Assessment and Suitability Study of Landfills in Jordan, Al-karak using Geographic Information Systems (GIS)

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Abstract

The rate of waste generation is gradually growing due to population growth and urbanization in Jordan, and the increasing population at risk due to forced migration from neighbouring countries. By 2050, waste production will rise to 3.04 billion tons by 70% since 2016. Specially, that the most sites in Jordan do not comply with the scientific standards. That led this study to aim for creating a suitability map, based on conducting two technical methods and surveying three existing landfill sites located in the target area(Al-Karak, Jordan), in addition to suggesting new landfill sites using GIS. 15 criteria were tested socially, economically, and environmentally. Data and GIS data were collected from different local and international websites. Through a predefined scale of sub-criteria, the first suitability map was extracted by equal weight after combining buffering zones and inverse distance weighted (IDW) by applying Algebra map into Arch map. Also, overlay weight was adopted by taking various weights, according to previous studies and authors' point of view. Two suitability maps were extracted and classified into four classes relative to DOS (degree of suitability), mapped out every existing and potential landfills. The results of the equal weight suitability map showed that 45% of the area is inadequate and 7% is fairly suitable for landfill, whereas different weight suitability map showed that only 4% is inadequate and 6% is fairly suitable for landfill. Each method showcased different areas, this indicates weight plays a major role, and the low effects of soil weight may be a result of the negative difference ratio (41%) between the two approaches in an inadequate ranking. This study is important because it provide necessary data on the viability of new dumps site based on important factors, leading to future research and new techniques. Improved landfills suitability will positively influence the economies of Jordan and the municipal economies. Finally, the authors recommend a long-term sustainability policy to counter the harmful impact of burying.

1. Introduction

Landfills of the Municipal Solid Waste(MSW) is the most popular disposal method in Jordan and it's a common method in Turkey (Sener et al., 2010). However, choosing sites for landfill demand stringent requirements that take specific criteria into account (Vasiljevic et al., 2012). Decisions should therefore be addressed based on measurements that serve the decision-makers' purposes (Saaty, 2008). Choosing landfill sites is a considerably complex task as it directly affects the environment and public health (Akbari, et al., 2008). Migration from country side into urban areas is the main cause of over population and high urbanization rates in addition to the increasing of services and employment opportunities in cities, especially in developing countries, which in turn resulted in a high MSW rate (Aljaradin, 2010). Municipal solid waste is classified as solid and semi-solid materials derived from homes and residential complexions, beside other waste materials related to the prior in terms of its nature and composition (offices, public institutions, commercial activities, etc.) (Jordan Green Buildings Council 2016).

MSW is considered as an expression of changes in lifestyle and social trends, especially with their rapid increase in China (Pla, 2015). The administration of Jordan Lacks any current legal waste management framework . About 2 million tonnes of MSW in Jordan are generated each year and buried into insalubrious landfills (EcoMENA, 2012). Dumping sites in Jordan have serious impacts on the environment and natural resources that their administrations do Not take into account. Typically, many waste disposal sites receive medical or industrial waste without treatment, and in other situations, waste gets incinerated out in the open, which damages the entire ecosystem.

The correct selection and maintenance of appropriate sites lead to a sustainable environment, therefore, Geographic Information Systems (GIS) has been used in study preparations that arerelated to assessing existing sites and how to operate them with high efficiency and lower cost. The study also addressed GIS utilization with several criteria to be used for the evaluation of acceptable dumping sites. Many authors have used GIS technology to assess possible landfill locations and a lot of researches results show that GIS has been commonly applied in waste management systemsaround the world, (Shahabi et al., 2014) focused on GIS through 13 layers to decide on an acceptable site, the chosen technical methods are Boolean, Weighted Linear Combination (WLC), Analytical Hierarchy Process (AHP). The created models illustrate that Boolean logic had lower credibility and flexibility rates than WLC and AHP. Decision-making skills have improved due to a wide variety of classification and practical practice that can be carried out to minimize economic and environmental costs. The WLC approach uses weighting to allow the decision-makers to use the key variables that would have the greatest effect on choosing the best location. (Yesilnacar et al., 2011) revealed that the conventional expert-based approaches have not always been able to test limitations at the same time, and therefore map replication is restricted as parameter maps are evolving rapidly over time. As the authors used GIS with Multi-Criteria Decision Analysis (MCDA) to select possible landfill location and compared to the original one. (Mussa et al., 2019) used AHP to obtain weights for each 10 selected criteria; this weight derivation method was used to compare two parameters at a time based on expert judgment and a pair-wise evaluation matrix. The outcomes of this study proved that by using AHP and GIS for the selection of suitable sanitary landfill sites; thus reducing environmental and human health issues.

2. Background

In Jordan, the effect of waste is more severe due to financial and natural resources (Al-Ansari et al., 2012). The studied city is shown in Figure 1; it suffers from the issue of not implementing all the criteria in selecting the most suitable landfill site. There are three solid waste dumps in the city, the largest of which is the Allajoun landfill, 488 acres, located 10 kilometers on the east side of Al-Karak on the Al-Karak-Al-Qetraneh road. It was established in 1996 and expired in 2006. This landfill is considered to be an environmental issue, presents many dangers, such as the spread of many infectious and dangerous diseases, since it emits unpleasant odors due to the regular burning of 150 tons in average of waste inside the landfill, which harms travelers on the main road that links the city to the desert road (road linking the city to the capital).

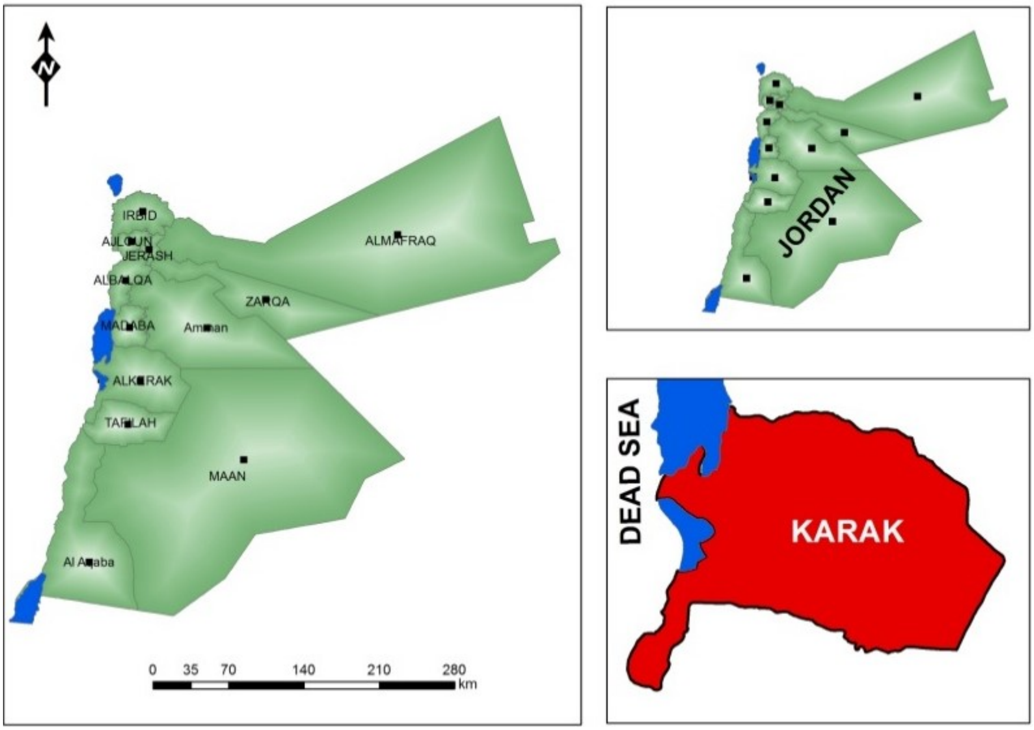


Figure 1: Location of Al-Karak City in Jordan

Albreka and Alsomer landfills are located in Al-Aghwwar Al-Janoobieh, where they represent sanitary and environmental issues due to the process of direct waste burning which produces toxic gasses are dispersed by wind. According to Jerie, (2017) researcher combined both quantitative and qualitative approaches. The author depended on the basic idea that such an arrangement makes more systematic data use than the distinctive compilation and analysis of quantitative and qualitative data separately. The major steps had implemented digitizing, buffering, overlaying, suitability maps against studied parameters. The results of the previous study show that GIS and remote sensing (RS) are invaluable tools for urban planning and problem-solving in evaluating the suitability of the existing dumpsites.

Many researchers have used weighted overlay analysis in GIS for selecting multiple functions to achieve corresponding results. Kuru et al., 2018 applied weight overlay to study the suitability of existing municipal landfill sites using GIS. The score of sub-criteria were determined (10% slope, 8% aspect, 13% land use, 7% erosion, 10% hydrology, 11% geology, 10% land use capability, 8% proximity of built-up environment, 14% proximity of transportation, and 10% proximity of urban facilities). The results of used weight overlay showed that the suitable areas were located in the northeast and northwest regions in the studied city and these results give standards for planning studies in futures. Carvalho et al., 2007 used three methods in GIS to compute vegetation vulnerability models. The first approach introduced is weight overlay, and the authors clarify reasons for using this strategy because they find it simple and the relative weight can describe the importance for each included variable. Meirelles et al., 2007 note that the use of weighted overlays requires the use of expert information and the modification of each variable's intrinsic characteristics in the model. The other approaches used by Carvalho et al., 2007 are fuzzy logic and neural networks. Fuzzy-based strategies are similar to weight overlay in modeling, with the advantage of the more flexible rules for the combination of the second method but the interval is between [0,1] for class values. The authors defined the weights through convex sum because the effects of the measures are not similar. For example, the subgroups of $A_1 \ldots A_k$, and non-negative weights of $w_1 \ldots w_k$ so the combination is shown below in Equation 1:

$$UA\Delta \sum wjUAj \qquad \text{Equation 1}$$

Where:
U_A=Fuzzy membership level
w_j= Weight($\sum wj = 1$)

This research will therefore concentrate on identifying the criteria for proper planning of solid waste landfills using algorithm techniques to design suitability models and to propose new places based on a selection of conditions and criteria. This research aims to achieve the following goals:

1. Are the current landfill sites in Karak Governorate suitable?
2. Are there standards and requirements for selecting suitable sites for landfills?
3. Where are the best locations in Al-Karak to suggest new landfills according to international standards and terms?

2.1 Literature Review

Ekmekcioglu et al., (2010) have conducted a fuzzy TOPSIS method to suggest disposal sites for the MSW in Catalca in Istanbul. A set of criteria were optimized as pollution, cost, feasibility, reliability, energy recovery, and emission and waste levels to find the best disposal MSW method. The authors relied on specific alternatives such as composting, and incineration of refuse-derived fuel (RDF). Weights assessment was carried out by the method of the Analytic Hierarchy Process (AHP). The results of the study found that RDF is the best alternative disposal method and the significance of weights when assessing the optimal location of dumpsites. Another study in Sekondi-Takoradi city in Ghana has used the same approach of the previous study of Multi-criteria Evaluation (MCE) and Fuzzy Logic method in order also to determine the suitable landfill sites where the analysis was restricted to criteria which are especially relevant for the site (Bilintoh and Stemn, 2015). A study focused on the AHP method and GIS to analyse eight criteria (geology, distance from settlements, distance from road networks, distance from Water bodies, vegetation, slope, elevation and aspect) for landfill selection in the municipality of Nevesinje in Srpska. The results of the suitability index show that 67% of the land belongs to the restricted area, 11%, 6.1%, and 5.9% belong to low, moderate, high suitability respectively, and very high suitability associated with 10% of the land. Furthermore, the authors conclude that more criteria should be investigated before choose the final sites, and this will be better to ensure an optimal location for their final landfill location (Sekulovic and Jakovljevic, 2016).

Results of a study conducted in Bardaskan city, Iran has motivated municipality officials to select the best location of landfills among several locations. The authors added that this study is useful for decision-makers to make appropriate decisions that reduce costs in economic and environmental standards as half of the study(51.97 %) area was not suitable and just (7.8%) is suitable for the landfill site using Fuzzy Logic with GIS analyzing (Khorram et al., 2014).

Each region has certain factors that satisfy its nature so is not required to consider all the combined factors where Younes et al., 2015 results study shown that the two most influential factors to achieve preferences on landfill site requirements are the topology of the land and surface water distance. Manoiu et al., 2013 have taken Euclidean distance to eliminate buffer zones to deiced landfill suitability in Prahova County, Romani. Barakat et al., 2017 investigated suitable landfill sites using GIS methods for multi-criteria evaluations. They categorized municipal landfill locations into five groups ranging from not suitable to highly suitable. Their study revealed that 54% of the study area was not suitable for landfill sites and just 10% is highly acceptable for disposal. Also, Pasalari et al., 2019 have examined 15 criteria in Iran as same as some of the studied criteria in this research with different ones as a protected area, fault in an environmental group, airport, village, infrastructure, and historical area. Alanbari et al., 2014 investigated criteria as pipes, energy lines, oil pipes, fluid gas pipes, and railways, etc to decide the best landfill sites.

2.2 Materials

The first stage of preparing the suitability map was to define the criteria to select the best sites for waste disposal in Al-Karak province. 15 criteria were selected according to the public local authorities' guidelines in Jordan and comparative research analysis of other quality criteria for landfills projects. The criteria contain residential and main roads, green areas, existing dumps, water bodies, soil, slope, land use, rain, temperature, and aspect. The digital form of the analytical approach was adopted in GIS (ArcGIS 10.3) through digitizing every criterion into a layer in raster form. The buffer zone was adopted to reclassify the criteria based on distance in a polygon shape. The interpolated raster for such criteria was implemented according to the IDW technique. Spatial analysis tools in GIS were adopted using Map Algebra to establish the integrated model of suitability map.

2.3 Data

The data was collected from official institutions as the Royal Jordanian Geographic Centre, Ministry of Agriculture, Ministry of Water, Ministry of Public Works, and Natural Resources Authority related to the study. Sources of data varied depending on the minor field of sub-criteria as shown in Tables 1-4.

Table 1: Classification of economic and social criteria by different factors

Minor Criteria	No.	Source	Minor criteria	Scale	DOS
social and economic	1	The European Bank for Reconstruction and Development (EBRD, 1991)	Distance from residential areas	>1500m	(1) <1500m
					(4) >1500m
	2		Distance from main roads and streets	>500m	(1)<500m
					(4)>500m
	3		Distance from agricultural land	It is safer to stay out of arable land and to choose landfill operation on low-value land	(1)Arable land
					(4) Non Arable land
	4	Department for Environment, Food and Rural Affairs, 2010	Distance from green areas and gardens	It is safer to stay away from green lands and gardens to make better use of them	(1)Green Areas
					(4) Nom Green Areas
	5		Distance from existing dumps	Existing landfills should be kept away from and choose locations close to waste generation centers to reduce cost and time	(1) <1500m
					(4) >1500m

Table 2: Classification of environmental by different factors

Minor Criteria	No.	Source	Minor criteria	Scale	DOS
Environmental	6	Alshmoli Amman plan(Greater Amman Municipality, 2007-2008)	Distance from valleys and torrents	>100m	(1) <100m
					(4) >100m
	7		Distance from springs	>360m	(1)<360m
					(4)>360m
	8		Distance from dams	>360m	(1)<360m
					(4)>360m
	9		Distance from wells	>360m	(1)<360m
					(4)>360m

Table 3: Classification of geology and morphology by different factors

Minor Criteria	No.	Source	Minor criteria	Scale	DOS
Geology and morphology	10	Basel Convention Regional Center For Training & Technology Transfer For The Arab States In Egypt (BCRC-CAIRO, 2005a)	Topography and slope ratio	Low-slope areas are preferred with ideal ratios of 1-5% and not appropriate for more than 25%	(1)>25%
					(2)10-25%
					(3)6-10%
					(4)1-5%
	11	(Yazdani et al., 2015 and Eskandari et al., 2015)	Soil	Preferred soil with low permeability	(1)>25%
					(2)12.7-25%
					(3)2-12.7%
					(4)<2%
	12		Geology of the region	Rock and desert areas are preferred	(1)Holocene
					(2)Sandstone
					(3)Limestone
					(4)Basalt

Table 4: Classification of climatic by different factors

Minor Criteria	No.	Source	Minor criteria	Scale	DOS
climatic	13	Alshmoli Amman plan(Greater Amman Municipality, 2007-2008)	Amount of rain	Preferred dry areas with less rain for a lower level of succulents	(1)>350
					(2)25-300
					(3)300-350
					(4)50-250
	14		Temperature	Preferably high temperature areas where the amount of evaporation is high	(1)>32
					(2)32-36
					(3)36-38
					(4)38-42
	15	(BCRC-CAIRO, 2005b)	Mountain slopes direction	Areas opposite to wind direction are preferred, particularly in areas close to the population	(1)202.5
					(2)160 -202.5
					(3)22.5-160
					(4)0-22.5

2.4 Study Area

The study area Al-Karak city is located in the south of Jordan as shown in Figure 2. It is located between two longitudes 35°19′48″and 36°13′12″and between two latitudes 30°49′24″and 31°24′36″ (Google Earth). The total area of the Governorate is 3495 km2 according to (The Department of Statistics, Jordan). The Governorate has faced a rapid population increase due to economic activities and forced migration, the population of the Governorateis 316,629 people with an average annual growth rate of 3.7% between 2004 and 2015. It consists of seven states and three districts. It is limited to Amman (capital of Jordan), and threeGovernorates: Madaba, Tafila, and Ma'an and to the Dead Sea at the west. The Governorate consists of seven states and three districts. There are three existing landfills received from Al-karak municipality:

(i) Albreka dumpsite located in Gore Al-Mazraa District in Al-Aghwwar Al-Janoobieh with coordinates (35°29'15.30″ E; 31°14′3.07″N).

(ii) Alsomer dumpsite located in Al-Aghwwar Al-Janoobieh with coordinates (35°28′37.67″E; 30°58′55.81″N).

(iii) Allajoun which located in Allajoun area in Al-Qetraneh with coordinates (35°56′32.06″E; 31°13′16.28″N), as seen in Figure 3. All locations are projected in WGS84.

Figure 2: Location of Al-Karak City with main states inside it

Figure 3: Location of existing dumpsites in Al-Karak

3. Methodology

The study aims to comprehend the relative significance of each sub-criterion in the identification of the most possible sites for landfills. Respective maps and information identified criteria were taken from various related organizations. All of these maps were digitized and converted from vector to raster form as polygon shapes as presented in Figure 4. Population sites and roads were extracted from the topographic map. Streams and springs were extracted from Spatial Analyst Tool in Hydrology using Basin, Stream link. Dams and wells were allocated as points according to each location. Land use map was stretched using vegetation index in layer property from -0.43 (low vegetation) to 0.64 (high vegetation). Also, Rain and Temperature maps were reclassified into legend form ranging from 50 to 400mm and from 31° to 42°. Soil temperature map was categorized into three classes. Permeability of soil was classified from <2 to >25.

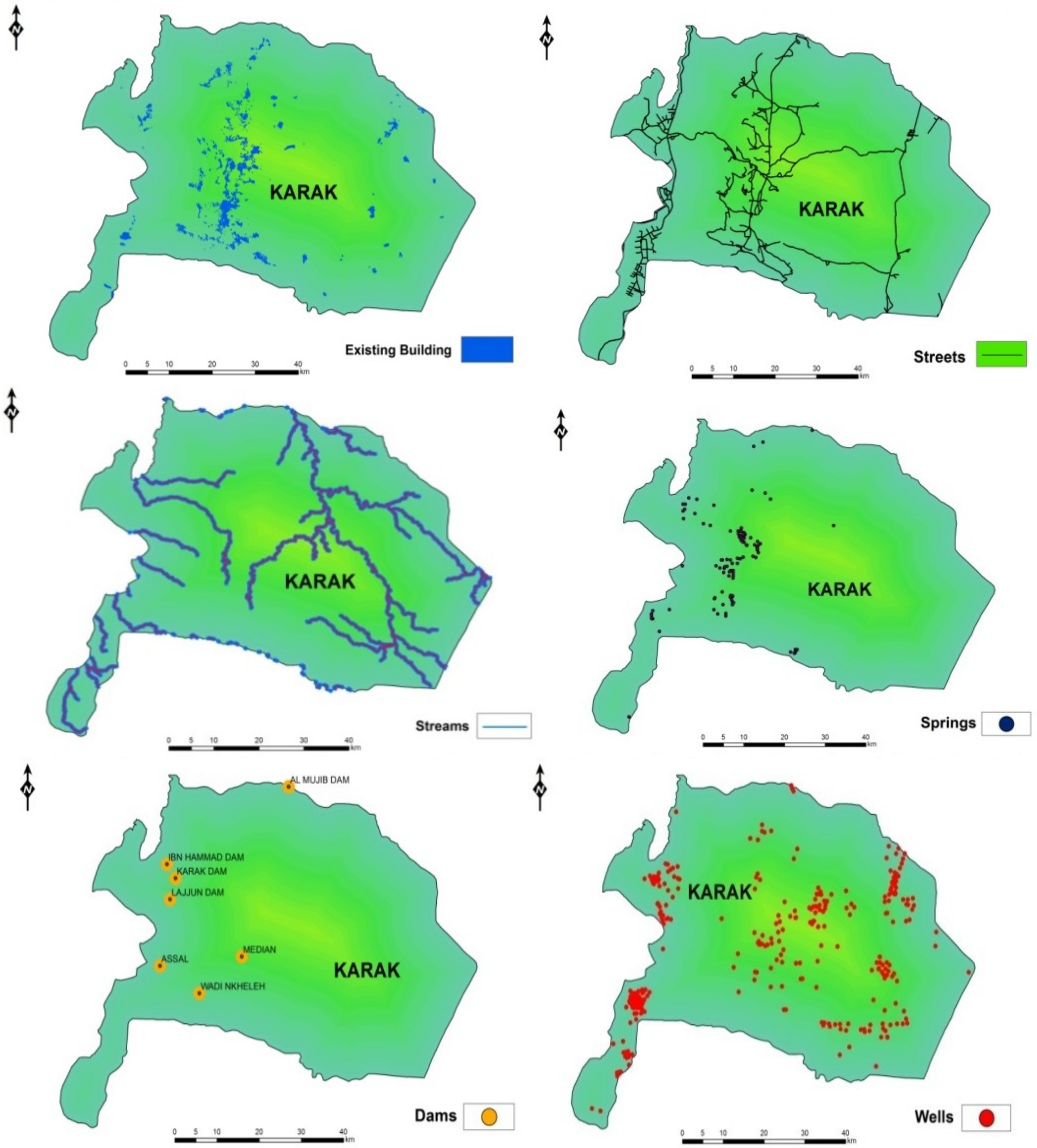


Figure 4: Raster maps of all criteria (continue next page)

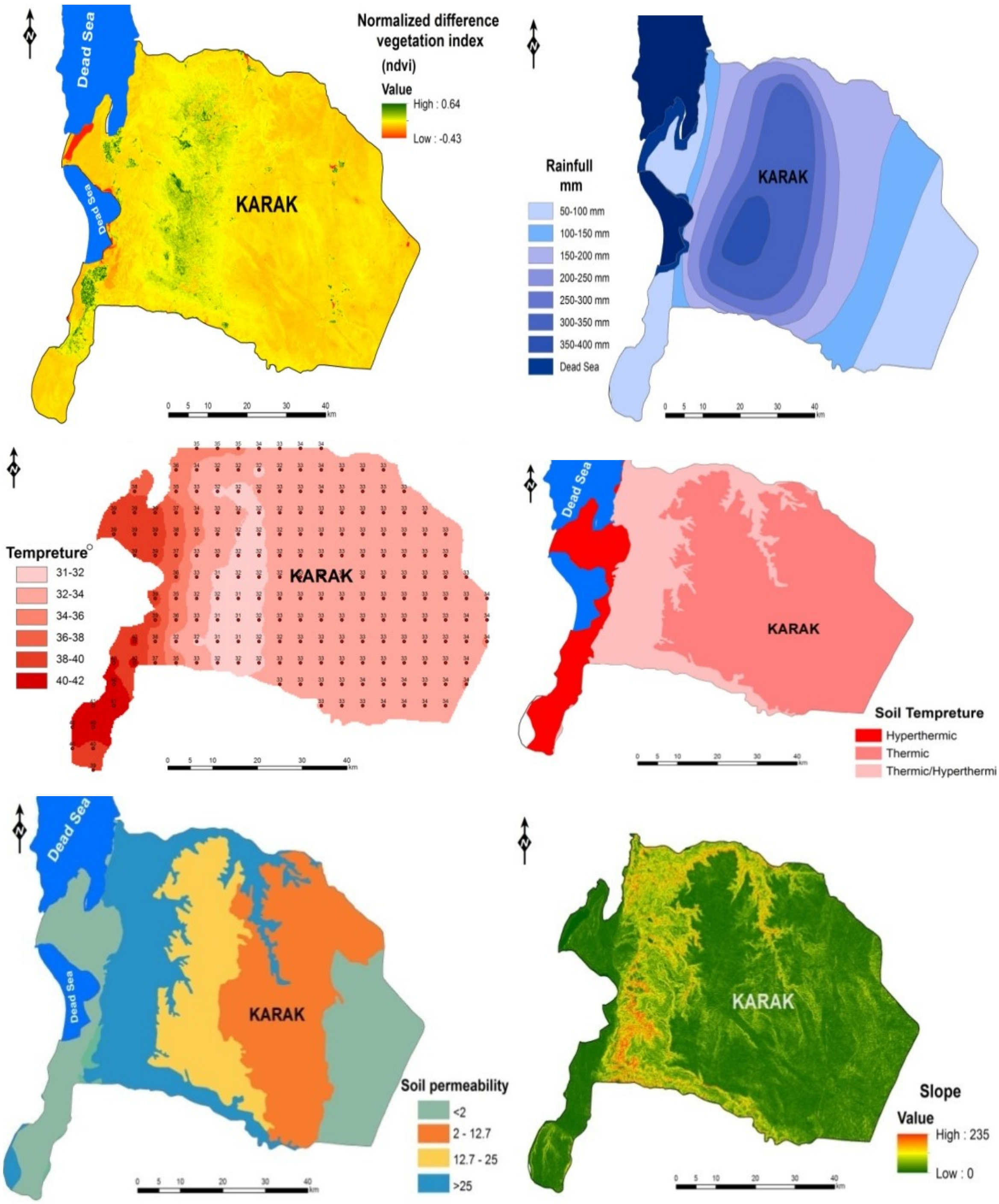


Figure 4: Raster Maps of All Criteria (continue next page)

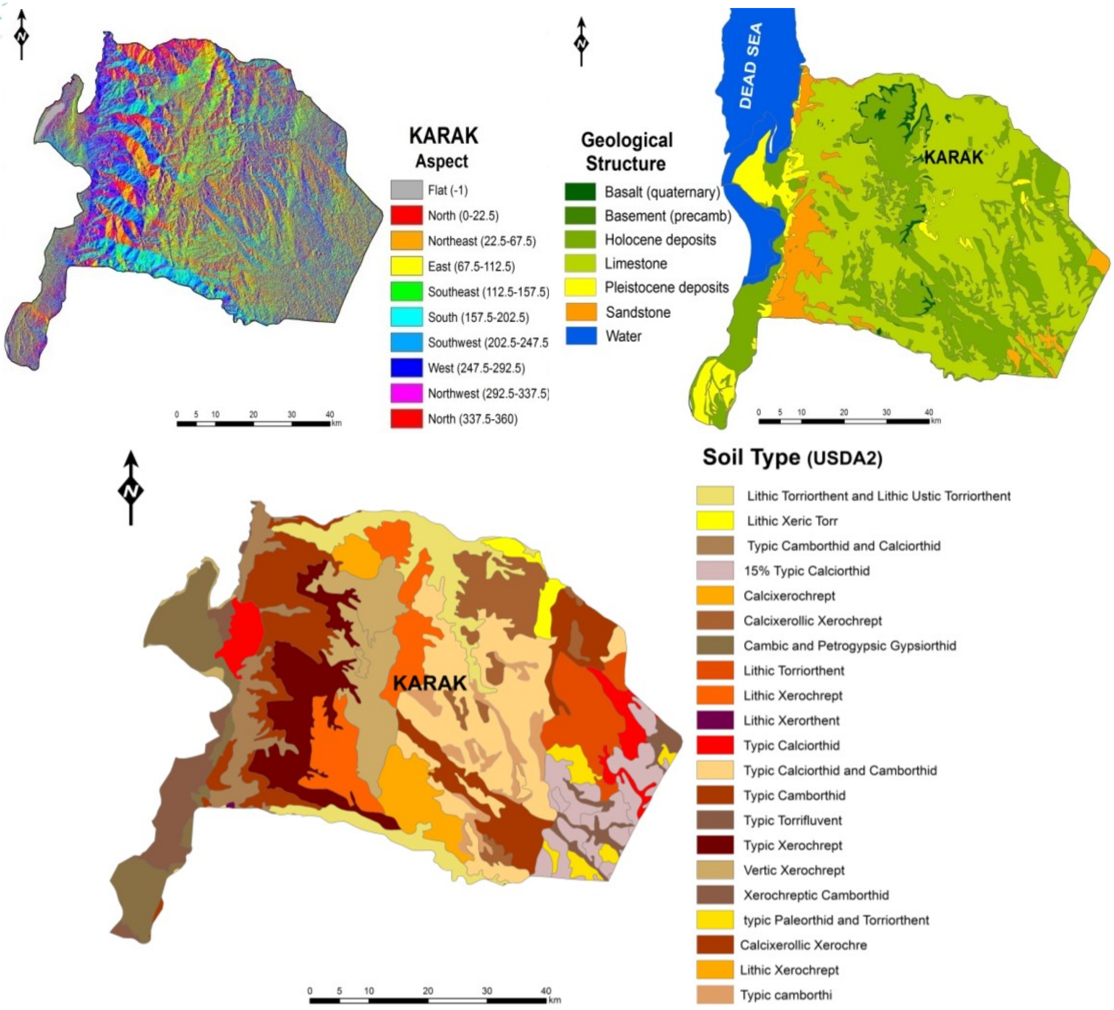


Figure 4: Raster maps of all criteria

Table 5: Soil permeability classes

Soil permeability classes	Permeability Rates (cm/hour)
Very Slow-Slow	<2%
Moderately Slow-Moderately Rapid	2-12.7%
Moderately Rapid-Rapid	12.7-25%
Very Rapid	>25%

The main soil classes are also classified into 21 types. The slope of the area was extracted from the Digital Elevation Model (DEM) in ArchToolbox and taken from 0 (low inclination) to 235 (high inclination). Another sub-criteria also extracted from DEM was aspect and listed from, flat (-1) to the north (360). The last parameter that was converted to the raster map was the Geological map and classified into 7 types. In linear and grid analysis, the following is developed:

- The Euclidean Distance function has been used which provides a geographical precinct or sphere of control to a particular object on the earth's surface over the area surrounding it based on a certain distance to remove these distances from the analysis.
- The reclassification function is useful for cell reorganization and distribution. This task makes the work easier with standard map in the layout, thus the parameters are classified, the most suitable cells are given the rank 4 and the least suitable is the rank 1 according to the Common Scale(from 1 to 10), resulting in the reclassification of each level and the automatic inclusion of a new layer to the system interface. The flow charts are shown in Figure 5 explain the basic phases of the used method.

- Overlay Weight function can connect all the factors and variables that influence the identification of the best sites by analysis and collection of their weights. Two maps were produced, equal weights were taken on the first map. Based on the previous results from the first map, a different map was created, and higher weights were given to specific factors based on previous studies and the importance of the factor from the point of view of the researchers

The assignment of integrated weights was dictated according to their suitability as a product of the weights assigned to the different layers. Higher weights are given to the residential, location of existing landfills, land use, and water body. This method allows for more flexible combination of different parameters and weights. The weighted suitability technique is designed using GIS to suggest sites suitable for applying the target objective on a variety of thematic levels and based on the Multi-Criteria Assessment theory. Each raster map is reclassified by weight according to the importance of each unit and finally compute the final weight by adding them to extract the approximate values for each position, this can be described by Equation 2(Eastman, 2001).

$$S = \sum Wi \times Xi$$

Equation 2

Where:
Wi = The weight of ith factor
Xi = Criteria score of ith factor
S =Suitability index
In this study, the total weight model is interpreted as shown below in Eq.3 (the total weights must be equal to 100% as shown in Table 6.

$$SM=10X1+9X2+4X3+7X4+10X5+8X6+5X7+8X8+8X9+6X10+6X11+4X12+5X13+2X14+8X15$$

Equation 3

Where:
X=The weight of factor
SM=Suitability model in the map

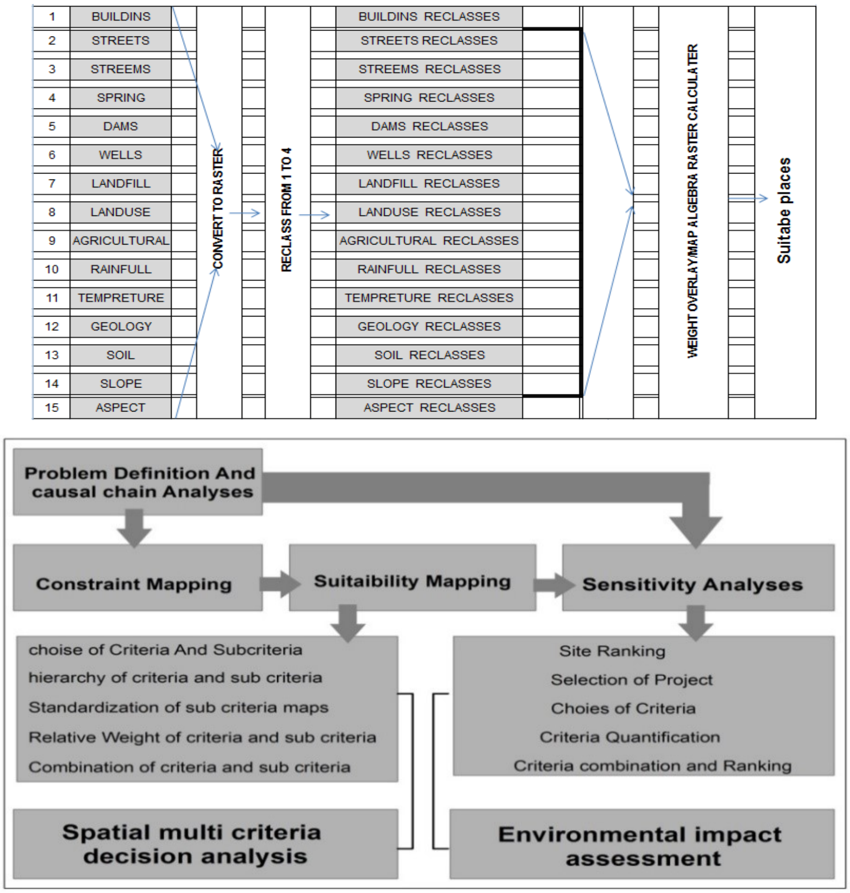


Figure 5: Flow charts of the study

Table 6: The relative weight of the major factors

No	Factors	Sub – Factors	Weight Overlay 100
X1	Social and economic criteria	Buildings	10
X2		Land use	9
X3		Agricultural	4
X4		Streets	7
X5		Landfill	10
X6	Ecology criteria	Dams	8
X7		Wells	5
X8		Spring	8
X9		Streams	8
X10	Climatology criteria	Aspect	6
X11		Rainfall	6
X12		Temperature	4
X13	Geology criteria	Geology	5
X14		Soil	2
X15		Slope	8

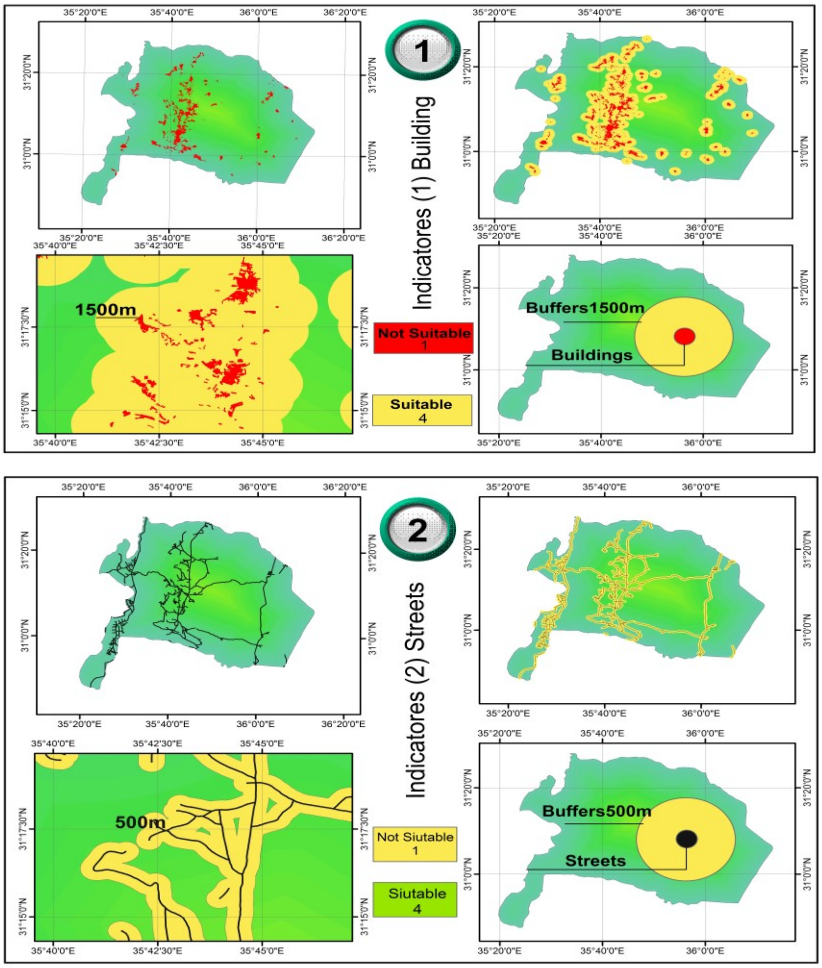


Figure 6: Buffer Raster for Population and Roads

3.1 Buffering Map Zone

A buffer area is a protected area that can reduce the effect on delicate areas or natural features of land use activities separated by grade (Alkaradaghi et al., 2019). Proximity Analysis was used to establishing buffer zone maps for all criteria except slope, Soil, Geology, rain, temperature, and aspect. A distance equal to 1500m, 500m from the margins of residential and road was performed as demonstrated in Figure 6. A buffer zone of 1500m was given to existing dumpsites as shown in Figure 7. The other parameters (agricultural land, green areas, rain, Temperature, Geology, soil, and slope) were classified according to the graduated color from 1(not suitable) to 4(suitable) as stated in Figure 8.

4. Result

The purpose of this study was to assess the current landfill sites in the studied city and to determine the optimal sites for new landfills. 15 standards were used to identify the best location. All requirements were displayed as a digital map. These criteria were generated using Map Algebra from Spatial Analyst Tools in order to extract the final map. The final map was classified into four classes distributed from not suitable to very suitable. Figure 9 identifies the suitability of landfill sites in the city by an equivalent weight for each factor. To achieve the final map form, a group of standardized maps has been integrated with specific requirements. Red circles in the figure below presented the location of the existing landfills. A new map was generated using various weights for factors as seen in Figure 10. The results indicated significant differences between two maps, the proportion of very suitable and not suitable fractions in equal relative weight are more than different relative weight technique.

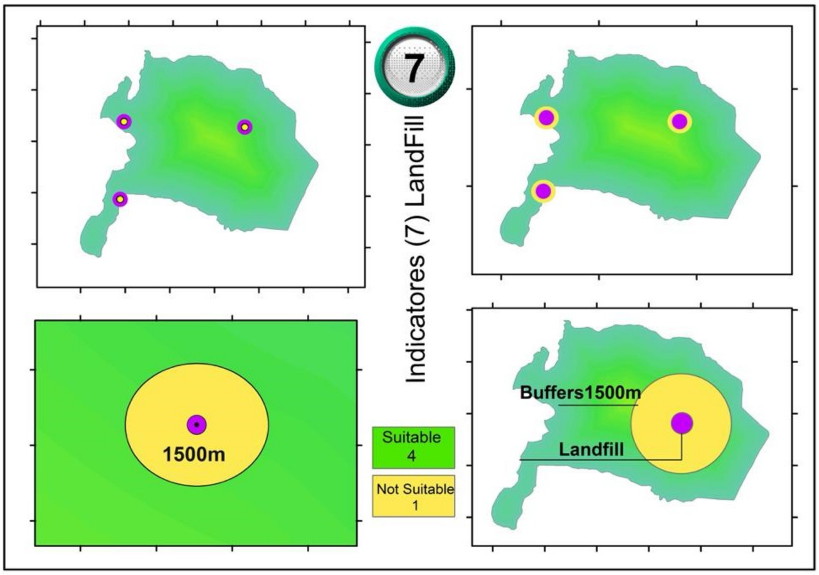


Figure 7: Buffer raster for existing dumpsites

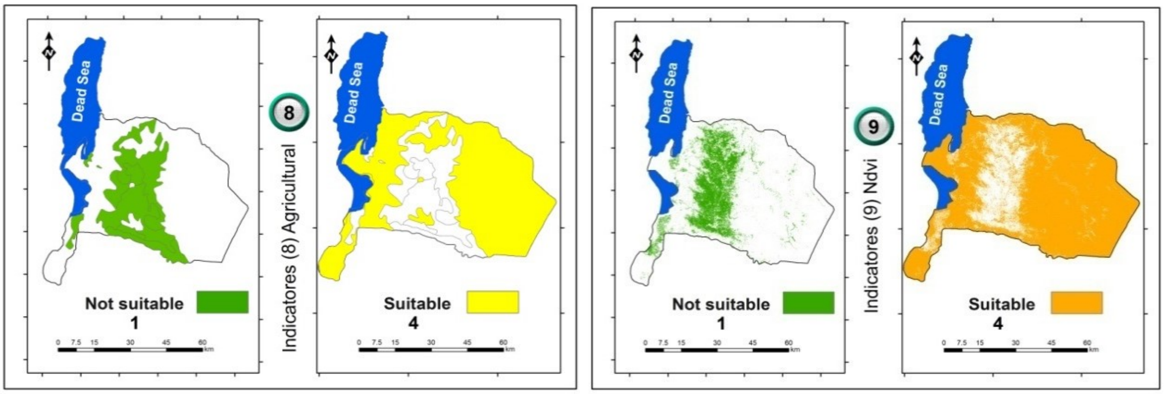
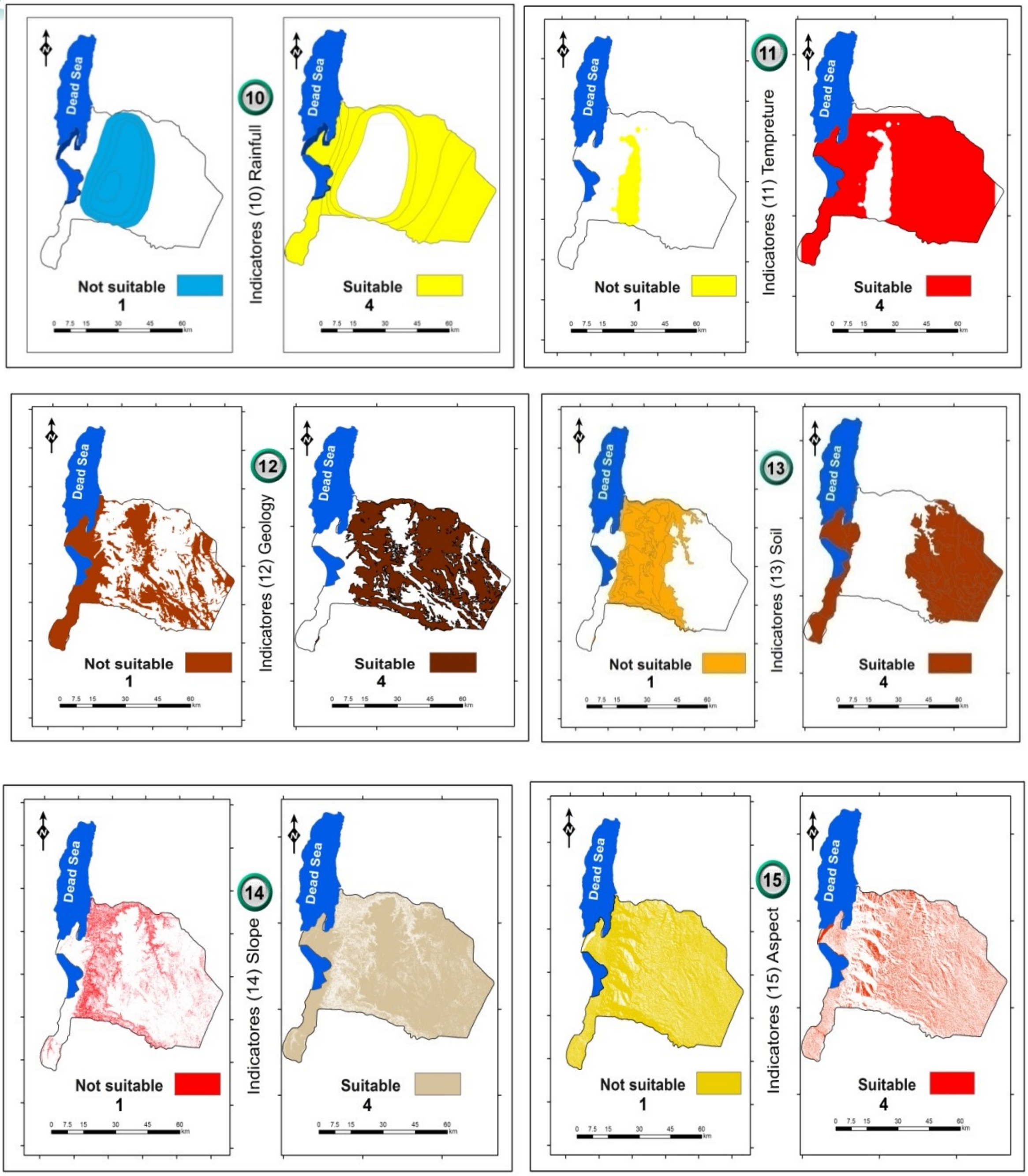


Figure 8: Graduated raster maps accodeing to their sutability (continue next page)



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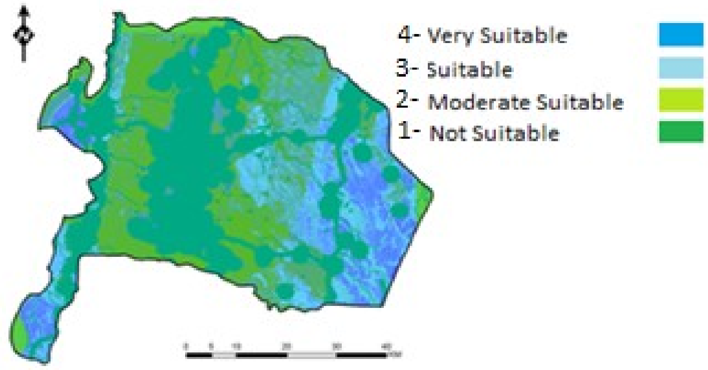

Figure 9: Final suitability map based on equal weights

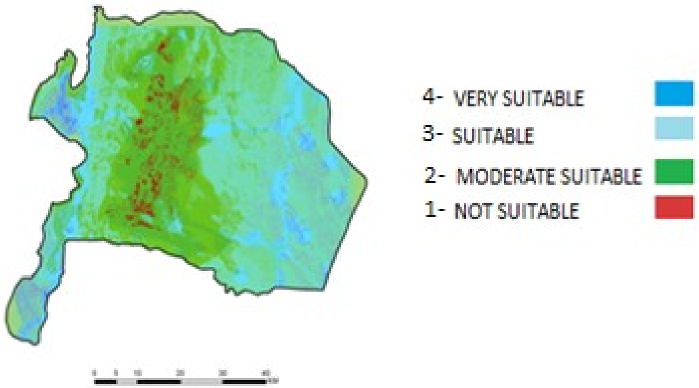

Figure 10: Final suitability map based on different weights

Table 7: Areas according to DOS

Suitability	Area (equal weight) (km^2)	Ratio (%)	Area (non equal weight)(km2)	Ratio(%)
Very suitable	259.287	7.36	204.91	5.82
Suitable	490.088	13.92	1928.98	54.78
Moderate suitable	1193.329	33.89	1248.40	35.45
Not suitable	1578.795	44.83	139.21	3.95

This demonstrates the deviation in accuracy among the two strategies in suitability models. According to Table 7, the areas classified as very suitable for a landfill in the equal and non-equal weights maps are approximately close(7%,6%) respectively. Also, in the moderate suitable class, the ratios are also slightly close(34%, 35%). But the major difference is in suitable and non suitable portion as the divided proportion of suitable class between non-equal and equal weights maps is 4% and 0.09% of the non suitable class. Every current landfill in the city was scaled according to their location in suitability maps as illustrated in Tables 8-10. From Table 8, the nearest spring appears to be the Allajoun spring (7 km), the nearest dam is Lajjun dam (24km) while the closest dam after Lajjun dam is Al-Mujib dam and is even further (28km), and Allajoun well further away(0.4km). From Table 9, it reveals that the closest spring is Ain-Alrushha spring and is located roughly (4.5 km). Also, the nearest dam is the Lajjun dam (6.9km) and the nearest well is Karim Al-Majali well (3.2km). Finally, Table 10 determines the location of the landfill site of Alsomer, the nearest spring is Umm-Hakim Spring (3km), the nearest dam is Wadi-Nkheleh(16km), the nearest well located(2.2km) and at present, it's an unused well, but the distance from working well is (3.4 km). Proposed sites of the landfill were suggested in UTM ZONE 36 projection system (Figure 11), site1 coordinates are X=794385.2931, and Y=3443730.033, and site2 coordinates are X=727601.5225, and Y=3419419.5986. Suitability classes of proposed landfills are shown in Table 11.

Table8: Class of suitability according to classification for allajoun landfill

Criteria	Value	DOS
Distance from residential areas	7130m	4
Distance from main roads and streets	1402m	4
Distance from valleys and torrents	2980m	4
Distance from springs	7410m	4
Distance from dams	23870m	4
Distance from wells	415m	4
Distance from existing dumps	43180m	4
Distance from agricultural land	9420m	4
Distance from green areas and gardens	6390m	4
Amount of rain	150-200mm	4
Temperature	32-33°	2
Geology of the region	Limestone	3
Soil	2-12.7%	3
Slope	15%	3
Mountain slopes direction(Angle)	36.57°	3

Table 9: Class of suitability according to classification for albrekalandfill

Criteria	Value	DOS
Distance from residential areas	3150m	4
Distance from main roads and streets	578m	4
Distance from valleys and torrents	4230m	4
Distance from springs	4550m	4
Distance from dams	6920m	4
Distance from wells	3220m	4
Distance from existing dumps	28110m	4
Distance from agricultural land	3580m	4
Distance from green areas and gardens	2590m	4
Amount of rain	50-100mm	4
Temperature	38-39°	4
Geology of the region	Holocene deposits-Pleistocene deposits	2
Soil	<2%	4
Slope	3.9%	4
Mountain slopes direction(Angle)	263°	1

Table 10: Class of suitability according to classification for alsomer landfill

Criteria	Value	DOS
Distance from residential areas	3930m	4
Distance from main roads and streets	1370m	4
Distance from valleys and torrents	2550m	4
Distance from springs	2840m	4
Distance from dams	15940m	4
Distance from wells	3420m	4
Distance from existing dumps	27910m	4
Distance from agricultural land	1000m	3
Distance from green areas and gardens	1045m	3
Amount of rain	50-100mm	4
Temperature	37-40°	4
Geology of the region	Holocene deposits-Pleistocene deposits	2
Soil	<2%	4
Slope	7.93%	3
Mountain slopes direction(Angle)	214°	1

5. Discussion

The landfill is the most commonly used method in the world for final disposal of MSW, due to its low cost (Babalola and Busu, 2011) But, this is really a difficult step because it relies on different criteria and factors to establish safe sites of waste (Alabdraba and Khudhair, 2011). The purpose of the current study is to review the existing sites and suggest new sites with different criteria.

The weighted overlay model was used in analyzing the decision in GIS and to present the maps. Multiple explained conditions were identified by adopting a multi-criteria strategy. The decision of new sites of the landfill was based on the results of two maps. The first map demonstrates the suitability sites according to the same scale for each factor while the final map overlays the factors with different measurement scales depending on its importance. Both maps show areas with various degrees of suitability for dumping in the studied area. The outcome is affected by different conditions in weighted overlays. So, all related factors in effecting landfill sites would be important to measure and classify preferred values. The map output of similar weight analysis identifies a suitable region for landfills along the northeasternside of the city. This is not quit e unlikely because those regions are not agricultural lands. While the same class is distributed along east-west of the city in different weights map. The current study found that 45% of the area is not suitable for landfills while only 4% of the same area is not suited by using overlay weight methods. The significant differences are occurred in class 3(suitable) and 1(not suitable) according to calculated Equation 4:

$$Difference = \frac{Area1 - Area2}{TotalArea} * 100\%$$

Equation 4

Where:

Difference= The difference in areas between two used method(equal and non equal weight) in the same class

Area1= The area in class(1,2,3, and 4) as described in Figure 11for non equal weight map

Arae2= The area in class (1, 2, 3, and 4) as described in Figure 12 for equal weight map

Total Area= The total area of the studied city (3521.5 m^2)

The outcomes of using the above equation are shown in Figure 12, the big negative difference in class 1(41%) is due to the small relative weight given to soil factor; this reflects the fact that soil is a very important and dominant factor in the selection of landfill sites in Jordan and in internationally whereas other parameters such as distance from residential areas and distance from existing dumpsites, which are two very important factors particularly locally, may make a positive difference(41%). The temperature parameter is very suitable for Albreka and Alsomer landfills but moderate suitable for the Allajoun landfill. The rain parameter has only been appropriate for Albreka and Alsomer landfills and the wind direction criteria have been perfect for Albreka landfill only, moderate suitable for Alsomer landfill, and not suitable for the Allajoun landfill. The DOS in the direction of the Allajoun mountain slope is low, which can be concluded from unpleasant odors surrounding the area, especially since this region receives numerous complaints from citizens and road users in this region. Geological parameters for all existing dumpsites are moderately appropriate, except for Allajoun landfills which exist on a limestone geological site. Lime can provide a useful chemical barrier to particular pollutants being transported as the limestone-soil mixture was used in designing landfills (Malone and May, 1987). In the recent process-integrated method used by Reich who proved that mixing hazardous waste with lime lead to different compounds with different solubility (Reich et al., 2002). Holocene-Pleistocene deposits geology lands existing in Albreka and Alsomer landfill are considered as sediments and a crust of fine sand that contains not only Glaciomarine deposits but also moderate marine sediment. The soil of Allajoun landfills varied between Typic-Vertic Xerochrept which is considered as semi-dry soils that reduce leakage. The soil of Albreka landfill varied between Typic-Typic Xerochrept which is considered as a type of shallowsurface s richwithsilt and mud, and also reduces leakage. Alsomer landfill soil varied between Typic-Vertic Xerochrept ranges between low to medium permeability. To confirm the accuracy of the results; Abu-El-Sha'r et al., 2001 found that the general condition of landfills in Al-karak city is bad and this due to several reasons such as possible groundwater pollution, rodent spread, and bad odours. The authors suggested that liquid should separate from solid waste and establish a treatment plan. Also, AL-Husban., 2019 recommended that an appropriate design should set for future landfills. Another research concluded that landfill design in Jordan should take into account accurate precipitation date, wind direction, temperature, location from water body and residential areas (Aljaradin and Persson, 2012).

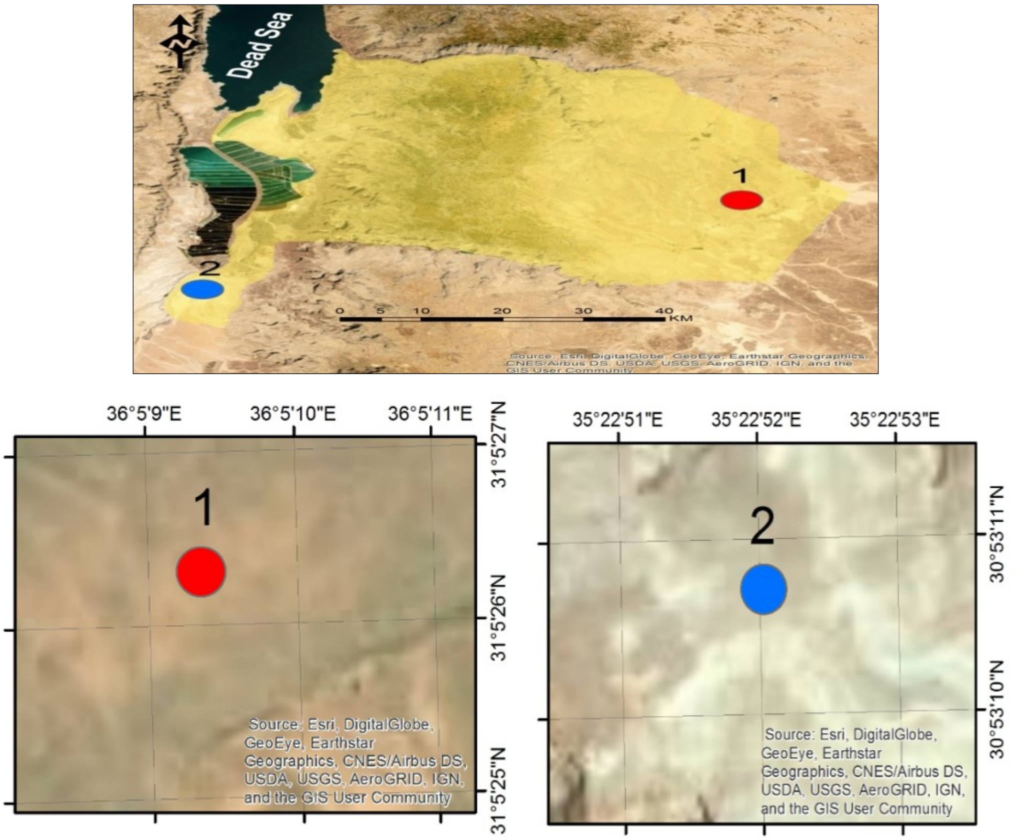

Figure 11: Locations of proposed sites

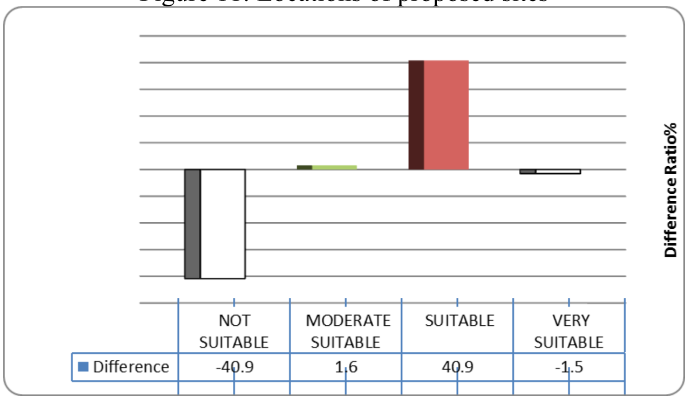

Figure 12: The Differences in areas according to suitability classes

6. Conclusion and Recommendation

The setting of landfills in Al-Karak city cannot generally be judged, but all criteria must be examined to determine the defects. The majority of requirements to be evaluated have also been analyzed to assess the nature of existing sites and to recommend locations that are more suited for environmental protection and better than those exist already. By using two integrated technique, the first suitability map (equal weight) showed that only 7% is very suitable and 45% is not suitable for dumping sites. The second suitability map (non-equal weight) presented that only 6% is very suitable and only 4% is not suitable. Although the highest percentage of over half (55%) was found in the last map related to the suitable class. The average amount of precipitation and distances from residents, main roads, water body, existing dumps, land use, and green areas were perfect (DOS=4) for all existing waste dumps. Also, temperature criteria registered excellent ranks for two existing landfills and the third (Allajoun landfill) scaled at a low rank (DOS=2). Geology criteria were on average between limestone -Holocene-Pleistocene deposits land (DOS=2,3). The significant negative effect on the scale was for wind direction criteria. In particular, the soil factor plays an important role in deciding the suitable areas, so it is advisable to give the soil parameter greater weight in future research. The accuracy between equal and non-equal overlay weight existed in not suitable areas, as the percentage was higher in the equal suitable map. This reflects that both approaches have different outcomes and that their adoption depends on the researchers' views, the nature of the field, and the factors introduced.

Two sites were proposed, the first located in Northeast of the city and the second in the Southwest of the city. Both locations meet appropriate standards (DOS=3,4). For the three existing landfills, environmental protection steps are recommended to minimize the harmful effects of the burial process on the nearby residents; as Dutta and V (Dutta et al., 2012a) have pointed out that the dust can be tackled with water spray, regardin gthe problems of disposing of insects, rats, mosquitoes and rodents, by placing a daily cover and eliminating standing water. The long-term environmental plan also is important to avoid released contaminants (Dutta et al. 2012b).

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