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Land Suitability Analysis for Physical Development Based on Natural Criteria (Case Study: Bojnord)

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A B S T R A C T

Objective: Ignoring suitable land for urban and non-urban development, especially in zones that have physical and natural problems, greatly influences security and the costs of living and eventually, leads to human and environmental disasters..
Methods: This research intended to evaluate urban land suitability for physical development in Bojnord in north Khorasan based on natural factors and by using the Analytic Hierarchy Process (AHP) technique. The library and field research methods were employed for collecting data and the Arc GIS and Global Mapper 16 software for analysing the data and for making calculations. The studied geographical zone was the entire city of Bojnord and its surrounding areas. The investigated indicators included slope, vegetation, fault, geological characteristics, elevation, river, groundwater, and type of soil and its erosion..
Results: The analysis of the results showed that, considering the geographical and topographic features of the city, only about 9 percent (8804 hectares) of the available areas (distributed in the north western and southern parts of the city) were very suitable or suitable, about 9.98 percent (9869 hectares) moderately suitable, and 81 percent unsuitable or very unsuitable.
Conclusion: land-use planning for this city is of high sensitivity, and it is essential that results of studies on land suitability be employed.

1. Introduction

Despite attempts and claims made by humans, natural and environmental factors still exert undeniable effects on human life and activities, and people cannot easily achieve their goals and objectives without paying attention to natural rules and conditions. That is why some people believe that the environment is a deciding phenomenon in human life (Nazarian, 2009), and ignorance of ecological differences and environmental potentials will have undesirable consequences including soil erosion, desertification, reduced forests and rangelands, etc. (Jalaiyan and Ayubi, 2010). Consequently, identification of the productive constituents, elements, and factors in the environment is considered the

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prerequisite for any activity (Soroor, 2008). The effects of human activities on the environment and the appearance of these effects as natural and man-caused disasters attract greater attention than before now that cities occupy greater areas and support higher population densities (Ghanavati and Goodarzi, 2013). The reason for this is that these activities have led to the destruction of orchards and agricultural lands, encroachment on river boundaries and infringement on environmental values, development on steep slopes, etc. (Karam and Mohammadi, 2009). All of this has happened at a time that urban development is unavoidable and sensitivity to the environment and attention to its protection have acquired more fundamental dimensions and urgencies (Mirkatouli, 2011). Therefore, it is necessary that urban development takes place in areas that will have minimal undesirable consequences (Karam and Mohammadi, 2009).

Bojnord, the subject of this research, accounts for about 56 percent of the population in North Khorasan Province; however, it faces topographic obstacles to its urban development. Nevertheless, the managers of this city, who favor development and progress, consider it as the center of development in the northeastern part of Iran and believe that Bojnord has the capacity for urban population growth and for various industrial and commercial activities (Ziari, 1999). To test these claims and determine their validity, the present research intended to show that this city is facing various natural and physical bottlenecks even now and will be confronted by them in its future development, and hence, these problems have to be addressed in making policy decisions for the future. Based on this, land suitability for physical development of Bojnord was evaluated using natural factors and agents and employing the AHP technique combined with a geographic information system (GIS).

2. Materials and methods

This was an analytical-descriptive research with Bojnord as its statistical population. The library method was used to collect information regarding the background of the study and theoretical principles and the field research method, which included a questionnaire and interviews with 30 experts, was employed to collect data required to answer the question and achieve the goals of the research. The studied indicators were slope, vegetation, fault, geological characteristics, elevation, river, groundwater, and soil type and its erosion. The AHP technique and the GIS software were used to analyze the information, and the stages below were followed to determine the suitable areas for the physical development of the city:

Stage 1: Information was obtained from the related organizations. Of course, some of the required information layers such as the elevation layer of the study region were acquired by using the Global Mapper 16 software. Landsat images were employed for determining the current boundaries of Bojnord.

Stage 2: After collecting the initial information, it was entered into the geographical information system software (ArcGIS). This information included spatial information layers and various characteristics of the study region (in tabular form) (Fig 2).

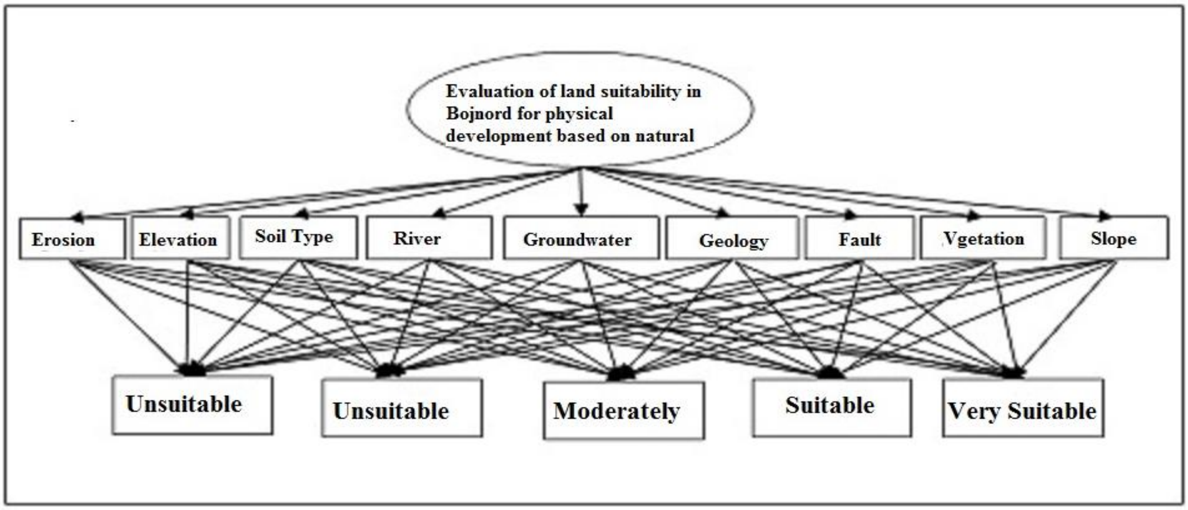

Fig 2: The model for determining land suitability for physical development based on natural criteria (theoretical principles)

Stage 3: Since the data entered into the GIS was in vector form, it was converted into the raster format so that various layers could be combined.

Stage 4: The indicators were classified and given scores. In this stage, all the raster layers were reclassified based on the various characteristics and each class was given a score according to its level of importance. For example, the percentage or degree scales and the meter scale, which are different from each other, were employed for measuring slope and distance from faults, respectively. Therefore, all of the constructed raster layers had to have the same scale, and hence, they were given the scores from 1 to 9 because these are the scores given in the AHP technique.

Stage 5: Each of the selected indicators for the physical urban development had a level of importance different from the others, and therefore, the weight of each index had to be determined, and the AHP technique was employed for this purpose.

Stage 6: In this stage, the weight obtained for each index was applied in the raster layers and finally, all the raster layers were combined.

Stage 7: the study region was prioritized with respect to physical development. Since most of the models and methods mentioned above have been described in previous studies, only the main model used in this research is illustrated briefly merely to show the methodology employed in it. The AHP technique is a comprehensive method for resolving the difficulties of multiple criteria decision-making (Tolga, 2004). It was introduced in 1971by Sa'ati as a tool for analyzing extended decision-making (Yu, 2002). This technique is based on paired comparisons and allows investigation of various conditions (Shokouhi and Moradi, 2012).

After the maps were prepared based on the indicators, and in order to blend and group them into specific classes, a table of indicators and scores was drawn up so that the AHP technique could be used together with GIS. The maps were then converted from the vector form into the raster format, and weight maps were prepared based on the new scores. The maps were then recalled in the combined AHP and GIS environment, and the priorities of the indicators in relation to each other were first determined based on the preference table introduced by Sa'ati. The weights and the coefficient of stability were then calculated and confirmed considering the standard value in the table mentioned above (which must be less than 0.1). Following that, the groundwork was prepared for the analysis stage and for combining the indicators to determine land suitability for physical development based on natural criteria.

The spatial realm in this research was Bojnord with the longitude of 57˚20′, latitude of 37˚29′, and altitude of 1070m. It is bounded to the north and southwest by a fault and to the north and east by a river and many channels (Fig 1).

Fig 1: The geographical and political position of the study region

3. Results

1.3 Analysis of the Information

Considering the main goal of the research, the findings can be grouped into the following classes:

A. Zoning the Study Region Based on Slope

Slope directly influences land use policies and, in addition, redoubles vulnerability through its effects on the process of developments in the neighboring geomorphological phenomena. In fact, these features keep the phenomena of creep, landslide, and erosion always dynamic and active, and thus, directly or indirectly influence natural and human activities (Taghvaei et al., 2013).

As was stated above, reverse scoring was used for the slope layer. The classification of and giving scores to the raster slope layer were based on five groups, the results of which are presented in Figure 3. According to this figure, the first and second priorities were given to lands with slopes of 0-30˚ (the score of 9) and to lands with slopes of3-5˚ (the score of 5), respectively. Therefore, lands with the first and second slope priorities are in the southwestern and in a section of the northeastern part of the current city limits, and lands with the third and fourth priorities (and lands without priority) are distributed in other urban areas.

B. Zoning the study region based on topography

Topographical features are one of the most important factors that influence urban development, and Topography is important in many urban issues including determination of the routes for water and gas pipes, etc. (Jabbari et al., 2010). Furthermore, high elevations and mountainsides cause problems for movement and transportation. Reverse scoring was also used for the classification of and assigning scores to the elevation layer. The first priority was allocated to lands with elevations of 800-1000 meters, and lands with elevations of more than 1750 meters lacked priority. Therefore, the most suitable elevations, which have the first priority in value, are located northeast of the area surrounding Bojnord, followed by lands with elevations of 1000-1250 meters, which cover most of the study region and especially the current city limits and areas surrounding the city to the northeast (Figure 4).

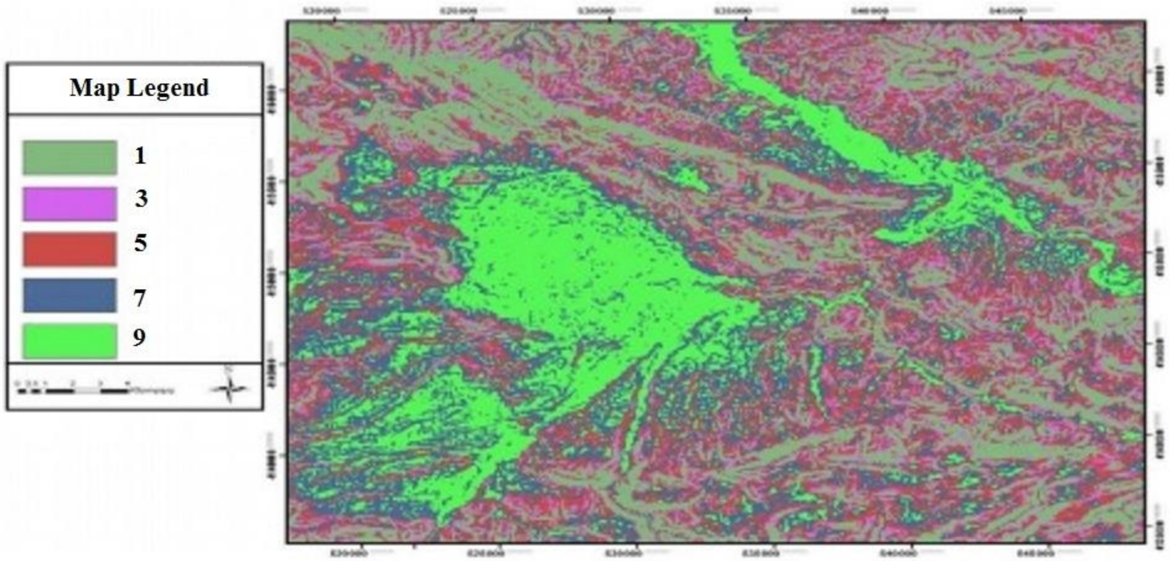

Fig 3: Classifying and reassigning scores to the slope layer (research findings, 2016)

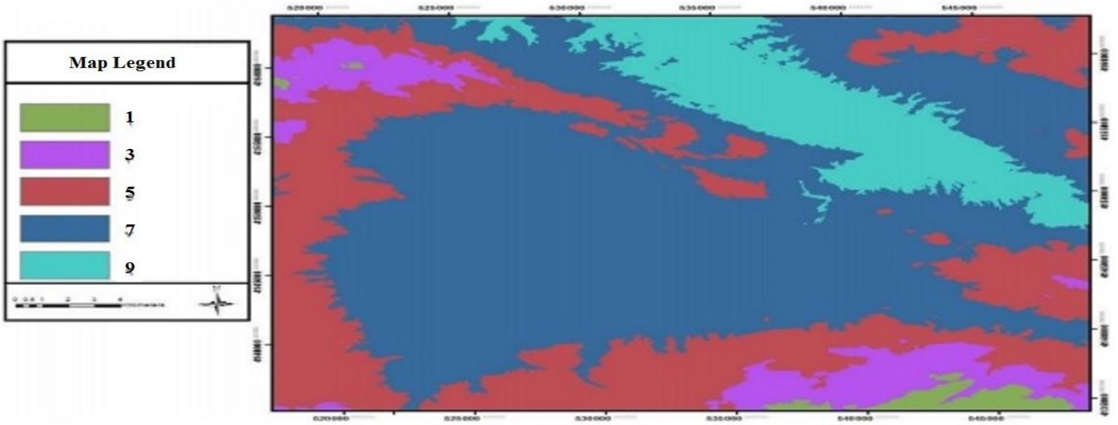

Fig 4: Classifying and reassigning scores to the elevation layer (research findings, 2016)

C. Zoning the study region based on water resources

The major water resources of Bojnord are its rivers, a number of deep wells, springs, and qanats. The layers formed by the wells, Qantas, and springs were changed into a single one, and the density rule was applied to convert this layer into the raster format. This function was used to determine the areas that contained the maximum amount of water (Table 1 and Fig 5).

D. Zoning the study region based on vegetation

The layer that represented vegetation was first converted into the raster format using the polygon to raster rule and was then classified and given scores based on vegetation type (Table 2 and Fig 6).

Table 1: Classifying and giving scores to the layer of water resources

Prioritization	Zoning based on access to water resources	Scores
First priority	0- 0.014	9
Second priority	0.014-0.048	7
Third priority	0.048-0.091	7
Fourth priority	0.091-0.146	3
Fifth priority	0.146-0.222	2

Reference: Research Findings, 2016

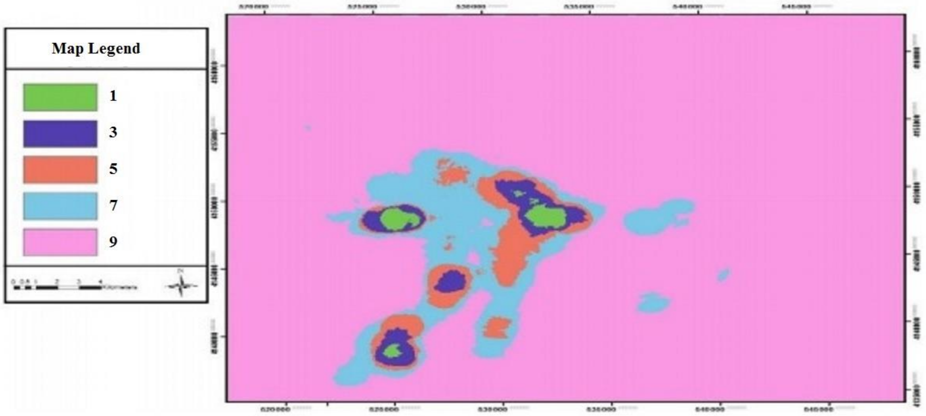

Fig 5: Classifying and reassigning scores to the layer of groundwater resources
Reference: Research Findings, 2016

Table 2: Classifying and giving scores to the vegetation layer

Prioritization	Zoning based on access to water resources	Scores
First priority	Built-up areas	9
Second priority	Low-density rangelands	7
Third priority	Moderately vegetated rangelands	5
Fourth priority	Densely vegetated rangelands	3
Fifth priority	Sparse forests, planted forests, rained and irrigated cultivation	1

Reference: Research Findings, 2016

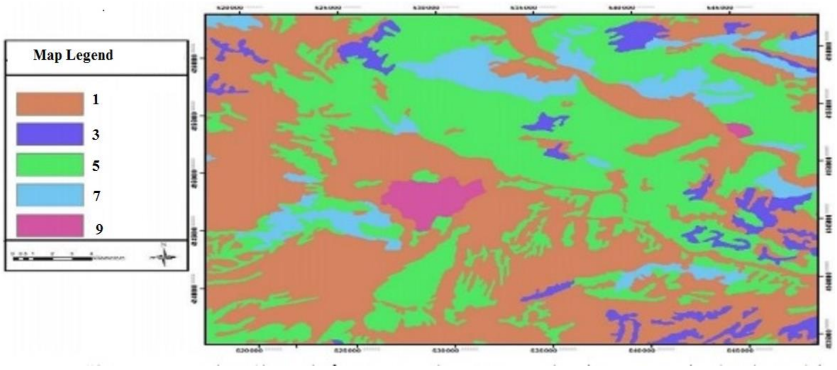

Fig 6: Classifying and reassigning scores to the vegetation layer

E: Zoning the study region based on distance from faults

In urban studies, it is necessary to observe fault zones, and type of land use must be considered with respect to fault lines (Babarian et al., 1992). Therefore, the study of the role played by this factor is very important and fundamental in determining land suitability. As usual, the types of information regarding this factor were given reverse scores (Table 3 and Fig 7).

Table 3: Classifying and giving scores to distances from the faults

Prioritization	Zoning the study region based on vulnerability to earthquakes	Scores
First priority	+6000	9
Second priority	5000-6000	7
Third priority	3000-40000	5
Fourth priority	1000-2000	3
Fifth priority	0-1000	1

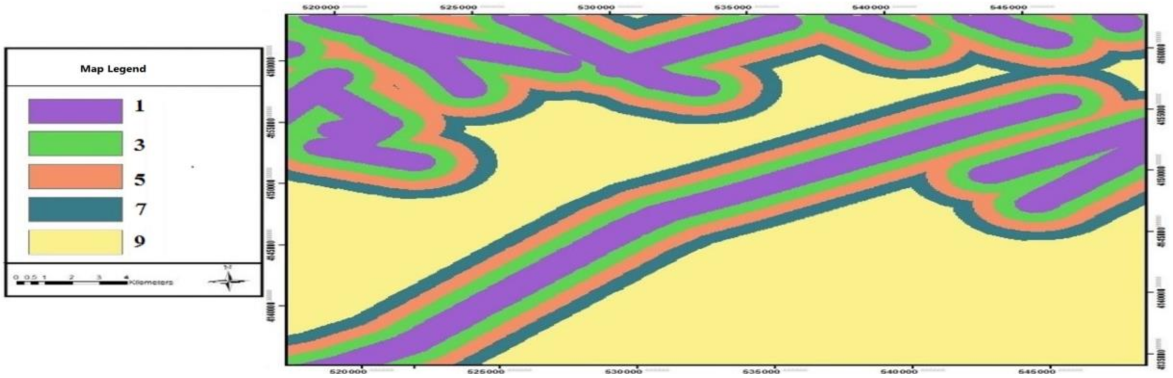

Fig 7: Classifying and reassigning scores to the layer of distance from faults
Reference: Research Findings, 2016

F: Zoning the study region based on distances from the rivers

Natural disasters resulting from river flooding and harmful environmental effects caused by river pollution and environmental pollution along river margins and banks are one of the problems cities and residential complexes face (Jabbari et al., 2010:40).In this research, areas at a distance of more than 3000 meters from the rivers were given the first priority, at 2000-3000 meters from the rivers the second priority, etc., and those at a distance of fewer than 1000 meters from the rivers the fifth priority (Fig 8).

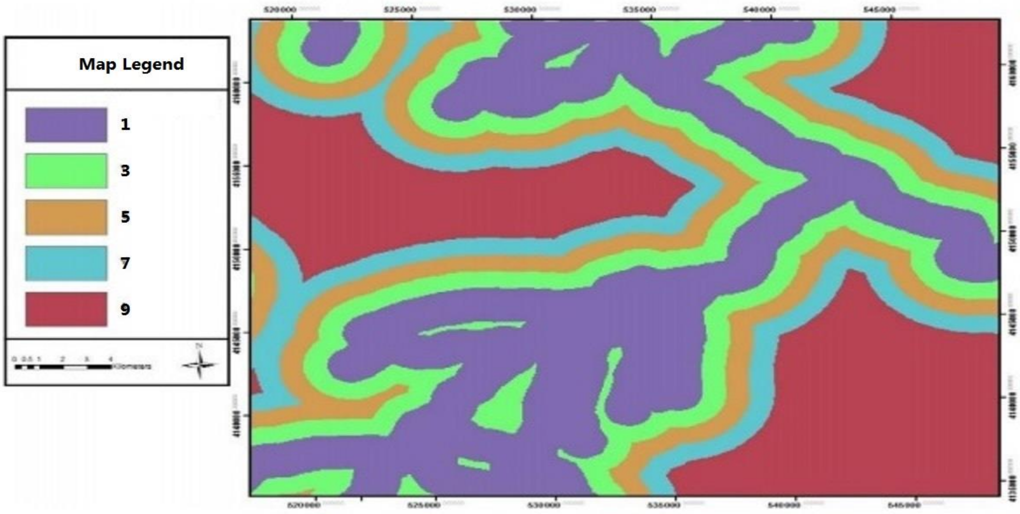

Fig 8: Classifying and reassigning scores to the layer of distance from the rivers
Reference: Research Findings, 2016

G: Zoning the study region based on soil type

The results of studies carried out in relation to zoning the soils in the study region are presented in Table 4 and Fig 9.

Table 4: Classifying and giving scores to soil type

Prioritization	Soil type	Scores
Fourth priority	Deep and fertile soils	1
Third priority	Relatively deep soils	3
Second priority	Moderately deep soils	5
First priority	Very shallow soils	7

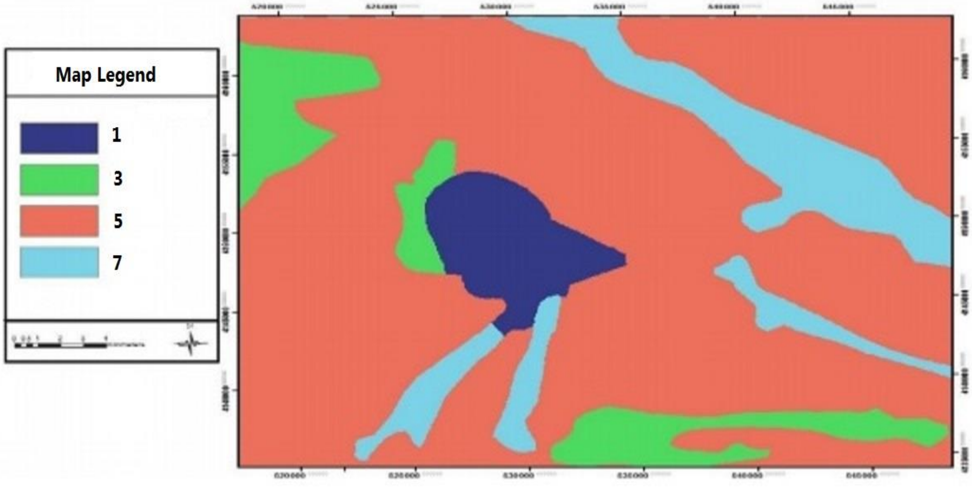

Fig 9: Classifying and reassigning scores to the soil layer - Reference: Research Findings, 2016

H: Zoning the study region based onthe intensity of soil erosion

This factor was classified and given scores to (in Figure 10) based on the first three priorities of moderate, slight, and very slight intensity of erosion**.**

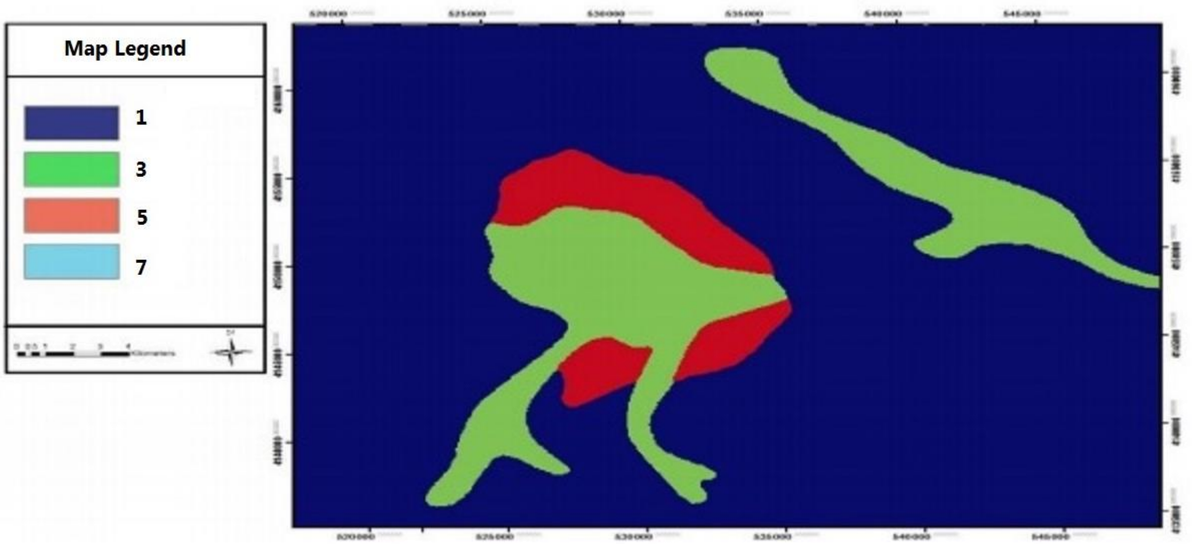

Fig 10: Classifying and reassigning scores to the intensity of soil erosion **-** Reference: Research Findings, 2016

I: Zoning the study region based on geological formations

Resistance to earthquakes and to digging required for urban infrastructure and capacity for wastewater disposal are provided by the existing geological formations. Moreover, considering other factors, these formations are prone to mass movement. Development on weak formations is accompanied by greater risk because these formations are more susceptible and less resistant to vibrations produced by earthquakes (Jabbari et al., 2010). The abovementioned conditions were given scores in Table 5 and Figure 11.

Table 5: Classifying and giving scores to geological formations

Prioritization	Geological formations	Scores
First priority	JkKsj.Jl.Ksn.Ksr	1
Second priority	Kat.Ktr.Ku	3
Third priority	Mur	5
Fourth priority	Peps	7
Fifth priority	Qft1.Qft2	9

Reference: Research Findings, 2016

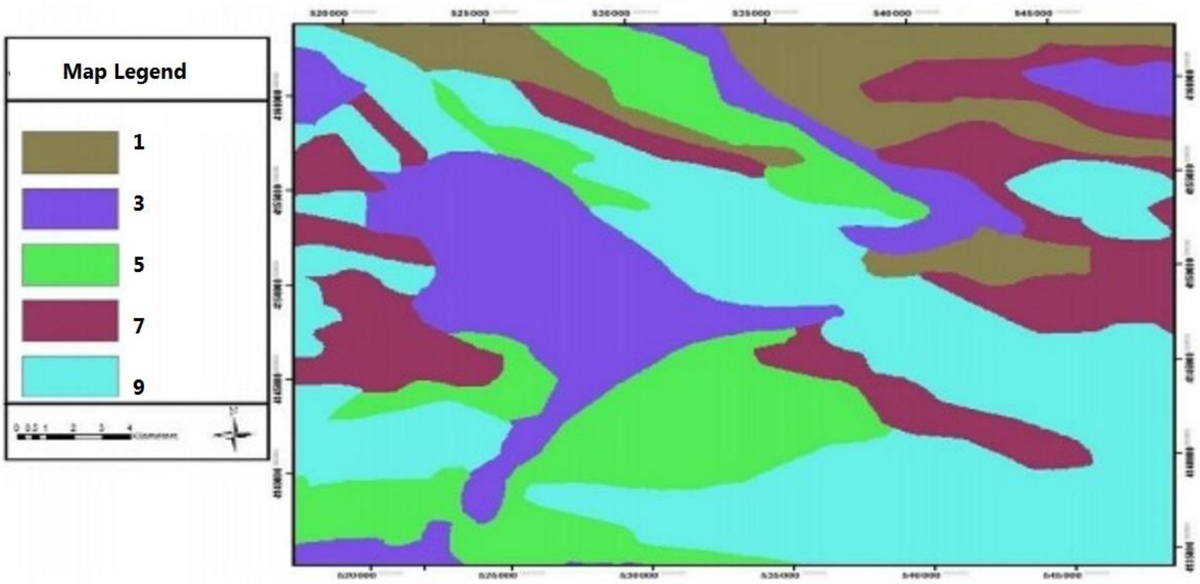

Fig 11: Classifying and reassigning scores to the geology layer - Reference: Research Findings, 2016

J: Zoning the study region based on urban surfaces

The indicator of the current city limits was also used in determining suitable sites for physical development. For this purpose, prioritization was performed in the form of built-up surfaces (score of 1) and unbuilt surfaces (score of 9) and the land areas were classified (Fig 12).

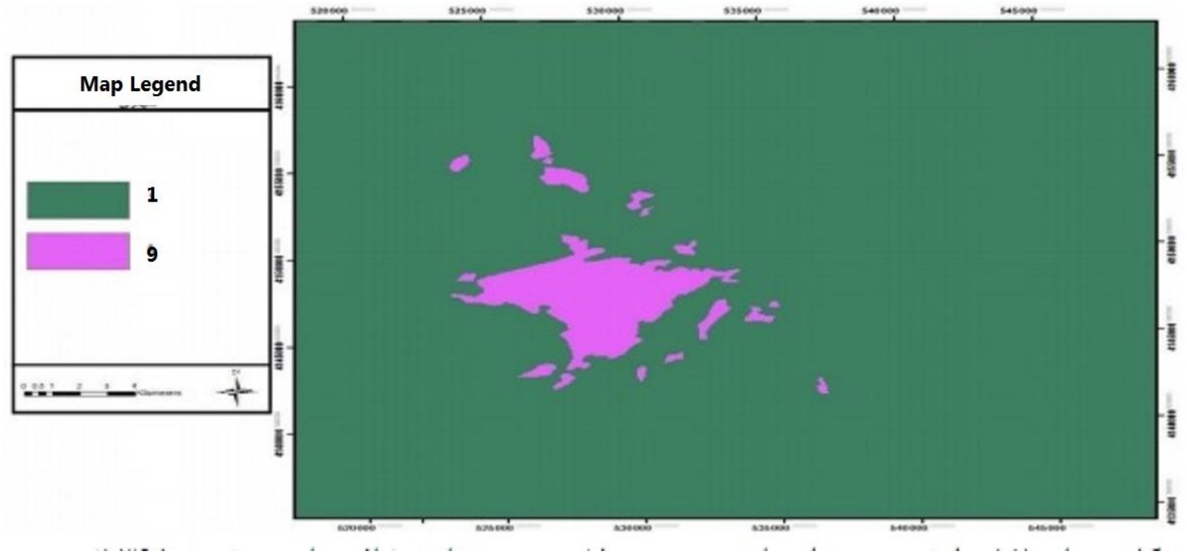

Fig 12: Classifying and reassigning scores to the geology layer
Reference: Research Findings, 2016

K: Determining the weights of indices

Since each of the utilized indicators had a different degree of importance, it was necessary to determine the degree of importance or the weight of each one. For this purpose, the AHP technique was used and the following stages were followed:

1: The pairwise comparison matrix of the criteria

A nine-point scale for pairwise comparison was used in prioritizing criteria. Taking the views of experts and researchers, the available references, and the executed projects and conducted research into consideration, weights were given to the criteria (Table 6).

Table 6: Pairwise comparison matrix of the criteria (research findings, 2016)

	Elevation	**Slope**	**City limits**	**Erosion**	**Geology**	**Fault**	**Groundwater**	**Vegetation**	**River**	**Soil**
Elevation		1.8	1.4	1.8	1.8	1.9	2.0	2.7	3.4	2.0
Slope			1.6	1.8	2.1	1.5	2.0	1.3	1.4	2.1
City limits				2.0	2.0	2.3	1.0	1.2	1.5	1.9
Erosion					1.8	2.0	1.2	3.0	2.1	2.1
Geology						1.0	1.0	1.7	2.6	1.4
Fault							3.0	1.4	2.1	1.0
Groundwater								1.6	1.0	1.4
Vegetation									3.0	2.0
River										1.2
Soil	Incon: 0.09									

M: The final weights of the criteria

The line average or, in other words, the row average related to each criterion was calculated to obtain its final weight. The sum of the weights given to each criterion was divided by the number of criteria, and the obtained number represented the weight and the effect of each criterion. In Table 7, average slope with the weight of 0.133received the highest score followed by the criteria of vegetation, faults, and geology that are very influential in the determination of urban land suitability for physical development based on natural factors. The criteria of elevation, river, groundwater, soil type, and soil erosion with weights of 0.0894, 0.0891, 0.082, 0.069, and 0.065, respectively, ranked fifth to ninth and had the least influence in determining land suitability for physical urban development.

Table 7: Final weights of the criteria

Criteria	**Soil erosion**	**Soil type**	**Groundwater**	**River**	**Elevation**	**Geology**	**Fault**	**Vegetation**	**Slope**
Final weight	0.065	0.069	0.082	0.0891	0.0894	0.117	0.119	0.121	0.133

Calculation of compatibility rate (CR): This rate expresses the degree of correctness and accuracy of prioritization in pairwise comparisons. If it is equal to or less than 0.1, the prioritizations and comparisons can be considered correct and accurate; otherwise, they must be repeated or corrected (Karam and Mohammadi, 2009). Compatibility rates are obtained by calculating compatibility indices (CI) from the following relation:

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

In the above relation, λ_{max} is the eigenvector and “n” the number of options present in the problem (the number of criteria).

Calculation of compatibility ratio: Compatibility ratio is obtained by dividing the compatibility index by the random index:

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

After weighing and before using the weights, the compatibility ratio must be compared to be sure of its accuracy, following which the compatibility rate can be calculated. The software automatically performed this stage of the calculations, and the determined compatibility index was 0.09.

Combining the weights of indices and layers: After obtaining the weights of all the layers, they were applied in the layers using the **overlay tools** in the ArcGIS software (Fig 13).

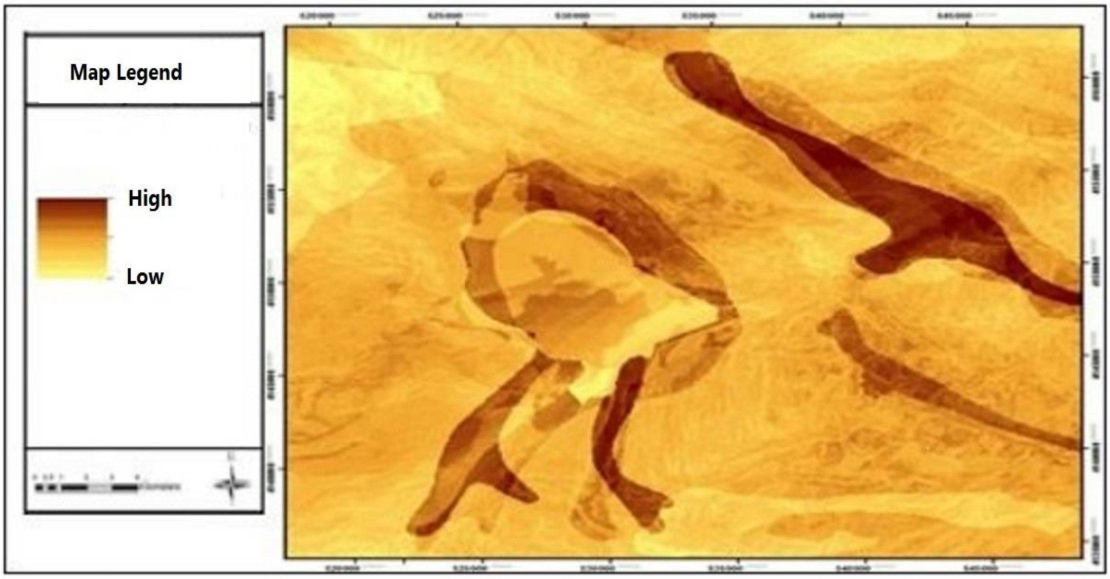

Fig 13: prioritization of the study region for development
Reference: Research Findings, 2016

4. Discussion and conclusions

The main purpose of this research was evaluating land suitability for the physical development of Bojnord and its surrounding areas based on natural factors. Natural factors (slope, vegetation, fault, geology, elevation, groundwater, and soil type and erosion) were first entered into the GIS software. The layers were then converted from vector form into the raster format, and the indicators were reclassified and scores were reassigned to them and their weights were determined.

Based on the results of the analyses (Fig 14), it was found that the city limits of Bojnord suitable for physical development were restricted to five areas that varied from very suitable to very unsuitable. In this classification, only 9 percent (8804 hectares) of the city limits distributed in the north western and southern parts of the city were very suitable or suitable. Moreover, about 9.98 percent (9869 hectares) of the urban areas were moderately suitable, and about 81 percent (80203 hectares) unsuitable or very unsuitable (Table 8).

Table 8: Zones suitable and unsuitable for physical development of Bojnord

Number	Conditions	Area in hectare	Percent of the total
1	Very unsuitable	45,153	45.67
2	Unsuitable	35,050	35.45
3	Moderately suitable	9869	9.98
4	Suitable	5006	5.06
5	Very suitable	3798	3.84
6		98877	100

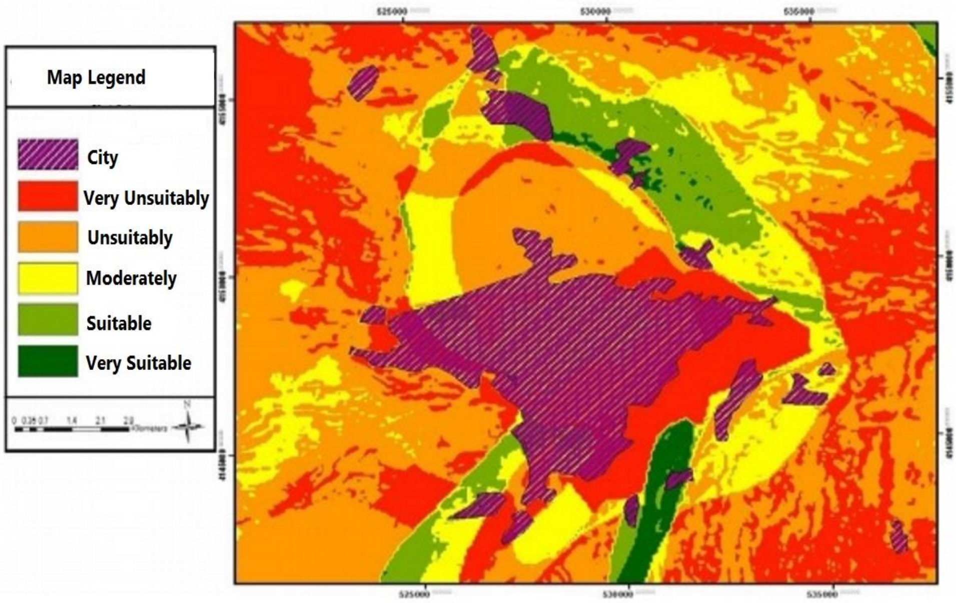

Fig 14: Prioritization of the study region with respect to land suitability
Reference: Research Findings, 2016

In general, suitable and very suitable areas for future development of Bojnord are in areas that have the best conditions with respect to elevation, are in suitable position in relation to slope, and are almost at a suitable distance from the rivers. Moreover, the soils in these areas are not suitable for agriculture, are of very shallow to average depths, experience an average intensity of erosion (with some places facing a very slight intensity of erosion), and their vegetation consists of spaces with low density and moderately vegetated rangelands. Furthermore, these areas have great access to groundwater resources and most of them are at a suitable distance (3000-6000 meters) from faults.

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