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Research Article

GIS AND THE ANALYTIC HIERARCHY PROCESS METHODS FOR SITE SELECTION OF WASTE LANDFILLS: A CASE STUDY IN IRAN

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ABSTRACT
Several criteria and indicators are relevant in the process of landfill site suggesting specific requirements for a suitable site. The criteria and sub-criteria involved in this study to establish the most proper landfill site were geomorphology, environmental, hydro-climate, land use and economic status. The objective of this study was to find the most suitable landfill site in Dezful city. Fifteen factors selected as criteria/sub-criteria were geomorphology, hydro climate, land use, transmission net, economic, pedology, geology, vegetation, distance from the waste center, routes network, slope, topography, surface and subsurface water. In the first step, weight coefficients for each criteria and sub-criteria computed according to AHP. Based on weighted sub-criteria, surface and subsurface water, vegetation, slope and routes layers were taken in to consideration in the process of overlay and preparation of final suitability map. Maps were then standardized and overlapped with weight Overlay method in GIS environment. The final map prepared was classified into completely suitable, relatively suitable and suitable classes. According to the results, 6 % (282 kg m^{-2}) of the studied area of Dezful (4700 kg $m^{-2)}$ is suitable for regional landfill siting. Determined areas with 74, 84 and 124 kg m^{-2} depends on completely suitable, suitable and relatively suitable classes, respectively.

INTRODUCTION
Municipal, industrial, medical waste management is one of the most important environmental concerns facing cities (Sartaj *et al.,* 2007). The strategy of waste management comprise of collection, transport, processing, recycling or disposing of waste, and monitoring of waste material. Appropriate site selection for waste landfill is an important process in municipal waste management (Vasiljevic *et al.,* 2012; Şener *et al.*, 2006). Unsuitable select of waste disposal site leads to contamination of water, soil and air and also threats human health. Several criteria and indicators are relevant in the process of landfill site suggesting specific requirements for a suitable site. The ultimate goal of landfill Site Selection is finding the most appropriate site to minimize the environment and natural resources adverse effects as well as the economic and engineering costs (Ghazban, 2006). A number of evaluation techniques have been used in the landfill siting processes in the past. GIS (geographical information system) is an innovative tool in landfill process in recent years (Kontos *et al.,* 2005). The extensive capability of GIS in the spatial data management and establish an appropriate platform for decision-making has led to the use of this technology in waste landfill selection (Sartaj *et al.*, 2007). In a study set out for the selection of waste landfill site in Vermont State, united state, Hendrix and Buckly (1992) investigated a 210-hectare area using GIS in terms of physical and economic indicators such as suitable soil, rock depth, land use, surface and ground water and altitudinal zoning and identified suitable landfill site. In another example a landfill siting process was performed by Siddiqui *et al.,* (1996) by combining GIS and AHP (the Analytic Hierarchy Process). They studied four criteria including close to the city, population center, and land use type and soil limitations. Lin *et al.,* (1996) to avoid errors when integrating and applying the different weights to with various scores, proposed a dynamic weighting method by combining GIS and fuzzy logic in which the final level of acceptable values for combining different layers of the correction factor is benchmark weights has been identified.

In another study, Chang and others (2008) integrated GIS and fuzzy multi-criteria decision-making for landfill selection process in the Lower Rio Grande Valley (Texas, USA). Also, Sener and others (2006) investigated the landfill site selection issue by combining GIS and multi-criteria decision analyses and defined a detailed ranking of potential landfill sites in accordance with the selected criteria.

To solve the landfill site selection problem in Nancy city around (France), Vastava and Nathawat, (2003) integrated GIS and RS considering criteria like geology, faults, land slope, rock, and soil type, surface waters, underground water depth, urban centers, the network and distance from airport. Five waste landfill sites were identified by paired comparisons and weighing of attributes.

To determine the most suitable landfill site in the Lake Beyşehir catchment area (Konya, Turkey), Sener *et al.,* (2010) combinined AHP with GIS for by examinining several criteria, such as geology/hydrogeology, land use, slope, height, aspect and distance from settlements, surface waters, roads, and protected areas (ecologic, scientific or historic). According to the result 73.70% of area studied was found to be completely unsuitable for a landfill site.

In Iran, solid waste landfills siting are often taken in city comprehensive plans and systemic and peripheral visions is quite blurred and landfills selection is performed by evaluating only one or a few indicators. In a study caried out by Khorshid dost and Adeli (2009), solid waste landfills siting in Bonab city, Iran, was performed by integrating AHP, GIS and Expert choice software.

To our knowledge no study has been conducted so far waste landfills siting in Dezfol city. The aim of this study was to evaluate multi-criteria methods of AHP and GIS to determine the most suitable site for waste landfill in Dezful city.

MATERIALS AND METHODS

Study Area

Dezful city (32°22' N, 48°24' E, and 140 m above sea level) covers an area of 4,700 km^2 located *in the north of Khuzestan, Iran*, with the mean annual rainfall of 400 mm and *mean temperature* of about 3°C in *winter* and 49°C in *summer*. The population in 2011 was 420 thousand, according to the information given in the 2011 census. The amount of waste in this city is different and in spring, summer, autumn and winter seasons is nearly 125 tons, 225 tons, 165 tons and 110 tons, respectively, which is found to be 160 tons per day. The position of Dezful city in Iran is presented in Figure 1. In the present study, the map of factors involved in the landfill site selection process was created and prepared to enter the GIS system. These maps comprised of topographic area, slope, land use, distance from the waste center, vegetation, geology, pedology, routes, distance from the water surface sources and groundwater depth maps. The process of present study is given in Figure 2

The Analytic Hierarchy Process Method (AHP)

AHP is one of the most important tools is a multi-criteria decision (Omkarprasad, 2004).

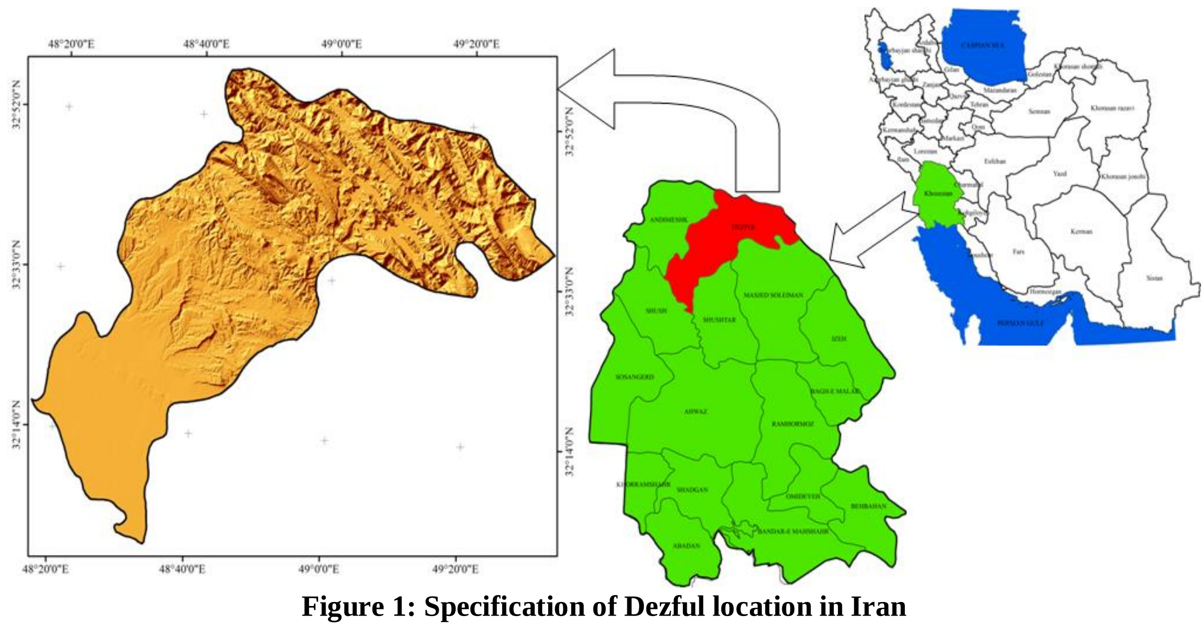

Figure 1: Specification of Dezful location in Iran

Given that the selection of a suitable landfill site play an important role in waste management and also the complexity of factors influencing the landfill siting process, the use of multiple-criteria decision-making systems is necessary (Onut, 2007). AHP is a flexible, powerful, and easy used to make decisions when decision criteria are different and contradictory and selection between options is difficult (Bertolini, 2006). The AHP, introduced by Saaty in1980, as a multi-objective has been widely used in the landfill siting process by researches. The main feature of this method is based on a pair-wise criteria comparison. In order to solve the waste landfill site selection problem in Dezful city, after weighing the factors, these factors were entered into the GIS software and then were overlaid. Coefficients used ranged from one (minimum) to five (maximum).

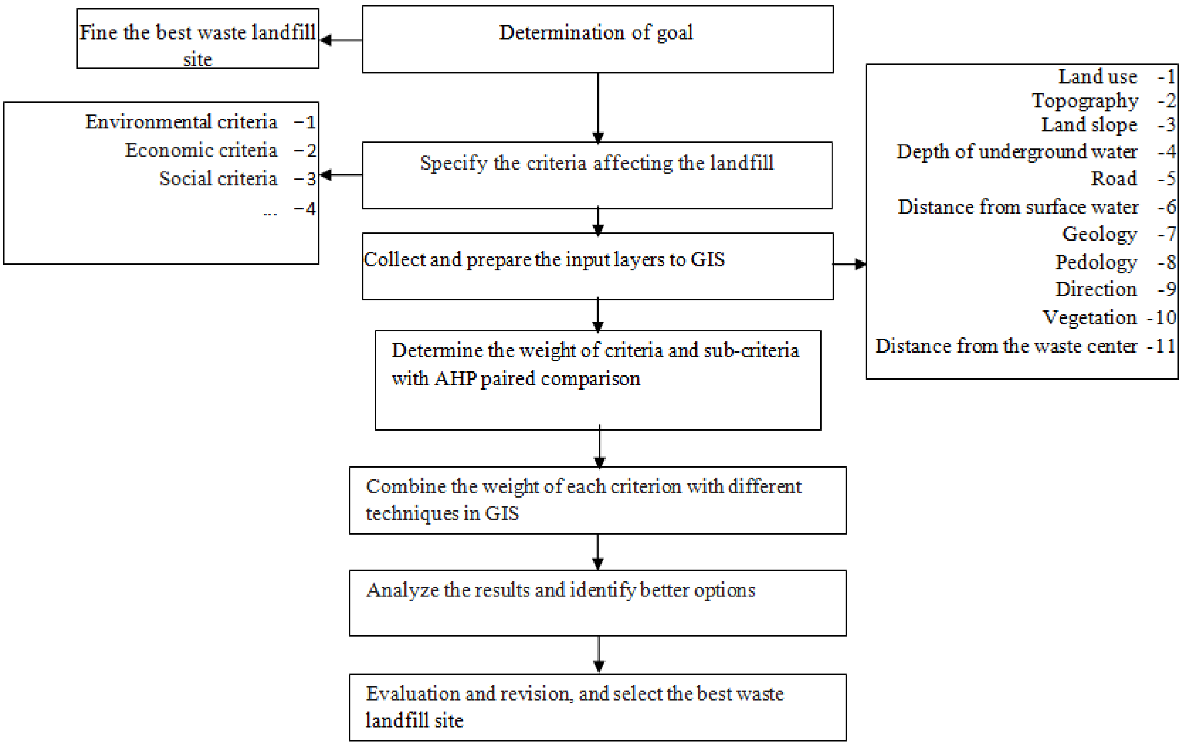

Figure 2: The landfill site selection processes in Dezful

Analysis of the factors affecting the location of municipal waste landfills:

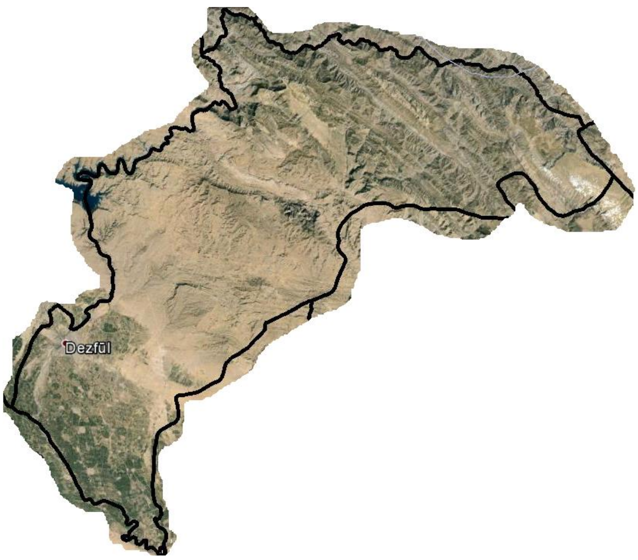

Figure 3: Land use factor map

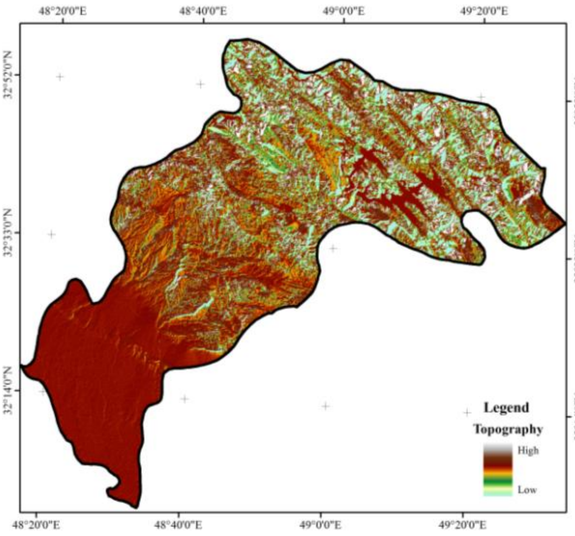

Figure 4: Topography factor map

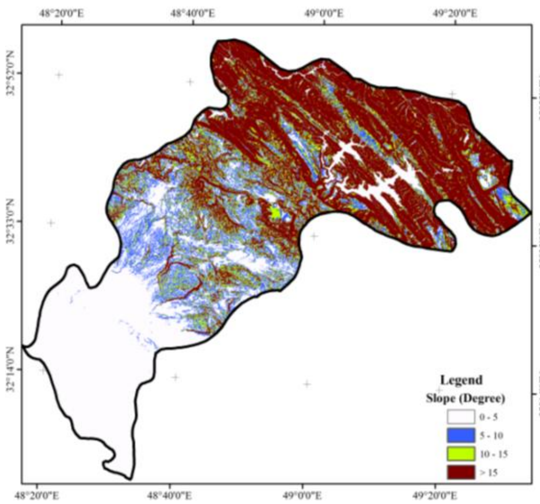

Figure 5: Land slope factor map

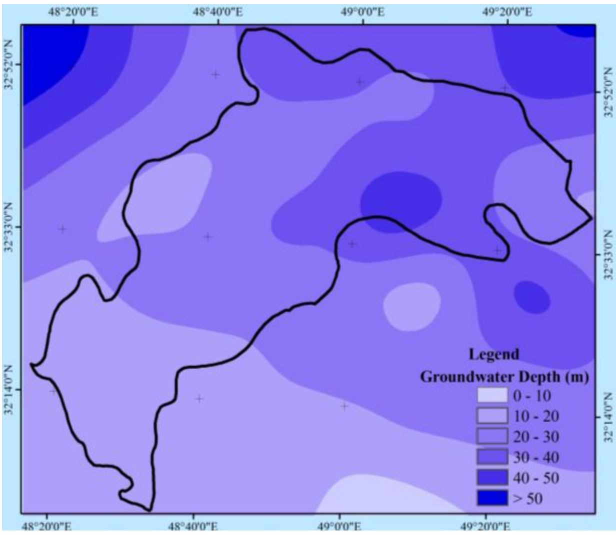

Figure 6: Groundwater depth factor map

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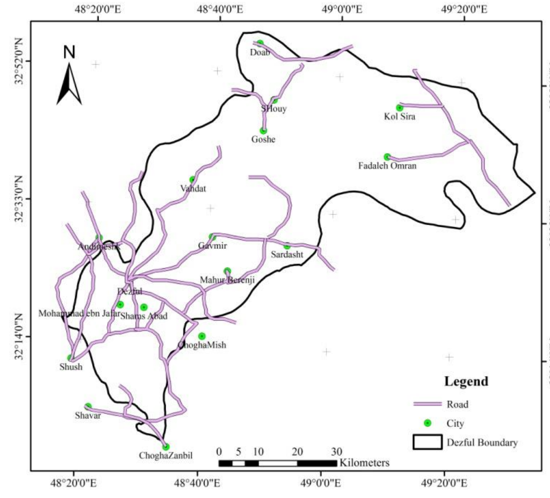

Figure 7: Roads factor map

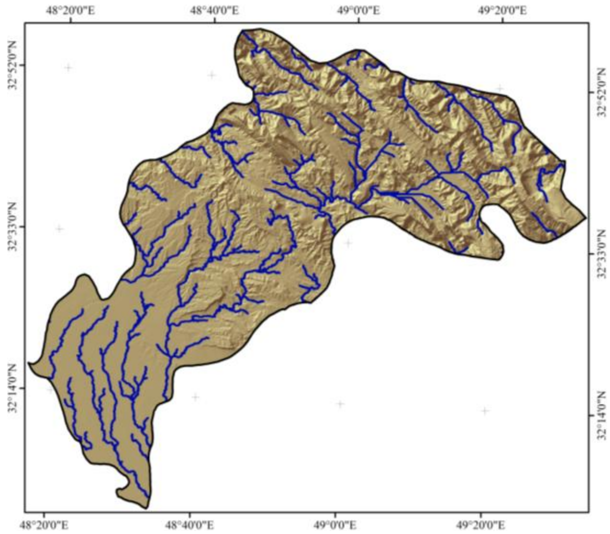

Figure 8: Surface water factor map

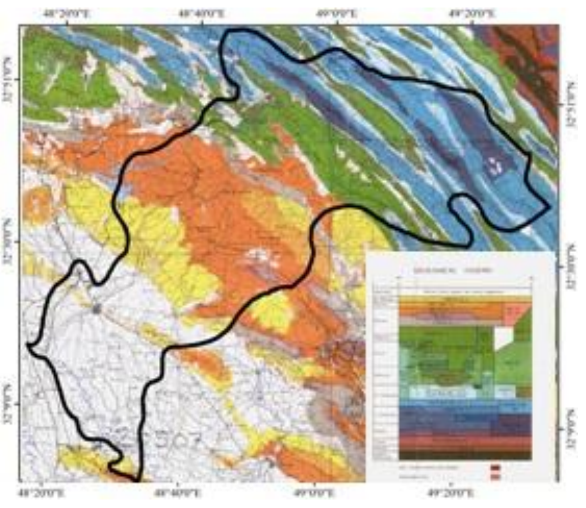

Figure 9: Geology factor map

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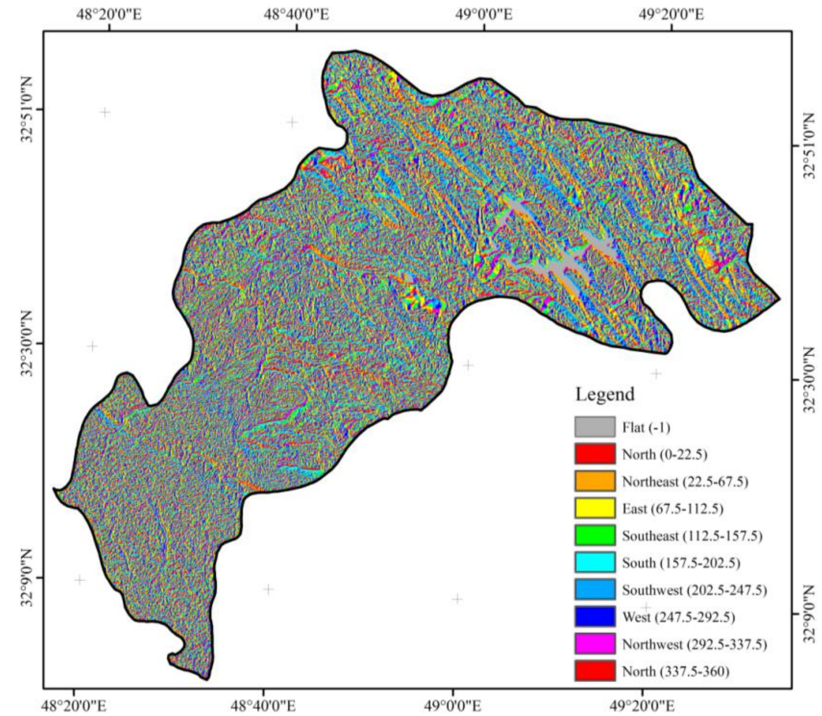

Figure 10: Direction factor map

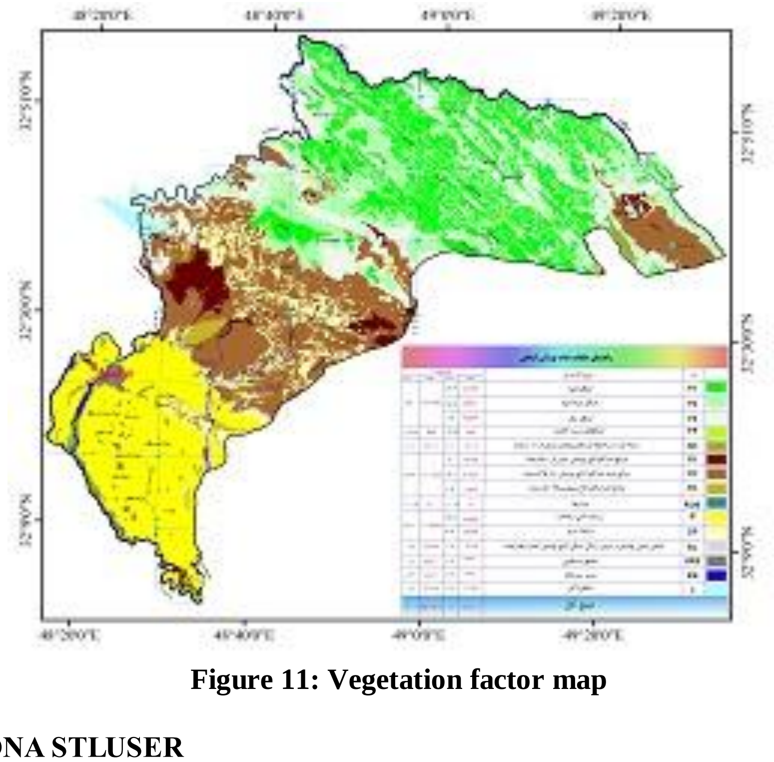

Figure 11: Vegetation factor map

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Results

In the first step of the AHP methodology, four hierarchies were considered, i.e., to identify the goals and identify criteria, sub-criteria and options relevant for landfill site selection in the Dezful region (Bowen, 1990). In the present study, finding the most suitable landfill site was taken into consideration as goal. Criteria were geomorphology, hydr-oclimate, land use, economic and transmission network. Sub-criteria comprised of land use, pedology, geology, vegetation, distance from the waste center, routes network, land slope, direction, topography, surface and sub-surface water.

In the AHP methodology, each criterion has a special weight determining with different method by user. Each criterion can also divide into several comparable sub-criteria.

In the second step, the weights of the criteria relative to goal (finding the most suitable landfill site) were determined with respect to the importance of each criterion. The weight coefficients for each sub-criteria and criteria were calculated by methodology proposed by Saaty (1980). Briefly, sub-criteria and criteria weights were identified for based on the nine point Saaty's scale (Table 2).

In the third step, the weights were then normalized by dividing each weight on the total weights of the same column (Cimren, 2007).The number of Table 3 were calculated according to the importance of horizontal row criterion relative to vertical row criterion.

In the forth step, the pair-wise comparisons of selected sub-criteria corresponding to the each criterion were performed. Since, the number of comparisons for sub-criteria was high, as a sample the results of sub-criteria comparisons relative to geomorphology criteria are given in Table 4.

In the fifth step, the selection of suitable landfill site was organized with regard to criteria and sub-criteria weights. Surface and subsurface water, vegetation, land slope and routes maps were selected to overlay and extract the final landfill map.

In the sixth step, layers map were integrated using Weight Overlay after standardizing the maps. The final map prepared was then classified at completely suitable, relatively suitable and suitable classes. The final map of classification for waste landfill suitable sites in Dezful city is shown in Figure 12.

The final suitability map shows that about 6 % (282 kg m^{-2}) of the studied area in Dezful city (4700 kg m^{-2}) was unsuitable for landfill siting.

Discussion

Landfill site selection is a difficult and complex process that requires many different criteria (Chang *et al.*, 2008). In the present study, the most suitable location for a waste landfil was set by considering the different information layers such as land use, vegetation, surface and usuusub-surface water, connection ways, geology, pedology, topography, land slope, direction and distance from the waste center. Landfill siting in this study through weighting the criteria and sub-criteria was done using AHP approach. Then, suitable options for waste landfill in Dezful were chosen by overlaying the layers in GIS environment. The final suitability map was presented according to completely suitable, relatively suitable and suitable classes. Results indicated that about 6 % (282 kg m^{-2}) of the studied area in Dezful city (4700 kg m^{-2}) was unsuitable for landfill siting. Determined areas with 74, 84 and 124 kg m^{-2} depends on completely suitable, suitable and relatively suitable classes, respectively.

This research focused on identifying suitable zones for regional landfill sitting in the Dezful city according to several criteria. It is suggested that mote criteria rake in to considerationin next researches that provides consistence and complete results.

Table 2: Saaty's scale for Pair wise comparisons of criteria

Num. values	concept	explanation
1	Equally important	Two criteria have equal importance
3	Moderately more important	i element is more slightly important than j element
5	Strongly more important	i element is more strongly important than j element
7	Very strongly more important	Dominance of i element to j element proved in practice
9	Extremely more important	The highest order dominance of i element over j element
2,4, 8	Intermediate values	Compromise is needed

Table 3: Pair wise comparisons for waste landfill siting criteria

criteria	Geomorphology	Hydro climate	Land use	Transmission network	economic	weight
Geomorphology	1	3	2	2	2	0.194
Hydro climate		2	2	3	3	0.202
Land use			1	3	2	0.225
Transmission network				1	2	0.178
economic					1	0.201

Inconsistency ratio= 0.03

Table 4: Pair wise comparisons for waste landfill siting sub-criteria

Sub-criteria	topography	pedology	geology	Land slope	direction	weight
topography	1	3	2	2	2	0.147
pedology		1	1	2	1	0.218
geology			1	2	1	0.270
Land slope				1	2	0.218
direction					1	0.147

Inconsistency ratio= 0.07

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