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Assessing Potential of Physical Development with an Emphasis on Geomorphological Indicators Using AHP-FUZZY (Case Study: Estahban City)

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Abstract: Today, in urban societies, planning plays a crucial role in analyzing land suitability for urban development and identification of suitable and preferred lands for their physical development. Hence, the aim of this study is determining suitable lands for future development of Estahban and emphasizing the capabilities of GIS in presenting optimum patterns of physical development of Estahban. For this purpose, eight indicators were taken into consideration including slope, slope direction, height, land use, geology, distance to the faults, river and lake beds. Then, using AHP model, each of these indicators was weighted and their fuzzy map prepared in Arc GIS software. Finally, using fuzzy Gamma operator, zoning map for the development of the city was used. The results indicated that suitable areas for development of the city are scattered with small spaces that are located in the city centre and these lands have better position than the other areas. On the other hand, very weak class owned the largest percentage compared to the other classes which due to reasons such as inappropriate land use and inappropriate geological formations, small distance of rivers and lakes and faults which are not-suitable lands for physical development of the city.

Key words: Location, physical development, geomorphological index, Estahban, AHP-FUZZY.

Introduction

City and urbanization is a prominent social process which results in a change in human interactions with the environment and other human beings (Nazarian, 2011). Today, the surge in urban populations with their social-economic issues is a completely new form of city; urbanization and urbanism have lots of differences with what we had observed in the first half of the twentieth century in the cities (Shokouhi & Kazemi, 2005). Basically, planning of urban development and physical development should result in land use (Nader Sefat, 2004) since the establishment and development of a city should be subject to geographical location and conditions more than anything else and the effects of natural phenomena in locating, sphere of influence, urban morphology and physical development have a decisive influence. Natural phenomena, sometimes act as positive and negative factors and inhibitors (Servati et al., 2009). Therefore, gaining information about

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geomorphology and land sciences, as well as assessment of some demands, can be a major factor in the regulation and planning policies (Nader Sefat, 2004).

Thus, since the urban population is growing in Iran and lack of foresight in sufficient lands and suitable urban development, using suitable land for urban development, by assessing the physical growth and development of cities associated with the specified directions, logic area and different stages of development within the city limits are necessarily required in the future in Estahban (Mahmoudi & Rostami, 2014). Based on the biological resources of Iran, regarding talent and capabilities of the country, ability and capacity of the environment, implementation of the thought and viewpoint and principles of sustainable development which is clearly balanced between development planning and national and regional development is essential (Mirdavoudi et al., 1999).

Estahban is located in the Eastern part of Fars Province. According to population and housing census in 2011, the population of the city is 66,172 persons which is 43.1% of the total population of the province and based on geomorphological barriers such as Bakhtegan lake, fault, direction of slope and so on, planning for locating urban development is necessary. Therefore the aim of this study is locating and determining the direction of development in the city by taking into account geomorphological inhibiting factors using FUZZY AHP model. Analysis process is a Hierarchy that reflects normal behaviour and thought of human being. This technique investigates complex issues based on their interacting effects and then tries to solve the issues and problems. Lots of studies have been conducted in Iran and other countries on this matter. For example Sudhira et al. (2004) investigated urban dynamics and modelling through GIS in India. Aly et al. (2005) assessed suitability of land in Egypt, new city of Minya using AHP and GIS. Ahmed Chandio et al. (2011) conducted a research on GIS-based land suitability analysis using AHP in planning of public parks in Malaysia, Larkana.

Bagan and Yamagata (2012) analyzed spatial and temporal growth of Tokyo during the past 40 years by processing Landsat satellite images in which spatial correlation analysis showed a strong positive correlation between population growth and expansion of the city and comprehensive change of population. Amanpour et al. (2013) investigated locating optimal directions for physical development using AHP model in Ardabil, and the results showed that Eastern directions were suitable for possible physical development of the city compared to other directions. Ghanavati and Goudarzi (2013) investigated locating optimal development of Boroujerd by Fuzzy AHP method; the results indicated that suitable areas for urban development is northern part of the city. Sorour et al. (2014) examined the role of environmental factors in feasibility of optimal physical development of Malakan using fuzzy AHP model and they mentioned a sector with east-west trend that is north-western of city centre and southern part of Vali-Asr town as the best direction for development of the downtown. Mousavi and Yazdani (2015) investigated suitability of land use for development of Tabriz city using AHP-OWA model. Conclusions from relative literature shows that currently, GIS and RS technology are the best methods for expanding city development researches and a lot of scholars use them.

Method and Materials

Study Area

Estahban is located on 53° 34′ 1″ to 54° 28′ 25″ of eastern longitude and 28° 49′ 24″ to 29° 30′ 46″ of northern latitude. Estahban is located in Eastern part of Fars province; the city is limited to Bakhtegan Lake from north, to Toudej (Toudeh) mountain from south, to Kharman-Kouh from West and to Darab Mountain from East (Figure 1). The area is flat covering 1994 sq. km (1.6 percent of total terrestrial area of the province) and the average height of 1731 metres above sea level, which is surrounded by mountains. Its most important highlands are Toudej which is Zagros mountain range (Estahban website government[1]). Geologically soil of the area is sedimentary mixed with sand and limestone; underlying parts also includes rock layers. By entrance of mountains from foothills, at the beginning sand changed to coarse and big rocks transformed to rocks. As a whole, in Estahban, soil type is fine-textured with lime plaster powder which is not made of a suitable physical structure (Badiee, 1983).

Data

The data used in this study include topographic and geological maps of topography organization, maps of land use housing and urban organization as well as Digital Elevation of Earth (DEM) in dimensions of 30 metres by ASTER sensor.

[1] http://estahban.farsp.ir/default.aspx.

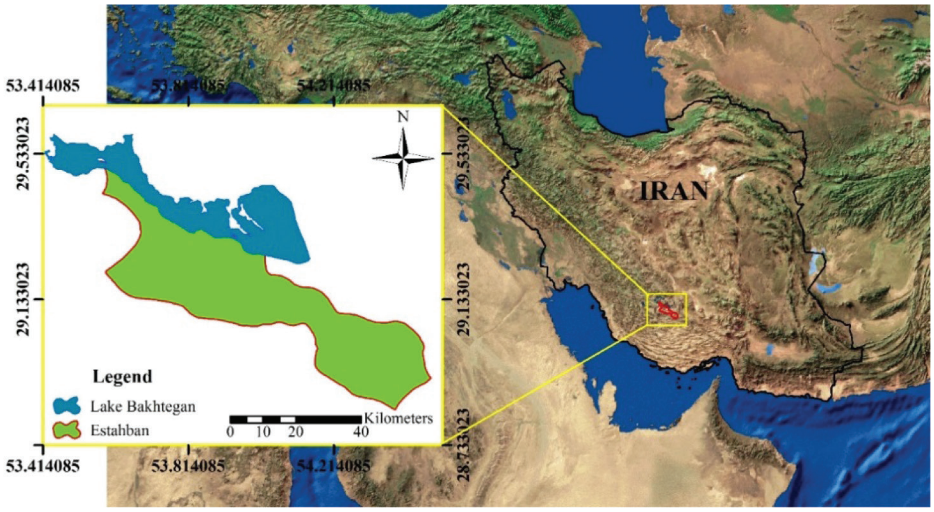

Figure 1: Location of the studied area in a map of Iran and Fars.

Method

The method used in this study is Fuzzy Analytic Hierarchy Process (Fuzzy - AHP). In general, criteria is classified into two categories of quantitative and qualitative classes; therefore, standardization of quantitative criteria was done by new Fuzzy method (Fuzzy) and standardization of qualitative criteria was conducted by Analytic Hierarchy Process (AHP).

Fuzzy Method (Fuzzy)

Fuzzy method was firstly presented by Lotfi Zadeh in 1965 in an article titled "fuzzy sets" in the *Journal of Information and Control*. In fuzzy set, zero means there is no membership in the set and one means a complete member of the set (Lotfi Zadeh, 1965; Gooijer, 2006). Through multi-criteria analysis to achieve a certain goal, specific measures or indicators must be defined and determined so that the targets would be achieved. These measures or indicators are called evaluation criteria. In this study geomorphological evaluation criteria for urban development include slope, slope direction, height, geology, land use, distance from the river, and distance from lake. Then, the mentioned criteria are changed to digits and entered to geographic information system using the basic functions (GIS); after that they were changed into criteria map.

As any criterion map or any characteristic owns a range of different measurement scale, analysis and multi-criteria evaluation criteria should be consistent with criteria measurement scale; hence, criteria standardization process was used to homogenize the measurement scales and their conversion into comparable units. In this study, fuzzy method was used to standardize quantitative data. In standardization of data, all amounts and values of evaluation criteria are converted into the same domain, for example, between zero to one or zero to 255. Standardization process in Fuzzy method is done by valuation of measured amount in the form of a set. In this case, the highest value means one in a maximum membership and the lowest value means zero that is attributed to the minimum membership in the set. Generally, fuzzy membership function determined a fuzzy set and indicated degree of membership in a set (Ami Azghadi, 2010). In Fuzzy standardization method, different membership functions such as Linear, Near, J-Shape and Sigmoidal were used for valuation of measures (Eastman, 1997). Mentioned functions are in IDRISI and ArcGIS 10.2.2 selected area.

In addition to these functions, the user can choose and define a function based on his/her own needs. In the present study, criterion maps were standardized using linear function in ArcGIS 10.2.2 software and their values were converted to comparable units from zero to one. In fuzzy logic, each region has a membership value based on a measure that complies with the relevant criteria which in turn indicated the desired value in that region. This means that in each area, the higher the membership value, the more desirable it is. On these scales, larger numbers are more desirable, that is one is the most desirable level and zero means not desirable and a range of colours falls between these two numbers (Lin et al., 1996). The point that must be considered in selecting a function is that the desired criterion is increasing or decreasing type. For example, in index of distance from the river, if the distance increases, the physical development is more suitable for physical development goal, as the result, increasing function is used here.

In fuzzy model, classes and spatial units with a membership degree between zero to one can define and then combine the criterion maps through fuzzy functions. These functions include: (1) Turning fuzzy function (AND) that is similar to subscribing to classical sets and this function is used when two or more criteria may help to solve a problem together. This function results in creating a conservative estimate of the membership of a set with a tendency to produce small amounts. (2) Seasonal fuzzy function (OR) which is similar to collection in classic sets; it is used when sufficient positive measure is available in case study area. This relationship extracts maximum degree of membership unit pixels from membership values of pixel units in each factor in a given situation for various factors, and presents it in the final maps. (3) Multiplicative function phase (Product) that multiplies pixel membership units in a specified situation in various factors, and present them in the final map. This function is used when the standard maps have decreasing effect on each other. (4) Fuzzy mass function (Sum) that complements the fuzzy multiplication function. This function is used when standard maps have an increasing effect on each other. In this function, fuzzy membership value increases in output and approaches one. (5) Gamma function that is a general form of collective and multiplicative fuzzy functions is used when there is a decrease and increase effect in interaction of criteria (Malczewski, 1999). In fact this function was introduced to adjust high sensitivity of Product Operator, low sensitivity of Sum Operator (Lotfi Zadeh, 1965). In this study due to increasing and decreasing effects of criteria, gamma fuzzy operator was used as a model for evaluation and determination of appropriate integration model.

Analytic Hierarchy Process (AHP)

One of the most important steps in the planning process is evaluation stage and selection of the most appropriate option. Locating is analysis of capabilities of a region regarding sufficient and suitable lands and its relation with other uses and facilities to choose a suitable site for a particular usage (Farhadi, 1999). Optimal location is possible when the researcher could create a reasonable and scientific relationship between information and data derived from relevant experts in locating field regarding priorities (Razavian, 2009). AHP process is one of the most popular techniques in multiple decision-making which was introduced by Thomas L. Saaty in 1970s for the first time. This model is the best option for decision-making and choosing the best options when there are several indicators and criteria for decision-making. This new model is based on hierarchical structuring of elements that are involved in decision-making and includes three main steps in the administrative process in GIS software: (1) creation of pairwise comparison matrices, (2) calculation of criterion measures and (3) estimation of agreement ratio.

After determination of the main goals and intentions in planning and preparing various options to achieve these goals and objectives of the plan, assessment is done based on the relative merits of each option, and desirable or optimal option is selected (Zebardast, 2001). Analytic Hierarchy Process is based on four principles namely reverse condition, homogeneous, dependency and expectations and following these principles is essential in their application. Reverse condition states that in comparing two binary elements, it was found that J is equal to N, importance of element J in comparison with I is equal to $1/N$. The principle of homogeneity states that I and J elements must be homogeneous and comparable. In other words, importance of I compared to J may be infinite or zero. Dependence principle means each hierarchical element depends on its upper element and this dependence can be linear (Pour Taheri, 2011). Expectation principle means whenever a change occurs in a hierarchical structure, evaluation process must be conducted again (Ghodousi Pour, 2000).

One of the advantages of AHP method is possibility of investigating compatibility in judgements to determine important co-efficient of criteria and sub criteria. A mechanism that this model uses to check inconsistency in judgements is a calculated co-efficient called mismatch co-efficient (CR). If CR $\leq$ 0/1, it indicates that the necessary adjustments in judgements have been met, otherwise the judgements should be revised. In other words, comparing binary matrix of indexes should be re-formed.

Results

The most important stage in any investigation is the revealed results which answer many questions; moreover, it is possible to provide suggestions to improve the existing situation. Thus, regarding the purpose of this study, firstly criteria maps relevant to classification were fuzzy using Fuzzy membership function in an environment of ArcGIS 10.2.2 software. The final weight of criteria was determined using AHP model in Expert Choice software and finally potentiometric map was created from fuzzy AHP.

Standardization Using Fuzzy Membership Function

1. **Slope:** Regarding geotechnical issues, land slope is an important and influential factor in static and dynamic stability of earth and steep areas are exposed to slip which is affected by water and rainfall and vibrations caused by earthquakes, so they are not suitable for city construction and urban mapping (Consulting Engineers Group of co-developed stable house builder, 2007). Therefor, 0-5 percent slopes have the highest weight and slopes greater than 20% have the lowest weight (Figure 2 and Table 1).
2. **Direction of slope:** Due to form of slope in the region, it can be stated that southern slopes may be appropriate for creating residential units and streets due to higher amount of sunlight and proper flow of air. Therefore, southern slopes gained the highest score and northern slopes received the lowest score for urban development (Figure 3 and Table 1).
3. **Height:** Roughness features are one of the most influential factors in physical form of landscape and spatial structures (Rahnamae, 1988). The case study area is located between elevations of 1300 to 3065 metres above sea level. There is steeper areas higher elevation, where areas with the lowest height

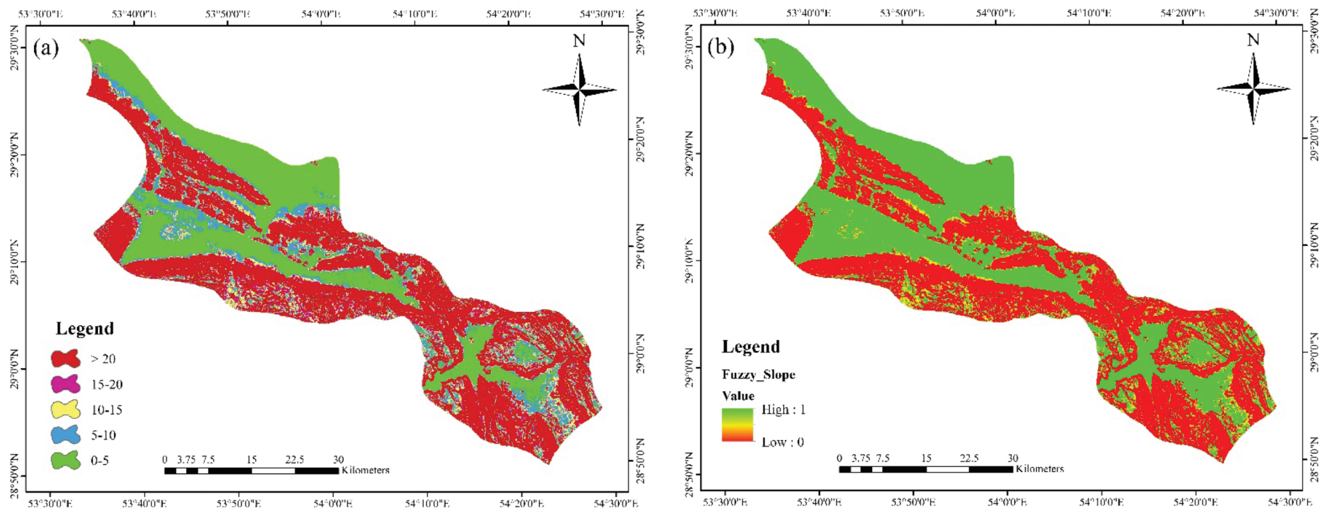

Figure 2: (a) Classification map of slope in Estahban; (b) Classified fuzzy map of slope in Estahban.

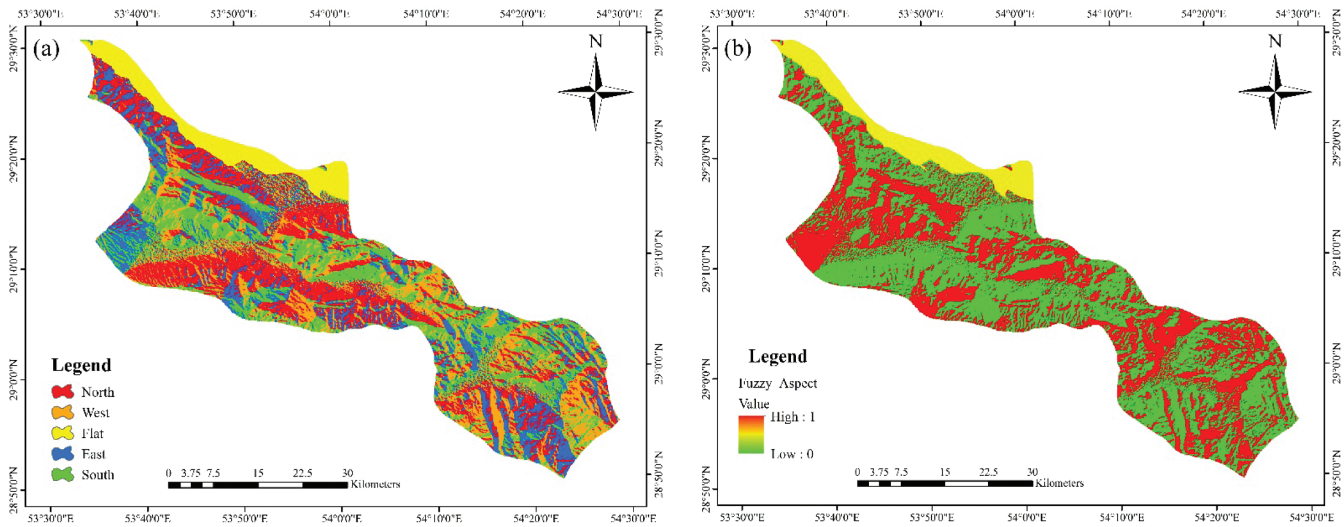

Figure 3: (a) Classification map of slope direction in Estahban; (b) Classified fuzzy map of slope direction in Estahban.

Table 1: Valuation of classification criteria

Criterion	*Following criteria*	*Valuation*	*Criterion*	*Following criteria*	*Valuation*
Slope (percent)	0-5	Perfectly fit	Height (m)	>1600	Perfectly fit
	5-10	Suitable		1600-1900	Suitable
	10-15	Neutral		1900-2100	Neutral
	15-20	Unsuitable		2100-2400	Unsuitable
	20 <	Completely unsuitable		2400 <	Completely unsuitable
Slope direction	South	Perfectly fit	Land use	Very good	Perfectly fit
	East	Suitable		Good	Suitable
	Flat	Neutral		average	Neutral
	West	Unsuitable		Poor	Unsuitable
	North	Completely unsuitable		Very poor	Completely unsuitable
Geology	Very high resistance formations	Perfectly fit	Distance to fault (m)	4000 <	Perfectly fit
	High resistance formations	Suitable		3000-4000	Suitable
	Semi-resistant formations	Neutral		2000-3000	Neutral
	Low resistance formations	Unsuitable		1000-2000	Unsuitable
	Very low resistance formations	Completely unsuitable		>1000	Completely unsuitable
Distance from river (m)	4000 <	Perfectly fit	Distance from the lake (m)	4000 <	Perfectly fit
	3000-4000	Suitable		3000-4000	Suitable
	2000-3000	Neutral		2000-3000	Neutral
	1000-2000	Unsuitable		1000-2000	Unsuitable
	>1000	Completely unsuitable		>1000	Completely unsuitable

own the most value and the highest areas have the lowest value (Figure 4 and Table 1).

4. **Geology:** Many phenomena that create current morphology of the region are related to lithological properties. So for optimal analysis of geomorphological evolution, precise examination of all the characteristics of lithology of the case area is required (Alae Taleghani, 2007). Generally geological formations in the region (Table 2) is divided into five groups in terms of lithology (Table 3) in which very strong structures are the most valuable formations and structure with very low resistance has the lowest value (Figure 5 and Table 1).
5. **Land use:** Land use planning leads direction of city development (Koomen et al., 2009). The need for proper maintenance of land is necessary for urban development, taking into account all the natural and economic considerations (Ready, 2003). So land use map was divided into five categories (Table 4) in which very good class gained the highest score and very weak class gained the lowest score (Figure 6 and Table 1).
6. **Distance to fault:** It is necessary to consider an area for the construction where fault boundaries are followed and have the required stability in order to reduce the risks of possible earthquakes. Based on recommendations of geological organization,

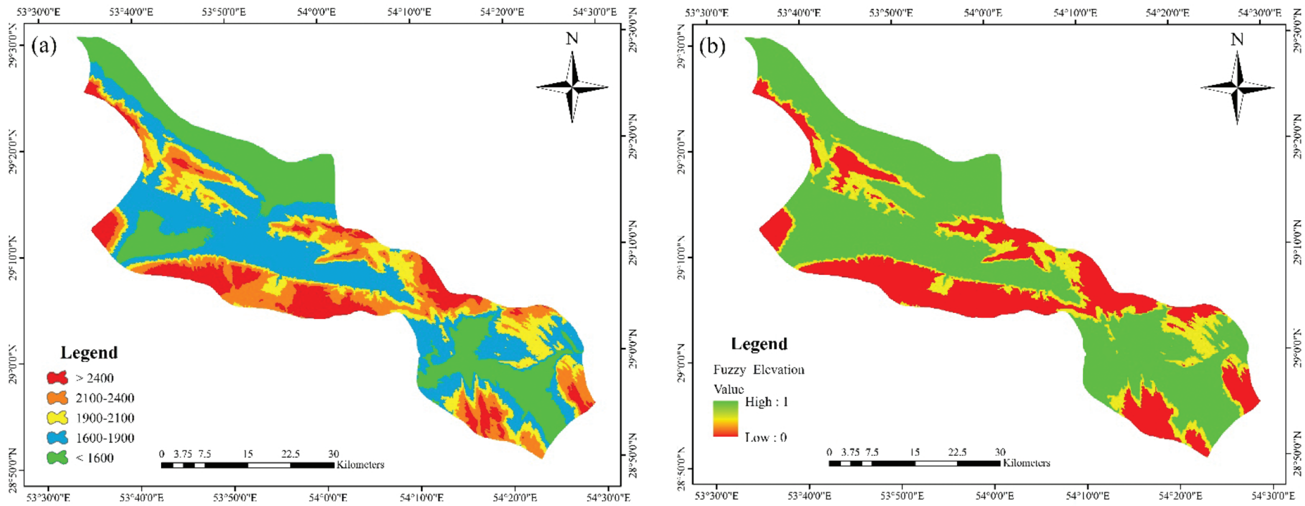

Figure 4: (a) Classification map of height in Estahban; (b) Classified fuzzy map of height in Estahban.

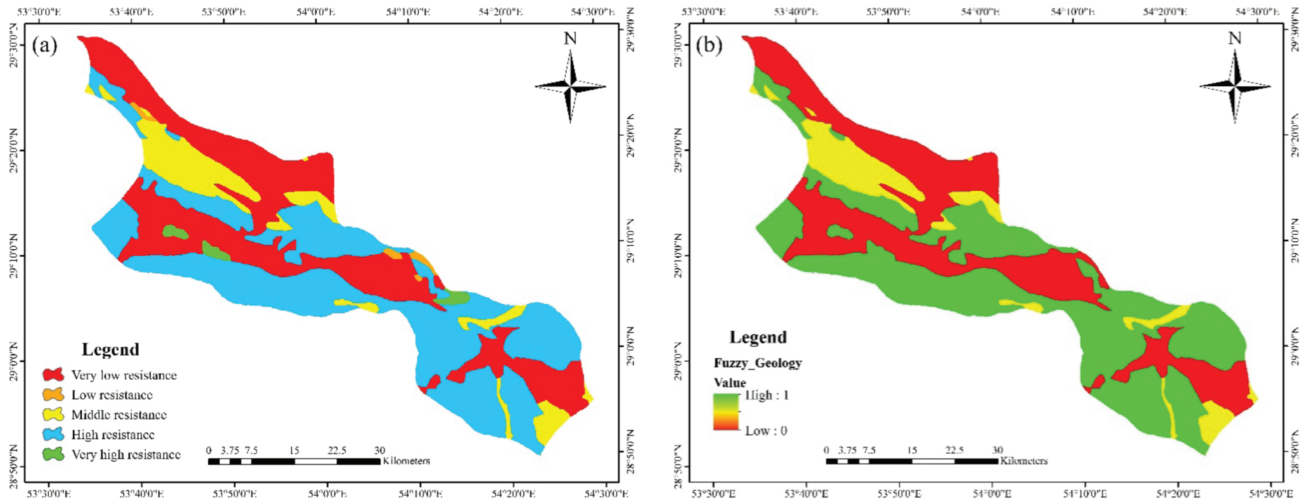

Figure 5: (a) Classification map of Geological in Estahban; (b) Classified fuzzy map of Geological in Estahban.

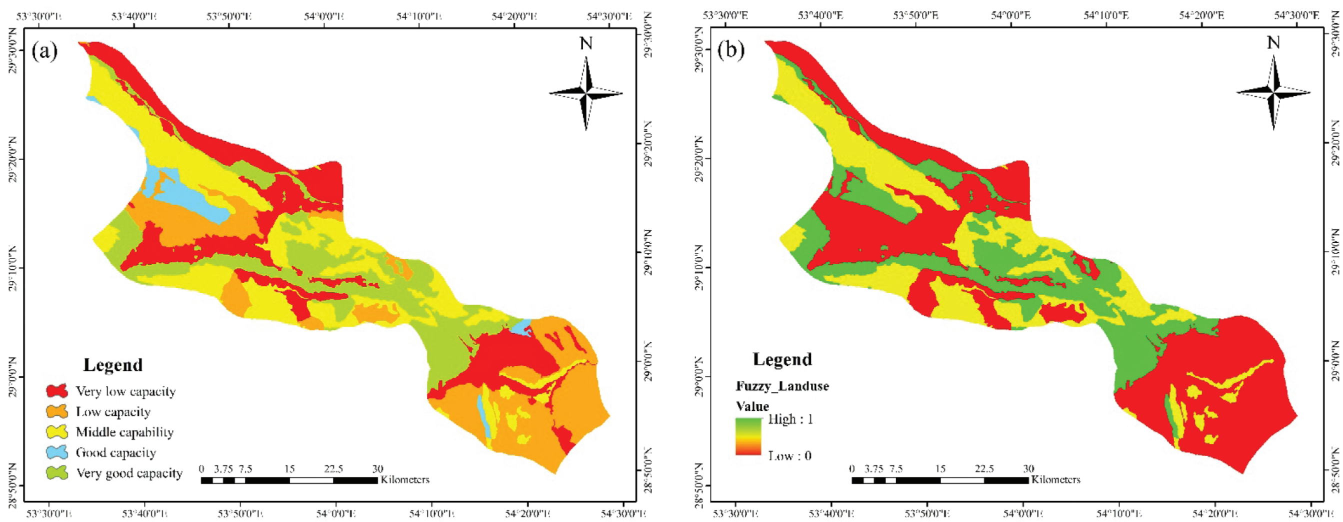

Figure 6: (a) Classification map of land use in Estahban; (b) Classified fuzzy map of land use in Estahban.

minimum area for fault is determined to be 1000-300 metres for each side. Generally it can be said that as the distance from the fault lines grows, locating will be more desirable in the place (Figure 7 and Table 1).

7. **Distance from river:** According to urban regulations, distance from the riverbed is 20 metres and it is necessary to follow the limitation to prevent natural disasters and use for urban development goals. This means that within this space, the majority of urban construction is not allowed. So, desirable places for physical development are as follows: as they are farther from the river gain a higher score and as they get closer to the river gain a lower score (Figure 8 and Table 1).
8. **Distance from lake:** The distance from small inland lakes, horizontally from the end of the bed is dependent on the area of the lake, taking into account legal considerations, and environmental and sustainable development criteria (Determination of distance to beaches, lakes, wetlands and estuaries guide, 2010). Width of wetlands (excluding marshes and natural ponds) is a 150 metres space wide that is immediately after the bed limitation (Determination of distance to beaches, lakes, wetlands and estuaries guide, 2010). So, desirable places for physical development are as follows: as they are farther from the lake gain a higher score and as they get closer to the lake gain a lower score.

Table 2: Formations in Estahban

Geo-unit	*Description*	*Geo-unit*	*Description*
PeEsa	Pale red marl, marlstone, limestone, gypsum and dolomite (SACHUN FM)	Qft2	Low level piedment fan and vally terrace deposits
TRKurl	Purple and red thin-bedded radiolarian chert with intercalations of neritic and pelagic limestone (Kerman and Neyzar Radiolarites)	Plbk	Alternating hard of consolidated, massive, feature forming conglomerate and low-weathering cross-bedded sandstone (BAKHTYARI FM)
Ktb	Massive, shelly, cliff-forming partly anhydritic limestone (TARBUR FM)	Kgu	Bluish grey marl and shale with subordinate thin-bedded argillaceous-limestone (GURPI FM)
TRJs	Dark grey shale and sandstone (SHEMSHAK FM)	Kepd-gu	Grey and brown, medium-bedded to massive fossiliferous limestone (KAZHDUMI FM)
JKkgp	Undivided Khami Group, consist of massive thin-bedded limestone comprising the following formations: Surmeh, Hith Anhydrite, Fahlian, Gadvan and Dariyan	Kbgp	Undivided Bangestan Group, mainly limestone and shale, Albian to Companian, comprising the following formations: Kazhdumi, Sarvak, Surgah and Ilam
Eja	Grey and brown weathered, massive dolomite, low weathered thin to medium-bedded dolomite and massive, feature forming, buff dolomitic limestone (JAHRUM FM)	Ek	Well bedded green tuff and tuffaceous shale (KARAJ FM)
		E	Undivided Eocene rocks
Omas	Cream to brown-weathering, feature-forming, well-jointed limestone with intercalations of shale (ASMARI FM)	pC-Ch	Rock salt, gypsum & blocks of contorted masses of sedimentary material such as black laminated fetid limestone, brown cherty dolomite, red sandstone and 10 ariegated shale in association with igneous rocks such as diabase, basalt, rhyolite and trachyte

Table 3: Valuation of formation resistance in Estahban

Formation type	Plbk, Ek	E, Eja, JKkgp, Kepd-gu, Ktb, Omas	Kbgp, Kgu, PeEsa, TRjs, Trkur	PC-Ch	lake, Qft2
Formation resistivity	Too much	Much	Moderately resistant	With low resistance	With very low resistance

Source: Shariat Jafari and Ghoyoomain, 2005

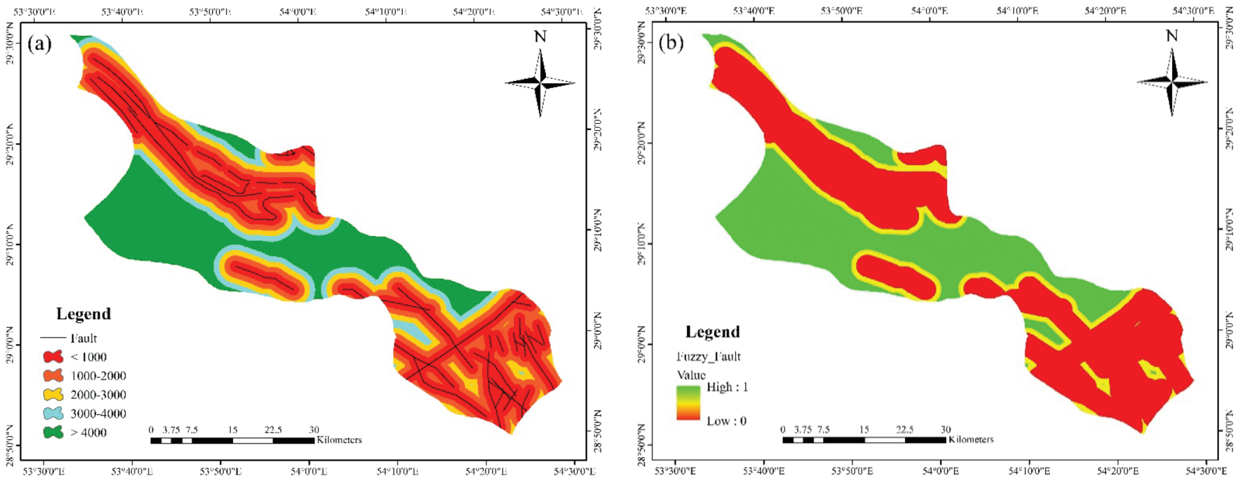

Figure 7: (a) Classification map of distance to fault in Estahban; (b) Classified fuzzy map of distance from fault in Estahban.

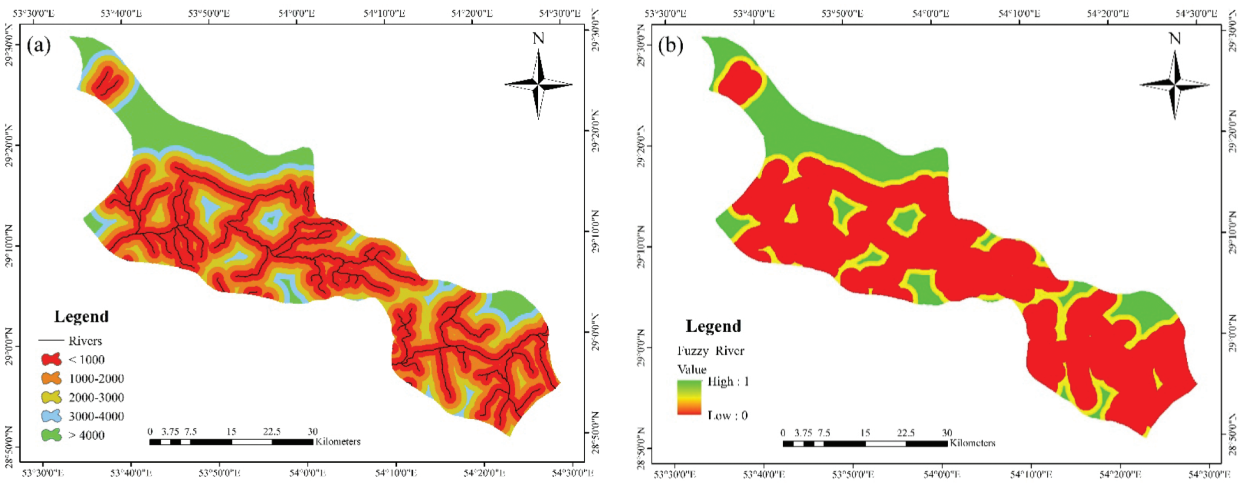

Figure 8: (a) Classification map of distance from river in Estahban; (b) Classified fuzzy map of distance from the river in Estahban.

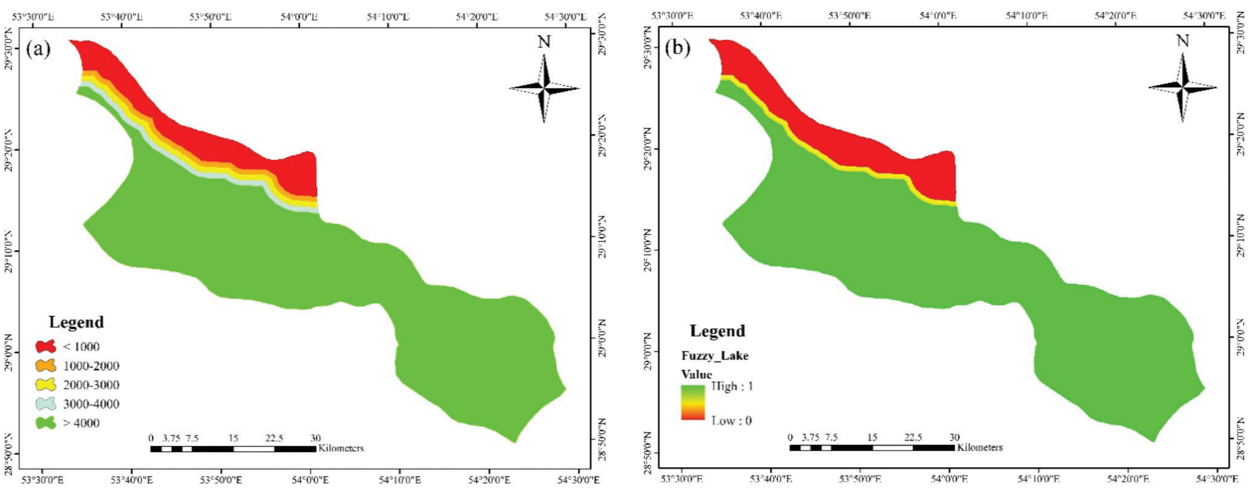

Figure 9: (a) Classification map of distance from lake in Estahban; (b) Classified fuzzy map of distance from lake in Estahban.

Table 4: Valuation of land use in Estahban

The land use capability	*Type of land use*
Very good	Mix (poor range) salt land, urban, mix (dry farming)
Good	Very low forest, mix (very low forest)
Average	Low forest, mix (low forest), poor range
Weak	Mix (med forest), mix (med range), med range, rock
Very weak	Bagh, agri, mix (agri), mix (agri-bagh), mix (agri-follow), mix (woodland), salt lake, wood land, water

Calculation of Criteria Weight

At this point, the intended measures were identified according to previous studies and experts' opinions. Then Analytical Hierarchy Process (AHP) model was designed based on questionnaires completed by experts in Expert Choice software environment and final weight of parameters were determined (Table 5). Moreover, incompatibility factor was 0.05 which is less than 0.1, so the final model was acceptable.

Table 5: Relative weight of the criteria used

Name of criteria	*Relative weight*	*Name of criteria*	*Relative weight*
Slope	0.141	Land use	0.314
Slope direction	0.035	Distance to fault	0.104
Height	0.183	Distance from river	0.048
Geology	0.128	Distance from lake	0.048

Table 6: Land suitability classes measures for development of land use in Estahban

Classification	*Area*	*Percent*
Very good	15.55	0.78
Appropriate	22.96	1.16
Average	30.42	1.53
Inappropriate	23.65	1.2
Very poor	1892.59	95.33

Preparation of Final Map

After calculating the final weight, potentiometric map physical development in Estahban was developed in ArcGIS software environment using fuzzy Gamma operator and it was divided into five categories from completely suitable to completely unsuitable (Figure 10).

Conclusion

Regarding the growing urban population in Iran and lack of adequate prediction in land use for urban development, locating suitable land for urban development is essential to determine the logic area and development of different stages within the city limits for future through evaluation of physical growth and development of existing cities with specified directions. The aim of this study was to identify environmental characteristics of Estahban with an emphasis on geomorphic indices to determine suitable sites for urban development by using AHP-FUZZY method. Optimal sites for urban development were determined using gamma function which was classified into five classes. Table 6 shows the area and percentage of each class available in case study area.

Suitable areas for urban development were mainly scattered in the city centre with a small area in Estahban and these lands were in a better location compared to other parts of the city. Moreover, the largest percentage belonged to very weak class due to unsuitable land use and unsuitable geological formations, little distance from the river, lake and fault—all of which are not suitable lands for urban physical development.

Geologically in northern and central regions, formations have low stability because of loose sediments and Quaternary terraces, shale, marl and gypsum; and due to frequency of these formations with sandstone and limestone, conditions for instability are created and in terms of land use in northern and southeastern parts due to existence of orchards and agricultural lands, physical development in these areas is irrational and unjustified. Besides, situation of the town (Estahban) was evaluated separately and it was found that Estahban is located in a very suitable area regarding distance from lake and fault, land use and slope percentage; in terms of height it is in a suitable area, and regarding distance from river, slope and geological situation is located in a completely unsuitable area. So these findings emphasize the importance of planning in this regard.

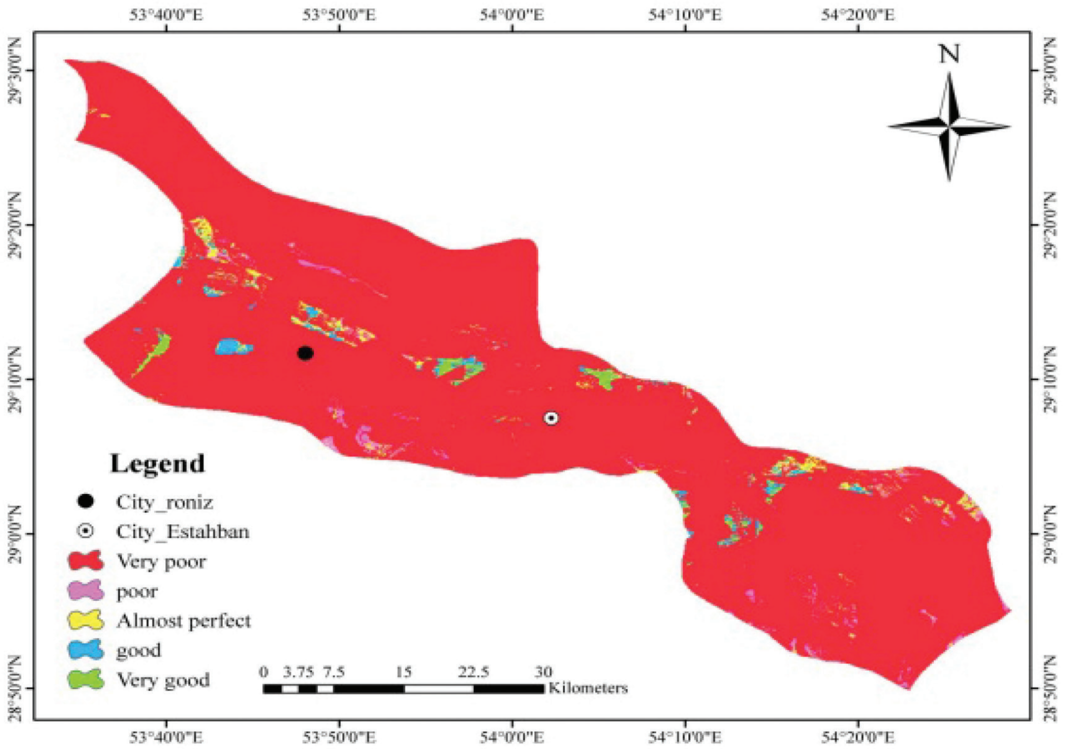

Figure 10: Final maps of optimized location for future physical development of Estahban.

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