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# Application of analytical hierarchy process in land suitability for forest park location (case study: Ilam county, Iran)

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**Abstract**

Currently, Human life is being sustained by recreation and leisure as they play an important role within the human lifestyles. Natural and forest park observed as recreational spaces have persistently received a greatest significance for pastime. This paper describes a GIS-based system that supports dynamic assessment of land suitability for forest park location in western Iran. Based on actual conditions of the study area, we considered affective factors, calculated criteria weights using the analytical hierarchy process (AHP), and built a hierarchy model for solving the forest park site selection problem in Ilam, Iran. A geographic information system (GIS) was used to manipulate and present spatial data. The maps prepared and reclassified and standardized using GIS. Finally, land suitability map for forest park location generated using WLC method and classified in 4 class including excellent suitability, moderate suitability, low suitability and not suitable. Result showed that 4.67% of the study area has excellent suitability for forest park location.

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## Introduction

Natural and forest locations observed as recreational spaces have persistently received a greatest significance for pastime (Lynn and Brown, 2003). Currently, human life is being sustained by recreation and leisure as they play an important role within the human day by day lifestyles. Consequently, demand has increased for recreation diversity with enhancement in transportation. Haphazard urban locations with recreational locations and facilities like green spaces motivate a lot of urban dwellers to pass their leisure time in the organic spaces where they can enjoy the benefits of nature rather than the urban areas. As a result, the utilization of the natural green areas is of paramount importance. Organic locations that offer numerous recreational prospects provide people with lots of benefits physically and psychologically. Hence, Planning for recreation is all about evaluating the demand, both the actual or present demand and the future demand; about evaluating the land capability to meet those demands; and about utilizing the resources which are available wisely (Lawal *et al.*, 2011). Parks and green spaces are the most important location for recreation and outing and Forests and woodlands are the most valuable parts of parks and urban green spaces (Majnounian, 1995). Forest parks are important recreational resources that can prepare bioenvironmental, economical and recreational purposes for human. The first step in forest parks planning and managing is evaluation of land suitability for forest park location because forest park location without land suitability might be cause of land degradation and waste of natural resources.

Regarding to importance of land suitability for forest parks location, in this study we evaluate land suitability of a region from Ilam country-Iran for forest park location. This paper is focused on the combining AHP with Geographic Information System GIS for the most appropriate forest park site selection in Ilam county. The Analytic Hierarchy Process (AHP) is one such multi criteria decision-making method and can be used to analyze and support decisions which have multiple and even competing objectives. The integration of GIS and AHP is a powerful tool to solve the site selection for forest park location.

The analytic hierarchy process (AHP), originally developed by Saaty (1980), is a widely used MCDM method and perhaps the most popular in many fields, including natural resource management. Mendoza and Sprouse (1989), Murray and von Gadow (1991), and Kangas (1992), among others, have used AHP in forestry applications, and the number of applications is continuously increasing (e.g.,Rauscher *et al.*, 2000; Vacik and Lexer, 2001). AHP has also gained interest among forestry practitioners. The Finnish Forest and Park Service, which governs the vast majority of state-owned lands, has used AHP, in practical natural resource planning (Pykalainen *et al.*, 1999). AHP also has been used in tourism and recreational planning research (Piran *et al.*, 2013; Kumari *et al.*, 2011; Mahdavi *et al.*. 2011).

AHP has several advantages from the viewpoints of multiple-use and participatory planning. Using AHP, objective information, expert knowledge, and subjective preferences can be considered together. Also, qualitative criteria can be included in the evaluation of alternative plans. AHP is based on a theory of ratio-scale estimation (Saaty, 1977), and by using it, pair-wise comparisons of qualitatively expressed measures can be transferred into a ratio scale. In contrast, other related methods usually require criteria values to be quantitative and to be measured in ratio or interval scale.

Suitability analysis in a GIS context is a geographic or GIS-based process used to determine the appropriateness of a given area for a particular use. The basic premise of GIS suitability analysis is that each aspect of the landscape has intrinsic characteristics that are in some degree either suitable or unsuitable for the activities being planned such as forest park land use. The results are often displayed on a map that is used to highlight areas from high to low suitability. A GIS suitability model typically answers the question, "Where is the best location?"

whether it involves finding the best location for new facilities (Malczewski, 2004).

The successful combination of GIS and technical decision support is that they are perfectly complementary tools. GIS offers the decision-maker or decision-maker group the possibility of carrying out the analysis, management, storage and visualization of all geospatial information. Based on such functions, the MCDM provide a range of techniques and procedures that allow to structure decision problems and evaluate the alternatives under study (Malczewski, 1999).

GIS combined with AHP can make full use of GIS functions such as space analysis, data processing and inquiry. It has following characteristics. In the process of location selection, the complex data and their mutual influence can be considered well. And it is not necessary to use massive complex mathematical equations to describe space position of each factor. Moreover, the analysis is more flexible and it is easy for data renewal. Location selective models are easier to understand. As a result, GIS combined with AHP is a tendency to planning recently, and many efforts have been made to conduct planning problems using GIS. However, mature planning and experiments are relatively few towards the selection of forest park location (Lai *et al.*, 2011).

Given that the study area is one of the tourist cities in Iran, So far, no studies have been done in relation to forest park localization. Thus, it is necessary to determine the most suitable recreational sites with multiple factors. In this study, suitable areas for local forest park determined in Ilam County using AHP and GIS to use them in future planning.

## Material and methods

*Study area*

The study area is located in west of Iran, Ilam province, Ilam country. The study area covers an area of 35,081 ha and an elevation range of 1200 to 2545 meters above sea level. The study area located in center of Ilam province and latitude from 33° 39′ 55″ to 33° 26′ 38″ northern, and longitude from 46° 39′ 58″ to 47° 21′ 07″ eastern (Fig. 1). This area is a mountainous region and has a diverse topography, generally.

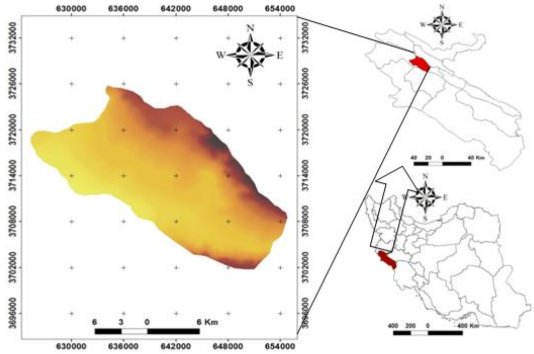

**Fig. 1.** location of the study area

The situation of the vegetation and forest cover is very desirable and forest dominate form of this forests is oak (*Quercus spp*). This area selected for research because of the canopy density of forest, closing to the center of the entertainment and recreational locations of the Ilam city (most populous region in Ilam province) and beautiful landscapes.

*Method*

In this study, in the first step the criteria and sub-criteria, which affect on land suitability evaluation for forest park location, determined using former studies (Gul *et al.*, 2006; Karami, 2010; Lawal *et al.*, 2011; Piran *et al.*, 2013 and etc) and expert's knowledge. Then, the weights of criteria and sub-criteria calculated. For this purpose, questionnaires were distributed among experts. Experts used pairwise comparisons and Saaty's scale to assess the importance of criteria and sub criteria. The weights of sub-criteria in each questionnaire were calculated using Expert choice software. Then, the sub-criteria weights of questionnaires were averaged and the final weights were calculated for sub-criteria.

The procedure of weights calculation in the each questionnaire is described as follows:

MCDM is a device which enables people to make the most appropriate choice among many criteria and it is a widely used concept (Cay and Uyan, 2013; Eastman et al., 1995). AHP is one such multi-criteria decision-making method.

The AHP, which is used as a decision analysis device (Saaty,1980) is a mathematical method developed by Saaty for analyzing complex decisions involving many criteria (Kurttila et al. 2000). It is widely used by decision-makers and researchers as an MCDM device.

Pairwise comparison, which is applied within the scope of the AHP technique, provides a comparison of criteria which are used in decision analysis and determines values for each of these criteria (Vaidya and Kumar, 2006). In AHP, a matrix is generated as a result of pairwise comparisons and criteria weights are reached as a result of these calculations. Also, it is possible to determine the consistency ratio (CR) of decisions in pairwise comparison. CR reveals the random probability of values being obtained in a pairwise comparison matrix (Cay and Uyan, 2013).

If n number criteria are determined for comparison, AHP performs the following process to ascertain the weight of these criteria (Chakraborty and Banik, 2006):

(a) Create (n × n) pairwise comparison matrix A for n objectives such as:

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \quad (1)$$

where $a_{ij}$ indicates how much more important the $i$th objective is than the $j$th objective, while making a suitable material handling/equipment selection decision. For all $i$ and $j$, it is necessary that $a_{ii} = 1$ and $a_{ij} = 1/a_{ji}$ . The possible assessment values of $a_{ij}$ in the pairwise comparison matrix, along with their corresponding interpretations, are shown in Table 1.

**Table 1.** AHP evaluation scale.

| Numerical value of $a_{ij}$ | Definition |
|---|---|
| 1 | Equal importance of *i* and *j* |
| 3 | Moderate importance of *i* over *j* |
| 5 | Strong importance of *i* over *j* |
| 7 | Very strong importance of *i* over *j* |
| 9 | Extreme importance of *i* over *j* |
| 2, 4, 6, 8 | Intermediate values |

(b) Divide each value in column $j$ by the total of the values in column $j$. The total of the values in each column of the new Aw matrix must be one. Thus, a normalized pairwise comparison matrix is found.

$$Aw = \begin{bmatrix} \frac{a_{11}}{\sum a_{i1}} & \frac{a_{12}}{\sum a_{i2}} & \cdots & \frac{a_{in}}{\sum a_{in}} \\ \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots \\ \frac{a_{n1}}{\sum a_{i1}} & \frac{a_{n2}}{\sum a_{i2}} & \cdots & \frac{a_{nn}}{\sum a_{in}} \end{bmatrix} \quad (2)$$

(c) In the AHP the $c_i$ are determined by finding the principal eigenvector of the matrix A. Here we used a simplified approach suitable for hand calculations with a first approximation to the eigenvector by calculating the $c_i$ as the average. Calculate $c_i$ as the average of the values in row $i$ of Aw matrix to yield the column vector C where $c_i$ value shows the relative degree of importance (weight) of the $i$th objective.

$$C = \begin{bmatrix} c_1 \\ c_2 \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ c_n \end{bmatrix} = \begin{bmatrix} \frac{\frac{a_{11}}{\sum a_{i1}}}{n} + & \frac{\frac{a_{12}}{\sum a_{i2}}}{n} + & \cdots & + \frac{\frac{a_{in}}{\sum a_{in}}}{n} \\ \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots \\ \frac{\frac{a_{n1}}{\sum a_{i1}}}{n} + & \frac{\frac{a_{n2}}{\sum a_{i2}}}{n} + & \cdots & + \frac{\frac{a_{nn}}{\sum a_{in}}}{n} \end{bmatrix} \quad (3)$$

(d) Control the consistency of the weight values ($c_i$). The procedure to be followed in order to determine consistency is as follows: First, calculate the A × C matrix (consistency vector).

$$A \times C = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \times \begin{bmatrix} c_1 \\ c_2 \\ \cdot \\ \cdot \\ \cdot \\ c_n \end{bmatrix} = \begin{bmatrix} x_1 \\ x_2 \\ \cdot \\ \cdot \\ \cdot \\ x_n \end{bmatrix} \quad (4)$$

Second, calculate the $x_i$ by multiplying A × C, which is a second, better, approximation to the eigenvector. We now estimate λ max using the following formula.

$$\lambda_{\max} = \frac{1}{n}\sum_{i=1}^{n}\frac{x_i}{c_i} \quad (5)$$

where λ maxis the eigenvalue of the pairwise comparison matrix. Then, calculate an approximation to the consistency index (CI).

Finally, to ensure the consistency of the pairwise comparison matrix, the consistency judgment must be checked for the appropriate value of n by CR (Cay and Uyan, 2013).

that is, CR = CI

$$CI = \frac{\lambda_{\max} - n}{n - 1} \quad (6)$$

Where RI is the random consistency index. The RI values for different numbers of n are shown in Table 2.

$$CR = \frac{CI}{RI} \quad (7)$$

If CR ≤ 0.10 the degree of consistency is satisfactory. If CR > 0.10 there are serious inconsistencies. In this case, the AHP may not yield meaningful results (Chakraborty and Banik, 2006).

After determining and calculating of weights of criteria and sub-criteria, in the next step, the requirement maps prepared, classified based on prior studies and experts knowledge (table 3) and standardized using GIS.

**Table 2.** The RI values for different numbers of n

| **n** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **RI** | 0 | 0 | 0.58 | 0.9 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.45 |

**Table 3.** Criteria, sub-criteria and maps classification

| **Criteria** | **Sub-criteria** | **Layers classification (suitability)** | | | |
|---|---|---|---|---|---|
| | | **High** | **moderate** | **low** | **Not suitable** |
| **Environ-mental** | Distance from Resources water (M) | 0 - 300 | 300 - 600 | 600 - 1200 | 1200 < |
| | Vegetation cover | Forest- high density cover | Forest- moderate density cover | Forest- low density cover | Other lands |
| **Socio-Econo-mic** | Distance from roads (KM) | 0 - 1 | 1 - 2 | 2 - 3 | 3 < |
| | Distance from settlement areas (KM) | 0 - 2 | 2 - 4 | 4 - 5 | 6 < |
| **morphol ogy** | Slope (percentage) | 0 - 12 | 12 - 25 | 25 - 45 | 45 < |
| | Aspect | Western | Northern | Southern | Eastern |
| | Elevation (M) | 1200-1500 | 1500-1800 | 1800-2100 | 2100 < |
| **geology** | Soil type | Deep with few rock particles | Deep with more rock particles | Shallow with many rock particles | Very shallow with most rock particles |
| | lithology | Silt Lime stones, good weathering | Lime stones, sedimentary stones with hard substrate | Silt Lime stones with hard substrate | Alluvial stones |

Spatial data were converted into raster layers and processed in Arc GIS. Slope, Aspect and elevation maps were generated from a 25 m resolution DEM, which was resampled to match the other four datasets at 20 m cell size using a cubic convolution algorithm. They were then classified into four classes as integer raster's representing different suitability levels based on assigned threshold values in Table 3, and loaded into the map frame of the tool. Maps of water resources, roads and settlements area prepared by field inventory using GPS and topography map and the buffer from these factors created based on assigned threshold values in Table 3. The maps of vegetation cover, soil and lithology prepared from department of natural resources of Ilam province.

For decision analysis the values and classes of all the maps should be converted into a common scale. Such a transformation is commonly referred to as standardization (Sharifi and Retsios, 2004).

Through standardization the original factor scores (each expressed in its own unit of measurement) are converted into dimensionless scores in the 1 (worst situation) or 4 (best situation) range. In the present study standardization was performed by using linear function.

In the final step in this study, final map of land suitability for forest park location prepared using WLC method. A common compensatory method used for the estimation and implementation of numerous criteria in a GIS is the weighted linear combination (WLC). This model simply combines successive variables on a linear basis, forming points of adaptability for specific purposes. The combination of the components, according to the WLC model, is carried out as in Eq. 8. (Svory *et al*, 2005)

$$S_j = \sum_{i=1}^{n} W_{ij} X_i \qquad (8)$$

Where Sj is defined as the level of adaptability to one of the four categories—j is the number of criteria; Wi is the weight of a criterion—i; and Xi is the rank of criterion according to the range of criterion (i) values. The criterion values in each layer were standardized in accordance with the four levels of adaptability (Table 3).

**Results**

*The hierarchy of the problem and expert evaluation*

In this study for determination and weighting to criteria and sub-criteria used from experts knowledge. Therefore, 4 criteria including environmental factors (vegetation cover, distance from water resources), morphology (slope, aspect and elevation), socio-economic (distance from road and distance from settlement areas) and geology (soil type and lithology) determined.

The result of weighting to sub-criteria showed that sub-criteria ranked as follows according to importance in land suitability evaluation for forest park location (Fig. 2): Vegetation cover (weight: 0.30664), distance from water resources (weight: 0.16301), slope (weight: 0.15589), distance from road (weight: 0.10086), distance from settlement areas (weight: 0.09471), aspect (weight: 0.06584), elevation (weight: 0.04998), soil type (weight: 0.03598) and lithology (weight: 0.02709). With respect to inconsistency rate in judgments was less than 0.1, these judgments were creditable and compatible.

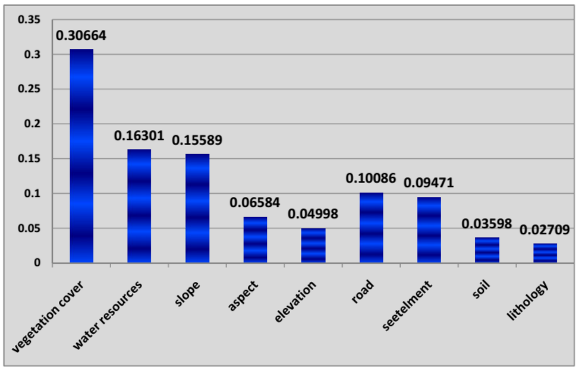


**Fig. 2.** Final weights of sub-criteria (maps)

*Land suitability map for forest park location*

Finally, the map of land suitability for forest park location of the study area prepared using WLC method and GIS (Fig. 3). Result showed that 1638.85 ha (4.67% of study area) has excellent suitability (class 1), 21836.94 ha (62.25% of study area) has moderate suitability (class 2), 9880.11 ha (28.16% of study area) has low suitability and 1725.27 ha hasn't suitability for forest park location (Fig. 4).

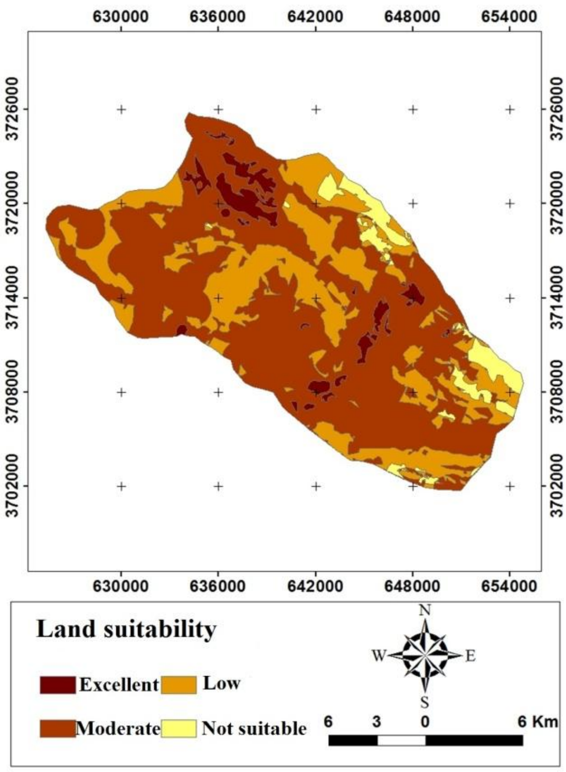


**Fig. 3.** Land suitability of study area for forest park location

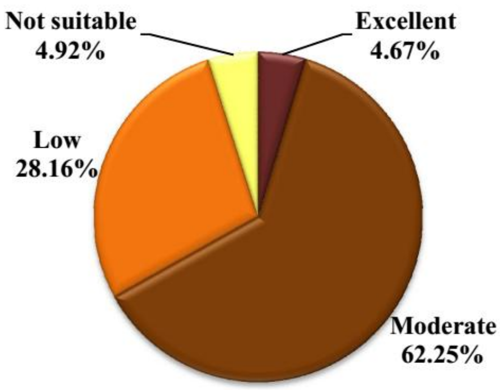


**Fig. 4.** The percentage area of different suitable classes for forest park location

**Discussion and conclusion**

The results of the weighting of affective criteria and sub-criteria in locating the park in the study area showed that the highest weights related to environmental factors, eco-social, morphological factors and geology, respectively.

Piran *et al.* (2013) and Mahdavi et al. (2011) in their studies expressed that environmental factors were the most important factor in the evaluation process. Summing up the results of the experts judgments indicated that vegetation cover, distance from water resources, slope and distance from access roads were most important factors in the selection of forest park location in the study area .

Studies of Gul *et al.* (2006), Mahdavi *et al.* (2011), Karami (2010) and Piran *et al.* (2013) showed that water resources is most important factor in the evaluation of the outing and recreational activities. The aim of this study was explore the suitable areas for forest park location, so it seems the result of this study is valid because the map of vegetation cover has most importance in land suitability evaluation for forest park location.

The results showed that 65% of the study area has excellent and moderate suitability for forest park location( class 1 and 2) that indicate that this area has a good potential for forest park location and recreation. According to the land suitability map, the northern part of the study area has more suitability than other parts for recreation and park location. In fact, about 5% of the study area has great potential for construction of the forest park, including areas with dense forest cover that has low slope. Due to the weight and importance of vegetation cover map in land suitability evaluation for the location of forest park.

About 5% of the study area was not suitable for forest park location. These areas located in the eastern and northern parts of the study area that have high elevation, high slope and are devoid of forest cover.

Contaminated land projects are uncertain due to incomplete or unknown data and the need for site specific information, and as such, use a combination of quantitative data and subjective expert judgment and intuition for decision making. The AHP provides a structure for inclusive, rational, consistent and defensible management decision-making. The AHP is capable of dealing with the associated complexities of contaminated land management and using mixed data – both qualitative and quantitative.

AHP has many obvious advantages. It helps simplify complex decision problem by decomposing them into hierarchies, and is simple enough to be understood by lay people. This helps make projects transparent and inclusive, and as a result provides a more rational, consistent, participatory and effective decision-making process. The AHP can calculate inconsistency as a ratio of a decision-makers consistency in judgments, and provides ways of dealing with this for better improved decisions. The philosophical background of AHP model in decision-making, clearly highlighting tradeoffs between different objectives and interests. The results of the case study show that the AHP can be used as a valuable decision analysis tool in the selection of appropriate remedial techniques in contaminated land management.

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