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Landfill Site Selection using GIS and AHP: a Case Study: Behbahan, Iran

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Abstract

Finding a suitable site to dispose solid waste is a difficult task for municipality because it is necessary to consider the different factors and criteria in the landfill siting process. In this study, in order to consider all parameters, a combination of Geographic Information System (GIS) and the Analytic Hierarchy Process (AHP) was used for landfill site selection. For the purpose of making decisions in landfill site selection a hierarchy structural was formed and different parameters have been identified, including distance to groundwater, distance to surface water, sensitive ecosystems, land cover, distance to urban and rural areas, land uses, distance to roads, slope, soil type and distance to waste generation places. At first, the rating method was used to evaluate each criterion individually. Then, the relative importance of criteria to each other was determined by an analytic hierarchy process (AHP). Simple Additive Weighting (SAW) method was applied to evaluate the land suitability. The results showed that 38% of the study area have high suitability for land filling. Finally, five sites were a candidate for field investigation with more details.

Keywords: *landfill, site selection, behbahan county, GIS, AHP*

1. Introduction

The generation of a huge amount of the solid waste is a major concern for municipal management system (Demesouka *et al.*, 2013; Vahidnia *et al.*, 2009). In developing countries, the ever increasing human population and the associated anthropogenic activities have accelerated the phenomenon of urbanization in the past decade. Different methods have been used for solid waste management, such as landfilling, incineration and composting (Zahari *et al.*, 2010; Giusquiani *et al.*, 1995; Humer and Lechner, 2001). Landfilling is one of the most common methods for waste disposal because it is a simple and low-cost method especially for developing countries (Khoram *et al*., 2014). Although many methods have been used for reducing and reusing of municipal solid waste, the disposal in sanitary landfill is an inevitable element of all solid waste management systems (Tchobanoglous *et al.*, 1993). Landfill site selection is a complicated decision because it considers different factors such as economic, social, and ecological (see Fig. 2). Environmental factor are very important because the landfill may effect the biophysical environment and the ecology of surrounding area (Alanbari *et al.*, 2014). Geographic Information System (GIS) is an ideal tool for this kind of preliminary studies due to its ability to manage large volumes of spatial data from a variety of sources (Kontos *et al.*, 2003; Malczewski, 2004). The AHP is a structured technique for organizing and analyzing complex decision-making, such as landfill site selection. In the site selection process, the AHP determines the relative weight or priority of criteria to each other and allows comparing elements to each other in a consistent manner (Sener *et al.*, 2010; Vahidnia *et al.*, 2009). Several researchers have used different methods for landfill site selection. Gorsevski *et al.* (2012) has used a GIS-based multi-criteria decision analysis approach for evaluating the suitability for landfill site selection in Polog Region, Macedonia. Eskandari *et al.* (2012) have used an integrating approach for landfill siting based on conflicting opinions among environmental, economic and

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social-cultural experts. Wang *et al.* (2009) used the AHP and a hierarchy model for solving the solid waste landfill site selection problem in Beijing. Gbanie *et al.* (2013) used an aggregation technique by combining weighted linear combination and ordered weighted averaging for identifying municipal landfill sites in urban areas in Southern Sierra Leone. Alavi *et al.* (2013) used a combination of AHP with GIS and field analysis for finding the best solid waste disposal sites in Mahshahr County, Iran. With the growing population and the related unsustainable activities in Iran, there has been a huge increase in the quantity as well as in the variety of the solid waste being produced.

The problem of solid waste has expected significant aspect, especially in the urban area. Domestic, industrial and other wastes, whether these are of low or intermediate level, have become a recurrent problem as they continue to cause environmental pollution. Inappropriate waste management systems results in increasing environmental problems with important local problems. The need of the era is to plan an efficient solid waste management system where decision-makers and waste management planners can deal with the increase in difficulty, uncertainty, multi-objectivity, and subjectivity associated with this problem. In this study, GIS techniques and AHP methods were combined to find the best solid waste disposal sites in Behbahan city, Iran.

2. Materials and Methods

2.1 The Study Area

Behbahan County is located in the south western of Khuzestan Province in Iran and covers a total area of 3195 km^2 (Fig. 1) (Bank Country division, 2010). The total population of Behbahan was about 100000 in 2013. Based on the future population expected for the next 25 years, the amount of Municipal Solid Waste (MSW) has been estimated as 936006 m^3 in the study area. There are 23 villages around the County. The municipal wastes generated in Behbahan are disposed through open dumping and create numerous environmental and public health problems such as pollution of water resources, deterioration of sensitive ecosystems and vectors-borne diseases (Bank Country division, 2010).

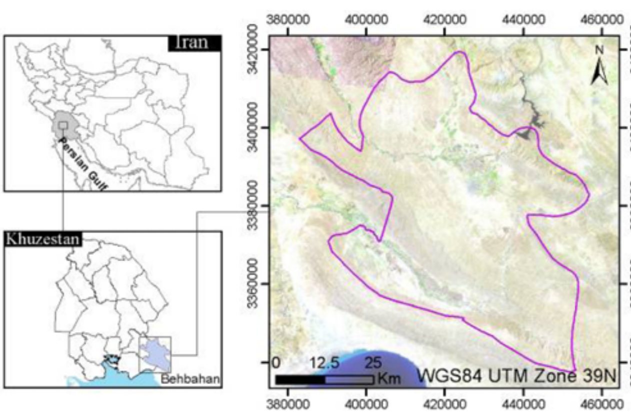

Fig. 1. Study Area Boundary

2.2 Methodology

In this study, Arc GIS and AHP were used for site selection. The AHP divides the decision problems into understandable parts; each of these parts is analyzed separately and integrated in a logical manner (Demesouka *et al.*, 2013). In this study, based on the national regulations and international literature 10 criteria were used. In order to evaluate each criterion, the point allocation method was applied. It is based on allocating points ranging from zero to 10, where zero specifies that the area is unsuitable and 10 describes the best condition for that criterion (Table 1).

2.2.1 Input Data

In this study, 10 input map layers, including topography, settlements (urban centers and villages), roads (main roads and village roads), sensitive ecosystems, slope, land type, land use, land cover, surface water and water wells were collected and prepared in a GIS environment. All layers were converted to the individual raster maps (Sener *et al.*, 2006; Sener *et al.*, 2011).

2.2.2 Determination of Relative Importance Weights of Criteria

The preferred alternatives were chosen among the prepared alternatives in the previous stages, and for this, we used AHP (Rezaei-Moghaddam and Karami, 2008). After determining importance of any criteria individually, the next step is the determination of the relative importance of criteria to each other. One of the most common methods that have been used in recent years is AHP. It is a multi attribute technique which has been incorporated into the GIS-based land-use suitability procedures (Saaty, 1980a). It is an accepted decision making method, which is applied to determine the relative importance of the different criteria in the landfill site selection (Kontos *et al.*, 2005; Moeinaddini *et al.*, 2010; Şener *et al.*, 2006; Şener *et al.*, 2011; Sener *et al.*, 2010; Sharifi *et al.*, 2009; Yes_ilnacar and Cetin, 2005). The AHP is based on pairwise comparisons and any criterion or sub-criterion is compared to another criterion at the same time. Decision makers can quantify their opinions about the criteria's magnitude.

For the decision making problem as mentioned above, a structural hierarchy formed (Fig. 2). Then, the obtained geometric means were normalized and the relative importance weights were extracted. For the decision-making problem mentioned earlier, a structural hierarchy is formed (Fig. 2). In the next stage, the Pairwise Comparison Matrix (PCM) is formed in which a_{ii} = 1 and a_{ij} = 1/a (Table 2). In the next step, the relative importance of the criteria's weights was calculated by the geometric mean of each row of the PCM (Saaty, 1980). The obtained geometric means were then normalized and the relative importance weights were shown (Table 2). The results showed that among the criteria studied, groundwater and surface waters were the most important ones while slope was the least important criterion.

Table 1. Grading Values for the Selected Criteria

Criterion	Base map (Scale)	Buffer zone	Rating	Area (%)
Distance to Groundwater	Iranian Cartography Organization (1:50000)	>1500 m	10	80
		400-1500 m	4	17
		<400 m	0	3
Distance to surfaces water	Iranian Cartography Organization (1:50000)	> 2500 m	10	80
		2000-2500 m	8	5
		1500-2000 m	6	4
		1000-1500 m	4	4
		300-1000 m	2	4
		< 300 m	0	3
Sensitive Ecosystems	Environment Department of Khuzestan (1:100000)	> 2500 m	10	80
		2000-2500 m	8	4
		1500-2000 m	6	4
		1000-1500 m	4	1
		300-1000 m	2	2
		< 300 m	0	9
Land cover	Khuzestan Natural Resources Head Office (1:100000)	Barren land	10	2
		Rangeland	8	29
		Dry farming	6	26
		Irrigated farming	3	41
		Wetland and forest	0	2
Distance to urban and rural areas	Iranian Cartography Organization (1:50000)	> 15 km	10	0
		10-15 km	8	4
		5-10 km	5	21
		2-5 km	2	44
		< 2 km	0	31
Land uses	Khuzestan Natural Resources Head Office (1:100000)	Unused lands	10	2
		Industrial	8	29
		Agricultural	4	67
		Tourist area	2	0
		Residential	0	2
Distance to roads	Iranian Cartography Organization (1:50000)	> 3 km	10	31
		1.5-3 km	6	22
		1-1.5 km	4	11
		300-1000 m	2	22
		< 300 m	0	14
Slope	Iranian Cartography Organization (1:50000)	< 10%	10	99
		10-20%	8	0
		20-25%	4	0
		25-45%	2	0
		> 45%	0	1
Soil Type	Iranian Soil and Water Research Institute (1:150000)	Land unit 1.2	10	22
		Land unit 3.4	8	13
		Land unit 8.2	5	54
		Land unit 5.1	2	11
Distance to waste generation places	Iranian Cartography Organization (1:50000)	<2 km	10	1
		2-3 km	8	4
		3-5 km	5	14
		5-10 km	2	60
		> 10 km	1	21

2.2.3 Evaluation of Land Suitability

The integration of the GIS and AHP method allows the user to determine a numerical value for the Landfill Suitability Index (LSI). Higher LSI values indicate areas more suitable for landll (Nas *et al.*, 2010). LSI for each point was calculated using Eq. (1):

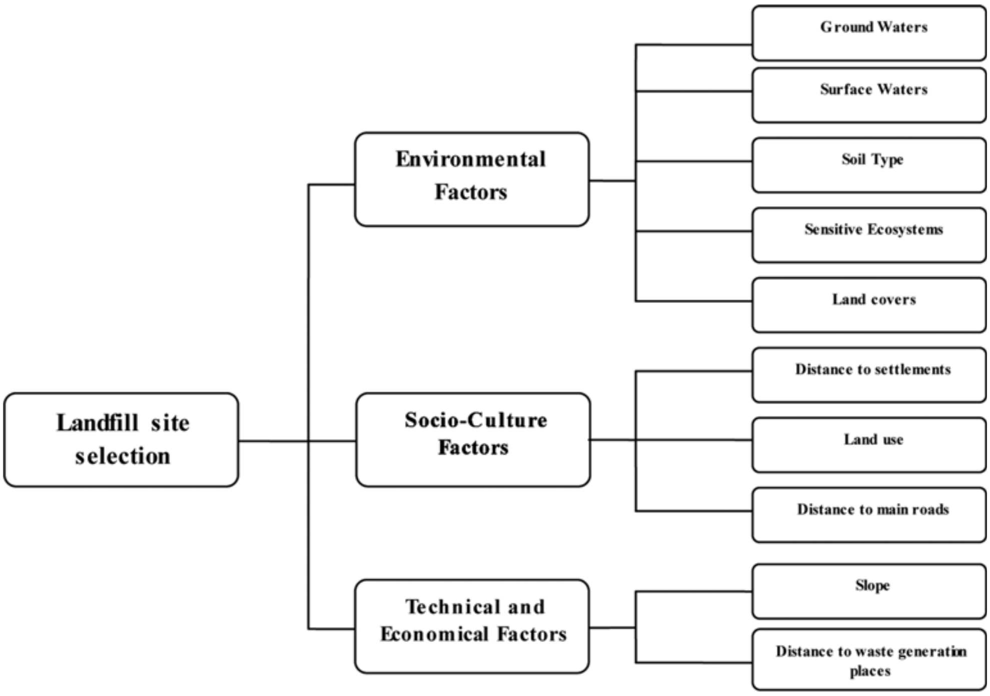

Fig. 2. Hierarchy Structure for the Landfill Site Selection

$$V_i = \sum_{j=1}^{n} W_j V_{ij} \tag{1}$$

Where Vi is the suitability index for each point i; W_j is the relative importance weight of criterion j; V_{ij} is the grading value of each point; i under criterion j; and n is the total number of criteria.

4. Results and Discussion

Due to the fast growth rate of the population in Behbahan like other cities in Iran, the amount of MSW production is increasing. One of the major public health problems and environmental pollutions in this region of Iran is MSW dumping. MSW dumping in this area caused environmental and health problems such as water pollution, breeding disease-causing vectors and odor, especially during summer (Tchobanoglous *et al.*, 1993). Most of these dumping places are temporary and will be filled soon. Hence, it is necessary to find appropriate places to dispose the MSW.

4.1 Criteria Evaluation

The most significant criteria were selected according to landfill site selection regulations in Iran and conditions of the study area. In order to protect sensitive areas, such as sensitive ecosystems, surface water, groundwater and urban and rural areas, these areas were removed from the study area by assigning a score of zero during the data preparation stage. Table 1 displays the grading values that were assigned to any criteria based on the experts' team opinions and regulations.

4.1.1 Surface Waters

Surface water is an important parameter for landfill siting. To prevent surface water pollution by landfill leachate, the minimum distance from surface water should be considered (Sener *et al.*, 2010). Maroon and Kheirabad are two main rivers that provide water for drinking and agriculture consumptions in the study area. According to the landfill siting regulations of the Iran department of environment, a buffer zone equal to 300 m was considered around main surface water bodies in the study area. A distance less than 300 m was scored zero and zones greater than 2500 m were scored as 10 (Moharamnejad, 2008). The score was increased by grades as distance increased from the buffer zone (Table 1); the results are shown in Fig. 3.

4.1.2 Sensitive Ecosystems

A landll should not be located near any sensitive ecosystem such as lakes, dams, or wetlands (Alavi *et al.*, 2013; Sener *et al.*, 2010). Behbahan County is located near some sensitive areas, such as Nargeszar and Maroun dam. For this reason, a 300 m buffer was placed around all sensitive ecosystems. Therefore, a score of zero was assigned when the distance to a sensitive ecosystem was less than 300 m. However, when the distance from the boundary was increased, the score was increased rationally according to the expert team. Therefore, if the distance to a sensitive ecosystem was more than 2500 m, a score of 10 was allocated (Table 1); the results are shown in Fig. 3.

4.1.3 Land Cover

Land cover is a significant criterion in landfill siting because during landfill construction and operation may deteriorate land

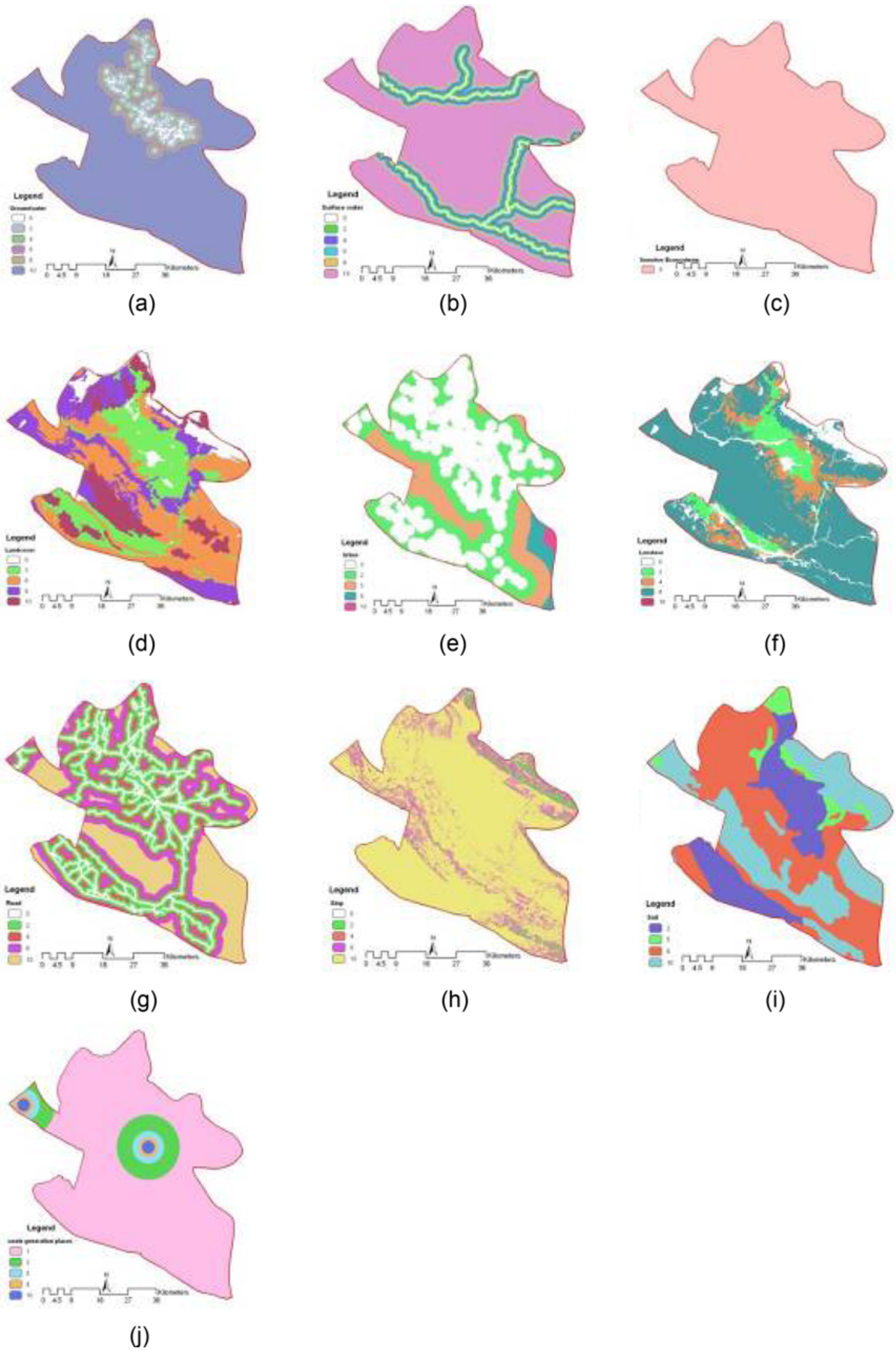

Fig. 3. (a). Ground water Suitability Index, (b) Surface Waters Suitability Index, (c) Sensitive Ecosystems Suitability Index, (d) Land cover Suitability Index, (e) Distance to Urban and Rural Areas, (f) Land uses Suitability Index, (g) Distance to Roads Suitability Index, (h) Slop Suitability Index, (i) Soil Suitability Index, (j) Distance to Waste Generation Places Suitability Index

cover (Nas *et al.*, 2010; Sener *et al.*, 2011). The wetlands were considered as totally unacceptable; thus, zero values were allocated to these areas. Irrigated farming lands considered as unsuitable area received a score of 3. As shown in Fig. 3, values of 6, 8 and 10 were assigned respectively to dry farming lands, rangelands and barren lands as suitable areas for landfill siting.

4.1.4 Urban and Rural Areas

Because of odor, dust and noise, landll sites' proximity to urban and rural areas can cause impacts on the population and the landscape (Uyan, 2014; Tchobanoglous *et al.*, 1993). According to the Iran department of environment guideline, a minimum distance of municipal solid waste landfill is at least 10 km from residential areas. In addition, according to the Iran department of environmental guideline, landfill sites should not be located near the airport. Conservatively, 8 km buffer zone was applied around airports to prevent bird hazards. In this study, scores of zero and 10 were given respectively to a distance less than 2 km and a distance more than 10 km from a residential area. Scores of 2 and 5 were assigned to the distances of 2-5 km and 5-10 km, respectively.

4.1.5 Land Uses

While land use planning in site selection, due to its reliance on an understanding both of the natural environment and the kinds of land uses envisaged, is an important criterion; unfortunately there is no land use planning in the study area; therefore, based on the general land uses in this area, land uses were divided into the residential, agricultural, industrial and unused lands. Disposal of MSW into residential lands is forbidden; so, residential lands were considered unsuitable for landll sites and received a grade of zero. Recreational and tourism areas were not excluded from consideration, although they received a low suitability score of 2. Finally, the most suitable areas were considered as the unused lands with a grade of 10. Agricultural and industrial lands received scores of 4 and 8, respectively. The results are presented in Fig. 3.

4.1.6 Distance to Roads

From the aesthetic viewpoint, distance to roads is an important criterion; hence, farther distances to main roads received higher grades. According to the landfill siting regulations in Iran, the distance of a landfill to a main road should be more than 300 m. To evaluate this criterion, 300 m buffer zones were determined around all roads. Distances of 300-1000 m received grading values of 2. The highest score, *i.e.* 10, was assigned to a distance more than 3 km (Table 1); the results are shown in Fig. 3.

4.1.7 Slope

Land slope is a basic parameter for the construction and operation of a landll site. Sites with steep slopes are usually not technically suitable for landll construction. The very steep areas (>45%), the steep areas (25-45%), the moderately steep areas (20-25%) and the inclined planes (10-20%) and the slightly sloping areas (<10%) received grades of 0, 2, 4, 8 and 10, respectively (Table 1). The most suitable areas were considered to be the inclined planes (10-20%) with a grading value of 8 and the slightly sloping areas (<10%) with a grading value of 10 (Kontos *et al.*, 2005). The results are shown in Fig. 3.

4.1.8 Soil Type

Soil type is classified based on the manual of the water and soil research institute of Iran. This classification is according to Mahler 212 manual (Mahler, 1970). The scoring of this criterion is shown on Table 1. Land unit 1.2 consists of shallow soil cover that is considered as barren land. Due to low porosity and impermeability, it was the best candidate for landfills and received the highest grade of 10. Land unit 5.1 is included as river alluvial plains. Alluvium deposits have high potential for water adsorption and are not suitable for landll sites. It consists of deep soil with moderate -to-heavy texture and low salt. Annual or perennial plants are cultivated in this area. This unit is permeable to water and suitable for cultivation; therefore, lowest score of 2 was allocated for landfill. Land unit 3.4 consists of thin to semi-deep and heavy soil with moderate-to-high alkalinity and salt. Salinity resistance plants in low canopy cover this soil type. It was considered as barren land and sometimes used as temporary rangeland. Permeability of this soil type into the water was moderate-to-low, therefore, it received a score of 8. Land unit of 8.2 included semi-deep and medium soil covered with average plants. It was covered in moderate canopy cover. Its permeability to water is moderate and it received a score of 5.

4.1.9 Distance from Generation Points

This criterion considers the costs related to hauling from the source of the waste produced. Therefore, proximity to the waste source decreases the hauling time and cost (Baban and Flannagan, 1998). Behbahan city was considered as a benchmark and the distance of all candidate landfill sites to this point was evaluated. As shown in Fig. 3, the distances to the production center with 2000 m, 2000-3000 m, 3000-5000 m, 5000-10000 m and more than 10000 m were scored 10, 8, 5, 2 and 1, respectively.

4.1.10 Distance from Groundwater

Due to landll leachate and transporting contaminants, groundwater pollution is a serious environmental concern (Al-Jarrah and Abu-Qdais, 2006). In order to avoid groundwater pollution, locating landlls on or close to aquifers should be avoided. According to the landfill siting regulations of the Iran department of environment, a 400 m buffer zone should be considered around main groundwater. Hence, a distance less than 400 m received a grading value of zero; in addition, an intermediate grade of 4 was given to distance 400-1500 m. Distances having more than 1500 m received a grading value of 10. The results are shown in Fig. 3.

The decision makers and experts are often not able to express consistent preferences in case of several criteria. Then, the inconsistency of the PCM should be measured and a moderate consistency threshold should be set. Consistency Ratio (CR) is

Table 2. Pairwise Comparison Matrix and Relative Importance Weights of the Criteria

Criteria	A	B	C	D	E	F	G	H	I	J	Weights
A	1	2	2	3	4	5	6	7	8	9	0.250
B	0.5	1	1	3	4	5	6	7	8	8	0.196
C	0.5	1	1	2	3	4	5	6	7	8	0.168
D	0.33	0.33	0.5	1	3	4	5	6	7	8	0.132
E	0.25	0.25	0.33	0.33	1	3	4	5	6	7	0.092
F	0.2	0.2	0.25	0.25	0.33	1	3	3	4	5	0.058
G	0.16	0.16	0.2	0.2	0.25	0.33	1	3	3	4	0.041
H	0.14	0.14	0.16	0.16	0.2	0.33	0.33	1	2	3	0.027
I	0.12	0.12	0.14	0.14	0.16	0.25	0.33	0.5	1	3	0.022
J	0.11	0.12	0.12	0.12	0.14	0.2	0.25	0.33	0.33	1	0.015

λmax =11.130, CI = 0.12 RI = 1.48; and CR = 0.085 ≤ 0.1
A: Ground waters; B: Surface waters; C: Sensitive Ecosystems; D: Distance to Settlements; E: Soil Type; F: Land Uses; G: Land Cover; H: Distance from waste generation; I: Roads; and j: Slope

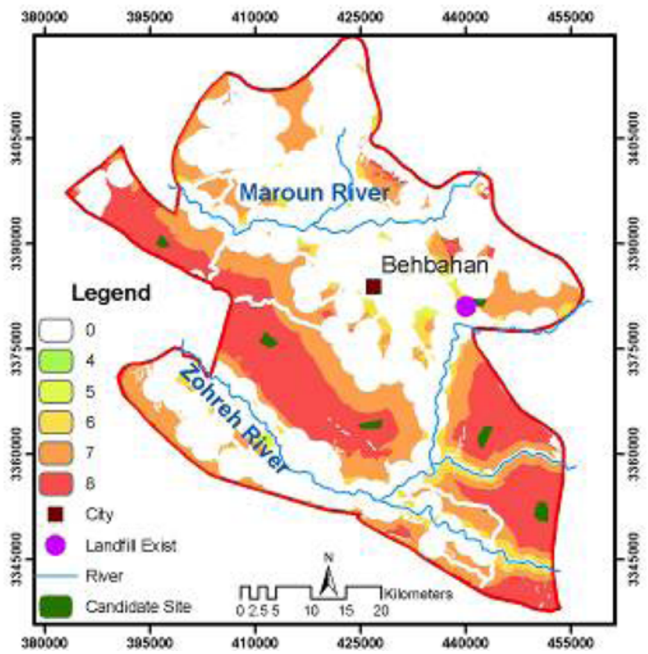

Fig. 4. Landfill Suitability Map and Area Recommended for Siting

calculated through dividing the Consistency Index (CI) by the Randomized Index (RI) to indicate the overall consistency of the PCM. If the value of CR is smaller or equal to 10%, the inconsistency is acceptable (Kontos *et al.*, 2005; Saaty, 1980). In this research, CR was less than 0.10 (0.085), which indicates a good consistency of the judgments used for the comparison (Gorsevski *et al.*, 2012).

By considering the parameters such as required area for landfill, distance to MSW generation points, wind direction, land ownership, political and management issues and public acceptance, three areas have been chosen for site visiting (Fig. 4).

According to the landfill suitability map (Fig. 4), areas under the study were divided into three classes: 1) low and very low suitable areas (57%); 2) moderately suitable areas (5%); and 3) high suitable areas (38%). Five candidate sites were suggested for the landll site in high suitability regions determined by the AHP and GIS techniques (Fig. 4). In order to check the suitability of the determined areas, field checks must be performed. After visiting sites, the best one should be selected based on wind direction, land ownership, political and management issues (Alavi *et al.*, 2013).

5. Conclusions

Disposing municipal solid waste to open dumps leads to many environmental and public health concerns in Behbahan. Therefore, the municipality of Behbahan is looking for a suitable site for a landfill. In order to consider all criteria in this extended area, we used a combination of GIS and AHP.

In this study, different data from various parameters were obtained and prepared in a GIS environment. Then, we used AHP to determine the relative importance of criteria to each other and SAW method to evaluate the land suitability. The results showed that among the studied criteria, groundwater and surface waters were the most important ones. The groundwater was the major criteria in this case study, while the least important criterion was slope. As a result, about 38% of the whole region under study was suitable for landfilling; however, ultimately five points were chosen as landfill site candidates.

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