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ASSESSMENT OF ECOLOGICAL POTENTIALS USING THE MCDM MODEL TO DETERMINE THE OPTIMAL DIRECTIONS FOR INDUSTRIAL DEVELOPMENT IN THE TABRIZ AND ARDEBIL CORRIDOR

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ABSTRACT

Urban and regional development, along with industrial expansion, will expose extensive land areas to various human activities. Unfortunately, the ecological aspects of these developments have often been neglected, resulting in a lack of effective assessment tools to guide stakeholders towards sustainable land use practices that minimize negative impacts on the ecosystem. Utilizing land without considering its environmental potential and ecological diversity can have severe and irreversible consequences, including environmental degradation that threatens natural resources and hinders the environment's ability to support ongoing development. Inappropriate and poorly planned industrial growth can lead to the loss of agricultural land, environmental imbalances, and disruptions to ecological harmony. This study aims to determine the optimal location for industrial development in Ardebil. To achieve this objective, an optimization algorithm with an adaptive inertia weight based on Multiple Criteria Decision Making Models was employed. Key factors considered in the study include natural parameters (such as topography, slope, distance to fault lines), hydrological parameters (including land use, communication infrastructure), and energy-related factors (such as energy and drainage density). The findings reveal that geological criteria like soil quality and texture, as well as land use patterns, have the most significant impact on industrial development, with coefficients of 0.11 and 0.14, respectively. As a result, Parsabad, Sarein, and Ardebil are identified as the top three locations for industrial ecological development, while Khalkhal and Kosar are ranked ninth and tenth, respectively.

***Keywords**: Industrial development; ecological potential; TOPSIS; regional development; human activities*

ABSTRAK

Perkembangan perkotaan dan regional, serta perluasan industri, akan membuka lahan yang luas terhadap berbagai aktivitas manusia. Sayangnya, aspek ekologi dari pembangunan ini sering kali diabaikan, sehingga mengakibatkan kurangnya alat penilaian yang efektif untuk memandu para pemangku kepentingan menuju praktik penggunaan lahan berkelanjutan yang meminimalkan dampak negatif terhadap ekosistem. Pemanfaatan lahan tanpa mempertimbangkan potensi lingkungan dan keanekaragaman ekologi dapat menimbulkan dampak yang parah dan tidak dapat diubah, termasuk degradasi lingkungan yang mengancam sumber daya alam dan menghambat kemampuan lingkungan dalam mendukung pembangunan yang sedang berlangsung. Pertumbuhan industri yang tidak tepat dan tidak terencana dapat mengakibatkan hilangnya lahan pertanian, ketidakseimbangan lingkungan, dan terganggunya keharmonisan ekologi. Penelitian ini bertujuan untuk menentukan lokasi optimal untuk pengembangan industri di Ardebil. Untuk mencapai tujuan ini, digunakan algoritma optimasi dengan bobot inersia adaptif berdasarkan Model Pengambilan Keputusan Beberapa Kriteria. Faktor-faktor

kunci yang dipertimbangkan dalam studi ini mencakup parameter alam (seperti topografi, kemiringan, jarak ke garis patahan), parameter hidrologi (termasuk penggunaan lahan, infrastruktur komunikasi), dan faktor terkait energi (seperti kepadatan energi dan drainase). Temuan menunjukkan bahwa kriteria geologi seperti kualitas dan tekstur tanah, serta pola penggunaan lahan, memiliki dampak paling signifikan terhadap pengembangan industri, dengan koefisien masing-masing sebesar 0,11 dan 0,14. Hasilnya, Parsabad, Sarein, dan Ardebil diidentifikasi sebagai tiga lokasi teratas untuk pengembangan ekologi industri, sementara Khalkhal dan Kosar masing-masing berada di peringkat kesembilan dan kesepuluh.
Kata Kunci: *Pembangunan industri; potensi ekologi; TOPSIS; pembangunan daerah; aktivitas manusia*

A. INTRODUCTION

Urban and regional development without ecological considerations has become a significant focus of study in international organizations and among scholars (Pickett et al., 2001; UNEP, 2002; Habitat, 2018; Ghalehteimouri et al., 2024; Ghalehteimouri et al., 2024; Assumma et al., 2024). Plans and policies for industrial development across provinces should consider a broad regional perspective and can have a significant impact on both national and sub-provincial policies (Zimmermann and Feiertag, 2024; Alipour and Meshkini, 2024). Therefore, it is crucial to carefully evaluate the challenges and opportunities in provinces, cities, and rural areas (Shamaei and Jafarpour Ghalehteimouri, 2024). This evaluation should inform the allocation of resources to the most suitable locations for current and future development plans, with the aim of improving decision-making processes at various levels while minimizing harm to natural resources. Conducting effective ecological assessments is essential to charting a sustainable course and achieving a balance between human activities and environmental resources (Steiner et al., 2000; Mensah, 2019; Liu et al., 2020; Halder et al., 2021; Rentschler et al., 2023). The primary goal of land use management and planning is to distribute economic, social, and population activities evenly across rural and urban areas, taking into account their capacities and changing needs over time (Fróna et al., 2019; Alrawi and Qasim, 2022). Technological advancements have enabled people to participate in activities across different locations, leading to a rapid rise in human activity and the utilization of natural resources. Recognizing the importance of land-use planning can play a vital role in promoting sustainable development, particularly in regions where these activities have a significant environmental impact, such as in the global south (Ghalehteimouri et al., 2021).

Urban ecology industrial development involves the study and implementation of sustainable industrial practices in urban areas to minimize environmental impact, promote resource efficiency, and improve the overall ecological health of urban environments. This approach aims to balance economic development, environmental conservation, and social well-being in urban settings (Jin et al., 2019; Jafarpour Ghalehteimouri, 2020). Land use for industrial development involves constructing factories and engaging in economic activities, requiring careful consideration of conflicting goals in land use planning and management (Hilhorst, 1971; Stevenson et al., 2016). Identifying urban ecological foundations is crucial for determining suitable areas for industrial activities, and integrating methods with greater integration capacity can help address gaps in ecological development and design (Alberti and Waddell, 2000; Davison et al., 2021; Enoguanbhor et al., 2021; Meraj et al., 2022; Quintas-Soriano et al., 2022; de Moura et al., 2024). The challenge lies in translating sustainable development concepts into practical solutions for current and future needs in industrial and urban development, which often consume large amounts of land. Geography plays a crucial role in integrating human and natural sciences and prioritizing various environmental values in geographical studies. Recent advancements in geographical studies, such as remote sensing and GIS technologies, have enhanced the accuracy of ecological assessment and evaluation.

Understanding the capacities of both human and environmental systems is crucial, as their interactions are complex and require identifying approaches to address these challenges (Ghalehteimouri, 2024). The capabilities of natural and human environments encompass the untapped potential of the area, which, if properly assessed, can predict future development trends (Hosseini, 2000). Ecological assessments play a significant role in determining construction costs and can inform economic planning, influencing development decisions. Evaluating ecological capabilities is essential for optimizing land potential through planning and environmental management studies to ensure sustainable development. Land suitability assessment, particularly through GIS-based Multi-criteria Decision Making (MCDM), has proven effective in ecological studies at various scales (Zoghi et al., 2017; Tashayo et al., 2020; Jafarpour, 2022; Shamai and Jafarpour Ghalehteimouri, 2024). MCDM methods have been utilized to evaluate natural resource conditions and human activities in relation to consumption, management, and sustainability goals, emphasizing ecological values (de Castro-Pardo et al., 2021).

Geographical information systems (GIS) are valuable tools for bio-environmental planning due to their robust data management capabilities and ability to offer new insights. The main objective of utilizing GIS is to support spatial decision-making. GIS can combine data for modeling, location analysis, and land balance assessment through land zoning evaluations, making it an essential tool (Rezai, 2005; Kamran et al., 2020). Previous research in this area is discussed in the subsequent sections. Jafari and Karimi (2005) conducted a study on the construction sector in Qom province, employing a systematic approach within a GIS framework. They evaluated Land Capability through a three-level sampling strategy with specific goals. By presenting a descriptive sample, they utilized a linear regression model to transform it into a mathematical model for assessing ecological, economic, and social capabilities. The study identified bio-environmental units, examined land maps, soil characteristics, vegetation cover, geology, geomorphology, climate, and their capabilities, with a focus on ecotourism potential. The results revealed a limited potential for centralized leisure activities, with only 10% of the area suitable for tourism centers and 90% unsuitable, while 19% was suitable for dispersed recreation. Fooladvand (2008) assessed the ecological capacity of the region using Analytic Hierarchy Process (AHP) and GIS in a thesis titled "Prioritizing Criteria for Ecotourism Assessment in Ashtarankooh, Lorestan, using AHP." Their evaluation extended beyond city or provincial boundaries, concentrating on regional assessments between Ardebil and Tabriz provinces and cities in Iran.

B. METHODS

According to the country's most recent administrative divisions in 2011, this province covers an area of 17,867 square kilometers, which is equivalent to 1/1 of the country's total area. It is located in the northern region of Iran, spanning from 37o45' to 39o42' north latitude and 47o30' to 48o55' east longitude from the Greenwich Meridian in the northwest of Iran. The average elevation above sea level in this province is over 1400 meters. The lowest point, with an elevation of 100 meters, is situated in Parsabad and Bilesavar, while the highest peak is Sabalan, reaching 4811 meters in the northern parts of Parsabad and Bilesavar, where the elevation is less than 100 meters above sea level. Ardebil province shares borders with the Republic of Azerbaijan to the north, Gilan province to the east, Zanjan province to the south, and East Azerbaijan province to the west. As per the latest administrative divisions, the province comprises 9 cities, 25 districts, 22 towns, and 66 villages.

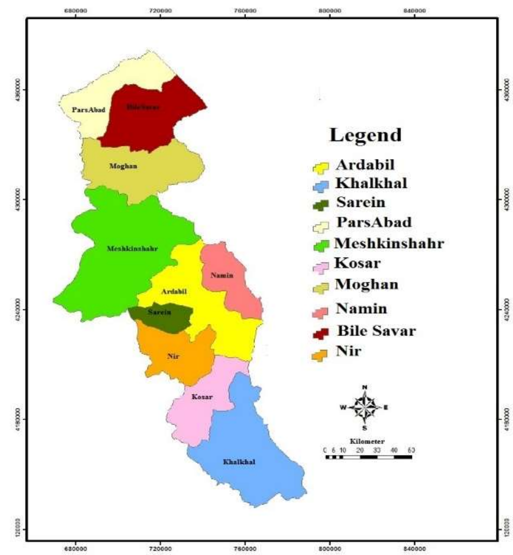

Figure 1. Location of study area

Ten natural and humanitarian parameters were selected for this model based on the research objectives and relevant data in the field. These parameters include temperature, rainfall, land use, landslide slope height, drainage density index, petrology, distance to fault, energy, infrastructure, and communication network. The VDEM Layer with 28-meter resolution topography, geology maps from the Army Geography Organization and Geology Organization, and Landsat satellite images were utilized to generate these layers from weather data. Each parameter plays a specific role in the model for potential industrial ecological growth in Ardebil Province. (Figure 2).

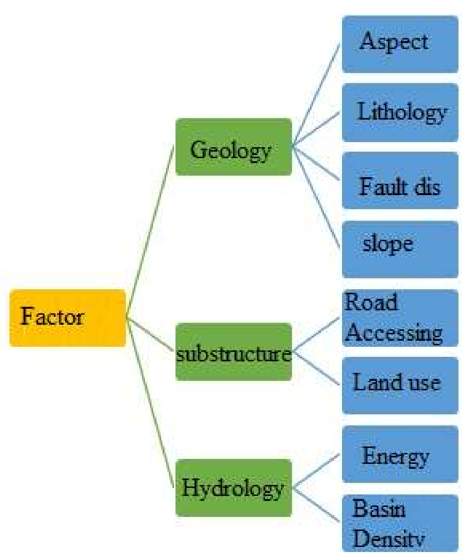

Figure 2. Effective Criteria and sub-criteria in industrial ecologic development.

This study employed a descriptive-analytical research design, utilizing fieldwork, observations, and library resources for data collection. Initially, an analysis was conducted on studys, research projects, and theses focusing on crucial elements in city location. Common criteria that have demonstrated adaptability in city location were identified as the major criteria. Data essential for the study were obtained from the Iran Statistic Center, the institution of water and soil researches, and the organization of environmental protection in Ardebil.

The study identified effective metrics for evaluating industrial development by analyzing data on Iran's ecological capability. Urban, rural, and industrial development were assessed using live and non-live factors. University degree holders, including bachelors, masters, experts, and specialists, were surveyed about the Iranian Industrial Ecology Model. Their responses were collected, and the criteria were averaged and weighted for balance. This process led to a consensus on evaluating the ecological capability of urban development in Ardebil province. Indexes were classified and rated using the dipole distance equation. The data layers were overlaid in the ArcGIS software to create a map of the ecological units in the study area.

This study utilizes the Multiple Criteria Decision-Making method (Ostovari et al., 2019) and employs multiple aim models for evaluation and selection. The models in the Multiple Criteria Decision Making (MCDM) framework define the attributes and number of potential alternatives (Asgharizadeh, 2005). The Multiple Attribute Decision Making (MADM) model is utilized to choose the most suitable alternative from a set of "m" alternatives. Various methods are available to assist in the Multi Criteria Decision Making process, which can be categorized as compensatory or non-compensatory, including the general satisfying method, specific satisfying method, dominance method, and prioritizing method (Chauvy et al., 2020). In 1981, Hwang and Yoon introduced the TOPSIS algorithm, which measures the proximity of an option to the optimal solution using Euclidean distance. TOPSIS selects alternatives that are closest to both the positive and negative ideal solutions from a given geometric position, making it one of the most effective multi-criteria decision-making methods with diverse applications. The m option of this process is evaluated by the n index, ensuring that the selected option is close to the positive ideal solution and far from the negative ideal solution. It is assumed that the desirability of all criteria consistently increases or decreases. The cities evaluated in this study have been ranked based on tourism infrastructure criteria, including travel agencies,

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lodging facilities, and catering establishments. The 2016 Ardebil Province Statistical Yearbook serves as the primary source for the statistics and data presented in Table 1.

A multi-criteria decision analysis approach is TOPSIS, or Technique for Order of Preference by Similarity to Ideal Solution. It evaluates a number of options according to a predetermined standard. Every time we need to make an analytical conclusion based on gathered facts, the method is employed in numerous areas of geographical studies where problems are more delicate and difficult across diverse changes in land use and land cover and environmental policies.

1. The data matrix formation based on m alternatives and n index as it shown in equation 1.

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

2. Standardize data and formation of standard matrix through the following equation 2.

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

3. Equation the weight of each index, index have higher weight are most important. The Matrix (v) is multiplying standard values of each index in their associated weight. In this stage need to access to all identifies criteria's to create the ecological raster layers for study/

$$V_{ij} = \begin{bmatrix} w_1 r_{11} & w_2 r_{12} & \cdots & w_n r_{1n} \\ w_1 r_{21} & w_2 r_{22} & \cdots & w_n r_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ w_1 r_{m1} & w_2 r_{m2} & \cdots & w_n r_{mn} \end{bmatrix} \quad (3)$$

4. Equation the distance I th alternative from the ideal alternative (highest performance index)

$$A^* = \left\{(\max_i v_{ij} \middle| j \in J), (\min_i v_{ij} \middle| j \in J^{'}\right\}$$
$$A^* = \{v_1^*, v_2^*, \ldots, v_n^*\} \quad (4)$$

5. Equation the distance I th alternative from the minimum (lowest performance index)

$$A^- = \left\{(\min_i v_{ij} \middle| j \in J), (\max_i v_{ij} \middle| j \in J^{'}\right\}$$
$$A^- = \{v_1^-, v_2^-, \ldots, v_n^-\} \quad (5)$$

6. Equation the interval criteria to the ideal alternative and the minimum alternative

$$S_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^{\text{r}}} \quad (6)$$

7. Equation the coefficient that is equal to the minimum alternative distance, divided by the total distance of the minimum alternative and the distance to the ideal alternative is calculated from the following equation.

$$S_i^* = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^*)^2} \quad (7)$$

8. Ranking alternatives has modulation based on the rates between 0 and 1. In this regard, 1 indicates the highest rating and zero represents the lowest rank.

$$C_i^* = \frac{S_i^-}{S_i^- + S_i^*} \quad (8)$$

C. RESULT AND DISCUSSION

The considered criteria for ecological evaluation are mentioned in table 1. These criteria consist the average temperature, rainfall, land usage, slope, slope direction.

Table 1. Classifying the studied Zone in terms of effective indexes in determining the usage of industrial development

Land use qualify	residential	garden	farming	pasture	greenwood
slope	6º	6º -9º	9º -15º	More than 15 degree	
Aspect	north	south	east	west	---
Accessing qualify	0-500	500-1000	1000-1500	1500-2000	More than 2000

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Basin density	Quite suitable	suitable	middle	unsuitable	---
Energy infrastructure	Quite suitable	suitable	middle	unsuitable	---
Lithology	Quite suitable	suitable	middle	unsuitable	---
Fault distance	More than 1200	900-1200	600-900	300-600	Less than 300
Annual average temperature	Less than 10	10-12	12-14	14-16	More than 16
Annual average precipitation	Less than 200	200-400	400-600	600-800	More than 800

Models such as AHP or ANP that determine values and other models for weighing criteria should be utilized in the initial step to establish the weight and importance of each criterion. Super Decision Software was used to assign weights to each criterion. The Decision Matrix was created in Stage 2, where each town was assessed based on various criteria using data from the Ardebil Statistic Calendar. This table displays the evaluation data for different counties in Ardebil Province regarding industrial development criteria. Each row represents a county, and each column represents a specific criterion. The values in the cells indicate the evaluation scores for each county-criterion pair.

The cell value at row "Ardebil" and column "slope" is 0.43, showing that Ardebil County scored 0.43 for the slope criterion. Similarly, the cell value at row "Nir" and column "Aspect" is 0.8, indicating that Nir County scored 0.8 for the aspect criterion (Table 2).

Table 2. Decision Matrix of ecological industrial evaluation of Ardebil Province:

index / county	slope	Aspect	Accessing qualify	Energy infrastructure	Fault dis	Lithology	Average temp	Average pri	Land use	Basin den
aij[1]	0.14	0.11	0.14	0.11	0.05	0.11	0.09	0.011	0.11	0.09
Ardebil	0.43	0.7	0.53	0.4	0.8	0.45	0.7	0.35	0.7	0.8
Bilesavar	0.35	0.45	0.3	0.35	0.3	0.7	0.8	0.45	0.35	0.75
Parsabad	0.63	0.4	0.25	0.3	0.1	0.35	0.5	0.35	0.8	0.45
Khalkhal	0.6	0.6	0.8	0.45	0.65	0.2	0.7	0.8	0.2	0.75
Sarein	0.5	0.35	0.83	0.7	0.25	0.7	0.4	0.4	0.6	0.35
Kosar	0.55	0.7	0.8	0.5	0.5	0.3	0.35	0.9	0.35	0.6
Meshkinshahr	0.66	0.4	0.5	0.65	0.75	0.6	0.55	0.4	0.55	0.7
Moghan	0.85	0.25	0.5	0.45	0.3	0.35	0.7	0.3	0.35	0.75
Namin	0.7	0.3	0.4	0.9	0.9	0.7	0.45	0.7	0.25	0.45
Nir	0.76	0.8	0.7	0.9	0.82	0.65	0.45	0.3	0.4	0.4

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Table 3 displays the normalized values derived from the decision matrix. Normalization ensures that the values from various criteria are standardized, enabling comparison. In Ardebil County, the normalized value for slope is 0.26497, representing the standardized slope score in Ardebil County. These normalized values facilitate equitable comparisons among counties based on different criteria, as they are all measured on a uniform scale of 0 to 1.

Table 3. Normalized matrix

Index / County	slope	Aspect	Accessing qualify	Energy infrastructure	Fault dis	Lithology	Average temp	Average pri	Land use	Basin den
aij	0.214976	0.402972	0.193657	0.212	0.421058	0.266468	0.382451	0.205971	0.449745	0.406926
Ardebil	0.26497	0.259053	0.165992	0.1855	0.157897	0.414506	0.437087	0.26482	0.224872	0.381493
Bilesavar	0.314965	0.230269	0.138326	0.159	0.052632	0.207253	0.273179	0.205971	0.513994	0.228896
Parsabad	0.299966	0.345404	0.442645	0.2385	0.34211	0.11843	0.382451	0.470792	0.128499	0.381493
Khalkhal	0.249972	0.201486	0.459244	0.370999	0.131581	0.414506	0.218543	0.235396	0.385496	0.17803
Sarein	0.274969	0.402972	0.442645	0.264999	0.263162	0.177645	0.191225	0.529641	0.224872	0.305194
Kosar	0.329963	0.230269	0.276653	0.344499	0.394742	0.355291	0.300497	0.235396	0.353371	0.35606
Meshkinshahr	0.424952	0.316621	0.193657	0.2385	0.157897	0.225018	0.382451	0.176547	0.224872	0.381493
Moghan	0.349961	0.172702	0.221322	0.476999	0.473691	0.414506	0.245861	0.411943	0.160623	0.228896
Namin	0.379957	0.460539	0.387314	0.476999	0.431585	0.384898	0.245861	0.176547	0.256997	0.203463
Nir	0.214976	0.402972	0.193657	0.212	0.421058	0.266468	0.382451	0.205971	0.449745	0.406926

Table 4 displays the weighted matrix, assigning a weight to each criterion's importance. These weights are then used to calculate a weighted score for each county based on the normalized values. In Ardebil County, the weighted score for slope is 0.027067, calculated by multiplying the normalized score (0.26497) by the weight assigned to slope. This methodology guarantees that criteria with higher importance have a greater impact on the final assessment.

Table 4. Weighted matrix

index / county	slope	Aspect	Accessing qualify	Energy infrastructure	Fault dis	Lithology	Average temp	Average pri	Land use	Basin den
aij	0.02196	0.040645	0.019197	0.02121	0.040692	0.026628	0.038801	0.020452	0.044626	0.041207
Ardebil	0.027067	0.026129	0.016454	0.018559	0.01526	0.041421	0.044344	0.026295	0.022313	0.038632
Bilesavar	0.032174	0.023226	0.013712	0.015908	0.005087	0.020711	0.027715	0.020452	0.051002	0.023179
Parsabad	0.030642	0.034838	0.043879	0.023862	0.033063	0.011835	0.038801	0.046747	0.01275	0.038632
Khalkhal	0.025535	0.020322	0.045524	0.037118	0.012716	0.041421	0.022172	0.023373	0.038251	0.018028
Sarein	0.028088	0.040645	0.043879	0.026513	0.025433	0.017752	0.0194	0.05259	0.022313	0.030905
Kosar	0.033706	0.023226	0.027424	0.034467	0.038149	0.035504	0.030486	0.023373	0.035064	0.036056
Meshkinshahr	0.043409	0.031935	0.019197	0.023862	0.01526	0.022486	0.038801	0.01753	0.022313	0.038632
Moghan	0.035749	0.017419	0.021939	0.047723	0.045779	0.041421	0.024943	0.040903	0.015938	0.023179

Namin	0.038813	0.046451	0.038394	0.047723	0.04171	0.038462	0.024943	0.01753	0.025501	0.020604
Nir	0.02196	0.040645	0.019197	0.02121	0.040692	0.026628	0.038801	0.020452	0.044626	0.041207

Table 5 presents the overall rating for each county, taking into account both positive and negative factors. This rating is used to determine the counties' suitability for industrial development. Ardebil County has a final rating of 0.59, which is determined by evaluating its performance across various criteria. Counties are then ranked according to their final ratings, with higher scores indicating a higher level of suitability for industrial development.

Table 5. Final rating

city	S^+	s^-	c	Rank
Ardebil	0.05691	0.063423	0.59	3
Bilesavar	0.069485	0.048066	0.44	8
Pars Abad	0.080057	0.042239	0.39	10
Khalkhal	0.058666	0.061557	0.57	4
Sarein	0.065214	0.055756	0.51	7
Kosar	0.056979	0.059455	0.55	5
Meshkinshar	0.05056	0.057771	0.53	6
Moghan	0.069662	0.043283	0.40	9
Namin	0.059373	0.066446	0.61	2
Nir	0.052704	0.0707	0.65	1

The passage outlines the methodology and analytical techniques used in the study for evaluating the ecological suitability of land resources for planned utilization, particularly for industrial development. Let's break down the key points:

1. **Analytical Strategy**:
   The study employs a systematic methodology, which is a subgroup of selection based on covering maps in charge method and multi-combinative map coding. This approach likely involves systematically analyzing and categorizing data using maps and coding techniques to identify patterns and relationships.
2. **Analytical Techniques**:
   a. **Fuzzy Logic**: Fuzzy logic is a mathematical approach that deals with reasoning that is approximate rather than precise. It allows for the handling of uncertainty and vagueness in data, which is particularly useful when dealing with complex systems like ecological evaluations.
   b. **Gamma Operator Models**: The gamma operator is a mathematical function used in fuzzy logic to model fuzzy implications. It plays a role in defining the

relationship between fuzzy sets and is likely used to establish the dependencies between different criteria in the evaluation.

c. **TOPSIS Optimization Algorithm**: TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) is a multi-criteria decision-making method used to determine the best alternative from a set of alternatives. It considers both the positive and negative aspects of each alternative to rank them accordingly.

3. **Fuzzy Selection**:
   The passage explains the concept of fuzzy selection, where an element may belong to a collection partially, with membership varying from 0 to 1. This concept is crucial for understanding how fuzzy logic is applied in the evaluation process.
4. **Membership Function**:
   The membership function in fuzzy logic, denoted as 'A', defines the dependence of a member on a reference collection. It quantifies the degree to which an element belongs to a particular set in the context of fuzzy logic. Therefore, the study employs a combination of systematic methodology and advanced analytical techniques, such as fuzzy logic and TOPSIS optimization, to evaluate the ecological suitability of land resources for industrial development in a nuanced and comprehensive manner. These techniques allow for the handling of uncertainty and the consideration of multiple criteria in decision-making.

The passage outlines the process of data preparation for a fuzzy model in ArcGIS, emphasizing the importance of fuzzification and integration of various layers for geographical evaluation.

1. **Fuzzification Process**:
   Before using layers in a fuzzy model, each layer needs to undergo a fuzzification process based on membership functions. This process involves transforming the layers into fuzzy states, typically represented by values ranging from 0 to 1. The aim is to capture the uncertainty and variability inherent in geographical data.
2. **Implementation in ArcGIS**:
   Fuzzification can be performed using functions available in ArcGIS, such as the "Raster Calculator." This tool allows for the formulation and application of membership functions to standard layers, converting them into fuzzy layers with values between 0 and 1. Poly vector layers, such as shapefiles, can also be treated as fuzzy layers by

encoding them appropriately. For example, when coded as 'I' or when transformed into layer states.

3. **Impact on Ecological Capabilities of Industrial Centers**:
   Each layer, based on its aim and the type of function applied, individually influences the restriction and potential of ecological capabilities of industrial centers. These layers likely represent different factors such as geological features, climate, hydrology, land use, etc., which are critical for assessing the suitability of land for industrial development.
4. **Integration in Geographical Evaluation**:
   Geographical evaluation requires the integration of various factors, including geological, climatological, hydrological, and land use data. Traditionally, integration methods were more theoretical, but advancements in GIS methodologies and the availability of satellite data have made integration more accurate and practical.
   This integrated approach allows for a comprehensive assessment of whether a piece of land is favorable or unfavorable for development, taking into account multiple factors that influence its suitability (Figure 3).

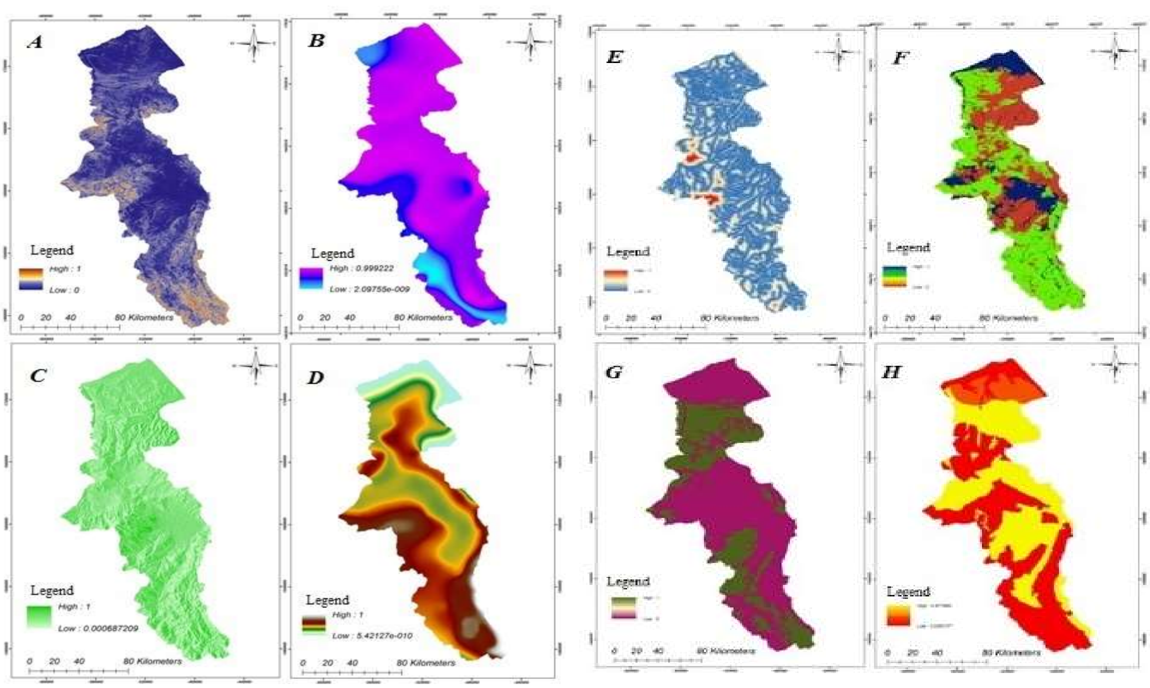

Figure 3. Ecologic criteria for industrial development of Ardebil are
Slop aspect (A), Accessing qualify (B), Basin density (C), Energy infrastructure (D), Lithology(E), Fault dis (F), Annual average temperature(G), Annual average precipitation(H)

Geographic information can be used to represent each chosen criterion and be displayed as a thematic map. The site selection problem can theoretically be solved by combining all the places on each map that are disqualified onto one map, then selecting from the qualified spots that are left. Of course, in actuality, it is not quite that easy (Shad et al., 2017). In this study, the fuzzy Gamma operator has been used for data collection and combination. Additionally, it plays a more balanced and realistic function when compared to the results of fuzzy addition and multiplication, which have high sensitivity of the fuzzy addition operator and low sensitivity of the fuzzy multiplication operator. According to fuzzy algebraic and fuzzy algebraic sum, this operator is defined.

And in that µCombination is the layer of fuzzy Gama and 8 is the determined parameter between zero and one. When 8 equals one, the Combination that is made is fuzzy algebraic addition and when 8 equals zero, the Combination will equal fuzzy algebraic multiplication. The considered value for 8 will create output values that are adaptive to an increase in algebraic sum and a decrease in fuzzy algebraic multiplication. We should pay attention that it is really useful for increasing the accuracy to choose the 8 value appropriately. The area of the studied map that has been highlighted in dark blue is completely suitable for industrial development according to the factors considered, while the areas highlighted in light blue have suitable conditions and the areas in green have somewhat suitable conditions, as shown in the above image. The northern and eastern portions of the examined zone have a greater area with favourable conditions for industrial growth than the southern and western halves, which includes a sizeable chunk of Nir, Namin, and Ardebil (Figure 4).

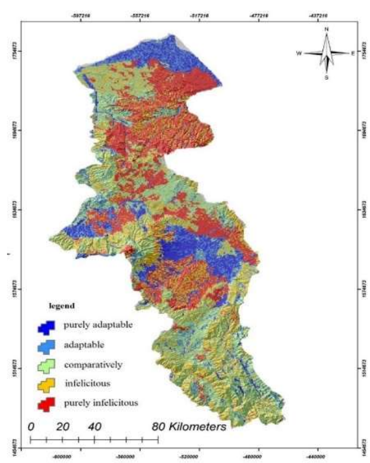

Figure 4. Acceptable capability for industrial development of Ardebil province

In conclusion, utilizing the MCDM method to evaluate the ecological viability of industrial development is truly a useful tool in evaluating the ecological viability for developing industrial development programmes to achieve a sustainable growth of metropolitan areas. The basis for evaluating ecological capability is the evaluation of the natural, human, and environmental structures. Therefore, it is necessary to evaluate each area's ecological capabilities using precise criteria that take into consideration its specific ecological characteristics. Industrial growth, which involves the logical and equitable division of economic activity, is one of the examples that may be explored by concentrating on ecological capability models. Regional development tries to situate industrial units following economic expansion and also concentrates on political and social issues. Better distribution will also lessen regional disputes and keep the disparities between urban and rural areas in check; social justice will follow.

Based on the characteristics that have been identified for industrial expansion, this study attempted to identify the optimum geographic boundaries for Ardebil industrial development. In addition to its results can be considered, Ardebil is significant for its participation in national and international agriculture, food, and transportation that are related to its exceptional natural and ecological conditions. By facilitating cooperation between those working on economic development, urban development economic agencies, and environmental ecological programmes, industrial development maps aid in achieving continuous development. To achieve this goal, ecological and natural criteria must be examined in accordance with indicators of ongoing development. The study's conclusions indicate that geological factors (slope, slope direction, distance to fault, and lithology), structural factors (power transfer lines, communication networks), and environmental factors (climate, rainfall) are the most helpful in analysing industrial ecological development that has been organised hierarchically.

According to the model's findings, the land criterion, ANP criteria, and a few other factors—such as soil texture and quality and land use—have the greatest effects on industrial growth, with the Topsis algorithm coming in second. It was discovered that Nir, Namin, and Ardebil rank first to third in terms of industrial ecological development, whereas Khalkhal and Kosar rank ninth and tenth, respectively, and have more unsuitable conditions. The maps created by combining effective layers show just how accurate the study's findings were. It means that the natural resources in particular land cover and surface richness and allocation to producing agricultural and food related produced made the southern part less suitable for industrial development. Then, industrial expansion is restricted both now and in the future in areas where it could lower land productivity and endanger human wellbeing. Since there is a considerable distance between the industrial development areas and metropolitan areas, pollution from industrial and environmental operations will not have a detrimental effect on the ecology of cities or the health of the population.

D. CONCLUSION

Changes in land use and cover, particularly from industrial development, often lead to ecological degradation in developing regions due to limited awareness of ecological services' significance. In Ardebil province, where fertile soil and adequate precipitation contribute significantly to regional and national ecology, balancing industrial expansion with environmental preservation is critical. An assessment in the Ardebil-Tabriz industrial corridor identified eight influential ecological factors—including slope, basin density, and climate metrics—using MDCM and AHP Fuzzy methods in ArcGIS to map suitable and unsuitable areas for development. Areas of high ecological value, especially those with fertile soil and abundant water, were found unsuitable for industry, while regions with challenging conditions were more ideal for industrial expansion. Ensuring that development minimizes ecological impact supports sustainable goals, as industrial progress should empower local communities by preserving essential natural resources, not by causing ecological harm.

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