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Modeling Landfill Suitability Based on GIS and Multicriteria Decision Analysis: Case Study in Al-Mahaweelqadaa

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Abstract

Waste management system is not regulated in Iraq. At present, there are various techniques used for solid waste management such as landfill, thermal treatment, biological treatment, recycling etc. Landfill is the most common mode for the disposal of solid waste. However, landfill site selection is a quite complex process and it depends on several criteria and regulations. In this study landfill site selection is performed for Al-Mahaweelqadaa using Multicriteria Decision Analysis (MCDA) and Geographic Information System (GIS). It should be mentioned however, that the existing landfill in this area, is temporary and does not fulfill the environmental conditions. To select suitable landfill site, several criteria were considered such as Urban centers, Land use, Airports, Pipes, Power lines, Railways, Roads, slope, streams, Surface water, Industrial areas, Oil pipes, Liquid gas pipes, Soil types which are prepared. (MCDA) was used to evaluate the relative importance of each criterion. Each map layers were formed with the aid of GIS and final suitability map was created by overlay analyses of each criterion map. According to obtained results, high and low suitable areas were determined in the study area. Field and office checks were performed out to determine the accuracy and suitability of the candidate sites.

Keywords

Multicriteria Decision Analysis, Geographic Information System, Iraq, Al-Mahaweel

1. Introduction and Research Objective

Waste was an early problem for mankind and the environment. This problem is growing with time and it is of

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major concern to every nation [1]. Source reduction, recycling and waste transformations are methods widely used to manage solid waste. However, in all these methods there is always a residual matter even after the recovery process to disposal. The necessity of getting rid of these waste yields in an economic approach which is called landfilling [2].

Landfill siting is an extremely difficult task to accomplish because the site selection process depends on different factors and regulations. It is becoming increasingly difficult due to growing environmental awareness, decreased amount of governmental and municipal funding with extreme political and social opposition. The increase of population growth rate, public health concerns, and less land available for landfill construction add more difficulties to the problem to overcome [3]. Environmental factors are very important to be considered in such work due to the fact that landfill might affect the biophysical environment and the ecology of the surrounding area [4].

Several techniques can be found for site selection of solid waste disposal in [5]-[20]. Such siting techniques combine multiple criteria analysis (MCDA) and GIS [21]-[30]. The result of these techniques is the evaluation of the suitability for the entire study region based on suitability index, which is useful in order to make an initial ranking of the most suitable areas.

GIS is a powerful tool that can integrate driven types of spatial data and perform a variety of spatial analysis. This evolution has been driven by significant advances in computer technology and the availability and quantity of data. GIS and environmental models functioning with a board spectrum of geospatial data are usually used for divers' applications and spatial analyses at different scales. The examination and organization of data into a useful form will enable appropriate analysis and modeling.

The objective of this study is to suggest sites for appropriate landfills within Al-Mahaweelqadaa in Babylon governorate using the integration of Geographic Information Systems (GIS) and Multicriteria Decision Analysis (MCDA). In addition, the required landfill area to cover generated Municipal Solid Waste (MSW) volume for at least five years was calculated. Using these approaches will lead to integrated environmental management, which is necessary to allow consideration of all components and processes in the environment; their spatial, temporal, and human dimensions; their interaction and correlation, coupled with social, economic, political, and legal impacts.

For this purpose, 14 input digital map layers (Urban centers, Land use, Airports, Pipes, Power lines, Railways, Roads, slope, streams, Surface water, Industrial areas, Oil pipes, Liquid gas pipes, Soil types) were prepared and multi criteria analysis was implemented with geographic information system. The digital maps are prepared according to environmental criteria of landfill sites selection stated by World Bank and published researches.

2. Materials and Methods

2.1. Study Area

Al-Mahaweelqadaa is located to the east of Babylon governorate in Iraq. Its center is the city of Al-Mahaweel (**Figure 1**) with a population of about 305,202. It lies approximately between latitudes 32˚26', 32˚51'N, and longitudes 44˚18', 45˚2'E longitude. The total area of the Al-Mahaweelqadaa is 1667 km^2. The population growth rate is 5%.

2.2. Methodology

Evaluation of criteria needed for landfill siting selection in Al-Mahaweelqadaa was identified. Local guidelines such as Town and Country Planning Department (TCPD) guideline for waste disposal siting and also guideline from the Department of Environment (DOE) were used. Other sources were the related information about landfill siting from the international practices like Environmental Protection Agency (EPA) [31] were also used. All the data pertaining to these parameters were taken from the relevant agencies, however not all parameters were included in this study due to the limitation of data.

Fourteen criteria (Urban centers, Land use, Airports, Pipes, Power lines, Railways, Roads, slope, streams, Surface water, Industrial areas, Oil pipes, Liquid gas pipes, Soil types) were used to identify the best landfill site for Al-Mahaweelqadd in the GIS and MCDA.

ArcGIS 9.3 software was used for imaging and analysis of spatial data. Additionally, several GIS analyses such as buffer zoning, distance, reclassify and overlay analysis were used. In order to evaluate the site selection

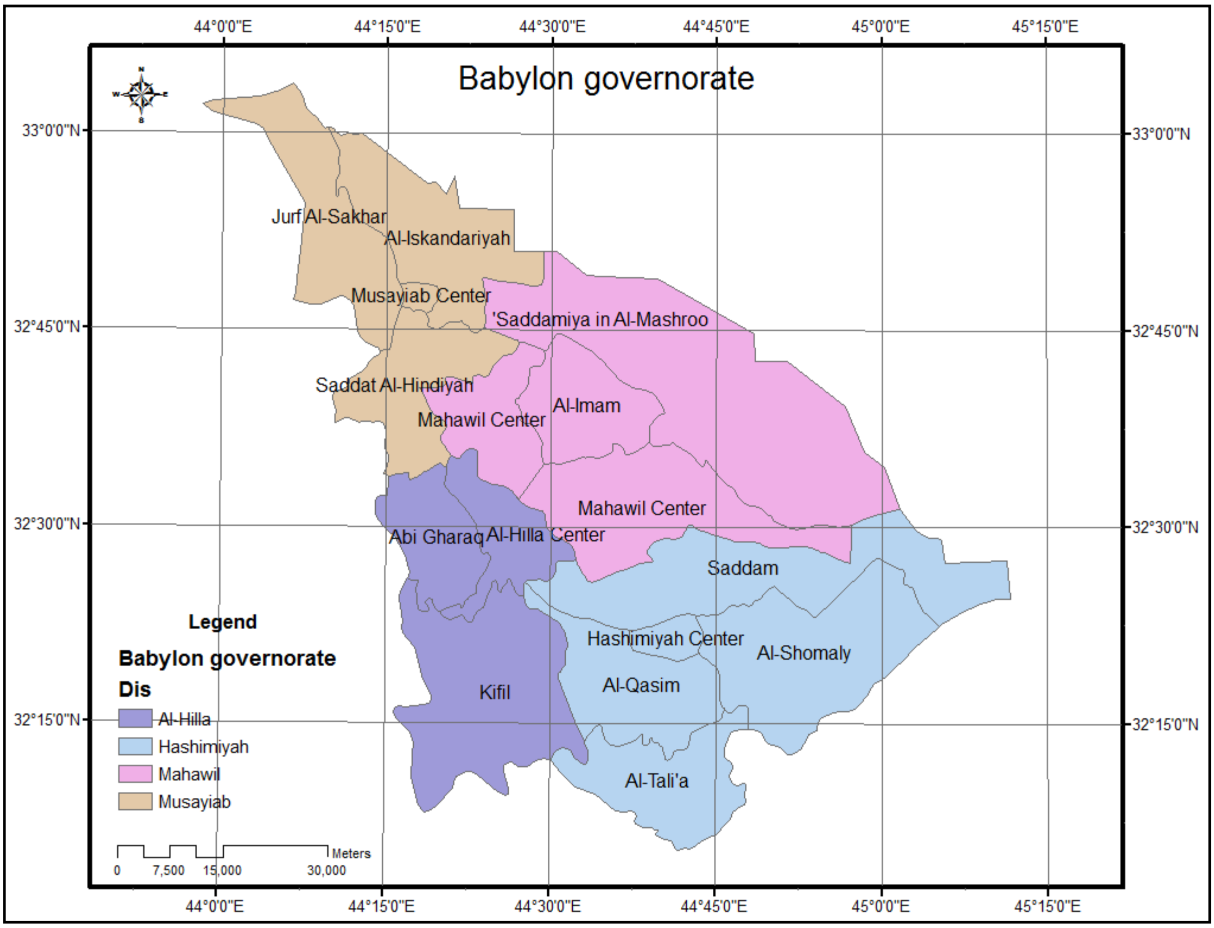

Figure 1. Map Babylon governorate.

criterion, (MCDA) was used to measure the relative importance weight for individual evaluation criteria. MCDA is to divide the decision problems into smaller understandable parts, analyze each part separately, and then integrate the parts in a logical manner [32].

2.3. Population Growth Rate

Population growth rate (r) was calculated based on estimates of population size of the Babylon governorate, for the period (2004-2010) that was obtained from the department of Statistics/Babylon as follow:

$$P_{2010} = p_{2004}(1+r)^n$$

where

n = number of years.

P = population.

Using the above growth rate equation for Al-Mahaweelqadaa in Babylon governorate, population size was calculated for each of the years from 2011 to 2017. The growth rate was found to be 5%.

2.4. Municipal Solid Waste Volume (MSW) for Site Area Requirement

The quantity of waste is closely linked with the population. For this reason, the population for the period 2004-2010 was correlated with the amount of waste generated in that period (see **Table 1**). The relationship obtained (**Figure 2**) was:

$$y = 0.226x - 35932$$

Table 1. Solid waste in Al-Mahaweelqadaa with its population.

Al-Mahaweelqadaa		
Year	Population	Solid waste (ton)
2004	225,063	13,140
2005	236,316	16,060
2006	248,132	20,805
2007	256,811	25,331
2008	274,409	30,728
2009	274,409	25,049
2010	305,202	30,248
2011	320,462	36,492
2012	336,485	40,114
2013	353,309	43,916
2014	370,975	47,908
2015	389,524	52,100
2016	408,999	56,502
2017	429,450	61,124

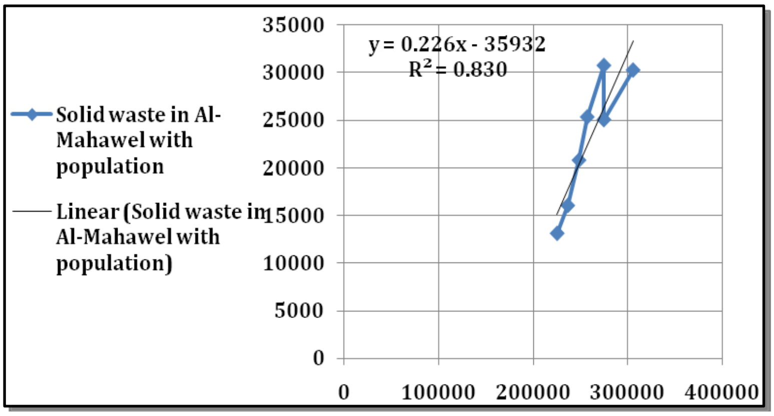

Figure 2. Solid waste (y-axis) in the center of Babylon governorate (Al-Mahaweelqadaa) with its population (x-axis) (x: Population in Al = Hashimyah; y: Solid waste for the same year in ton).

$$R^2 = 0.830$$

The sum of calculated solid waste in five years (2013-2017) for Al-Mahaweelqadaa was 261,550 ton (**Table 2**). This makes a volume of 581,222 m^3 which was calculated according to Al-Baidhani [33] where he cited that Iraqi municipal solid waste equals 0.45 t/m^3.

Table 3 represented compacted and accumulated waste volume for Al-Mahaweelqadaa in Babylon governorate from 2013 to 2017.

2.5. Criteria Analysis

The decision tree developed for the landfill site selection problem in Al-Mahaweelqadaa is illustrated in **Figure 3**. Fourteen criteria were prepared as input digital map layers including Urban centers, Land use, Airports, Pipes, Power lines, Railways, Roads, slope, streams, Surface water, Industrial areas, Oil pipes, Liquid gas pipes, and Soil types.

Table 2. The sum of the solid waste in five years Al-Mahaweelqadaa.

Year	Solid waste (ton) in Al-Mahaweelqadaa
2013	43,916
2014	47,908
2015	52,100
2016	56,502
2017	61,124
Sum	261,550

Table 3. Discarded and compacted waste volume in Al-Mahaweelqada.

Al-Mahaweelqadaa	Accumulated Waste from 2013 to 2017 Weight (ton)*	Volume in Landfill (m^3)*
	261,550	**581,222**

*Compacting density of Iraqi municipal solid waste = 0.45 t/m^3 [32].

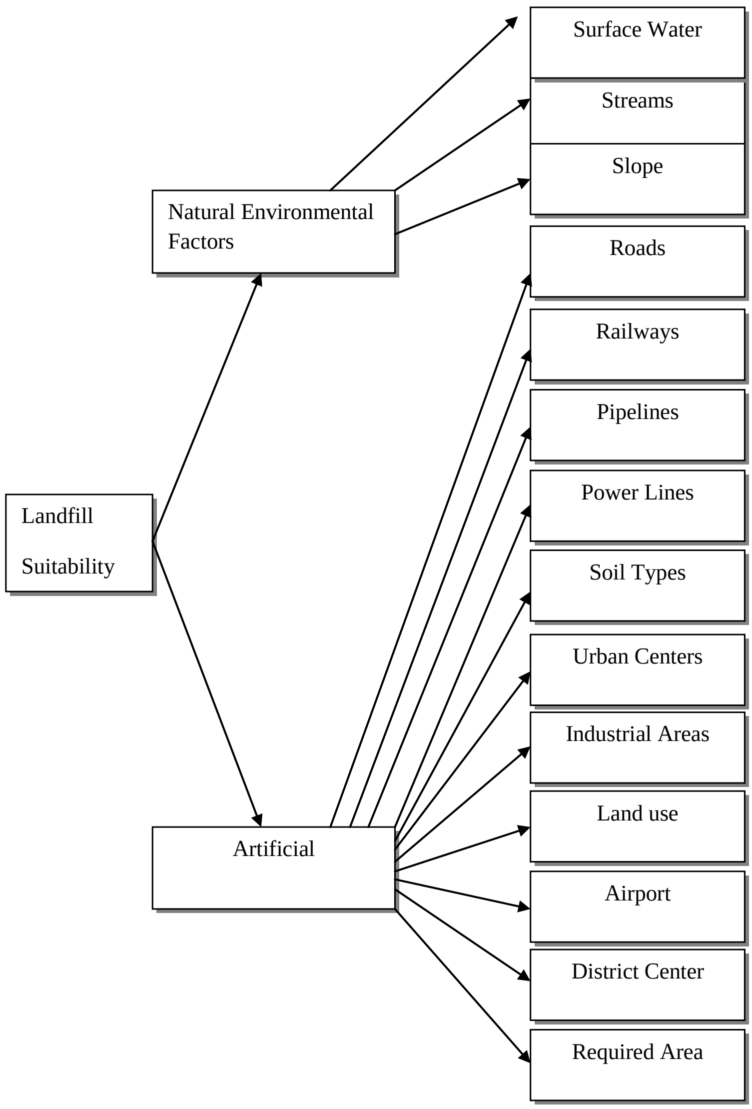

Figure 3. The decision tree developed for the landfill site selection problem in Al-Mahaweelqadaa.

2.5.1. Criteria Weights

A weight can be defined as a value assigned to an evaluation criterion which indicates its importance relative to other criteria under consideration .Assigning weights of importance to evaluation criteria accounts for 1) the changes in the range of variation for each evaluation criterion, and 2) the different degrees of importance being attached to these ranges of variation [14]. There are four different techniques when assigning the weights: Ranking, Rating, Pairwise Comparison and Trade of Analysis Method [14]. Calculating weight for the criteria using the method of pairwise comparison method, the weights of criteria have been computed using comparison matrix shown in **Figure 4** by using scale values of 1 - 9 as shown in **Table 4**.

The comparison matrix indicating the relative importance of the criterion in the columns compared to the criterion in the rows. (For each comparison, it will decided which of the two criteria are the most important, and then a score is assigned to show how much more important it is). The resulting weights are given in **Table 5**.

2.5.2. Digital Environmental Maps

It is evident that many factors must be incorporated into landfill siting decisions. Geographic information systems (GIS) is ideal for this kind of preliminary studies due to its ability to manage large volumes of spatial data from a variety of sources. It efficiently stores, retrieves, analyzes and displays information according to user-defined specifications [4].

1) Settlement Areas

Settlement areas were subdivided into two layers. First layer consists of residential areas, and the second layer was for industrial areas.

The reason for this division is the necessity of applying different buffer zones to residential and industrial areas. According to Allen *et al.* [23], the location of a landfill should be at a distance of at least 5 km from residential areas should be and 500 m from isolated houses. The buffer distances for towns and villages within a population greater than 500 people were determined as 1000 m, and 500 m for all other identified centers of population and 250 m for private residences, businesses, social and community buildings by Cantwell [35]. Siddiqui *et al.* [4] suggested that no new landfill site should be located closer than 0.4 km (0.25 mi) from a collection of ten or more houses. On the other hand, the landfill site should be located within 10 km of an urban area due to economic considerations [36]. Accordingly; minimum distances for the study area were considered as 5 km for residential areas and 250 m for industrial areas. These distances were used to create buffer zones around settlement areas and it was excluded from the study area. After exclusion of absolutely unsuitable areas for a landfill site, the remained areas are classified according to their suitability. The layer of industrial areas are classified as suitable or unsuitable by assigning values 1 and 0 respectively (**Table 6**) and map shown in **Figure 5**.

The layer concerning residential areas was divided into four classes. The classes and related ranks can be seen in **Table 7**. The residential areas layer was then prepared based on the ranking values shown in same table that is presented in **Figure 6**.

2) Roads

Minimum distance from the network is imported in order to avoid visual impact and other nuisances. Roads plus 100 m around them applied as a buffer zone [37].

As stated by Cantwell [35], all roads including primary, secondary, regional and third class roads should be avoided and have a buffer of at least 30 m on both sides. According to Allen *et al.* (2000), distance greater than 1 km from main roads and highways should be avoided. On the other hand, the landfill site should not be placed too far away from existing road networks to avoid the expensive cost of constructing connecting roads [22]. Distance from main access roads should be smaller than 3 km according to Allen *et al.* [23] and between 0.2 km and 10 km of a major road according to World Bank [36].

By considering these suggested values, the buffer zones and related ranks were determined for roads which are shown in **Table 8**.

The values of **Table 8** were entered to the database and each value was assigned to its related class. Finally, the vector maps were converted to raster maps as shown in **Figure 7**.

3) Railways

The necessary buffer zone distances and related rankings are directly used as shown in **Table 9** according to World Bank [36].

The buffer zones were created (**Table 9**). The layer of railways was classified as suitable or unsuitable by assigning values 1 and 0 respectively. Then, the vector map prepared was converted to a raster map as shown in **Figure 8**.

	Ur	Lu	Ai	Pi	Pl	Ra	Ro	Sl	St	Sw	In	Oi	Lg	St
Ur	1	5	7	5	7	9	7	5	3	3	5	5	5	4
Lu	1/5	1	3	2	3	4	3	2	1/3	1/3	1	2	2	1/2
Ai	1/7	1/3	1	1/2	1	2	1	1/2	1/5	1/5	1/3	1/2	1/2	1/4
Pi	1/5	1/2	2	1	2	3	2	1	1/4	1/4	1/2	1	1	1/3
Pl	1/7	1/3	1	1/2	1	2	1	1/2	1/5	1/5	1/3	1/2	1/2	1/4
Ra	1/9	1/4	1/2	1/3	1/2	1	1/2	1/3	1/7	1/7	1/4	1/3	1/3	1/5
Ro	1/7	1/3	1	1/2	1	2	1	1/2	1/5	1/5	1/3	1/2	1/2	1/4
Sl	1/5	1/2	2	1	2	3	2	1	1/4	1/4	1/2	1	1	1/3
St	1/3	3	5	4	5	7	5	4	1	1	3	4	4	2
Sw	1/3	3	5	4	5	7	5	4	1	1	3	4	4	2
In	1/5	1	3	2	3	4	3	2	1/3	1/3	1	2	2	1/2
Oi	1/5	1/2	2	1	2	3	2	1	1/4	1/4	1/2	1	1	1/3
Lg	1/5	1/2	2	1	2	3	2	1	1/4	1/4	1/2	1	1	1/3
St	1/4	2	4	3	4	5	4	3	1/2	1/2	2	3	3	1

Figure 4. Comparison matrix. *Ur: Urban centers, Lu: Land use, Ai: Airports, Pi: Pipes, Pl: Power lines, Ra: Railways, Ro: Roads, Sl: slope, St: streams, Sw: Surface water, In: Industrial areas, Oi: Oil pipes, Lg: Liquid gas pipes, St: Soil types. *Source: [16], λmax = 14.327, CI = 0.025, RI = 1.57 and CR = 0.016 < 0.1.

Table 4. Scale for pairwise comparison [34].

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

Table 5. Resulting weights.

Criteria	Weights
Urban centers	0.265
Land use	0.071
Airports	0.026
Pipes	0.044
Power lines	0.026
Railways	0.017
Roads	0.026
Slope	0.044
Streams	0.155
Surface water	0.155
Industrial areas	0.071
Oil pipes	0.044
Liquid gas pipes	0.044
Soil types	0.097

Table 6. Classes produced for the industrial areas of settlement criteria according to the suitability for landfill.

Distance to industrial area	Ranking
0 m - 250 m	**0**
>250 m	**1**

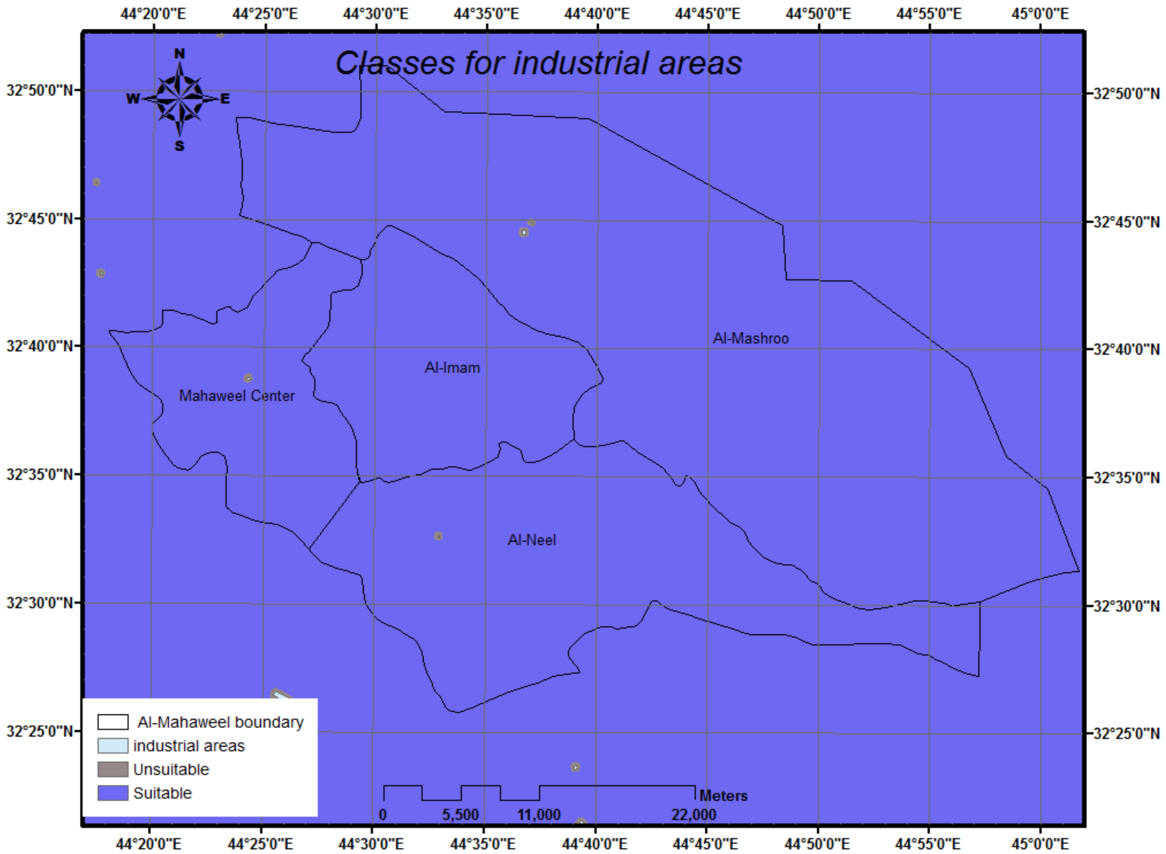

Figure 5. Classes for industrial areas. *Source for industrial areas: Babylon sewer directorate, Iraq, 2012.

Table 7. Classes produced for the residential areas of settlement criteria according to the suitability for landfill.

Distance to urban centers	Ranking
0 m - 5000 m	0
5000 m - 10,000 m	10
10,000 m - 15,000 m	5
>15,000 m	1

4) Airports

There are different values related to the safe distances from airports like 3000 m according to Chalkias and Stournaras [38] and 3.048 m according to Bagchi [39]. As stated by Allen *et al.* [23], distance of 10 to 13 km from flight path should be considered as a buffer zone.

By considering these suggested values, the safe distance for an airport was considered as 3000 m. The layer of airport was classified as suitable or unsuitable for a landfill site by assigning values 1 and 0 respectively (**Table 10**). To finalize the map for analysis, the vector map was converted to raster map (**Figure 9**).

5) Surface water

The necessary buffer zone for swamp areas was considered 250 m [40]. The layer of wetlands was classified as suitable or unsuitable by assigning values 1 and 0, respectively (**Table 11**). The buffer zones were created and

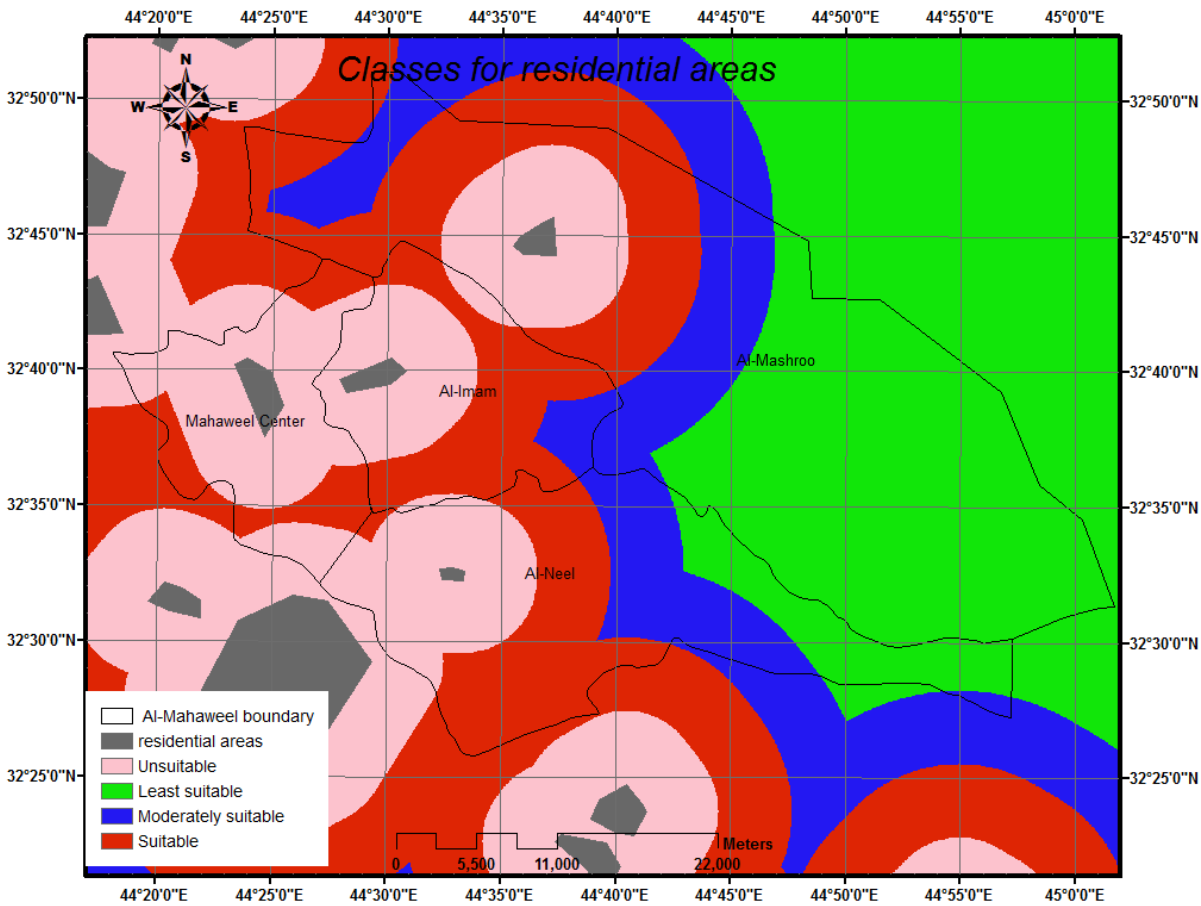

Figure 6. Classes for residential areas. *Source for residential areas: Babylon sewer directorate, Iraq, 2012.

Table 8. Classes produced for the main roads of road criteria according to the suitability for landfill.

Distance to and main roads	Ranking
0 m - 500 m	0
500 m - 1000 m	3
1000 m - 2000 m	2
>2000 m	1

Table 9. Classes produced for the railways according to the suitability for landfill.

Distance to railways	Ranking
0 m - 500 m	0
>500 m	1

Table 10. Classes produced for airport according to the suitability for landfill.

Distance to airport	Ranking
0 m - 3000 m	0
>3000 m	1

the study area was divided into two classes in the GIS environment. Then, the vector map prepared is converted to a raster map shown in **Figure 10**.

6) Pipelines

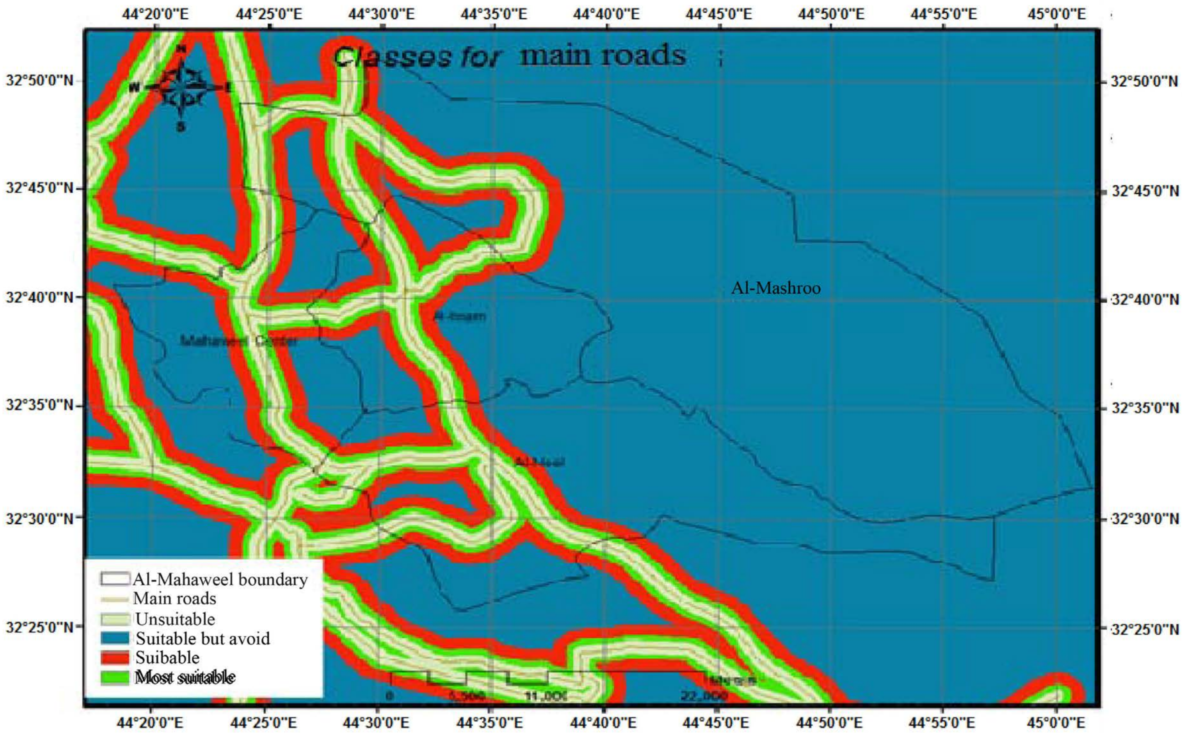

Figure 7. Classes for main roads. *Source for main roads: Babylon sewer directorate, Iraq, 2012.

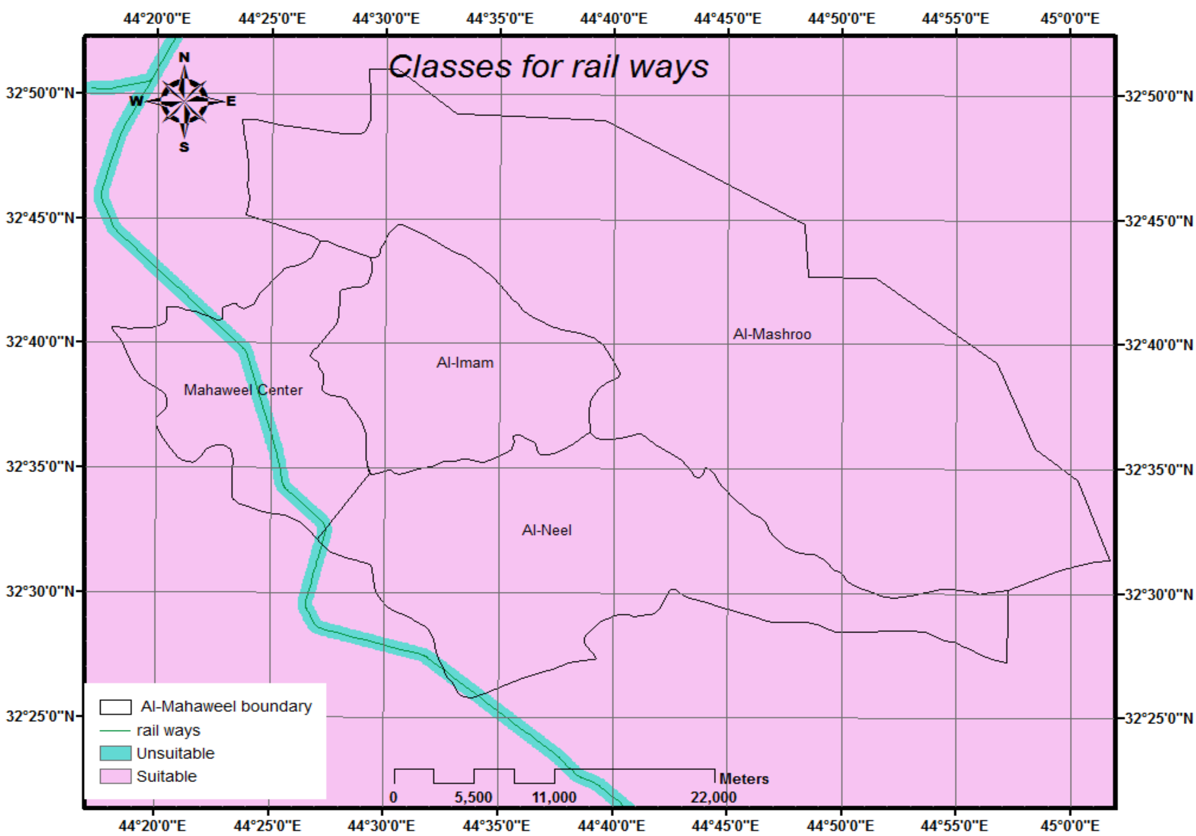

Figure 8. Classes for rail ways. *Source for rail road: Babylon sewer directorate, Iraq, 2012.

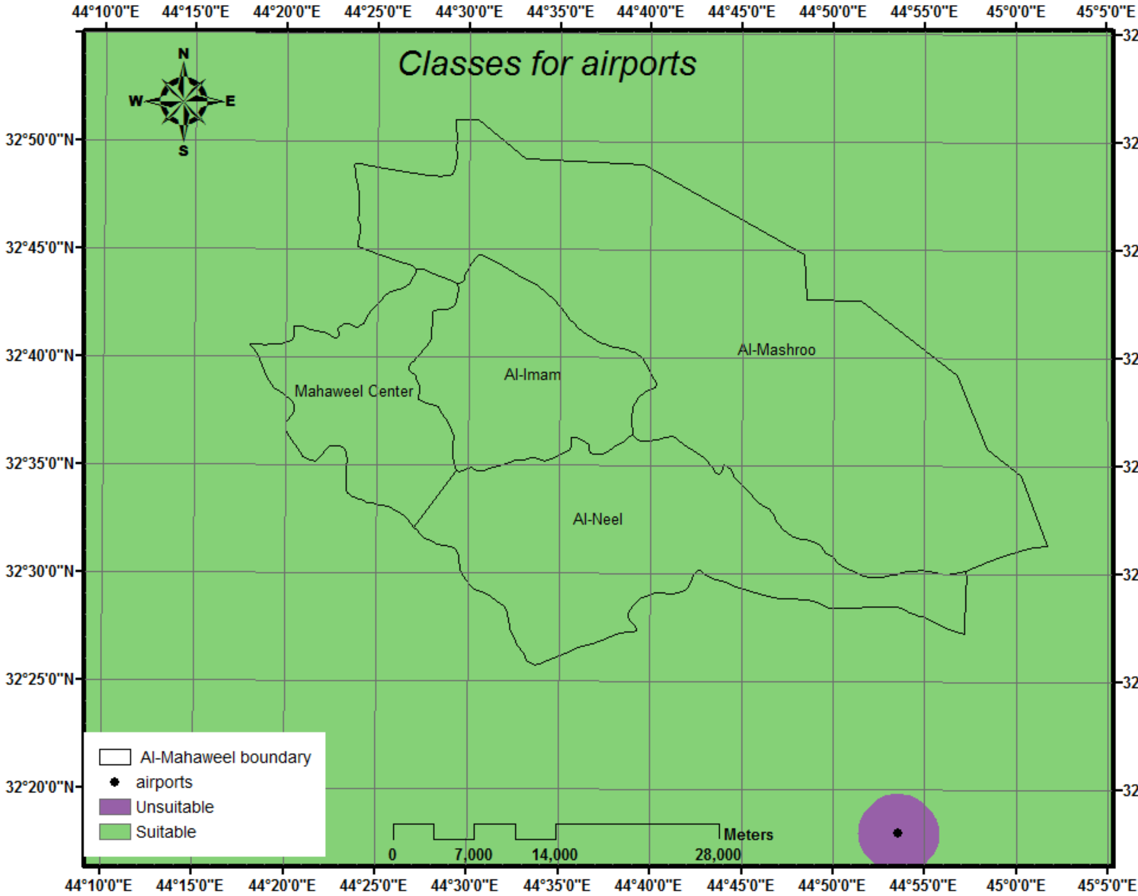

Figure 9. Classes for airports. *Source for airports: Babylon sewer directorate, Iraq, 2012.

Table 11. Classes produced for surface water according to the suitability for landfill.

Distance to surface water	Ranking
0 m - 250 m	0
>250 m	1

Pipelines in Babylon are for water and Waste Water Treatment Plants passing through the study area. The necessary buffer zone for pipeline was considered as 250 m on both sides [40]. The pipeline layer was classified as suitable or unsuitable for a landfill site by assigning values 1 and 0, respectively (**Table 12**). After the creation of buffer zones, the vector map prepared was converted to a raster map as shown in **Figure 11**.

7) Power Lines

The necessary buffer zone distance according to Cantwell [35], should have a buffer of 30 m on both sides. The buffer zones were created in the GIS environment. The layer of power lines was classified as suitable or unsuitable for a landfill site by assigning values 1 and 0 respectively (**Table 13**). Then, the vector map of Babylon electricity directorate was converted to a raster map shown in **Figure 12**.

8) Soil Texture

According to Alsharify [41], the texture of Babylon soil is almost silt clay loam. **Table 14** shows adopted test results of texture of Babylon soil [41].

Using the information in **Table 14** and **Table 15** plus **Figure 13**, **Figure 14** was prepared which is a raster map to be used as an input map in the analysis.

9) Stream

The necessary buffer zone for stream was considered as 300 m on both sides [40]. The surface water layer was classified as suitable or unsuitable for a landfill site by assigning values 1 and 0, respectively (**Table 16**). After

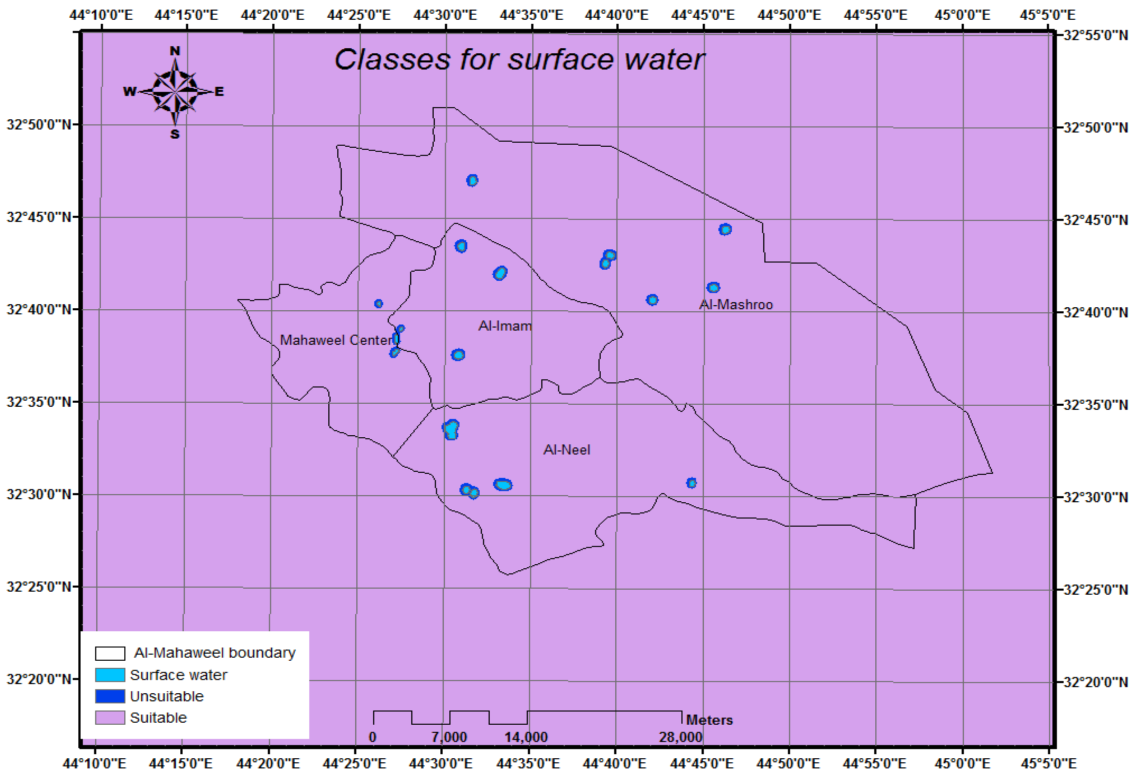

Figure 10. Classes for surface water. *Source for surface water: Geology department, Babylon University, Iraq, 2012.

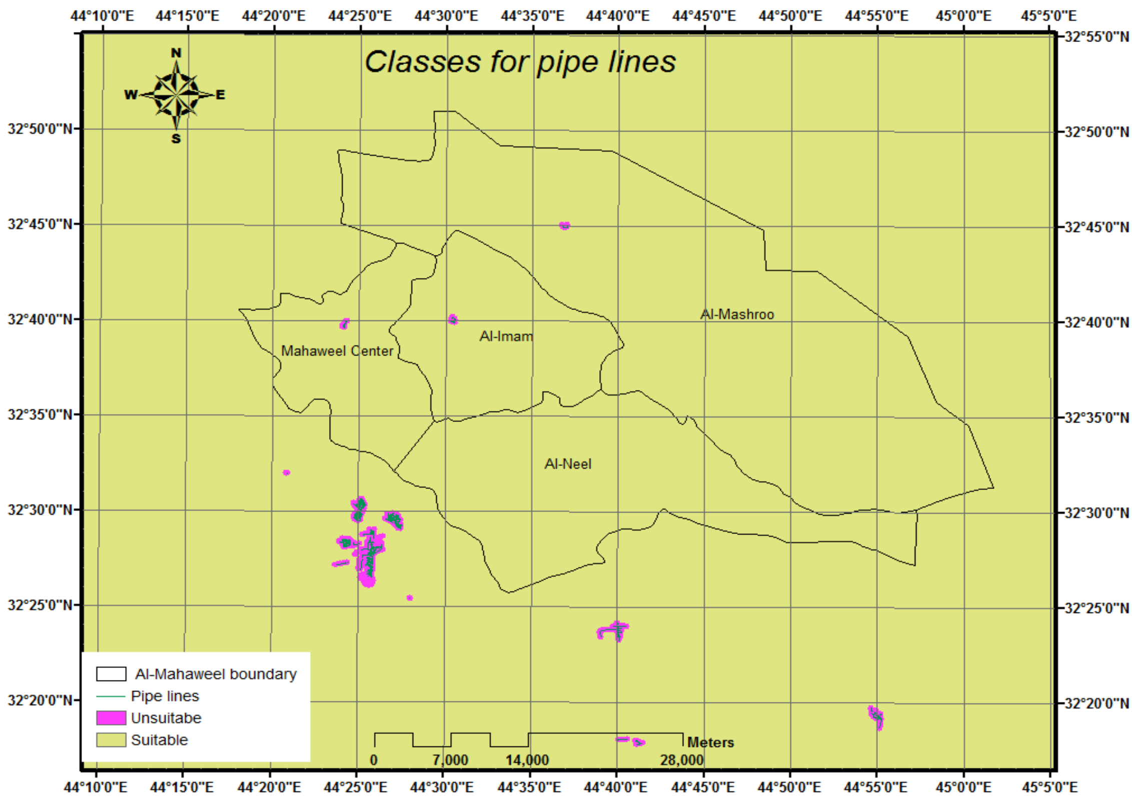

Figure 11. Classes for pipe lines. *Source for pipe lines: Babylon sewer directorate, Iraq, 2012.

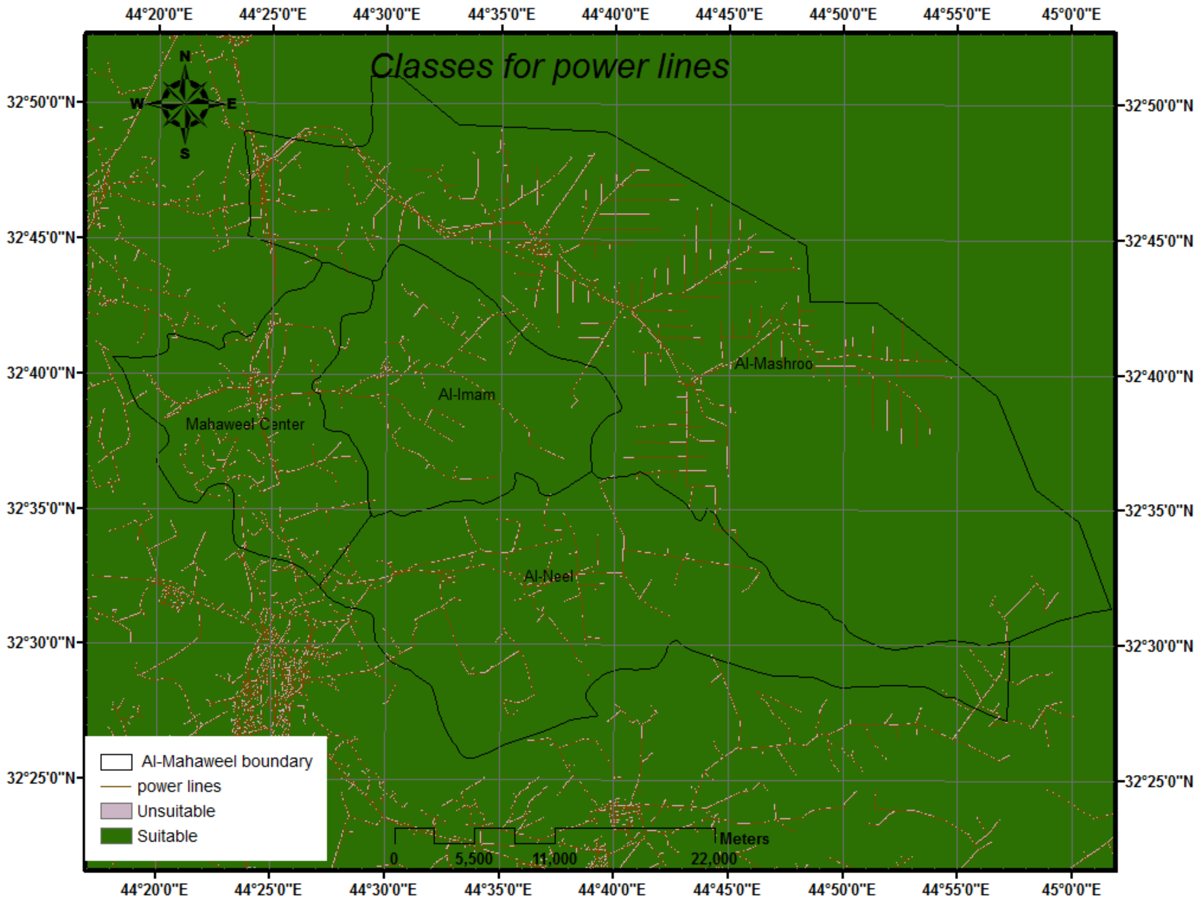

Figure 12. Classes for power lines. *Source for pipe lines: Babylon electricity directorate, Iraq, 2012.

Table 12. Classes produced for pipelines according to the suitability for landfill.

Distance to pipelines	Ranking
0 m - 250 m	**0**
>250 m	**1**

Table 13. Classes produced for high voltage power lines according to the suitability for landfill.

Distance to power lines	Ranking
0 m - 30 m	**0**
>30 m	**1**

the creation of buffer zones, the vector map prepared was converted to a raster map shown in **Figure 15**.

10) Oil Pipes

The necessary buffer zone for oil pipes was considered 75 m on both sides. The surface water layer was classified as suitable or unsuitable for a landfill site by assigning values 1 and 0, respectively (**Table 17**). After the creation of buffer zones, the vector map prepared was converted to a raster map shown in **Figure 16**.

11) Liquid Gas Pipes

The necessary buffer zone for liquid gas pipes was considered300 m on both sides. The surface water layer was classified as suitable or unsuitable for a landfill site by assigning values 1 and 0, respectively (**Table 18**). After the creation of buffer zones, the vector map prepared was converted to a raster map shown in **Figure 17**.

12) Land Use

In the study area, there are different types of land uses (see **Table 19** and **Figure 18**). The types of land use

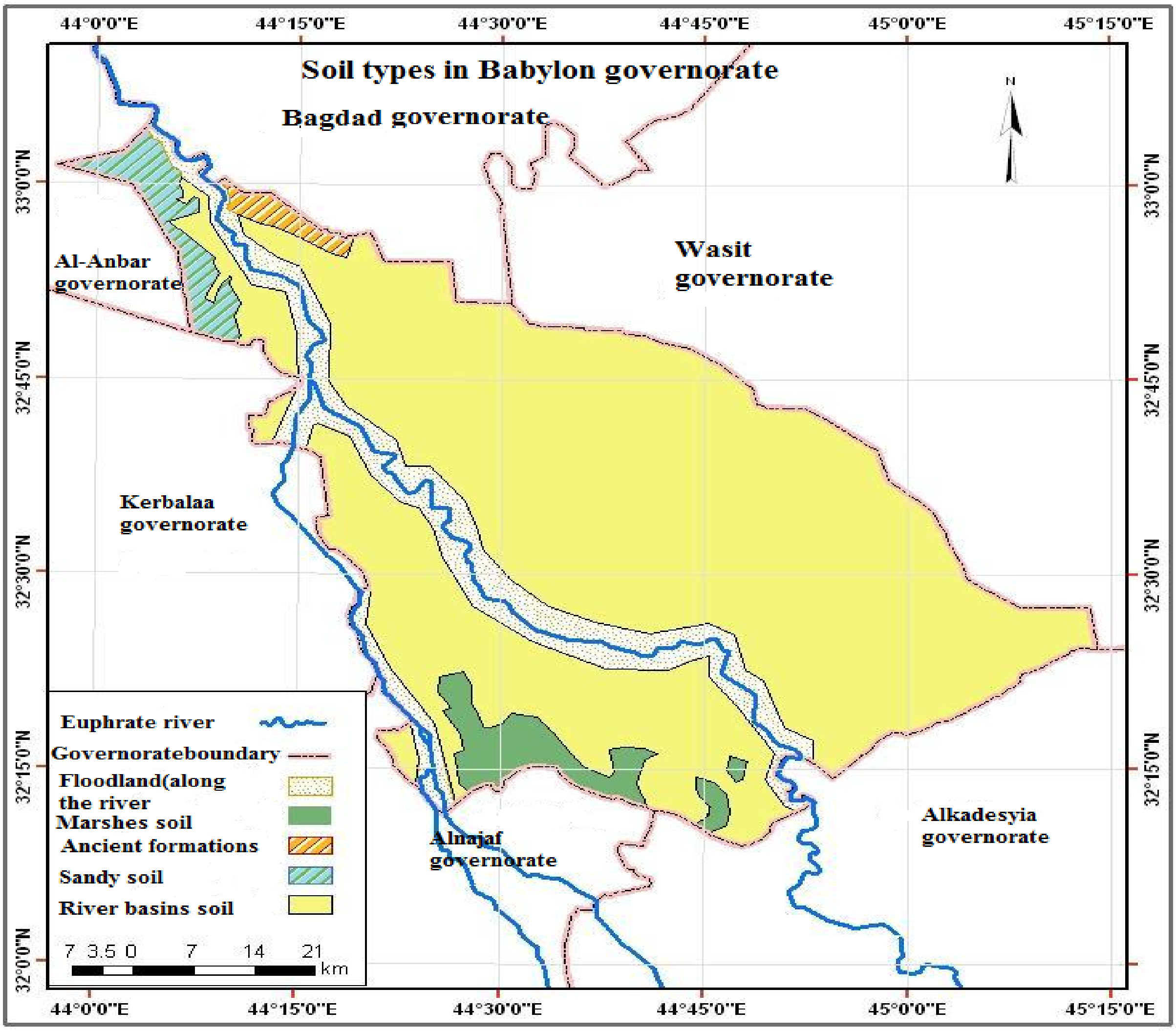

Figure 13. Soil types in Babylon. *Source Babylon agricultural directorate.

Table 14. Adopted test results of texture of Babylon soil.

Depth(cm)	Sample	Sand gm/Kg	Alluvial gm/Kg	Clay gm/Kg	Texture type
0 - 15	1	151.04	466	383	
	2	146.00	489	365	
	3	159.98	470.02	370	
	Av	152.34	475	373	Silt clay loam
15 - 20	1	166.65	461.35	372.66	
	2	169.00	441	390	
	3	163.00	479	358	
	Av	166.22	460.45	373.33	Silt clay loam
20 - 25	1	170.00	450	380	
	2	170.00	470	360	
	3	180.00	450	370	
	Av	173.33	456.66	370	Silt clay loam
Tot-Av		163.96	464.04	372	

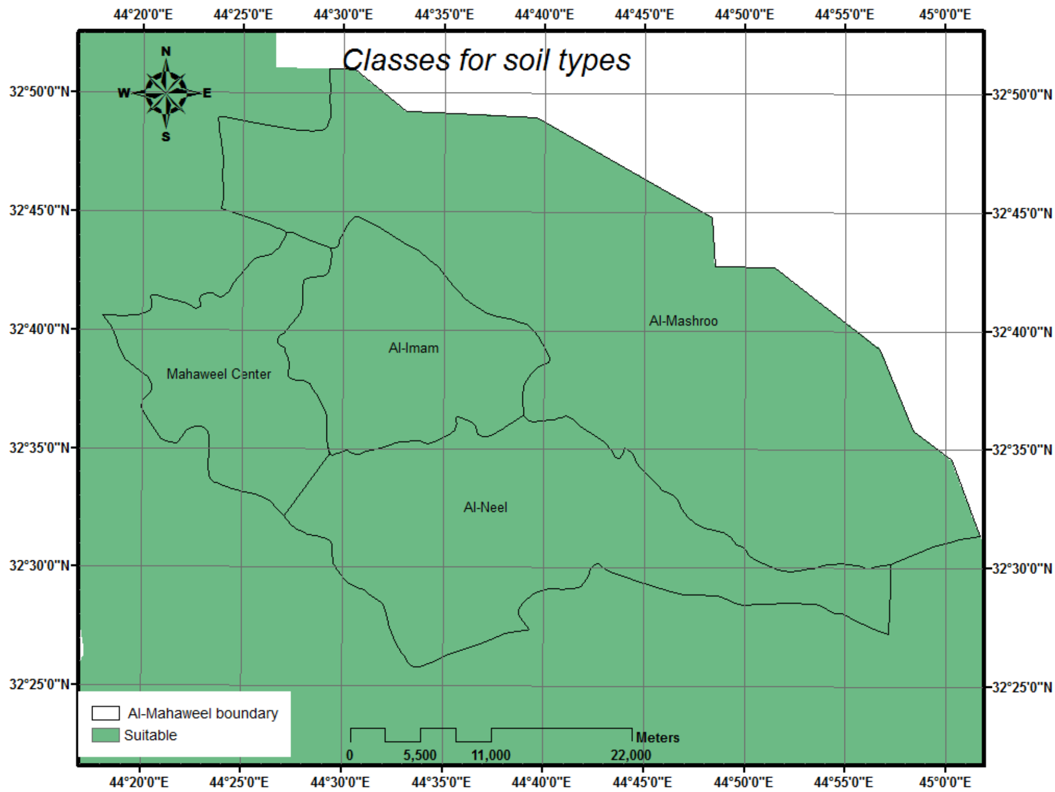

Figure 14. Classes for soil types.

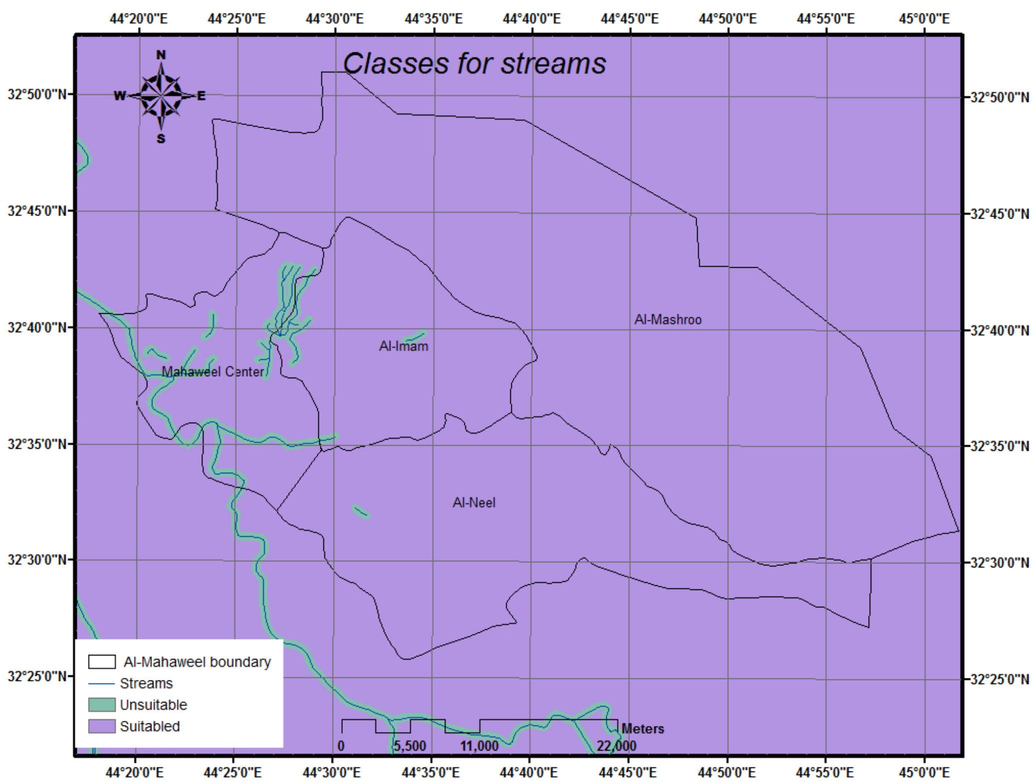

Figure 15. Classes for streams. *Source for surface water: Geology department, Babylon University, Iraq, 2012.

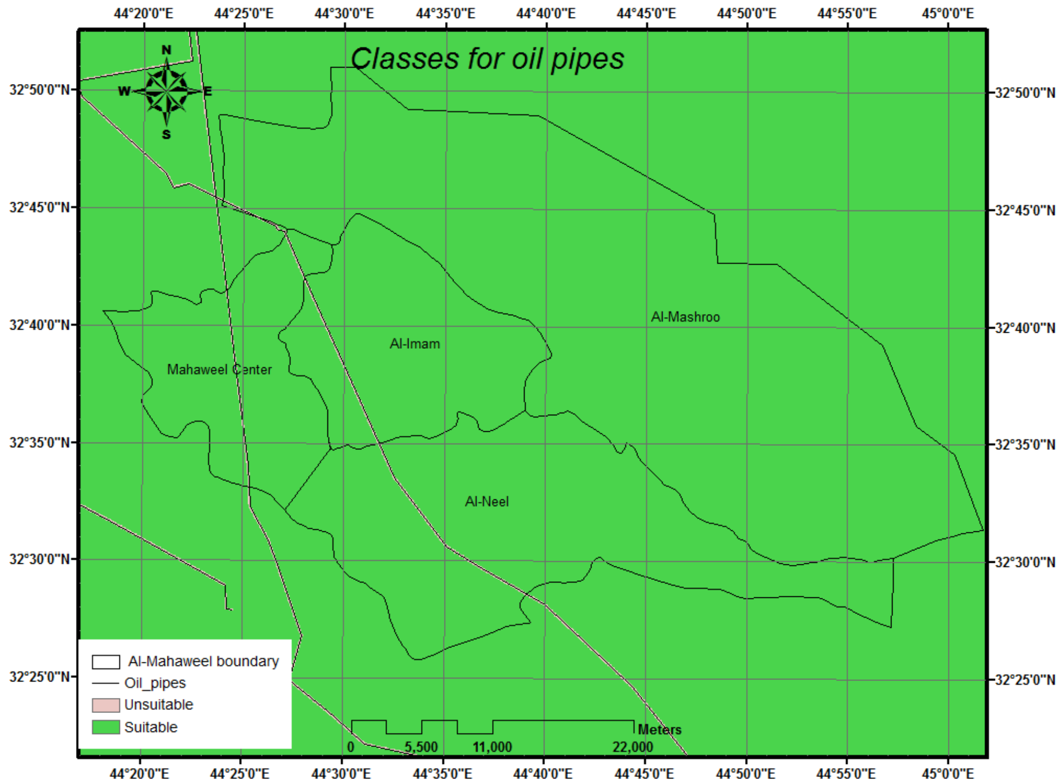

Figure 16. Classes for oil pipes. *Source for pipe lines: pipe lines company, Babylon, Iraq, 2012.

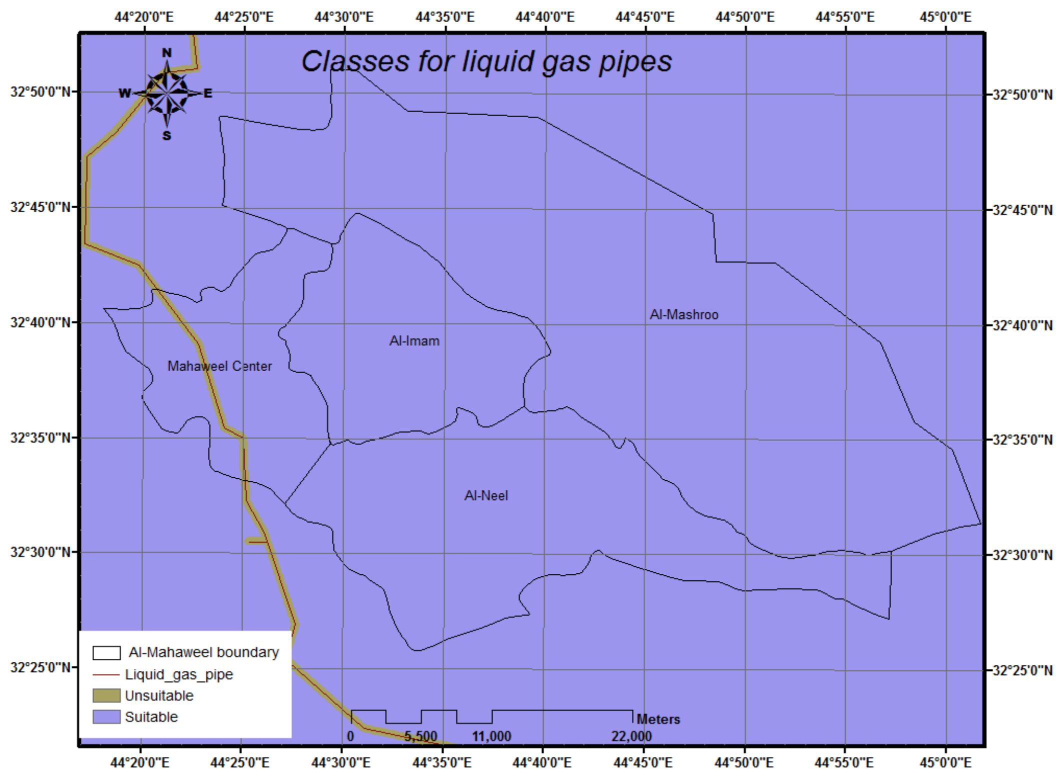

Figure 17. Classes for liquid gas pipes. *Source for pipe lines: pipe lines company, Babylon, Iraq, 2012.

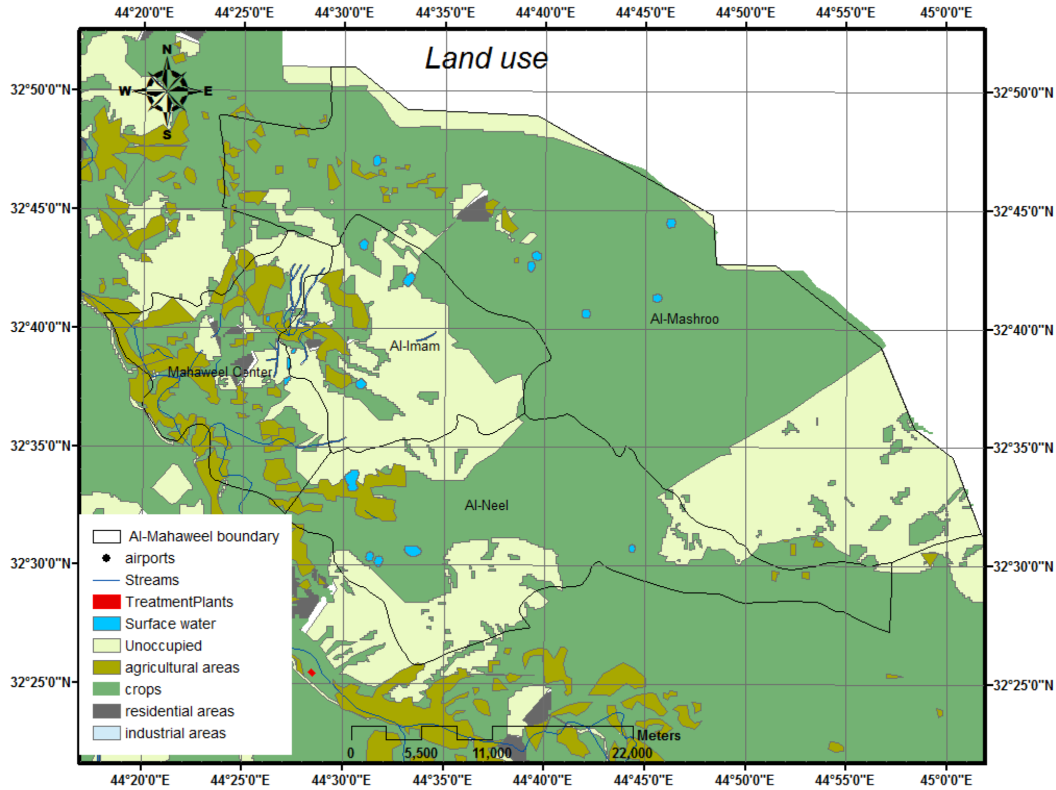

Figure 18. Land use. *Source for land use Geology department, Babylon University Babylon sewer directorate, Iraq, 2012.

Table 15. Soil textures and landfill suitability [42].

Soil Type	Suitability
Silt to very fine silty clay	Very high
Clay	High
Mixed	Moderate
Sandy	Low
Clean sand/gravel	Unsuitable

Table 16. Classes produced for streams according to the suitability for landfill.

Distance to streams	Ranking
0 - 300 m	0
>300 m	1

Table 17. Classes produced for oil pipes according to the suitability for landfill.

Distance to oil pipes	Ranking
0 - 75 m	0
>75 m	1

Table 18. Classes produced for liquid gas pipes according to the suitability for landfill.

Distance to liquid gas pipes	Ranking
0 - 300 m	0
>300 m	1

Table 19. Land use types and their rankings.

Land use type	Ranking
Residential areas	0
Industrial areas	0
Water & waste water treatment plant	0
Agricultural areas	0
Streams	0
Surface water	0
Airports	0
Crops	5
Unoccupied land	10

were grouped and ranked according to their suitability for landfill site as unsuitable, moderate suitable and suitable by assigning values 0, 5 and 10 respectively. The land use vector map was then converted to a raster map (**Figure 19**).

13) Digital Elevation Model

Digital Elevation Model (DEM), also referred as the Digital Terrain Analysis, is a digital representation of earth's topography in a continuous way [43]. Slope map are usually generated from DEM.

The potential for slope failure was related to the degree or grade of the topography. Slope failure underneath or adjacent to landfills, will result in waste containment failure and release of debris into the surrounding area. Land with slopes greater than 15% should be considered unsuitable for waste disposal sites [39]. The slope layer was classified as suitable or unsuitable for a landfill site by assigning values 1 and 0, respectively (**Table 20** and **Figure 20**).

14) Overlay Analysis

An output value of the resultant map which is the final suitability map was prepared using overlay analyses of ArcGIS Spatial Analyst. Land suitability of the study area was calculated by the Land Suitability Index LSI. Calculated LSI is varies between 0.436 and 4.161. The very high and very low suitable areas were determined. Pixels with 0.436 (colored red) are considered as very low suitable and were excluded from the alternative candidates' sites to be examined as disposal areas. On the other hand pixels with values around 4.161 suggested sites that are likely to be more suitable and were colored blue (see **Figure 21**).

2.5.3. Actual Case Requirement

1) District (Nahia) Center

Technically, the distance from the center of a collection route to the landfill should be less than 20 - 25 km [23]. Therefore, a distance about 20 km (to cover all zigzag roads) was adopted from centers of each districts (Nahia) to restrict suitable lands according to this criterion. The output map produced is shown in **Figure 22**.

The suitable land intersected with specific layers of buffer zones around district centers selected as landfill sites. The output map produced is given in **Figure 23**. This map shows the landfill site selected to cover all Al-Mahaweelqadaa municipal solid wastes disposal.

2) Landfill Area

To achieve right decision in landfill site selection, the area should be conformable or greater than the required area to municipal solid wastes assumption for disposal.

According to Tchobanoglous *et al.* [2] the principle methods used for landfilling dry areas may be classified as: 1) Area, 2) Trench, and 3) depression. The adopted method in this research was area method that is more suitable with Babylon environs lands of shallow ground water depth range from 3 to 4 m. Available areas of the selected landfill, and Nahias serve are shown in **Table 21**.

Once the amount of waste generated had been estimated, landfills should be designed in cells with sufficient capacity to receive the cumulative volume of waste generated. The optimal capacity of a landfill site should be not less than 5 years in order to ensure that the major investments required by the landfill are spread over large tonnage of waste.

The cumulative volume of wastes expected to be generated between 2013 and 2017 of the selected landfill is presented in **Table 22**. The adopted density of the waste in the landfill is 450 kg/m^3. It has not accounted for any reduction in the waste going to the landfill through recycling or composting at this stage.

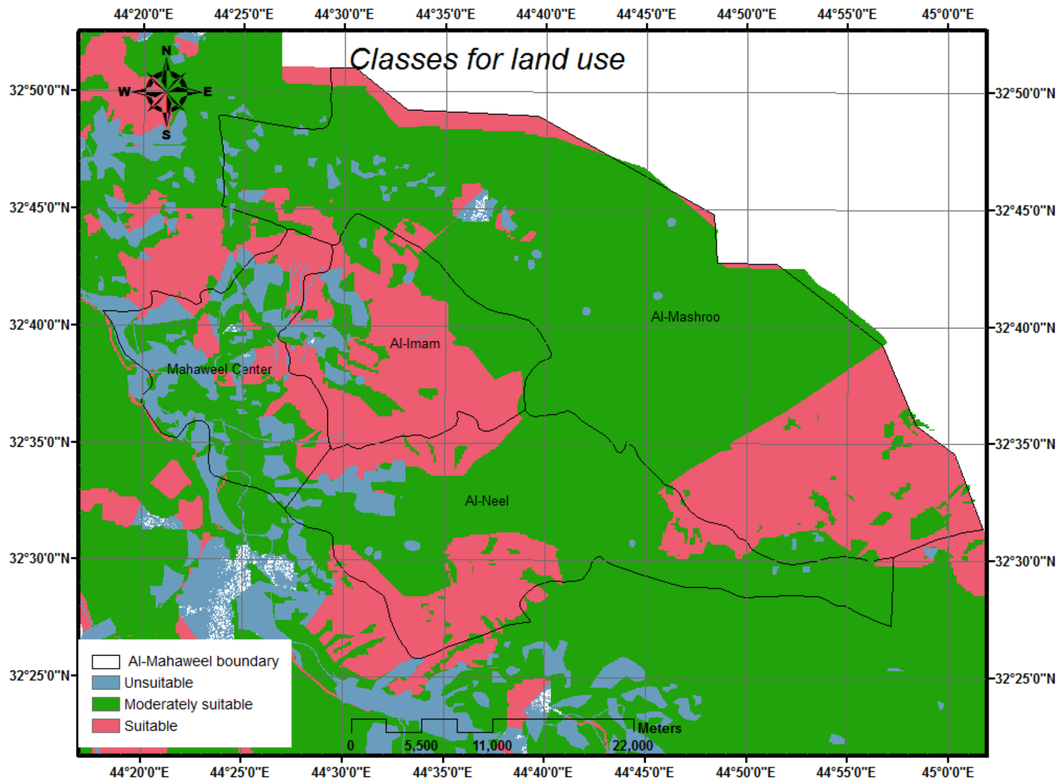

Figure 19. Classes for land use.

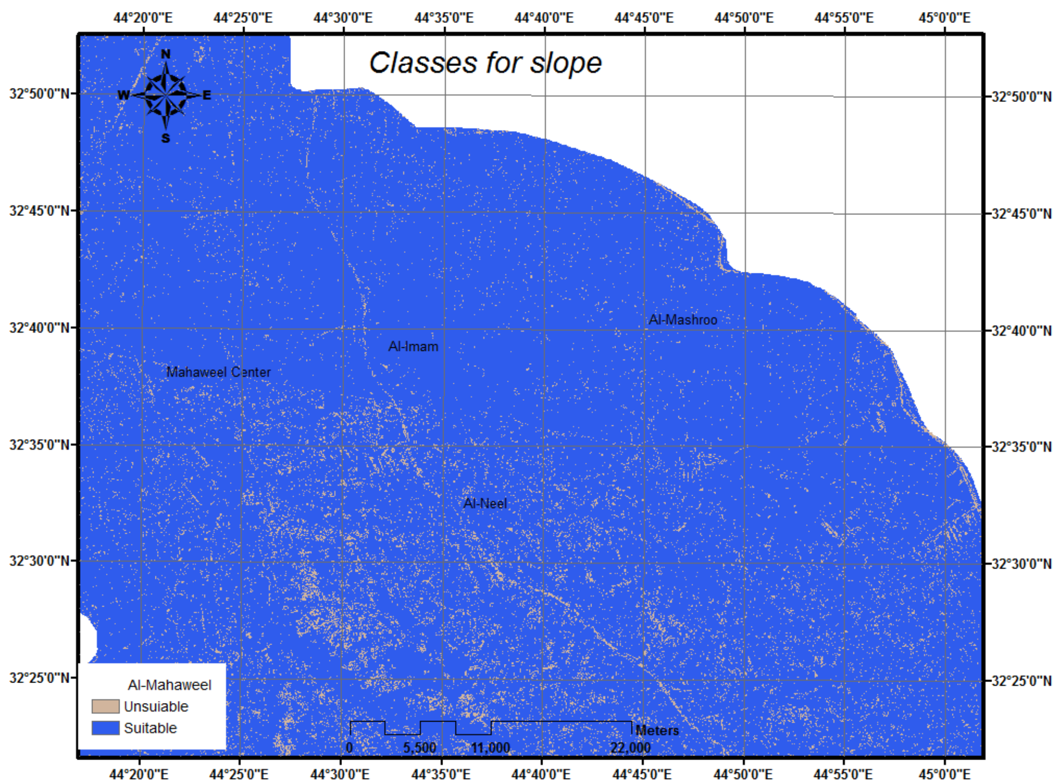

Figure 20. Classes for slope.

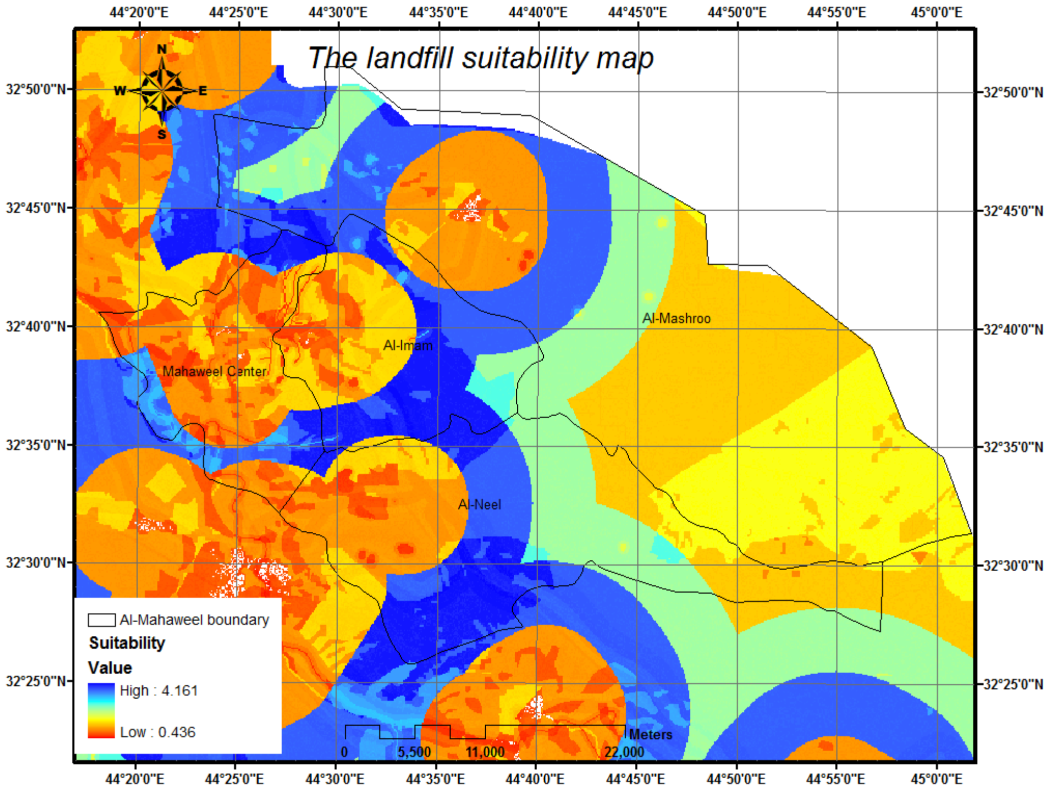

Figure 21. Output map produced with its suitability index.

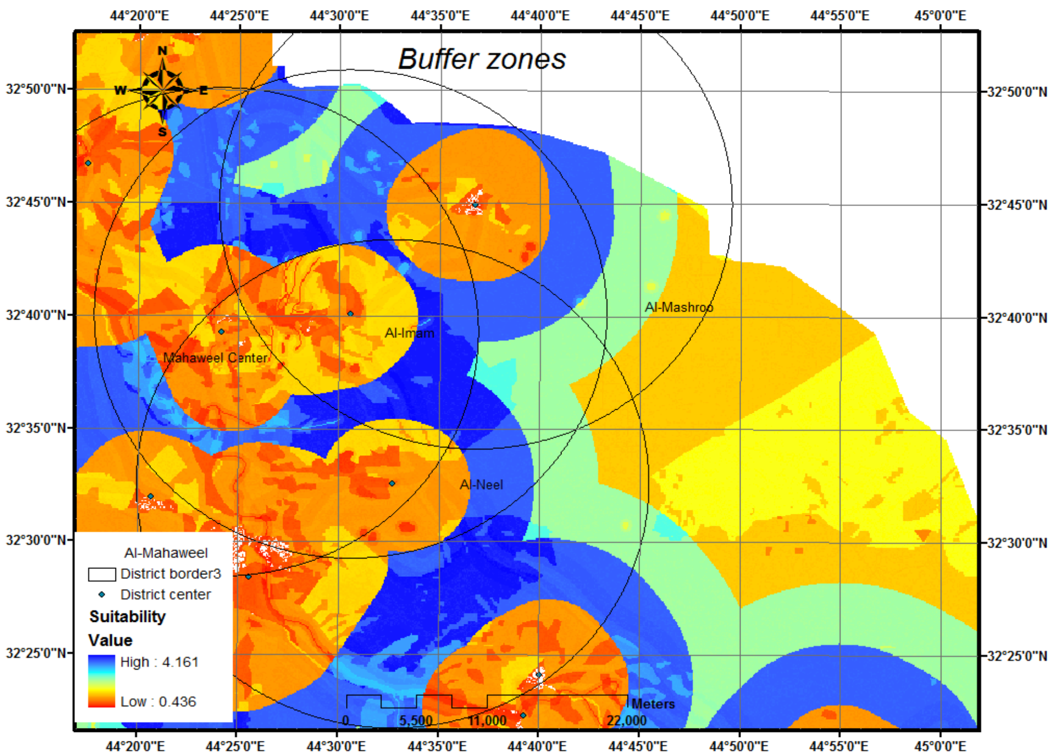

Figure 22. Buffer zones. *Source/submitted by the researcher.

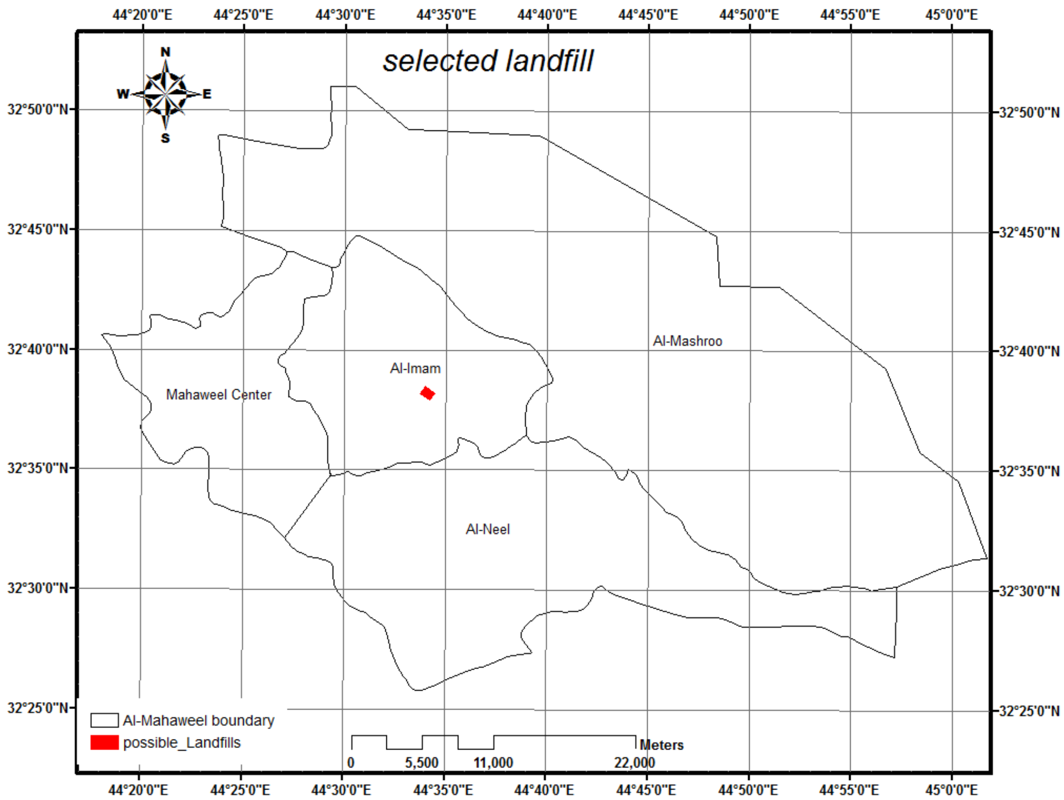

Figure 23. The selected landfill. *Source/submitted by the researcher.

Waste in the landfill should be covered daily by a cover in order to minimize health, safety and environmental impacts and nuisances. The volume of daily cover in the landfill varies between 10% and 15% of the waste volume [40]. Adopting a value of 10% of the waste volume, the required capacity of the landfill over the next five years can be estimated as shown in **Table 22**.

Wastes are unloaded to landfill site and spread in long narrow strips on the surface of land in series of layers of 50 cm depth. Each layer is compacted at the filling progresses during the course of the day until the thickness of the compacted wastes reaches a high of 3 m. The cover material must be hauled in by earth moving equipment from adjacent land or from borrow bet areas. The width over which the wastes are compacted is 6 m [40]. Required area of the selected landfill is shown in **Table 22**.

From **Table 21** and **Table 22**, it can be recognized that the available area of selected landfill is quite more than the required areas estimated for 5 years. Therefore, the right decision is taken.

Table 23 shows the selected landfill with its location and coordinates in addition to the required and available area.

3) Official and Field Visits Review

The candidate site had been revealed. In order to check the suitable area derived from the analysis and the actual case requirement (Nahia center and landfill area), office and field checks were performed out to determine the accuracy and suitability of candidate sites.

The selected site was checked using satellite image for year 2006. Two directorates in Babylon Governorate (Physical Planning and Agriculture directorates) were consulted for the land ownership and other restrictions if exists. Accordingly, some adjustments were made on the areas chosen.

Antiquities directorate in Babylon Governorate didn't have coordinates for all the religious and antique locations. Because of that, no layer for that criterion was prepared. This was solved by field visits to the selected site.

In view of the visits conducted with official departments concerned, no conflicts with activities of these departments were noticed about the site proposed.

Table 20. Classes produced for slope according to the suitability for landfill.

Classes for slope	Ranking
≤15%	0
>15%	1

Table 21. Selected landfill site and its available area.

Landfill name	Township serve (Nahia)	Available areas (m^2)	Suitability index
Al-Mahaweel landfill	The center of Al-Mahaweelqadaa, Al-Neel, Al-Imam, Al-Mashroaa	538,262	4.161

Table 22. Cumulative and compacted waste volumes for the landfill and its required area.

	Al-Mahaweel landfill
Accumulated Volume (m^3)	581,222
+10% Cover	639344.2
Area m^2 3 m depth	213115

Table 23. The selected landfill.

Landfill	Location	Coordinates	Required Areas (m^2)	Available Areas (m^2)
Al-Mahaweel landfill	Al-Mahaweelqadaa in Al-Imam Nahia	32˚38'15"N and 44o34'5"E	213,115	538,262

3. Conclusions

The landfill sites in Al-Mahaweelqadaa in the Babylon governorate (as well as in most of Iraq's governorates) were selected using the traditional method which is not-specific and mostly random, depending on some initial criteria in a static form and without attention to the dynamic analysis, and by focusing on the aspect of solid waste as one of the most important aspects; this study finds an alternative method in the process of selecting landfill sites in the governorate involving more criteria by using GIS technology where these multiple criteria are used in the form of several maps and analyzed in a dynamic form, non-static (as is the current method in selection of sites).

Landfill site selection is performed for Al-Mahaweelqadaa by using Multicriteria Decision Analysis (MCDA) and Geographic Information System (GIS). Several criteria were considered (Urban centers, Land use, Airports, Pipes, Power lines, Railways, Roads, slope, streams, Surface water, Industrial areas, Oil pipes, Liquid gas pipes, Soil types) to select a proper site. MCDA was used to measure and evaluate the relative importance weighting of each criterion. Each map layers were formed with the aid of GIS and final suitability map was created by overlay analyses of each criterion map. Field visits were conducted to check the selected site. In addition, the expected solid waste volume for the coming five years was calculated to make sure that the selected site can occupy this volume.

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