this process in 2013 was 15,894,716 USD (Chabuk et al., 2015).

The groundwater depth in Babylon Governorate is shallow, where represent the main problem on human and environment when selecting the systematic sites for landfill. The water table in the whole area in the governorate varies in depth from 0.423 m to 15.97 m below the ground level (Iraqi Ministry of Water Resources, 2015).

The integration of the Geographic Information System (GIS) and Multi-Criteria Decision-Making methods were used to solve the problem of landfill siting. The GIS software has an important role for the analysis of the input data and producing the required data for the landfill siting, because it has a high ability to manage large volumes of spatial data. It also can consider many factors from a variety of sources (Kontos et al., 2003, Delgado et al., 2008; El Alfy et al., 2010; Sener et al., 2011).

Multi-Criteria Decision-Making methods are used to derive the weights of criteria for the selected criteria. Then these weights are applied on the maps of criteria in the GIS to produce a suitable site for landfill. Examples of such methods which were used in the current study are Analytical Hierarchy Process (AHP) and Ratio Scale Weighting (RSW).

The AHP is one of the most common multi criteria decision making methods, and it was originally developed by Thomas Saaty in 1980. It is used to estimate the consistency weightings of criteria that resulted from constructing the matrix of pair-wise comparisons. The ratio scales weighting (RSW) was used to determine the criteria weightings through giving a ratio score value for each criterion by decision makers based on previous studies in this field and the opinion of experts. The change detection method was used in this study to compare the two raster final maps which were resulted from using the AHP and RSW methods, where this method was applied to determine the pixels' percentage of matching and non-matching areas for two maps.

The main objective of this study is to obtained suitable candidate sites for landfill in Babylon Governorate, Iraq using the two methods of multi-criteria decision making (AHP and RSW) and GIS software. In addition, using the comparison method (change detection) to find the pixels percentage of matching and non-matching for the two raster maps of multi-criteria decision-making methods and to check the suitability of the selected sites for landfill on both resulted maps using these two methods.

Study area

Babylon Governorate located in the middle part of Iraq about 100 km to the southwest of the Iraqi capital, Baghdad (Al-Khalidy et al., 2010). It is located between longitude 44˚2'43"E and 45˚12'11"E and latitude 32˚5'41"N and 33˚7'36"N (Figure 1). Babylon Governorate has a rich history, and it is home to number of important archaeological and religious sites; it includes one of the famous cities of the ancient world. Babylon Governorate has a population of about 2,200,000 up the year 2017 and, the inhabitants are distributed throughout its cities (Iraqi Ministry of Planning, 2015). Babylon Governorate covers an area of 5315 km^2 (Iraqi Ministry of Municipalities and Public Works, 2009). Administratively, Babylon Governorate is divided into five major cities, referred to as a district (Qadhaa). These districts are Al-Hillah (capital of Babylon Governorate), Al-Hashimiyah, Al-Musayiab, Al-Mahawil and Al-Qasim). These districts include sixteen smaller cities and are called Nahiah.

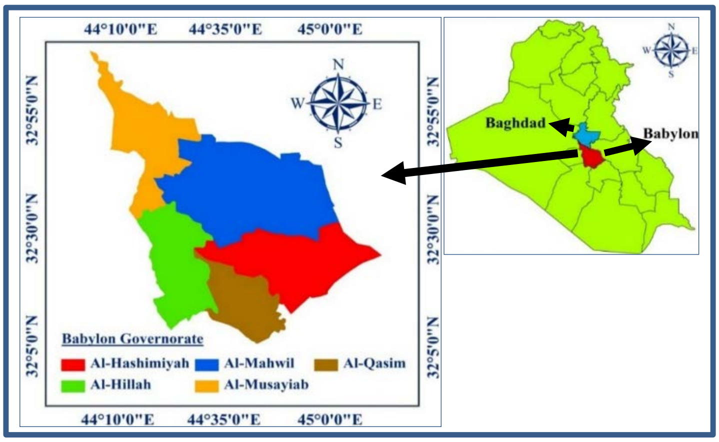

Figure 1: Babylon Governorate, Iraq.

Methodology

To evaluate the study area for the selection of a suitable site for landfill, GIS software was used to prepare map layers of the most significant fifteen criteria in Babylon Governorate according to expert's opinion in this field. The model of landfill siting, depending on the current criteria is shown in **Figure 2.**

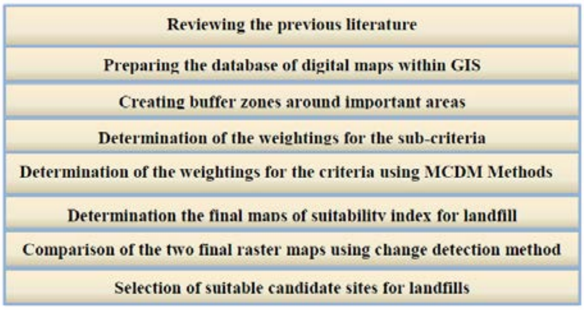

Figure 2. The model for landfill siting in Babylon Governorate, Iraq

Buffer zones

Buffer zones were created around important areas or on both sides of specific geographic features for each criterion in the GIS software. In the buffer zones, the siting of a landfill is not permitted to avoid the risk to the human and environment, as well as to fulfill the requirements of governmental regulation (Siddiqui et al., 1996; Ersoy and Bulut, 2009). The buffer zones for urban centers, rivers, villages, roads, archaeological sites, gas pipelines, oil pipelines, power lines and railways were created at distances of 5 km, 1km, 1km, 0.5 km, 1 km, 300 m, 75 m 30 m and 0.5 km respectively.

Layers of the criteria maps

There are fourth sources used to prepare the required map layers in GIS software for the current study. The first source was the digital maps (shape file) and the internal reports of the Iraqi Ministry of Education (Iraqi Ministry of Education, 2015). The first source was contributed to produce the individual shape file maps for urban centers, villages, river, road, elevation, slope, gas pipelines, oil pipelines, power lines and railways. The second source was the drawn maps based on relevant information in published maps. These were converted into digital maps. The shape file of "soil types" was obtained from the map of exploratory soil of Iraq (scale 1:1000, 000) (Buringh, 1960). To indicate the archeological and religious sites in Babylon Governorate, the shape file of "archaeological sites" was produced from the archaeological map of Iraq (2013) (scale 1:1500, 000) (World Digital Library, 2013). The shape file of "agricultural land use" was created using the land capability map of Iraq (scale 1:1000,000) (Iraqi Ministry of Water Resources, 1990), and the categories of agricultural land use were verified using analyzing satellite images of the Babylon Governorate from 2011 (Iraqi Ministry of Municipalities and Public Works, 2011). The published maps of industrial areas, treatment plants, and universities (scale 1:400, 000) (Iraqi Ministry of Municipalities and Public Works, 2009) were used to define the locations of industrial areas, treatment plants, and universities contributed to the industrial areas within Babylon Governorate. The third source was the readings of 170 wells for the groundwater depths distributed in the governorate (Iraqi Ministry of Water Resources, 2015). These data were entered into GIS to generate an interpolation between them using the special extension tool, "kriging". Then, the map of groundwater depths was produced.

Determination of the sub-criteria weights

In this study, after analysing the collected data for the fifteen criteria, each criterion was classified into categories (sub-criteria), and each category was given a deserve value. This process was done based on literature reviews in this field, the experts' judgement and available data for the study area. The fifteen criterion and sub-criteria weights are presented briefly as follows:

1. Groundwater depth

The groundwater in the Babylon Governorate is varied in depth from 0.42 m to 15.97 m beneath the surface to the groundwater table in most of the areas. The highest value of depth was given the highest rating, while the lowest value of groundwater depths was given the lowest rating (Figure 3.a). In literature, Alves et al. (2009) suggested that a depth of 1.5 m from a surface of landfill to the groundwater table, Effat and Hegazy (2012) suggested 6 m, Delgado et al. (2008) suggested 10m, Ouma et al. (2011) proposed 15 m, and Sadek et al. (2006) suggested 30 m.

2. Urban centres

For the current study, buffer zones of less than 5 km were given a grading of 0 (Şener, 2004; Effat and Hegazy, 2012; Isalou et al., 2013), while the buffer zones of 5–10 km were given the highest score which was 10. Buffer zones of 10–15 km and more than 15 km were given a score of 7 and 4, respectively (Figure 3.b).

3. Rivers

In this study, a buffer zone of more than 1 km from any river boundary was adopted in order to protect surface water from contamination (Sharifi et al., 2009; Eskandari et al., 2012; Kara and Doratli, 2012; Yildirim, 2012). Any distance less than 1 km, thus, given a grading value of zero and any distance greater than 1 km was given a score value of 10 (Figure 3.c).

4. Villages

In the current study, buffer zones less than 1km were given a grading value of zero (Charnpratheep et al., 1997; Sener, 2004; Şener et al., 2006). The buffer zones greater than 1km were given a score of 10 (Figure 3.d).

5. Soil types

There are eleventh types of soils in Babylon Governorate (Figure 3.e) (Buringh, 1960). The soil in Babylon Governorate is covered by alluvial deposits at depth of more than 50 m, where no rocks are exposed in this area (Jassim and Goff, 2006). The types of soil in the study area, according to Buringh (1960), and their weights are: periodically flooded soils A7 (10); haur soils B (9) and basin depression soils C6 (9); river basin soils, poorly drained phase E5' (8); river basin soils, poorly drained phase D5 (7); silted haur and marsh soils F9 (6); river levee soils G4 (5); active dune land H11 (4); sand dune land I18 (3); mixed gypsiferous desert land J17 (2); gypsiferous gravel soils K1 (1).

6. Roads

The layer of "roads" in the Babylon Governorate consists of main roads and highway roads. In this study, buffer zones from roads to landfill sites of less than 0.5 km were given a grade of zero in the rating of this layer (Şener et al., 2006; Şener et al., 2011; Effat and Hegazy, 2012). Buffer zones of 0.5 - 1 km was given a grade of 7, whilst the buffer zones of 1 - 2 km were given the highest score of 10. Buffer zones of 2 - 3 km and those greater than 3 km were given a grading of 5 and 3, respectively (Figure 3.f).

7. Elevation

The digital elevation model (DEM) was adopted in this study (Iraqi Ministry of Education, 2015). The raster elevation map was divided into three categories according to the study area. In this study, the most suitable elevations were 34–72 m above mean sea level (a.m.s.l.) and assigned values of 10. Elevations between 28–34 m and between 28–34 were and assigned values of 7 and 3, respectively (Figure 3.g).

8. Slope

The digital elevation model (DEM) of the study area was used to create the map of "slope". The most of the land in the study area has a slope of 0-5° and it was assigned a rating value of 10 (Figure 3. h).

9. Agricultural land use

The map of "agricultural land use" for Babylon Governorate and was divided into three categories: agricultural land, orchards and unused land. The category of unused land category was given the highest possible score of 10. The "orchards" category was given a value of 5. The category of agricultural land was given a value of zero (Figure 3.i).

10. Archaeological sites.

Babylon Governorate is home to a number of important archaeological and religious sites. These areas are considered absolutely unsuitable to be within or near a landfill site because of their high historical value and importance for tourism. In this study, for the "archaeological sites" layer, buffer zones of less than 1 km around these areas were assigned a value of zero (Gupta et al., 2003; Ersoy and Bulut, 2009). The buffer zones more than 3 km around archaeological were assigned a value of 10, whilst buffer zones of 1-3 km were assigned 5 (Figure 3.j).

11. Power lines.

For the "power lines" map, buffer zones smaller than 30 m on both sides were given a score value of zero (Sener, 2004; Yildirim, 2012), whilst buffer zones higher than 30 m were given a score value of 10 (Figure 3.k).

12. Gas pipelines.

For the map of "gas pipelines", buffer zone less than 300 m from a landfill site to gas pipelines was given a grading value of zero depending on the determinants of the Iraqi Ministry of Oil/Oil Pipelines Company/Iraq No. 40145 in 1989 (Iraqi Ministry of Oil, 2015). Buffer zone more than 300 m was given a score value of 10 (Figure 3.l).

13. Oil pipelines.

The buffer zones more than 75 m on both sides for oil pipelines was given a score of 10 based on the determinants of the Iraqi Ministry of Oil/Oil Pipelines Company/Iraq No. 40145 in 1989 (Iraqi Ministry of Oil, 2015). Buffer zones less than 75 m, on both sides of oil pipelines, was given a score value of zero (Figure 3.m).

14. Railway.

For the "railway" map, buffer distances of more than 500 m on both sides of the railway were given a value of 10. Buffer Distance less than 500 m was given a value of zero (Wang et al., 2009; Nas et al., 2010; Demesouka et al., 2013) (Figure 3.n).

15. Land use.

In Babylon Governorate, eleven categories were used to prepare the "land use" layer; these are urban centres, villages, industrial areas, archaeological sites, universities, treatment plant, agricultural airport, rivers, agricultural land, orchards and unused land. The categories of orchards and unused lands were given ratings of 5 and 10, respectively, whilst other categories were assigned a score of zero (Figure 3.o)).

Multi-criteria decision-making (MCDM) methods:

Two methods of multi-criteria decision making (MCDM) were applied to derive the weights of criteria in different procedure. These methods are Analytical Hierarchy Process (AHP) and Ratio Scale Weighting (RSW). These methods can be summarized as follow:

1. Analytical Hierarchy Process (AHP) method

Saaty (1980) developed the Analytic Hierarchy Process (AHP) method. It is based on theoretical foundation. This method was used to derive the important weightings for the selected criteria in Babylon Governorate, using a matrix of pair-wise comparisons. The numerical scale of 9 points was used, where each point equates to an expression of the relative importance of the two factors.

The eigenvector (Eg_i) for each criterion was calculated through multiplying the value for each criterion in each column in the same row in the matrix of the pair-wise comparison. Then, put the output value under the n^{th} root for numbers of elements in this row. The priority vectors (Pr_i) or relative weights of criteria were resulted from normalized the eigenvalue for each criterion through divided each eigenvalue by their sum.

To verify the consistency between the resultant weightings of criteria from the matrix of pair-wise comparisons, the value of the Consistency Ratio (CR) was calculated through dividing the Consistency Index (CI) by the Random Index (RI). Where, CI is equivalent to the standard deviation of evaluation error, and RI is the mean deviation of randomness for matrices with different sizes for various values (Saaty, 1980).

In this study, the values of (λ_{max}), (CI) and (RI15) were 15.61, 0.43 and 1.59 respectively. If the Consistency Ratio value is smaller than 0.1, then the consistency is acceptable. Here, the CR value was $0.027 < 0.1$. The matrix Pair-wise comparisons for determining significance criteria weights for landfill siting using AHP method can be seen in Figure 4.

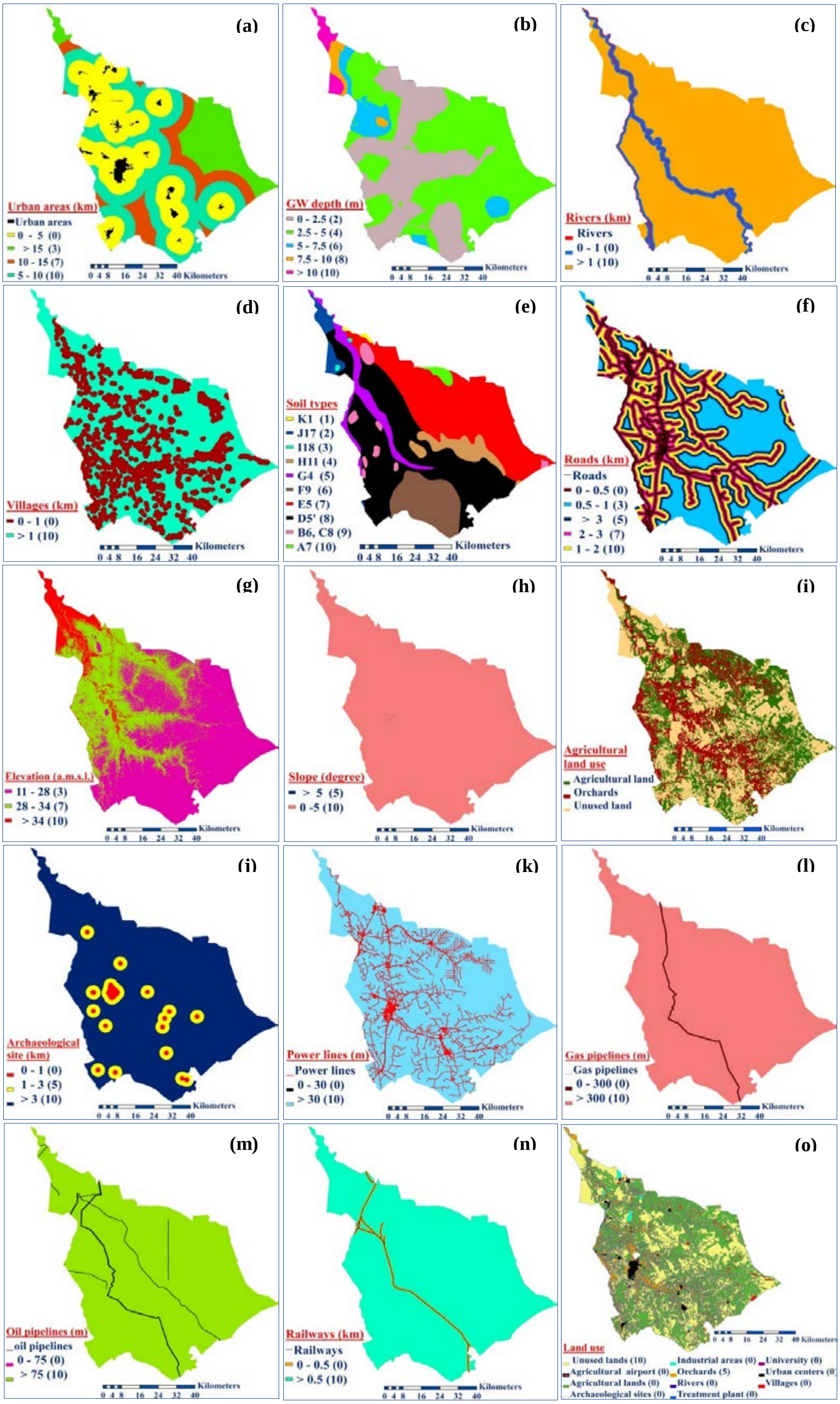

Figure 3: Classified maps of Babylon Governorate for (a): Ground water depth; (b): Urban center; (c): Rivers; (d): Villages; (e): Soil types; (f): Roads; (g): Elevation; (h): Slope; (i): Agricultural land use; (j): Archaeological site; (k): Power lines, (l): Gas pipelines; (m): Oil pipelines; (n): Railways, (o): Land use.

2. **Ratio Scale Weighting (RSW) method**

The second method which was applied in this study was the Ratio Scale Weighting (RSW) method. In this method, the weights of criteria are given directly by decision makers based on previous studies in this field. The decision process in this method is based on allocating a suitable ratio score value for each criterion, where the value of 100 is given to the most important criterion to be the basis for the values of other criteria. Values smaller than 100, are proportionally allocated to criteria that are lower in the order according to the importance of each criterion with respect for the others (Şener, 2004). Table 1 shows the weights of criteria for landfill siting using the SRS Method.

To estimate the standard weightings for criteria (SW_i) using the Ratio Scale Weighting (RSW) method, the value of proportional weight of each criterion was divided by the value of proportional weight of the lowest importance criterion. Then, the normalized weights for criteria of the RSW method were estimated using Eq. (**1**).

$$NW_i = \frac{SW_i}{\sum_{j=1}^{n} SW_j} \quad j = 1, 2, \ldots, n \tag{1}$$

where, NWi is the normalized weight of each criterion which was divided by the new weight of each criterion by their sum; SW_i is the new weight of each criterion of area i under criterion j; n is number of criteria.

Criteria	Groundwater depth	Urban centers	Villages	Rivers	Elevation	Slope	Roads	Soils types	Gas pipelines	Oil pipelines	Power lines	Land use	Agricultural land use	Archaeological sites	Railways	normarlized Weights
Groundwater depth	1	2	3	2	4	5	5	4	8	8	7	6	5	6	9	0.2004
Urban centers	0.50	1	2	1	3	4	4	3	7	7	6	5	4	5	8	0.1471
Villages	0.33	0.50	1	0.5	2	3	3	2	6	6	5	4	3	4	7	0.1038
Rivers	0.50	1.00	2.00	1	3	4	4	3	7	7	6	5	4	5	8	0.1471
Elevation	0.25	0.33	0.50	0.33	1	2	2	1	5	5	4	3	2	3	6	0.0709
Slope	0.20	0.25	0.33	0.25	050	1	1	0.5	4	4	3	2	1	2	5	0.0463
Roads	0.20	0.25	0.33	0.25	0.50	1.00	1	0.5	4	4	3	2	1	2	5	0.0463
Soils types	0.25	0.33	0.50	0.33	1.00	2.00	2.00	1	5	5	4	3	2	3	6	0.0709
Gas pipelines	0.13	0.14	0.17	0.14	0.20	0.25	0.25	0.20	1	1	0.5	0.34	0.25	0.34	2	0.0146
Oil pipelines	0.13	0.14	0.17	0.14	0.20	0.25	0.25	0.20	1.00	1	0.5	0.34	0.25	0.34	2	0.0146
Power lines	0.14	0.17	0.20	0.17	0.25	0.33	0.33	0.25	2.00	2.00	1	0.5	0.34	0.5	3	0.0207
Land use	0.17	0.20	0.25	0.20	0.33	0.50	0.50	0.33	2.94	2.94	2.00	1	0.5	1	4	0.0302
Agricultural land use	0.20	0.25	0.33	0.25	0.50	1.00	1.00	0.50	4.00	4.00	2.94	2.00	1	2	5	0.0462
Archaeological sites	0.17	0.20	0.25	0.20	0.33	0.50	0.50	0.33	2.94	2.94	2.00	1.00	0.50	1	4	0.0302
Railways	0.11	0.13	0.14	0.13	0.17	0.20	0.20	0.17	0.50	0.50	0.33	0.25	0.20	0.25	1	0.0107

Figure 4: Pair-wise comparisons' matrix for determining significance criteria weights for landfill siting.

Table 1: The criterion weightings defined for the RSW method and normalized weights.

No.	Criteria	Ratio scale value	New weight (SW_i)	Normalized weights (NW_i)
1	Groundwater depth	100	20	0.2012
2	Urban centers	74	14.8	0.1489
3	Rivers	73	14.6	0.1469
4	Villages	52	10.4	0.1046
5	Elevation	35	7	0.0704
6	Soils types	35	7	0.0704
7	Slope	23	4.6	0.0463
8	Roads	23	4.6	0.0463
9	Agricultural land use	23	4.6	0.0463
10	Land use	15	3	0.0302
11	Archaeological sites	15	3	0.0302
12	Power lines	10	2	0.0201
13	Gas pipelines	7	1.4	0.0141
14	Oil pipelines	7	1.4	0.0141
15	Railways	5	1	0.0100
	Sum		99.4	1

Results and Discussion

Final maps of suitability index for land fill

After produced the weightings of the fifteen criteria from AHP and RSW methods and the weights of sub-criteria for each criterion, the special analysis tool "Map Algebra" in GIS was used to create the final raster maps of the suitability index for landfills. This done through summation the products to multiplying the weight of each criterion by the weight of each sub-criteria of each criterion. **Figure 5** shows the final raster maps of the suitability index of the selection sites for landfill using AHP and RSW.

Comparison of the two final raster maps using Change Detection method

The U.S. National Land Cover Database (NLCD) (Jin et al., 2013) was introduced the method of change detection. This method was applied to compare the pixels of two raster maps in the same area (http://digitalcommons.unl.edu/cgi/viewcontent-.cgi?article=1720&context=usgsstaffpub). The change detection method is used to calculate the matching pixels for all categories and the non-matching pixels for each two similar categories for all categories.

In this study, the change detection method was used to compare the final raster maps for each category, where each raster map was classified into four categories.

The fourth categories are: (1) unsuitable areas (US), (2) moderately suitable areas (MOS), (3) suitable areas (S) and (4) most suitable areas (MS). In the GIS, the spatial analysis tool 'Map Algebra' was applied the formula "(AHP raster map) Diff (RSW raster map)" for comprising between the two maps using the change detection method.

The comparison process was used to determine and check the suitability of the selected sites for landfill on both resulted maps from the two methods. The comparing map was resulted from combining two methods of AHP and RSW in Babylon Governorate.

The compression map that was resulted from using the change detection method was classified into two main categories matching areas for all categories and non-matching areas for each two similar categories, as shown in **Table 2**. The proportion of matching pixels in comparison map was 76.20 % (in yellow), whilst the proportion of the non-matching pixels for all categories was 23.80 % (blue) (**Figure 6**).

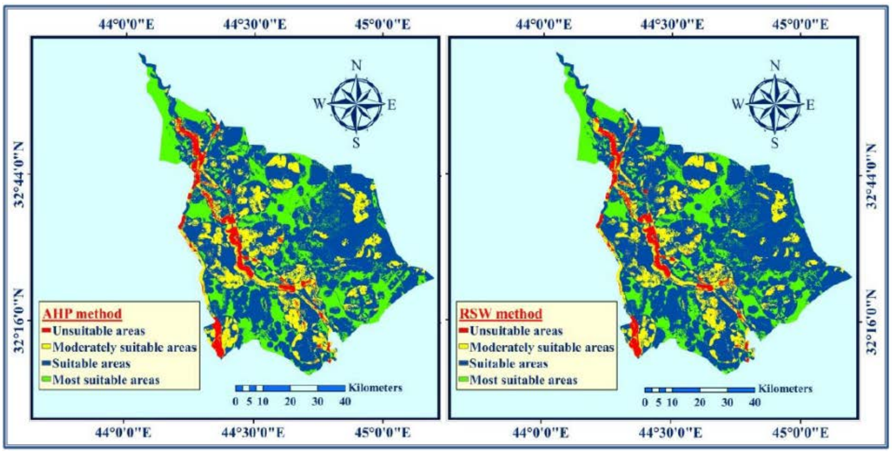

Figure 5: The comparison map between AHP and RSW methods using change detection method.

Table 2: The results of comparison two maps resulted from (AHP) and (RSW) methods.

Value	Count	Categories (AHP)	Categories (SRS)	Pixels ratios	Classification
1	6485765	All similar categories	All similar categories	76.20	Matching
2	121002	(US) 1	(US) 1	1.42	Non-matching
3	84924	(MOS) 2	(MOS) 2	1.00	Non-matching
4	1000520	(S) 3	(S) 3	11.76	Non-matching
5	818891	(MS) 4	(MS) 4	9.62	Non-matching

Notes: US: Unsuitable areas; MOS: Moderately suitable areas; S: Suitable areas; MS: Most suitable areas.

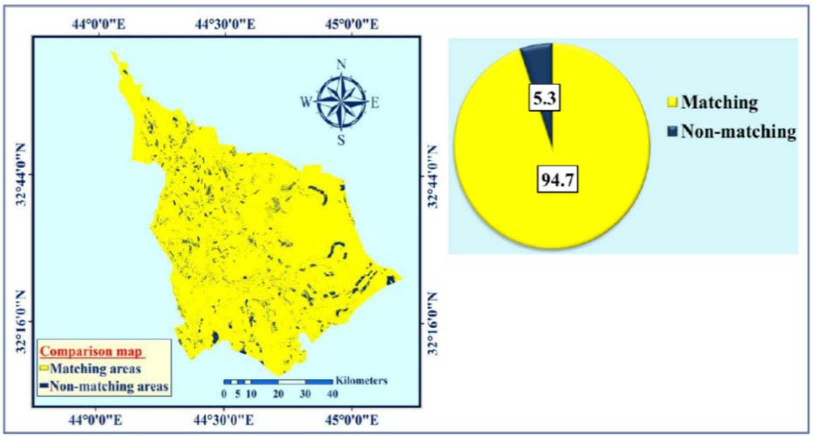

Figure 6: The comparison map between AHP and RSW methods using change detection method.

Selecting candidate sites for landfill

To calculate the quantity of waste produced for the year 2030 in the Babylon Governorate and its districts, equation (2) was used for this purpose according to Chabuk et al. (2015).

$$Q_s \text{ (for specific year)} = ((P_{0(2013)}\,(1 + 0.0299)^n) \times (GRW_{(2013)}\,(1 + 0.01)^n) \times (365/1000)) \qquad (2)$$

This equation was constructed based on two factors. These factors are: (i) the rate of increment of (1%) for waste generation rate (RGI) of Babylon Governorate districts starting from the year 2013; (ii) the future population for the year (2030) based on the present population in 2013 with the annual rate of growth (2.99%). The cumulative quantity of solid waste for the years 2020 - 2030 in the Babylon Governorate and its districts was estimated using Eq. (2) (**Table 3)**. The cumulative quantity of solid waste generated by 2030 can be calculated, as shown in Eq. (3):

$$Q_{s(c)} = Q_{s(ct)} + Q_{s(ct-1)} \qquad (3)$$

Where, $Q_{s(c)}$: Cumulative quantity of solid waste for the specific year (tonne); $Q_{s(ct)}$: Quantity of solid waste for the specific year (tonne); $Q_{s(ct-1)}$: Cumulative quantity of solid waste for the last year before specific year (tonne).

Table 3: The summary of the **third method** for calculating the quantity of solid waste in 2030, and the cumulative quantity of solid waste for year 2020-2030 (Chabuk et al., 2015).

District	Present population $Po_{(2013)}$	Future population $P_{t(2030)}$	Solid waste quantity (T) (2013)	(GRW) (kg/ (capita. day)) (2013)	Solid waste quantity Qs (T) (2030)	Cumulative quantity of solid waste $Qs_{(c)}$ (T) (2020-2030)
Al-Hillah	807,777	1,332,930	238,244	0.82	472,474	4,300,864
Al-Qasim	184,605	304,621	38,913	0.57	76,374	695,219
Al-Mahawil	336,148	554,685	49,377	0.4	96,389	877,419
Al-Hashimiyah	270,020	445,566	51491	0.52	100,155	911,695
Al-Musayiab	374,684	618,274	105,196	0.77	205,792	1,873,295
Babylon Governorate	1,973,234	3,556,966	483,221	0.67	1,030,174	8,752,506

The volume of waste for the year 2030 and the volume of cumulative waste from 2020 to 2030 in Babylon Governorate and its districts are shown in **Table 4**. These values were calculated based on the following information:

- The information given in **Table 3**.
- The waste density in waste disposal sites is 700 kg m^{-3} in Babylon Governorate according to (Oweis and Khera, 1998; Vesilind et al., 2002; UNEP-IETC, 2006).
- These values of waste volume in 2030 were resulted by divided the quantity solid waste in 2030 and cumulative quantity of solid waste from 2020-2030 by the density of waste (700 kg m^{-3}).

Table 4: The volume of waste in 2030 and the volume of cumulative waste from 2020 to 2030 in Babylon Governorate and its districts using the third method.

District	**Volume of waste in 2030 (m^3)**	**Cumulative volume of waste from 2020 to 2030 (m^3)**
Al-Hillah	674,963	6,144,091
Al-Qasim	109,106	993,170
Al-Mahawil	137,699	1,253,456
Al-Hashimiyah	143,079	1,302,421
Al-Musayiab	293,989	2,676,136
Babylon Governorate	1,471,677	12,503,580

The required area of candidate sites for landfills was calculated through dividing the expected cumulative volume of solid waste generated from 2020 to 2030 in each district by the 2 m height of solid waste that will be placed on the top surface of the candidate sites. Then, the resulted value of the required area in each district, and it was multiplied by 10% to provide a factor of safety when selecting the candidate sites (Chabuk et al., 2015). The initial reasons of selecting the height of solid waste in these sites as 2 m are as follows:

- The groundwater depth in the study areas is shallow.
- To reduce the cost of constructing a perimeter berm around the sites.
- To reduce soil subsidence or settlement under the load of cumulative waste, that will be placed over the surface at the selected sites.

In each district, two candidate sites were selected for landfill among many sites that were located within the category of the “most suitable”. The summary of required areas and the areas of candidate sites for landfill in each district, as well as the available area for design are shown in **Table 5**.

Table 5: The required area, and the areas and location of candidate sites for landfill in the districts of Babylon Governorate, and available area for design (Chabuk et al., 2017).

District	Requited area (km^2)	Requited area (km^2) + 10 %	Area of candidate sites		Location
			Site	Area (km^2)	
Al-Hillah	3.1	3.4	Hi-1	6.768	Latitude 32° 15' 46" N Longitude 44° 28' 55" E
			Hi-2	8.204	Latitude 32° 13' 43" N Longitude 44° 29' 15" E
Al-Qasim	0.5	0.55	Q-1	2.766	Latitude 32° 11' 43" N Longitude 44° 32' 26" E
			Q-2	2.055	Latitude 32° 14' 38" N Longitude 44° 37' 10" E
Al-Hashimiyah	0.65	0.72	Hs-1	1.288	Latitude 32° 15' 54" N Longitude 44° 53' 38" E
			Hs-2	1.374	Latitude 32° 24' 43" N Longitude 44° 55' 43" E
Al-Mahawil	0.63	0.7	Ma-1	2.950	Latitude 32° 29' 59" N Longitude 44° 41' 2" E
			Ma-2	2.218	Latitude 32° 38' 12" N Longitude 44° 34' 9" E
Al-Musayiab	1.3	1.4	Mu-1	7.965	Latitude 32° 48' 39" N Longitude 44° 8' 59" E
			Mu-2	5.952	Latitude 33° 0' 14" N Longitude 44° 6' 46" E

These sites were checked on the satellite images of the governorate to make sure that these sites were suitable for landfill in the districts of Babylon Governorate (**Figure 7**).

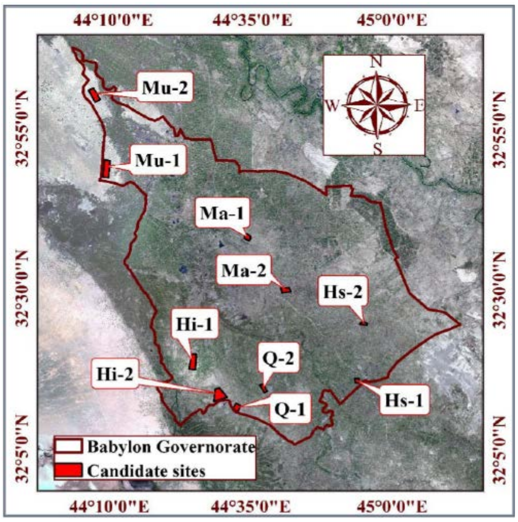

Figure 7: The candidate sites for landfill on the satellite images of the Babylon Governorate.

Conclusions

The present waste disposal sites in Babylon Governorate do not conform to the environmental and scientific criteria, and it has an effect on human health. The purpose of current study is to select the most suitable sites for landfill in Babylon Governorate using the GIS software and Multi Criteria Decision Making methods (AHP and RSW). Thus, fifteen maps of criteria were entered into GIS to produce the final map for landfill siting. The fifteen layers are: groundwater depth, urban centres, rivers, villages, soil types, elevation, agriculture lands use, roads, slope, land use, archaeological sites, gas pipelines, oil pipelines, power lines and railways.

The two methods of multi-criteria decision making were used in different styles to find the relative weights for each criteria. The Analytic Hierarchy Process (AHP) was the first method, where a matrix of pair-wise comparisons between each criterion to derive the weight to each criterion was used. The second method was the ratio scale weighting (RSW). This method is based on the experts' opinion and previous studies in this field by giving proportion values for each criterion according to its importance among other criteria. Then, the special analysis tool in GIS "Map Algebra" was used to generate the final map to select the candidate sites for landfill for each method.

The two final maps that were resulted from the two methods of MCDM (AHP and RSW) were combined in the GIS. Then, the change detection method was used to find the matching and non-matching areas on the final raster maps of AHP and RSW methods. The comparison process of the change detection method was used to obtained and check the suitability of the selected sites for landfill in Babylon Governorate.

Finally, ten candidate sites were obtained on the final maps for landfill in Babylon Governorate among several sites (two for each district). All the selected sites were located within the category of "most suitable" on the final maps of MCDM methods and within the matching areas in the comparison map. It was found that, the required areas for candidate sites are suitable to accommodate the cumulative solid waste for the years 2020-2030 compared with the needed areas for landfills in each district in Babylon Governorate.

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