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Ecological Capability Assessment of Tabriz Suburb, Iran, for Urban Development using Multi Criteria Evaluation Approach

Capacidad ecológica de los suburbios de la ciudad de Tabriz, Irán, para el desarrollo urbano utilizando la evaluación con criterios múltiples

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CAPACIDAD DE EVALUACIÓN ECOLÓGICA, DESARROLLO URBANO, MULTI CRITERIOS DE EVALUACIÓN, TELEDETECCIÓN, SISTEMAS DE INFORMACIÓN GEOGRÁFICA, TABRIZ.

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Abstract

In order to achieve sustainable development, it is necessary to obtain and adopt planning procedures on the basis of Multi Criteria Evaluation of natural environment. Since biophysical (natural) environment has limited ecological capabilities for human use, ecological capability assessment, as an essence for environmental studies and with the aim of preventing existing crises, yields proper grounds for environmental planning. The analysis of land capability and sufficiency for urban development is one of the main categories with which urban planners deal. In this paper, by means of Weighted Linear Combination (WLC) through the perspective of Multi Criteria Evaluation (MCE) Approach and within Geographic Information Systems (GIS), ecological capability of the suburbs surrounding Tabriz city was assessed (natural and human in terms of 12 criteria) to examine physical development of Tabriz city and final mapping of the region was provided. This mapping shows regions suitable for physical urban development of the city. The results and finding of this research were applied by urban planners.

Resumen

Con el fin de lograr el desarrollo sostenible es necesario obtener y aprobar los procedimientos de planificación sobre la base de múltiples criterios de evaluación del medio ambiente natural. Desde lo biofísico (natural) el ambiente ha limitado las capacidades ecológicas para el uso humano; la evaluación de las capacidades ecológicas es la esencia de los estudios ambientales y su objetivo es prevenir las crisis actuales, mostrando los rendimientos adecuados para la planificación ambiental. El análisis de la suficiencia y la capacidad de la tierra para el desarrollo urbano es una de las categorías principales a considerar por los

planificadores urbanos. En este documento, por medio de la Combinación Lineal Ponderada (WLC), a través de la perspectiva de Múltiples Criterios de Evaluación (MCE) y dentro de Enfoque de Sistemas de Información Geográfica (SIG), se evaluó la capacidad ecológica de los suburbios que rodean la ciudad de Tabriz (naturales y humanos en términos de 12 criterios) para examinar el desarrollo físico de la ciudad, proporcionando una cartografía que muestra regiones adecuadas para el desarrollo urbano de la ciudad. Los resultados y la búsqueda de esta investigación fueron aplicados por los planificadores urbanos.

Introduction

Tabriz is 131 square kilometers in terms of area and located in 46° 23' of east longitude and 38° 1' and 38° 9' north latitude and stands on 1.430 meters of height above sea level (Suburb Study Plans, 2005). Satellite Image Classification was used to confine the area of study and discover the variations. It is advantageous to apply Satellite Image Classification because position, location, type and nature of variation are indicated, precisely (Mesgari, 2002).

The method follows the procedures below:

1.-Transverse Mercator (TM)
2.-Confirmation of coordinates of satellite images of the study area
3.-The ordination of satellite images of the study area
4.-Longitudinal comparison of land use from 1989 to 2005

Ultimately, comparison method of urban land use was applied to calculate the variations (the conversion of land to urban areas) during these 2 years.

With respect to the development during past 15 years, the probability of further development in next 15 years was anticipated to be about 336294046 square meters, i.e. approximately Tabriz suburb with the coverage of 10 kms in radius. Marginal development and suburb settlement are among the remarkable indications of rapid and uncontrolled development of this metropolitan city, i.e. Tabriz and this has caused various environmental troubles.

Figure 1 and 2 show satellite images of Tabriz in 1989 and 2005, respectively and figure 3 shows the map of study area.

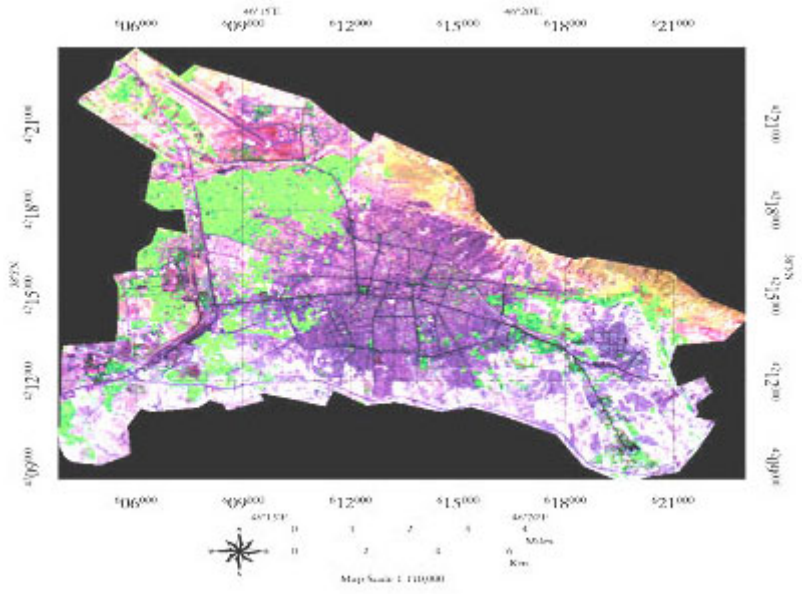

Fig. 1.1 Satellite image of Tabriz city on 1989

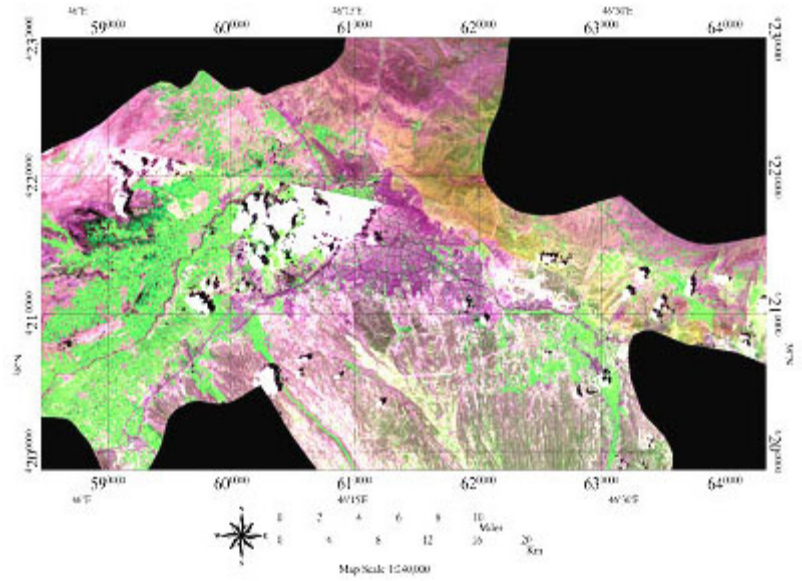

Fig. 1.2 satellite image of Tabriz city on 2005

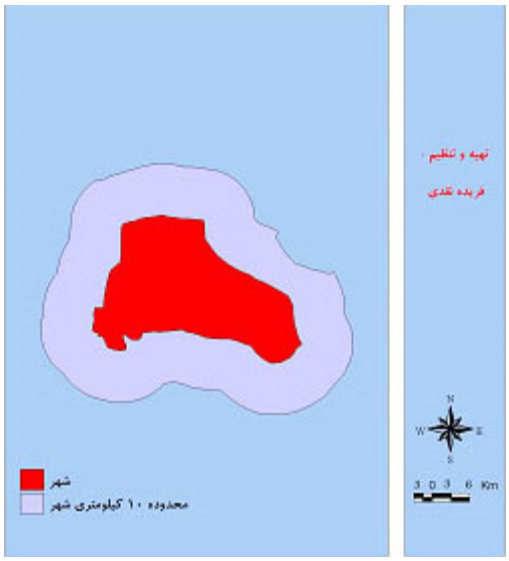

Fig. 1.3 map limits of study area

Exigency of Research

Unplanned development of Tabriz city and its inharmonious configuration are the results of political-historical and Socioeconomical factors and it has caused several environmental crises and problems as well. On the one hand, urban development and from thence social welfare can be observed, on the other hand, disastrous impacts of unplanned and accelerated development prevail. Since biophysical (natural) environment has limited ecological capabilities for human use, ecological capability assessment, as an essence for environmental studies and with the aim of preventing existing crises, yield proper grounds for environmental planning. The analysis of land capability and sufficiency for urban development is one of the main categories with which urban planners deal. (karam, 2005) Assessment of land suitability is a sophisticated process that requires multiple simultaneous environmental factors or criteria to proceed.

In this respect, GIS with capacities in managing the data and presenting the new outputs has become highly efficient tool and device for environmental planning. This system has various capabilities in collecting, storing, editing, analyzing the data and modeling, hence, useful tool for planning based on MCE (Karam, 2005). Marginal development and suburb settlement are among uncontrolled development of Tabriz city and this has caused various environmental troubles. Therefore, optimum planning based on scientific principles, ecological standards and land use potentiality assessment can reduce and even prevent future problems in urban development and lead to appropriate development in proportion to the land use capability and potentiality. Therefore, it is essential to carry out this study in order to assess ecological capability of Tabriz city suburb to figure out land use development with the aid of scientific standards and Multi Criteria Evaluation methodology based on Analytical Hierarchy Process (AHP) and fuzzy logic in GIS environment.

Research Assumptions

The assumptions in this research include:

1. Different aspects of Tabriz development possess different capabilities
2. The development of Tabriz during past 15 years was not harmonious
3. The city expansion happened not on the basis of ecological capability but on the basis of roads.

Research Objectives

The objectives of the research include:

1. General Objectives: Ecological capability assessment for city development in future
2. Secondary Objectives:

- Identifying the current potentialities of Tabriz for future development
- Choosing the best alternative based on ranking through MCE Approach
- Introducing and applying the features and uses of MCE Approach, spatial planning for urban development, fuzzy logic, AHP, GIS as a suitable approach to support Secondary applied objectives:

On the basis of the research finding, Department of the Environment and ministry of building and urbanization will be able to execute plans and of urban s in the region for region and city planning and easier supervision on the whole process will be possible by state organizations.

Materials and procedures

At first, following basic data and information were collected to carry out the research:

1. Topography maps of Tabriz were obtained from Armed forces Geographic organization in the scale of 1:25000.
2. Geology maps of the region in the scale of 1:100000 were used which were supplied by Geology Organization.
3. The maps of underground waters and the distances from wells were provided by the Organization of water and Sewage, Eastern Azerbaijan, Iran.
4. Image data from SPOT satellite on 4 spectrum band which were taken from the region on 25.04.2005.

Besides the abovementioned maps and data, slope classes map, the map of geographic directions, elevation classes map, the map of distances from main roads, the map electric power lines and surface water resources were also provided with the help of existing topography maps and also fault maps were extracted from geology maps and classified into two groups of major and minor faults. Mean while, land use was also provided by SPOT satellite, 2005.

The following computer softwares were used to collect, process, analyse and model different data to prepare and compile this research.

- Autodesk Map 2004 to do digital operations and edit the maps.
- Envi 4.3 to process the images and prepare land use maps.
- Idrisi 15 to normalize the maps.
- Expert Choice to give weight to criteria with the help of AHP and MCE.
- Arc GIS to create and complete database, to georefrence the maps, to identify coordinates systems and image systems. Spatial Analysis Functions were used to do MCE. Information layers were created, summarized and questioned with the aid of this software because of its high capability in editing questioning and analysis the data.

Research Method

The objective is to analyse Multi Criteria decision, choose the best or most preferable alternatives in descending order. There are various rules for decision- making in this field from which the following are the most well-known:

– Simple Additive Weighting (SAW)
– Value/ Utility Function
– AHP
– Ideal Point Method

These rules, procedures and methods can be studied in deterministic, probabilistic and fuzzy decision-making situations as well as in collective and individual ones (Parhizgar, Ghaffari, 2006). In this research, Weighted Linear Combination (WLC) was used to combine the layers and decide in Multi Criteria manner. This procedures are based on the concepts of weighted mean. The decision-maker allocates ratio importance weights To each attribute, then he creates a total score through multiplying indicated importance weight for each attribute by scaled amount for alternative in that attribute and, at last, he adds them up. When the total scores for all the alternative were calculated, the alternative having the highest total score is picked out. For each alternative there will be:

Where:

XiJ is the score of Jth alternative observing Jth attribute.

Wjis the normalized weight (*Σ Wj=1*) and shows relative importance of each attribute. The most preferable alternative is chosen in terms of the highest value of *Ai(j=1,2,...m)* (Eastman, 1997)

WLC on the basis of GIS include the following phases:

1. Defining a set of evaluation Criteria (Information layers) and alternatives.
2. Standardizing each layer of criterion map.
3. Defining the weights attributed to each criterion so that a weight of relative importance can be allocated directly to criterion map.
4. Creating the layers of weighted standardized map so that the layers of standardized map can be multiplied by related weights.
5. Allocating the total score to each alternative with the aid of overlaying the sum for each weighted layers of standardized map.
6. Putting the alternatives in accordance with their total prefer ability order – The alternative with the highest rank is the best one.

WLC can be executed by GIS and its overlaying features. Over laying features in GIS systems allow the combination and incorporation of criterion map layers, i.e. input maps to produce a combined map, i.e. output map. It is practical to apply this method in both rastar and vector format of GIS (Gruff, 1990, Heywood et al, 1995).

The Assessment Criteria and Standardization of the Criteria with Fuzzy Method

In MCE, indexes or measures ought to be identified and defined to achieve a particular objective. These indexes or measures are called criteria or attributes of assessment. In this study, ecological capability assessment for urban development (natural and human criteria in 12 layers) include, slope of land, altitude, aspect of slope, geology , water supplies, land use, land capability, distance from faults, distance from main roads, distance from airports, distance from electric power lines. Having been digitalized and input to the GIS, the above- mentioned criterions were converted into criterion maps via basic GIS applications. Since each criterion map or attribute possess different measuring scales. Their measuring scales should be synchronized and process is applied to make the measuring scales proportionate and synchronized and also to convert them into measurable units. In GIS, there are some main approaches to prepare comparable and

standardized criterion maps which include deterministic, probabilistic and fuzzy approaches. In this study, fuzzy approach has been used to standardize the data.

Data standardization converts all the value of the map layers into a range between 0 and 1 or 1 and 255.

Standardization process in fuzzy method is possible via reformatting the values in the form of a set of membership. In this case, the highest value is allocated to the maximum membership and the lowest value to the minimum membership (Soui, 1999). In fuzzy method of standardization, sigmadial – shape (S – shape), I-shape and linear functions are used to format the values.

In this research, the existing maps were standardized with the help of Idrisi software and their values were converted into comparable units ranging from 0 to 1, i.e. reclassing was carried out after standardizing.

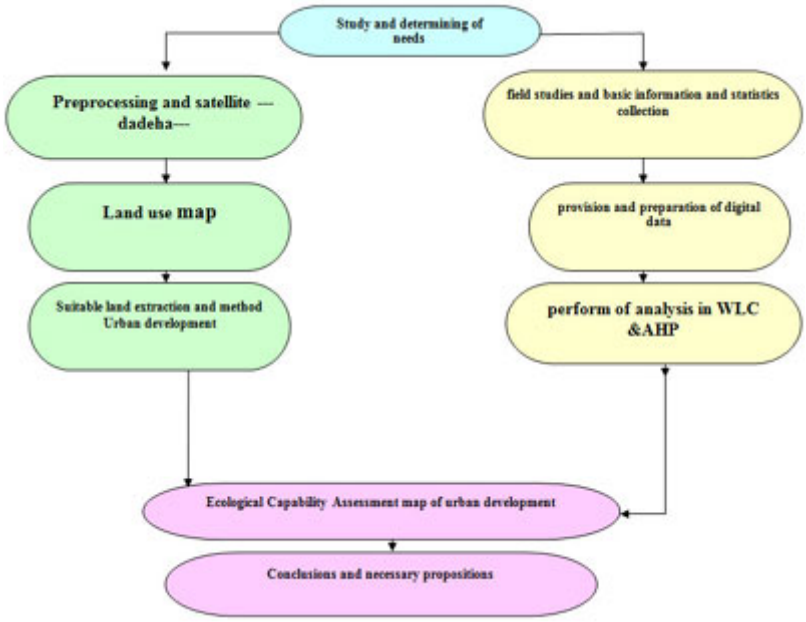

Fig. 2.1 general outlook of ecological burden evaluation

Weighting Method

After the evaluation criteria had been converted into comparable and standard scales, weight and relative importance of each one was identified concerning the objective in mind. In this research, Saati's AHP method was used to identify relative weights of each criterion (Saat, 1980). This method presents a versatile and powerful tool to investigate multi criterion qualitative and quantitative problems. Its main feature is based on twosome comparison of layers (Nagi, 2005). This method include three main phases.

1. Defining and organizing the criteria in a Heirarchy (criteria matri formation)

In this research, a set of twosome comparison of relative importance of the criterion was made. These twosome comparisons were analysed to create a series of weights (whose algebraic sums were equal to 1) (Ghaffari, 2003).

To determine the degree of accuracy and precision, compatibility Indexes (CI) was used and it was calculated on the basis of vector approach peculiar to Graph theory (Saat, 1980). Weighting would be

accurate if CI is equal to or less than 0.1. otherwise, the relative weights given to criteria had to be altered.

Table (1-2) shows threshold limit and the type of fuzzy function used for standardization of maps in fuzzy logic method in this study

Name of fuzzy function	type of fuzzy functio	Threshold limit		Map layer
		d	a,b,c	
Sigmodial	Decrease	30	2	Slope
Sigmodial	Decrease	15	5	Distance from main road (Km)
Sigmodial	Decrease	500	50	ground level waters (Km)
J-shape	Decrease	20	5	airport (Km)
Sigmodial	Decrease	1000	100	Wheels (m)
Sigmodial	Increase	1000	500	power lines (m)
Sigmodial	Increase	3	1	Fault (Km)
Sigmodial	Decrease	6	1	Type of land*1
Sigmodial	Decrease	2000	1200	Altitude (M)
Sigmodial	Decrease	6	1	Land use*2
Sigmodial	Decrease	5	1	Aspect*3
Sigmodial	Decrease	5	1	Land capability

*1alluvial Equal to 1, limestone and sandstone from 1 to 0, Marne stones equal to 0.

*2City and populated areas equal to 1, pasture lands with medium or low density, Farming land from 1 to 0, farming lands and gardens with high or medium capability, riverbeds equal to 0.

*3plain and south equal to 1, east and west from 1 to 0 – North equal o 0.

Research Findings

With respect to the above method, weighting has been carried out for each criterion and the results are illustrated in Table (1-3), obtained Compatibility Index to give weight to criterion weight is allocated, MCE was done in GIS with help of overlaying method and cumulative and final map (synthesis) of land capability for physical development of city was prepared (figure 1-3).

Table 3.1 weighting for each criterion using AHP for urban development

	Power	Airport	Altitude	Land	Aspect	Road	Land	Fault	Geology	Slope	Wheels	Ground level	Total

	lines			use			capability					waters	weight
Power lines	1	1	1	1	2	3	5	5	5	8	8	9	0.1721
Airport	1	1	1	1	2	3	5	5	5	8	8	9	0.00316
Altitude	1	1	1	1	1	3	4	5	5	7	8	8	0.0969
Land use	1	1	1	1	1	2	3	4	4	6	7	8	0.0571
Aspect	0.5	0.5	1	1	1	1	3	3	3	5	6	7	0.1435
Road	0.33	0.33	0.33	0.5	1	1	1	2	2	4	5	6	0.1083
Land capability	0.2	0.2	0.25	0.33	0.33	1	1	1	1	3	3	4	0.0316
Fault	0.2	0.2	0.2	0.25	0.33	0.5	1	1	1	2	3	3	0.0141
Geology	0.2	0.2	0.2	0.25	0.33	0.5	1	1	1	2	3	3	0.0362
Slope	0.125	0.125	0.1429	0.16	0.2	0.25	0.33	0.5	0.5	1	1	1	0.1721
Wheels	0.125	0.125	0.125	0.1429	0.16	0.2	0.33	0.33	0.33	1	1	1	0.0141
Ground level waters	0.11	0.11	0.125	0.125	0.1429	0.16	0.25	0.33	0.33	1	1	1	0.1083

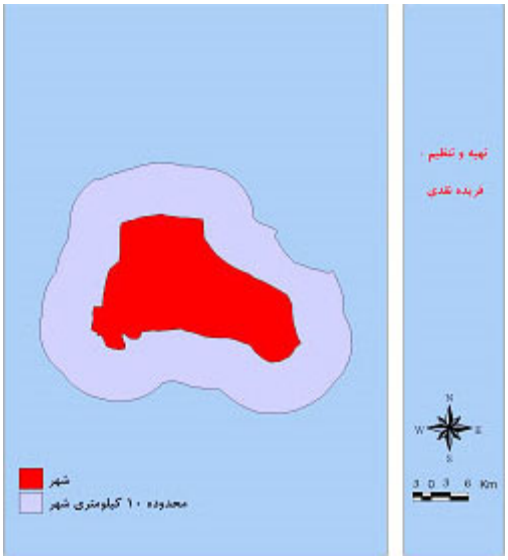

Fig. 3.1. final map (synthesis) of land capability for physical development of city

Discussion and conclusion

Primary map produced by MCE for ecological of Tabriz suburb is a combinatorial map having raster format with values ranging from 0 to 1.

After the preparation of the map with the help of reclassing method (and mean while the conversion of the format from raster to vector). Primary out-put map was converted into a classified map whose values and quantities were classified in three groups. In fact, this map demonstrates appropriate land classification for urban development (based on 12 criteria under study). Results suggest that with the help of WLC model and on the basis of field evidences and result comparisons, the directions for development are in accordance with existing realities. On the basis of development directions specified in WLC, the best alternative was selected according to their ranking. The study shows that the city is surrounded by slope highlands to the north and at present, some parts of these highland hillsides which have high slope have already been populated by suburban settlers. This part of the city not only lacks development capability but also will lose

some portion of its population due to modernization operations done on the aged texture of the city. There is very limited capacity for eastward development to establish or house usage and function and employment centers along Tabriz-Bostanabad-Ahar axis. Topographical complexities cause this axis of the city not to be able to play a key a key role in development for further settlement by more population. South axis of the city is limited by highland hillsides which has lower slope compared to northern highlands.

Since souther axis of the city has a negative downslope and it seriously conflicts with ecological and climatic necessities, it is deficient in population capacity; However, such land with less slope cam be used for such urban megacomplexes as scientific parks, Academic education institutes, research centers, play grounds, etc.

Westward, the city is occupied with oversized industries. Also facing with strong winds, it has no chance for more development or urbanization.

Development potentiality in this axis and also south-west is low and should be taken into consideration, since this axis stands in close vicinity of Sahand town and it accelerates unification with Tabriz.

North-eastern lands of Arpadarasi village is the remaining potentiality of urban development of Tabriz and it has relative limitations due to either area position or land morphology.

North and north-west of Tabriz-Sofiyan higway has the best possibility for Tabriz development, because it possesses lands facing the sun and with appropriate slope; however, some suggestions ought to be considered about using north western lands. First, regarding the fact that there exists main transit cross-country highway and its high capacity, it is essential that a national cargo complex be built in suitable vicinity, and because of its relative closeness to big factories, it is possible to establish pollution-free manufacturing companied around the region. Southern side of Tabriz-Sofiyan highway can be dedicated for that purpose.

Second, because of huge fault crossing these lands in northern Tabriz, it is urgent to take precautions about setting appropriate boundaries and regulation with the highest standards. Third, because of Tabriz Airport, it is necessary to set boundaries for protection against pollution and other possible hazards. Furthermore, other studies also call attention to development on northwest axis of Tabriz city from which the following studies can be named out:

According to Comprehensive Physical Development Plan of Tabriz city the following axes are considered as effective:

- The town located in outskirts of Ammand village of Tabriz city along Tabriz-Marand highway.
- The town of Andisheh located in southwest of Tabriz city along Tabriz-Khosrowshahr highway.

According to the studies carried out in suburban Settlement plan of Tabriz and on the basis of field surveys, North, south and southwest areas of Tabriz are generally considered suitable for suburban settlement and development. And these areas are main suburban settlers neighbourhood of Tabriz since north-west axis has plains and suitable slope.

Development potentiality in south-western axis is low and should be taken into consideration, since this axis stands in close vicinity of Sahand town and it accelerates its unification with Tabriz.

Advantages of WLC and AHP methods should be brought into consideration in correctly selecting weights and properly using data layers. Despite the use of numerous layers, improper weighting in decision-making would produce improper results.

In general, our results from this study suggests that Geographical Information Systems (GIS) with their applicability in variety of functions, changeability, edition of given data, extensive ability in combining different data layers, possibility of using satellite images and results obtained from the analysis of these images are exceptional leap ahead in evaluation operations.

Needless to say that in the absence of GIS, it might not be possible to bring such studies to a speedy and accurate conclusions.

Exceptional features of GIS allows us to reduce expenses and save time in operations. Hence, we suggest the following:

1. Since it is a necessity to have reliable data layers for GIS operations, establishing an accurate and complete database for this region and making it publicly available is of vital importance.

2. Regarding considerable importance of data layers in multi criteria evaluation and determining layer weights, also considering variability of ecological and environmental criteria and their importance, it is necessary that specialists determine related parameters for each region and exert efforts to localize for every different ecological environment.

Regarding the suitability analysis of land for physical development, other than MCE, multi purpose land use allocation method in the basis of Boolin logic can also be used. Meanwhile, the amount of evaluation criterion can be increased in accordance with limitation and potentialities of the project. This collection of methodologies are useful in other geological science such as countryside planning services and the identification of potentials.

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