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A GIS-MCDA-Based Analysis for Spatial Ecotourism Suitability Assessment in Saudi Arabia's Hail Province

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| Keywords | Abstract |
|-------------------------------|---|
| Ecotourism | Ecotourism was developed to combine culture, education, and tourism, but it has now evolved into a fundamental idea for global ecological sustainability. Ecotourism has the potential to help protect natural assets while also fostering beneficial synergies among tourism sector agents, visitors, and local residents. Low-density communities gain from rising interest in low-impact tourist products that assist the local economy. Based on this approach, the current research aims to assess the potential of existing natural and rural characteristics in the Hail area, situated in the center of Saudi Arabia, to underpin the development of sustainable tourist goods. In the research, natural ecotourism locations in Saudi Arabia's Hail province were evaluated for their spatial suitability. The methodology of the research included a number of steps and procedures, beginning with the creation of a geographic database on the area's natural resources for tourists. After extracting data from various sources and determining the criteria for the spatial suitability of natural tourist sites, which are represented in a set of natural and human criteria that directly affect the success of any tourist site based on the standards of the Saudi Commission for Tourism and National Heritage, the Ministry of Municipal and Rural Affairs and Housing, and standards derived from literary references, a total of 27 highly suitable sites were identified. Based on GIS (Geographic Information System)-based multicriteria decision analysis (GIS-MCDA) methodology, nine criteria were identified and represented in the form of layers, which were merged with each other through the overlay mechanism, after assigning a weight to each criterion based on its importance, to create a map identifying relevant natural environment tourist locations in the research region. The locate region for ecotourism, which covers 24501.225 km ² , produced by the suitability modeler tool within ArcGIS Pro software and defined by the presence of ecotourism sites that fulfill the needs and standards of environmental tourism sites according to four degrees of suitability (high, moderate, marginal, and low). From a total of 64 sites, 27 exhibit a high suitability for ecotourism, accounting for 42.18% of all sites. While the number of sites with a moderate suitability rating reached 37 sites, representing 57.81% of all sites. |
| Suitability Map | |
| Geographic Information System | |
| GIS-MCDA | |
| Hail | |
| Saudi Arabia | |

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1. INTRODUCTION

The significance of tourism stems from the concept that it is one of the activities that contributes to the achievement of scientific, social, cultural, and economic objectives, as it allows for the identification of various places and their specific geographical laboratories. Tourism boosts individual productivity, increases the interconnection of social relationships, and raises cultural and social awareness at the communal level. Individually, tourism helps to reduce job demands and create a lifestyle change by broadening the individual's perspectives and awareness and learning about different civilizations, cultures, and customs. Therefore, it has become an area for many scientific research in several fields of the social sciences. Geography evolved as one of the most significant sciences for studying this phenomenon from its numerous perspectives in its spatial

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context, as well as its interactions and influences with other geographical phenomena. Traveling responsibly to natural regions that preserves the environment, supports community well-being, and includes interpretation and education is known as ecotourism (Primavera et al., 2019). It may use the many natural and cultural ecosystem services that Hail offer to enhance local livelihoods. Tourism geography or ecotourism is concerned with the study of tourism and its associated activities with a specific focus on the characteristics of location, linkages, and reciprocal impacts of these activities. ecotourism emphasizes the spatial extension and spatial relationships of phenomena caused by travel and leisure, as well as the geographical components of the three pillars of tourism activity: reception (tourist supply environment), sending areas (demand environment), and tourist transportation.

Ecotourism combines conservation, community, and sustainable travel. This implies that people who develop, engage in, and sell ecotourism activities should follow the ecotourism principles outlined below:

- Reduce the physical, social, behavioral, and psychological consequences.
- Increase cultural and environmental knowledge and respect.
- Ensure that both guests and hosts have a great experience.
- Make direct financial rewards available for conservation.
- Create financial advantages for both the local community and private enterprise.
- Visitors should have memorable interpretive experiences that help them become more sensitive to the political, environmental, and social climates of the host nations.
- Create, build, and manage low-impact facilities.
- Recognize Indigenous Peoples' rights and spiritual beliefs in your community and collaborate with them to generate empowerment.

The Hail area is rich in natural tourist components such as mountain tourism, valleys, sand, natural flora, and climatic appropriateness, suggesting that this unique system is available throughout most months of the year. The findings also suggested that the relatively natural features that maintain these unique locations for future generations and the population of the area, secondarily, need care and attention by tourist planners first.

The natural plant is one of the cornerstones of the tourism industry and one of the natural components that play an important role in tourist attractions due to the Hail area's inherent aesthetic value, cultural significance, and use as a location for numerous significant tourism and recreation activities in such environments that are distinct in nature, emptiness, and continuous extension. It is also one of the most unique tourist ranges in the field of tourism, based on natural plant patterns. Perennial and seasonal vegetation make up the two primary types of vegetation in the Hail area.

The Hail province has various historical monuments, including the remains of Barzan Palace, which was built in 1808 under the reign of Muhammad bin Abdul Mohsen Al Ali and consists of two towers. The Seduction Gate is a park with numerous structures used for weddings and parties. The Al-Qishla Palace was built of mud during the reign of Abdul Aziz bin Musaed. The Aesthetic water bladder model is located near Tabarjal's Al-Sumail roundabout on the international route. The Machar Park, with a total area of 20,000 square meters, is one of the governorate's best-known parks. Shuaib Jaw in the Aja Mountains, Al-Riya Resort at the beginning of the Aqdah Road, an artistic model of incense burners and pampering, the Hatim Al-Ta'i burner in Jabal Al-Samra, Al-Magwa Tourist and Recreational Park, and Aeref Castle in the midst of Hail are the other sights. Despite the province's potential natural resources, a lack of tourism planning and suitability analysis prevents potential tourism investment from being realized. The primary goal of this study is to evaluate land suitability in the Hail region for ecotourism, using the GIS (Geographic Information System)-based multi-criteria decision analysis (GIS-MCDA) method within the GIS platform. GIS-MCDA methodology was used in suitability assessment (Modica et al., 2014; Bakirman & Gumusay, 2020; Doljak et al., 2021; Mentzafou et al., 2021). Based on geographical evaluation and the integration of many spatial layers, the study's research attempts to highlight locations best suited for ecotourism and develop maps of potential sites across the region.

2. STUDY AREA AND MATERIALS

2.1. Study Area

For the purposes of this study, the province of Hail was considered the base unit, and their suitability for the practice of ecotourism activities was determined by integrating a set of criteria and support for the development of tourist activities based on ecotourism principles, using the ArcGIS Pro software.

Hail province is a region in the Kingdom of Saudi Arabia. It is the eighth-largest, lying between 25° 30' and 29° N latitude and 39° and 44° 30' E longitude, encompassing a total surface area of 117,0151 km² and a population of 731,000 people in 2019. The municipality of Hail is made up of five municipalities: Hail, Baqa, Alghazalah,

Asshinan, and Hail (Figure 1) The Nefud Al-Kebir and the Aja Mountains are close to the Hail city (Great Sand Dune Desert). Hail has long been protected from outside invasion by these insurmountable mountains and the equally famed desert. Hail is an agricultural oasis that produces grain, dates, and fruit, with the irrigated gardens of the Hail Province accounting for a substantial percentage of the Kingdom's wheat output. Hail has a diverse geography with distinctive characteristics such as caverns, mountains, plains, and volcanoes, with enormous potential for adventure and sports activities to complement existing events such as the Hail Rally and Hail Season (Figure 1).

The study of the tourist area's physical location and the degree to which it is connected to the surrounding area and other major cities through transportation and communication lines have a clear impact on the region's tourism potential; for example, if the area is easily accessible from and to other locations, it offers constant communication and frequency. The higher the demand for a tourism region, the more conveniently and affordably it may be accessible to travelers and leisure seekers.

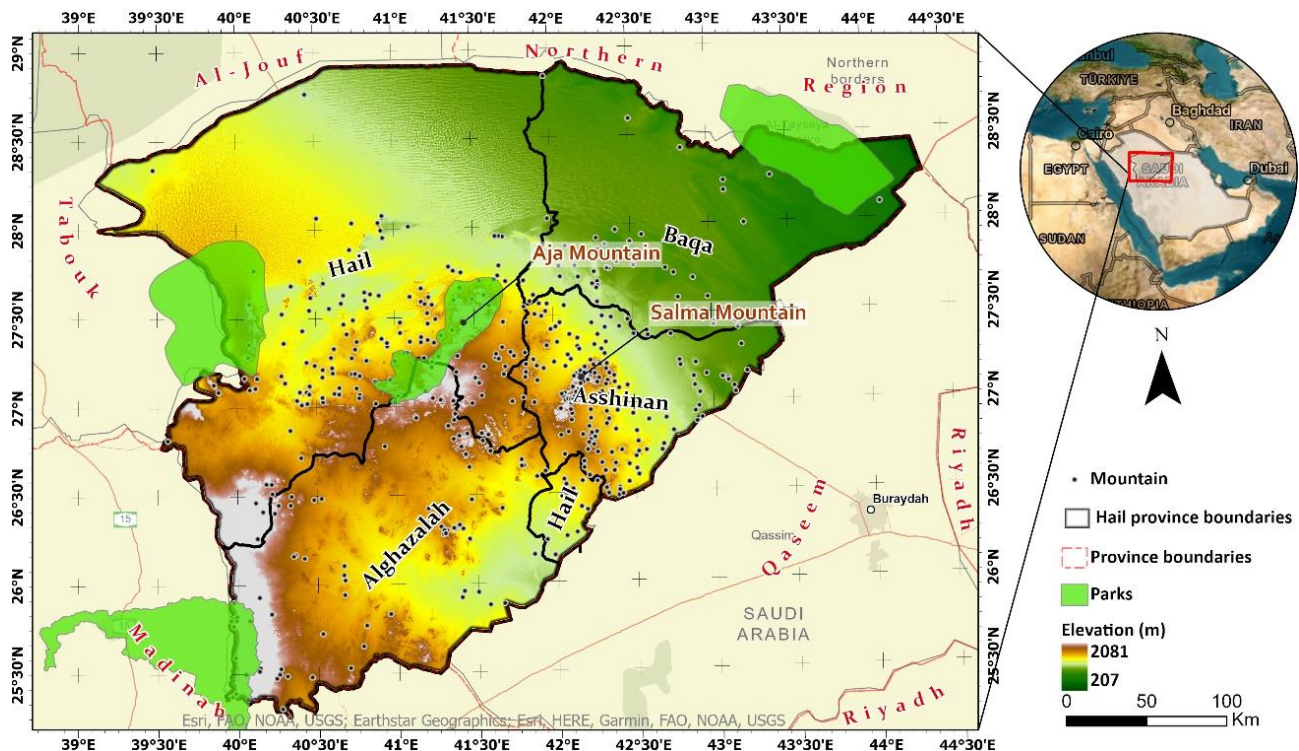


Figure 1. Location of the study area

2.2. Data Sources and Analysis

The collected spatial datasets include 9 criteria comprising environmental, topographical, ecological, and natural areas with various measurement scales and are therefore normalized for comparison. Various geographic and attribute datasets were developed and aggregated from the sources listed below (Table 1).

Several topographical (elevation, and slope), ecological (flora and fauna habitats, and protected zones), and land use (road network, towns, and utilities) resources were used to construct several criteria in order to perform a suitability site study for ecotourism. Sentinel-2 satellite data and the Normalized Difference Vegetation Index (NDVI) were used to study the geographical differences in vegetation cover in the Hail province in 2022. Google Earth Engine (GEE) was employed for this purpose. A multi-petabyte collection of geospatial information and satellite imagery is combined with planetary-scale analytical tools in Google Earth Engine. The Earth Engine is used by scientists, researchers, and developers to identify changes, chart trends, and measure variations on the surface of the planet. While still free for use in education and research, Earth Engine is now accessible for commercial usage. The produced map was transferred into ArcGIS Pro 2.8.4 after preparing the code in GEE and producing the NDVI in 2022.

Table 1. Data sources

| Data Layers | Sources |
|---|---|
| DEM (Digital Elevation Model) | NASA SRTM 30-meter data |
| NDVI (Normalized Difference Vegetation Index) | Sentinel-2 time-series data |
| Hail Municipality Data | https://webgis.amanathail.gov.sa/HailGeoExplorer/ |
| Road network | The OpenStreetMap Foundation, 2022 |
| Village, Fuel Stations, Service Sites, Urban Areas, Industrial Areas and Historic Sites | https://webgis.amanathail.gov.sa/HailGeoExplorer/ |

To perform an ecotourism suitability site study, datasets were utilized to establish nine criteria with varying scales of measurement that were then standardized for comparison.

3. METHODS

The criterion generation and geographical analysis, standardization, AHP, and suitability evaluation stages make up the study's methodology. Based on a literature analysis, field investigation, and local knowledge, every component and criterion were chosen. A suitability model was used to identify high-priority locations for monitoring ecotourism appropriateness in Hail province. In this study, the GIS-MCDA approach was applied using ESRI's ArcGIS Pro 2.8.4 software. GIS-MCDA is a prominent suitability analysis technique (Malczewski, 2006) that is often used to assist environmental decision-making (Eastman, 1999; Watson & Hudson, 2015; Shorabeh et al., 2022). The typical GIS-MCDA multi-attribute decision analysis (MADA) approach was utilized in this study, which contains a fixed, limited number of options and maintains spatial homogeneity of preferences for different levels of criterion values (Kiker et al., 2005; Wang et al., 2009; Malczewski & Rinner, 2015; Domazetović et al., 2019). The GAMA approach is created as an easy-to-use, three-step procedure that minimizes and streamlines needed processing to make the entire GIS-MCDA susceptibility modeling process simpler and more practical. The developed GAMA approach enables the automation of processes 3, 4, and 5, which are detailed below (Figure 2).

A suitability model was used to find the optimum position to put goods or regions to conserve, such as determining the best ecotourism site. Figure 2 depicts the various steps involved in land suitability assessment, which include data collection, pre-processing attribute and spatial data (including slope, vegetation, roads, fuel stations, historic sites, villages, urban areas, industrial sites, and service sites), and application of the suitability assessment functionality.

GIS-MCDA suitability mapping includes the following steps: (1) defining the objective; (2) determining the criteria; (3) harmonizing the criteria (value scaling); (4) criterion weighting; (5) criteria aggregation; and (6) assessing the accuracy of the suitability model (Malczewski, 1999; Greene et al., 2011; Atici et al., 2015). The decision-maker's judgment, the study's scope, and the availability of data all have a role in the first two stages (steps 1 and 2), but the availability of reference data is a major factor in step 6 (Stubelj Ars, 2014; Domazetović et al., 2019; Islam et al., 2022).

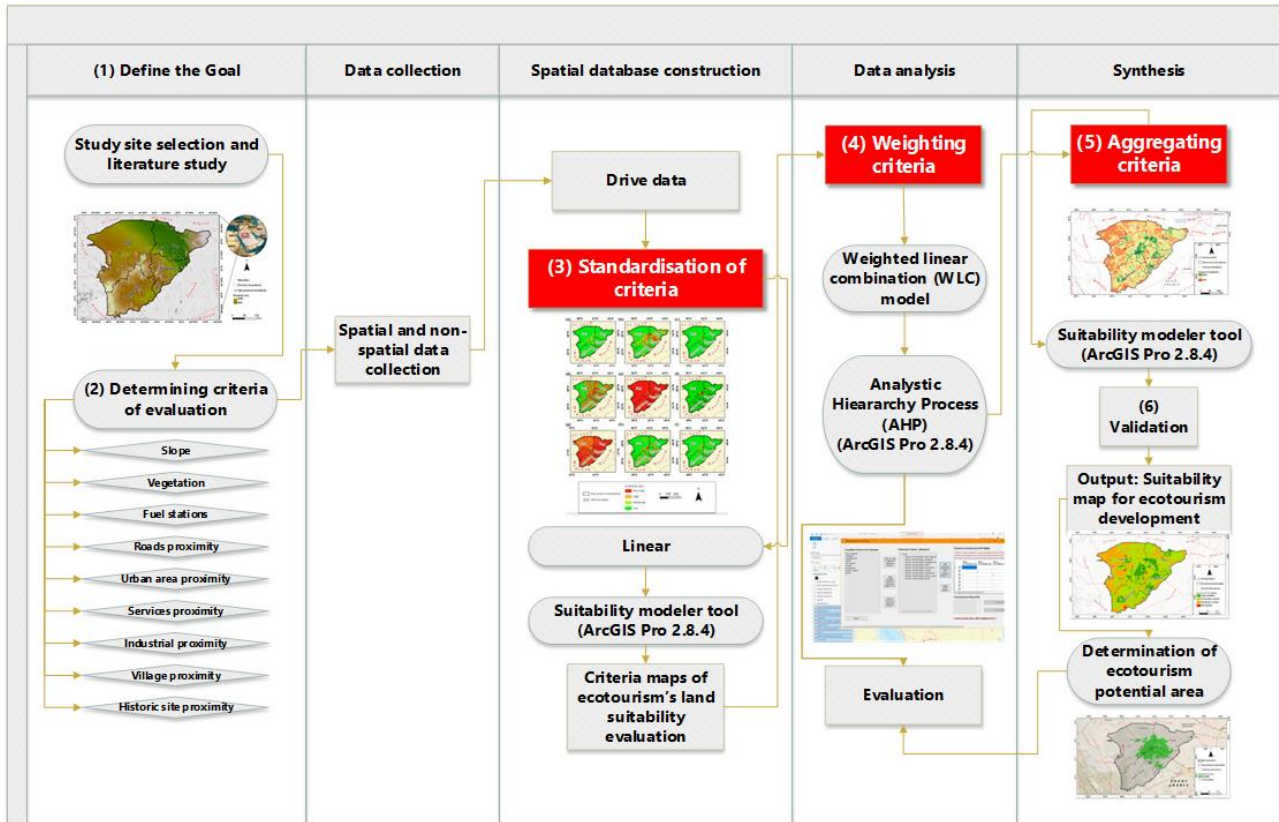


Figure 2. Conceptual framework of the suitability model employed in this research. Red rectangle: GAMA technique automates three phases (3-5) of the GIS-MCDA cycle

The score range process (Malczewski, 1999; Greene et al., 2011; Atici et al., 2015) is the most often used GIS-based method for standardizing assessment criteria (step 3) (Figure 2). The correctness of standardization is determined by the expert's judgment, experience, and knowledge (Stubelj Ars, 2014; Domazetović et al., 2019). In this particular attempt, criterion standardization was accomplished on the premise that the value function had a linear shape (equation 1):

$$xi = (R_i - R_{min}) / (R_{max} - R_{min}) * SR \quad (1)$$

where R_i denotes the raw score i , R_{min} the lowest score of each component, R_{max} the highest score of each factor, and SR the standardized range, which is set to 100 in this case (Voogd, 1983; Rinner, 2007; Drobne & Lisec, 2009; Bottero et al., 2018). When it comes to qualitative factors, the ordering of scores may be subjective. Criterion weighting (step 4) is the process of assigning a value to an assessment criterion in order to demonstrate its importance in contrast to the other criteria being considered (Malczewski, 1999; Greene et al., 2011; Atici et al., 2015) (Figure 2). In this work, the weighted linear combination (WLC) model was adopted, which is the most basic and extensively used GIS-MCDA model (Malczewski, 2011; Carter & Rinner, 2014; Zoghi et al., 2017).

The weighted linear combination (WLC) technique is a decision procedure used in geographic information systems (GIS) to build composite maps. It is a decision model that is often used in geographic information systems. However, the tactic is commonly used without a clear understanding of the assumptions behind this approach.

Weighted linear combination is a multi-criteria decision-making method that helps decision-makers to choose the best location from a range of possibilities. The local variant of the range-sensitivity concept considers the range of attribute values within a user-defined neighborhood (Carter & Rinner, 2014; Zoghi et al., 2017).

The decision rule in WLC assesses each option using the following value function, (equation 2):

$$S = \sum_j w_j v_j(x_i) = \sum_j w_j r_{ij} \tag{2}$$

where w_j is the normalized weight ($w_j = 1$), $v_j(x_i)$ is the value function for the j attribute, $x_i = x_{i1}, x_{i2}, \dots, x_{in}$, and r_{ij} is the attribute translated into the comparable scale (Drobne & Lisec, 2009; Zoghi et al., 2017). Criterion weighting was based on the pairwise comparisons approach in the context of the Analytic Hierarchy Process (AHP) (Saaty, 1977; 2001), which is an adaptation of WLC that depends on expert judgment to establish priority scales.

Saaty and Vargas (2012) recommended that the priority scales be produced by synthesizing their judgments using the geometric mean of the final outputs. AHP uses a basic scale of numbers ranging from 1 to 9 to express the intensities of judgments (Tables 2 and 3) (Saaty, 2002; 2006; Tjader et al., 2014).

Table 2. Values of preferences for paired Comparison (Gourabi & Rad, 2013)

| Preferences (oral judgments) | Value |
|---|---------|
| Extremely Preferred | 9 |
| Very Strongly Preferred | 7 |
| Strongly Preferred | 5 |
| Moderately Preferred | 3 |
| Equally Preferred | 1 |
| Preferences between the above intervals | 2,4,6,8 |

Table 3. Random Consistency Index (RI) (Saaty & Vargas, 2012)

| n | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|----|------|------|------|------|------|------|------|------|------|
| RI | 0.00 | 0.00 | 0.52 | 0.89 | 1.11 | 1.25 | 1.35 | 1.40 | 1.45 |

All chosen criteria are compared to one another in a pairwise comparison matrix. Following the construction of the pairwise comparison matrix, $w = (w_1, w_2, \dots, w_n)$ may be calculated as a vector of criteria weights. The weights are calculated based on the unique answer to:

$$C_w = \lambda_{max} w \tag{3}$$

where λ_{max} is the biggest eigenvalue of C. The consistency ratio CR of a pairwise comparison matrix describes the likelihood that the matrix ratings (ratings of each criterion against each other in terms of relative significance) were generated at random is described by the CR of a pairwise comparison matrix (Saaty, 1977). Here is how CR is defined:

$$CR = \lambda_{max} - n / RI(n - 1) \tag{4}$$

where n is the number of criteria examined and RI denotes the random index, which is the consistency index of a randomly generated pairwise comparison matrix and is dependent on the number n of items being compared (Table 3). CR ratings less than 0.10, on the other hand, imply that the pairwise comparisons are reasonably consistent and that the adjustment is minor in relation to the actual values of the eigenvector entries (Saaty & Vargas, 2012). Pairwise judgments with CR ratings greater than 0.10 are almost randomly generated and unreliable (Fang et al., 2017; Xu & Zhang, 2017; Mansour et al., 2020; Tian & Yan, 2021). The initial weights should be revised if the value is larger than 0.10 since this indicates an inconsistent evaluation (Mansour et al., 2020).

The Suitability Modeler tool was used in ArcGIS Pro 2.8.4 to execute the criteria aggregation (step 5) and the suitability modeling technique. Finally, the correctness of the appropriateness model was validated (step 6) (Figure 2).

4. RESULTS AND DISCUSSION

The suitability model is a decision-making process with several criteria. It is applied in GIS, such as ArcGIS Pro, and provides for in-depth analytical answers to challenges in a variety of fields. Suitability modeling, in particular, is recommended for the location of ecotourism sites and selecting the best regions for them. The selection of the best ecotourism locations in this model is based on nine data layers (as presented in Table 4). The suitability model was created using ArcGIS Pro 2.8.4's Suitability Modeler Panel. All the data was converted to a 1–10 suitability scale. For weighing criteria, the multiplier method was utilized. The AHP Method (ArcGIS Pro Add-In tool) was used to allocate weights to the criteria (Mendadhala, 2018).

4.1. Criteria Maps Generation and Standardization

All of the attractions for performing nature-based activities, as well as the existence of infrastructure and equipment that allow for better use of the region, were taken into consideration when determining whether the territory in question was acceptable for the practice of ecotourism activities. The selection of the criteria was the result of a thorough review of the literature, and discussions with specialists who were aware of the objectives of the study (Table 4). The criteria were developed based on experience, professional views, and data from numerous sources. Many significant criteria are considered in ecotourism planning and site selection, such as attraction assets, services, and accessibility, which might be biological, cultural, physical, infrastructural, ecological, and environmental. Discussions with specialists in relevant areas of study, a search of authorized literature, and an examination of historical facts were used to acquire knowledge.

Table 4. Analyzing land suitability for ecotourism using certain criteria

| Criteria | Unit | Suitability Rating | | | | References |
|-------------------------------------|--------|--------------------|------------|-------------|---------|--|
| | | High | Moderate | Marginal | Not | |
| Slope Criteria | Degree | 0-5 | 5-15 | 15-20 | >20 | (Bunruamkaew & Murayam, 2011) (Tjong et al., 2021) (Zabihi et al., 2020) |
| Vegetation Proximity Criteria | Meter | 0-250 | 250-750 | 750-2000 | >2000 | (Bishop & Hulse, 1994) (Burkart et al., 2016) (Gourabi & Rad, 2013) |
| Industrial Proximity Criteria | Meter | >6000 | 6000-4000 | 4000-2000 | 2000-0 | (Piran et al., 2013) (Al-Balawi & Ouerghi, 2022). |
| Road Proximity Criteria | Meter | 0-1000 | 1000-2000 | 2000-3000 | >3000 | (Chakrabarty, 2011) (Suryabagavan et al., 2015) (Sahani, 2020) |
| Urban Areas Proximity Criteria | Meter | 0-3000 | 3000-6000 | 6000-9000 | >9000 | (Weaver, 2005) (Mahdavi & Niknejad, 2014) (Çetinkaya et al., 2018) |
| Villages Proximity Criteria | Meter | 0-1000 | 1000-3000 | 3000-5000 | >5000 | (Sahani, 2019) (Sahani, 2020) (Al-Balawi & Ouerghi, 2022) |
| Historical Sites Proximity Criteria | Meter | 0-5000 | 5000-10000 | 10000-15000 | >150000 | (El-Harami, 2014) (Deribew et al., 2022) |
| Service Sites Proximity Criteria | Meter | 0-2000 | 2000-4000 | 4000-6000 | >6000 | (Suryabagavan et al., 2015) (Nahuelhual et al., 2013) |
| Fuel Station Proximity Criteria | Meter | 0-2000 | 2000-4000 | 4000-6000 | >6000 | (Gigović et al., 2016) (Ahmad et al., 2022) |

This stage included the creation of a spatial database, which was then rasterized and converted into raster. This spatial database contained all vector and raster layers (maps), as well as data models like points, lines, and polygons. Euclidean distances and buffers were calculated using a variety of recommendations to identify characteristics and indicators of land suitable for ecotourism. All spatial layers were created using the ArcGIS

Pro program, and coordinate consistency was maintained. The elevation criterion was calculated using a DEM with a resolution of 30 m, and the slope criterion was classified using a degree measurement unit. A proximity analysis using the Euclidean distance classification tool was performed to divide regions into eligible areas for ecotourism based on the criteria of service locations, villages, historic sites, fuel stations, and metropolitan areas (Figure 3).

Similarly, the distance to the closest road for each place will then be shown using a distance raster that was created from the roads datasets. Using the Euclidean Distance tool, you will be able to extract the distance raster from the roads layer. In order to identify the best locations that are distant from industrial sites, proximity analysis utilizing Euclidean distance classification was also used to obtain the industrial factor (Figure 3).

The nine criteria, represented as nine grid layers (raster), are classified into four suitability classes: high suitability, moderate suitability, marginal suitability, and not suitable. The generated maps have all been standardized on a uniform scale from 1 to 4, in order to enable comparison. Values are arranged in ascending order according to their filling, with very proportional values receiving the highest value in weight (4) and disproportionate ones receiving the lowest weight (1) (Figure 3). Because each criteria have different measurement attributes, it is impossible to compare them with their raw scores. We noticed that the significance of the values in the definition of ranges of impact varied depending on the relevance of the effect of distance and closeness to each criterion. When evaluating closeness to urban agglomerations, for example, the agglomeration's proximity regions were represented by a larger value than the distant areas, whose ranges were represented by weak values, while the proximity range was represented. The industrial region criteria had low values, while the distant ranges had large values, and so on, depending on the nature of the criterion in terms of attraction or expulsion. GIS software such as ArcGIS provides various options for reclassification, depending on the Reclassify tool, with the goal of establishing standards and assigning a value that signifies a degree of completeness on a continuous scale ranging from one to four.

4.2. Criteria Weight Assignment Using AHP

The simple multi-attribute rating technique (SMART), the point allocation method, the direct rating method, the analytic hierarchy process (AHP), the best worst method (BWM), the full consistency method (FUCOM), and others are among the weight coefficient calculation (CWC) methods available. Depending on the research aims and purpose, all accessible CWC techniques offer benefits and limitations (Teknomo, 2006; Salabun et al., 2016; Pamučar et al., 2018). The analytical hierarchical process (AHP), which has been efficiently applied within the framework of the GAMA approach for gully erosion susceptibility modeling (Pamučar et al., 2018; Matić et al., 2019; Žižović & Pamučar, 2019), is one of the most often used CWC methodologies. In a paired approach, the AHP method offers a structural framework for quantifying the comparison of decision-making components and criteria (Laskar, 2003). Experts are asked to rate the value of a criteria map for a paired matrix using Saaty's scale (Saaty, 1977). The approach investigates the relative relevance of all factors by giving weight to each of them in a hierarchical sequence, with the suitability weight for each class of variables utilized at the top of the hierarchy. Expert suggestions often determine the relevance of each factor in the AHP study (Baniya, 2008). AHP also gives quantitative tools to evaluate judgment inconsistency to assure the legitimacy of the relative significance utilized. The consistency ratio index (CR), as indicated in Equation (4), may be determined using the characteristics of reciprocal matrices. According to Saaty (1977), the degree of consistency is sufficient if the CR is less than 0.10. If it is more than 0.10, the assessment process is incoherent, and the AHP technique may fail to provide appropriate results.

AHP was used to establish a hierarchy of selected criteria in order to find the best places for ecotourism activities. Each criterion layer was created using ArcGIS Pro Spatial Analyst, and the produced maps were then converted into raster models using weight values obtained from AHP. Table 5 shows the estimated and assigned weights and scores for the criteria for ecotourism appropriateness development in Hail province. The relevance, usefulness, and appropriateness rates for creating ecotourism are the rationales for assessing each sub-criterion. As a result of their importance and appropriateness for ecotourism, the priority scores and rankings for the criteria were determined. For example, in terms of closeness to industrial sites, low scores were assigned to locations that are near industrial sites, while higher priority values were assigned to locations that are far away from industrial sites (Figure 4).

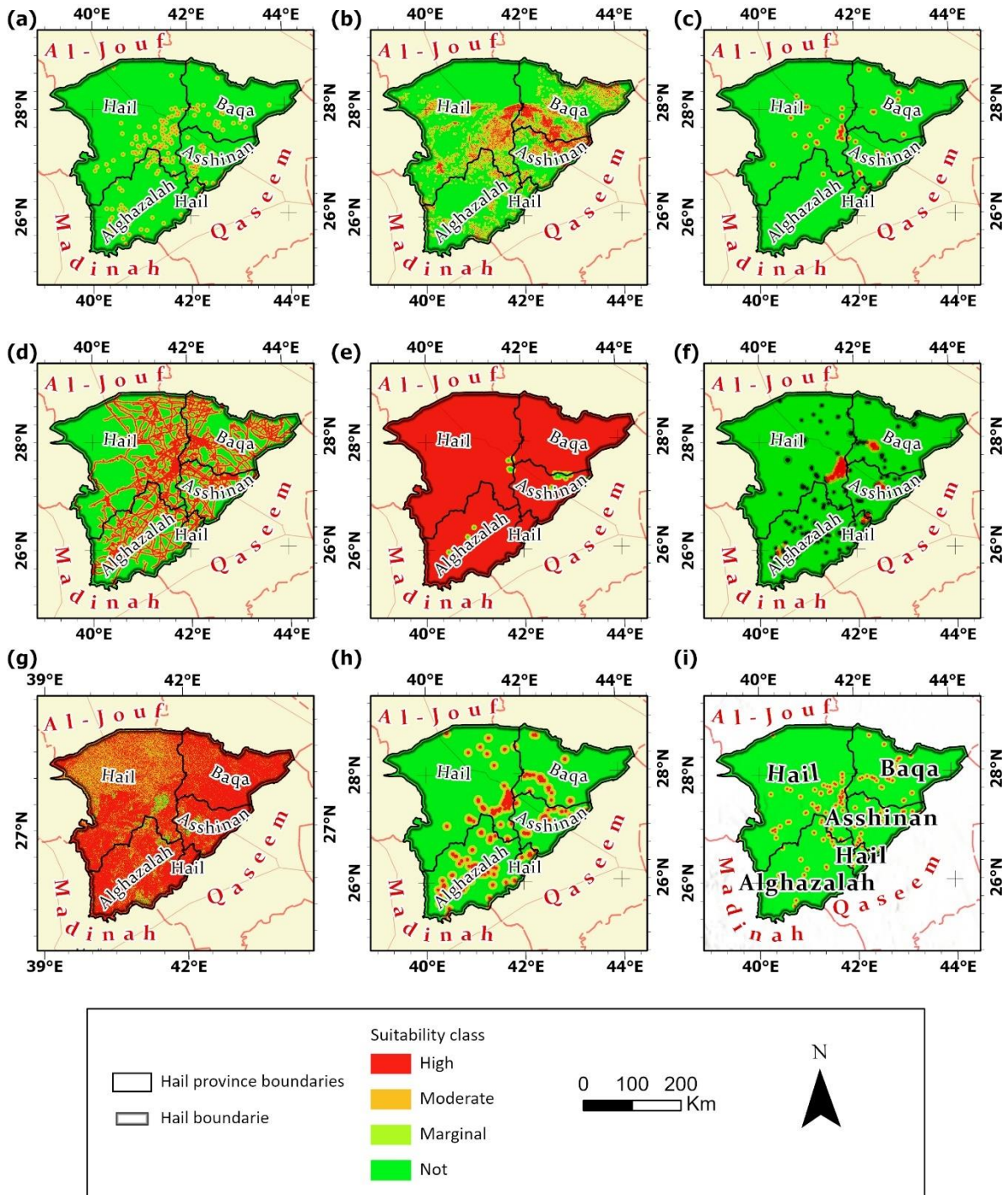


Figure 3. Nine spatial criteria for ecotourism monitoring in Hail province. **a)** village, **b)** vegetation, **c)** service stations, **d)** Road's proximity, **e)** industrial, **f)** historic, **g)** slope, **h)** urban areas, **i)** fuel stations

To find potential areas for ecotourism, all factors included in the study had to be standardized, using the AHP approach and the ArcGIS Pro suitability modeler. AHP makes it possible to compare qualitative and quantitative criteria consistently by integrating different input layer scales. Using the same measurement units across all spatial levels is ensured through standardization (Pereira & Duckstein, 1993; Bojórquez-Tapia et al., 2001; Chen et al., 2010). Therefore, the ArcGIS Pro suitability modeler tool was used to standardize and assign values to each criterion, after which all classed raster layers were converted to raster binary format. The most influential criteria are closeness to vegetation zones and distance from industrial regions, followed by proximity to the road network, historic places, and service locations.

The attribute factors are stored in the GIS database as map layers that include attribute values for each pixel in raster data (Kiker et al., 2005; Khalili & Duecker, 2013; Goyal et al., 2020). In the acquired data, there were nine key criteria in the form of nine GIS-based layers included for ecotourism (Figure 3). For criteria that may be expressed by continuous values, including slope, or distance from roads, the Continuous Functions technique works well. The values are continually transformed using this approach to the appropriateness scale by using a linear function. With each rise in the criteria value, the resultant appropriateness value continually changes since this technique applies a continuous function to the criteria values. With each step taken away from a road, for instance, the suitability can rapidly decline.

Table 5. The Analytic Hierarchy Process (AHP) approach was used to create a pairwise comparison matrix with nine criteria

| Item Description | Slope | Village Proximity | Vegetation Proximity | Urban Areas Proximity | Service Sites Proximity | Road Proximity | Industrial Proximity | Historical Sites Proximity | Fuel Station Proximity | Weight |
|-----------------------------|-------|-------------------|----------------------|-----------------------|-------------------------|----------------|----------------------|----------------------------|------------------------|------------|
| Slope | 1 | 2 | 0.5 | 0.5 | 0.33 | 0.5 | 3 | 0.33 | 3 | 10% |
| Village Proximity | 0.5 | 1 | 0.5 | 0.33 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 5% |
| Vegetation Proximity | 2 | 2 | 1 | 2 | 2 | 3 | 0.5 | 0.5 | 2 | 15% |
| Urban Areas Proximity | 2 | 3 | 0.5 | 1 | 2 | 0.5 | 0.5 | 0.33 | 2 | 10% |
| Service Sites Proximity | 3 | 2 | 0.5 | 0.5 | 1 | 2 | 2 | 0.33 | 2 | 12% |
| Road Proximity | 2 | 2 | 0.33 | 2 | 0.5 | 1 | 2 | 0.5 | 2 | 11% |
| Industrial Proximity | 0.33 | 2 | 2 | 2 | 0.5 | 0.5 | 1 | 0.5 | 2 | 11% |
| Historical Sites Proximity | 3 | 2 | 2 | 3 | 3 | 2 | 2 | 1 | 2 | 20% |
| Fuel Station Proximity | 0.33 | 2 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 1 | 6% |
| Consistency Ratio CR | | | | | | | | | | 0.1 |

4.3. Suitability Map Generation

During this procedure, experts' opinions were sought to evaluate the relative importance of the factors and criteria at issue. The CR for ecotourism was assessed to be 0.1, which is appropriate for use in the suitability analysis. Table 5 ranks the nine (9) criteria used to determine the increasing requirement for ecotourism suitability monitoring in Hail province, which led to the creation of the maps shown in (Figure 4). As a result of data pre-processing, 9 raster layers are determined using GIS techniques (Figure 3). Figure 4 illustrates the suitability map that was developed by weighing and combining all of the aforementioned factors. The maximum model value was 900, while the lowest was 1. Higher values indicate appropriate and lower values indicate fewer ideal locations for ecotourism sites in the suitability map, which provides the summarized values of each raster datasets.

A spatial suitability map (Figure 4) was produced based on the results of the integration of raster maps of the nine criteria, demonstrating that Hail province is characterized by the presence of tourist sites that meet the conditions of the criteria of natural ecological tourist sites in varying degrees of suitability.

The suitability map was created using all procedure steps, and it shows four suitability classes: very suitable (0.75-1.00), moderately suitable (0.50-0.75), marginally suitable (0.25-0.50), and not suitable (0.00-0.25).

According to the ecotourism suitability map (Figure 4), the highly suitable region accounts for about 12.21% (14293.71871 km²) of the total area and is largely located in the Hail province's center and eastern regions. Furthermore, two distinct zones are situated in the midwest and northeast, near the northern region. The moderately appropriate area accounts for about 58.50% of the overall region's size and is located in the province's southern and northeastern regions. Similarly, a larger proportion (28.21%) of the region is classified as marginally suitable. These locations are predominantly located in the island's north and center (Table 6). A small portion of the territory (1.07%) was labeled as Not suitable, with the majority of it located in and around Alghazalah's built-up regions and settlements in the south (Figure 4). Furthermore, small areas of the province's center and southern regions are unsuited for ecotourism and should be excluded from any successful tourist strategy (Figure 4).

Table 6. Land suitable for ecotourism coverage

| Category of suitability | Range of scores | Area coverage | |
|-------------------------|-----------------|--------------------|------------|
| | | (Km ²) | % |
| Highly suitable | 0.75–1.00 | 14293.718 | 12.21 |
| Moderately suitable | 0.50–0.75 | 68459.627 | 58.50 |
| Marginally suitable | 0.25–0.50 | 33009.764 | 28.21 |
| Not suitable | 0.00–0.25 | 1252.037 | 1.07 |
| Total area | | 117015.100 | 100 |

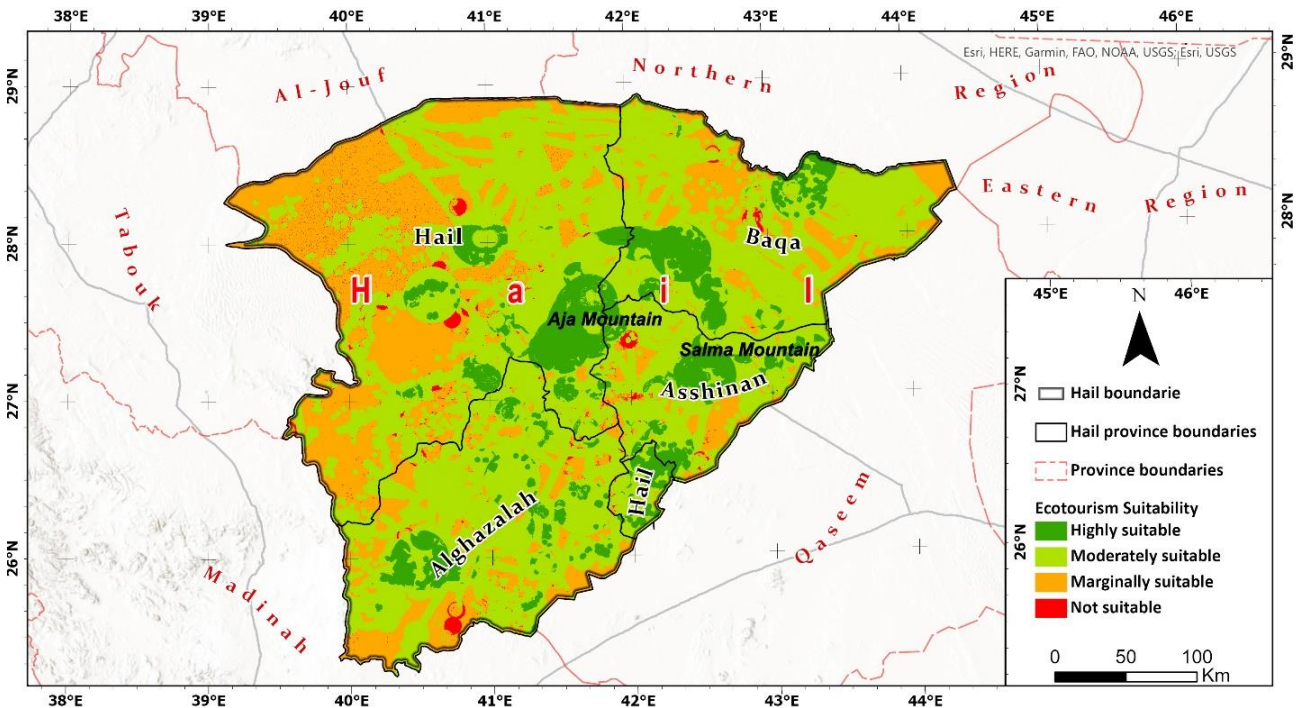


Figure 4. Ecotourism suitability map for Hail province

4.4. Locate the Areas for the Siting or to Preserve

The suitability map that results is the input data within the Suitability Modeler. The spatial requirements are specified by the Locate component of the suitability modeling technique. Within the suitability modeler tool, we defined the geographic criteria for the suitability model and selected the optimal area for the ecotourism region, which covers 24,5012 km² (20.93% of the total research area) (Figure 5).

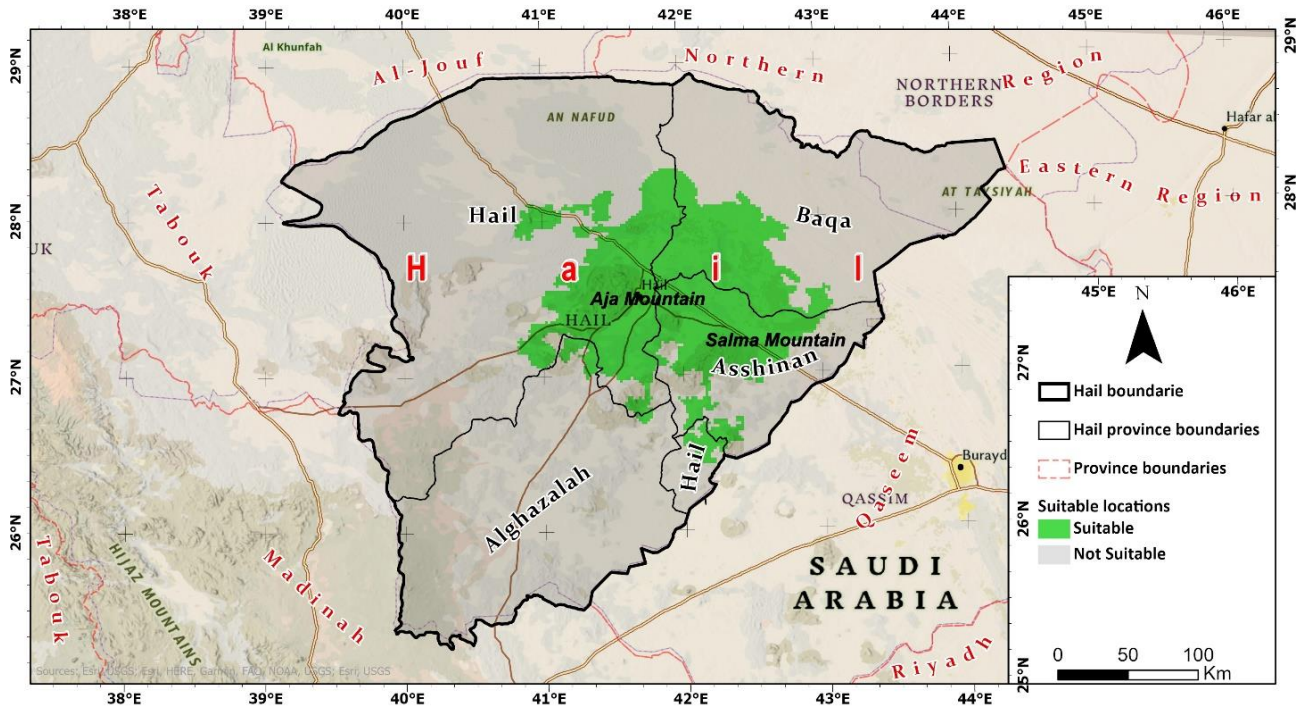


Figure 5. Ecotourism locations map for Hail province

4.5. Validation of the Methodological Approach

The overall area of the mountains in the Hail region is around 6818 square kilometers, accounting for 77.5% of the entire area of the region. These mountains are divided into two major mountain ranges, the Aja Mountains and the Salma Mountains, which extend parallel from the southwest to the northeast. The highest peak of Aja Mountain reaches more than 1400 meters above sea level and the Aja Mountain range extends over an area of 100 kilometers. The Salma mountains extend more than 60 square kilometers from the northeastern side of Hail city to the southwestern part. The highest peak stands at 1100 meters above sea level. ArcGIS Pro software was used as part of the test approach to check the validity of the model computations and output values. First, an Esri Mountain point feature class of 464 points, including lowlands, plateaus, and mountains, is applied to an input parameter. The Extract Values to Points tools (Spatial Analyst) were then used to save parameter values associated with each point position in the attribute table of an output feature class. As a result, the suitability pixel value for each mountain was derived by intersecting the mountain feature class with the ecotourism suitability map. Following this step, 64 mountains in the Locate area were chosen (Figure 6). The Hail region's mountains are distinguished by their pristine nature and lack of settlement, which exists in the form of small agricultural villages in the valleys and mountains such as Jebel Aja and Salma, and one of the most famous of these villages is the village of Oqda in the AJA mountains, as this village is beautiful for the residents of Hail and its surroundings, aided by its proximity to the city and its natural tourist importance. In addition, certain natural tourist activities, such as bird viewing, should be observed (Abdullah, 1996). According to the four levels of appropriateness, the existence of ecotourism sites that meet the requirements and criteria of environmental tourism sites defines the study area (high, moderate, marginal, and not).

Out of a total of 64 sites (including lowlands, plateaus, and mountains), 27 (Jabal Aja, Hazm ar Radum, Hazm ad Dab'ah, Jabal al 'Arfa', Jabal Si'aynin, Jabal al Qufayl, Jabal Dakhana, Ja'ad al Hamra', Jabal al Khubay, Jabal 'Itifah, Jibal Shatib, Jibal al 'Uqaylah, Humr al Qaltah, Jabal Ruwayyah, Jibal Minshar, Qarat as Sanduq, Huzum al Jithamiyah, Jabal Busrah, Huzum al Mukhtibi, Qarat ar Riha, Qur al Qish'ummah, Burqan al Ghidayyat, Qarat al Milayda', Jabal Malq, Jabal Salma, Hazm Eldhabaa, and Om Rkiba) show a high level of ecotourism suitability, making up 42.18% of all the sites. 37 locations were assigned a moderate appropriateness grade (Jabal Ghisil, Dulay' al Ashqar, Jabal al Muthalbat, Hadb 'Alya', Hazm Munayfah, Jabal Jidid, Hudaybat al 'Urayfa', Dulay'at ash Shighay, Jabal Sayid, Jabal Suwayqah, Jabal Thi'alabah, Jabal al Kaththanah, Burqan al Ajfar, Jibal as Sahabin, Abraç Abu Rijm, Jabal Sawa, Jabal Dab', Jibal Aja,

Kadis, Jabal ar Ra'ilah, Qarat Munaysifah, Jabal al Hamra', Qarat Munaysifah, Jabal Rukhaymah, Jibal ar Rawd, Jabal al Gharra', Jilan at Tayyim, Jabal 'Unayzah, Jabal al Ushayhib), accounting for 57.81% of all sites (Figure 6).

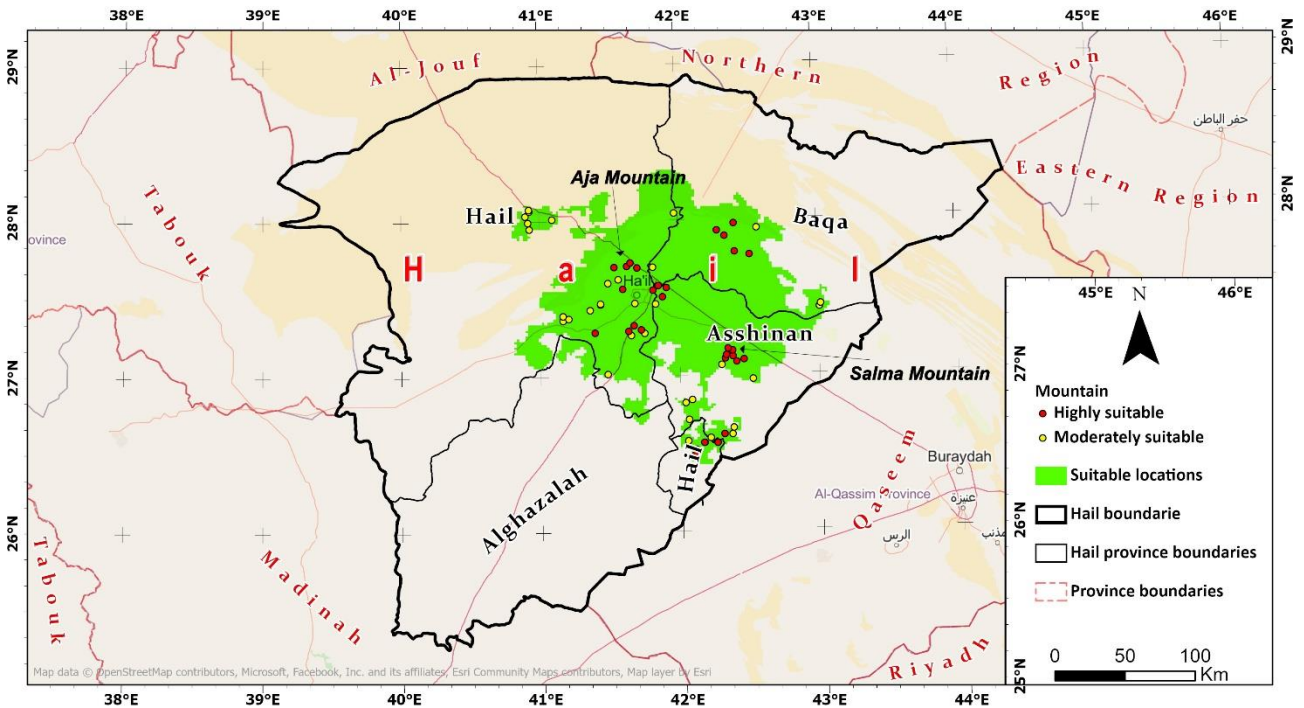


Figure 6. Mountains for ecotourism in Hail province

5. CONCLUSION

Ecotourism is certainly a major source of economic activity and rejuvenation in Hail province, as well as a means of preserving natural heritage assets. Ecotourism potential site selection criteria were developed with the input of nine raster datasets. The final ecotourism suitability map was created using a Geographic Information System's integrated weighted overlay approach. It aims to assess the potential of existing natural and rural characteristics in the Hail area, situated in the center of Saudi Arabia. The new suitability modeling tool in ArcGIS Pro optimizes site planning and suitability processes by allowing users to quickly perform suitability modeling with integrated tools. With the ability to manage, analyze, and display a variety of data related to tourism activity and produce maps that assist decision-making, geographic information systems technology, which provided advanced methods and mechanisms for analyzing spatial information, was used to assess the spatial suitability of natural ecotourism sites in the Hail province. The study's main contribution was the modern applied technical approach adopted. The study also used advanced methods and analysis methods, such as determining the weights of criteria, which is a very important process in the final model's results, and using the method of weighted superposition of all criteria within the framework of Multi-Criteria Analysis to integrate the values previously calibrated and unified by a common scale that allows giving one value to each point, where it processes all the inputs represented in the criteria. The outcome shows index values that enable categorization into four categories: unfit, slightly acceptable, moderately suitable, and highly suitable. These zones represent 24501.225 km² and 20.93% of the total research area, respectively. In order to reach an ideal solution for ecotourism site selection, comprehensive and regular monitoring in the appropriate and most suitable zones should be carried out.

CONFLICT OF INTEREST

The author declares no conflict of interest.

REFERENCES

- Abdullah, N. W. (1996). *Geological and Geomorphological: Saudi Arabia: Forms of the Earth's Surface. Research in the Natural Geography of Saudi Arabia*. King Fahd National Library.
- Ahmad, A. A., Hama, A. R., & Alawn, I. A. (2022). Ecotourist and Picnic Area Assessment Using AHP Analytical Tools in Sulaimani– Tourism Region, Iraq. *Engineering and Technology Journal*, 40(11), 1560-1572.
- Al-Balawi, A. B., & Ouerghi, S. A.-H. (2022). Assessment of spatial suitability of ecotourism sites in Al-Ahsa governorate, Saudi Arabia, by using GIS. *Journal of Humanities and Social Sciences*, 6(1), 64-87. doi:[10.26389/AJSRP.L180921](https://doi.org/10.26389/AJSRP.L180921)
- Atici, K. B., Simsek, A. B., Ulucan, A., & Tosun, M. U. (2015). A GIS-based Multiple Criteria Decision Analysis approach for wind power plant site selection. *Utilities Policy*, 37, 86–96. doi:[10.1016/j.jup.2015.06.001](https://doi.org/10.1016/j.jup.2015.06.001)
- Bakirman, T., & Gumusay, M. U. (2020). A novel GIS-MCDA-based spatial habitat suitability model for *Posidonia oceanica* in the Mediterranean. *Environmental Monitoring and Assessment*, 192(4), 231. doi:[10.1007/s10661-020-8198-1](https://doi.org/10.1007/s10661-020-8198-1)
- Baniya, N. (2008). *Land Suitability Evaluation Using GIS for Vegetable Crops in Kathmandu Valley, Nepal*. PhD Thesis, Humboldt-Universitat zu Berlin.
- Bishop, I. D., & Hulse, D. W. (1994). Prediction of scenic beauty using mapped data and geographic information systems. *Landscape and Urban Planning*, 30(1-2), 59–70. doi:[10.1016/0169-2046\(94\)90067-1](https://doi.org/10.1016/0169-2046(94)90067-1)
- Bojórquez-Tapia, L. A., Diaz-Mondragón, S., & Ezcurra, E. (2001). GIS-based approach for participatory decision making and land suitability assessment. *International Journal of Geographical Information Science*, 15(2), 129–151. doi:[10.1080/13658810010005534](https://doi.org/10.1080/13658810010005534)
- Bottero, M., D'Alpaos, C., & Oppio, A. (2018). Multicriteria Evaluation of Urban Regeneration Processes: An Application of PROMETHEE Method in Northern Italy. *Advances in Operations Research*, 9276075. doi:[10.1155/2018/9276075](https://doi.org/10.1155/2018/9276075)
- Bunruamkaew, K., & Murayam, Y. (2011). Site Suitability Evaluation for Ecotourism Using GIS & AHP: A Case Study of Surat Thani Province, Thailand. *Procedia-Social and Behavioral Sciences*, 21, 269–278. doi:[10.1016/j.sbspro.2011.07.024](https://doi.org/10.1016/j.sbspro.2011.07.024)
- Burkart, K., Meier, F., Schneider, A., Breitner, S., Canário, P., Alcoforado, M. J., Scherer, D., & Endlicher, W. (2016). Modification of Heat-Related Mortality in an Elderly Urban Population by Vegetation (Urban Green) and Proximity to Water (Urban Blue): Evidence from Lisbon, Portugal. *Environmental Health Perspectives*, 124(7), 927–934. doi:[10.1289/ehp.1409529](https://doi.org/10.1289/ehp.1409529)
- Carter, B., & Rinner, C. (2014). Locally weighted linear combination in a vector geographic information system. *Journal of Geographical Systems*, 16(3), 343–361. doi:[10.1007/s10109-013-0194-3](https://doi.org/10.1007/s10109-013-0194-3)
- Çetinkaya, C., Kabak, M., Erbaş, M., & Özceylan, E. (2018). Evaluation of ecotourism sites: a GIS-based multi-criteria decision analysis. *Kybernetes*, 47(8), 1664-1686. doi:[10.1108/K-10-2017-0392](https://doi.org/10.1108/K-10-2017-0392)
- Chakrabarty, A. (2011). Ecotourism Development and Security Restructuring: A GI Based Planning for Peaceful Dissuasion of Anarchism in Forest Provinces of India. *Procedia-Social and Behavioral Sciences*, 21, 108–115. doi:[10.1016/j.sbspro.2011.07.006](https://doi.org/10.1016/j.sbspro.2011.07.006)
- Chen, Y., Yu, J., & Khan, S. (2010). Spatial sensitivity analysis of multi-criteria weights in GIS-based land suitability evaluation. *Environmental Modelling & Software*, 25(12), 1582–1591. doi:[10.1016/j.envsoft.2010.06.001](https://doi.org/10.1016/j.envsoft.2010.06.001)
- Deribew, K. T., Mihretu, Y., Abreha, G., & Gemed, D. O. (2022). Spatial analysis of potential ecological sites in the northeastern parts of Ethiopia using multi-criteria decision-making models. *Asia-Pacific Journal of Regional Science*, 6(3), 961–991. doi:[10.1007/s41685-022-00248-5](https://doi.org/10.1007/s41685-022-00248-5)

- Doljak, D., Stanojević, G., & Miljanović, D. (2021). A GIS-MCDA based assessment for siting wind farms and estimation of the technical generation potential for wind power in Serbia. *International Journal of Green Energy*, 18(4), 363–380. doi:[10.1080/15435075.2020.1865363](https://doi.org/10.1080/15435075.2020.1865363)
- Domazetović, F., Šiljeg, A., Lončar, N., & Marić, I. (2019). GIS automated multicriteria analysis (GAMA) method for susceptibility modelling. *MethodsX*, 6, 2553–2561. doi:[10.1016/j.mex.2019.10.031](https://doi.org/10.1016/j.mex.2019.10.031)
- Drobne, S., & Lisec, A. (2009). Multi-attribute Decision Analysis in GIS: Weighted Linear Combination and Ordered Weighted Averaging. *Informatica*, 33(4), 459-474.
- Eastman, J. R. (1999). Multi-criteria evaluation and GIS. In: P. A. Longley, M. F. Goodchild, D. J. Maguire, & D. W. Rhind (Eds.), *Geographical Information Systems* (pp. 493–502), John Wiley & Sons, New York.
- El-Harami, J. (2014, December 9-11). The Diversity of Ecology and Nature Reserves as an Ecotourism Attraction in Jordan. In: M.A. Othuman Mydin & A. Marzuki (Eds.), 4th International Conference on Tourism Research (4ICTR), SHS Web of Conferences, (vol. 12, 01056), Kola Kinabalu, Malaysia. doi:[10.1051/shsconf/20141201056](https://doi.org/10.1051/shsconf/20141201056)
- Fang, Q., Tong, Z., Qiao, M., & Ren, L. (2017). The Evaluation System of Online P2P Lending Platforms Based on AHP -- in the Perspective of Lenders. In: The Sixteenth Wuhan International Conference on E-Business—Social Network and Commerce (pp. 507-514).
- Gigović, L., Pamučar, D., Lukić, D., & Marković, S. (2016). GIS-Fuzzy DEMATEL MCDA model for the evaluation of the sites for ecotourism development: A case study of “Dunavski ključ” region, Serbia. *Land Use Policy*, 58, 348–365. doi:[10.1016/j.landusepol.2016.07.030](https://doi.org/10.1016/j.landusepol.2016.07.030)
- Gourabi, B. R., & Rad, T. G. (2013). The analysis of ecotourism potential in Boujagh wetland with AHP method. *Life Science Journal*, 10(2s), 251–258.
- Goyal, P., Kumar, D., & Kumar, V. (2020). Application of multicriteria decision analysis (MCDA) in the area of sustainability: a literature review. *International Journal of the Analytic Hierarchy Process*, 12(3), 512-545. doi:[10.13033/ijahp.v12i3.720](https://doi.org/10.13033/ijahp.v12i3.720)
- Greene, R., Devillers, R., Luther, J. E., & Eddy, B. G. (2011). GIS-Based Multiple-Criteria Decision Analysis. *Geography Compass*, 5(6), 412–432. doi:[10.1111/j.1749-8198.2011.00431.x](https://doi.org/10.1111/j.1749-8198.2011.00431.x)
- Islam, N., Sarkar, B., Basak, A., Das, P., Paul, I., Debnath, M., & Roy, R. (2022). A novel GIS-based MCDM approach to identify the potential eco-tourism sites in the Eastern Dooars region (Himalayan foothill) of West Bengal, India. *Geocarto International*, 37(26), 13145-13175. doi:[10.1080/10106049.2022.2076917](https://doi.org/10.1080/10106049.2022.2076917)
- Khalili, N. R., & Duecker, S. (2013). Application of multi-criteria decision analysis in design of sustainable environmental management system framework. *Journal of Cleaner Production*, 47, 188–198. doi:[10.1016/j.jclepro.2012.10.044](https://doi.org/10.1016/j.jclepro.2012.10.044)
- Kiker, G. A., Bridges, T. S., Varghese, A., Seager, T. P., & Linkov, I. (2005). Application of multicriteria decision analysis in environmental decision making. *Integrated Environmental Assessment and Management*, 1(2), 95–108. doi:[10.1897/IEAM_2004a-015.1](https://doi.org/10.1897/IEAM_2004a-015.1)
- Laskar, A. (2003). *Integrating GIS and Multi-Criteria Decision Making Techniques for Land Resource Planning*. MSc Thesis, International Institute for Geo-Information Science and Earth Observation, Enschede.
- Mahdavi, A., & Niknejad, M. (2014). Site suitability evaluation for ecotourism using MCDM methods and GIS: case study - Lorestan province, Iran. *Journal of Biodiversity and Environmental Sciences*, 4(6), 425–437.
- Malczewski, J. (1999). *GIS and Multicriteria Decision Analysis*. John Wiley & Sons.
- Malczewski, J. (2006). GIS-based multicriteria decision analysis: a survey of the literature. *International Journal of Geographical Information Science*, 20(7), 703–726. doi:[10.1080/13658810600661508](https://doi.org/10.1080/13658810600661508)
- Malczewski, J. (2011). Local weighted linear combination. *Transactions in GIS*, 15(4), 439–455. doi:[10.1111/j.1467-9671.2011.01275.x](https://doi.org/10.1111/j.1467-9671.2011.01275.x)
- Malczewski, J., & Rinner, C. (2015). *Multicriteria Decision Analysis in Geographic Information Science*. Springer. doi:[10.1007/978-3-540-74757-4](https://doi.org/10.1007/978-3-540-74757-4)

- Mansour, S., Al-Awhadi, T., & Al-Hatrusi, S. (2020). *Geospatial based multi-criteria analysis for ecotourism land suitability using GIS & AHP: a case study of Masirah Island, Oman*. *Journal of Ecotourism*, 19(2), 148–167. doi:[10.1080/14724049.2019.1663202](https://doi.org/10.1080/14724049.2019.1663202)
- Matić, B., Jovanović, S., Das, D. K., Zavadskas, E. K., Stević, Ž., Sremac, S., & Marinković, M. (2019). *A New Hybrid MCDM Model: Sustainable Supplier Selection in a Construction Company*. *Symmetry*, 11(3), 353. doi:[10.3390/sym11030353](https://doi.org/10.3390/sym11030353)
- Mendadhala, R. G. (2018). *Automating Spatial Multi-Criteria Decision Analysis (MCDA) of housing development sites in Richardson, TX using ArcGIS Pro SDK for .Net - An accessibility level perspective*. MSc Thesis, The University of Texas at Dallas.
- Mentzafou, A., Blagojević, M., & Dimitriou, E. (2021). A GIS-MCDA-Based Suitability Analysis for Meeting Targets 6.3 and 6.5 of the Sustainable Development Goals. *Sustainability*, 13(8), 4153. doi:[10.3390/su13084153](https://doi.org/10.3390/su13084153)
- Modica, G., Laudari, L., Barreca, F., & Fichera, C. R. (2014). A GIS-MCDA Based Model for the Suitability Evaluation of Traditional Grape Varieties: The Case-Study of 'Mantonico' Grape (Calabria, Italy). *International Journal of Agricultural and Environmental Information Systems (IJAEIS)*, 5(3), 1–16.
- Nahuelhual, L., Carmona, A., Lozada, P., Jaramillo, A., & Aguayo, M. (2013). Mapping recreation and ecotourism as a cultural ecosystem service: An application at the local level in Southern Chile. *Applied Geography*, 40, 71–82. doi:[10.1016/j.apgeog.2012.12.004](https://doi.org/10.1016/j.apgeog.2012.12.004)
- Pamučar, D., Stević, Ž., & Sremac, S. (2018). A New Model for Determining Weight Coefficients of Criteria in MCDM Models: Full Consistency Method (FUCOM). *Symmetry*, 10(9), 393. doi:[10.3390/sym10090393](https://doi.org/10.3390/sym10090393)
- Pereira, J. M. C., & Duckstein, L. (1993). A multiple criteria decision-making approach to GIS-based land suitability evaluation. *International Journal of Geographical Information Systems*, 7(5), 407–424. doi:[10.1080/02693799308901971](https://doi.org/10.1080/02693799308901971)
- Piran, H., Maleknia, R., Akbari, H., Soosani, J., & Karami O. (2013). Site selection for local forest park using analytic hierarchy process and geographic information system (case study: Badreh County). *International Research Journal of Applied and Basic Sciences*, 6(7), 930–935.
- Primavera, J. H., Friess, D. A., Van Lavieren, H., & Lee, S. Y. (2019). The Mangrove Ecosystem. In: C. Sheppard (Eds.), *World Seas: An Environmental Evaluation (Second Edition)*, (pp. 1-34). doi:[10.1016/B978-0-12-805052-1.00001-2](https://doi.org/10.1016/B978-0-12-805052-1.00001-2)
- Rinner, C. (2007). A geographic visualization approach to multi-criteria evaluation of urban quality of life. *International Journal of Geographical Information Science*, 21(8), 907–919. doi:[10.1080/13658810701349060](https://doi.org/10.1080/13658810701349060)
- Saaty, T. L. (1977). A scaling method for priorities in hierarchical structures. *Journal of Mathematical Psychology*, 15(3), 234–281. doi:[10.1016/0022-2496\(77\)90033-5](https://doi.org/10.1016/0022-2496(77)90033-5)
- Saaty, T. L. (2001). *Decision Making for Leaders: The Analytic Hierarchy Process for Decisions in a Complex World*. RWS Publications.
- Saaty, T. L. (2002). How to make and justify a decision: the analytic hierarchy process. Part 1. Examples and Applications *System Research and Information Technologies*, 2002(1), 95-108.
- Saaty, T. L. (2006). The Analytic Network Process. In: T. L. Saaty, & L. G. Vargas (Eds.), *Decision Making with the Analytic Network Process Economic, Political, Social and Technological Applications with Benefits, Opportunities, Costs and Risks* (pp. 1-26). Springer. doi:[10.1007/0-387-33987-6_1](https://doi.org/10.1007/0-387-33987-6_1)
- Saaty, T. L., & Vargas, L. (2012). *Models, Methods, Concepts & Applications of the Analytic Hierarchy Process*. Springer. doi:[10.1007/978-1-4614-3597-6](https://doi.org/10.1007/978-1-4614-3597-6)
- Sahani, N. (2019). Assessment of ecotourism potentiality in GHNPCA, Himachal Pradesh, India, using remote sensing, GIS and MCDA techniques. *Asia-Pacific Journal of Regional Science*, 3(2), 623–646. doi:[10.1007/s41685-019-00116-9](https://doi.org/10.1007/s41685-019-00116-9)

- Sahani, N. (2020). Application of analytical hierarchy process and GIS for ecotourism potentiality mapping in Kullu District, Himachal Pradesh, India. *Environment, Development and Sustainability*, 22(7), 6187–6211. doi:[10.1007/s10668-019-00470-w](https://doi.org/10.1007/s10668-019-00470-w)
- Salabun, W., Ziembra, P., & Wątróbski, J. (2016, June 15-17). *The Rank Reversals Paradox in Management Decisions: The Comparison of the AHP and COMET Methods* In: I. Czarnowski, A. M. Caballero, R. J. Howlett, & L. C. Jain (Eds.), Proceedings of the 8th International KES Conference on INTELLIGENT DECISION TECHNOLOGIES KES-IDT-16 (pp. 181–191), Puerto de la Cruz, Tenerife, Spain. doi:[10.1007/978-3-319-39630-9_15](https://doi.org/10.1007/978-3-319-39630-9_15)
- Shorabeh, S. N., Firozjaei, H. K., Firozjaei, M. K., Jelokhani-Niaraki, M., Homaei, M., & Nematollahi, O. (2022). The site selection of wind energy power plant using GIS-multi-criteria evaluation from economic perspectives. *Renewable and Sustainable Energy Reviews*, 168, 112778. doi:[10.1016/j.rser.2022.112778](https://doi.org/10.1016/j.rser.2022.112778)
- Stubelj Ars, M. (2014). Decision support in the implementation of sustainable development in protected areas regarding environmental education and ecotourism. PhD Thesis, Univerze v Novi Gorici.
- Suryabhadgavan, K. V., Tamirat, H., & Balakrishnan, M. (2015). Multi-criteria evaluation in identification of potential ecotourism sites in Hawassa town and its surroundings, Ethiopia. *Journal of Geomatics*, 9(1), 86–92.
- Teknomo, K. (2006). Analytic Hierarchy Process (AHP) Tutorial. [URL](#)
- Tian, M., & Yan, S. (2021). Study on the Assessment of Internet-Financial Risk Based on Fuzzy Analytic Hierarchy Process. *Journal of Simulation*, 9, 121-126.
- Tjader, Y., May, J. H., Shang, J., Vargas, L. G., & Gao, N. (2014). Firm-level outsourcing decision making: A balanced scorecard-based analytic network process model. *International Journal of Production Economics*, 147, Part C, 614–623. doi:[10.1016/j.ijpe.2013.04.017](https://doi.org/10.1016/j.ijpe.2013.04.017)
- Tjong, G. P., Supriatna, J., Takarina, N. D., & Tambunan, R. P. (2021). Mangrove diversity and suitability assessments for ecotourism in Cimalaya Wetan Coast, Karawang District, Indonesia. *Biodiversitas Journal of Biological Diversity*, 22(2), 803-810. doi:[10.13057/biodiv/d220234](https://doi.org/10.13057/biodiv/d220234)
- Voogd, H. (1983). *Multicriteria Evaluation for Urban and Regional Planning*. Pion.
- Wang, J.-J., Jing, Y.-Y., Zhang, C.-F., & Zhao, J.-H. (2009). Review on multi-criteria decision analysis aid in sustainable energy decision-making. *Renewable and Sustainable Energy Reviews*, 13(9), 2263–2278. doi:[10.1016/j.rser.2009.06.021](https://doi.org/10.1016/j.rser.2009.06.021)
- Watson, J. J. W., & Hudson, M. D. (2015). Regional Scale wind farm and solar farm suitability assessment using GIS-assisted multi-criteria evaluation. *Landscape and Urban Planning*, 138, 20–31. doi:[10.1016/j.landurbplan.2015.02.001](https://doi.org/10.1016/j.landurbplan.2015.02.001)
- Weaver, D. B. (2005). Mass and Urban Ecotourism: New Manifestions of an Old Concept. *Tourism Recreation Research*, 30(1), 19–26. doi:[10.1080/02508281.2005.11081230](https://doi.org/10.1080/02508281.2005.11081230)
- Xu, L., & Zhang, Y. (2017). A Credit Rating Model for Online P2P Lending Based on Analytic Hierarchy Process. In: J. Xu, A. Hajiyev, S. Nickel, & M. Gen (Eds.), Proceedings of the Tenth International Conference on Management Science and Engineering Management, (pp. 537–549). doi:[10.1007/978-981-10-1837-4_46](https://doi.org/10.1007/978-981-10-1837-4_46)
- Zabihi, H., Alizadeh, M., Wolf, I. D., Karami, M., Ahmad, A., & Salamian, H. (2020). A GIS-based fuzzy-analytic hierarchy process (F-AHP) for ecotourism suitability decision making: A case study of Babol in Iran. *Tourism Management Perspectives*, 36, 100726. doi:[10.1016/j.tmp.2020.100726](https://doi.org/10.1016/j.tmp.2020.100726)
- Žižović, M., & Pamučar, D. (2019). New model for determining criteria weights: Level Based Weight Assessment (LBWA) model. *Decision Making: Applications in Management and Engineering*, 2(2), 126–137. doi:[10.31181/dmame1902102z](https://doi.org/10.31181/dmame1902102z)
- Zoghi, M., Houshang Ehsani, A., Sadat, M., javad Amiri, M., & Karimi, S. (2017). Optimization solar site selection by fuzzy logic model and weighted linear combination method in arid and semi-arid region: A case study Isfahan-IRAN. *Renewable and Sustainable Energy Reviews*, 68, Part 2, 986–996. doi:[10.1016/j.rser.2015.07.014](https://doi.org/10.1016/j.rser.2015.07.014)