Landfill Sites Selection Using MCDM and Comparing Method of Change Detection for Babylon Governorate, Iraq

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Outline

- Introduction
- Background
- Goals of study
- Methodology
- Results
- Conclusion

Introduction

The site selection for a landfill is considered as a complex process related to many factors and restrictions such as:

- Government funding.
- Government regulations.
- Social and environmental factors.
- Economic factors.
- Public/political opposition to the landfill sites establishment.

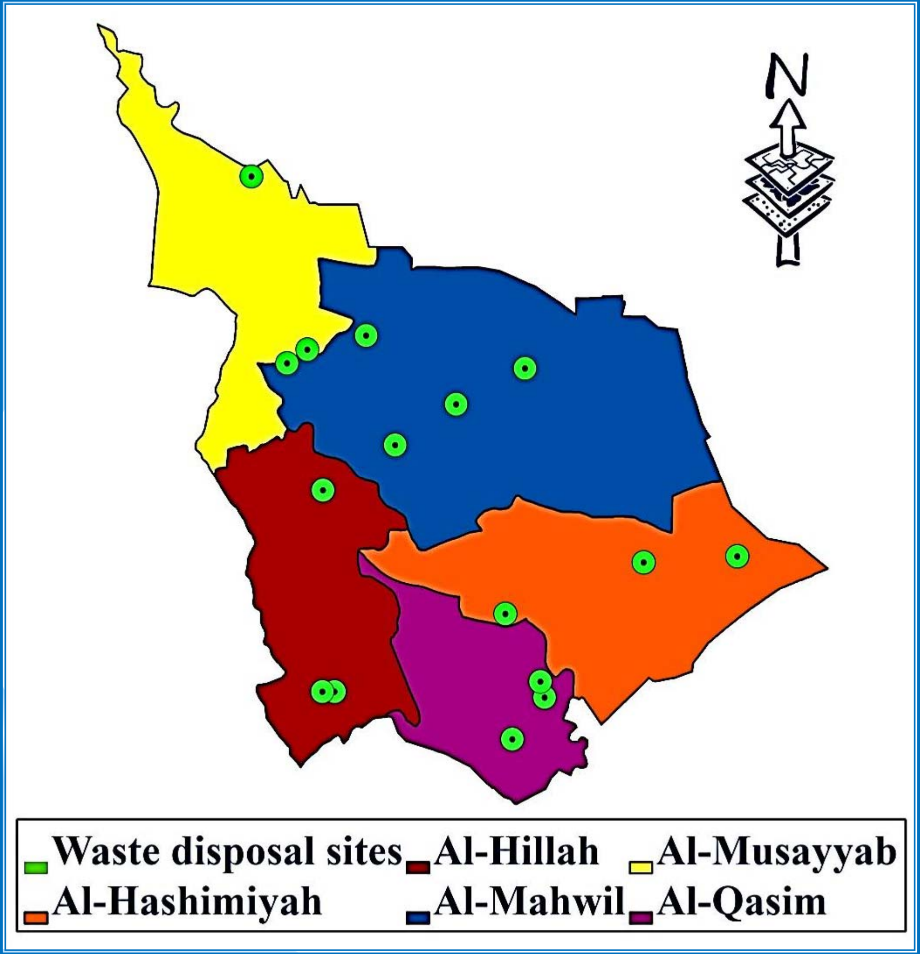
http://whitemosslandfill.co.uk/

Background

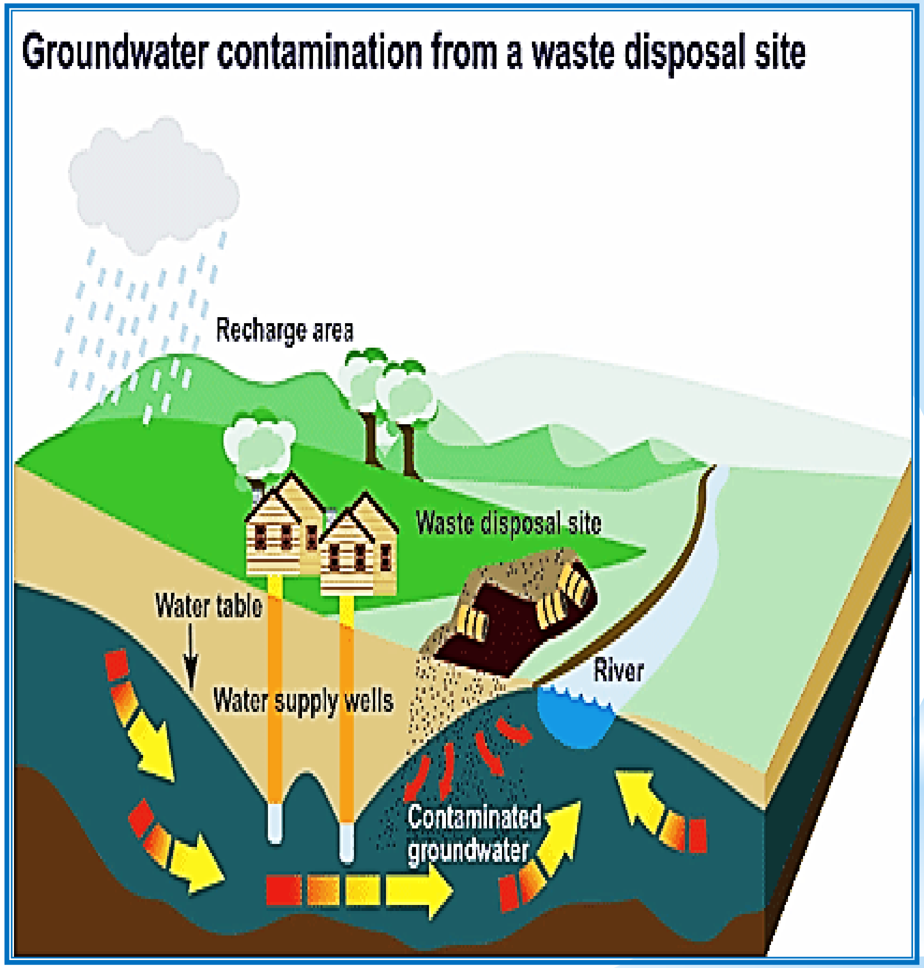
What are the main problems in this study?

1. There are no landfill sites.

2. Groundwater pollution by leachate from the waste disposal sites.



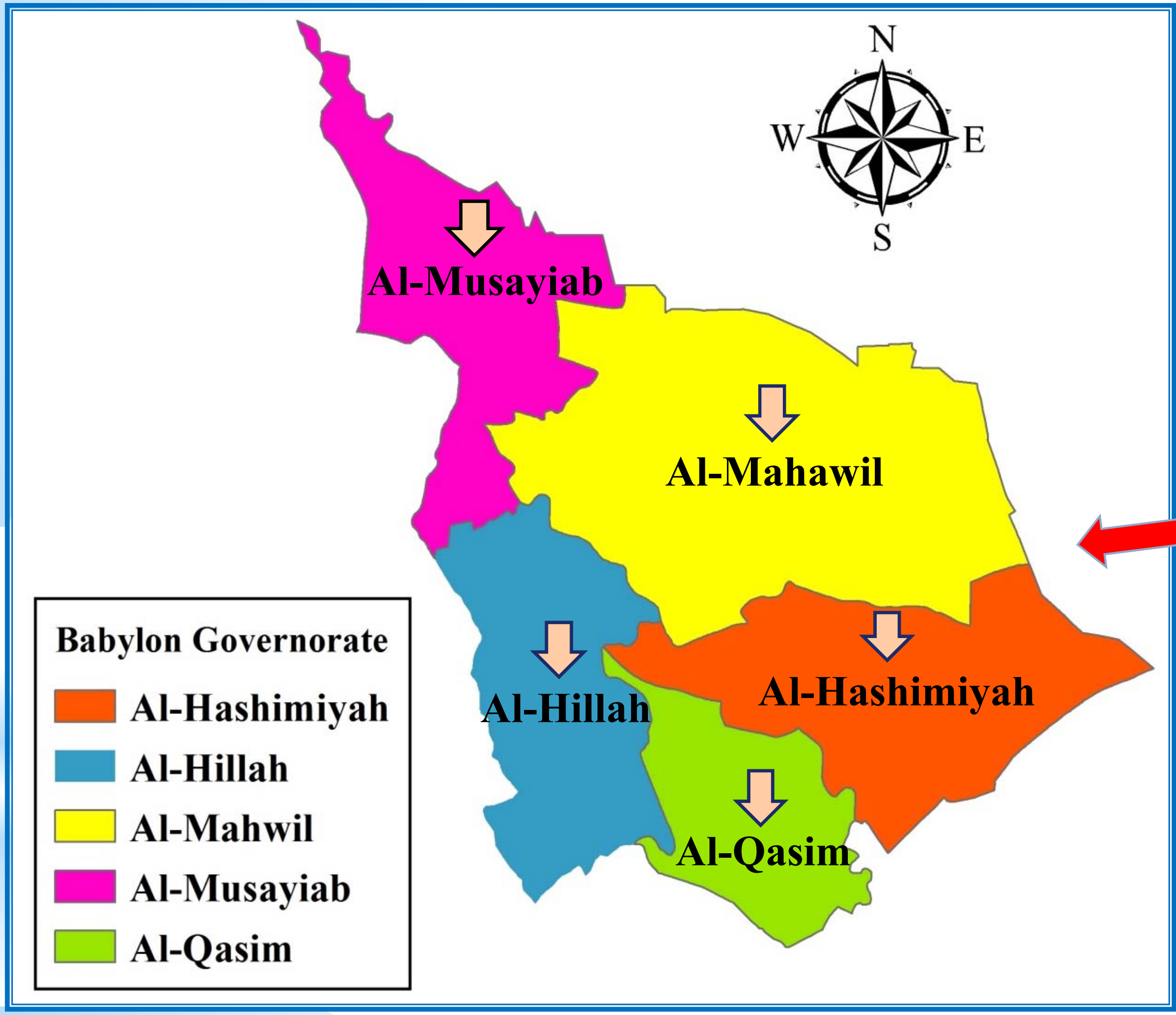
The waste disposal sites in Babylon Governorate.

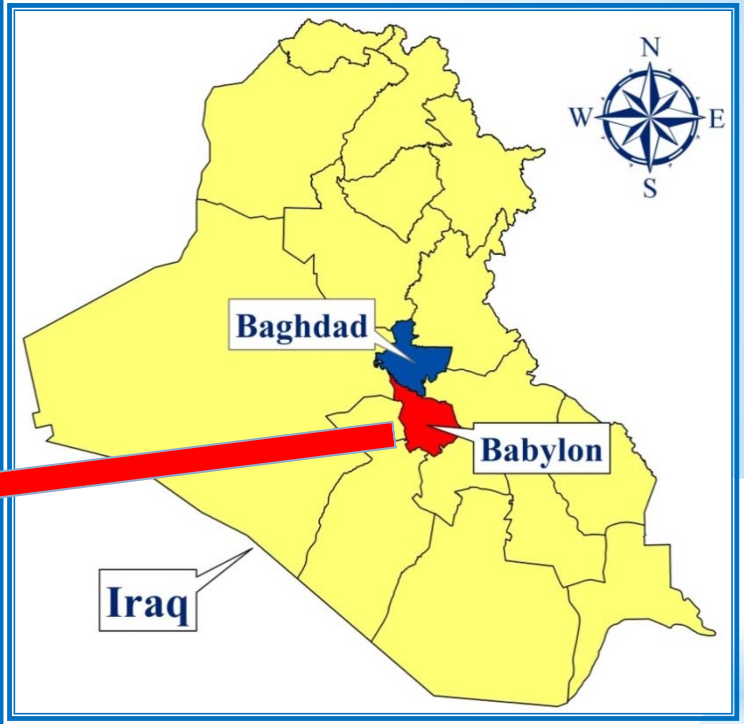


https://www.ec.gc.ca/eauwater/default.asp?lang=En&n=6A7FB7B2-1

Background → Babylon Governorate

Area 5315 Km^2. Population 2,200,000 inhabitants (2017).





Map of Babylon Governorate.

Goals of study

1. Identifying the suitable candidate sites for landfill using GIS and MCDM methods for each district in Babylon Governorate that conform with international and environmental criteria.

2. Using comparison method between the final raster maps to determine and check the suitability of the selected sites for landfill.

Methodology

1. Identifying suitable candidate sites for landfill

15 criteria were selected:

- 1- Groundwater depth
- 2- Rivers
- 3- Elevation
- 4- Slope
- 5- Soils types
- 6- Land use
- 7- Agricultural land use
- 8- Roads
- 9- Railways
- 10- Urban centers
- 11- Villages
- 12-Archaeological sites
- 13- Gas pipelines
- 14- Oil pipelines
- 15- Power lines

Methodology → **2- Sources of input data to prepare the required maps**

a) The first source was as available digital maps (shape files) (internal reports of the Iraqi Ministry of Education, 2015).

b) The second source was drawn from published maps based on relevant information in each map (Buringh, 1960).

c) The third source was available data which were entered in GIS to produce a digital map after generating the interpolation between the selected data.

In this study, two models were used to derive the weights of criteria.

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

- **Analytic Hierarchy Process (AHP) method.**

Methodology

2. Comparison method between two final raster maps

The goals of using Comparison method

1. To find the pixels percentage of matching and non-matching for two raster maps of multi-criteria decision making methods.

2. To check the suitability of the selected sites for landfill on both resulted maps using each two methods.

Results

1. Identifying suitable candidate sites for landfill

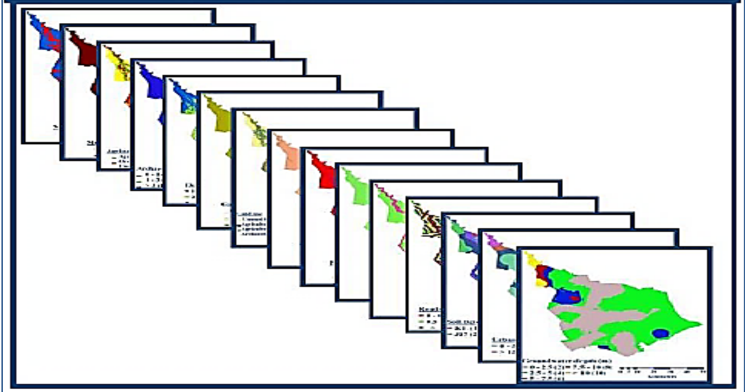
Results → The final map of suitability index value of potential areas

After identifying
Weights for all criteria

The weights of sub-criteria for each criterion

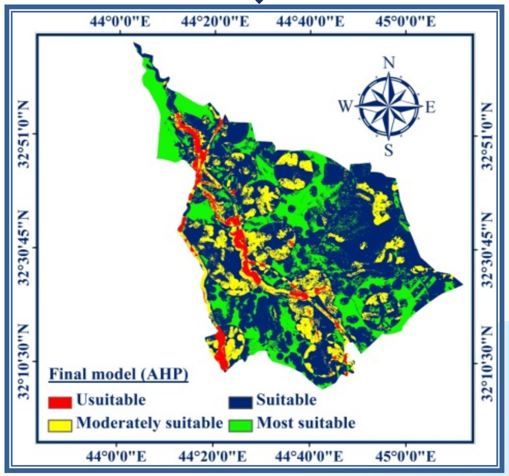
Criteria	Sub-criteria values	Sub-criteria weights	Criteria weights
Criterion 1	A	1	W1 (0.0302)
	B	4	
	C	10	
Criterion 2	A	0	W2 (0.1471)
	B	10	
Criterion 3	A	3	W3 (0.0462)
	B	7	
	C	10	
Criterion 4	A	10	W4 (0.0146)
	B	5	
Criterion 5	A	10	W5 (0.0709)
	B	9	
	C	7	
Criterion (n)	A	0	Wn
	B	0	
	D	5	

Enter 15 of raster maps with their categories' weights into GIS



The special analysis tool "Map Algebra" in GIS

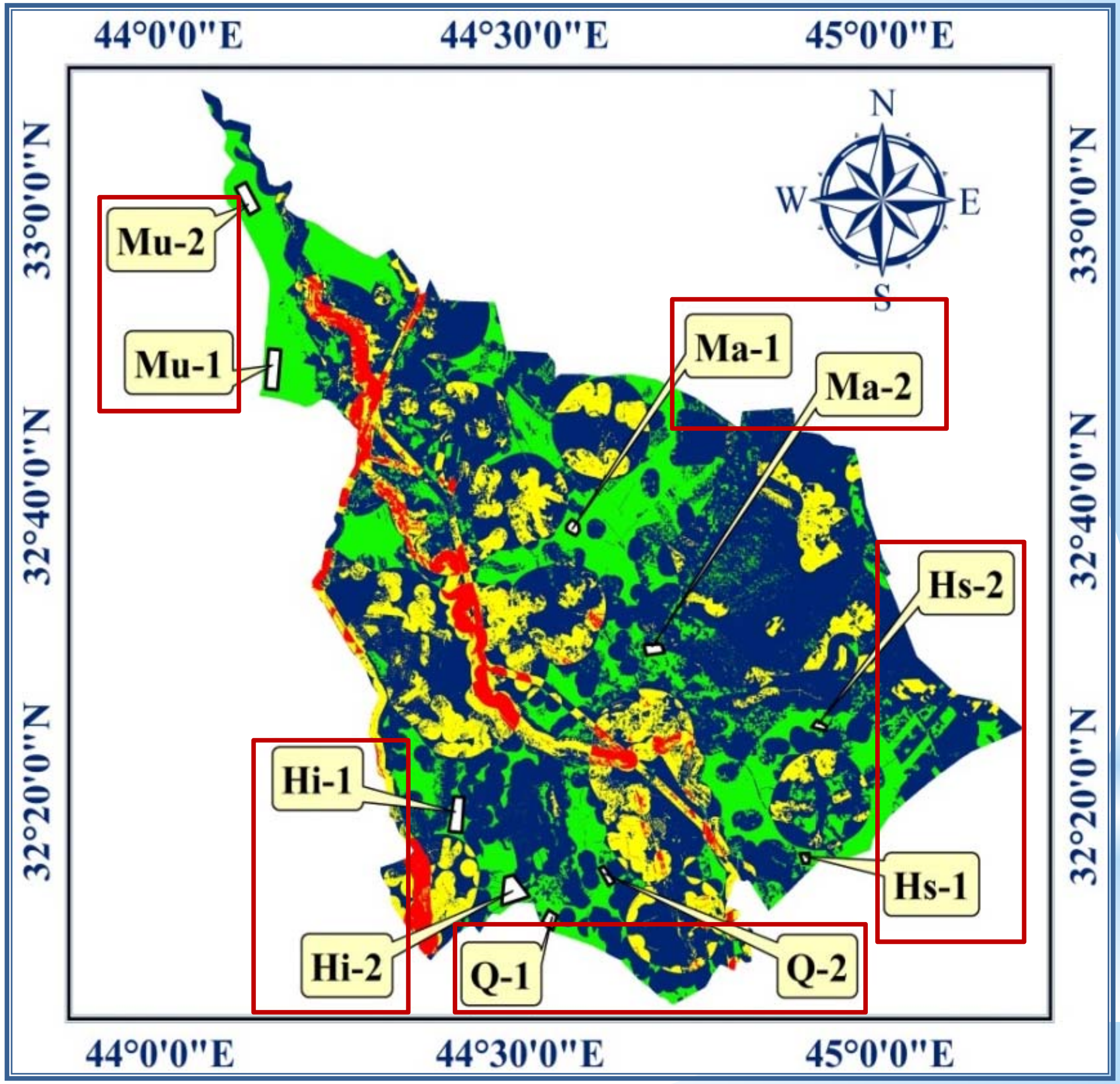
Ai = ∑ (The weight of each criterion) × The weights of sub-criteria for each criterion)



The final map of suitability index for landfill sites

Results

- The resultant final map was divided into **four categories** are:

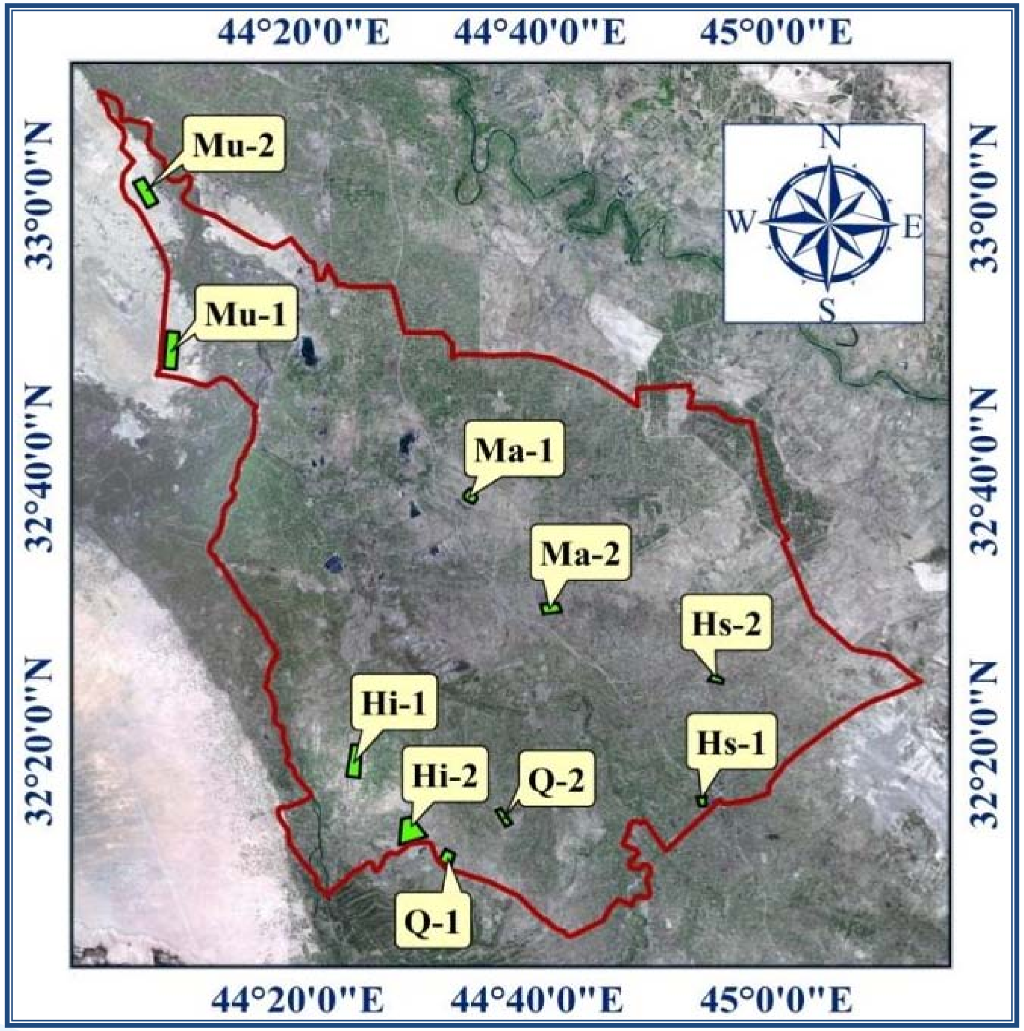


- Usuitable areas
- Moderately suitable areas
- Suitable areas
- Most suitable areas

Final map of suitability index for landfills in Babylon Governorate.

Results

- The candidate sites were checked on the satellite images of Babylon Governorate, and recent field visits to make sure that these sites were suitable for landfill in each district.



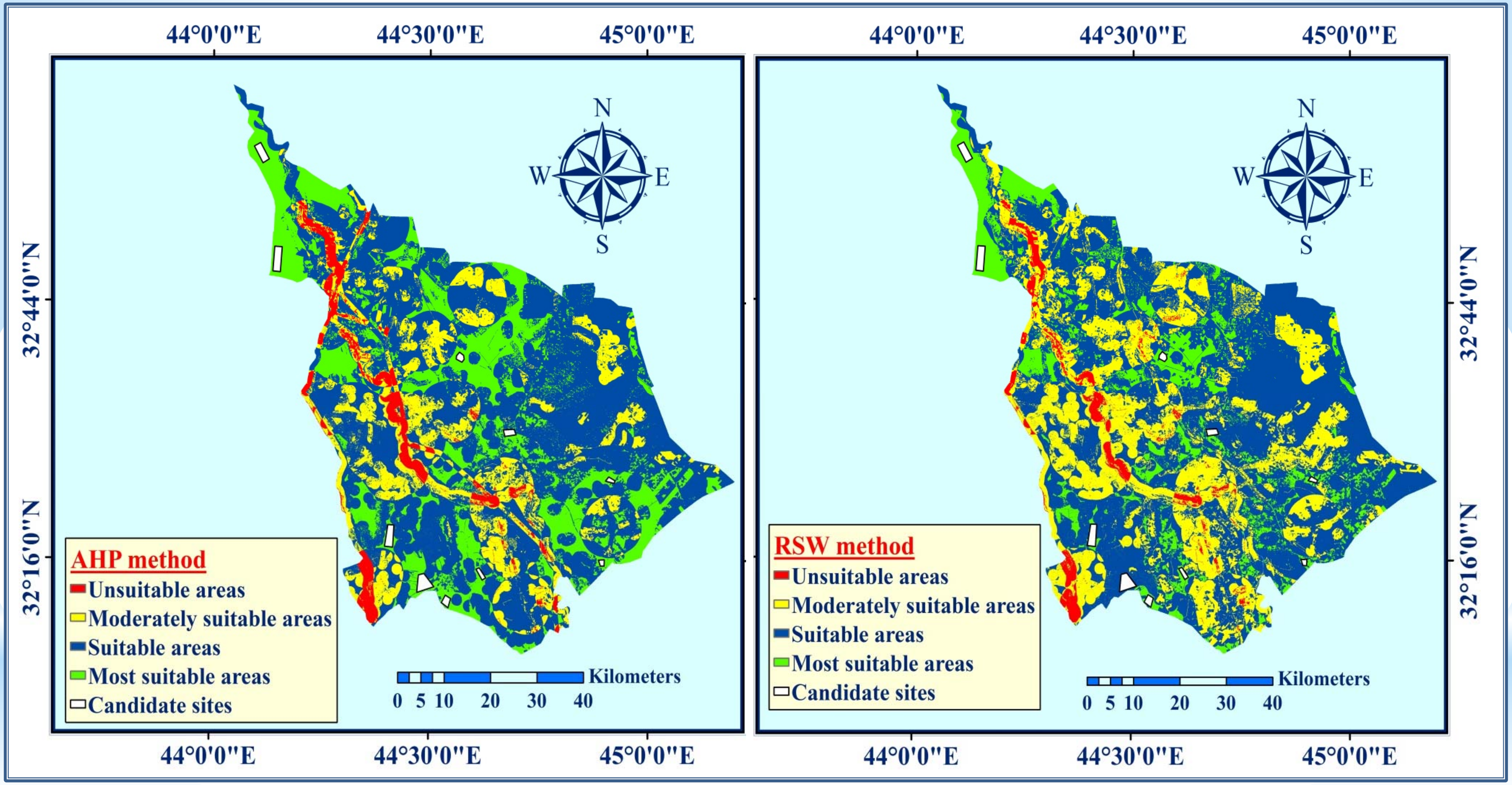
The candidate sites for landfill in Babylon Governorate.

Results

2. Comparison method between two final raster maps

Results → **Comparison methods between final maps**

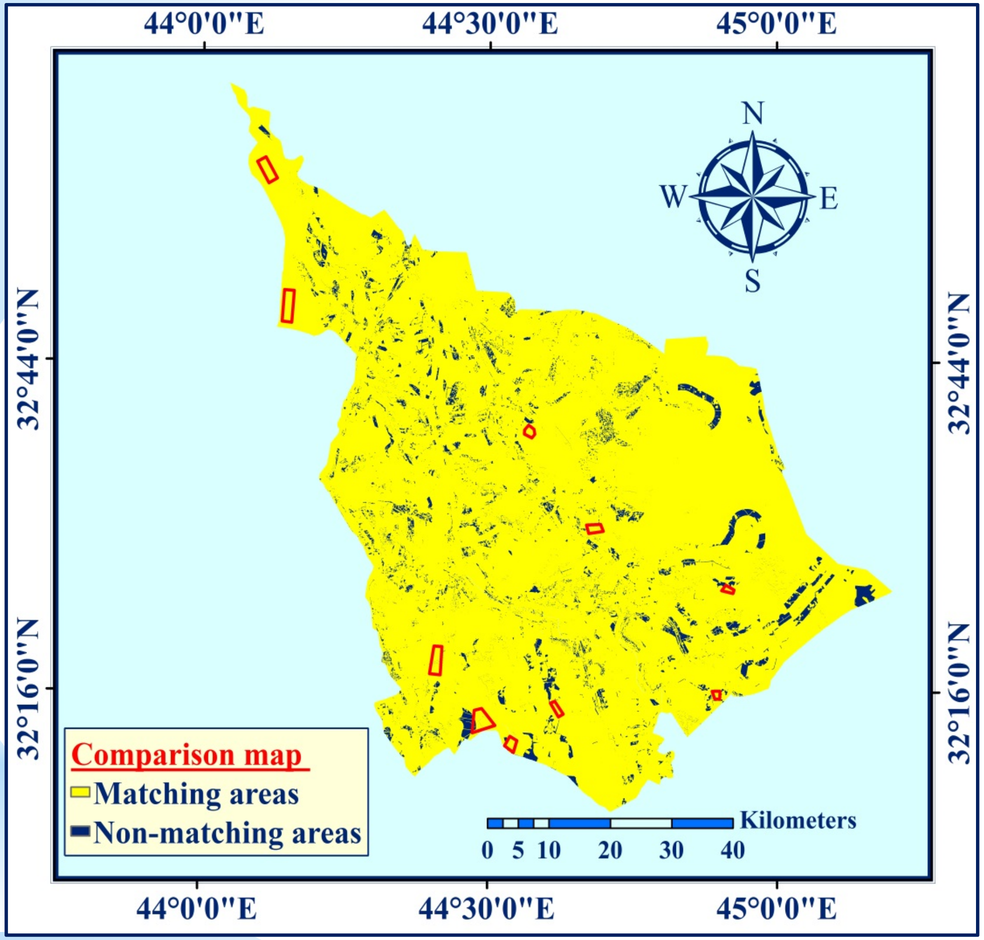
The two final raster maps with their categories were combined in GIS, using the comparison method.

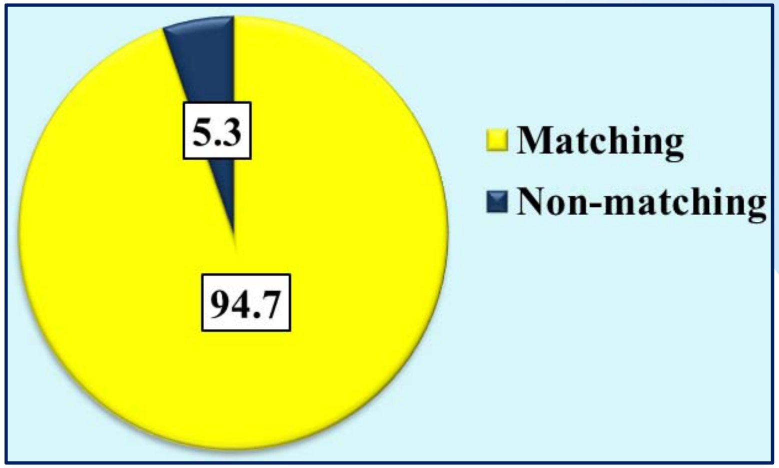


The final maps of AHP and RSW methods with their categories

Results → Comparison methods between final maps

Using change deduction method, the comparison map was created, and the pixels percentage of matching and non-matching for two maps were produced.





The comparison map using **Change Detection method**

Conclusions

Conclusions

1. The weights for all criteria were identified through using multi-criteria decision making methods.

2. In each district, two candidate sites were identified for landfill on the final map produced using GIS.

3. The Comparison method was used to determine the pixels' percentage of matching and non-matching, as well as to confirm the results of the suitability of the selected sites for landfill on two final maps.

Thank you for your attention

Methodology → 3- How to determine the sub-criteria and their weights?

Table: The example of determintion the sub-criteria of each criterion and their weights **based on previous studies, available data, and view of experts.**

No.	Criteria	Al-Musayiab district	
		Sub-criteria values	Sub-criteria weights
1	Roads (km)	0 - 0.5	0
		0.5 - 1	7
		1 - 2	10
		2 - 3	5
		> 3	3
2	Villages (km)	0 - 1	0
		> 1	10
3	Archaeological sites (km)	0 - 1	0
		1 - 3	5
		> 3	10
4	Railways (km)	0 - 0.5	0
		> 0.5	10
…..	…………	…………	……….
…..	…………	………..	……….
15	…………	………..	……….

Methodology → 5- Calculation of the weights of criteria

1. Ratio Scale Weighting (RSW) method

In this method, the value of proportional weight of each criterion was divided by the proportional weight value of the least importance criterion.

No.	Criteria	Ratio scale value	New weight	Normalized weights
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

Table: Numerical scale of 9 points for pairwise comparison between each two factors *(Saaty, 2000)*.

Intensity of Importance	Definition
1	The similar factors have an equal importance
2	**A** equal to moderately importance over **B**
3	**A** is moderate importance over **B**
4	**A** is moderate to strong importance than **B**
5	**A** is strong importance over **B**
6	An activity of **A** is Strong to very strong importance over **B**
7	**A** is very strong importance over **B**
8	**A** is very to extremely strong over **B**
9	**A** is extreme importance over **B**

Methodology → **The main steps of (AHP) method**

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1. Creating a matrix of pairwise comparisons between the selected criteria.

Table: Pair wise comparisons matrix for landfill siting, Relative weights 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	Relative Weights of criteria
Groundwater depth	1	2	3	2	4	5	5	4	8	8	7	6	5	6	9	0.2004
Urban centers	0.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.1471
Villages	0.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.1038
Rivers	0.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	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

aij=1/aji

2. Determination of the relative weights of criteria using series of equations (e.g. priority vector, eigenvalue, λmax, so on).

3. Checking the consistency between the resultant weights of criteria using the value of Consistency Ratio (CR).

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}}$$

where:

CI: is equivalent to the standard deviation of evaluation error.

(RI): is the mean deviation of randomly for matrices with different size.

Table: Random inconsistency indices (RI) for the number of elements (n) (Saaty, 1980).

(n)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

To know if the consistency is acceptable, the value of **CR** **should be smaller than** **0.1**.

In this study, CR = 0.027 < 0.1.

2. Analytic Hierarchy Process (AHP) method

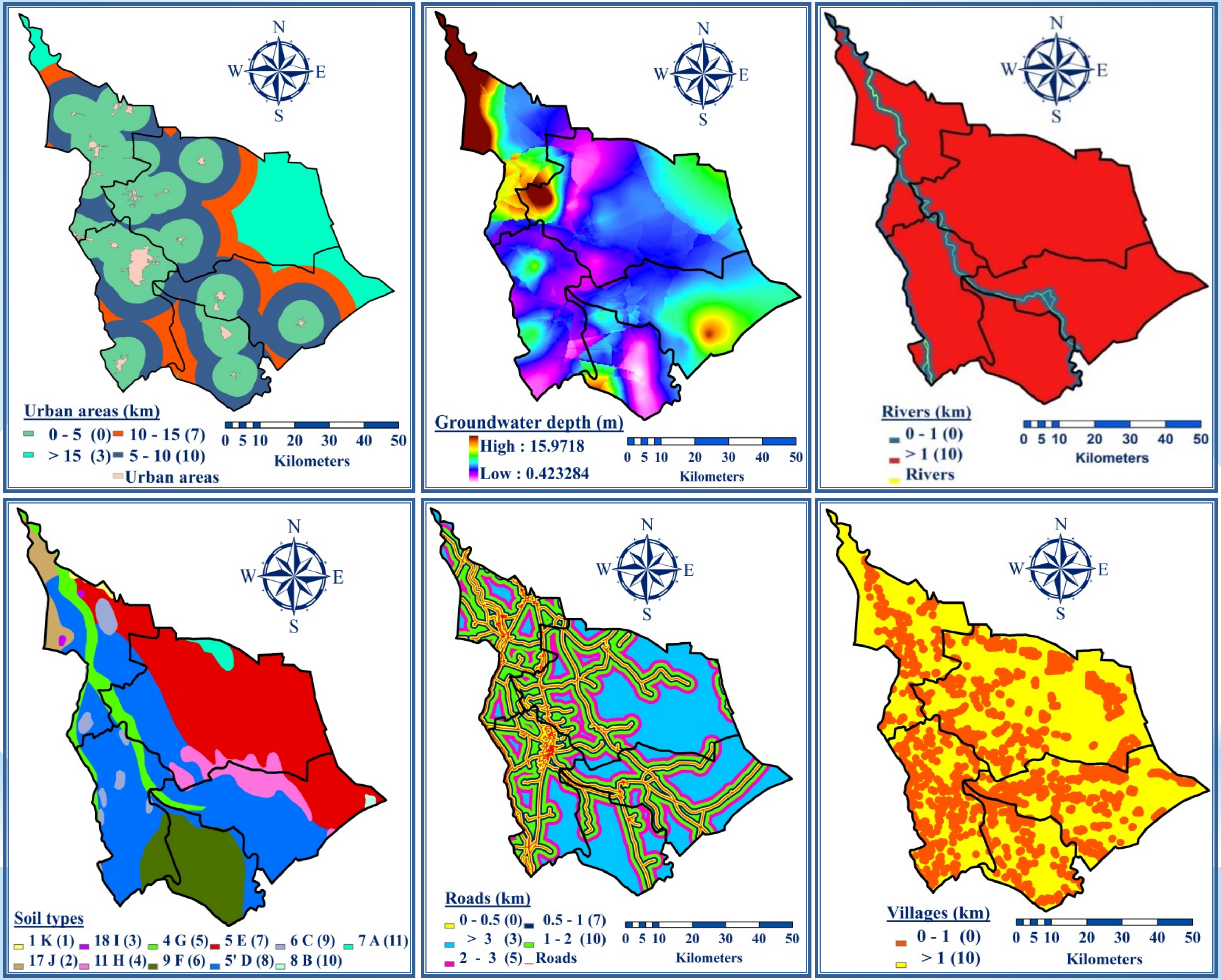
- AHP is one of the most common Multi Criteria Decision Making methods.
- This method uses the matrix of pairwise comparisons.
- **AHP**, check the consistency of judgments.

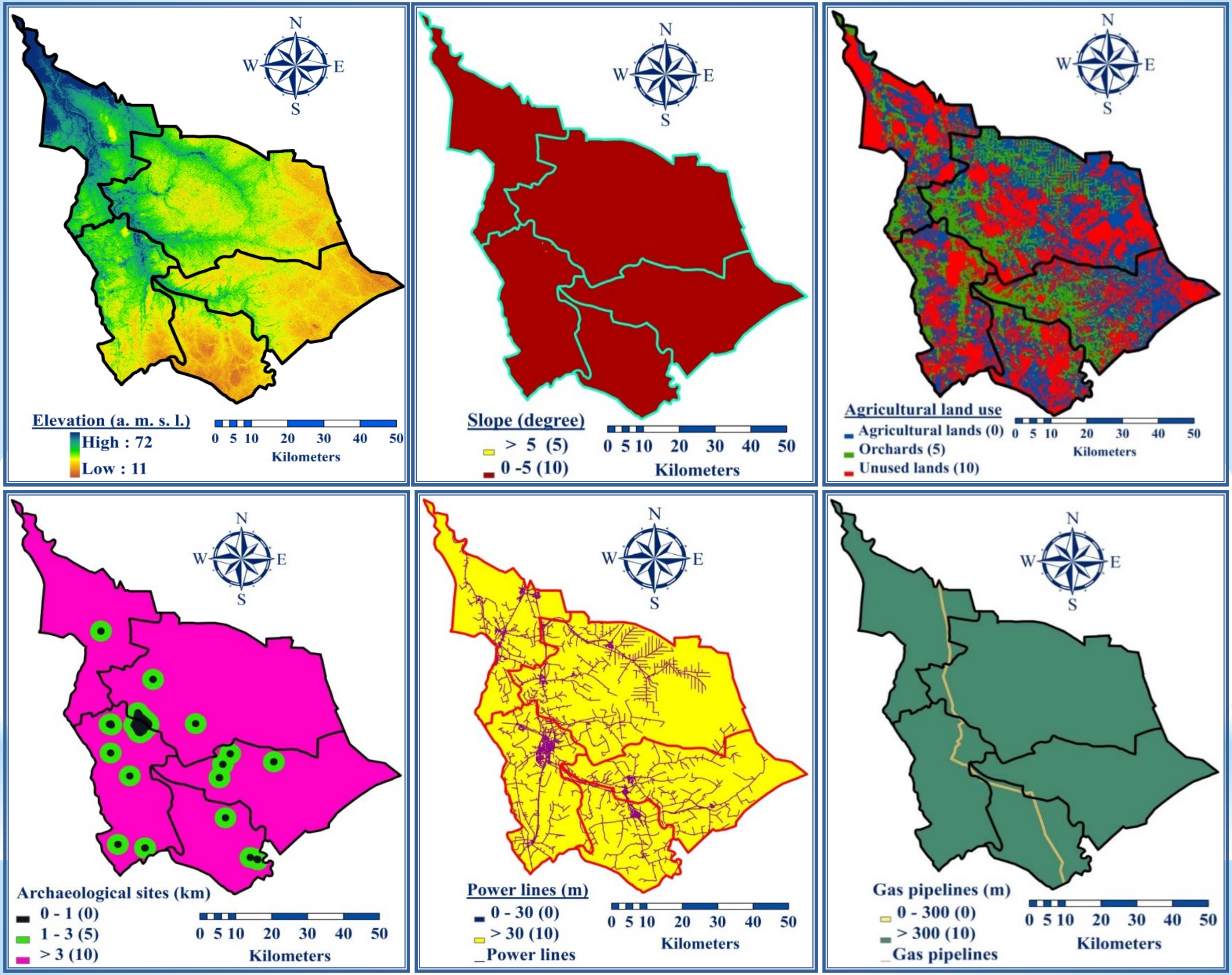
The main steps of (AHP) method

1. Creating a matrix of pairwise comparisons between the selected criteria.
2. Determination of the relative importance or the weights for each criterion using series of equations.
3. Checking the consistency between the resultant weights of criteria using the value of Consistency Ratio (CR).
4. Finally, if the value of CR is smaller than 0.1, the consistency between the resultant weights of criteria will be acceptable.
5. In this study, CR = 0.027 < 0.1.

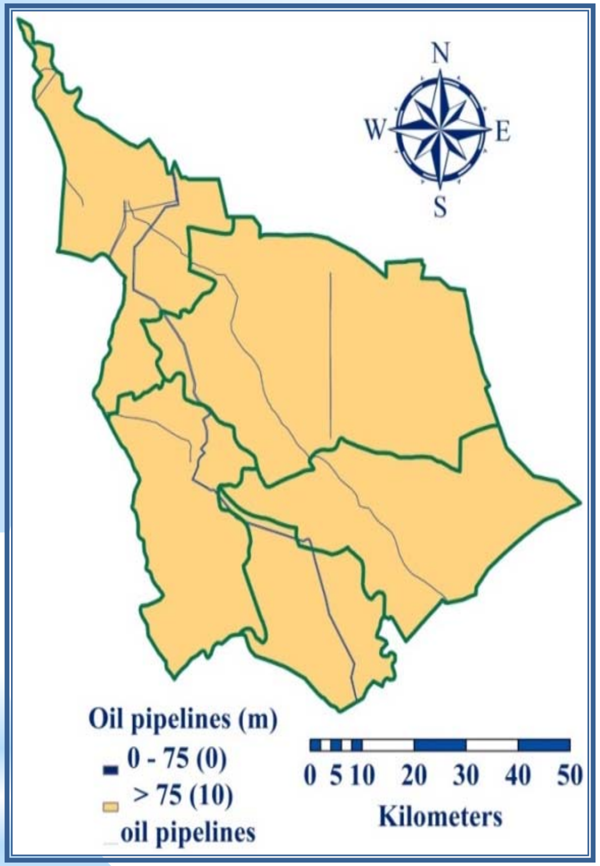
Change Detection method.

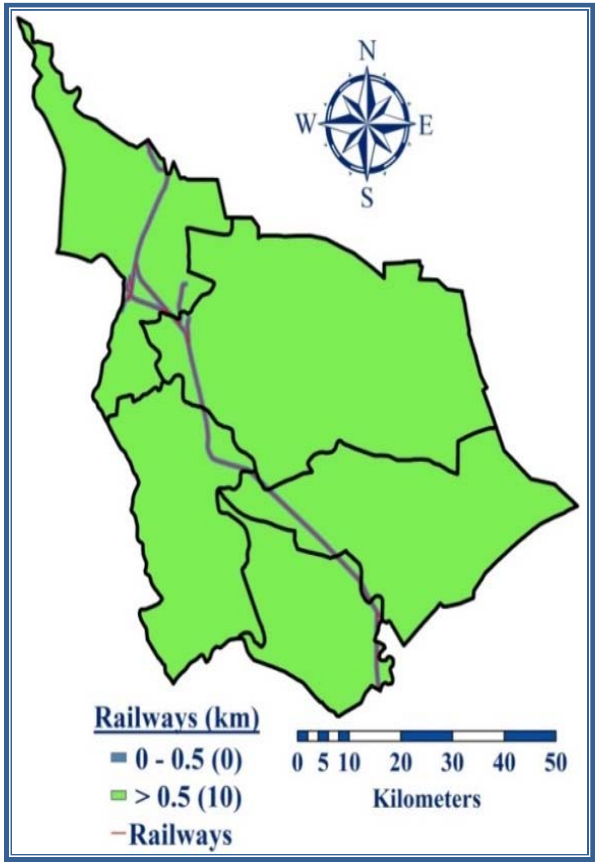
value	count	Category AHP	Category SRS	Corresponding pixels ratio	classification
1	8,059,847	All categories	All categories	**94.70**	matching
2	35,109	(US)1	(US)1	**0.41**	Non-matching
3	194,227	(MOS) 2	(MOS) 2	**2.28**	Non-matching
4	221,919	(MS) 4	(MS) 4	**2.61**	Non-matching

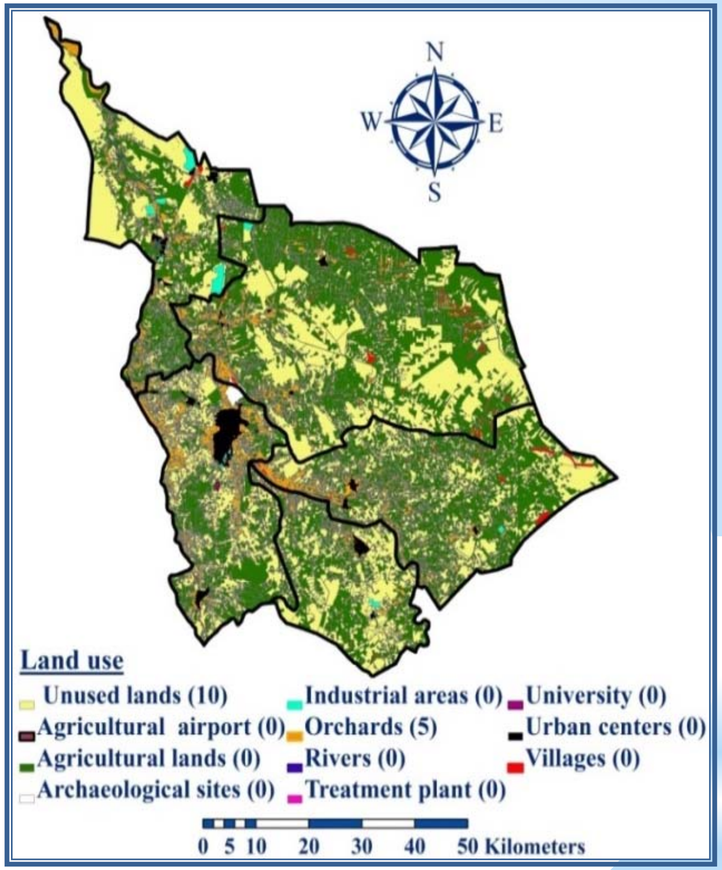

N
W
E
S
Urban areas (km)
0 - 5 (0)
10 - 15 (7)
> 15 (3)
5 - 10 (10)
Urban areas
0 5 10 20 30 40 50
Kilometers
Groundwater depth (m)
High : 15.9718
Low : 0.423284
Kilometers
Rivers (km)
0 - 1 (0)
> 1 (10)
Rivers
Kilometers
Soil types
1 K (1)
18 I (3)
4 G (5)
5 E (7)
6 C (9)
7 A (11)
17 J (2)
11 H (4)
9 F (6)
5' D (8)
8 B (10)
Roads (km)
0 - 0.5 (0)
0.5 - 1 (7)
> 3 (3)
1 - 2 (10)
2 - 3 (5)
Roads
Kilometers
Villages (km)
0 - 1 (0)
> 1 (10)
Kilometers



N
W
E
S
Elevation (a. m. s. l.)
High : 72
Low : 11
0 5 10 20 30 40 50
Kilometers
Slope (degree)
> 5 (5)
0 -5 (10)
Agricultural land use
Agricultural lands (0)
Orchards (5)
Unused lands (10)
Archaeological sites (km)
0 - 1 (0)
1 - 3 (5)
> 3 (10)
Power lines (m)
0 - 30 (0)
> 30 (10)
Power lines
Gas pipelines (m)
0 - 300 (0)
> 300 (10)
Gas pipelines


N
W
E
S
Oil pipelines (m)
0 - 75 (0)
> 75 (10)
oil pipelines
0 5 10 20 30 40 50
Kilometers


N
W
E
S
Railways (km)
0 - 0.5 (0)
> 0.5 (10)
Railways
0 5 10 20 30 40 50
Kilometers


N
W
E
S
Land use
Unused lands (10)
Agricultural airport (0)
Agricultural lands (0)
Archaeological sites (0)
Industrial areas (0)
Orchards (5)
Rivers (0)
Treatment plant (0)
University (0)
Urban centers (0)
Villages (0)
0 5 10 20 30 40 50 Kilometers

$$S_c = \left(\frac{C_c}{1+e_0}\right) \cdot H \cdot \log\left(\frac{\sigma_0' + \Delta\sigma_0'}{\sigma_0'}\right)$$

H = thickness of the layer after excavation to be evaluated,

C_c = primary compression index,

e_o = initial void ratio,

σ_o' = effective vertical stress at the middle of the layer after excavation, but before loading, and

$\Delta\sigma_o$' = increase or change in effective vertical stress due to loading.

Background

Reality of waste disposal sites in Babylon Governorate.

Conclusions

1. Open dumping of waste leads to many environmental problems, including ground and surface water contamination, insect and rodent infestation, odors, noise, disease, sometimes population suffocation because of burning the waste in these sites.

2. The expected values in 2030 for the waste generation rate in (kg/capita/day) are 0.96 (Babylon Governorate), 0.97 (Al-Hillah), 0.69 (Al-Qasim), 0.48 (Al-Mahawil), 0.62 (Al-Hashimiyah) and 0.91 (Al-Musayiab), with the annual increment rate of generation waste of 1%.

3. The comparison of generation rate of solid waste with other studies puts Babylon Governorate, Al-Hillah and Al-Musayiab districts as middle-income cities, while Al-Qasim, Al-Mahawil and Al-Hashimiyah districts as low-income cities.

The HELP 3.95 D model

- The Hydrologic Evaluation of Landfill Performance (HELP 3.95 D) model is the most commonly applied model in the world for landfill design.
- The HELP model adopts many hydrologic processes of one dimensional in two directions. Therefore, the HELP model is known as a "quasi-two dimensional" layer model.
- This model is used to calculate the rate of leachate through the layers of soil and the head of leachate on the bottom layer at various times based on different weather parameters.

Methodology → Landfill design

The required input data

1. **Daily weather data** in Babylon governorate from 2005 – 2016, as follows:

- ❖ Precipitation (daily depths).
- ❖ Air temperature (daily means).
- ❖ Solar radiation (daily sum).
- ❖ Evapotranspiration (mm).

Table: Average annual data of weather parameters for the years (2005-2016) in Babylon Governorate

Parameters	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Precipitation mm (daily depth)	73.2	170.3	41	51.8	52.4	87.3	41.7	128.8	182.9	125	133.4	135.4
Temperature ˚C (daily mean)	23.1	23.5	23.5	23.6	23.9	23.6	23.2	24.1	23.3	24.2	24.6	24.5
Solar radiation MJ/m^2 (daily sum)	5630	5638	5636	5673	5643	5628	5628	5702	5647	5639	5736	5729

The required input data

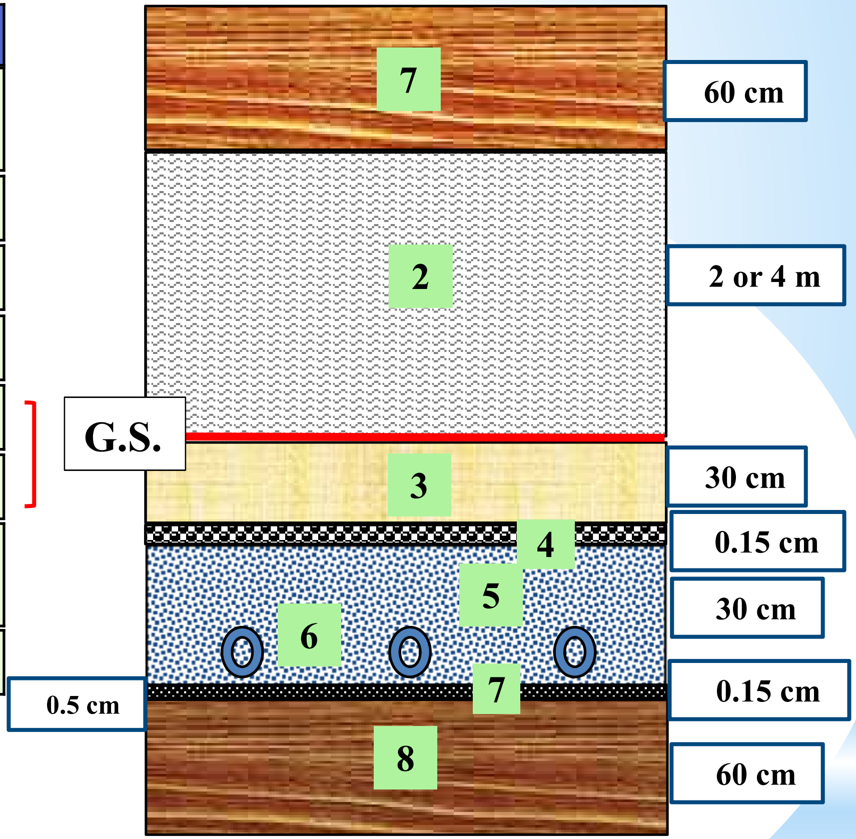
2. Soil data

- Types of soil layers in the HELP model are: (vertical percolation layer, lateral drainage layer, barrier soil layer and Geo-membrane liner).
- The required data for soil layers are: (Porosity, field capacity, wilting point and saturated hydraulic conductivity).

3. Suggested soils layers data

Based on soil investigations, the distance from the base of the landfill to the GW table was > 2 m.

No.	Type of layer	Material	H.C. (cm/s)
1	Vertical percolation	**Moderate compacted Sandy Clay**	7.8×10^{-7}
2	Vertical percolation	Municipal waste (2 & 4m)	1×10^{-5}
3	Vertical percolation	Loam Fine Sand	1×10^{-3}
4	Geotextile	Butyl Rubber	1×10^{-12}
5	Lateral drainage	Gravel	3×10^{-1}
6	Lateral drainage	Drain net	$1 \times 10^{+1}$
7	Geomembrane	HDPE (High density polyethylene)	2×10^{-13}
8	Barrier soil liner	High compacted Clay	3×10^{-7}



The First Method: → **Increasing population growth rate, and constant value of S.W. generation**

- The quantity of solid waste **(Qs)** producing for 2030 was calculated using:

$$Qs\ (\text{for specific year (2030)}) = \boxed{(P_{(2030)})} \times \boxed{GRWA} \times \frac{(365)}{1000}$$

1. Increasing **population growth rate** for 2013-2030 with annual growth rate of (2.99%) using the follow Equation:

$$P_t = P_o\,(1+0.0299)^{t}$$ *(Jarabi, 2015; United Nations, 1952).*

Where: P_t (Future population), P_o (Present population) and t: Number of years.

2. The **constant value** of solid waste generation **(GRWA)** for the years 2009-2013:

(average quantity of solid waste / average population)

(Iraqi Ministry of Municipalities and Public Works, 2013& Iraqi Ministry of planning, 2013).

- The cumulative quantity of solid waste generated by 2030 can be calculated, using the follow Equation:

$$Qs(c)_{(2030)} = Qs_{(2030)} + Qs(c)_{(2020\text{-}2029)}$$

The Second Method: → **Increasing population growth rate and, increasing S.W. generation**

➢ The quantity of solid waste (Qs) was calculated for each year until year 2030 based on:

$$Qs\ (2030) = \boxed{(P_{(2030)} = P_{(2013)}\ (1+0.0299)^{t})} \times \boxed{GRW_{(2030)} = GRW_{(2013)}\ (1 + 0.01)^{t})} \times (365/1000)$$

(Al-Rawi and Al-Tayyar, 2012)

1. **Increasing population growth rate (P_t).**

2. **Increasing solid waste generation** for specific year starting from year 2013, with annual increment rate of solid waste generation (0.01) (kg/capita/day).

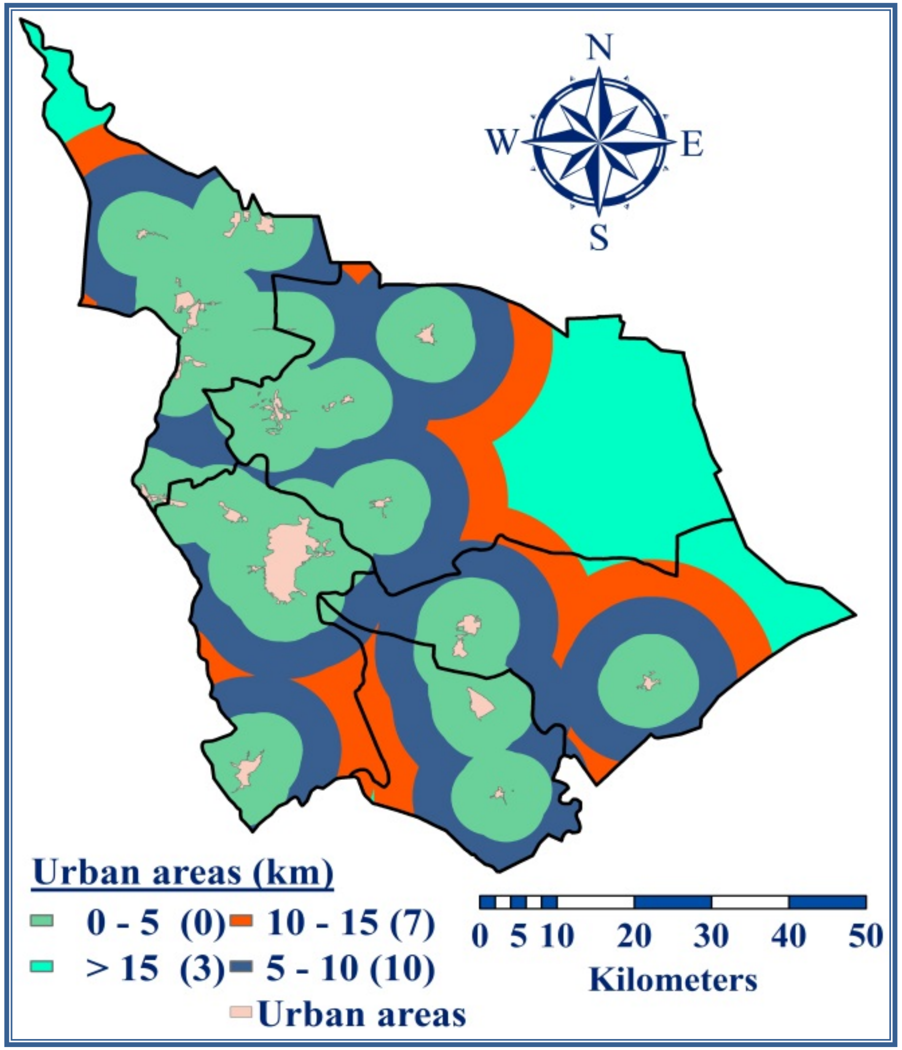
(Iraqi Ministry of Municipalities and Public Works, 2009 &2013).

➢ The cumulative quantity of solid waste generated by 2030 can be calculated, as shown in the follow Equation.

$$Qs(c)_{(2030)} = Qs_{(2030)} + Qs(c)_{(2020\text{-}2029)}$$

Urban centers map

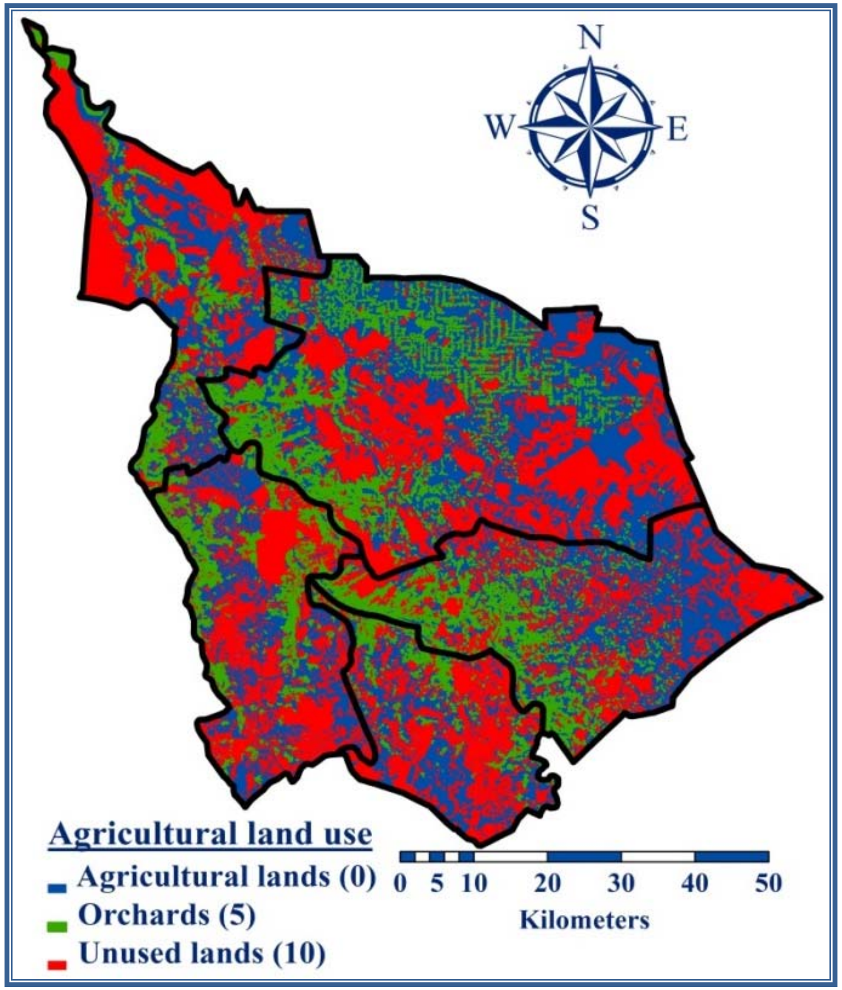
Buffer zone of 5km was created around the borders of urban centers.



Map of "Urban centres" in Babylon Governorate .

Agricultural land use map

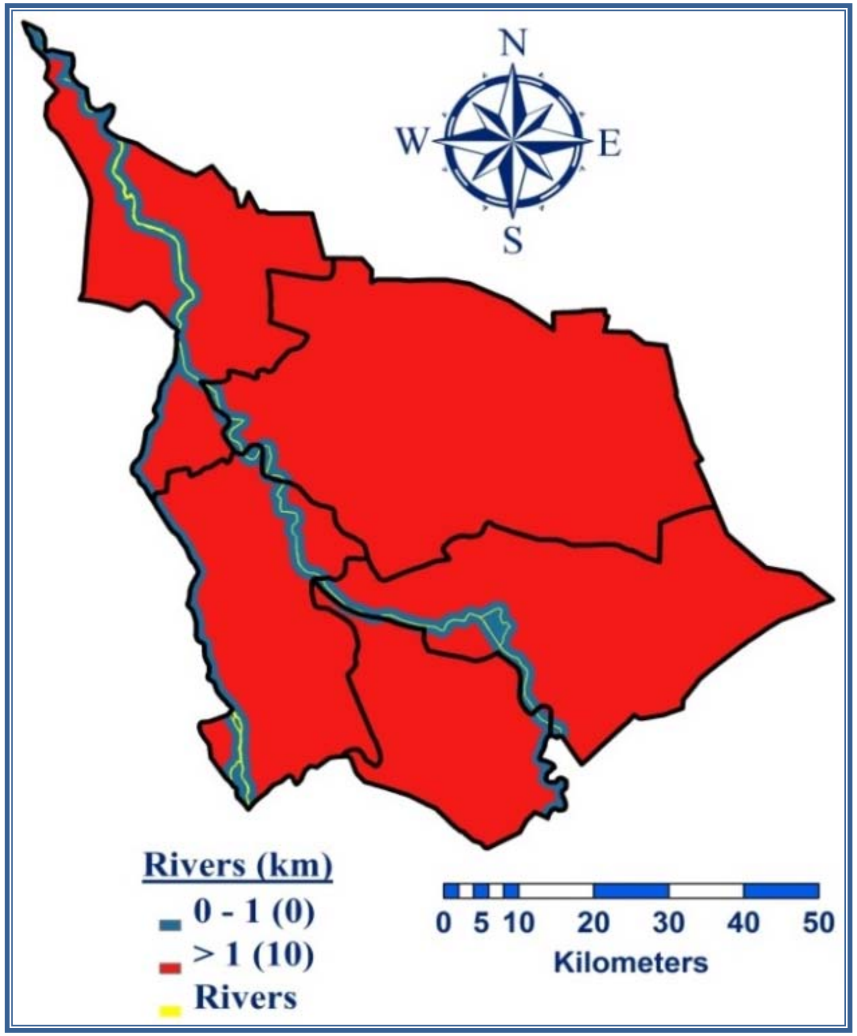
These categories were drawn in polygon form in separate shape files.



Map of "Agricultural land use" in Babylon Governorate .

Rivers map

The buffer distances of 1 km which were created from any river boundary.



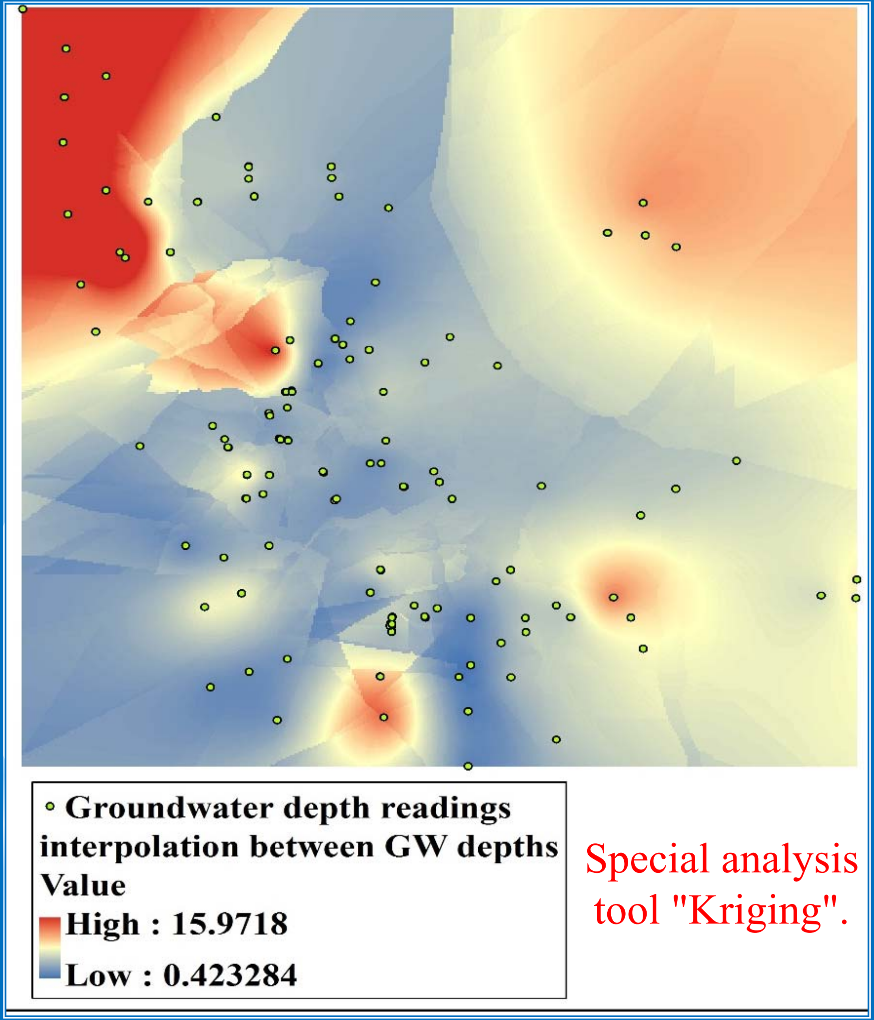
Map of "Rivers" in Babylon Governorate .

Table 3: The example of determintion the sub-criteria of each criterion and their weights **based on previous studies, available data, and view of experts**.

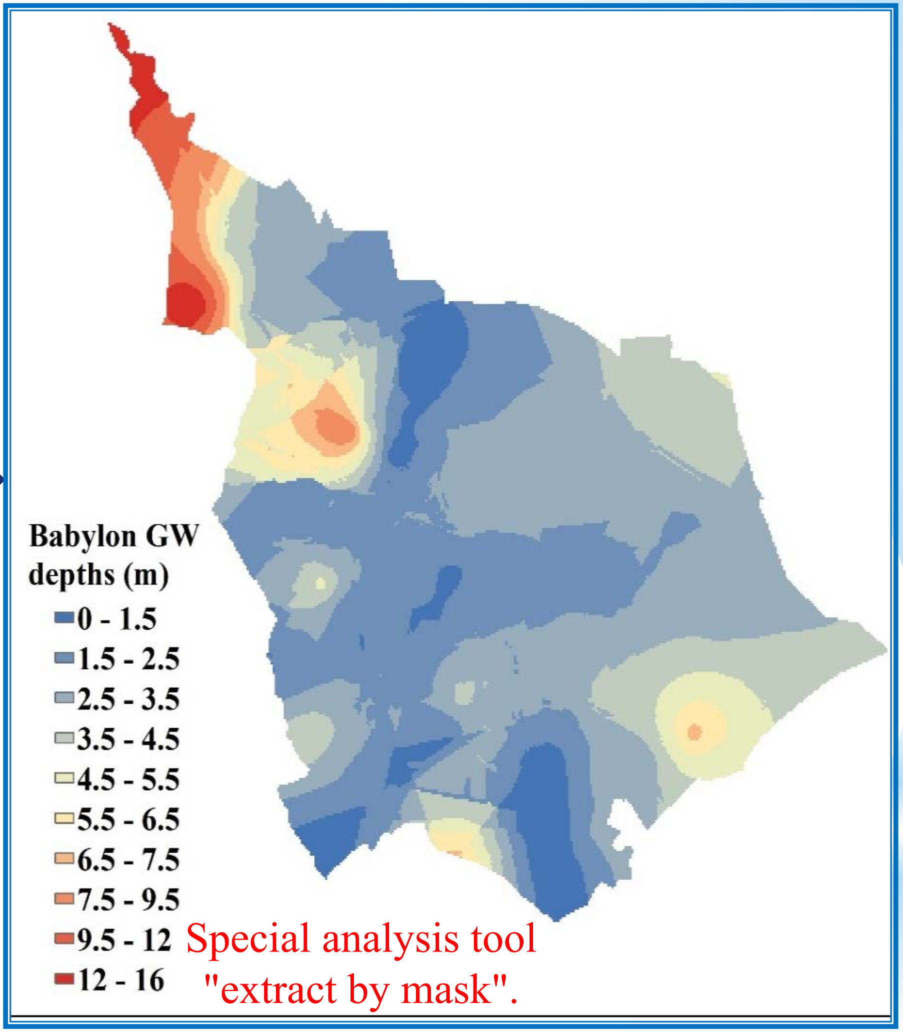
No.	Criteria	Al-Hillah Qadhaa	
		Sub-criteria values	Sub-criteria weights
1	Roads (km)	0 - 0.5	0
		0.5 - 1	7
		1 - 2	10
		2 - 3	5
		> 3	3
2	Villages (km)	0 - 1	0
		> 1	10
3	Archaeological sites (km)	0 - 1	0
		1 - 3	5
		> 3	10
4	Railways (km)	0 - 0.5	0
		> 0.5	10
…..	…………	…………	……….
…..	…………	……….	……….
15	…………	……….	……….

Methodology

c) 185 wells for groundwater depths.



Special analysis tool "Kriging".



Special analysis tool "extract by mask".

Map of GW depths after generating the interpolation between theses data.

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* **Table 4: Numerical scale of relative importance for pairwise comparison between each two factors *(Saaty, 2000)*.**

Intensity of Importance	Definition
1	The similar elements **(F1, F2, F3, F4)** have an equal importance
2	A equal to moderately importance over B
3	**F1** is moderate importance over **F2**
4	A is moderate to strong importance than B
5	**F1** is strong importance over **F3**
6	An activity of A is Strong to very strong importance over B
7	**F2** is very strong importance over **F4**
8	A is very to extremely strong over B
9	**F1** is extreme importance over **F4**

Pair wise comparisons matrix

Table 5: The example of pair wise comparisons matrix.

	Groundwater depth (F1)	Villages (F2)	Roads (F3)	Railways (F4)
Groundwater depth (F1)	**1**	3	5	9
Villages (F2)		**1**	3	7
Roads (F3)			**1**	5
Railways (F4)				**1**

Methodology → Analytic Hierarchy Process (AHP) method

*Table 5: The example of pair wise comparisons matrix.

	Groundwater depth (F1)	Villages (F2)	Roads (F3)	Railways (F4)	Eigenvector (Egi)	Priorety Vectors (Weights) (Pri)	λmax
Groundwater depth (F1)	A1=(1)	B1=(3)	C1=(5)	D1=(9)	Eg1	Pr1	λ1
Villages (F2)	A2=(1/3)	B2=(1)	C2=(3)	D2=(7)	Eg2	Pr2	λ2
Roads (F3)	A3=(1/5)	B3=(1/3)	C3=(1)	D3=(5)	Eg3	Pr3	λ3
Railways (F4)	A4=(1/9)	B4=(1/7)	C4=(1/5)	D4=(1)	Eg4	Pr4	λ4
Sum	$\sum_{n}^{i=1} Ai$	$\sum_{n}^{i=1} Bi$	$\sum_{n}^{i=1} Ci$	$\sum_{n}^{i=1} Di$	$\sum_{n}^{i=1} Egi$		$\sum_{n=4}^{i=1} \lambda_i$

aij=1/aji

$$Eg1 = \sqrt[n]{A1 * B1 * C1 * D1}$$

$$Pr1 = \frac{Eg1}{\sum_4^1 Egi}$$

The second part

Determination of the weights of criteria

The third part (consistency analysis):

$$\lambda max = (\sum_{n}^{i=1} Ai * Pr1) + (\sum_{n}^{i=1} Bi * Pr2) + (\sum_{n}^{i=1} Ci * Pr3) + (\sum_{n}^{i=1} Di * Pr4)$$

Principal eigenvector.

$$CI = \frac{\lambda_{max} - n}{n-1}$$

consistency index:
Which is equivalent to the standard deviation of evaluation error.

* **Consistency Ratio :** check the consistency between the resulted weights of criteria.

$$CR = \frac{CI}{RI}$$

* Where (RI): is the mean deviation of randomly for matrices with different size.

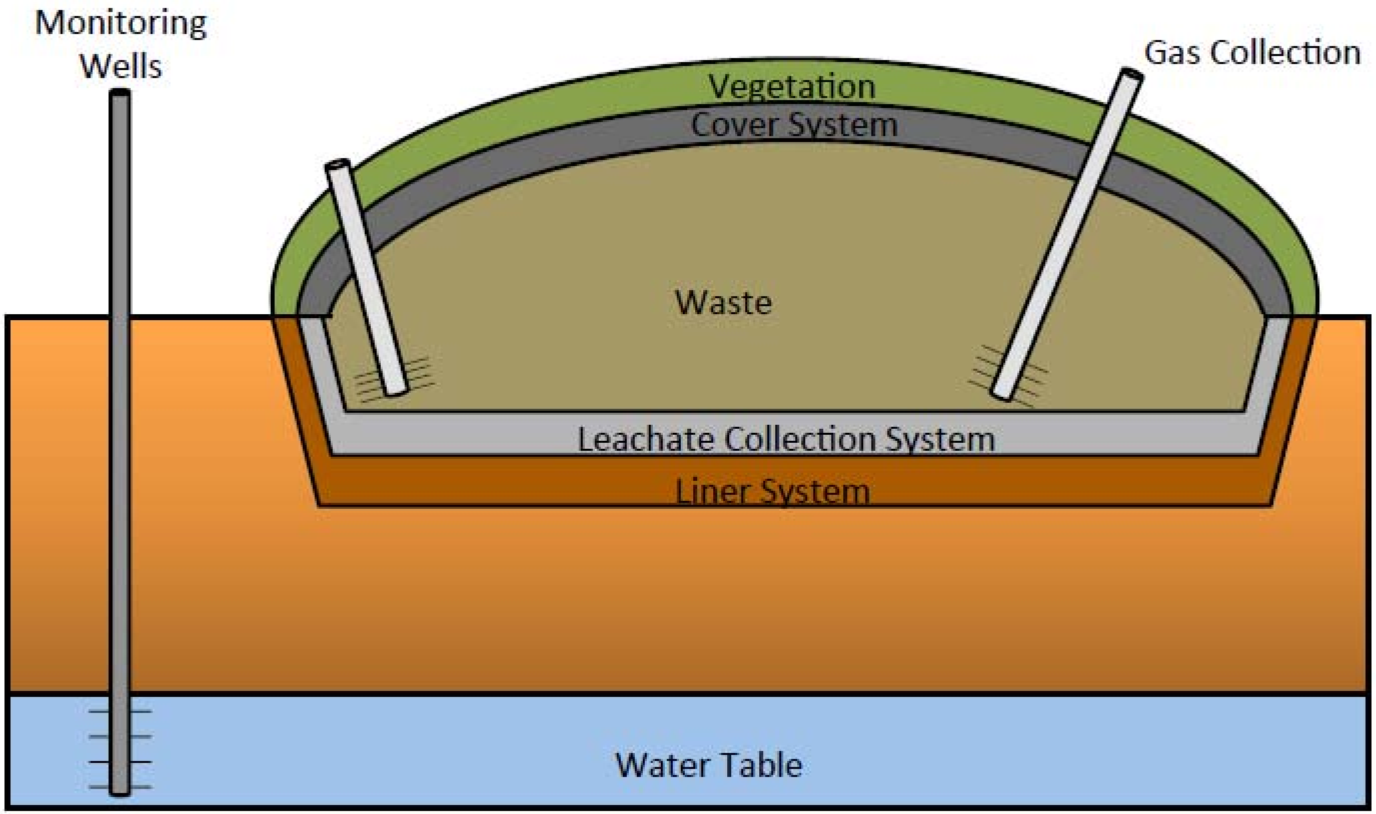
Table 6: Random inconsistency indices (RI) for the number of elements (n) (Saaty, 1980, Chang et al. 2007).

(n)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

* To know if the consistency is acceptable, the value of **CR should be smaller than 0.1**.

* In this study **CR** = 0.027 < 0.1.

Landfill Cross Section (simplified)



Compacted waste

In this study, there were two scenarios for placing the compacted waste on top of the protective layer over the surface based on bearing capacity of soil 50 KN/m2.

* The first scenario was 2 m of compacted solid waste.

* The second scenario was 4 m of compacted solid waste.

3. Accuracy assessment method (Kappa method) (applied in Al-Mahawil district).

The correlation matrix resulting from combining the final maps from the AHP and RSW methods.

Category	Ratio-1	Ratio-2	Ratio-3	Ratio-4	Sum
AHP-1	44682	3016	65	0	47763
AHP-2	0	659794	2051	60	661905
AHP-3	0	679	1709979	2564	1713222
AHP-4	0	0	998	604843	605841
	44682	663489	1713093	607467	3028731

$$K = \frac{N \sum_{i=1}^{r} X_{ii} - \sum_{i=1}^{r}(X_{i+} \times X_{+i})}{N^2 - \sum_{i=1}^{r}(X_{i+} \times X_{+i})}$$ (Cohen, 1960).

where:

N: Sum of cells number in the error matrix = 3028731

X_{ii}: Sum of correct number in row i and in column i = (44682+659794+1709979+604843) = 3019298

$(X_{i+} \times X_{+i})$: Sum of multiplying the sum for row i (X_{+i}) by the total for column i (X_{i+}).

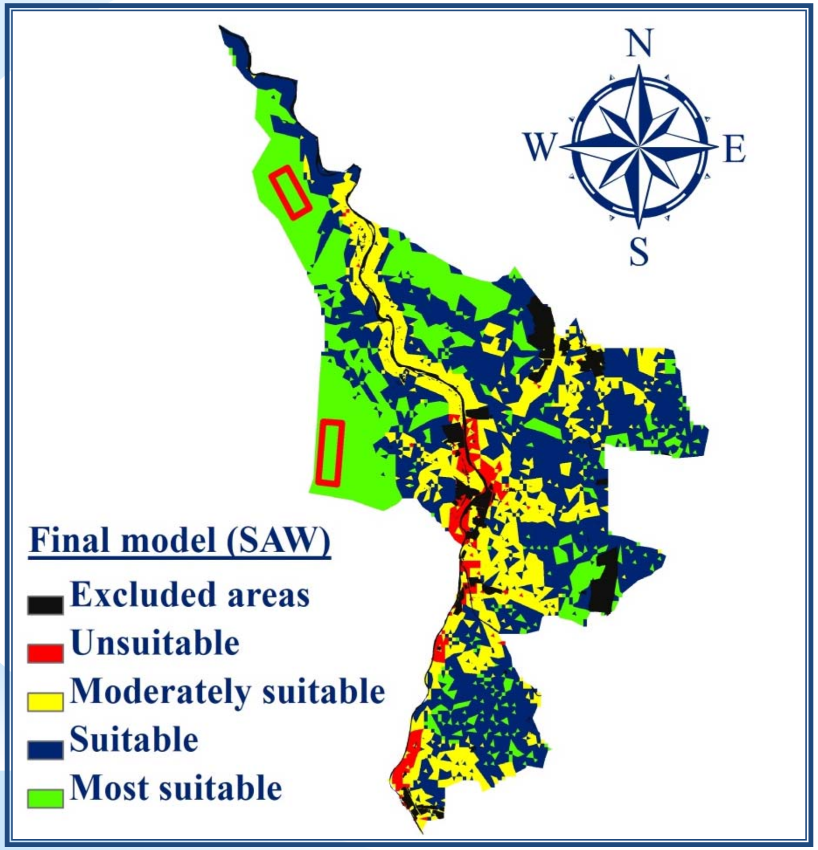
(47763 × 44682 + 661905 × 663489 + 1713222 × 1713093 + 605841 × 607467) = 3.74424E+12

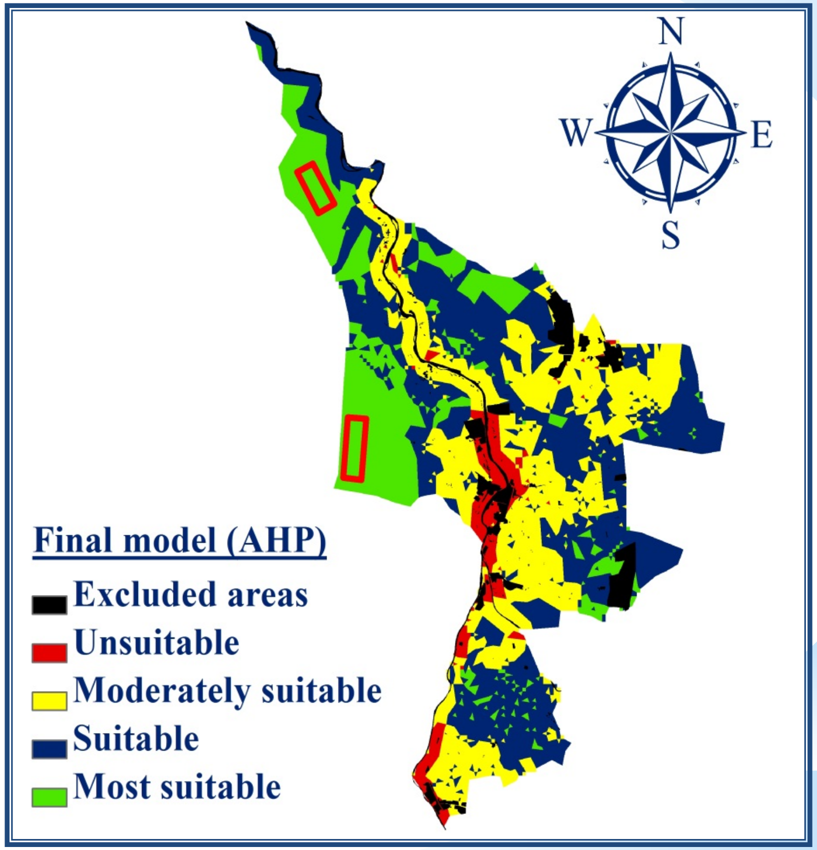
$$K = \frac{(3028731 \times 3019298) - (3.74424E+12)}{(9.17321E+12 - 3.74424E+12)} = 99.474\%$$

Results → Comparison methods

After combining the two final maps with their categories in GIS using the comparison methods.

EX. In Al-Musayiab district, the combination method was used for comparing between the two final maps of AHP and SAW methods.





Results → **Comparison methods**

Finally, the comparison map was created, and the pixels percentage of matching and non-matching for two maps were produced.