International Journal of Modern Agriculture, Volume 10, No.2, 2021
ISSN: 2305-7246

Evaluation and Ranking of Ecological Capability of Urban Development Using MCDM And GIS (Case Study: Tabriz County)

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Abstract

Among the wide range of urban resources, land resources are the most important and most sensitive. Although, urban growth and concentration of population in urban areas and curves upward trend of unbalanced urban development on land and natural areas are limited, many social problems at the local level, regional and global created. Therefore, the present study aimed to determine suitable land for future development of Tabriz County, using a multi-criteria decision model, respectively. Methods The study was Descriptive and – analytical and to determine appropriate land for development after collecting the required data Using GIS and the analytic network process in stages where input variables and parameters, providing layers of new information, classification, and valuation of variables and data layers and composition of these layers, suitable locations for development the county is further specified. Variables and data layers are intended to identify land suitable for future development of the county, consisting of layers of elevation, slope, roads, utilities, and municipal facilities, access to water, power transmission lines, communication networks, and centers around the Our findings indicate that the development of land primarily in the direction of Tabriz Province, East, South East have And this land a better position to expand in the future than are other parts of the northern and southern halves, with the natural limitations - and proximity to the mountains of Sahand artificial and lack of efficiency for Awn ibn Ali, the future development of the county.

Keywords: Ecological Capability Multi-Criteria Decision Making, Development of Tabriz, Network Analysis, GIS

Introduction

Environmental protection requires a balance between the development of population centers and natural areas. The evaluation of ecological capability helps to create this balance; it is used as a tool for deciding and planning the use of land in order to select the optimal use and environmental management (Makhdoom 2011). Ecological capability evaluation is used as a basis for land use decision-making and planning in all parts of the world (Firoozi et al., 2013: 154). It is the evaluation of each uniform and homogeneous spot of the land for different types of land uses (Sante-Riveira, 2008: 263. The development programs are planned in line with nature, and nature identifies the land's talents for development by identifying and evaluating ecological features in each region (Sadeghi and Dehkordi, 2008). If the capability land does not have the appropriate ecological capability for the implementation of a particular use (even in the case of socio-economic need for that use) the implementation of the plan not only does not improve the environment of the region, but it will also bring more destruction to the environment. The construct of the county has always been considered by the governments since the formation of human civilization. Urban problems are interconnected and if one does not pay attention to one of them, other problems will arise (Shenavar et al., 2011: 131). Ecological capability evaluation is the possible human use of land for agricultural, rangeland, forestry, aquaculture, urban, industrial and rural development in the context of agricultural, industrial, service and commercial use (Manwari, 2001: 200). Urbanization has threatened and destroyed the living conditions of urban residents by human interference in the natural face of the earth. However, urban development and changes in land use

patterns cause the far-reaching social and environmental impacts. The effects include reducing natural spaces, increasing the accumulation of vehicles, reducing agricultural lands with high production capacity, natural drainage and reducing water quality (Kamyab et al., 2011: 100). The development and growth of metropolises absorbs, deforms and transforms a large part of the best and most suitable lands near to the cities, including adjacent agricultural and forest lands, and has a negative impact on the biodiversity of the region. Currently, the most logical way to conduct environmental studies in the framework of regional planning is involvement of the ecological aspects of land use planning and organization (Gharkhloo et al., 2009: 53-52). This paper aimed to study the application of the criteria in accordance with urban development considerations in order to determine the criteria and weighted model and evaluate the ecological capability of urban development in determining suitable areas for urban development in Tabriz, which has the least adverse effects now and in the long run.

Literature Review

Badr (2000), in his research to determine the appropriate range of physical expansion of Razi city in Ardabil province, used the GIS as a database and Landsat's TM sensor images. He indicated suitable areas for future physical development by multi-criteria analysis. Pourebrahim (2001) in determining the future development of Qeshm Island used the systematic analysis method and optimal integration of overlap on appropriate planning units to determine the types of land uses, including urban development land use. Mozaffari and Olazadeh (2008) determined the optimal directions of future development of Saqez city by descriptive-analytical method and GIS software. Ebrahimzadeh and Rafiei (2009) with 10 indices, practically used spatial analysis techniques in GIS environment in the optimal location to expand Marvdasht city. Gharkhloo and Zanganeh Shahraki (2009) used a set of quantitative patterns in recognizing the physical-spatial growth pattern of Tehran. The patterns in four methods of degree of aggregation, degree of balanced distribution, density and size of the metropolis, has been classified and used. The results have been used to describe the realities of physical-spatial development in Tehran. Malchfsky (2006) has described GIS and a set of multi-criteria decision-making techniques with practical examples that can be a guide for researchers. Cheng & Masser (2003), using exploratory data analysis and spatial logistic regression, studied and modeled the determinants of Wuhan urban growth between 1993 and 2000. While acknowledging the decisive role of communication network infrastructure and developed areas in the development of the city, this study shows that the role of the master plan in a particular period is being questioned. Sudhira et al. (2004) examined the criteria, dynamics and modeling of urban development with the help of GIS in Mngalvr, India, and then made it possible to predict the type of future urban development. Sante-Riveira et al. (2008) used GIS-based planning support system to locate rural land use in the Tracha region of Spain. Leo et al. (2009) modeled the spatial variability of urban growth patterns in China by selecting Nanjing as a case study. In this study, local and global logistic regressions have been used to model the probability of urban land expansion that can be formed in relation to a set of spatial variables. It has been emphasized the central importance of reviewing policies and guidelines as well as the importance of field studies in interpreting the results of modeling based on statistical methods and GIS. Hahn et al. (2009) tested the application of an integrated system dynamics model and automated cells in assessing urban growth in Shanghai. In this test, the efficiency of the mentioned model in tracking and predicting urban development has been proved and the physical development scenario in specific dimensions and directions has been described.

The most obvious difference between the present study and other studies is determining the appropriate lands for future development of Tabriz county using multi-criteria decision models. After collecting the required information and using the process of network analysis in the GIS, classifying and evaluating variables and information layers and combining these layers, suitable places for future development of the county have been identified to identify suitable lands for development. Variables and information layers intended to determine suitable lands for future development of the county, include topographic lines, slopes, communication network, urban facilities and equipment, water access, transmission lines and communication network and centers around the county.

Materials and Methods

Study Area

Tabriz county with an area of 2167 square kilometers (4.8% of the province) is the center of East Azerbaijan province and its approximate altitude is 1350 meters above sea level. In terms of relative position, it is located 619 km northwest of Tehran and 150 km southeast of the border town of Jolfa (border among Iran, Azerbaijan and Armenia), where is bounded on the north by Ahar, and Heris on Bostan Abad by east, on Maragheh by south and on Shabestar and Lake Urmia by west. According to the latest divisions of the country, Tabriz county has two parts called Markazi (including Mehraneh river, Sard-e Sahra, Aji Chay and Esperan villages) and Khosrowshah (including Lahijan and Tazeh Kandvillages), three urban points named Tabriz, Sardrood and Khosrowshah and 75 villages. Tabriz is the most populous city in the province and one of the most populous cities in the country. 45% of the province's population lives in Tabriz county and more than 40% live in Tabriz county.

The research method is descriptive-analytical and library tools, field studies and observations have been used to collect data. To this end, in the first step, articles, research projects and dissertations that have examined the effective factors in locating cities have been reviewed and common criteria among them, which are more consistent in locating cities, have been considered as primary criteria. The required information has also been collected from the Statistics Center of Iran, the Road and Urban Development Organization, the Meteorological Organization, the Geological Survey of Iran, the Soil and Water Research Institute and the General Department of Environmental Protection of East Azerbaijan Province. In this study, after reviewing the available information about the study area, first the effective indices in determining the use of urban development based on the indices of the ecological capability evaluation model of urban, rural and industrial development in Iran and based on the status of living and non-living factors and available information were reviewed. Accordingly, each member of the expert group, including university professors, experts and thinkers, separately distributed questionnaires containing the criteria of the ecological model of urban development and requested based on their experiences, knowledge and scientific reserves. The views of the expert group were then summarized and the arithmetic and geometric mean of the criteria were calculated and returned to the members for weighing, reviewing and revision. This process continued until the third round, when a general agreement was reached on the criteria for evaluating the ecological capability of urban development in the Tabriz county. Then, each of the indices was classified and considering that the above indices were different and sometimes in conflict with each other in terms of the scale of measurement, quantitative and qualitative indices were ranked according to the effect of the amplitude of each indicator using the bipolar interval scale method. Then the above layers in the network data structure were stacked using GIS overlap functions in Arc GIS software environment version 10.2 and the layer of ecological units of the study area was prepared.

Multi-objective models have been used for evaluation and selection and are basically process-oriented models (Asgharpour, 2004: 43). One of the advantages of this model is high power of these techniques in reducing decision complexity, and the simultaneous use of quantitative and qualitative criteria (Mazidi and Safarzadeh, 2011: 87). Multi-branch models are used for evaluation and are basically result-oriented models. In Multi Criteria Decision Making (MCDM) model, the criterion is limited by the definition attributes and the number of possible options (Asgharizadeh and Sakhdari, 2005). Multi Attribute Decision Making (MADM) model is used to select the most appropriate option from m options. Various methods have been proposed to support the multi-criteria decision-making process, which can be divided into two categories: compensatory and non-compensatory (general satisfactory method, special satisfactory method, dominance method and priority sequential method) (Ziari et al., 2010; 17). TOPSIS model which is suitable only for prioritization models (Faraji Sabkbar et al., 2009, 81). The TOPSIS method is one of the most useful multi-criteria decision-making methods in the study of real-world problems which was first proposed by Huang Yun (Hugh et al., 2008, 57). The TOPSIS

technique is one of the compensatory models (models that are important in the exchange between indices) and is a compromise subgroup. In the compromise subgroup models, it will be the preferred option that is closest to the ideal solution (Jadidi et al. 2008, 763). In this method, the selected option should have the shortest interval from the ideal answer and the farthest interval from the most inefficient answer (Nastaran et al., 2010, 90). The advantages of this method over other spatial prioritization techniques include the following (Elson, 2004): 1- Involves quantitative and qualitative criteria in the issue of location. 2- Its output can determine the order of priority of the options and express this priority quantitatively. 3- Considers the contradiction and correspondence between the indices. 4- Working method is simple and its speed is appropriate. 5- It accepts the initial weight coefficients (Taghipour Jari, 2009, 43). The basis of this technique is based on the concept that the selected option should have the shortest interval with the positive ideal solution and the maximum interval with the negative ideal solution (Ortoglu and Caracas Oglu, 702,2007). It is assumed that the desirability of each index is uniformly increasing or decreasing (Mo'meni, 2012, 160).

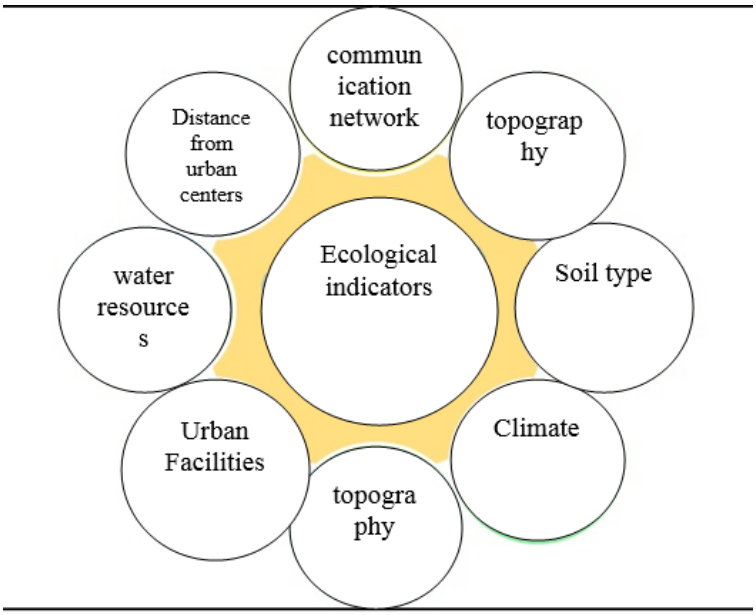

Figure 1. Ecological indices of urban development

Source: Authors

Introduction of Variables and Indices

The present study is based on the ecological parameters of Tabriz county. The parameters of ecological capability evaluation of urban development are: urban facilities, topography, soil type, communication network, water resources, lithology, distance from urban centers and climate (Table 1).

Table 1. Classification of the study area in terms of effective indices in determining the use of urban development

Urban Facilities	very good	good	average	weak	Very weak
topography	Up to 6 degrees	6-9 degrees	9-15 degrees	More than 15 degrees	
Soil type	Very appropriate	appropriate	average	inappropriate	Very inappropriate
communication network	0 -500	500-1000	1000 -1500	1500 - 2000	More than 2000
water resources	Very appropriate	appropriate	average	inappropriate	

Lithology	Very appropriate	appropriate	average	inappropriate	
Distance from urban centers	More than 1200	900-1200	600-900	300-600	Less than 300
Climate	Very appropriate	appropriate	average	inappropriate	Very inappropriate

Source: Authors

Weighting method of standard maps: The study of the relationships between the types of factors and ecological characteristics of the land shows that most of the factors affecting the determination of land suitability are not of equal importance. Therefore, for a more accurate evaluation, it is necessary to determine the relative importance of each factor and based on that, special coefficients as weights are applied in data analysis.

Weighting Method of Standard Maps Using Network Analysis Model

Network analysis process is one of the newest multi-criteria decision-making techniques presented by Professor Saati. This model is designed based on hierarchical analysis process and has replaced "network" with "hierarchy" (Ghodsipour, 2005). The principle in AHP is based on the independent operation of hierarchical upper groups from all its lower parts and from the criteria of each level and class (Dyson, 2004). Many decision-making issues cannot be placed in a hierarchical structure, and this is due to the interactions between different factors, some of which are highly dependent on low-level factors. The structuring of an operation with operational dependencies allows feedback to be received between the identified clusters in the network system. Saati has proposed the use of Analytic Hierarchy Process (AHP) to solve problems with independent criteria and alternatives and has established a network analysis model to solve problems with related criteria and alternatives. Thus, the Analytical Network Process (ANP) method was presented as a generalization of AHP. The ANP network structure has replaced the feedback approach with a hierarchical structure, and this indicates that the relationships between different levels of decision-making cannot be simply thought of as high-low, dominant-defeated or direct-indirect. For example, it can be said that not only the importance between criteria determines the importance between options in the hierarchy, but also the importance of options may affect the importance between criteria. Therefore, providing a hierarchical structure with top-down linear relationships may not be appropriate for complex systems (Saati, 1980) (Momoh, 1998) (Lee, 2011).

In general, the ANP method has three parts: the first part is the control hierarchy for the network of criteria and sub-criteria, the second part is the network of relationships between elements and clusters and the third part is the feedback between different clusters and elements within a cluster (Yuksel & Metin, 2007: 3367).

1. Model structure and problem structure: The problem must be clearly explained and decomposed into a logical and rational system such as a network.

2. Binary comparison matrix and preference vector: This part is similar to a hierarchical comparison matrix in which the elements of the system in each group are compared according to their importance to the criterion control. The groups themselves are also compared according to their importance in goal formation.

3- Formation of excellent matrix: To select the general preferences in a system with interdependence, the internal priority vector is inserted in a specific column of the matrix.

4- The fourth stage of ANP model is the best choice of alternative or strategy based on its weight.

Model and structure of the subject: After determining the criteria and indices to measure the place for development, now the development of the county is to determine the coefficients of importance of each component. The second stage is the analysis of the problem into a network structure that includes the goal, criteria, sub-criteria and strategies and finally creates the network structure of the research. Then, with clarifying the problem and analyzing it in each format, a set of factors in the sub-criteria were performed separately in Super Decision software. The relative weight of each of the sub-criteria was determined by the method of special value (final value), and the final weights of each criterion were determined.

The criteria for ecological evaluation are listed in Table 1. These criteria include average temperature, rainfall, land use, slope, and slope direction.

Findings

In this model all values attributed to the criteria must be quantitative and if they are qualitative attributed to the criteria, they must be converted to quantitative values. However, it is suggested that the TOPSIS method be used when the number of indices and information available is limited. The following steps are performed to use this technique.

1. Format the data matrix based on m options and n indices:

$$A_{ij} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix}$$

(1)

Table 2. Decision matrix of ecological evaluation of Tabriz urban development

Dehestan index	Urban Facilities	topography	Soil type	communication network	water resources	Lithology	Distance from urban centers	Climate
Esperan	60	45	55	65	70	55	55	50
Mehraneh river	50	50	60	60	65	60	55	70
Sard-e Sahra	45	40	50	35	50	50	40	55
Lahijan	50	50	45	48	35	45	50	60
Tazeh Kand	30	60	40	40	20	30	30	35
Aji Chay	35	65	50	35	30	30	40	40

Source: Authors' calculations

2. Standardize the data and form a standard matrix through the following formula

$$r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{k=1}^{m} a_{kj}^2}}$$

(2)

Table 3. DN scale matrix of ecological evaluation of urban development in Tabriz county

Dehestan index	Urban Facilities	topography	Soil type	communication network	water resources	Lithology	Distance from urban centers	Climate
Esperan	0/531	0/351	0/445	0/546	0/588	0/483	0/489	0/385
Mehraneh river	0/443	0/39	0/486	0/504	0/546	0/527	0/489	0/539
Sard-e Sahra	0/399	0/312	0/405	0/294	0/42	0/439	0/356	0/424
Lahijan	0/443	0/39	0/364	0/403	0/294	0/395	0/445	0/462
Tazeh Kand	0/266	0/468	0/324	0/336	0/168	0/264	0/267	0/27
Aji Chay	0/31	0/507	0/405	0/294	0/252	0/264	0/356	0/308

3. The most important indices have a higher weight. In fact, the matrix (v) is the product of the standard values of each index in its respective weights. It is worth mentioning that the sum of the weights for the indices of the decision maker should be equal to one (Akbari, 2008, 48).

$$V_{ij} = \begin{bmatrix} w_1 r_{11} & w_2 r_{12} & \cdots & w_n r_{1n} \\ w_1 r_{21} & w_2 r_{22} & \cdots & w_n r_{2n} \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ w_1 r_{m1} & w_2 r_{m2} & \cdots & w_n r_{mn} \end{bmatrix}$$

(3)

Table 4. V_{ij} matrix of ecological evaluation of urban development

Dehestan index	Urban Facilities	topography	Soil type	communication network	water resources	Lithology	Distance from urban centers	Climate
Esperan	0.125	0/021	0/013	0/081	0/01	0/011	0/147	0/035
Mehraneh river	0.104	0/023	0/015	0/074	0/009	0/012	0/147	0/049
Sard-e Sahra	0/093	0/018	0/012	0/043	0/007	0/01	0/107	0/038
Lahijan	0/104	0/023	0/011	0/059	0/005	0/009	0/133	0/042
Tazeh Kand	0/062	0/027	0/01	0/05	0/003	0/006	0/08	0/024
Aji Chay	0/073	0/03	0/012	0/043	0/004	0/006	0/107	0/028

Source: Authors' calculations

4. Determining the interval of the i^{th} alternative from the ideal alternative (highest performance of each index)

$$A^* = \left\{ (\max_i v_{ij} \,|\, j \in J), (\min_i v_{ij} \,|\, j \in J') \right\}$$

$$A^* = \left\{ v_1^*, v_2^*, \ldots, v_n^* \right\}$$

(4)

5. Determining the interval of the i[th] minimum alternative (lowest performance of each index)

$$A^- = \left\{ (\min_i v_{ij} \mid j \in J), (\max_i v_{ij} \mid j \in J') \right\}$$
$$A^- = \left\{ v_1^-, v_2^-, ..., v_n^- \right\}$$

(5)

6. Determining the interval criterion for the ideal alternative and the minimum alternative, and determination of the coefficient equal to the minimum alternative interval divided by the sum of the minimum alternative interval and the ideal alternative interval, which is calculated from the following equation.

$$S_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2} \qquad S_i^* = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^*)^2} \qquad C_i^* = \frac{S_i^-}{S_i^- + S_i^*}$$

(6)

Table 5. Comparing of cli +, di +, di – of ecological evaluation of urban development

Dehestan	cli+	di+	di-	rank
Esperan	0/855880406	0/0167650	0/099562	2
Mehraneh river	0/795702981	0/0227450	0/088588	3
Sard-e Sahra	4/79946	0/03457	0/031149	1
Lahijan	0/558712774	0/64901	0/043769	4
Tazeh Kand	0/418314456	0/09999	0/071907	5
Aji Chay	0/123194544	0/078674	0/011054	6

Table 6. Final ranking of ecological evaluation of urban development

Dehestan	cli+	rank
Esperan	0/855880406	2
Mehraneh river	0/795702981	3
Sard-e Sahra	4/79946	1
Lahijan	0/558712774	4
Tazeh Kand	0/418314456	5
Aji Chay	0/123194544	6

Source: Authors' calculations

Classification and Preparation of Maps

Data analysis is performed in power evaluation to extract regular data sets in the irregularity of an area. The basis of such analysis, which is in fact the basis of systemic analysis, is based on finding order in

disorder. Resources are grouped and prepared in the first step to regulate disorder. In the present study, the types of maps have been grouped and classified according to the criteria used in the construction of the ecological model; the results can be used in the process of combining data and finally, power evaluation. This classification is done again on the following information layers.

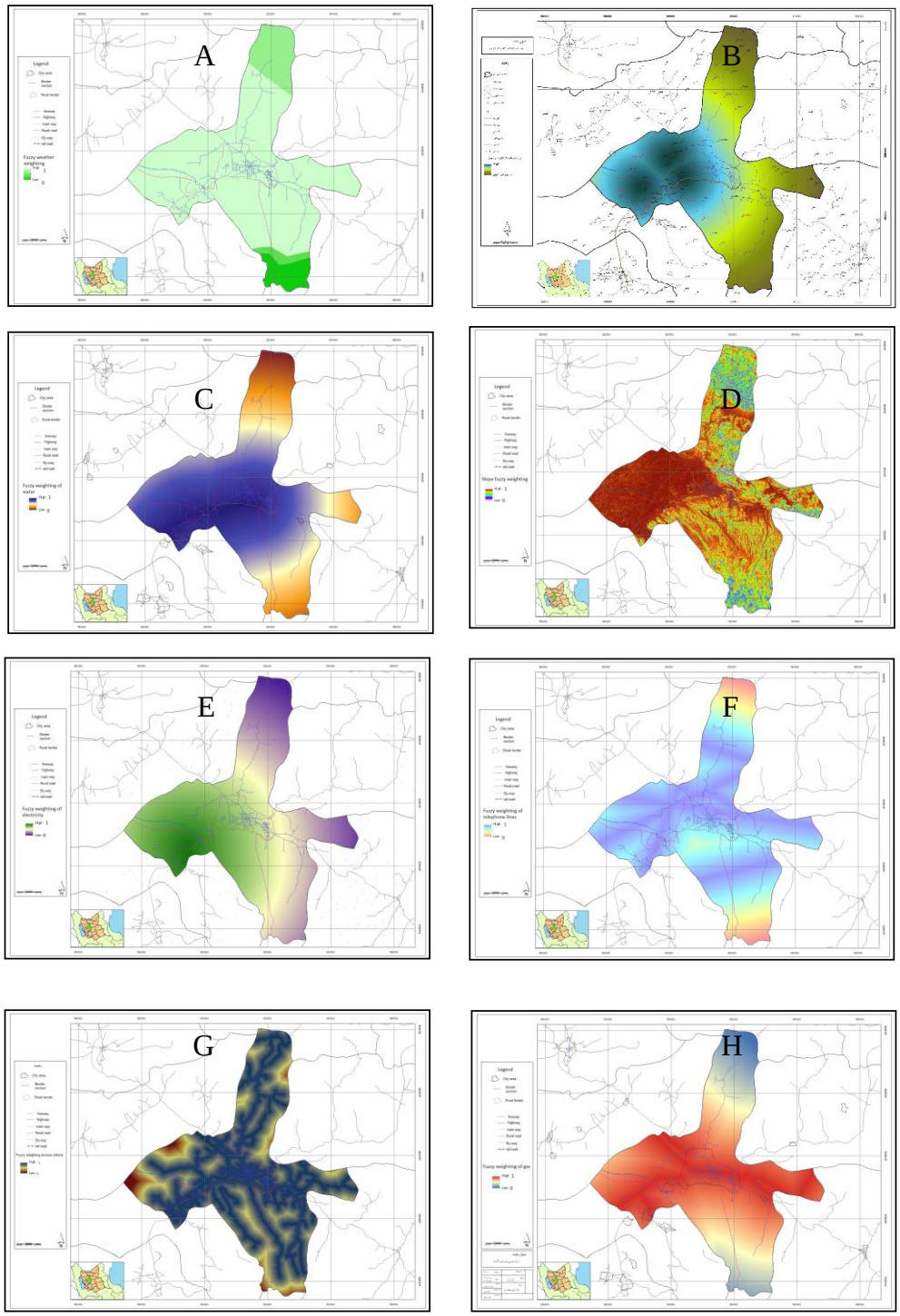

Figure 2. Ecological criteria for the development of Tabriz, climate (A), distance from the city center (B), access to water (C), topography (D), power lines (E), telephone lines (F), access to communication network (G), gas lines (H)

To combine and summarize the data, the method of superimposing overlaying information layers has been used. The process of integrating data and preparing the map of environmental units that is done in the GIS include combining sustainable resource classes (land shape, soil) with each other and producing a map of environmental units with a table of characteristics of environmental units. Finally, this table is completed by considering other unsustainable ecological features (climate, water resources) for each unit. The result of the data integration process is a map of the environmental units along with a table of sustainable and unstable ecological characteristics of the units that will be used in the power evaluation process. It is worth mentioning that in evaluating the ecological capability of Tabriz county, the use of GIS tools is such that there is no need to complete the table (conventional method in GIS); Rather, the ecological capability of the area has been evaluated by converting the maps to raster format and using the weight overlay method based on raster data. In fact, the final overlay map will contain all the model information and data.

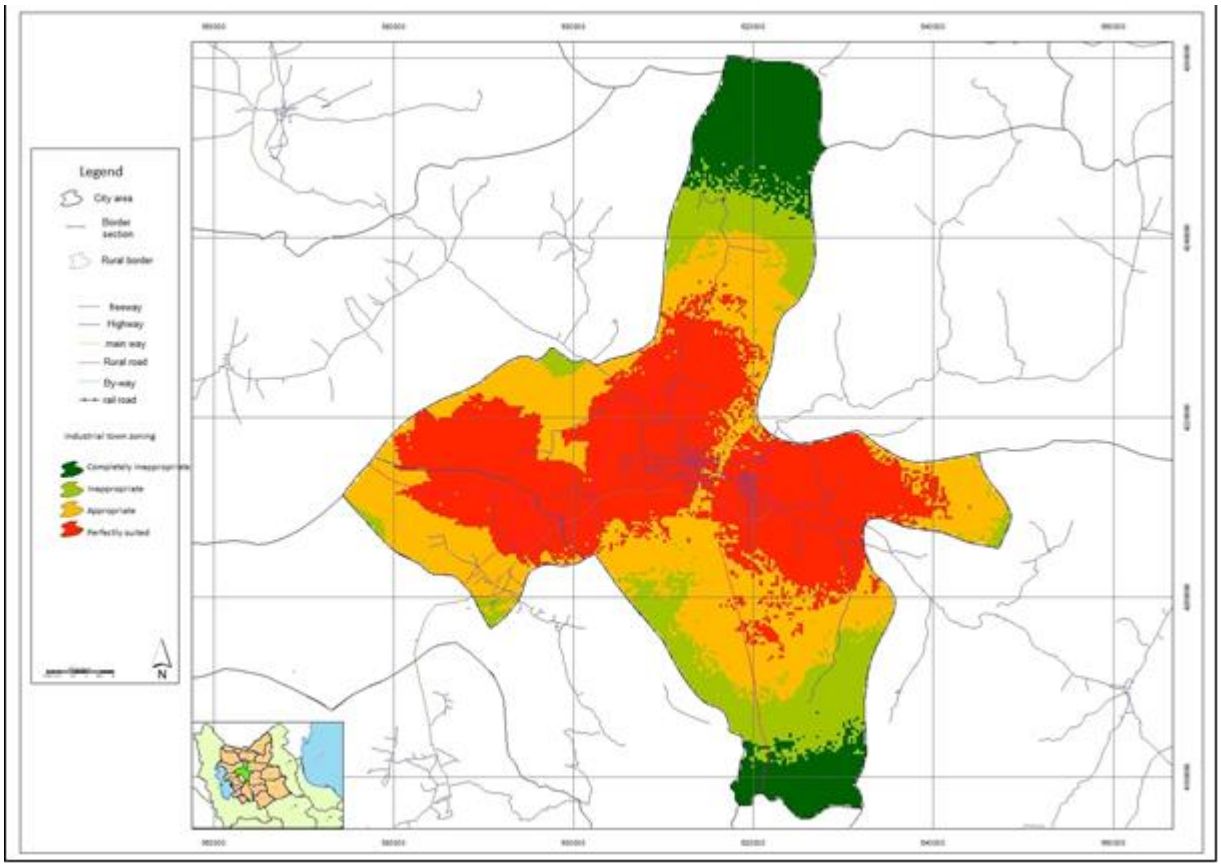

Figure 3. Areas with acceptable capability for the development of Tabriz

Discussion and Conclusion

Urban development is inevitable and is not naturally a matter of concern. But if it is not planned, there will be disruption in the development path. The need for planning and orientation in the development of city seems necessary. This is also true for Tabriz county. In this research, the evaluation of the ecological capability of urban development with a view to ecological parameters in a management area as a unit of land planning and management is considered. In this regard, ecological indices (topography, slope, communication network, fault, slope direction, water access, urban facilities, and urban centers) were studied and identified. Entering these layers into the GIS environment, analyzing them in this database, and suitable lands for future development of the city were identified using the ANP model. These lands are mainly located in the east, southeast of the city and other directions with having natural and artificial constraints lacked the efficiency needed for future development.

The most important reasons for determining the east-southeast directions for the future development of the city are summarized in the following factors:

Existence of orchards and pristine agricultural lands in the west and southwest of the city and the benefit of urban infrastructure such as water, communication lines, power transmission network in this area of the city and the ease of their expansion in these areas.

Studies show that the north and south sides are surrounded by steep heights. A part of the range of these heights, where have significant slopes are unsuitable for urban development.

- Northwest of the north of the Tabriz-Sufian road is the main and most natural possibility for the development of Tabriz due to having lands with suitable slope and facing the sun. However, there are some important points about the use of lands in the northwest of Tabriz: relative proximity to large factories provides the possibility of establishing unpolluted production units to which the southern parts of the Tabriz- Sufian road can be assigned.

Secondly, it is necessary to make the necessary arrangements to apply appropriate privacy and observe building regulations with the highest standard due to the passage of the North Tabriz fault through these lands.

Thirdly, it is necessary to determine and maintain the necessary privacy to prevent the transmission of pollution and the possible dangers of inevitable establishment due to the existence of Tabriz Airport.

On the other hand, previous studies have emphasized the development of Tabriz in the northwest direction of the city, among which the following can be mentioned.

Based on the above plans, the following aspects have been considered for the development of Tabriz:

Town located in Amand village in the northwest of Tabriz, located on the Tabriz-Marand route.

Andisheh town in the southwest of Tabriz, located on the Tabriz-Khosroshahr route.

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