INDUSTRIAL ZONING OF EAST AZERBAIJAN PROVINCE OF IRAN USING MULTICRITERIA EVALUATION MODELING

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Abstract. Industrialization potential and industrial zoning dependence on bioenvironmental conditions have been under special research focus. Having analyzed national and global standards and models, 22 ecological and human related parameters affecting industrial zoning were selected and evaluated. Then, information layers and digital maps were generated. The layers were statistically analyzed and compared within evaluation models of WLC, SAW and TOPSIS to determine each model's sensitivity in industrial zoning. Zoning outcomes by different evaluation models demonstrated that sensitivity to ecological parameters were different among the models. The three models diagnosed differing regional areas that were suitable for industrialization. The statistical comparisons of different categories among the evaluation models showed that the total areas suitable for industrialization varied by model. The total areas suitable for industrial development obtained by TOPSIS method was less than that found by WLC and SAW methods. This was due to prioritizing human related factors in weighing different parameters for industrial zoning by TOPSIS vs. WLC and SAW. Despite the models' differences in the total area suitable for industrialization, the types of areas were widely common among the models. In all models, Myaneh, Shabestar and Charoymagh regions were specified to be suitable for industrialization. It is implied that the above regions should be given priority in policy-making and future investment programming for industrial expansion. Such a priority stems from specific ecological, social and economic properties, their current industrial infrastructures, and suitable population density in these regions.
Keywords: *evaluation model; multicriteria analysis; ecology; industry; Iran*

Introduction

Effective management of natural, human, and economic resources for industrial development requires multidisciplinary bioenvironmental and zoning considerations (Ruiz Puente et al., 2007). Industrial site selection and zoning is a multicriteria decision-making process (Atthiawong and MacCarthy, 2002). The land zoning procedures are conducted using multicriteria evaluation methods that are based on Fuzzy algorithms and logics (Geneletti and van Duren, 2008; Store, 2009). Evaluation and capability assessment methods such as Fuzzy OWA (Malczewski, 2006), combined WLC and AHP (UP&ARCI, 2000) and TOPSIS (Kazemi Rad et al., 2012) are widely recognized and commonly used in site selection and industrial zoning programs. For instance, combinations of AHP-TOPSIS (Chang et al., 2012) and AHP-WLC (Hosseini et al., 2009; Monavvari et al., 2013; Naghdi et al., 2011; Raeesi and Safianian, 2011; Ranjbar and Naghdi, 2013; Naghdi and Nikkhah, 2014) have been used in coasts bioenvironmental protection and site selection for lands with industrial, agricultural and

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urban applications. In addition, TOPSIS (Lee, 2013; Kazemi Rad et al., 2012), Fuzzy (Jiang and Eastman, 2000), and Fuzzy-TOPSIS (Alavi and Alinejad-Rokny, 2011; Aryanezhad et al., 2011; Mokhtarian and Hadi-Vencheh, 2012; Yayla et al., 2012) methods have been applied to evaluate flood risk and land zoning for different industries such as power plans, mines and garments, manufactures, and bridge risk assessment.

East Azerbaijan as an important province (45490.88 square km area) in northwest Iran is host to enormous industries and manufactures that are mostly located around the capital populated city of Tabriz. The province contributes by 7.44% to Iran's industrial added value and by 13.13% to national GDP (Statistical Yearbook of East Azerbaijan, 2006). However, industrial land use and development have been in many cases scientifically and ecologically suboptimal. The province has been encountering increasing environmental pollutions; while no major inclusive and decisive industrial zoning research based on already recognized global methods has been conducted. Therefore, the objective of this study was to establish, for the first time, site selection and industrial zoning on the basis of ecological and nonecological parameters.

Materials and Methods

Study area

This study was conducted in the northwestern Iranian province of East Azerbaijan, an economically and environmentally important and relatively densely populated region. The province is located in 45º 7' to 48º 20' East and 36º 45' to 39º 26' North, with an area equal to 45846.572 square kilometers (approximately 2.81% of total country area) (Khorshiddoost et al., 2007). East Azerbaijan is a mountainous area with 40% of its surface being high mountains, 28.2% foothills, and 31.8% intermountain plains (*Figure 1*).

Research methodology

1. Library and field studies and documentations
2. Delphi questionnaire and interviews
3. Statistical and locational analyses

Research procedures and processes

Establishing the criteria affecting industrial zoning

Numerous parameters must be taken into account in industrial zoning programs (Mokhtarian and Hadi-Vencheh, 2012; Yu and Hu, 2010). To establish the influential criteria and indices for industrial site selection, a questionnaire was developed according to Delphi methodology. In addition, complementary criteria were determined based on widely accepted national and international standard models of industrial placing. After determining the foremost criteria, specialized bioenvironmental maps were generated using Remote Sensing (RS) and Geographical Information System (GIS) programs. These programs were used for statistical data analysis, satellite images processing, potential evaluation, and land zoning.

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Figure 1. *Location of the study area in the country.*

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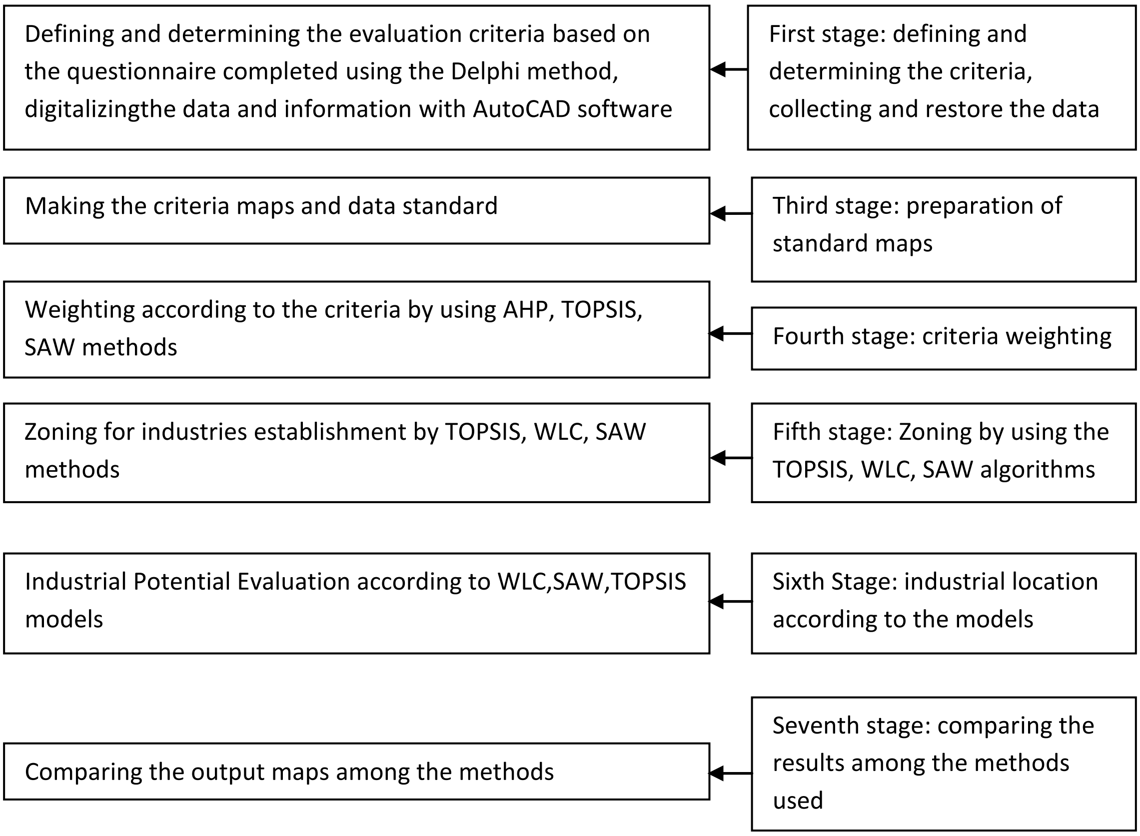
A total of 22 evaluation criteria (information layers) for site selection and industrial zoning were finalized. These consisted of ecological and nonecological (human functions related) parameters including erosion sensitivity, soil depth, soil texture, climate, altitude ,slope, aspect, stone, distance from fault, distance from permanent rivers and permanent aqueduct, distance from deep and semi-deep wells, vegetation density, distance from protected areas, distance from cities, distance from villages, distance from water lines, distance from power lines, distance from existent industrials, distance from airport, distance from main roads and highways, land use planning, population density.

Site selection analysis

On the basis of the data collected, multicriteria analyses were conducted to order the parameters based on their degree of importance for decision-making in the provincial site selection for industrialization. To optimally combine the information layers and make multicriteria decisions, the Weighted Linear Combination (WLC; Burrough, 1990), Simple Additive Weighting (SAW; Eastman, 1997) and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS; Chen, 2000; Wang and Elhag, 2006) algorithms were utilized. These methods and models are founded on the weight means concept. Briefly, the order of preference for each evaluation parameter or criterion was calculated by multiplying the weight of relative importance that is allocated in the model by the known scaling standard for that parameter (Parhizgar and Ghafari Gilandeh, 2006). Next, the parameters were ordered based on their final scaled value that was the sum of the above-mentioned products (Jozi and Saffariyan, 2011).

Study stages



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Criteria standardization using Fuzzy method

The evaluation criteria for industrial zoning were selected and finalized based on nationally and internationally recognized standards. These standards included EPA, Guidelines On Sustainable Industrial Zone, Guidelines for Siting of Industry, Industrial Park Site Selection, UNEP, GIS, Zoning Atlas of India, Makhdoom Ecological Model, Iranian Organization of Environmental Protection, Iranian Food and Drug Deputy: Health Rules, Atthiawong and MacCarthy (2002), Monavvari et al. (2013), Raghu Babu (2002), Gupta (2005), Dudukovic et al. (2005), Jiang (2007), Eldin and Eldrandly (2004), Church (2002).

The standard maps (layers) generated for all evaluation parameters were optimized using Idrisi Software (Alizadeh et al., 2013). Then, the maps were co-scaled to be comparable with each other (Sui, 1999). The threshold limit (TL) and the type of Fuzzy function (Bellman and Zadeh, 1977; Zadeh, 1975)used for layers standardization are given in *Table 1* (EPA, 1999; UNEP, 1997; GEUFP, 2007).

Table 1. *Threshold limit and type of Fuzzy function used for maps standardization within Fuzzy logic method*

Map layer	Threshold limit		Name of Fuzzy function	Type of Fuzzy function
	a,b,c	d		
Slope	1	20	Sigmodial	Decreasing
Distance from main roads and highway (m)	250	5000	Sigmodial	Increasing
Distance from surface water (m)	1000	2500	Sigmodial	Linear- Increasing
Distance from Airport (km)	5	10	J-shape	Increasing
Distance from Well (m)	100	1000	Sigmodial	Increasing
Distance from power lines (m)	250	2000	Sigmodial	Increasing
Distance from Fault (km)	2	10	J-shape	Linear- Increasing
Ston[1]	1	5	None	Increasing
Altitude (m)	400	1800	Sigmodial	Decreasing
Land use Planning[2]	1	5	None	Increasing
Aspect[3]	1	5	None	Decreasing
Soil texture[4]	0	1	None	None
Soil depth (m)	30	180	J-shape	Increasing
Soil erosion[5]	0	1	None	Increasing
Vegetation density	5	75	J-shape	Decreasing
Distance from protected areas[6]	0	1	Linear	Increasing
Climate[7]	0	1	None	Increasing
Distance from Cities (m)	1500	5000	Linear	Linear- Increasing
Distance from Villages (m)	1500	2000	Linear	Linear-Increasing
Reservoirs of water transfers (m)	1000	8000	Sigmodial	Increasing
Distance from Existent Industrials (m)	250	1000	Sigmodial	Decreasing
Population	50000	1000000	J-shape	Increasing

[1]Score 1: Sandstone, and basalt flows, alluvialsediment (alluvial continental shelf); Score 0-1: limestone, clay, granite, fractured tuffs, less stone; Score 0:Marn or Marn layers beneath the rock, seismicity, schist, sand dunes and floodplains.
[2]Score 1: Salt marsh and pasture land, wasteland and semi-intensive low-density;Score 0-1:Agriculture without Water, Forest with low density; Score 0: forests and Pastures with high density, Agriculture to Water, river and city center.
[3]Score 1: Flat and South ; Score 0-1: East, West, North.
[4]Score 1: Loam, loam - clay ; Score 0-1: Deep sand, sandy loam shallow to deep, loam and clay loam shallow to Average depth ; Score 0: Shallow sandy, Heavy clay , Soil Hydromorphic.
[5]Score 1: Erodible<5% ; Score 0-1: Erodible 5-70; Score 0: Erodible >70%.
[6] Score 1: Distance from protected areas >1KM ; Score 0-1: Distance from protected areas 150 M- 1 KM ; Score 0: in the protected areas.
[7] Score 0: Tornado path and Mousemi winds; Score 0-1: the rest.

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Weighing procedures

After the evaluation criteria for industrialization were converted to comparable and standard scales, their weight and relative importance to industrial zoning were determined. This was accomplished using the Analytic Hierarchy Process (AHP), Simple Additive Weighting (SAW), and TOPSIS algorithm procedures (*Table 2*).

Table 2. *Relative weight of evaluation criteria using different weighting methods*

N	Criteria	Standardized weight	SAW	AHP
1	Erosion Sensivity	0.0512	3.4	0.063
2	Soil Depth	0.0512	3.4	0.060
3	Soil Texture	0.03719	6	0.063
4	Climate	0.05356	3	0.035
5	Altitude (meter)	0.045	4.5	0.047
6	Slope (%)	0.03333	6.8	0.066
7	Aspect	0.04074	5.3	0.054
8	Stone	0.03475	6.5	0.063
9	Distance from Fault	0.04890	3.8	0.0382
10	Distance from permanent rivers and permanent Aqueduct	0.03719	6	0.057
11	Distance from Deep and Semi-deep Wells	0.03719	6	0.047
12	Vegetation Density	0.04338	4.8	0.040
13	istance from protected areas	0.04777	4	0.041
14	istance from Cities	0.04777	4	0.034
15	Distance from Villages	0.04777	4	0.034
16	Distance from water lines	0.03240	7	0.031
17	Distance from power lines	0.05356	3	0.031
18	Distance from Existent Industrials	0.05356	3	0.028
19	Distance from Airport	0.05658	2.5	.0.25
20	Distance from main roads and highways.	0.05658	3	0.028
21	Land use Planning	0.03971	5.5	0.043
22	Population Density	0.05356	4	0.06

Results and Discussion

Findings, as presented in *Figures 2-4*, demonstrated that the total area being suitable and highly suitable for industrialization (categories 4 and 5) was different among the three methods of site selection (i.e., WLC, SAW, TOPSIS). According to ANOVA outputs, the total area being unsuitable for industrialization (category 1) was significantly different among the methods. This occurred since the methods assigned different weights to all the environmental parameters utilized in the evaluation.

The means comparisons specified that TOPSIS and SAW methods differed in the total area evaluated to be unsuitable for industrialization ($P<0.05$). However, these two methods were not different in other industrial zone categories. The total area that was decided to be suitable and highly suitable for industrialization was lower in WLC and SAW than in TOPSIS. The main reason for this finding was the greater importance of ecological factors such as water resources, regional slope, and soil texture in the evaluation procedures of WLC and SAW. East Azerbaijan's landscape is usually considered suboptimal in terms of some ecological properties (e.g., physical properties).

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As such, since WLC and SAW give higher weights to these physical properties, the total area calculated to be suitable for industrialization was lower in WLC and SAW vs. TOPSIS.

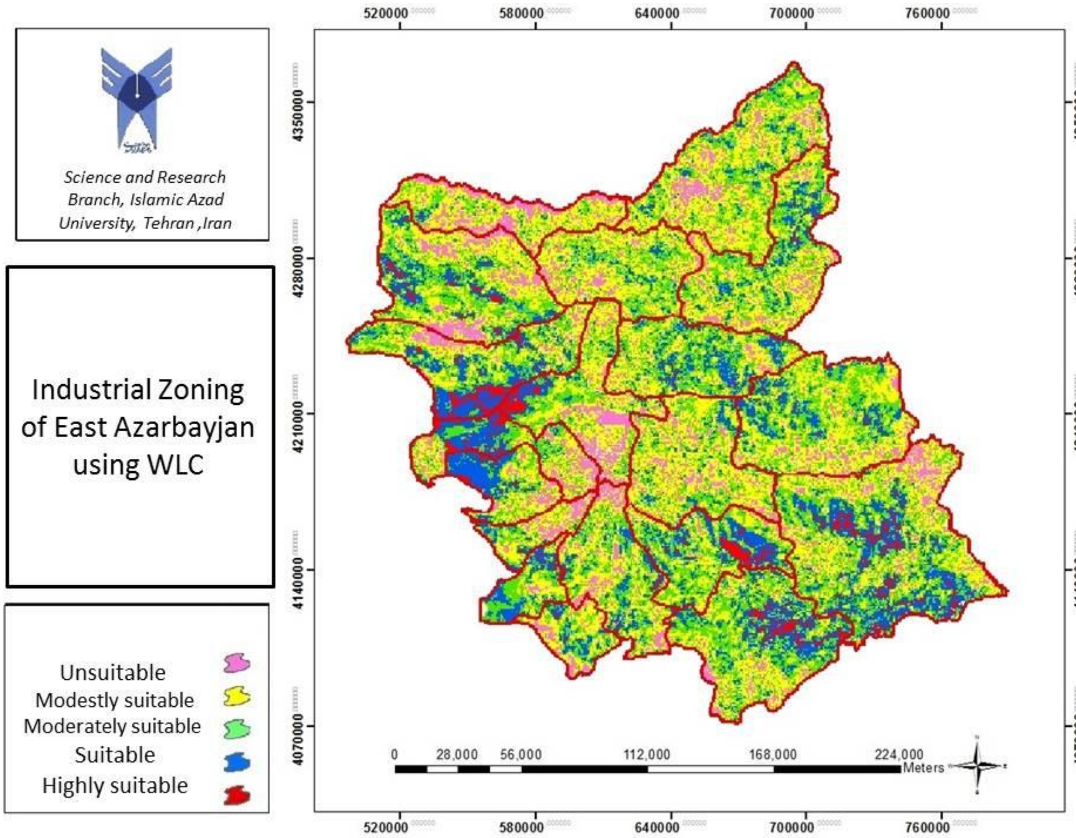

Figure 2. *Industrial zoning of East Azerbaijan using WLC. Based on this method, after weighing of layers and summing of 22 criterial for industrial zoning, 119167 and 751156 ha lands were respectively identified as highly suitable and suitable areas for industrial establishment. This mostly included districts of Myaneh, Shabestar and Charoymagh. In addition, this method suggested that more of province had weak potential for industrial establishment that were located in Kaleybar and Jolfa.*

With the greater weight of human related parameters (e.g., road, the already present industries, power transfer lines) and the smaller weight of ecological parameters (e.g., slope, height, erosion) in TOPSIS, the total areas decided to be highly suitable and suitable for industrialization were lower in TOPSIS compared to other two evaluation methods. In TOPSIS vs. WLC and SAW models, the nonecological parameters related the current human uses of landscape received greater weight in the evaluation process. Thus, because of the vast regions of the province with such nonecological human related properties, the total area calculated to be unsuitable for industrialization was greater in TOPSIS vs. WLC and SAW methods.

This study for the first time establishes land zoning for industrialization in East Azerbaijan, an ecologically and economically important province in northwest of Iran. In addition, the findings of this research provide comparative evidence on industrial expansion capacity of East Azerbaijan among three global evaluation models of

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TOPSIS, WLC (combined Fuzzy and AHP models) and SAW. The multicriteria weighting and evaluation methods based on ecological and socioeconomical parameters have been successfully used to optimize land site selection for industrialization in China (Jiang, 2007). Comparing Fuzzy and Boolian evaluation models for industrial land zoning in Iran, Khorasani et al. (2004) and Mahmoodi (2007) found that Fuzzy method proved more suitable because of the quantitative and continuous nature of its evaluation scale. The Boolian method, in contrast, is a discrete evaluation model that reports merely whether a given site is suitable or otherwise unsuitable for selection, but it cannot continuously score how suitable or unsuitable the site is (Raeesi, 2011).

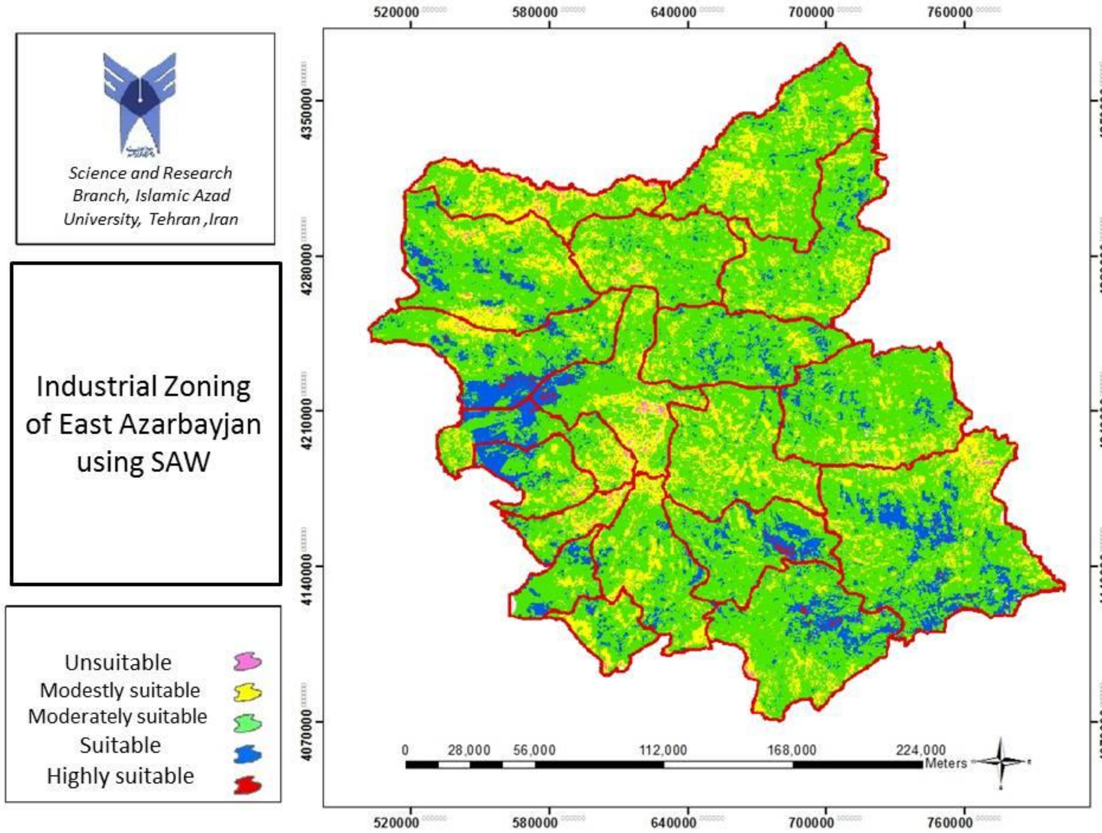

Figure 3. *Industrial zoning of East Azerbaijan using SAW. After weighing of layers and summing of 22 criteria for industrial zoning, 10149 and 454494 ha lands were respectively identified as highly suitable and suitable areas for industrial establishment. This mostly included districts of Hashtrood, Myaneh, Shabestar and Charoymagh. This method also suggested that greater provincial areas were identified as having weak industrial potential that were located in Jolfa and Tabriz.*

The TOPSIS method along with the AHP has been effectively used in different selection programs (Alavi and Alinejad-Rokny, 2011). As demonstrated in the current study for industrial site selection, the TOPSIS has been reported to be a highly flexible, precise and realistic method in grading plant species for mine restructuring and in ranking land sites for dairy manufacturing (Alavi and Alinejad-Rokny, 2011; Mokhtarian and Hadi-Vencheh, 2012). Since the criteria adopted for industrialization

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capacity assessment are of varying significance in land site selection, the present study utilized three different major evaluation methods to obtain comparative insights into zoning programs to help optimize future decision and policy making.

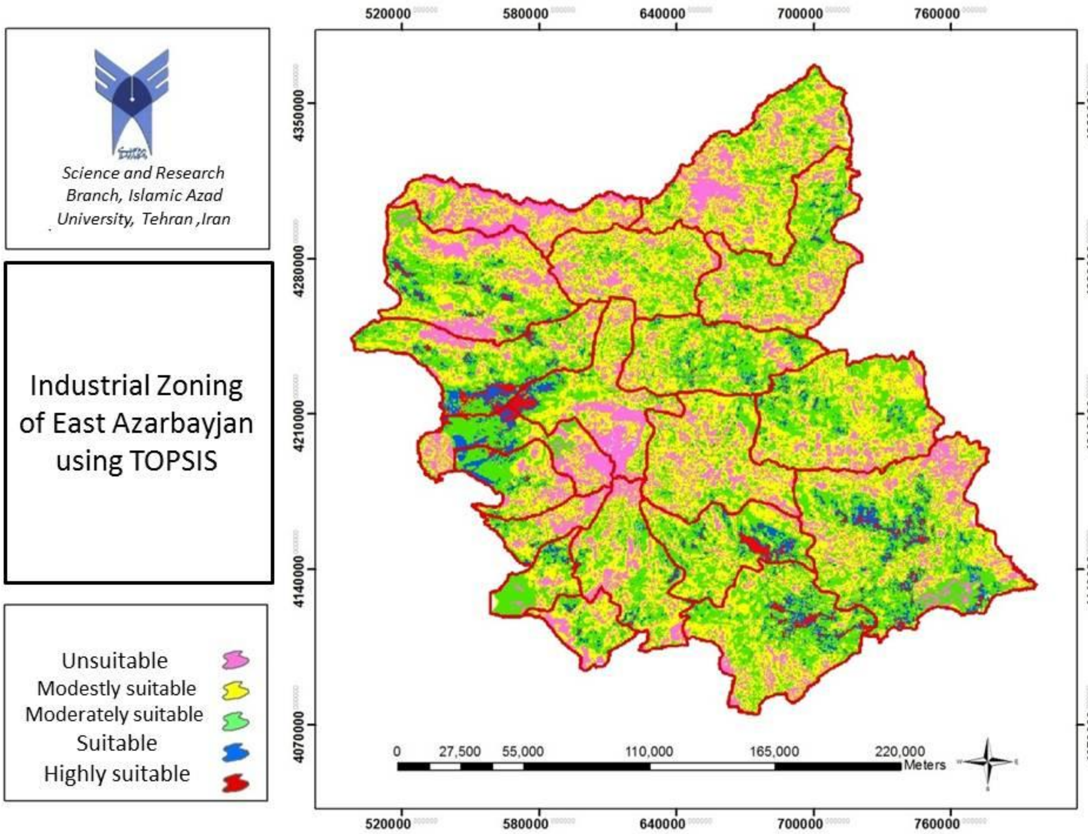

Figure 4. *Industrial zoning of East Azerbaijan using TOPSIS. After weighing of layers and summing of 22 criteria for industrial zoning, 69119 and 200086 ha lands were respectively identified as highly suitable and suitable zones for industrial establishment. These zones were mostly located in districts of Shabestar, Myaneh and Charoymagh. This method also suggested that more of province had less suitable area for industrial establishment that were located in Kaleybar and Jolfa.*

Conclusions

The multicriteria evaluation methods of WLC, TOPSIS and SAW enabled decision making on site selection for industrialization in East Azerbaijan based on different quantitative and qualitative environmental criteria and their relative importance. Because of the higher preference of nonecological parameters (related to human activity) modeled for industrial zoning by TOPSIS method, the total area with suitable industrialization capacity was found to be lower in TOPSIS vs. WLC and SAW. However, despite the differences of the evaluation methods in calculating the total land area with suitable industrialization capacity, the areas were overlapped among the methods. Miyaneh, Shabestar and Charoymagh were found to be the most capable regions of East Azerbaijan for industrialization. This information can be most effectively utilized in prospective policy and decision making for the provincial industrial expansion programs.

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