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Delineation of Suitable Areas for *Acer Monspessulanum* Using a Multi-Criteria Evaluation Approach and Landuse/Cover Mapping (Case Study: Golestan Province in the North of Iran)

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Abstract

Acer monspessulanum plays a key role in determining the function of forest ecosystems in the semi-arid lands. Therefore, assessment of *Acer monspessulanum* habitat is important to understand the ecosystem functioning in these regions and for applied purposes, such as reforestation management and land evaluation.

Reforestation planning, evaluation and implementation are important in areas where abiotic, biotic and anthropogenic disturbances have changed forest areas. This paper presents a model to assess *Acer monspessulanum* habitat in a semi-arid region. The model is based on geographic information system (GIS) and fuzzy logic, comprising nine variables. MCE modeling provides a tool for evaluating land suitability.

In this article, we provide a framework to use MCE model for reforestation. Specifically, we present a case study using MCE simulation model of reforestation in Gharnaveh watershed of Golestan Province in the north of Iran. The AHP method was applied to identify the priority weight of each factor. Nine spatial layers with their corresponding weights were linearly combined to prepare the suitability map. The map was classified as high, medium and low suitable land for the reforestation.

According to the results, in the study area there are approximately 542, 4508 and 1056 ha with high, medium and low suitability respectively. We conclude that in this particular case active reforestation is the most effective method to quickly restore forest cover. Our research suggests that MCE model are valuable tools in the land suitability evaluation for reforestation decision making process.

Keywords: Fuzzy logic, MCE, AHP, Habitat, *Acer monspessulanum*

INTRODUCTION

Arid and semiarid areas currently cover over one-third of total Earth's land surface [28] and its extension may increase as a consequence of expected climatic changes [32]. These areas are particularly prone to degradation because of environmental constraints and intense and continued human pressure [32-27]. Restoration of degraded arid and semiarid lands by the reintroduction of woody species has become increasingly important worldwide as a measure to protect soils [5] to combat desertification [28], to supply natural resources [14] and to provide space for recreation [31]. Its importance may also increase in the future due to the role of forest plantations in carbon sequestration in arid and semiarid areas [17]. Reforestation planning, evaluation and implementation are important in forested areas in many regions of the world [33]. In Iran reforestation has been identified as an important factor for sustainable development. Reforestation is generally accepted as the reestablishment of natural ecological processes that produce certain dynamic ecosystem properties of structure and function [33]. We broadly define reforestation as the reestablishment of natural ecological processes that promote specific, historically relevant properties of forest structure and function, after and despite the effects of deleterious anthropogenic influences. Spatially explicit MCE model are promising tolls for evaluating land suitability, including reforestation strategies in damaged forest areas [15-34]. Plantations were also implemented for controlling catchments hydrology, protecting soils and fostering forest productivity.

Acer monspessulanum was preferentially chosen because of low-technical requirements for nursery production, high-resistance to adverse climatic and soil conditions, and because it was either considered a pioneer species, favoring the establishment of late succession. Despite the extent of *Acer monspessulanum* plantations, and the time passed since the onset of vast afforestation plans, a critical review of the ecological needs of these plantations in the semiarid areas of the Mediterranean Basin has not been performed. The objective of this paper is to review the main results obtained, and to identify the main ecological needs of the introduction of *Acer monspessulanum* with extensive plantations in suitable land of semiarid areas. In this article we briefly present the reforestation processes and focus mainly on land suitability assessment of *Acer monspessulanum* using MCE method in IDRISI Kilimanjaro.

Acer monspessulanum is locate in the Yelaq plain, in southern part of the Golestan national park, with elevation of between 1000-1400 m, Mean annual rainfall equals 450 mm, Mean monthly temperature –11.8°C, and temperate semi-arid climate prevails [12-13]. The minimum limit of *Acer monepessulanum* is in Goli dagh in altitute of 250 m and in areas of Gifan determine the upper elevation limits of the species with altitude of 1050 m [30]. In the northwest, where scrub gives way to oak forests and the demarcation line is often not clear, the scrub is very rich in species, but their number declines toward the southeast, reflecting decreasing annual and summer precipitation. At Shiraz, where annual precipitation is ca. 400 mm, a large proportion of the scrub species has already

Table 1. Ecological need of species (Ellenberg, 1992)

Species	Light figure	Temperature figure	Continentality figure	Moisture figure	Reaction figure
Acer monspessulanum	6	8	4	3	8

- ✓ Light figure: Occurrence in relation to relative irradiance intensity (r.i.).at the time when the deciduous plants are full in leaf. 6: plant generally with more than 10% r.i., and in well lit place,but also occurring in partial shade.
- ✓ Temperature figure: Occurrence in the temperature gradients from the Arctic and the Mediterranean and from alpine level to lowland. 8: Warmth indicator, in warm lowland sites and colline levels.
- ✓ Continentality figure: Occurrence in the gradient from the Atlantic coast to the inner part of Eurasia,especially with regard to temperature ranges. 4: suboceanic, mainly in Central Europe, but spreading eastward
- ✓ Moisture figure: Occurrence in the gradient from dry, shallow-soil rocky slopes to swampy ground. 3: dry-site indicator,more often found on dry ground than on moist place, never on damp soil.
- ✓ Reaction figure: Occurrence in the gradient of soil acidity and lime content (after numerous own measurements and literature references). 8: indicator of weakly acid to weakly basic conditions; never found on very acid soils

disappeared. The one of species is *Acer monspessulanum*, which constitute very sparse complex of open xeromorphic scrub [36]. *Acer monspessulanum* may be suggested for Italy in Horizon of heliophilous broadleave, with annual rainfall 800-1500 mm; mean temp 0-5°C in January, 17-20°C in July [26]. This review refers to Mediterranean vegetation as in the [23] approach. Soil of mesic with well drainage, is suitable for reforestation. Ecological need of Acer monspessulanum is shown in Table 1.

MATERIALS AND METHODS

Study Area

The area is located in north-east of Iran and south-east of Caspian Sea (Figure 1; latitude, 37˚30′-37˚47′ N; longitude, 55˚ 30′-56˚20′ E.; elevation, 100-1400 m). The climate is typically temperate. The mean annual temperature is 13.8 ºc. Annual precipitation averages 500 mm. The predominant soils are clay. The predominant forest cover types are *Quercus iberica, Zelkova Carpinifolia, Parrotia Persica* and *Betula* sp. Understory shrubs are mainly *Bromus danthonic, Artemisia herba alba, Kochia, Dactylus glomerata, Prastrata* and *Agropyron* sp.

Methods

The methodology involves three phases: First, selection of habitat variables, then, the AHP method is implemented based on expert knowledge. Finally, the Geographical Information Systems analysis is used to assess the potential of the study area for reforestation with *Acer monspessulanum.*

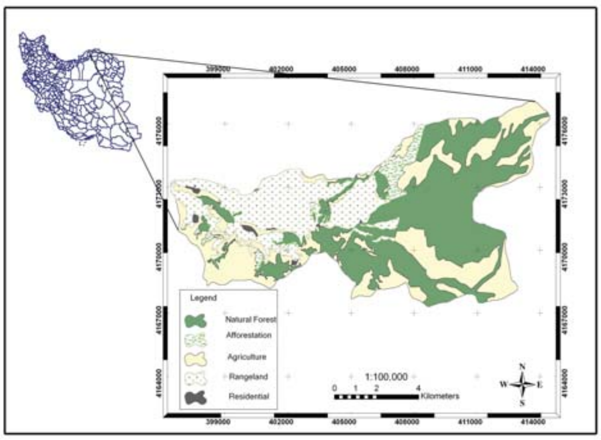

Fig.1. Case study

From expert knowledge, a list of potentially important environmental variables was compiled that affect habitat suitability of a given site for *Acer monspessulanum*. These variables are toposhape, wetness index, solar radiation, soil pH, slope, aspect, DEM, annual mean precipitation and annual mean temperature. Spatial variation in soil water content is strongly dependent on topographic conditions through surface and subsurface runoff convergence and dispersion [21]. A study conducted by Chaplot and Walter [7] showed that lower areas in the catchments are more moist due to the accumulated water reaching these areas through upper and lower runoff flows. Among the topographic variables that play a primary role in surface hydrology, the local slope and catchment area determine the hydraulic gradient and the potential water flux to a given area [1]. The use of these two variables in conjunction as a wetness index to represent areas of dry and wet conditions was applied successfully by [2] and later by [3].

The local aspect represents changes in solar radiation flux, which affects evapotranspiration rate. As a result, in the northern hemisphere, south-facing slopes are commonly less humid than slopes oriented to the north, east or west [24-18]. The wetness index and solar radiation were determined from digital elevation data with 30m ×30m pixel resolution in DIGEM software. The local aspect, slope and toposhape were determined from DEM in IDRISI Kilimanjaro software, while soil data were gathered in a field survey. Meteorological information was obtained from 10 weather stations located within the study area and the surrounding zone. The number of years registered at the weather stations ranged from 12 to 24. Annual mean temperature and annual mean precipitation were calculated and an interpolation procedure was applied in IDRISI [9]. Information about the soil conditions (pH, sand, silt and clay) at stratified random sampling points was obtained within the landform of the study area. The total number of sample point varied from 51 (pH) to 50 (sand, silt and clay). Soil texture and soil pH maps were made by means of an interpolation procedure within IDRISI. The Analytic Hierarchy Process (AHP) is a decision making process that provides a systematic method of considering all the elements of a problem. It organizes the problem into smaller parts and then only calls for simple pair wise judgments to develop a hierarchy. This hierarchy is then manipulated analytically to produce a final matrix representing the overall priorities of the alternatives in comparison to each other criteria. One can then make a logical decision based on the pair-wise comparisons made between the alternatives and the criteria being used in the decision. There are two specific characteristics that distinguish this method from the other methods of this family: a hierarchical structure has to be constructed, and the pair-wise comparisons made between different criteria to weight them with respect to the overall objective. Saaty (1980) recommends a scale of 1–9 for the pair-wise comparisons, where a score of 1 implies similar importance of the criteria being estimated, while 9 indicates an extreme level of importance of one over the other. The layers of toposhape, wetness index, solar radiation, soil pH, slope, aspect, DEM, annual mean precipitation and annual mean temperature, according to the AHP expert evaluation, have a value of 0.199, 0.217, 0.230, 0.234, 0.316, 0.382, 0.205, 0.575, and 0.273. Modeling the nine variables in conjunction may represent the potential for reforestation with *Acer monspessulanum* in the study area.

However, the weight of each variable might be different. According to an Analytic Hierarchy Process (AHP), the annual mean precipitation of the environment constitutes the most important factor to represent reforestation, second in importance is the local aspect and third is the slope. The habitat with low slope, the low of the wetness index, on the north-facing aspects, the high solar radiation and neutral soil provide better conditions for reforestation with *Acer monspessulanum*. To perform modeling of the nine variables with explicit rules, an approach that can solve the problem is required. Among the most flexible modeling techniques, the fuzzy logic that proposed by Zadeh [35] was the first one. Fuzzy logic provides the ability to model in exact, imprecise and ambiguous entities, and relationships between different model components [3]. The habitat is an indeterminate geographical entity that is not characterized by a sharply defined boundary, fuzzy logic was chosen here as the modeling approach. The certainty of an entity belonging to a fuzzy set is derived from a fuzzy membership function. The degree of membership takes values from 0 to1, with 1 representing complete certainty of membership and 0 representing non-membership. The fuzzy membership function can have different shapes. Triangular, trapezoidal and bell-shaped functions are often seen. In this paper we will not discuss when to choose which shape. You can find a discussion on this in [3]. The ecological requirements of *Acer monspessulanum* has been described by Ellenberg [10], summarized in Table 1.

MCE

The general procedure of MCE included several phases. First, the relevant criteria (Factors and constraints), Eastman [9] were established [6]. Using the above mentioned factors/ variables as criteria, a pair wise comparison matrix was constructed. Although a variety of techniques exist for the development of weight, one of the most promising techniques is the pair wise comparison matrix developed by Saaty (1980) in the context of a decision making process known as the Analytical Hierarchy Process [8]. The comparison concerns the relative importance of the two criteria involved in determining the suitability of the stated objective [8]. Ratings were provided on a nine-point continuous scale, which ranges from 1 to 9. This method has been tested theoretically and empirically for a variety of decision making situations, including spatial decision making and has been incorporated into a GIS based decision making procedure [20]. In the procedure for MCE using weighted linear combination, it is necessary that the weights sum to 1 [25]. The MCE method used weighted requires that

Table 2. Specific suitability level per factor for the *Acer monspessulanum*

Factor	High suitability
Soil pH	6.5 - 7
Slope	0- 65%
Mean annual precipitation	400- 1500 mm
Altitude	1000- 2000 m
Mean annual temperature	5 ºC
Aspect	North, North-eastern or North-western aspect
Solar radiation	Warmth area
Wetness index	Dry site
Toposhape	Flat and hillside

all factors must be standardized [9] or transformed into units that can subsequently be compared [20]. In this study, the factor maps were ranked according to Saaty᾽s underlying scale with values 1 to 9 by discussion with local crop specialist. The purpose of weighting is to express the importance or preference of each factor relative to other factors affect reforestation. Factor established in this phase are not unique, but they are the most relevant. Expert opinion of species specialization was very important in this phase. Researchers of arboriculture have identified the following variables as relevant to suitable *Acer monspessulanum* growing areas: annual mean precipitation, annual mean temperature, DEM, slope, aspect, solar radiation, wetness index, toposhape, soil texture and soil pH as well as a relevant set of criterion.

According to expert᾽s opinion and literature review, a specific suitability level per factor for *Acer monspessulanum* species was defined (Table 2).

RESULTS AND DISCUSSION

Image Processing Result

The land use/cover map derived from Landsat satellite image that was obtained from the supervised classification which is shown in Figure2. This map shows 5 land use/cover types, which were produced from the combination of the multi spectral bands corresponding to green, red and near infrared (G, R, NIR) which were found to be appropriate to identify the land use/cover types in the study area. Image processing, by means of the supervised classification approach and the maximum likelihood algorithm, ensured that an acceptable percentage of the classified pixels were correctly classified [25].

MCE process and overlaying land use/cover and suitability map for *Acer monspessulanum* species

The land suitability analysis was carried out in two steps. The first step comprised of delineating the total arable land into different suitability classes using AHP through MCE, as above. In the second step, the land use/cover map derived from the satellite data was overlaid and the extent of each suitability level per land use/cover class was calculated. The pair-wise comparison matrix was constructed with the 9 important factors mentioned previously and the relative importance of each one was measured through the calculation of weights. Fifteen experts were then asked for their evaluation of the importance of the variables in terms of its influence on reforestation. The

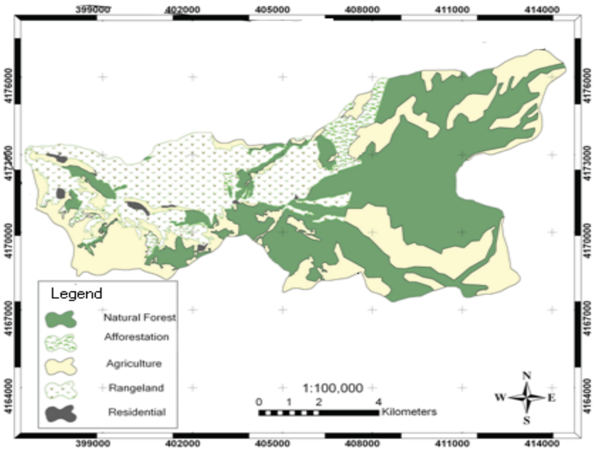

Fig.2. The land-cover map in the case study

Table 3. The weighting matrix for land sustainability assessment

Criteria	Weight
Mean annual precipitation	0.575
Aspect	0.382
Slope	0.316
Mean annual temperature	0.273
pH	0.234
Solar radiation	0.230
Wetness index	0.217
Altitude	0.205
Toposhape	0.199

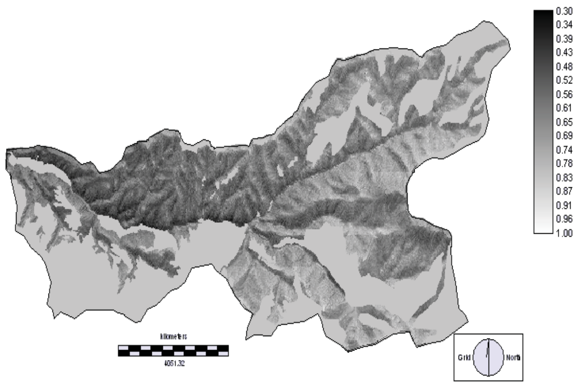

Fig.3. Map of suitable areas for *Acer monspessulanum* in the Gharnaveh watershed of Golestan Province, Iran.

aggregated judgements of the experts are presented in Table 3. As Table 3 shows, mean annual precipitation was evaluated as a more important with a 0.575 weighting, followed by aspect with 0.382. Toposhape obtained the lowest weighting 0.199. At first map of factors were designed, afterward weighting were performed and then the physical suitability map at three suitability classes was evaluated for the *Acer monspessulanum* species (Figure 3). According to Figure 3 the number of hectares available to each suitability class is as follows: highly suitable 542.43 ha, moderately suitable 4508 ha and low suitable 1056 ha which represent 8.8%, 73.8% and 17.29% of land area respectively. As the figure increases towards 1, the suitability increases. The results of this investigation were adequate in terms of the evaluation criteria set used here because, in a particular project, only a limited number of land qualities need be selected for use in evaluation [11]. Analyzing the crossed suitability and land use/cover maps indicated that the very high suitability level was located principally in the current forest areas. In this investigation, the evaluation criteria were selected taking into considering the species requirements regarding local conditions. In this MCE, the factors were selected based on afforestation knowledge of local experts and reviews of existing literature. Such an approach produced valuable information about the relative importance of the factors that were evaluated and could be a useful precedent for future studies of *Acer monspessulanum* and other species.

CONCLUSION

Due to competition between human activities and reforestation for the same habitats in many areas of Iran, it is important to be able to identify the most suitable areas for reforestation at present. Geographical Information Systems play an important role in our study as a platform for the preparation, management and representation of spatial information [22]. Combining the potential of GIS with the AHP multicriteria analysis enables us to understand the potential value of the *Acer monspessulanum*.

The model offered here can be easily modified and has relatively small input data requirements. This enables the model to be implemented in other parts of Iran, always bearing in mind that the conditions of study area should be concerned. Furthermore, its results could be used as input for other types of analysis. It is interesting to report some similarities between the results obtained in this study and those provided by [4], who used multicriteria evaluation (MCE) to determine the most suitable land for Eucalyptus plantation. Finally, the model presented here for land suitability assessment is an interesting line for future research. Lexer [19] and Ruger [29] proposed three areas must be considered to identify land suitability for species including an area of high suitability, medium suitability and low suitability. So, land suitability for planting

Acer monspessulanum species with high suitability, medium suitability and low suitability was identified in our survey.

The present study provides a methodological approach to assessing the suitability of lands for reforestation. Introducing native species as a reforestation tool can be a crucial step to combat desertification and degradation in the areas. However, their use in reforestation must be carefully evaluated considering their effect on microhabitat conditions and other aspects of their ecology. Our research suggests that MCE models are a useful research tool and a valuable aid for the reforestation decision making process. The MCE approach allows forest managers to determine the land suitability of reforestation with tree species. The introduction of *Acer monspessulanum* can be of interest for various reasons, including the production of fodder, fuel wood, furniture, and the positive effects on soil and vegetation. Global climate change research has shown that warming trends are correlated with the rise in greenhouse gases, most notably, carbon dioxide [16]. Forest plays a significant role in offsetting CO2 emissions by converting CO2 into wood through photosynthesis and storing it for decades or centuries.

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