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Location of municipal landfills Analytical Hierarchy process (AHP) In GIS environment (Case study of Qazvin city)

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Abstract

Solid waste is an integral part of human life and the production of its types in different quantities and qualities is one of the most important environmental problems of the present age. To prevent environmental pollution in the community, waste must be disposed of hygienically and engineeringly. One of the methods of waste disposal is engineering waste disposal method. In this study, our emphasis is on the impact of ecological factors on the location of urban solid waste landfills in Qazvin city using spatial analysis in GIS environment for optimal location of municipal landfills. For this purpose, the required digital data was collected and then transferred to the ArcGIS environment. After creating the database, multi-criteria analytical decision-making models were implemented, the reliable method of AHP hierarchical analysis. As a result, by using the AHP method, hierarchical criteria have been used to locate a suitable sanitary place for landfilling of generated waste in Qazon city, and the most optimal place has been selected from 4 proposed places for sanitary landfilling of waste.

***Keywords**:* AHP, GIS, Landfill, Location

1.Introduction

Municipal solid waste (MSW) is one of the most important environmental issues. The increase in urban population and especially the change in consumption patterns in recent decades has led to a significant increase in the per capita volume of waste generated (Saednia;2003) in general, the more we progress, the more natural resources are used More waste was produced in different types until in the urban environment due to lack of proper management of solid waste deteriorated day by day and every citizen was concerned about this issue (Bishnu;2001), waste causes odor, ugliness The face of nature and endangering the health of citizens and environmental pollution (water, soil and air) (Abduli;2008), so in developed countries much attention has been paid to the management of municipal solid waste and extensive research on that face. has taken. Solid waste disposal methods are diverse and include dumping and incineration in the open air, using waste incinerators, landfilling and composting (Saednia;2003), one of the most common and reliable methods of municipal solid waste disposal in the world. And Iran is a method of sanitary landfill (Abduli;2000), in the environmental assessment of municipal waste landfill, the selection of a suitable landfill is the most important factor. Due to the growth of municipal waste volume, the need to determine the appropriate location, the issue of zoning, attention to the use of adjacent land and the growth of resources is important. Therefore, the landfill should not be located for the future development of the city. This is important both in terms of generating traffic due to the movement of garbage trucks and in terms of issues related to the implementation of landfill operations (Shamsaefard;2016), the basic approach to locating the location of each activity requires Considering a set of environmental limiting factors such as slope, protected areas, surface water and groundwater resources, as well as reinforcing factors such as access and land use, in fact, a multi-criteria decision is analysis hierarchical process (AHP). One of the comprehensive systems designed for decision making is multiple criteria, which is a graphical representation of the real problem, at the top of which is the overall goal and at the other level are the criteria and options (Kaviyanirad;2011), The use of geographic information systems (GIS) in landfill location is a relatively new topic that has become common in the last decade regarding the use of AHP in the GIS environment in locating landfills outside

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and Inside the country, we can mention the following (Lou;2020), in a study entitled Application of GIS in locating suitable landfills in the US state of Vermont, the 210-hectare area in terms of physical, geomorphological and economic indicators such as soil suitable for rock depth in land use, surface and groundwater, elevation zoning, Data and identified a suitable landfill around the area (Huo;2021), integrated an intelligent model of the Expert system with GIS and provided an environment for assessing and locating landfills using GIS (Abuabdou;2020). They also conducted a study in which they combined the AHP method with fuzzy set theory in the GIS raster environment to obtain initial screening of landfills in Thailand (Yamani;2016). In a study for location for fuzzy set theory and hierarchical method for the location of four hospitals in the state of Punjab, India has been presented. In this study, geographic information system was used and criteria of topography, land use, distance from population centers, vegetation Geology and soil science, groundwater depth and surface water were used. Therefore, the need to pay attention to urban waste management can improve the health of people in the community and the need to create a beautiful and pleasant environment for citizens (Singh;2019). Waste management has been neglected in small towns, which could jeopardize the city's future. Due to the problems of Qazvin city in the field of waste management, including the selection of the optimal location for sanitary landfilling of waste, the need for a study in this field seems necessary.

2.The Study Area

Qazvin province with an area of 15623 square kilometers in central Iran between 48 degrees and 44 minutes to 50 degrees and 51 minutes east longitude of the Greenwich meridian and 35 degrees 24 minutes to 36 minutes to 36 degrees and 48 minutes north latitude relative to the equator contract. The population of Qazvin province according to the statistics of 2016 is equal to 1.3 million people, of which 600,000 are residents of Qazvin city. It is central and is limited to Tehran province from the east. This province is located in the southern foothills of the Alborz Mountains, which is one of the temperate parts of the country due to its numerous heights and moderate rainfall.

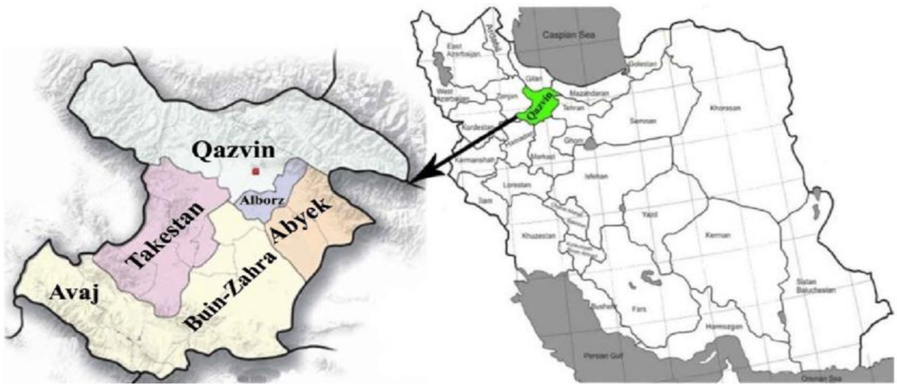


Fig 1. Study area

3. Materials and Methods

3.1 GIS Technique

The first step in GIS software is to determine the distance map so that 5 classes in the province can be prioritized in the order of codes 9, 7, 5, 3, 1, respectively. Based on these priorities, different important areas were determined. These 5 classes were identified in order of suitability: ultra-strong importance, very strong importance, strong importance, medium importance and low importance, each of which has assigned codes 9, 7, 5, 3, and 1, respectively (1).

Table1
Scoring and coding parameters

code	Score
Nonsignificant	1
Medium importance	3
Strong importance	5
Very strong importance	7
Extremely strong importance	9

city and population centers - distance They are protected areas and distance from access roads. Initially, for each of the above parameters, if necessary, a distance map is prepared in the GIS software environment. Then each of the above parameters is classified in the GIS environment according to the following description. Using satellite images and topographic maps, the scale of the study area was examined and the boundaries were determined. Then the required information layers should be zoned in Arc GIS 9.3 environment as follows: first layers of distance from protected areas,

3.1.1 Groundwater Level

The average groundwater level in Qazvin province is 29.5 meters, with a maximum depth of 55.98 meters and a minimum depth of 0.48 meters. The following classifications were made for the location of the landfill based on the groundwater level:A- If the groundwater level is between 0 to 10 meters, the desired area in terms of landfill is insignificant or in other words unsuitable and gets a score of 1.B- If the groundwater level is between 10 and 15 meters, it is of medium importance and gets a score of 3.C- If the groundwater level is between 15 to 20 meters, it is of great importance and gets a score of 5.D- If the groundwater level is between 20 to 25 meters, it is very important and gets a score of 7.E- If the groundwater level is more than 25 meters, it is very strong and gets a score of 9. distance from faults, distance from population centers, distance from access road, distance from water Groundwater surface and depth were prepared using Distcnce Tool in Spatial Analyst Tools, then maps classified into 5 classes were prepared using Reclass Tool. Geological and land use layers were defined by Conversion Tools and classified as previous layers, slope layers (topography) were coded by Slope Surface tool. Scoring different parameters between 1 to 9 is selected and is as follows.

3.1.2 Distance from Surface Water Sources

The distance from surface water sources or rivers in the study area is 929.89 meters on average. The maximum distance is 1310/11077 meters and the minimum is zero. To consider the landfill based on the distance from surface water sources, the following classification has been done:A- If the distance from surface water sources is between 0-1000 meters, the desired area is insignificant or inadequate in terms of landfilling and gets a score of 1.B- If the distance from surface water sources is between 1000 to 2000 meters, it is of medium importance and gets a score of 3.C- If the distance from surface water sources is between 2000 and 3000 meters, it is of great importance and gets a score of 5.D- If the distance from surface water sources is between 3000 to 4000 meters, it is very important and gets a score of 7.E- If the distance from surface water sources is more than 4000 meters, it is very strong and gets a score of 9.

3.1.3.Distance from Faults

The maximum distance from the faults is more than 34196.6 meters, while the average distance is 7304.78 meters and the minimum distance is considered zero.To consider the landfill based on the distance from the faults, the following division has been made:A- If the distance from the faults is between 0-3000 meters, the desired area in terms of landfill is insignificant or in other words unsuitable and gets a score of 9.B- If the distance from the faults is between 3000-6000 meters, it is of medium importance and gets a score of 7.C- If the distance from the faults is between 6000-9000 meters, it is of great importance and gets a score of 5.D- If the distance from the faults is between 9000-12000 meters, it is very important and gets a score of 3.E- If the distance from the faults is more than 12000 meters, it has a very strong importance and gets a score of 1.

3.1.4.Slope (Topography)

To consider the landfill based on the slope of the following division has been done:A- If the slope is between 0 to 15%, the desired area is very strong in terms of landfill and gets a score of 9.B- If the slope is between 15 to 20%, it is very strong and gets a score of 7.C- If the slope is between 20 to 30%, it is very important and gets a score of 5.D- If the slope is between 30 to 45%, it is of medium importance and gets a score of 3.E- If the slope is more than 45%, it is insignificant or in other words inappropriate and gets a score of 1.

3.1.5.Geology

To consider the landfill based on the type and material of stones, the following classification has been done:
A- If the type and material of rocks are limestone, creek, gypsum, floodplain, the desired area is less important in terms of landfill and gets a score of 1.
B- If the type and type of rocks are sand-trust types, it is of medium importance and gets a score of 3.
C- If the type and material of rocks are basalt-andesite and dacite and rocks are not separated, it is of great importance and gets a score of 5.
D- If the type and material of rocks is shale, it is very strong and gets a score of 7.
E- If the type and material of the stones are clay, the importance is extremely strong and it gets a score of 9**.**

3.1.6.Distance from the City and Population Centers

The maximum distance from the city and population centers is more than 12710.86 meters, while the average distance is 1700.003 meters and the minimum distance is considered zero. To consider the landfill based on the distance from the city and population centers, the following division has been made:
A- If the distance from the city and population centers is between 0 to 3000 meters, the desired area is insignificant or in other words unsuitable in terms of landfilling and gets a score of 1.
B- If the distance from the city and population centers is between 3000 and 6000 meters, it is of medium importance and gets a score of 3.
C- If the distance from the city and population centers is between 6000 to 9000 meters, it is of great importance and gets a score of 5.
D- If the distance from the city and population centers is between 9000 to 12000 meters, it is very strong and gets a score of 7.
E- If the distance from the city and population centers is more than 12000 meters, it has a very strong importance and gets a score of 9.

3.1.7.Distance from Access Roads

The maximum distance from the access roads is more than 44633 meters, while the average distance is 8555 meters and the minimum distance is considered zero. To consider the landfill based on the distance from the access roads, the following division has been made:
A. If the distance from the access roads is between 0 and 4000 meters, the desired area is extremely strong in terms of landfill and 9 points.
B- If the distance from the access roads is between 4000 to 6000 meters, it is very strong and gets 7 points.
C- If the distance from access roads is between 6000 to 8000 meters, it is of great importance and gets a score of 5.
D- If the distance from the access roads is between 8000 to 12000 meters, it is of medium importance and gets a score of 3.
E- If the distance from the access roads is more than 12000 meters, it is insignificant or in other words inappropriate and gets a score of 1.

3.1.8.Distance from Protected Areas

The maximum distance from the protected areas is more than 110166.59 meters, while the average distance is 45458.14 meters and the minimum distance is considered zero. To consider the landfill based on the distance from the protected areas, the following division has been made:
A- If the distance from the protected areas is between 0 and 1000 meters, the desired area is insignificant in terms of landfill or in other words unsuitable and gets a score of 1.
B- If the distance from the protection areas is between 1000 to 2000 meters, it is of medium importance and gets a score of 3.
C- If the distance from the protection areas is between 2000 to 3000 meters, it is of great importance and gets a score of 5.
D- If the distance from the protected areas is between 3000 and 4000 meters, it is very strong and gets a score of 7.
E- If the distance from the protected areas is more than 4000 meters, it is very strong and gets a score of 9.

3.1.9.Land Use

To consider the landfill based on land use, the following division has been made:
A- If the type of water is mixed with wetlands, medium forests, groves, wetlands, sparse forests,

urban, the area is less important in terms of landfilling and gets a score of 1.
B- If the type of mixing of garden and, mixing of groves and, mixing of rich pastures and, mixing of agriculture and, mixing of agriculture and garden, garden, agriculture, is of medium importance and gets 3 points.
C- If the type of mixing is medium rangelands and medium rangelands, it is of great importance and gets a score of 5.
D- If the type of mixing of dry fields is the mixture of agriculture and dry fields, it is very strong and gets a score of 7.
E- If the type of mixing of poor pastures and dry fields, barren lands, salinities, rocks, pastures weak, the importance is extremely strong and it gets 9 points.

3.2 .Analytical Hierarchy Process

The process of hierarchical analysis is one of the most efficient multi-criteria decision making techniques, first proposed by Saaty. This method is based on pairwise comparisons of factors and allows managers and decision makers to examine different scenarios. Most systems are designed to make multiple criteria decisions. Because it allows the formulation of complex natural problems in a hierarchical way, as well as the possibility of considering different quantitative and qualitative interpretations of the radar problem (Saaty;1986).

A) Develop a Hierarchical Structure for the Location of Landfills

The first step in the hierarchical process is to create a graphical representation of the problem in which the purpose of the criteria and options are shown. Although there is no fixed and definite rule for drawing a hierarchy, some people have tried to establish some general rules in this field. To express. Bowen and Forman state that the hierarchical structure may be in one of the following ways:
Objective-criteria-sub-criteria-options
Objective-Criteria-Factors-Sub-Factors-Options (Forman;1991),
In this research, in order to compile the hierarchical structure of waste disposal in Qazvin province, the first structure including (objective-criteria-sub-criteria-options) has been used, which includes the following levels:

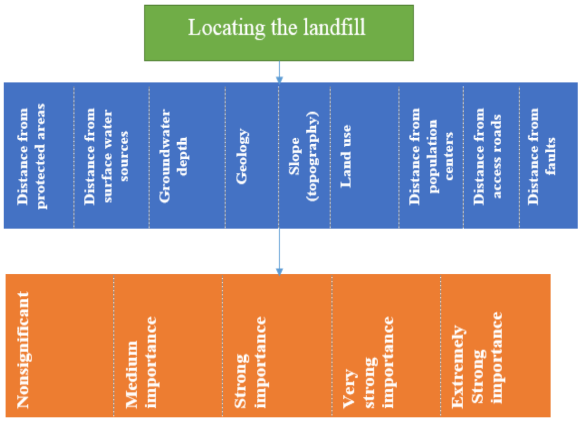


Fig2. Hierarchical tree structure

B) Weighing the Effective Factors in Locating the Landfill

In assessing the location of the landfill, not all parameters are weighted and some criteria act as a key factor, so that even if other parameters are appropriate, it will cause the study area to be considered inappropriate. For this reason, in order to obtain the ranking, the importance of the criteria for deciding on the landfill, the parameters have been weighted. After determining the parameters, the degree of importance of the parameters relative to each other was obtained as paired comparison matrices and based on the range of each parameter in the range of 1 to 9. This was done by performing a pairwise comparison of the decision elements (pairwise comparison) through numerical scoring, which indicates the importance of importance between the two decision elements. The calculated weight is called the relative weight. In decisions that compare the differences between options or indicators is less sensitive. Instead of using nine comparisons, a five-point scale (9,7,5,3,3) can be used. All steps of pairwise comparisons and obtaining the weight of each parameter were performed under GIS software, during which the normalized comparison table was obtained. Determining the weight for each parameter determines the importance of those two scales with other factors, so each parameter that has more weight is prioritized for attention and location. In this study, a pairwise comparison matrix questionnaire was prepared, which was completed by 40 experts in the field of environment and geotechnics, and then using the geometric mean method, which is one of the best methods to combine the Roji comparison table. Geometry is the most appropriate mathematical rule for combining judgments in AHP (Ghodsipuor;2000).

C)AHP Survey Questionnaire

The criteria are compared to each other on the basis of importance. For example, below A (in a row) is three times better than B (in a column). Variable A (in a row) is 5 times better than C (in a column) and B (in a row) is 3 times better than C (in a column) (Table 2).

Table2
Example of a paired comparison matrix

Criteria	A	B	C
A	1	3	5
B		1	3
C			1

There are four main methods in extracting weights from the decision matrix, which include the least squares method, the logarithmic least squares method, the eigenvector method and the approximate methods. The approximate methods themselves are divided into four methods:
The line sum method - column sum method - arithmetic mean method - geometric mean method divided, which in this study the geometric mean method is discussed. The mechanism of using this method in a collective decision making is that the geometric mean is calculated for each of the matrix pairs of decision makers (Shayesth;2010).

D) Calculate the Incompatibility Rate
After weighting and before applying weights, the consistency of the comparisons should be ensured and the rate of incompatibility calculated. In the compatibility index analysis, if this value is less than 0.1, the comparisons are acceptable, otherwise the comparisons should be revised. This step consists of three parts.

1) Calculation of special vector (λ max)

Step 1: Multiply the matrix by the weight vector, Step 2: Divide the numbers obtained from the above step by the weight of the relevant indices; Step 3: Averaging all the numbers obtained,

2) Incompatibility Index (I.I)

The following formula is used to calculate the incompatibility index.

$$I.I = \frac{\lambda_{max} - n}{n-1}$$

n, Number of options (matrix dimensions)

3) Incompatibility Rate (I.R)

$$I.R = \frac{I.I}{R.I}$$

I.I incompatibility index and R.I Incompatibility Rate is a random matrix obtained from Table 3 (Shayesth;2010):

Table 3
The value of the incompatibility index for the next n matrix

N	11	10	9	8	7	6	5	4	3	2
R.I	1.51	1.49	1.45	1.41	1.32	1.24	1.12	0.90	0.58	0.00

3.3 The Final Map

To calculate the final weight of each of the hydrogeomorphic factors in the optimal location of the landfill, the weight of the layer prepared by the hierarchical method must be multiplied in its layer and then all the layers are added together and the final map in 5 classes respectively Extremely strong importance, very strong importance, strong importance, medium importance and low importance are classified, the best points for landfill are marked with the degree of extremely strong importance.

4.Findings and discussion
Results of groundwater surface layer classification - Distance from surface water sources Distance from faults - Slope (topography) - Geology - Land use - Distance from city and population centers - Distance from protected areas and distance from access roads Weighting of factors, matrix comparison pairs and normalization of effective factors in locating landfills in the study area are described in Tables (2) to (4) and Figures (2) to (3).

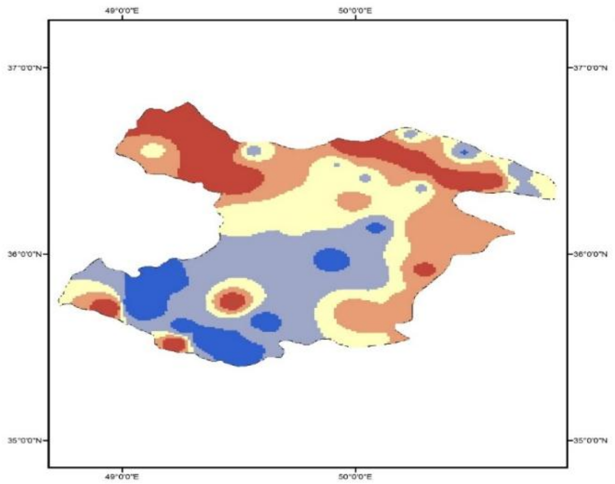


Fig. 2. (a) Groundwater depth classification map

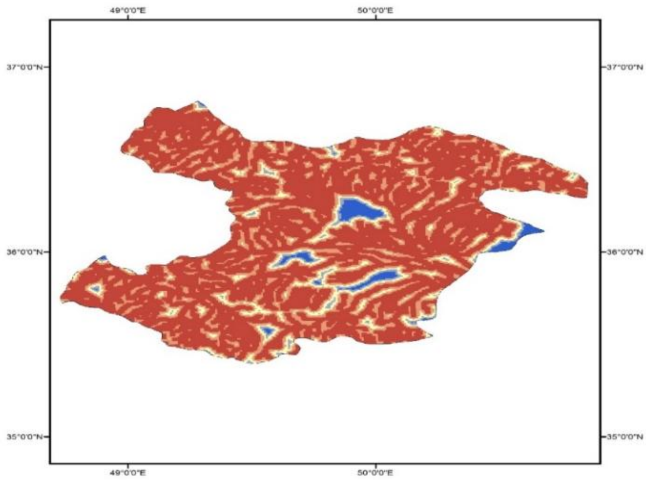


Fig. 2. (b) Surface water classification map

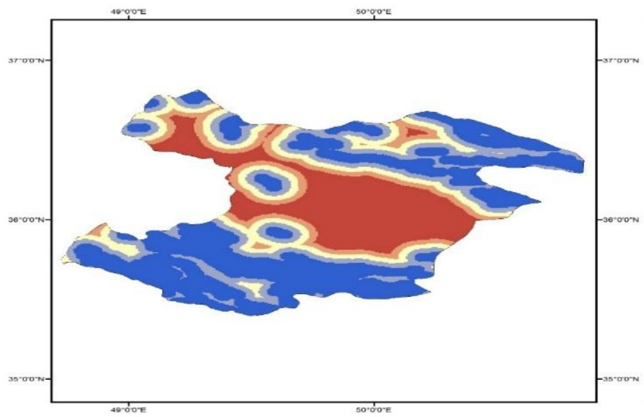


Fig. 2. (c) Fault classification map

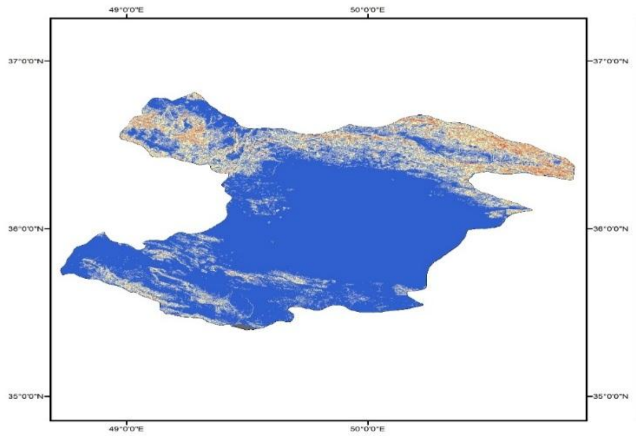


Fig.2. (d) Slope classification map (topography)

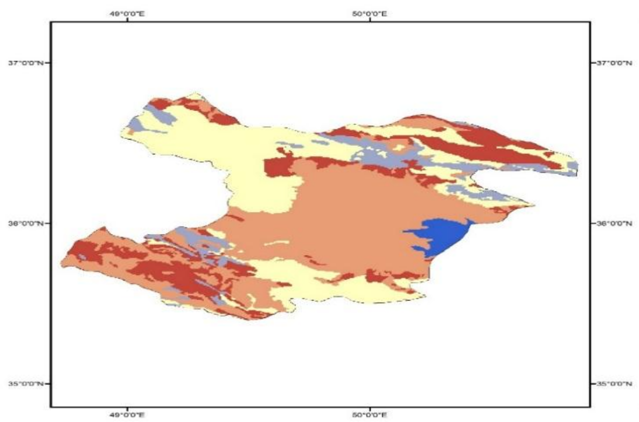


Fig.2. (e) Geological classification map

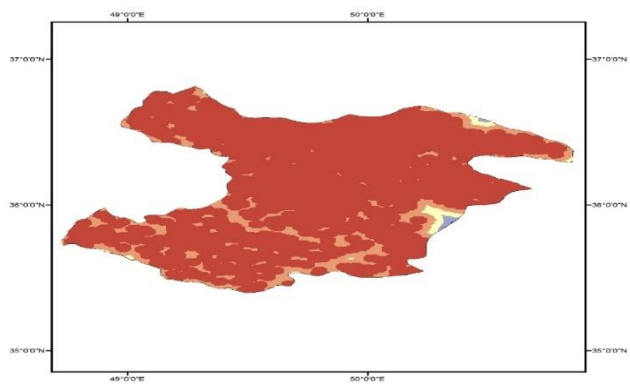
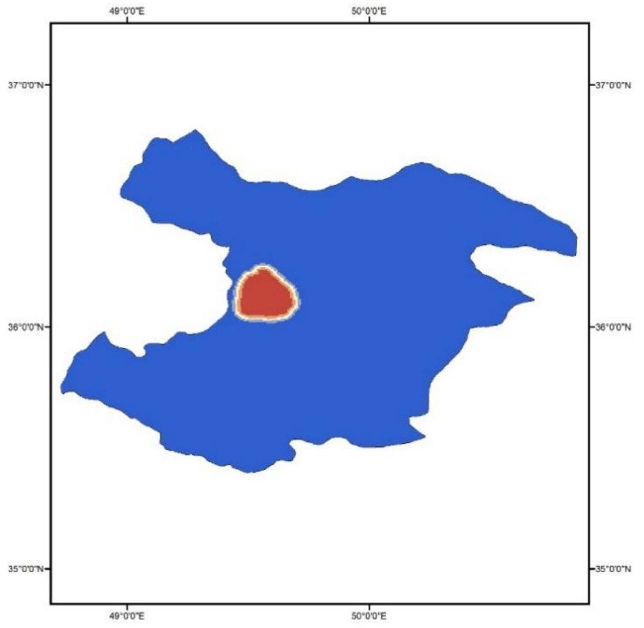


Fig. 2. (f) Classification map of distance from population centers



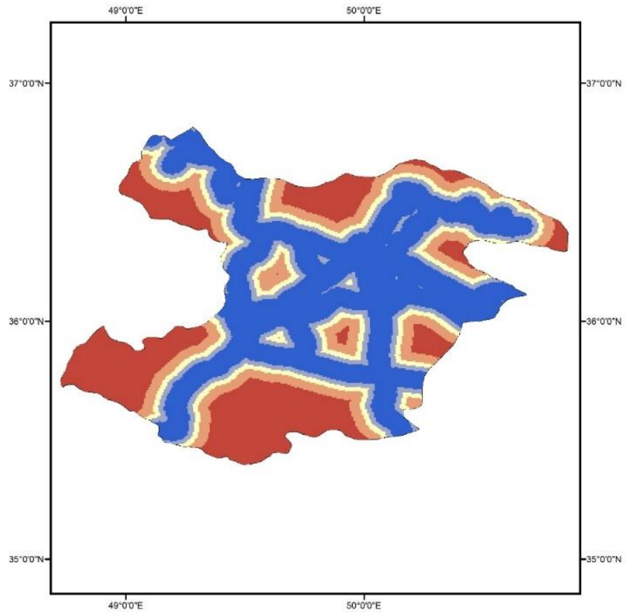


Fig. 2. (g) Map distances classification of protected areas

Fig. 2. (h) Map distance classification from access road

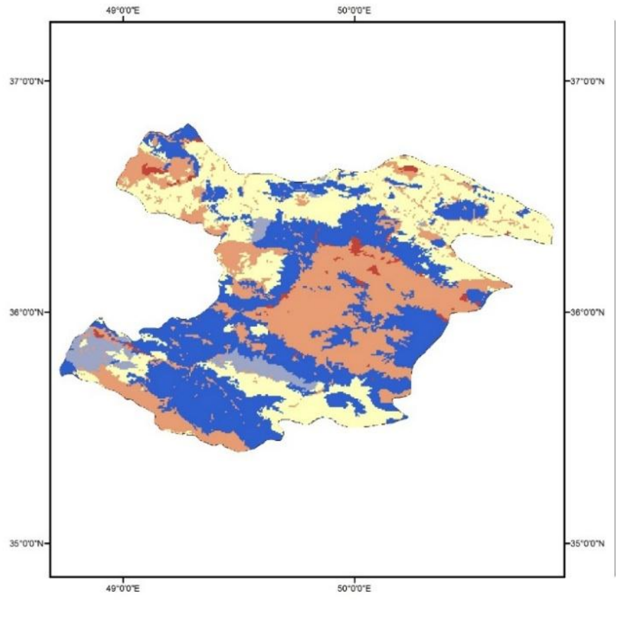


Fig. 2. (i) Land Use Classification Map

Fig. 2. Classified layers maps

Table4
Paired comparison of criteria with one another

	Distance from protected areas	Distance from surface water sources	Groundwater depth	Geology	Slope (topography)	Land use	Distance from population centers	Distance from access roads	Distance from faults
Distance from protected areas	1	1	1	3	3	3	3	3	3
Distance from surface water sources	1	1	1	1	5	3	3	5	3
Groundwater depth	1	1	1	1	3	3	3	3	3
Geology	0.33	1	1	1	3	1	3	3	5
Slope (topography)	0.33	0.2	0.33	0.33	1	3	3	3	3
Land use	0.33	0.33	0.33	1	0.33	1	1	3	3
Distance from population centers	0.33	0.33	0.33	0.33	0.33	1	1	3	3
Distance from access roads	0.33	0.2	0.33	0.33	0.33	0.33	0.33	1	3
Distance from faults	0.33	0.33	0.33	0.2	0.33	0.33	0.33	0.33	1

Table3
Incompatibility index values and incompatibility rates

Criteria	**-**
Incompatibility Index (I.I)	0.1023
Incompatibility Rate (I.R)	0.0706

The rate of incompatibility of the criteria matrices was shown in Table (3).
The incompatibility rate is less than 0.1. By calculating the geometric mean, the weight of each criterion and sub-criterion was obtained.

Table4
Normalized weight of each criterion

Criterion	Geometric mean	Weight
Distance from protected areas	2.080	0.193
Distance from surface water sources	2.062	0.191
Groundwater depth	1.841	0.171
Geology	1.526	0.142
Slope (topography)	0.944	0.087
Land use	0.783	0.072
Distance from population centers	0.693	0.064
Distance from access roads	0.454	0.042
Distance from faults	0.355	0.033
Total	10.741	1

The final map in the GIS environment was extracted from the created layers in such a way that the weights obtained in the hierarchical section are multiplied by the prioritized layer and then added to the next layer, which is also multiplied by its weight, for 9 layers of the floor. These steps are done with high precision. In this study, based on the opinions of ten geotechnical and environmental experts, the highest weight is assigned to protected areas and the lowest weight is assigned to the distance from the fault. According to the final map, an area with a criterion of extremely strong importance as the best place for Sanitary landfilling of waste in Qazvin province has been determined and according to the field operations performed and in accordance with the map extracted in the GIS environment, the most suitable area for landfilling in Qazvin city was identified as 4 areas, which according to field studies is the best place in region 1 nearby. The village of Mohammad Abad is located at km 28 of Qazvin-Buin Zahra road, which is located at 49 ° 58 'east longitude of the Greenwich meridian and 36 ° 58' north latitude above the equator and 1193.4 m above sea level (Figure 3). The currently selected location is located in the location map along with the field survey away from residential, recreational and tourist centers and in terms of roughness and land value, distance from surface and groundwater and other parameters are analyzed and According to the obtained results, it has sufficient capacity for at least 15 years of landfilling for Qazvin city. It should be noted that an important factor in choosing this place is the existence of waste compost plant in this area and also the proximity of landfill to Qazvin city - Takestan - Buin Zahra - Alvand It is almost at a distance so that if needed in the located area (Mohammad Abad) for three other cities in Qazvin province, including Takestan-Buin Zahra-Alvand, another landfill can be built in this area. This place can bury 500 tons. It has garbage per day according to the multi-year perspective of Qazvin Waste Management, it is considered to transfer all garbage from these cities to this landfill.

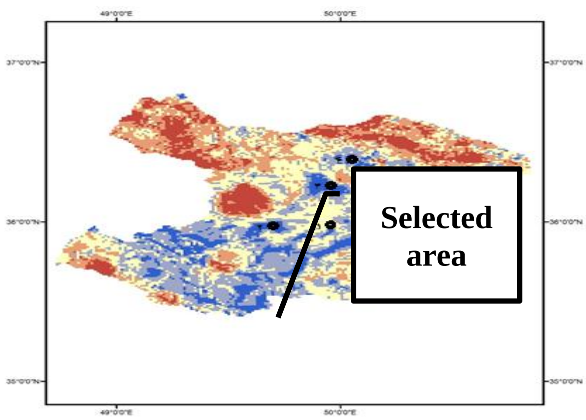


Fig 3. Final map of 4 classified areas of Qazvin province

4.Conclusion

Choosing the right landfill and municipal waste management for developing countries is one of the major problems they face most of the time. Locating a sanitary landfill requires proper studies and management practices, and several criteria affect the selection of a suitable landfill, which if not addressed, will cause severe environmental pollution and harm to humans. As a result, creating a national strategy to protect natural resources and prevent environmental pollution is very important and necessary. The choice of municipal landfill may be made for each city, but this is very difficult and costly through conventional and traditional methods. Therefore, GIS technique, due to its ability to manage large volumes of spatial information, is a powerful tool for this type of study. A variety of models, such as AHP, have been used by planners to solve the complex management problems they face. In the present study, hierarchical method and combination with GIS technique were used to locate the landfill in Qazvin province. In general, this method makes it possible to select the most appropriate option in this research, which is the optimal location of the landfill, by analyzing the decision-making and ranking parameters. The hierarchical analysis process is one of the most comprehensive systems designed for decision making with multiple criteria. Because this technique provides the possibility of formulating problems in a hierarchical manner and also allows the consideration of different quantitative and quantitative criteria in the year, initially 9 layers including distance from access roads, distance from population centers, land use, groundwater level Slope, geology, distance from surface water sources, distance from protected areas, distance from fault were created and then evaluation was done using spatial analyst method and after using hierarchical analysis method, based on priority Landfill location Two-way comparison was performed on the criteria and the final weight of each layer was extracted and based on the weights of each of the evaluated criteria, the final map of Figure (3) in the GIS environment was extracted from the created layers. In this study, the highest weight is assigned to the layer of protected areas and the lowest weight to the distance layer from the fault. From the final map, suitable areas for sanitary landfilling were determined. Among these areas, the best place for sanitary landfilling of Qazvin province was determined. The area near Mohammadabad village was selected as the landfill of Qazvin city. It should be noted that important factors in the selection This burial place is close to the city of Qazvin-Takestan-Buin Zahra-Alvand is approximately one place distance so that if needed in the location (Mohammad Abad) for three other cities of Qazvin province including Takestan-Buin Zahra-Alvand burial place another waste was constructed in this area due to the size of the area in question, and also due to the wind and the existence of a compost factory in this area, it has become an important factor in choosing this place as a landfill.

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