

Ecological assessment of shallot (*Allium altissimum* Regel) habitats using fuzzy logic approach (case study: Khorasan Razavi, Iran)

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Abstract. Last decades, most ecological scientists focused on modeling of floristic distribution because of an observable decrease in plant communities as well as their habitat limits. In this paper, ecological necessities of *Allium altissimum* Regel (as a valuable medicinal and industrial plant) were modeled using a fuzzy and AHP (Analytical Hierarchical Process) model based on field studies and the literature in its habitats in Khorasan Razavi province, Iran, 2014–2015. Different ecological resources including sea level, aspect, slope, vegetation cover density, soil texture, distance from river, distance from access roads, distance from human habitats, land use, isohyet areas and climatic features of the study area plus AHP model were utilized in GIS environment to recognize the species habitat. The results showed habitats of Shallot through field studies and fuzzified maps basing on AHP model. The prepared suitability maps were divided into low, moderate and high quality classes and zoning maps were finally produced. The produced maps revealed 13 % (18.85 thousand square kilometers), 54 % (78.3 thousand square kilometers) and 33 % (47.85 thousand square kilometers) of the area in low, moderate, and high suitable classes, respectively, which are mostly located in cold semi-arid climates with an elevation more than 1200 meters that provides a managerial tool for policy makers of the studied area.

Key words. *Allium altissimum* Regel, multivariate assessment, AHP, Khorasan Razavi.

1. Introduction

Last decades, increased population growth has been resulted in an imposed pressure on natural resources concomitant with unmanaged exploitations and land use changes leading to ecosystem degradation [1], while irrecoverable damages has been happened in a global scale [2]. Consequently, we faced little intact areas in a major-

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ity of regions all over the planet [3]. Changes in vegetation patterns as a result of vegetation degradation is considered as a critical threat for biodiversity [4]. In fact, increased data on species extinctions has caused a global concern among the environmentalists [5]. Therefore, nowadays, integrated policies in environmental issues are mainly based on fully recognition of land capacities and its production capabilities which allow classifying species habitats for their suitability to exist [1]. Assessment of land suitability is a complicated process that requires considering multiple variables in which managers and policy makers confront a multivariate special analysis. Furthermore, uncertain nature of the information used in natural contexts makes the subject more critical. Hence, the managers applied more integrated methods to use natural resources. In this context, multivariable decision-making models solve the majority of these challenges. Therefore, multi- criteria evaluation (MCE) model was introduced as a tool for special decision making support systems.

In this paper, ecological necessities of *Allium altissimum* Regel in its habitat were evaluated through using fuzzy-AHP model, in order to suggest some managerial solutions to prevent the species from extinction.

2. Materials and methods

2.1. Studied area

The studied zone was Khorasan Razavi province with an area about 145 thousand square kilometers, during 2014–2015. The province is the fourth largest province in the north east of Iran located between 55–61 degrees of eastern longitude and 30–38 degrees of northern latitude (Fig. 1). The province is regarded as arid and semi-arid region in Saint-Martin-du-Var. Different environmental factors (parameters) including high mountains, desert depressions, far distance from sea, and different climatic fronts that enter the region from western, northern, north eastern, north western and southern parts of the country lead to ecosystem diversity in the studied area. A decrease in rainfall is seen from northern to southern parts so that the highest records are reported for Ghochan and Daregaz (304.9 mm annually) and the lowest records for Gonabad and Taibad (143.9 mm annually) [4]. Totally, northern ecosystems in the province reveal more biological diversities than fragile and sensitive southern ecosystems.

2.2. Criteria determination

The first step in each MCE model is to determine the measurable criteria on which the evaluation is settled and the ultimate decision will be made. According to previous literature and experts' opinions, the influencing criteria on *Allium altissimum* Regel distribution pattern were determined. Table 1 shows the criteria and the maps used in the model. It is worth mentioning that all data layers were transformed into UTM zone 40 rasterized format. IDRISI, ArcGIS ver. 9.3 software package and Google Earth online database were used to run the model in this study.

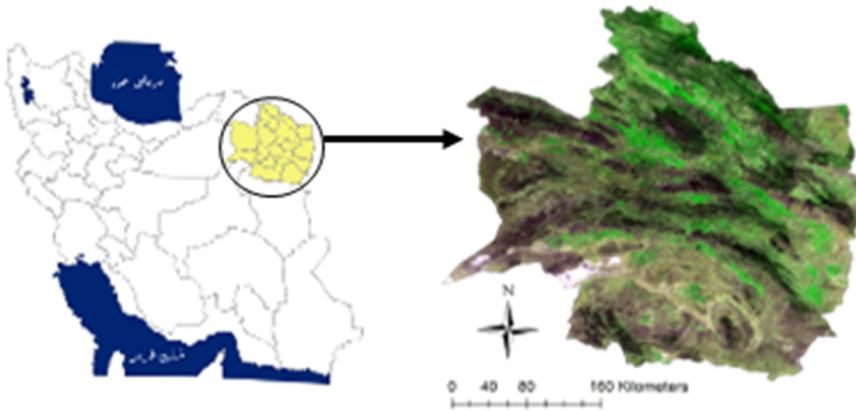


Fig. 1. Geographical location of Khorasan Razavi province

Table 1. Applied materials and maps

Materials and maps	Materials and maps
1. DEM regional radar (Survey Organization)	6. Use map (Organization of Forest, Rangeland and Watershed)
2. Topographic map of the area (1/50000)	7. Map pedology 1/250000 (Organization of Forest, Rangeland and Watershed)
3. Vegetation density layer of Modis sensor	8. Isolite map area (Meteorological Organization of Iran)
4. Map of urban areas and rural areas (Ministry of Interior)	9. Map of rivers, waterways and roads (1/50000) (Organization of Forest, Rangeland and Watershed)
5. Climate map (Organization of Forest, Rangeland and Watershed)	10. Gradient maps and digital elevation model for the area extracted from the map (DEM) in ArcGIS 9.3 software

2.3. Criteria of standardization

All the prepared maps are not comparable simultaneously because of their different natures (i.e. their scales or geographic unit). Therefore, they need to be standardized in order to be usable in the process of decision-making. Standardization, in this paper, was conducted through fuzzy logic methods. In this study standardization is based on linear function in fuzzy logic in bytes scale (0–255) by means of membership function; so when the score is higher, the factor is more suitable for habitat. It is necessary to determine the thresholds as well as the membership function's shape in order to fuzzify factor maps. Since there is no specific standards for evaluating *Allium altissimum* Regel habitat, experts' opinions and the literature were used to determine the threshold numbers. Four types of fuzzy membership

functions including symmetrical trapezoid, discrete, lowering—uniform linear and increasing—uniform linear were applied (Table 2).

Table 2. Maps of the threshold criteria and forms of their membership function

Shape and type of membership function	Efficiency	Factors
Symmetrical trapezoid	0–1400 = 0–255, 1400–1700 = 255, 1700–3200 = 255–0	Elevation
Lowering - uniform linear	-	Slope
Discrete	North = 255, West = 220, East = 180, South = 120	Aspect
Increasing - uniform linear	-	Density of vegetation cover
Lowering - uniform linear	-	Distance from the stream network
Increasing - uniform linear	-	Distance from access roads
Increasing - uniform linear	-	Distance from residential area
Discrete	2 = 230, 3 = 210, 4 = 170, 5 and 6 = 0	Land use
Discrete	2 = 240, 3 = 210, 4 = 180, 5 = 70, 6 = 30	Climate
Discrete	2 = 230, 3 = 200, 4 = 170, 5 = 150, 6 = 120	Pedology
Increasing - uniform linear	-	Isopluvial

To weigh the factors, paired comparison square matrix was firstly produced. Secondly, a 9-point continuous Likert scale (Table 3) and experts' opinions were applied to determine each factor preference. The incompatibility coefficient was calculated less than 0.1 which shows a good compatibility among the compared factors. Finally, the relative weights were entered into IDRISI software package that was calculated the ultimate weights for every factor [3] in order to begin a multiple criteria evaluation process from the species habitat.

3. Results and discussion

The results indicated that AHP can be regarded as an advantageous approach in regional managerial plans. Some of the advantages of this approach are flexibility, evaluating criteria and sub-criteria and ranking the listed attributes which can affect

studying of the site location and zoning the suitable lands for *Allium altissimum* Regel. Table 4 shows the AHP weighed factors. The incompatibility index was 0.09. The standardized maps were overlaid and suitability was calculated by using WLC approach in GIS environment. Finally, the suitability map was classified into high, moderate and low suitable classes.

Table 3. Degree of importance for paired comparison

9	7	5	3	1	1.3	1.5	1.7	1.9
Great	Very strong	Strong	Mediocre	Equal	Mediocre	Strong	Very strong	Great
(More) ← - - - - -				- - - - - → (Less)				

Sustainable development, especially in agricultural and environmental sectors that definitely leads Iran into economic growth, needs precise plans, which is settled on determining land ecological capacities. One of the natural capitals on which long-term plans could be settled, are medicinal plants including shallot (*Allium altissimum* Regel) which is the subject of study in this paper. Fuzzy AHP approach, in addition to experts’ opinions (as an effective way in solving environmental problems), is used to ecologically evaluate the species habitat in Khorasan Razavi Province, Iran. Factors relative weights were efficiently calculated through AHP model. The highest weights were dedicated to elevation from sea level, climate and distance from rivers, respectively. However, distance from human residencies and vegetation had the lowest scores.

Table 4. The results of weighted criteria

Weight	Criteria
0.2189	Elevation
0.0835	Slope
0.1365	Aspect
0.0128	Vegetation cover density
0.1592	Distance from the Waterways
0.0275	Distance from access roads
0.0156	Distance from Residential area
0.0245	Land use
0.1355	Climate
0.0476	Pedology
0.1276	Isopluvial
Consistency ratio = 0.09	

WLC approach was used to evaluate the suitable habitats of species. Each cell’s suitability was efficiently calculated in this approach. Figures 2 and 3 show ecological assessment raster layer of shallot and its map priority suitable habitat in the study area. Totally, 13% (= 1200050 ha) and 54% (= 6381312 ha) of the study area show

low and moderate suitability for the species to exist and the rest 33% (= 3859006 ha) are classified in highly suitable areas with the last generally located at semi-arid cold parts with more than 1200 meters from sea level. Local environmental policy makers can use the results of our study in order to efficiently manage, domesticate and conserve the species as a valuable medicinal plant. Based on field data (215 points where shallot existed) and habitat suitability map derived from fuzzy logic model, it was proved that 73%, 21% and 6% of the shallot observed in areas with high, medium and low habitat suitability, respectively, which indicates good accuracy of the model.

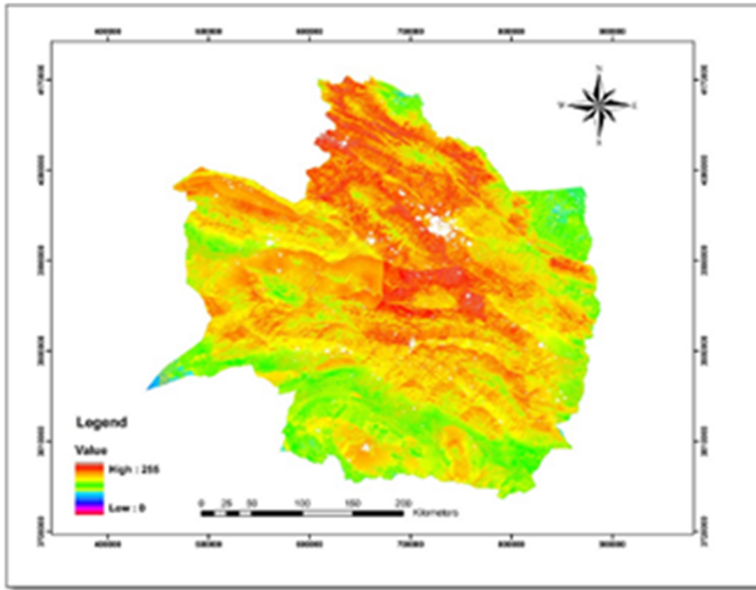


Fig. 2. Ecological assessment raster layer of shallot

4. Conclusion

This paper showed that GIS-based multicriteria evaluation approach in decision making programs is an outstanding solution for ecological problems; so that the obtained results revealed a significant concordance among model produced maps and the real field data. Uncertainty in environmental subjects is a source that forces policy makers to use fuzzy approaches in designing decision-making systems for ecological landscapes, since these are capable of involving multidimensional factors interactively. Furthermore, these approaches provide a systematic solution to determine a decision criteria and goals, involving measurable and immeasurable factors in their analysis and considering experts' opinion as a source of decreasing uncertainties. In addition, compared to other experimental models, fuzzy logic approaches are cheap and easy to run. Predictive modeling in a specific area aims to locate the

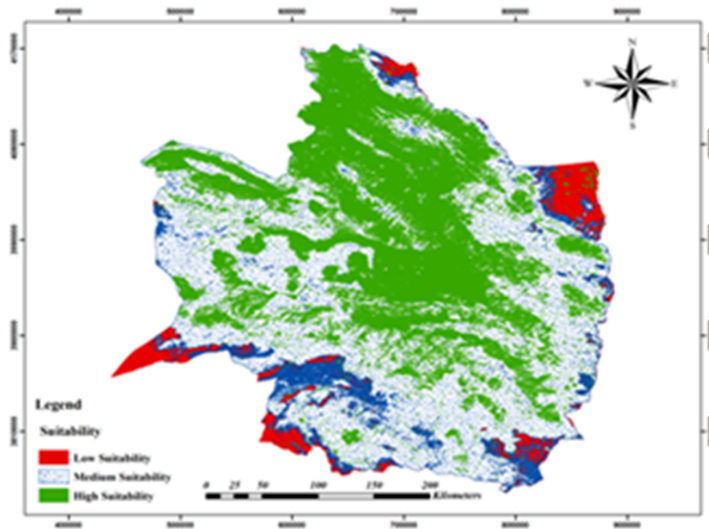


Fig. 3. Map priority suitable habitat of Shallot in the area

places where the ecological requirements of plant species could be provided or the portion of species potential distribution could be estimated.

Totally, 13% and 54% of the study area show low and moderate suitability for the species existence and the rest 33% are classified in highly suitable areas with the last generally located at semi-arid cold parts with more than 1200 meters from sea level. Local environmental policy makers can use the results of our study in order to efficiently manage, domesticate and conserve the species as a valuable medicinal plant. Predictive modeling of habitat distribution belonged to the plant species and identification of their potential habitats play important roles in the restoration of disturbed range lands. Modeling the range land plants habitat distribution map with GIS Accessories and statistical-Mathematical methods has been developed very much. Other view points, distribution patterns and ecological niche of many plant species in the range land ecosystems have experienced some considerable changes by the means of human activities and natural factors.

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