Industrial Zoning of East Azarbayjan Province of Iran using Multicriteria Evaluation Modeling: Ecological and Nonecological Analysis

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ABSTRACT

Industrialization potential and industrial zoning dependence on bioenvironmental conditions has been under special research focus. The objective of this research was to evaluate East Azarbayjan's industrialization potential and to establish its industrial zoning in light of ecological and nonecological conditions. 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 5 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: Industrial zoning, Multicriteria evaluation model, East Azarbayjan, Environment

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 (Athirawong and MacCarthy, 2002). The land zoning procedures are conducted using multicriteria evaluation methods that are based on Fuzzy algorithms and logics (Genelettiand 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 (Hsien-kuo et al., 2012) and AHP-WLC (Hosseini et al., 2009; Monavvari et al., 2013; Naghdi et al., 2011; Raeesi and Safianian, 2011; Ranjbariand naghdi., 2013) have been used in coasts bioenvironmental protection and site selection for lands with industrial, agricultural and urban applications. In addition, TOPSIS (Lee, 2013; Kazemi Rad et al., 2012), Fuzzy (Jiang et al., 2000), and Fuzzy-TOPSIS (Alavi and Alinejad-Rokny, 2011; Aryanezhad et al., 2011; Mokhtarianand 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 Azarbayjan as an important province (45490.88 square km area) in northwest of 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 North West Iranian province of East Azarbayjan, an economically and environmentally important and relatively densely populated region. The province is located in 45° 7’ to 48° 20’ East and 36° 45’ to 39° 26’ North, with an area equal to 458,465.72 square kilometers (approximately 2.81% of total country area) (Khorshidost et al., 2007). East Azarbayjan is a mountainous area with 40% of its surface being high mountains, 28.2% foothills, and 31.8% intermountain plains (Figure 1).

**Fig1. Location of the study area in country.**

**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.

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 GhafariGilandeh, 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

<table>
<thead>
<tr>
<th>First stage: defining and determining the criteria, collecting and restore the data</th>
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</thead>
<tbody>
<tr>
<td>Third stage: preparation of standard maps</td>
</tr>
<tr>
<td>Making the criteria maps and data standard</td>
</tr>
<tr>
<td>Fourth stage: criteria weighting</td>
</tr>
<tr>
<td>Weighting according to the criteria by using AHP, TOPSIS, SAW methods</td>
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<tr>
<td>Fifth stage: Zoning by using the TOPSIS, WLC, SAW algorithms</td>
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<tr>
<td>Zoning for industries establishment by TOPSIS, WLC, SAW methods</td>
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<tr>
<td>Sixth Stage: industrial location according to the models</td>
</tr>
<tr>
<td>Industrial Potential Evaluation according to WLC, SAW, TOPSIS models</td>
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<tr>
<td>Seventh stage: comparing the results among the methods used</td>
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<tr>
<td>Comparing the output maps among the methods</td>
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</table>

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, Atthrirawong and MacCarthy (2002), Monavvari et al. (2013), Raghu Babu (2002), Gupta (2005), Dudukovic et al. (2005), Jing Jian (2007), Eldrandly (2004), Church (2002), Neil and et al. (2004). 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.

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

<table>
<thead>
<tr>
<th>Map layer</th>
<th>Threshold limit</th>
<th>Type of Fuzzy function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope</td>
<td>1 20</td>
<td>Sigma, Decreasing</td>
</tr>
<tr>
<td>Distance from main roads and highway (m)</td>
<td>250 5000</td>
<td>Sigma, Increasing</td>
</tr>
<tr>
<td>Distance from surface water (m)</td>
<td>1000 2500</td>
<td>Sigma, Linear-Increasing</td>
</tr>
<tr>
<td>Distance from Airport (km)</td>
<td>5 10</td>
<td>J-shape, Increasing</td>
</tr>
<tr>
<td>Distance from Well (m)</td>
<td>100 1000</td>
<td>Sigma, Increasing</td>
</tr>
<tr>
<td>Distance from power lines (m)</td>
<td>250 2000</td>
<td>Sigma, Increasing</td>
</tr>
<tr>
<td>Distance from Fault (km)</td>
<td>2 10</td>
<td>J-shape, Linear-Increasing</td>
</tr>
<tr>
<td>Ston1</td>
<td>1 5</td>
<td>None, Increasing</td>
</tr>
<tr>
<td>Altitude (m)</td>
<td>400 1800</td>
<td>Sigma, Decreasing</td>
</tr>
<tr>
<td>Land use Planning^2</td>
<td>1 5</td>
<td>None, Increasing</td>
</tr>
<tr>
<td>Aspect^3</td>
<td>1 5</td>
<td>None, Decreasing</td>
</tr>
<tr>
<td>Soil texture^4</td>
<td>0 1</td>
<td>None, None</td>
</tr>
<tr>
<td>Soil depth (m)</td>
<td>30 180</td>
<td>J-shape, Increasing</td>
</tr>
<tr>
<td>Soil erosion^2</td>
<td>0 1</td>
<td>None, Increasing</td>
</tr>
<tr>
<td>Vegetation density</td>
<td>5 75</td>
<td>J-shape, Decreasing</td>
</tr>
<tr>
<td>Distance from protected areas^6</td>
<td>0 1</td>
<td>Linear, Increasing</td>
</tr>
<tr>
<td>Climate^7</td>
<td>0 1</td>
<td>None, Increasing</td>
</tr>
<tr>
<td>Distance from Cities (m)</td>
<td>1500 5000</td>
<td>Linear, Linear-Increasing</td>
</tr>
<tr>
<td>Distance from Villages (m)</td>
<td>1500 2000</td>
<td>Linear, Linear-Increasing</td>
</tr>
<tr>
<td>Reservoirs of water transfers (m)</td>
<td>1000 8000</td>
<td>Sigma, Increasing</td>
</tr>
<tr>
<td>Distance from Existent Industrials (m)</td>
<td>250 1000</td>
<td>Sigma, Decreasing</td>
</tr>
</tbody>
</table>

| Population                                     | 50000 100000    | J-shape, Increasing    |

^1Score 1: Sandstone, and basalt flows, alluvial sediment (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.

^2Score 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.

^3Score 1: Flat and South; Score 0-1: East, West, North.

^4Score 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.

^5Score 1: Erodible<5%; Score 0-1: Erodible 5-70; Score 0: Erodible >70%.

^6Score 1: Distance from protected areas >1KM; Score 0-1: Distance from protected areas 150 M-1 KM; Score 0: in the protected areas.

^7Score 0: Tornado path and Mousemi winds; Score 0-1: the rest.

**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

<table>
<thead>
<tr>
<th>N</th>
<th>Criteria</th>
<th>Standardized weight</th>
<th>SAW</th>
<th>AHP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Erosion Sensivity</td>
<td>0.0512</td>
<td>3.4</td>
<td>0.063</td>
</tr>
<tr>
<td>2</td>
<td>Soil Depth</td>
<td>0.0512</td>
<td>3.4</td>
<td>0.060</td>
</tr>
<tr>
<td>3</td>
<td>Soil Texture</td>
<td>0.03719</td>
<td>6</td>
<td>0.063</td>
</tr>
</tbody>
</table>
RESULT 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 Azarbayjan's landscape is usually considered suboptimal in terms of some ecological properties (e.g., physical properties). 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.

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 non ecological 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 non ecological 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 Azarbayjan, an ecologically and economically important province in North West of Iran. In addition, the findings of this research provide comparative evidence on industrial expansion
capacity of East Azarbayjan among three global evaluation models of 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 (Jing Jiang, 2007). Comparing Fuzzy and Boolean 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 Boolean 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 (Raeisi, 2008).

The TOPSIS method along with the AHP has been effectively used in different selection programs (Alaviand 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 (Alaviand Alinejad-Rokny, 2011; Mokhtarian and Hadi-Vencheh, 2012). Since the criteria adopted for industrialization 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.

CONCLUSION

The multicriteria evaluation methods of WLC, TOPSIS and SAW enabled decision making on site selection for industrialization in East Azarbayjan 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 Charooymagh were found to be the most capable regions of East Azarbayjan 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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Industrial Zoning of East Azarbayjan using SAW

Industrial Zoning of East Azarbayjan using TOPSIS

**Fig 3.** Industrial Zoning of East Azarbayjan using SAW

**Fig 4.** Industrial Zoning of East Azarbayjan using TOPSIS

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