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LANDFILL SITE SELECTION IN KARBALA GOVERNORATE, IRAQ

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Abstract: It is worth mentioning that site of Karbala religious has great importance to attract people from other provinces and other countries because of the site of shrine Imam Hussein Ibn Ali (PBUH), The main objective of this study is to choose the most suitable landfill in a manner consistent with environmental determinants by the use of geographic information system (GIS) and Multi-Criteria Decision Analysis (MCDA) for the management of municipal solid waste for the governorate. In this study, were used 19 including (Socioeconomic criteria, Accessibility criteria, Infrastructural criteria, Morphology criteria and Hydrology criteria) as inputs digital map layers. Analytic hierarchy process (AHP) method was used to weighting the criteria.Ten suitable candidate landfill sites were finding.

Keywords: *Landfill, Multi-criteria decision analysis, GIS, Analytical hierarchy process, Karbala, Iraq.*

اختيار موقع الطمر الصحي في محافظة كربلاء، العراق

الخلاصة: من الجدير بالذكر أن موقع كربلاء الديني له أهمية كبيرة في جذب الناس من محافظات أخرى ودول أخرى بسبب موقع الإمام الحسين بن علي (عليه الصلاة والسلام) ، والهدف الرئيسي من هذه الدراسة هو اختيار المدفن الأنسب بطريقة تتفق مع المحددات البيئية من خلال استخدام نظام المعلومات الجغرافية (GIS) وتحليل القرار متعدد المعايير (MCDA) لإدارة النفايات الصلبة البلدية للمحافظة. استخدمت في هذه الدراسة 19 معيار (بما في ذلك المعايير الاجتماعية-الاقتصادية ومعايير إمكانية الوصول ومعايير البنية التحتية ومعايير المورفولوجيا ومعايير الهيدرولوجيا) كمدخلات لطبقات الخرائط الرقمية. وقد تم استخدام طريقة التحليل الهرمي التحليلي (AHP) في تقييم المعايير.

1. Introduction

Historically, landfills have made various problems, for example, ground water contamination, since these problems have a great impact on the society, the community has become more and more aware of landfill issues. So, associated problems could be decreased by employing a proper siting technique that involves gatherings such as planners, politicians, engineers, in addition to representatives of the public. Accordingly, numerous regulations, criteria, and factors must be considerate, such as avoiding wetlands, surface waters, floodplain areas, residential areas, etc. [1].

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In fast growing areas, site selection is necessary and important for waste management issue. Due to waste management systems complexity, the suitable solid waste landfill site selection requires evaluation criteria and multi alternative solutions [3].

One of the most populated Arab countries is Iraq where populace exceeding 32 million people. Quick growth of economy, height growth of population, sectarian battles and growing of individual income, each of this reasons led to bad solid waste management. 31,000 ton of solid waste each day was produced in Iraq, where waste generation beyond 1.4 kg per day per capita. Production exceeding of 1.5 million ton of solid wastes each year in Baghdad governorate. Quick increase in waste generation production is led to tremendous straining on Iraqi waste treatment infrastructure which have very damaged after decades of conflicts and mismanagement.

Becauseof the absence of efficient and modern waste treatment and disposal infrastructure, most of the wastes are disposed in unregulated landfills around of Iraq, without or little concern for both environment and human-health.Groundwater contamination, surface water pollution, spontaneous fires and great scale greenhouse gas emissions have been the hallmarks landfills of Iraq [4].

2. Study Area

Karbala is located on 44°19′55.261" E longitude and 32°45′15.457" N latitude, with area about 5463 km^2 [5].

Administratively, Karbala Governorate includes three Districts (Karbala, Ain Al-tamur, Al-Hindiya). The three districts are shown in Fig.1

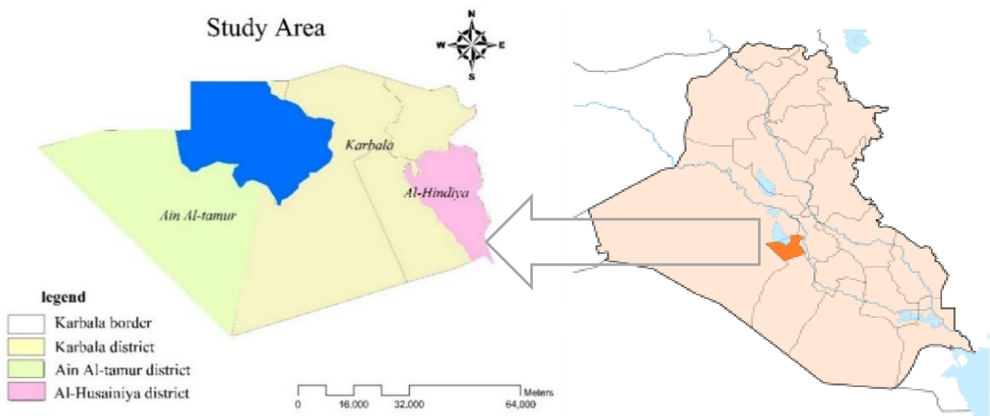

Figure 1. Map of study Area.

3.Methodology

3.1 Weighting of criteria

In this study, GIS was used to analyze digital maps as input after calculating the weights of criteria by AHP method and inserting the weights in the GIS program to

obtain a suitability index map as outlet for the most suitable areas for sanitary landfill to select the best area which have higher suitability index. Nineteen criteria were used, these were (urban centers, Historical site, Village, Industrial sites, Health center, Main Road, Sub Road, Railway, Airport, Oil pipeline, Power plant, Power line, Cell phone tower, Slope, Elevation, land use, Stream, Surface water, Ground water).
Decision making include evaluation of various alternative solutions upon a set of criteria. A weight is a measure of the relative importance of a criterion as judged by the decision maker.

The 1 to 9 scale is used in typical analytic hierarchy studies where each number equivalent to expression of the relative importance for two of factors. It uses scale ranging from 1 to 9 as showed in Table 1.

Where the decision maker will be able to evaluate the contribution every factor in order to reach the goal independently by pairwise comparison [6].

Table 1. Relative importance scale for pairwise comparison [7] Saaty, 1980.

Intensity of importance	Definition
1	Equally important
3	Moderately more important
5	Strongly more important
7	Very strongly more important
9	Extremely more important
8,6,4,2	Intermediate values between adjacent scale values

In this study, each criterion is compared in terms of importance based on the experts judgment who have knowledge in this field, where each criteria is given what deserves of the weight and then use these weights in preparing the AHP matrix to obtain actual weights for each criteria.

Tables 2, 3, 4, 5, 6, and 7 show the matrix of pairwise comparison for socioeconomic criteria, accessibility criteria, infrastructural criteria, morphology criteria, hydrology criteria and its sub criteria respectively. After sub-criteria accounted, their ultimate weight is computed by multiplying the obtained weight of sub-criteria with the criteria weight related in the upper level (Table 8).

After extracting relative importance of matrix and weights criteria. It must be identified the consistency of pairwise comparison. This process declared by Saaty, where the consistency index known as the consistency ratio)CR).

The probability of random ratio producing for matrix is shown by consistency ratio, which must be less than 0.1. Otherwise it must be reevaluating the relative importance. If the consistency ratio is lower than 0.1 then the accounted weights are effective on the layers of criteria map [8], as shown in the following tables:

Table 2. Comparison matrix of socioeconomic criteria, Accessibility criteria, Infrastructural criteria, Morphology criteria and Hydrology criteria

A	B1	B2	B3	B4	B5
B1	1	3	4	2	3
B2	1/3	1	2	1/2	1
B3	1/4	1/2	1	1/2	1/2
B4	1/2	2	2	1	2
B5	1/3	1	2	1/2	1

CR = 0.013 < 0.1

A: landfill site selection, B1: socio-economic criteria, B2: Accessibility criteria, B3: Morphology criteria, B4: Hydrology criteria, B5: Infrastructural criteria *

Table 3. Comparison matrix of socio-economic criteria.

B1	C1	C2	C3	C4	C5
C1	1	4	3	2	4
C2	1/4	1	1/2	1/3	2
C3	1/3	2	1	1/2	2
C4	1/2	3	2	1	2
C5	1/4	1/2	1/2	1/2	1

CR = 0.03 < 0.1

C1: urban centers, C2: Industrial site, C3: Historical site, C4: Village, C5: Health center *

Table 4. Comparison matrix of Accessibility criteria.

B2	C6	C7	C8	C9
C6	1	2	3	3
C7	1/2	1	2	2
C8	1/3	1/2	1	2
C9	1/3	1/2	1/2	1

CR = 0.026 < 0.1

C6: Main Road, C7: Sub Road, C8: Airport, C9: Railway. *

Table 5. Comparison matrix of Morphology criteria.

B3	C10	C11	C12
C10	1	2	1/2
C11	1/2	1	1/2
C12	2	2	1

CR = 0.046 < 0.1

C10: Slope, C11: Elevation, C12: Landuse *

Table 6. Comparison matrix of Hydrology criteria.

B4	C13	C14	C15
C13	1	1/2	1/2
C14	2	1	1/2
C15	2	2	1

CR = 0.046 < 0.1 RC = 0.046 < 0.1

C13: Ground water, C14: Stream, C15: Surface water. *

Table 7. Comparison matrix of Infrastructural criteria.

B5	C16	C17	C18	C19
C16	1	2	2	1
C17	1/2	1	2	1/2
C18	1/2	1/2	1	1/2
C19	1	2	2	1

CR = 0.022 < 0.1

C16: Power line, C17: Power plant C18: Cell phone tower, C19: Oil pipe. *

Table 8. Final Weights assigned to socio-economic, Accessibility, Infrastructural, Morphology and Hydrology sub criteria in the evaluation phase.

GOAL A	Hierarchy B	Hierarchy C	Wi
A	B1	C1	0.167
		C2	0.043
		C3	0.063
		C4	0.097
		C5	0.035
	B2	C6	0.063
		C7	0.036
		C8	0.024
		C9	0.017
	B3	C10	0.027
		C11	0.017
		C12	0.043
	B4	C13	0.045
		C14	0.071
		C15	0.112
	B5	C16	0.046
		C17	0.028
		C18	0.020
		C19	0.046
		SUM	1.000

3.2 Digital Environmental Maps

In this study, 19 input map layers were used. Studies of landfill site selection depend on the artificial and natural state of the area. In this study, the criteria and principles to be consider are divided into three categories of the artificial aspect (Socioeconomic, Accessibility and Infrastructural criteria), and two categories of natural aspect include (Morphology and Hydrology criteria), see Fig.2 and Fig 3.

A scale of 0 to 5 was used to determine the suitability (0 is unsuitability) while (5 is more suitability) as shown in Table 9.

(1) socio-economic: In this study, socio-economic criteria classified into five types: first layer which consists of urban centers, second, third, fourth and fifth layer consists of Industrial sites, Historical sites, Villages and Health centers respectively, the buffer zone distances to the urban centers, Industrial sites and Villages were used according to [9], the minimum distance from urban centers, Industrial sites and Villages must be at least 5 km, 250 m, 1000m, respectively, Table 9 shows the classes of urban centers and Industrial sites respectively. The buffer zone distances to the Historical sites was

used according to [10], 1,500 m buffer zone was adopted. The buffer zone distances to the Health centers used according to [11], 1 km buffer zone was adopted.

(2) Accessibility: In this study, Accessibility classified into four types:

- Main Road: the selected site should be away from main roads in order to prevent the potential interference between the main traffic and the vehicles of solid waste transferring [8] [9], 500 m buffer zone was taken from the main.
- Sub Road: 100m buffer zone was taken from sub roads as Ref. [8] [9].
- Airport: 3 Km was considered as buffer zones as Ref. [13], the area was classified according as show in Table 9
- Railway: the suggested distance as a buffer zones for railway in [14]. Taken 500 m buffer zone for the railways.

(3) Land Morphology: classified into three types:

- Slope: The slope of land is a significant factor in landfill site selection. Increase drain of pollutants from landfill site to the surrounding areas when the area have extremely steep slope. [7], the slope was classified as suitable (equal or less than 15 %) and unsuitable (more than 15 %) for a landfill site.
- Elevation: This study adopted on the digital elevation model (DEM).The most appropriate elevations were from 30–100 m, moderate suitable were from 30- 155 m and the less appropriate elevations were from 20–30 m, all highs was estimated above mean sea level.
- Landuse: landuse for Karbala Governorate was divided into 9 categories: urban center, desertification land, salty land, reclaimed land, non-reclaimed land, Airport, non-used land, Agricultural land and Razaza Lake.

(4) Hydrology: classified into three types:

- Ground water: the selected landfill should be far away from the well otherwise, it effect on human and environment, 400 m was taken as buffer zone around each well [10].
- Stream: An appropriate distance from the river boundary must be taken to protect it from contamination as suggested by many researchers. 300m a buffer zone were suggested [15].
- Surface water; the necessary buffer zone for the lake is determined as 250 m [15].

(5) Infrastructural: Infrastructural classified into four types:

- Power lines, [12], suggested 30 m as a buffer zone on both sides of power line, this buffer was adopted.
- Power plant must be avoided from site selection process for landfill, 250 m was suggested as a buffer zone [10].
- Cell phone tower must be avoided from site selection process for landfill, 250 m was suggested as a buffer zone [10].
- Oil pipeline, buffer zone is needed from both sides of the pipeline. [12], used 75 m as a buffer zone for both sides of oil pipe, this buffer was adopted.

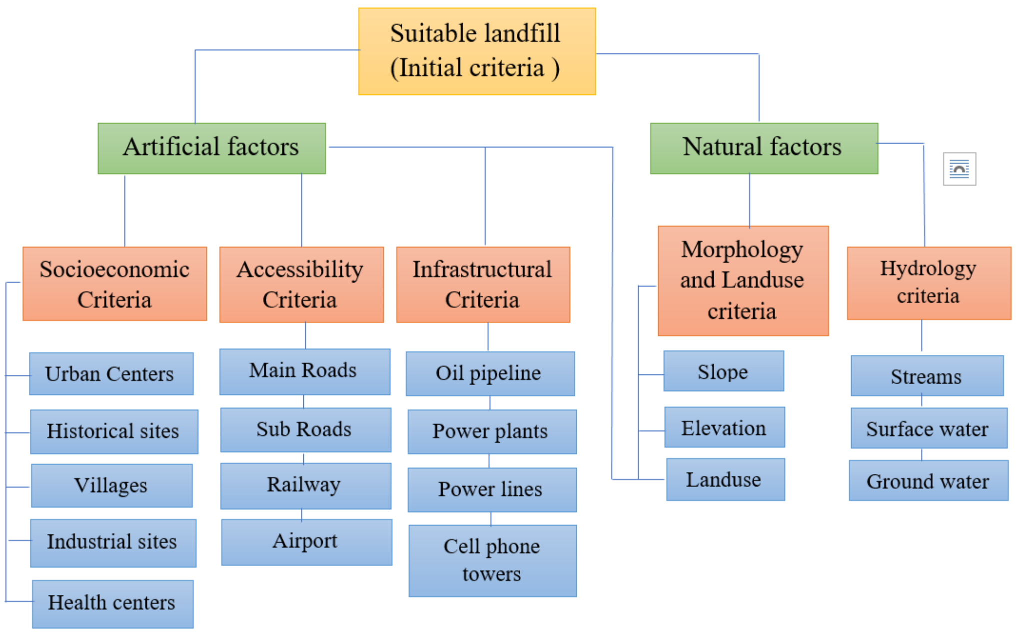

Figure 2. Criteria decision tree developed for the landfill site selection problem in study area

Table 9. Input layers summary.

No.	Buffer zone	ranking
urban centers	0 - 5 km	0
	5 – 10 km	5
	10 -15 km	4
	15 – 20 km	2
	> 20 km	1
Industrial sites	0 – 250 m	0
	> 250 m	5
Historical sites	0 - 1500 m	0
	> 1500 m	5
Villages	0 – 1000 m	0
	> 1000 m	5
Health centers	0 – 1 km	0
	1- 2 km	3
	> 2 km	5
Main Roads	0 – 500 m	0
	500 – 1000 m	5
	1000 - 1500 m	4
	1500 -2000m	2
	> 2000 m	1
Sub Roads	0 – 100 m	0
	100 – 500 m	5
	500 – 1000 m	3
	> 1000	1

Airport	0 – 3 km 3 - 6 km 6 – 9 km 9 – 12 km > 12 km	0 2 3 4 5
Railway	0 – 500 m > 500	0 5
slope	> 15 % ≤ 15 %	0 5
Elevation	20 -30 m 30 – 100 m 100- 155 m	0 5 3
Landuse	urban center desertification land salty land reclimed land Non reclimed lands (near of the lake) Airport non-used land Agricultural land Razaza lake	0 5 5 0 0 0 5 0 0
Ground water	0 – 400 m > 400 m	0 5
Stream	0- 300 m > 300 m	0 5
Surface water	0 – 250 m 250 – 500 m 500 – 750 m 750 – 1000 m > 1000 m	0 1 2 4 5
Power lines	0 – 30 m > 30 m	0 5
Power plants	0 – 250 m > 250 m	0 5
Cell phone towers	0 – 250 m > 250 m	0 5
Oil pipeline	0 – 75 m > 75 m	0 5

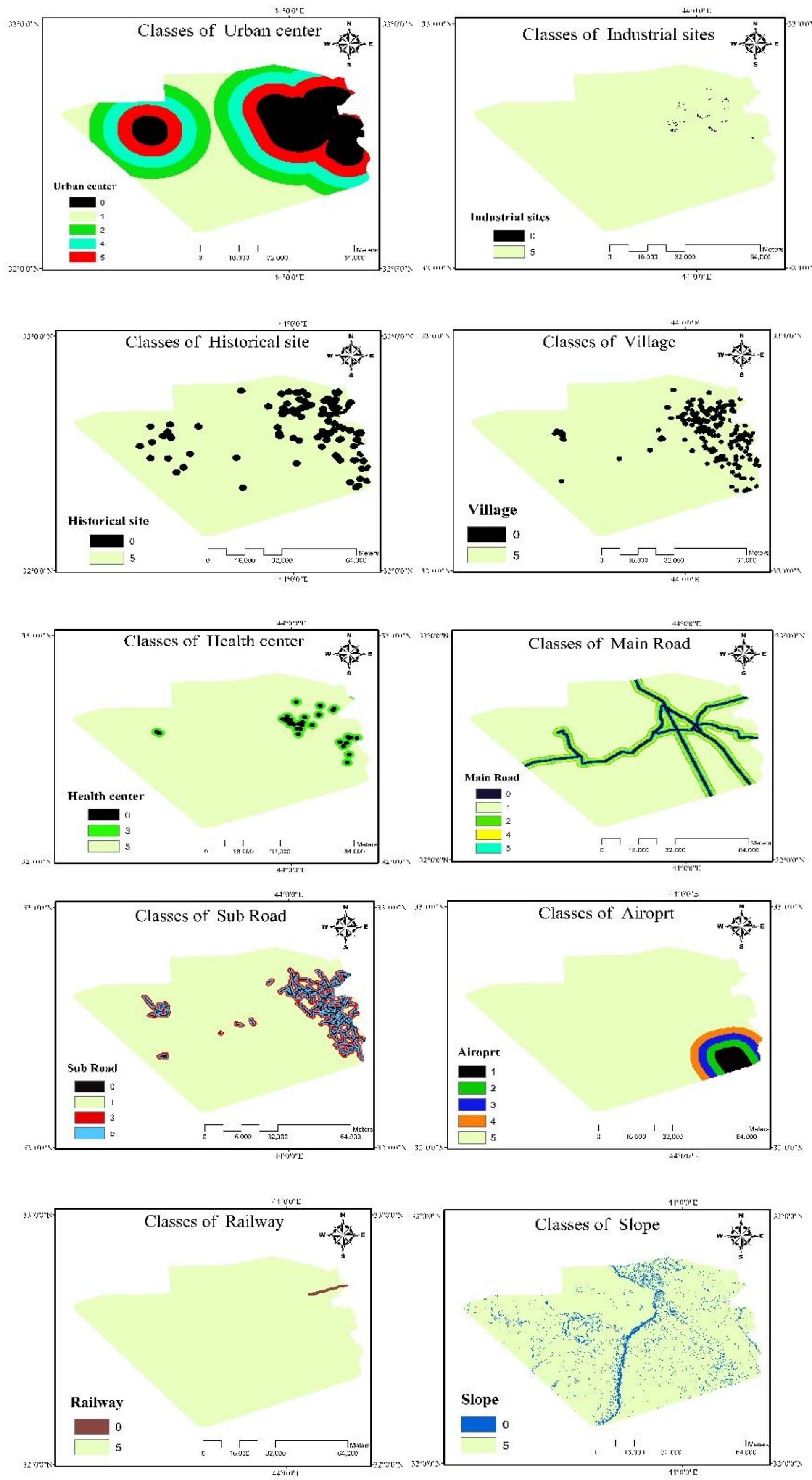

Figure 3. Classification of criteria's maps layers according to the buffer zone for each criterion

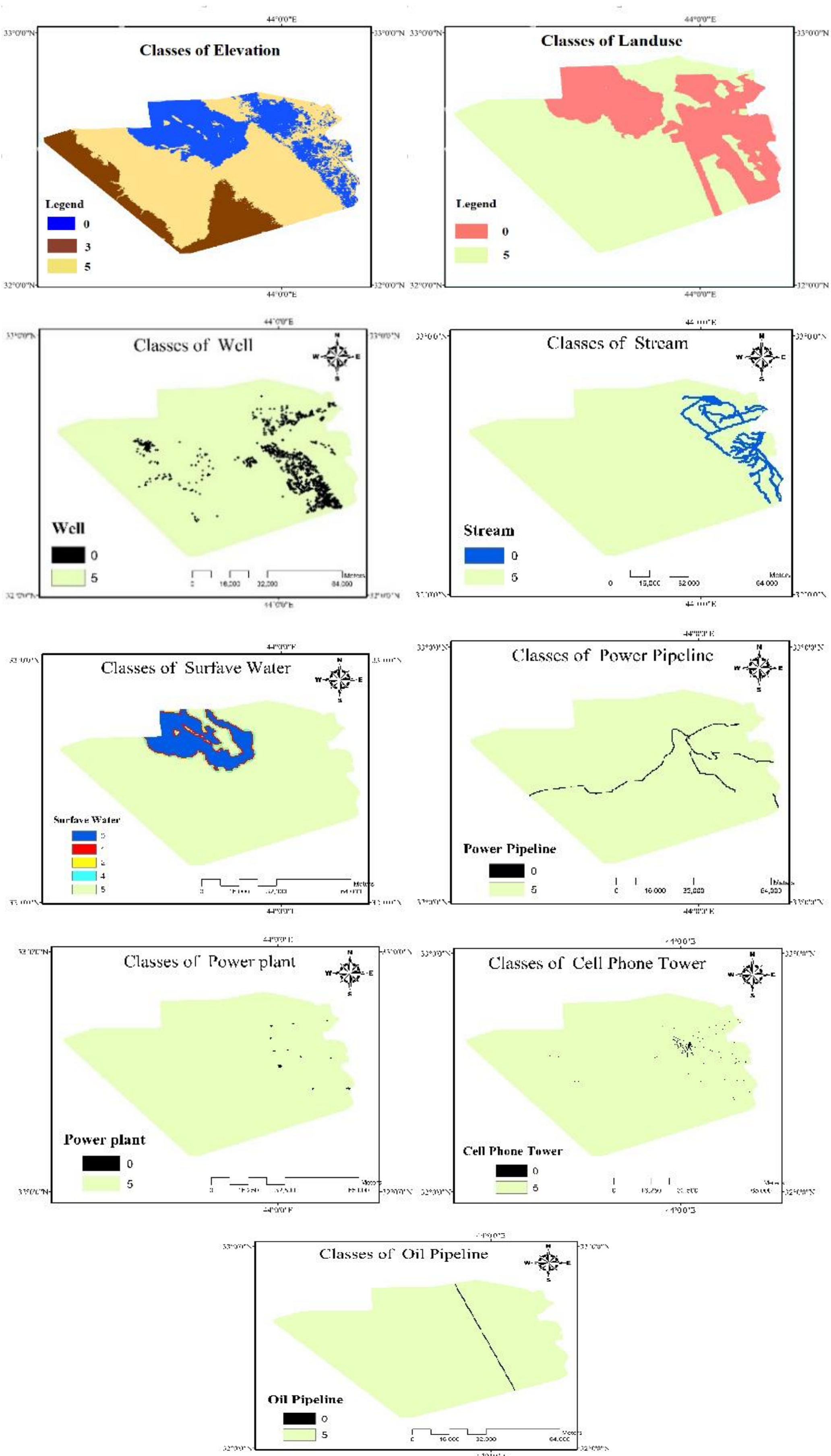

Figure 3. Continuous.

3.3 Suitability Map

After finding the weight for each AHP criterion, these weights were introduced in GIS, where each map was given its weight. All maps were combined to obtain a suitability index map of indicating the most suitable sites for sanitary landfill.

In Fig.4 the study area were divided into 6 classes, suitability indicator ranges between (1.38 - 4.97), were the ranges from (1.38 - 2.57) are low suitability, (2.57 – 4.46) are moderate suitability and (4.46 - 4.97) are high suitability, Suitability map shows that there are ten landfill sites that could be selected having higher suitability index value (4.46 - 4.97). Table 10 shows the details of the ten suitable landfill sites.

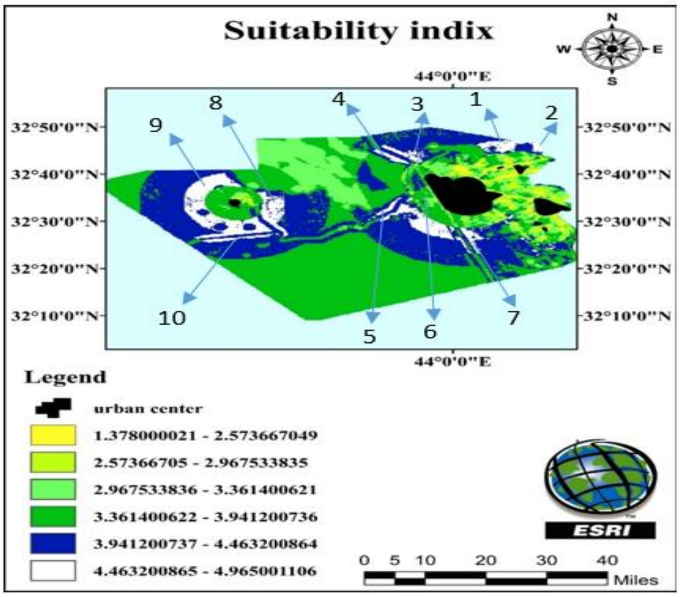

Figure 4. Final suitability map.

Table 9. Selected landfill sites.

Landfill Site No.	District serve	Coordinates	Area, km^2
1	Karbala + Al-Hindia	44° 6' 43.57" E 32° 46' 4.12" N	25.648
2	Karbala + Al-Hindia	44° 11' 47.98" E 32 45' 49.86" N	7.014
3	Karbala	43° 53' 12.84" E 32° 44' 16.8" N	16.867
4	Karbala	43° 51' 7.2" E 32° 43' 39.72" N	10.886
5	Karbala	43° 50' 48.41" E 32° 32' 52.44" N	8.036
6	Karbala	43° 55' 43.63" E 32° 20' 37.62" N	67.387
7	Karbala + Al-Hindia	44° 2' 6.72" E 32° 27' 19.08" N	16.599
8	Ain Al-Tamur	43° 34' 17.34" E 32° 32' 13.77" N	51.775
9	Ain Al-Tamur	43° 26' 10.64" E 32° 32' 48.28" N	160.218
10	Ain Al-Tamur	43° 28' 46.46" E 32° 26' 16.7" N	13.931

4. Conclusions

This study goals to find the best sites for sanitary landfill in Karbala Governorate, where natural and artificial factors were taken into account. GIS has been relied upon as a powerful tool capable of selecting the appropriate site for landfill by dealing with a lot of data and a variety set of sources by using AHP method to extract the weights of the input data. This helps decision makers to get results quickly and whatever complexity the problem is.

GIS and MCDA were used based on 19 criteria including Socio-economic criteria, Accessibility criteria, Infrastructural criteria, Morphology and Landuse criteria and Hydrology criteria converted to input digital map layers to find the most suitable landfill sites to be used. From the result of the analysis indicator, it turns out that urban centers, surface water and Villages criteria are the most important criteria for selection of the landfill site. Furthermore, the suitability map showed that there are ten landfill sites that have been selected after obtaining the highest index value of suitability (4.46 - 4.97) as shown in Fig.4.

5. Recommendations

In order to reach the objective of the research and its achievement, research should be carried out about predicting the numbers of the population in Karbala governorate and Increase that number in the future and considering if the selected landfill sites are accommodate those population, especially, Karbala is consider as religious site and attracting the people to its during the year as well as the increase in population of the fortieth day of the martyrdom of Imam Hussein (PBUH).

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