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Locating Ornamental and Medicinal Saffron Cultivation Based on AHP Analysis in GIS Environment in Ardabil Province

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Abstract

The ornamental and medicinal saffron with high economic value encompasses a great share of non-oil exports in Iran. As a result, identification of suitable areas for saffron cultivation in Ardabil province located in the northwestern part of Iran requires effective planning for expanding cultivation and production of this crop. Given the effect of various environmental factors on growth and yield of saffron, land evaluation process requires comprehensive spatial and descriptive information for the cultivation of this plant. Geographic Information System (GIS) allows taking advantage of this type of data and facilitates spatial analysis of collected data based on the identified models. In this study, multi-criteria decision-making (MCDM) and analytic hierarchy process (AHP) were used based on environmental ecological needs for saffron cultivation. Modeling and spatial analysis of data layers were performed in ArcGIS software. Research methods encompass data collection and entry, statistical calculations and analyses, criteria clustering and valuation, spatial modeling and integration of diverse information. Accordingly, land capability of Ardabil province was assessed for saffron cultivation. Final zoning map was prepared. The results showed effectiveness of hierarchical analysis in assessment of land capability for cultivation of saffron. According to this criterion, Ardabil province was divided into four parts as follows: 19.8% of this province had highly suitable capability (355429.8 ha), 26.7% had suitable capability (479291.7 ha), 29.3% had moderate suitability (525964.3 ha) and 24.2% had no suitability for growing this crop (434414.2 ha). As a result, it is recommended to cultivate saffron in the northern part of Ardabil (Moghan).

Keywords: Decision-making, Land capability, Multi-criteria, Spatial analysis, Zoning.

INTRODUCTION

In recent years, water deficit has become one of the most important problems in maintaining urban green space. In this regard, one of the approaches is the use of drought-tolerant plants with little water requirement and low agro-needs (Wolch *et al*., 2014). Saffron (*Crocus sativus* L.) is one of the important plants that could be cultivated in specific conditions. Saffron consists of some house plants with beautiful flowers, as ornamentals in home gardens, rock gardens, parks, and in wild nature where they are usually dispersed in vast groups and produce interesting sceneries of colorful flowers. Solid corms of saffron, which are covered within the sheath of different orientations and terminate to adventitious basal roots, keep saffron actively growing from autumn to late spring (Rashed-Mohassel, 2006). Saffron, or Red Gold, is growing in arid and semi-arid regions (Amirghassemi and Iranshahi, 2008). This plant belongs to the Iridaceae family which is basically growing in regions with low annual rainfall, cold winters, and hot summers. Iran is the leading country in saffron production with 47,200 ha cultivated area. Totally, about 160 tons saffron is produced in Iran annually (average yield is 3.4 kg ha^{-1}) (Kafi, 2006). The three-branch style of saffron flowers is the most important economic part of the plant (Sepaskhah and Kamgar-Haghighi, 2009) and is used in medication as anti-spasmodic, carminative, diaphoretic, all pains, light to moderate depression (Razavi and Hosseinzadeh, 2015). In order to improve agricultural productivity, it is essential to get information about the productivity of each plant in geographical locations.

To get maximum production suitable land, local environmental and geological conditions are prime necessity. Identification of suitable sites for cultivating agricultural crops requires consideration of different climatic conditions, topological environment and geophysical limitations (Kamkar *et al*., 2014). Therefore, accurate and recent land use/land cover (LULC) and other geophysical data should be considered for assessing environmental concerns (Deep and Saklani, 2014). Geospatial tools can be used to identify the suitable lands for the saffron cultivation on different criteria like soil quality, geology, drainage, topography of the place. This technique can also help to identify and prioritize the potential sites for the organic farming. Analytical Hierarchical Process (AHP) is used as a decision-making tool for the identification of suitable saffron cultivation sites. AHP was developed by Saaty (1980) for setting up a hierarchical model based on criteria and alternatives for representing the complex problems (Roig-Tierno *et al*., 2013). As a multi-criteria decision-making method, the AHP has been applied for solving a wide variety of problems that involve complex criteria across different levels, where the interaction among criteria is common (Feizizadeh *et al*., 2014). Weighted overlay along with the AHP gives a very promising result for the site suitability analysis of saffron cultivation. It can be used to multi-level hierarchical structure on different criteria and constraints (Triantaphyllou and Mann, 1995; Boroushaki and Malczewski, 2008). The method has steps to determine the relative importance of weights on each criterion before determining the final score (Bunruamkaew and Murayam, 2011). AHP is one of the promising methods used for the agricultural land suitability analysis based on individual criteria through quantitative analysis (Chen *et al*., 2010; Akinci *et al*., 2013). Pairwise comparison method is used to estimate the overall weight of the individual criteria or elements. Integration of AHP and GIS helps in decision support system by the creation of suitability maps. GIS is used as a decision-making tool for the site suitability analysis and for developmental activities (Khahro *et al*., 2014). Land use suitability mapping and its analysis is one of the most useful applications of the GIS (Javadian *et al*., 2011). Integration of GIS with multi-criteria evaluation methods reveals its extreme applicability to site suitability analysis. GIS technology is used to formulate different criteria maps which are used in AHP to construct the site suitability model for saffron cultivation (Shokati *et al*., 2016). The AHP is a multi-attribute weighting method, utilized to derive ratio scales from paired evaluation and to present objectivity in weight assignment. To derive the AHP weights, relevant criteria for cultivating saffron were prepared using AHP's pairwise comparison. It is believed that suitability assessment is an important approach to recognize areas with high potentiality for cultivating medicinal plants according to their physiological requirements. In this way, the goal of the paper is investigating the suitability of saffron cultivation in Ardabil province.

MATERIALS AND METHODS

Study site and dataset

The studied area is located in the north-west of Iran (38.25 14°N, 48.29 73°E). The total area of this region is almost 17951 km2. The area is limited to the Republic of Azerbaijan from the north, Guilan province from the south-east, Zanjan province from the south, and East Azerbaijan province from the east (Fig. 1).

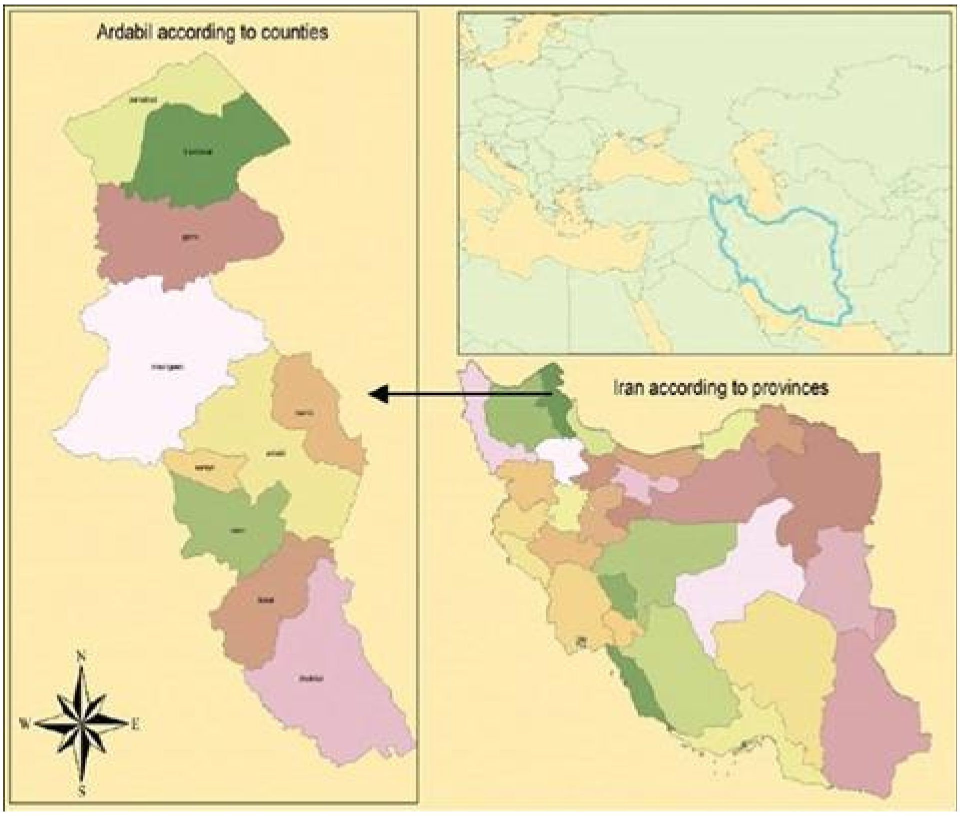

Fig. 1. The location of the studied area and stations.

Data on initial requirements for saffron phenology were identified and collected from different sources:

1.Data on climatic parameters such as rainfall, maximum, mean and minimum temperatures, relative humidity, number of daylight hours, evapotranspiration, and the number of frost days were collected from 15 meteorological stations;

2.Data were collected on height, slope and slope angle (topographic maps) and land use and pH of the soil at 1: 50000 scale;

3.SPSS, Excel, and GIS were used to analyze the collected data and plotted maps.

Based on these conditions, alternative crops tolerant to the water deficit are in policy and priority of decision makers and authorities. The results of this research could be a base for decision plans by identifying suitable area for cultivating saffron which is tolerant to the water deficit as well. The climate of this area is arid and semi-arid and the annual precipitation amounts to approximately 300 mm (Meteorological Organization of Iran, 2015). In order to model the suitability of saffron cultivation, the saffron plant ecological requirements criteria were considered as dataset which are described below. Further details about calculating and preparing each criterion are also represented in Table 4. Meteorological data were collected from 15 synoptic stations for a period of 15 years. This dataset was used to create maps of average precipitation, temperatures, sunny hours, evaporation, and humidity percentage, and soil temperatures at the depth of 5 and 10 cm. Digital topographical maps were used at a scale of 1:50,000 to create Digital Elevation Model (DEM) which was accordingly used to obtain slope and aspect maps, respectively. Land use/cover maps were derived from Landsat ETM $^{+}$ satellite images with a spatial resolution of 30 m based on image processing techniques (MANR, 2013).

Calculation of criterion weights

Criterion weights are the weights assigned to the goal and characteristic maps (Meng *et al*., 2010; Feizizadeh and Blaschke, 2013). In order to calculate criterion weights given in Equation (10), the AHP could rank the criteria based on their relative important degrees (Chen and Zhu, 2010). This mathematical function could analyze complex decision problems (Saaty, 1977). GIS-based AHP has become prominence due to its capability to coordinate an expansive amount of heterogeneous information, and because obtaining the required weights can be used even for a large number of criteria (Nekhay *et al*., 2008; Hossain and Das, 2010). Using the AHP, the indicators are organized in hierarchical order with the assigned 'weight' obtained from the 'pairwise comparison' procedure (Vukicevic and Nedovic-Budic, 2012). The pairwise comparison method employs an underlying semantic scale with values from 1 to 9 in order to rate the relative preferences for two elements of the hierarchy (Table 1). The pairwise comparison matrix for the objective level has the following form:

$$A = [a_{qt}] \quad (2)$$

where a_{qt} is the pairwise comparison rating for objective q and objective *t*. The same principles apply to the attribute level as well. At the attribute level, a pairwise comparison matrix is obtained for each of the objectives by comparing associated attributes, thus:

$$A_{(g)} = [a_{kh\ (q)}]\ for\ q = 1.2.\ \dots .\ p \quad (3)$$

where $a_{kh\,(q)}$ is the pairwise comparison rating for attribute *k* and attribute *h* associated with objective *q* (Boroushaki and Malczewski, 2008). The most critical step in the AHP is preparing comparison matrix. In our case, a nine-point continuous rating scale is adopted, which is shown in Table 1. Thus, the comparison matrix produced by this technique is a positive reciprocal matrix. Therefore, only the higher/lower triangular half which includes *n(nl)/2* elements needs to be filled in (Chen and Zhu, 2010). The maximum latent root of l Max in the comparison matrix A has an eigenvector of W; the estimation of criterion weights is to calculate eigenvector W, which makes:

$$AW = \lambda_{max}.\ w \quad (4)$$

The eigenvector is calculated as follows:

$$\bar{a}_{ij}\ \frac{a_{ij}}{\sum_{k=1}^{n} a_{kj}} \quad i, j = 1, 2, \dots, n \quad (5)$$

Then adding by row:

$$W\bar{i} = \sum_{j=1}^{n} \bar{a}_{ij} \quad i, j = 1, 2, \dots, n \quad (6)$$

Vector W= [W_1; W_2; . . . ; W_n] ^{T} is standardized as follows:

$$W_{i=} \frac{\bar{w_i}}{\sum_{j=1}^{n} \bar{w}_{ij}} \quad i, j = 1, 2, \dots, n \quad (7)$$

Eigenvector Wi = $[W_1, W_2 . . . W_n]^T$ is obtained. But, consistency verification is necessary, and maximum latent root ƛMax is calculated firstly as follows:

$$\lambda_{max} = \sum_{j=1}^{n} \frac{(AW)i}{nWi} \qquad (8)$$

Where (AW_i) represents the *i*-th element in AW, and consistency index (CI) is calculated as follows:

$$CI = \lambda_{max} - n/(n-1) \qquad (9)$$

The consistency ratio (CR) is calculated with a random consistency index (RI) as follows:

$$CR = \frac{CI}{RI} \qquad (10)$$

Table 1. Scales for pairwise comparisons (Saaty and Vargas, 1991).

Intensity of importance	Description
1	Equal importance
3	Moderate importance
5	Strong or essential importance
7	Very strong or demonstrated importance
9	Extreme importance
2,4,6,8 Reciprocals	Intermediate values Values for inverse comparison

Table 2. Random inconsistency indices (RI).

Number of criteria	1	2	3	4	5	6	7	8	9	10	11	12
R1	0	0	0.85	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.52	1.54

Note: Adapted from Saaty (1980)

Table 3. Pairwise comparison matrix for dataset layers of susceptibility areas analysis.

Factors	1	2	3	4	5	6	7	8	9	10	11	12
(1) Mean temp.	1	3	0.2	0.33	0.5	2	2	2	0.5	2	3	3
(2) Min temp.		1	2	0.5	0.33	0.5	0.5	2	2	2	0.5	2
(3) Max temp.			1	0.52	0.33	3	2	0.5	2	2	2	0.5
(4) Precipitation				1	0.5	0.5	0.33	0.5	0.5	2	2	2
(5) Elevation					1	2	3	2	3	2	2	2
(6) Humidity						1	1	2	0.5	0.33	0.5	0.5
(7) Evaporation							1	2	3	3	0.5	2
(8) Sunny hours								1	2	2	3	3
(9) Aspect									1	2	2	3
(10) pH										1	3	3
(11) Slope											1	2
(12) Land type												1

When many pairwise comparisons are performed, some inconsistencies may typically arise. The CR is a very important indicator for achieving the reliability of an individual's pairwise comparisons. Then, the consistency ratio (CR) is calculated as the ratio of consistency index and random consistency index (RI). The RI is the random index representing the consistency of a randomly generated pairwise comparison matrix (Gorsevski *et al*., 2006). It is clearly demonstrated in Table 2 that the RI depends on the number of elements being compared. If CR ≤ 0.1, the pairwise comparison matrix is considered to be consistent enough. In the case of CR ≥ 0.1, the comparison matrix should be improved (Boroushaki and Malczewski, 2008). To achieve a pairwise comparison matrix in our study, 20 'expert' opinions informed the relative weight of the factors and the criteria involved (Table 3). Scaling of criteria and obtaining value range of each criterion is also determined as 13 questionnaires separately filled out by experts during this step.

Table 4. Saffron plant agro-ecological requirements.

Precipitation	X >200 mm	(Alavi-Zadeh *et al*., 2013)
Mean Temp.	12-15 ˚C	(Alizadeh *et al*., 2009)
Elevation	1000-1800 meters	(Kafi, 2006)
Relative Humidity	60-50 percentage	(Amirghassemi and Iranshahi, 2008)
Slope	0-13	(Razavi and Hosseinzadeh, 2015)
GDD	410-600	(Farajzadeh *et al*., 2007)
Sunny hours	More than 225 h	(Kafi, 2006)
pH	7-8	(Dhar, 2000)
Land type	Flat, Southeast, South, Southwest, Northwest	(Kumar *et al*., 2009)
Evaporation	X< 85% evaporation from A class pan (lowest amount evaporation)	(Alavi-Shahri *et al*., 1994)

RESULTS AND DISCUSSION

Precipitation

The water requirement of saffron plants would be supplied by late autumn, winter and spring precipitations or supplementary irrigations. However, early precipitation or irrigation before the flowering of saffron may stimulate plant vegetative growth (Sepaskhah and Kamgar-Haghighi, 2009) and elongation of this stage will increase the risk of late-autumn precipitations or freezing which could decrease the yield. According to scale of classifying to each criterion represented in Table 5, areas with high suitability for saffron cultivation included 49.0% (87,959,900 ha) of the total studied province, and 40.6% (54,930,060 ha) had suitable conditions. Based on results, about 12.6% was identified as unsuitable areas for this purpose (14,181,290 ha). In addition, west, north -west and south-east of Ardebil province had minimum precipitation rate for this purpose (Fig. 2).

Mean, maximum and minimum temperature

Temperature is the most important environmental factor controlling growth and flowering in *Crocus* species (Benschop, 1993). The influence of a constant temperature regime on flower formation of saffron is quite important. As more difference between day and night temperatures (as maximum and minimum temperature, respectively) could well induce flowering of this plant, thus areas with relatively high day temperature and low night temperature were more important in this study. According to Figs. 3, 4 and 5, the northern regions (around Parsabad and Biliehsavar cities) had suitable thermal conditions for the cultivation of the saffron plants.

About 51.9% (89,216,470 ha) of this province had a highly suitable mean temperature, 42.7% had a highly suitable maximum temperature (18.21-21.23˚C) and 51.3% had a highly suitable minimum temperature (5.9-8.80˚C). An average of 6.3% of the area (11,309,130 ha) would

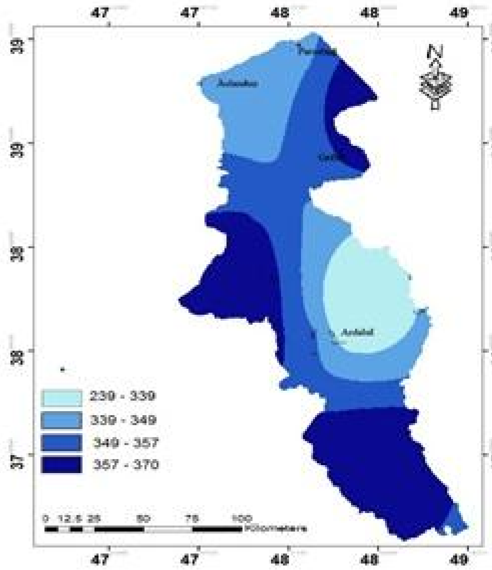

Fig. 2. Map of precipitation during October and November.

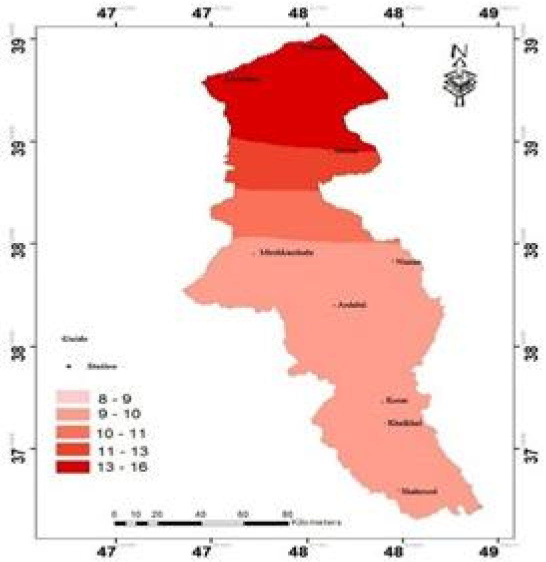

Fig. 3. Map of mean temperature during October and November.

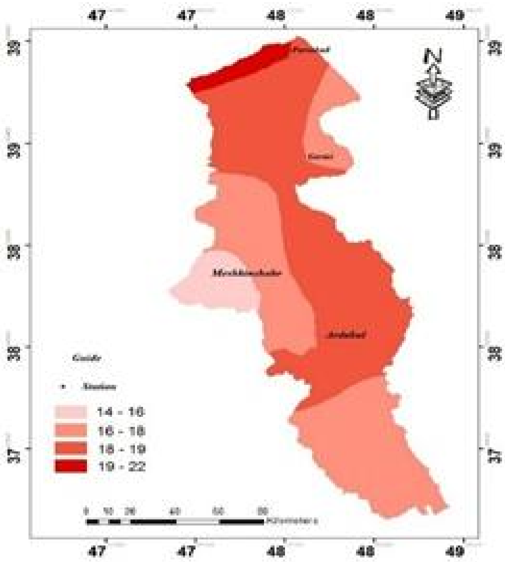

Fig. 4. Map of maximum temperature during October and November.

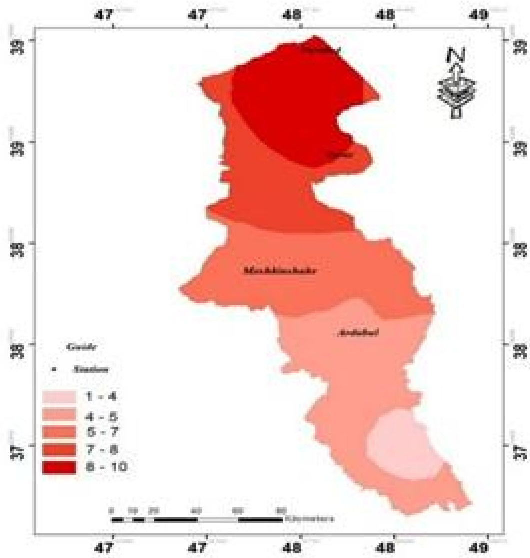

Fig. 5. Map of minimum temperature during October and November.

fail to supply the thermal requirement of the plant (Table 5). Mashayekhi *et al*. (2006) assessed the effect of environmental temperature on the flowering behavior of saffron. The results indicated that the mean and minimum temperatures were the most important driving forces to determine flower emergence and flower initiation in saffron, respectively.

Elevation and relative humidity percentage

The altitude or elevation of the land from sea level influences plant growth and development primarily through temperature effect. Ardabil mountainous province elevation varies from flat to mountains altitudes where south-west, south-east and around north-west (around Meshginshahr and Khalkhal cities) of this province could provide optimum saffron elevation requirement (Fig. 6). As 34.6% of the land's elevation vary between 1373-4811 meters above sea level. Areas with higher precipitation have higher relative humidity, but it is well-known that areas with low humidity percentage are more suitable for saffron growth (Alavi-Zadeh *et al*., 2013). As such, areas with relative humidity percentage of 50-60% were categorized as susceptible areas. According to Table 5, about 54.9% of this province had highly suitable areas. Also, the west of Ardabil had less than 58-63% of relative humidity (Fig. 7).

Table 5. Weighting of the effective parameters underpinning saffron cultivation based on AHP.

Effective parameters in saffron cultivation	Relative weight	Factors	Relative weight	Sub-factors	Relative weight	Final weight	Hectare
Topography	0.073	Elevation	0.312	Suitable	0.659	0.015	118297090
				Moderate	0.282	0.006	50621820
				Unsuitable	0.059	0.001	10591090
		Slope	0.490	Highly suitable	0.507	0.018	91011570
				Suitable	0.280	0.010	50262800
				Moderate	0.157	0.005	28183070
				Unsuitable	0.055	0.001	9873050
		Aspect	0.198	Highly suitable	0.540	0.007	96935400
				Suitable	0.299	0.004	53673490
				Moderate	0.107	0.001	19207570
				Unsuitable	0.055	0.001	9873050
Land and soil coverage	0.257	Land type	0.143	Highly suitable	0.521	0.019	93524710
				Suitable	0.311	0.011	55827610
				Moderate	0.114	0.004	20464140
				Unsuitable	0.054	0.001	9693540
		pH	0.571	Highly suitable	0.490	0.071	87959900
				Suitable	0.306	0.044	54930060
				Moderate	0.079	0.011	14181290
Climate	0.670	Min temp.	0.300	Highly suitable	0.513	0.103	92088630
				Suitable	0.257	0.051	46134070
				Moderate	0.157	0.031	28183070
				Unsuitable	0.073	0.014	13104230
		Mean temp.	0.223	Highly suitable	0.519	0.077	93165690
				Suitable	0.268	0.040	48108680
				Moderate	0.151	0.022	27106010
				Unsuitable	0.063	0.009	11309130
		Sunny hours	0.097	Highly suitable	0.555	0.036	99628050
				Suitable	0.270	0.017	48467700
				Moderate	0.116	0.007	20823160
				Unsuitable	0.059	0.003	10591090
		Precipitation	0.079	Highly suitable	0.490	0.025	87959900
				Suitable	0.306	0.016	54930060
				Moderate	0.126	0.006	22618260
				Unsuitable	0.079	0.004	14181290
		Max temp.	0.058	Highly suitable	0.497	0.019	892164.7
				Suitable	0.268	0.010	481086.8
				Moderate	0.154	0.005	276445.4
				Unsuitable	0.081	0.002	145403.1
		Humidity	0.028	Highly suitable	0.549	0.010	98550990
				Suitable	0.281	0.005	50442310
				Moderate	0.115	0.002	20643650
				Unsuitable	0.056	0.001	10052560
		Evaporation	0.036	Highly suitable	0.498	0.012	89395980
				Suitable	0.297	0.007	53314470
				Moderate	0.139	0.003	24951890
				Unsuitable	0.066	0.001	11847660

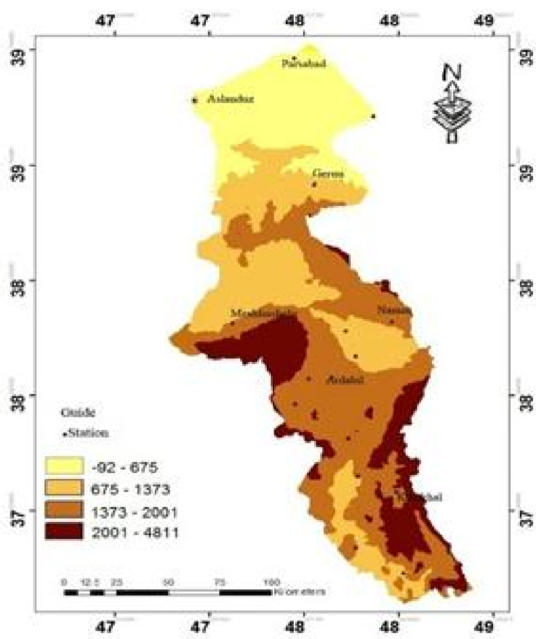

Fig. 6. Map of digital elevation model of Ardabil province.

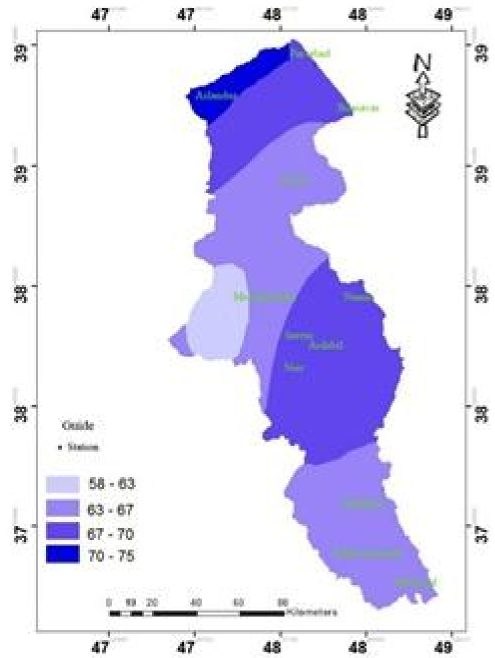

Fig. 7. Map of relative humidity percentage during October and November.

Evaporation

According to Fig. 8, the south-east of Ardabil had higher evaporation ratio which indicates that 55.14% of this area had more than 100 mm evaporation during October and November (Table 5). High evaporation ratio results in lower water availability in the soil. Previously, Alavi-Shahri *et al*. (1994) indicated that high evaporation ratio in saffron plant cultivation leads to a significant reduction of its yield as optimum evaporation was 85% from class A pan. Similar results were also found by early researchers (Eftekharzadeh-Maraghei, 1994; Azizi-Zohan *et al*., 2009) when they revealed that higher irrigation intervals result in the loss of saffron yield. Based on this assumption, areas with higher evaporation rate were given lower value (Table 5).

Sunny hours

Saffron plants grow poorly in shady conditions and grow best in direct sunlight. Thus, planting is best done in fields with a slope towards the sunlight (i.e., southward sloping in the northern hemisphere). Thereby, in this study, regions with high sunny hours get more value and also high influence priorities resulted from agricultural experts' opinions confirmed this issue (Table 5). Areas with high sunny hours (208-236 hours) included 55.5% of Ardabil province (Table 6) which is mostly placed in the east, southwest and southeast of this region (Fig. 9). Khalkhal, Khoresh Rostam and Hashjin counties had the highest sum of sunny hours, whereas 16.10% of this province especially Germi, Bilesavar and Parsabad cities had the lowest values (Fig. 9).

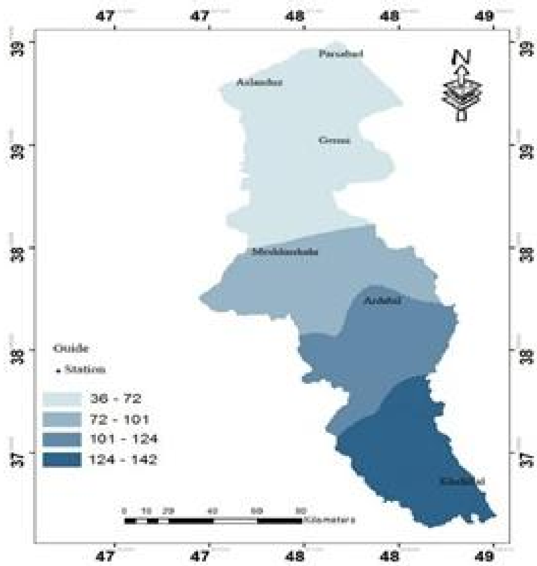

Fig. 8. Map of average evaporation during November and October.

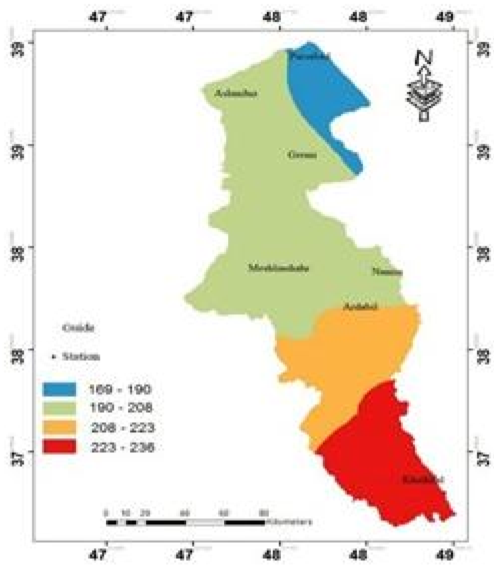

Fig. 9. Map of snyun hours during October and November.

Table 6. Group characteristics of saffron-prone areas in Ardabil province.

Weight factor	Capability description	Cover area (%)	Cover area (ha)
1	No capability	24.2	434414.2
3	Moderate capability	29.3	525964.3
5	Suitable capability	26.7	479291.7
7	Highly suitable capability	19.8	355429.8

Slope, pH and aspect

The results in Table 5 indicated that 73.37% of Ardabil province had a pH in the range of 6.50 -8.60 but just 19.93% had and unsuitable pH for this plant. As shown in Fig. 10, almost south of the province, margins of Noaur Lake (due to the high concentration of NaCl), the south of Ardabil city and southeast of the studied province had unsuitable pH. According to Tables 5 and 6, the slope of 75.49% of Ardabil province varies in the range of 1-13.5°. As Fig. 11 indicates, most of the studied area had an acceptable slope and only 7.13% of the mountainous area was unsuitable for the cultivation of this plant. The west, south and southeast of this region which have more flat areas are suitable for getting more sunshine and optimum temperature. Lower slope increases the penetration of water and soil moisture storage and in the critical period of growth, water supply solves the problem of water deficit (Alavi-Zadeh *et al*., 2013). In the northern hemisphere of the earth facing south and horizontal surfaces always have maximum power of the sun at noon. The eastern slopes compared to the southern slopes take advantage of the radiation in the earlier morning. But, western slopes receive more radiation than the southern slopes in the afternoon. So, in this study, the southern, western and eastern slopes were more appropriate for saffron plant cultivation (Fig. 12).

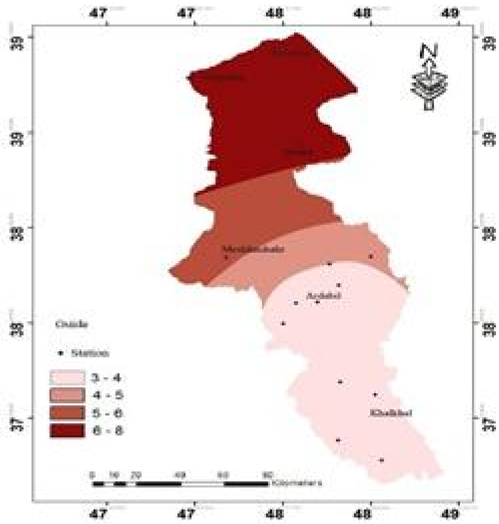

Fig. 10. Map of soil pH in 2016.

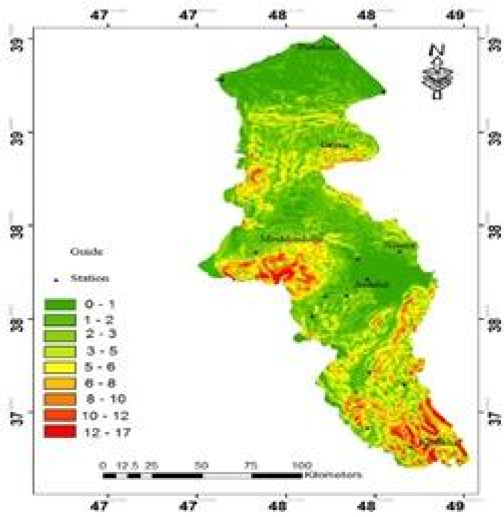

Fig. 11. Map of slope of Ardabil province.

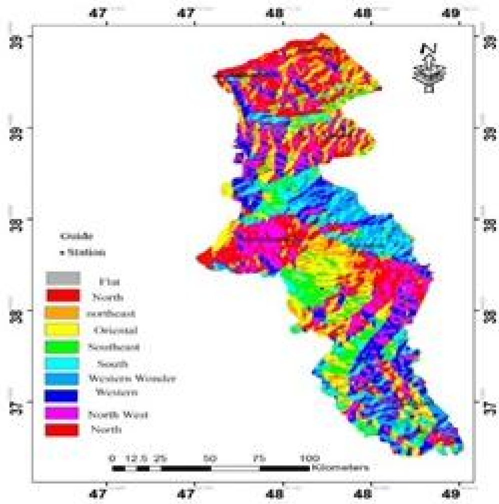

Fig. 12. Map of aspect of Ardabil province.

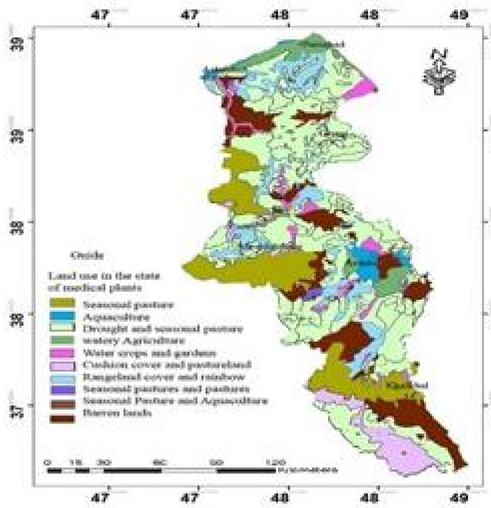

Fig. 13. Map of land type of Ardabil province.

Land type

The most suitable land type is agricultural land which covers a large proportion of the studied area (Fig. 13). According to Table 5, the northern regions (around Parsabad and Biliehsavar cities) had suitable land use conditions for the cultivation of the saffron plant. About 52.1% (93,524,710 ha) of this province was highly suitable for agronomical operations that is suitable for saffron cultivation. The soil and geology type of the area is equally important for saffron cultivation. The younger alluvial soil was found to be the most suitable for the saffron cultivation because it has clay and good capacity to bound water (Akinci *et al*., 2013). The Moghan region in Ardabil province is one of the important regions for agriculture, especially crops, and the soil of this region is mostly alluvial (Azizi-Zohan *et al*., 2009). Soil texture is an effective factor influencing root development so that unsuitable texture could inhibit the growth of the roots (Sadeghi *et al*., 2014).

AHP

Considering the important factors influencing plant growth and yield, analytic hierarchy process (AHP) makes a chance for weighting and finding the importance of the studied factors (Table 5) and finally could suggest the best regions for the cultivation of saffron. As such, the final map of saffron plant cultivation feasibility was prepared using the opinions of the agricultural scientists and a questionnaire. According to Fig. 14, Germi, Parsabad, Aslandoz and Bilehsavar regions had high potential to produce saffron. Although some parts of Khalkhal, Khoreshrostam, Shahrod and Kosar regions had a lower potential for this purpose, other parts of this province had moderate suitability for the cultivation of saffron while there will be an expected decrease in yield compared to the regions with high susceptibility conditions. All in all, 19.8% of this province had highly suitable capability (355,429.8 ha), 26.7% had suitable capability (479,291.7 ha), 29.3% had moderate suitability (525,964.3 ha), and 24.2% had no suitability for the cultivation of this plant (434,414.2 ha). In this study, there was no region that could supply all plant requirements to produce the highest possible yield. Moreover, there was no region completely unsuitable for the cultivation of this plant (Table 6).

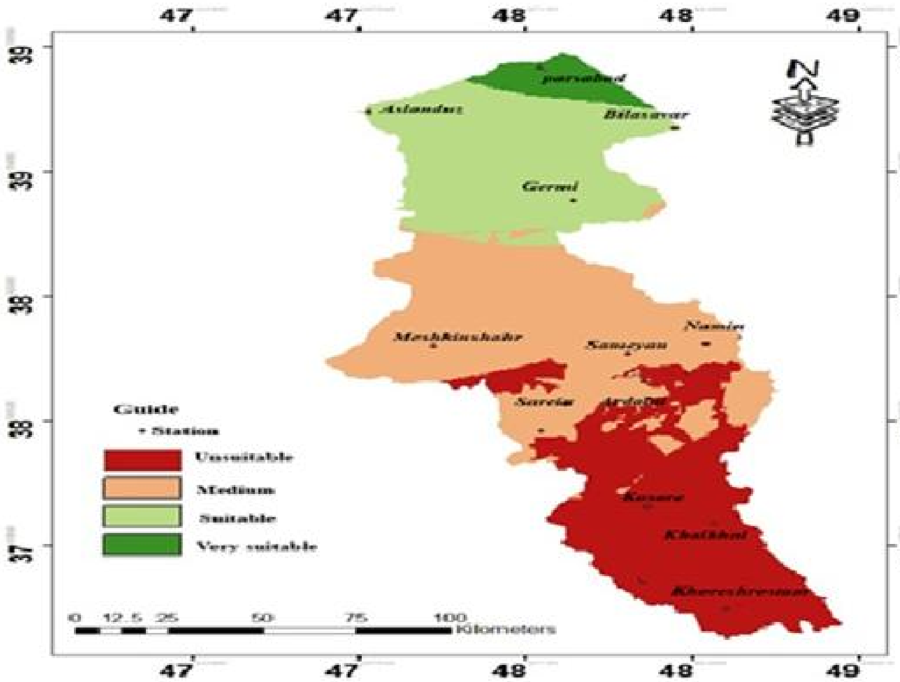

Fig. 14. Suitable areas for cultivation of saffron based on AHP technique.

As the main goal of the paper is creating a new attitude and knowledge about saffron cultivation in Ardabil province, so, the evaluation of the areas under cultivation of saffron during 2015 could be useful for better understanding of this issue. As shown in Fig. 14, farmers of Bilehsavar and Parsabad regions seem to be well aware of the possibility of cultivating this plant as these areas account for most saffron farms of this province. The lands of the Germi and Aslandoz regions in comparison of the Bilehsavar and Parsabad regions are less planted with saffron despite their high potential for saffron production. Unlike these regions, the farmers of the Khalkhal and Meshginshahr regions seem to be well aware of this fact that these regions have low suitability for cultivating saffron plant as the least cultivated areas belong to these regions. Also, given the land cover of Ardabil (Fig. 13), it could be found that the Shahrod and Khoreshrostam regions have moderate and low range lands and could make better use of these natural resources and develop their agricultural crops by cultivating saffron (Table 6).

With respect to the factors influencing yield and quality of the saffron crop, it was found that as the length of daylight starts to decrease in autumn, sunny hours could well induce the flowering of the saffron plant by increasing the differences between day and night temperatures. Thereby, among the important factors affecting this plant cultivation, the sum of sunny hours which influences temperature is the most important factor for saffron flowering (Table 5). Also, irregular precipitation (rate and distribution) could affect the quality and yield of saffron by stimulating vegetation stage, so it is considered as a factor limiting saffron production.

CONCLUSION

The selection of medicinal plant species adapted to the arid and semi-arid areas and the better use of natural resources with higher efficiency in these regions are very important for the sustainable agriculture. As we discussed in Introduction, one of the first steps to grow any plant is to consider regions and plant requirements. AHP uses a combination of the prepared dataset to suggest the best regions for the cultivation of an individual plant. This study evaluated Ardabil, collected the important factors that influence saffron cultivation and matched them with plant requirements. It was found that this province had a high potential for the production of saffron and that the Germi, Parsabad, Aslandoz and Bilehsavar regions are very suitable for this purpose. Also, employing the GIS spatial analysis, we identified areas with a high potential for the saffron crop production. However, saffron in these areas may be affected by other factors which were not evaluated, such as soil parameters and could make partial contradiction with the reality. So, we acknowledge that the application of sensitivity and uncertainty analysis would provide more accurate results which is going to be performed in future works. By taking the advantage of results from current research, our future work will focus on applying GIS spatial explicit sensitivity and uncertainty analysis for GIS-MCDA-based suitability assessment. Applying this approach would lead to the assessment of the reliability of results spatial and the measurement of the accuracy of results in each spot. The results obtained from this research can be used as the basis for decision plans in managing water scarcity at this basin and are of great importance for regional planning and decision-makers for understanding the physical conditions of Ardabil and its potentiality for saffron growth.

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