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Suitability assessment of Saffron cultivation using GIS based multi-criteria decision analysis approach; study area: East-Azerbaijan province

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Abstract

In the way of finding economic and tolerable plant to the arid and semi-arid climatic conditions and prevent desertification in these areas, this study aims to assess Agro-climatic suitability for producing Saffron in East-Azerbaijan province based on Geographic Information System (GIS) spatial analysis technique. For this goal, several criteria including soil conditions, climatological indicators, topography situation and agro-climatology criteria were taken into account of modeling process. For this to happen, standardization process was performed on criteria and weighting process was done by using of Analytic Hierarchy Process (AHP) approach. GIS based Multi-criteria Decision Analysis (MCDA) was employed for weighted overlapping of indicators and results were achieved based on GIS-MCDA method. Initial results indicated that East-Azerbaijan province has potential for cultivating of Saffron. Our research results indicated that about 42.7 percentage (1954416.9 ha) of this province has high suitability for Saffron producing. While, about 55.4 percentage (2537492.0 ha) of the study area has moderate suitability. In addition, about 1.8 percentage (84643.2 ha) of the study area represents low suitability. The results also indicated that, sum of sun hours and precipitation were supposed as important and limiting factors in the cultivation of this plant respectively. The founds of this research are great of importance for the purpose of regional planning in East-Azerbaijan province and also important in terms of developing methodology for precision agriculture which is one the main aspects of modern agriculture.

***Keywords**:* Analytic Hierarchy Process; Climate; *Crocus sativus;* GIS; Suitability assessment

1. Introduction

Medicinal plants are known as important resources of medicine. Reports indicated that medicinal plants are widespread and because of their availability, about 80% of the Asian populations were used these plants as primary health care (Kiran Kumari *et al*., 2012). As food and drug demand projected to increase in the future, associated destruction of natural resources from this sector will also rise (Fischer *et al*., 2002). Thereby cultivation and trade of medicinal plants are getting more attraction (TITZ, 2004). However, the farming of most of them is limited to scant hectares of lands in various regions of East-Azerbaijan province, Iran.

Saffron is one of the important plants could be cultivated in specific conditions. Saffron (*Crocus sativus* L.) or Red Gold is growing in arid and semi-arid regions (Amirghassemi and Iranshahi, 2008). This plant belongs to Iridaceae family which is basically growing in regions with low annual rainfall, cold winters and hot summers. Iran is leading country in saffron production with 47200 ha cultivated area. Totally, about 160 tons Saffron are producing 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 parts of the plant (Sepaskhah and Kamgar-Haghighi, 2009) and in medication is used as anti-spasmodic,

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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 productivity of each plant in geographical locations. In this regards, using the capability Geographical Information System (GIS) is a novel approach which leads to spatially examine the capability of each area for cultivating agricultural crops (Mennecke and Lawrence, 2001). Recent progress in GIS leads to analysis whether crop can be cultivated geographical area and what would be the rate of productivity based on the physical condition that an area holds (FAO, 2006). In particular, by using of this technique stakeholders, farmers, researchers, agricultural extension services, policy makers and consumers could be able to use more efficient and effective from natural resources both in national and subnational levels (Mechan *et al*., 2003). In this sense, GIS- Multi-criteria Decision Analysis (MCDA) creates a precious collection of procedures and techniques for structuring decision designing and problems, prioritizing and evaluating alternative decisions. In fact, GIS-MCDA is a process that combines and transforms geographical data and value judgments to provide information for decision-making (Malczewski, 2006). It is in the context of the synergetic abilities of GIS and MCDA that one can see the profit for advancing applied and theoretical research on GIS-MCDA (Malczewski, 2006). While GIS is generally identified as an integrated and powerful tool with unique abilities for storing, manipulating, analyzing and visualizing spatial data for decision-making, MCDA provides a valuable collection of algorithms and procedures for structuring decision problems, designing, evaluating and prioritizing alternative decisions (Boroushaki and Malczewski, 2010). The Analytical Hierarchical Process (AHP) method is a well-known technique of the multi-criteria method (Saaty and Vargas, 1991), which has been synthesized into GIS-based suitability procedures (Marinoni, 2004). The AHP can help in recognizing and weighting selection of criteria and expediting the process of decision-making (Sener *et al*., 2010; Yahaya *et al*., 2010). The AHP is a multi-attribute weighting method, utilized to derive ratio scales from paired evaluation and to present objectivity in weight assignment. Within this study, in order to derive the AHP weights relevant criteria for cultivating saffron were taken into account of AHP's pairwise comparison. It is believed that suitability assessment is an important approach which leads to recognize area 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 East-Azerbaijan Province.

2. Materials and Methods

2.1. Study area and dataset

The study area was East-Azerbaijan Province (EAP[1]). This area is located in the north-west of Iran, which lie between latitude 36° to 39° N and longitude 45° to 48° E (See Fig. 1). The EAP with area of 45637.35km^2 includes 20 counties, 62 cities and 3076 villages. This area with about more than 3.7 million populations is important in terms of housing, industrial and farming practices. (Statistical center of Iran, 2015). Agricultural activities are the main income of this study area which has been under threat due to the shrinking of Urmia Lake. Based on these condition alternative crops tolerant to the water deficit are in policy and priority of decision makers and authorizations. Based on these observation results of this research could be base of decision plans by means of 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 amount is approximately 300 mm (Meteorological organization of Iran, 2015).

In order to model the suitability of saffron cultivating, the saffron plant ecological requirements criteria were considered as dataset which are described in blow. The further detailed about calculating and preparing each criterion is also represented in Table 4.

- Meteorological data were collected from 15 synoptic stations for period of 15 years. This dataset was used to create average precipitation, temperatures, sun hours, evaporation, humidity percentage, soil temperatures in depth of 5 and 10 cm, maps.
- Digital topographical maps were used in 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 spatial resolution of 30 m based on image processing techniques (MANR, 2013).

[1] East-Azerbaijan Province

- The pH of soil map and saffron production data were derived from Department of Agriculture, East-Azerbaijan Province.

The Meteorological data was used to compute plant Growth Degree-Day (GDD) as an important index for cultivation of crops.

It has been used a thermal index of GDD, for investigating the required energy value of Saffron plant for flowering. In this research, we employed the thermal index of GDD (Mohammadi et al. 2011) to evaluate the degree-day which is computed as follows:

$$GDD = \sum_{i=1}^{n} \left[\frac{(\mathrm{Tmax} + \mathrm{Tmin})}{2} - Tb \right] \qquad (1)$$

Here, GDD indicates the degree-day gathered for n days. T_{max}: daily maximum temperature, T_{min}: daily minimum temperature, T_b: basic temperature and/or physiologic zero of plant which for saffron is 5 °C (Mirzabayati, 2005), n: number of days for a given time.

Fig. 1. Location of the case study area within Iran and East-Azerbaijan

2.2. Criteria standardization

In order to perform suability process, it is necessary to collect data and prepare them in raster format. Thus, there were a variety of units that should be converted to the comparable mode. The initial step included standardizing the indicator variables to a typical numeric range using re-class function. In our research, criteria at the lowest importance get 5 rank and the highest important criteria get 1 rank. Based on this approach, the cells in a map, which were highly suitable for achieving the goal, obtained high standardized values, and less suitable cells obtained low values (Azizur Rahman *et al*., 2012). In order to map the results of the selected criteria, a spatial interpolation technique, i.e. Inverse Distance Weighting (IDW) was used in this research. Accordingly, the value range of each criterion prepared based on physical condition of the study area and considering relevant references for ranging each criterion. Results of this step are represented in Table 5 as priority influence and scale value of the data layers according to the questionnaire.

2.3. 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 (B.1), the AHP could rank the criteria based on their relative important degrees (Chen and Zhu, 2010). This mathematical function could analysis complex decision problems (Saaty, 1977). GIS-based AHP has become prominence due to its ability 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 αqt 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,

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

where $\alpha_{kh(q)}$ 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(n-l)/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 calculation of the eigenvector is as follows:

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

Then adding by row:

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

Vector W= [W1; W2; . . . ;Wn]^{T}is standardized as follows:

$$W_i = \frac{\bar{w}_i}{\sum_{j=1}^{n} \bar{w}_i} \quad i,j = 1,2, \ldots, n \quad (7)$$

Eigenvector Wi=[W1, W2, . . . , Wn]^T is obtained. But consistency verification is necessary, and maximum latent root λ_{Max} is calculated firstly as follows:

$$\lambda_{max} = \sum_{j=1}^{n} \frac{(AW)_i}{nW_i} \quad (8)$$

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

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (9)$$

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

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

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 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 criteria is also determined as 13 separate questionnaires which are filed out by expert during this step.

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
RI	0	0	0.58	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 resulted from questionnaire

Factors	1	2	3	4	5	6	7	8	9	10	11	12	13
(1) Mean temp.	1	3	1/2	1/2	1/2	2	2	1/2	2	3	3	3	3
(2) Min temp.		1	1	1/3	1/2	3	1/2	1/3	3	2	2	2	1/2
(3) Max temp.			1	1/3	1/2	2	1/3	1/2	3	2	2	2	2
(4) Precipitation				1	1/2	3	3	1	3	2	3	3	3
(5) Elevation					1	3	2	1/2	3	1	2	2	2
(6) Humidity						1	1/3	1/4	1/3	1/3	3	2	1/2
(7) Evaporation							1	1/3	3	3	3	3	1/2
(8) Sun hours								1	3	3	3	3	3
(9) pH									1	2	3	3	2
(10) Slope										1	3	3	1
(11) Soil temp.5cm											1	2	1/3
(12) Soil temp.10cm												1	1/3
(13) Aspect													1
Inconsistency	0.08												

3. Results and Discussion

3.1. Precipitation

The Saffron plant water requirement would be supplied by late autumn, winter and spring precipitations or supplementary irrigations, however, early precipitation or irrigation before 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 the table 6, areas with high suitability for saffron cultivation included 6.02 percentage (276139.0 ha) of total studied province however, 44.72 percentage of areas (2048467.1 ha) had suitable condition. Based on results about 2.65% areas identified as unsuitable areas for this purpose (121750.4 ha). In addition, north-west, south-west and south-east of East Azerbaijan province had minimum precipitation rate for this purpose (Fig. 2).

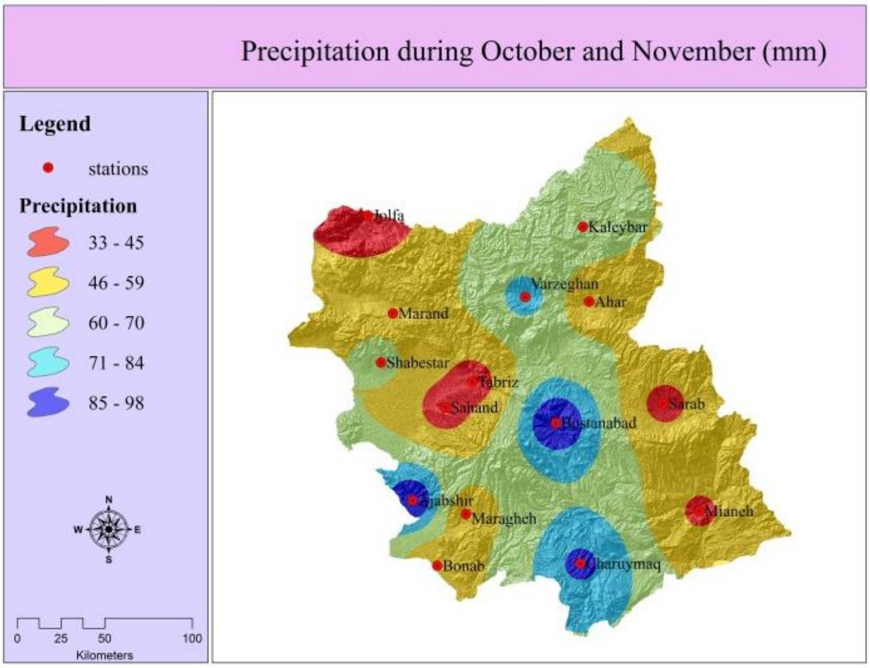

Fig. 2. Map of precipitation during October and November

3.2. Mean Temperature, Max Temperature, Min 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 degrees (As maximum and minimum temperature respectively) could well induce flowering of this plant, thus, areas with relative high degree day and low degree night were more important in this study. According to figures 3, 4 and 5 south-east (around Mianeh city) and west of EAP especially north-west and south-west of this region (Jolfa, Ajabshir, Bonab cities) had suitable thermal conditions for cultivation of saffron plant. About 45.59% (2088799.8 ha) of this province had highly suitable (high suitable+suitable) mean temperature, 23.08% had highly suitable maximum temperature (18.21-21.23˚C) and 57.44% had highly suitable min temperature (5.9-8.80˚C). As an average 2.92 percentage of area (134188.5 ha) couldn't supply plant thermal require (Table 6). Mashayekhi *et al*., (2006) assessed the effect of environmental temperature on flowering behavior of saffron. The results indicated that mean and minimum temperature were the most important driving forces to determine flower emergence and flower initiation in saffron, respectively.

3.3. Elevation and Relative humidity percentage

The altitude or elevation of the land with respect to the level of the sea surface influences plant growth and development primarily through temperature effect. East-Azerbaijan mountainous province elevation varies from flat to mountains altitudes where south-west, south-east and around north-west (around Marand and Shabestar cities) of this province could provide optimum saffron elevation requirement (Fig. 6). As 33.51 percentage of the land's elevation vary between 958-1877 meters above sea level. High precipitation areas addressed to high relative humidity percentage areas, thereby, areas with low humidity percentage is more suitable for Saffron (Alavi-Zadeh *et al*. 2013). In this way, areas with relative humidity percentage varies between 60-50 percentage were arranged in susceptible categories. According to the table 6, about 68.98% of this province had suitable and moderate suitable areas. Also, West and south-east of East-Azerbaijan had less than 56 percentage of relative humidity (Fig.7).

3.4. Evaporation

According to the figure 8, west and south- parts of EAP had high evaporation ratio which indicates 55.14 percentage of this area had more than 100 mm evaporation during the October and November (Table 5). High evaporation ratio resulted to low available water in the soil. Previously Alavi-Shahri (1994) indicated that high evaporation ratio in saffron plant cultivation leads to meaningful reduction in the yield as, optimum evaporation was 85% from class A pan. These results also found out by early researchers (Eftekharzadeh-Maraghei, 1994; Azizi-Zohan, 2009) when it carried out that increasing of irrigation intervals cause to decrease of saffron yield. Based on this assumption, within in this study high evaporation rate areas take low value (Table 5).

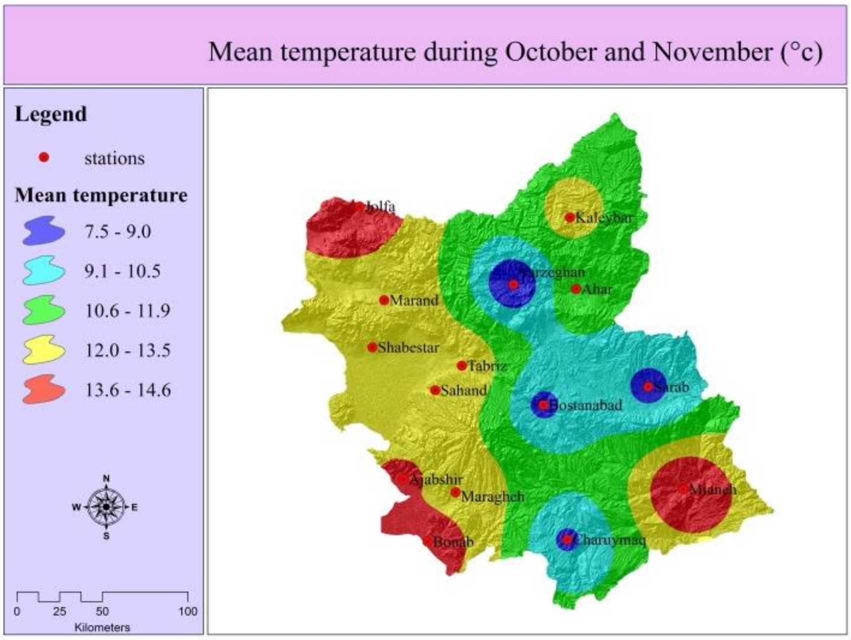

Fig. 3. Map of Mean temperature during October and November

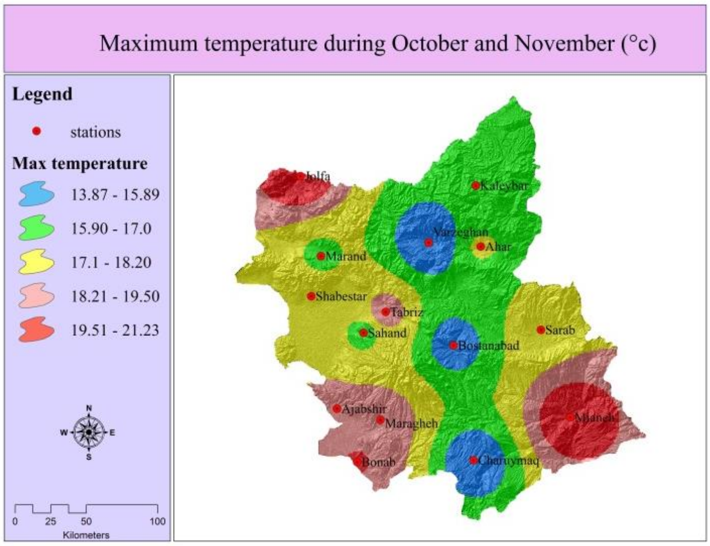

Fig. 4. Map of maximum temperature during October and November

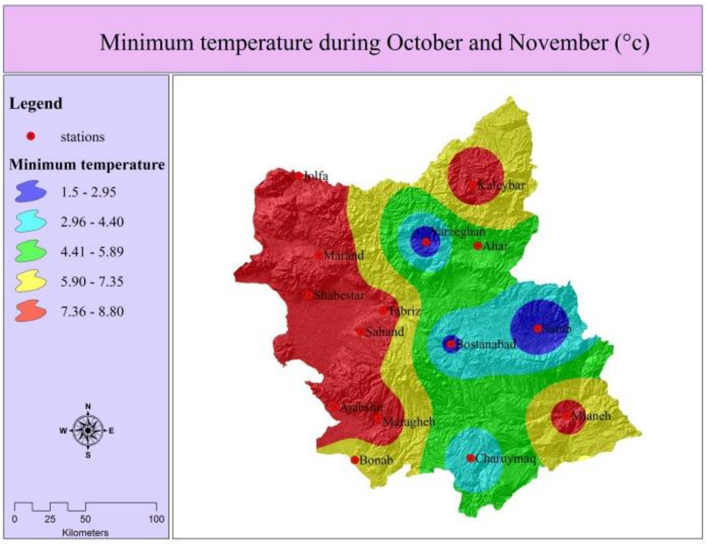

Fig. 5. Map of minimum temperature during October and November

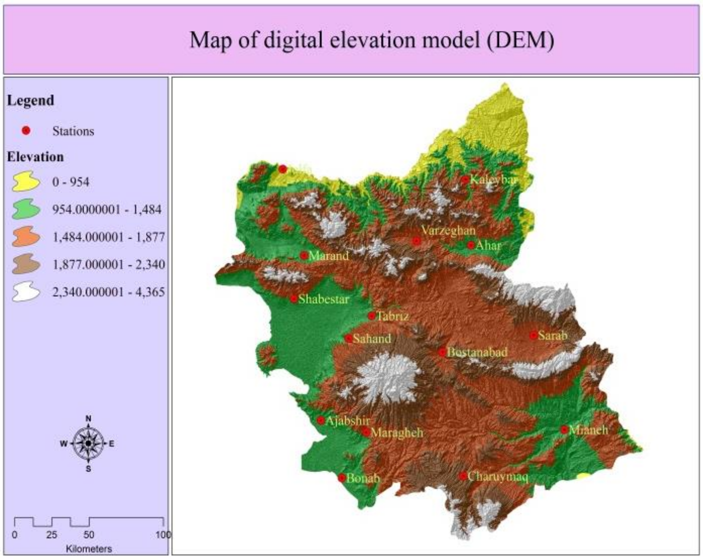

Fig. 6. Map of digital elevation model of East-Azerbaijan

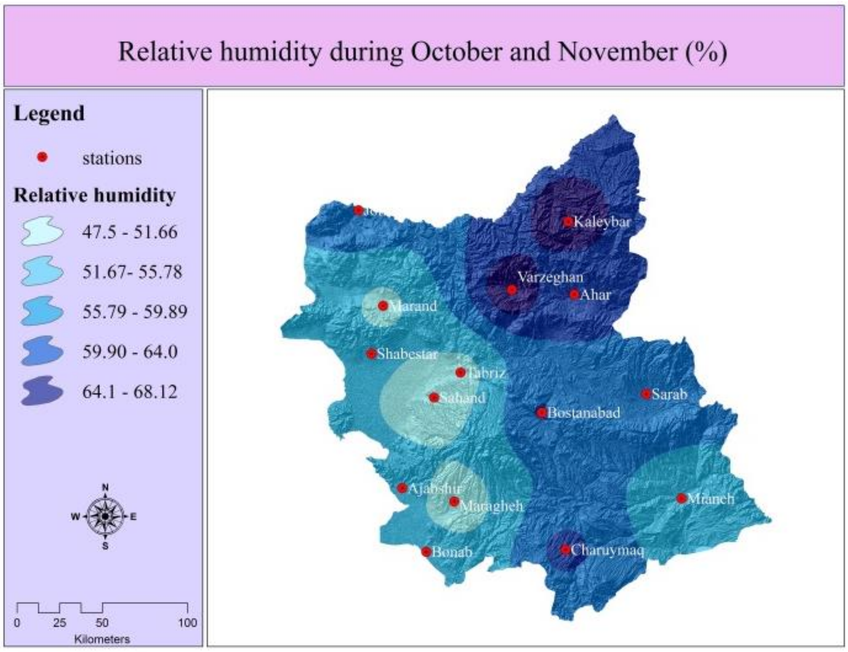

Fig. 7. Map of relative humidity percentage during October and November

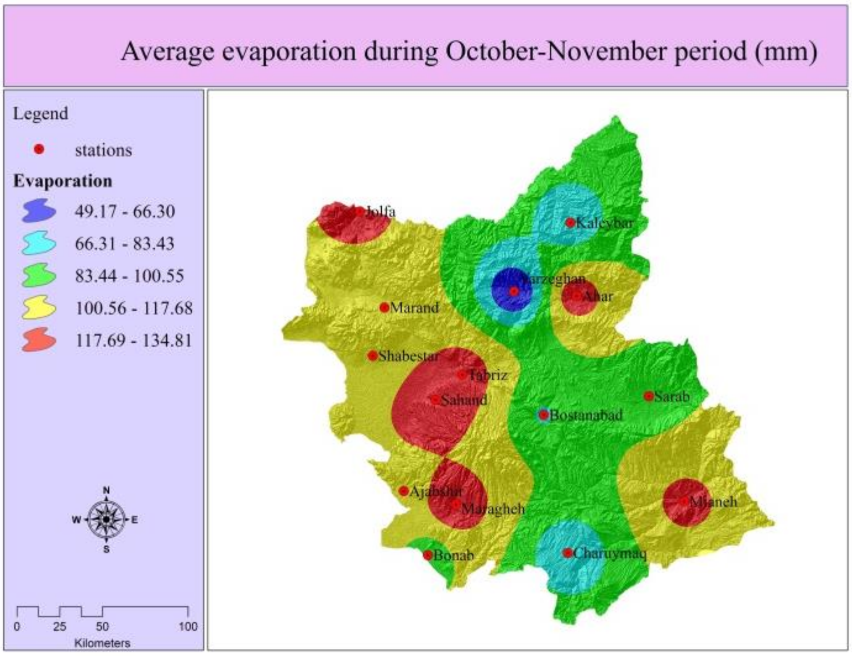

Fig. 8. Map of average evaporation during November and October

Table 4. Saffron plant Agro-ecological requirements

Precipitation	x>200 mm	(Alavi-Zadeh *et al*., 2013)
Mean Temperature	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; Behdani *et al*., 2008)
Sun hours	More than 225 h	(Kafi, 2006)
pH	7-8	(Dhar, 2000)
Aspect	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)

Table 5. Factors, priority influence and scale value of the data layers according to the questionnaire

Criteria	High suitable	suitable	Moderate suitable	Low suitable	No suitable	Priority influence
Mean temperature (◦c)	13.6-14.6	12.0-13.5	10.6-11.9	9.1-10.5	7.5-9.0	0.098
Maximum temperature (◦c)	19.51-21.23	18.21-19.50	17.1-18.20	15.90-17.0	13.87-15.89	0.079
Minimum temperature (◦c)	7.36-8.80	5.90-7.35	4.41-5.89	2.96-4.40	1.50-2.95	0. 062
Elevation	1485-1877	958-1484	0-957	1877-2340	2340-4365	0.119
Relative humidity percentage	47.5-51.66	51.67-55.78	55.79-59.89	59.90-64.0	64.1-68.12	0.033
Precipitation (mm)	33-45	46-59	60-70	71-84	85-98	0.137
Evaporation	49.17-66.30	66.31-88.43	88.44-100.55	100.56-117.68	117.69-134.81	0.090
Sun hours	442-466	418-441	393-417	369-392	343-368	0.150
pH	7.71-8.60	6.51-7.70	4.41-6.50	8.61-11.35	1.5-4.40	0.057
Slope	5.528-13.128	0-5.527	13.129-23.147	23.148-52.514	52.514-88.100	0.055
Soil 5 cm temperature (◦c)	11.51-13.0	13.1-14.65	9.9-11.50	14.66-16.23	16.24-17.81	0.027
Soil 10 cm temperature (◦c)	10.80-13.50	13.51-16.20	16.21-18.92	18.93-21. 64	21.65-24.35	0.031
Aspect	Flat, Southeast South Southwest	West Northwest	East	Northeast	North	0.063

Table 6. Factors susceptibility percentages and covered areas

Criteria	covered area (%)					Coverd area (ha)				
	High suitable	suitable	Moderate suitable	Low suitable	No suitable	High suitable	suitable	Moderate suitable	Low suitable	No suitable
Mean temperature (◦c)	10.34	35.25	30.2	21.25	2.92	473984.5	1614815.3	1383440.9	973673.9	134188.5
Maximum temperature (◦c)	7.39	15.69	33.53	34.1	9.24	338878.4	719058.3	1535901.2	1562154.4	423426.4
Minimum temperature (◦c)	31.46	25.98	23.94	14.73	3.86	1441057.1	1190327.8	1096710.7	675012.8	176981.9
Elevation	6.29	27.22	36.01	22.33	8.23	288151.1	1246979.0	1649498.4	1023139.7	377043.1
Relative humidity percentage	8.97	34.31	34.67	16.47	5.55	411218.5	1571718.0	1588042.3	754673.4	254458.1
Precipitation (mm)	6.02	44.72	35.66	10.92	2.65	276139.0	2048467.1	1633352.4	500400.4	121750.4
Evaporation	1.06	8.33	35.44	43.51	11.63	48815.5	381887.2	1623526.4	1992850.9	533015.0
Sun hours	11.51	43.72	28.64	12.81	3.29	57582.2	2002458.9	1312104.0	586970.0	150972.9
pH	42.12	31.25	6.78	19.05	0.88	19229451.7	1431721.2	310628.6	872525.2	40524.6
Slope	44.41	31.08	17.46	6.95	0.18	2034386.8	1423760.1	799774.5	318339.9	8375.1
Soil 5 cm temperature (◦c)	27.36	40.76	5.12	24.31	2.48	1252611.2	1866020.8	234427.4	1113083.5	113962.7
Soil 10 cm temperature (◦c)	32.57	57.51	7.79	1.41	0.7	1491866.9	2634005.0	356837.9	69978.4	32390.9
GDD	12.67	29.82	24.8	23.51	9.28	580613.5	1365922.0	1135994.3	1077033.9	425250.3
AHP	0	42.73	55.47	1.8	0	0	1954416.9	2537492.0	84643.2	0

3.5. Sun hours

Saffron plants grow poorly in shady conditions and grow best in direct sunlight. Thus, planting is best done in fields that slope towards the sunlight (i.e., south sloping in the Northern Hemisphere). Thereby, in this study, regions with high sun hours get more value and also high influence priorities resulted from agricultural experts' opinions confirmed this issue (Table 5). Areas with high sun hours (441-466 hours) included 55.23 percentage of East-Azerbaijan province (Table 6) which is more placed in west and south-east of this region (Fig. 9). Mianeh, Sahand, Shabestar and Maragheh city's vicinities had the highest sum of sun hours. While 16.10 percentage of this province especially Charuymaq and Kaleybar cities had the lowest values (Fig. 9).

3.6. pH, Slope and Aspect

The results of table 6 indicated that 73.37 percentage of East-Azerbaijan province pH varied between 6.50-8.60 but just 19.93 percentage of this province had unsuitable pH for this plant. As it shown in figure 10, almost south of the province, margins of Urmia lake (due to the high concentration of NaCl), North of Maragheh City, east of Marand City and north-east of studied province had unsuitable pH.

According to the table 5 and 6, 75.49 percentages of East-Azerbaijan province slopes vary between 1-13.5 degrees. As figure 11 indicates, most of the studied area had acceptable slope and only 7.13 percentage of mountainous area are unsuitable for cultivation of this plant. West, south and south-east of this region by almost more flat areas are suitable for getting more sunshine and optimum temperature. Low slope degree increases better penetration of water and soil moisture storage and in the critical period of growth, water supply will eliminate the problem of water deficit (Alavi-Zadeh *et al*., 2013).

In the northern hemisphere of earth facing south and horizontal surfaces always have maximum power of the sun at noon. The eastern slopes compared to the southern slopes take effective interest radiation in the earlier morning. But western slopes receive more radiation than the southern slopes in the afternoon. So in this study southern, western and eastern slopes were more appropriate for saffron plant cultivation (Fig. 12).

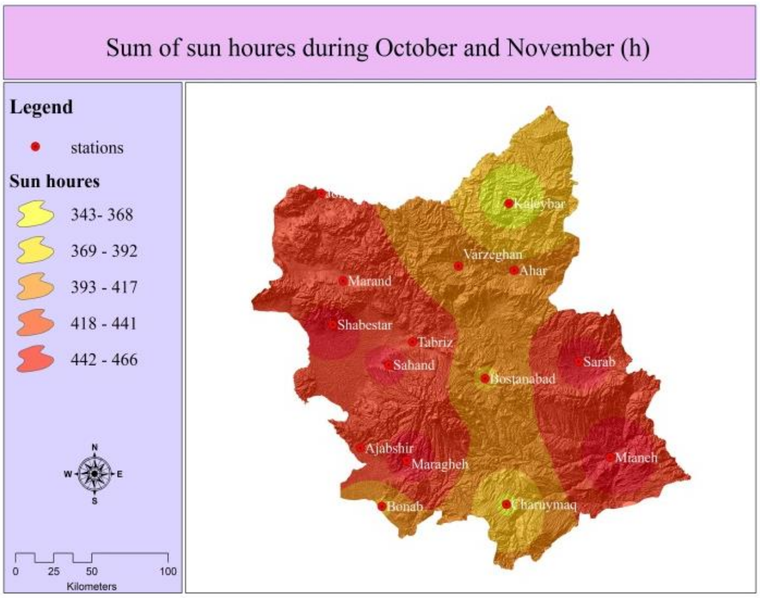

Fig. 9. Map of sun hours during October and November

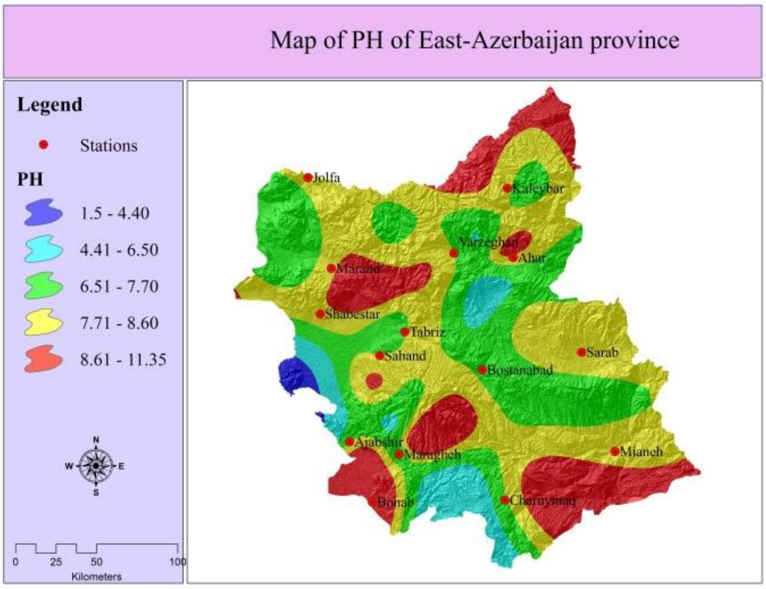

Fig. 10. Map of soil pH in 2013

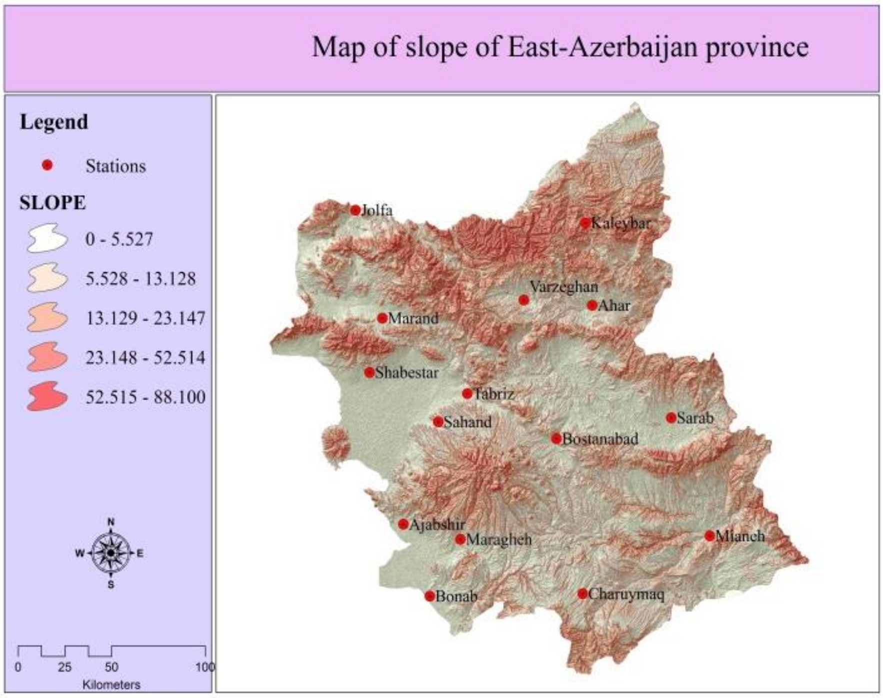

Fig. 11. Map of slope of East-Azerbaijan

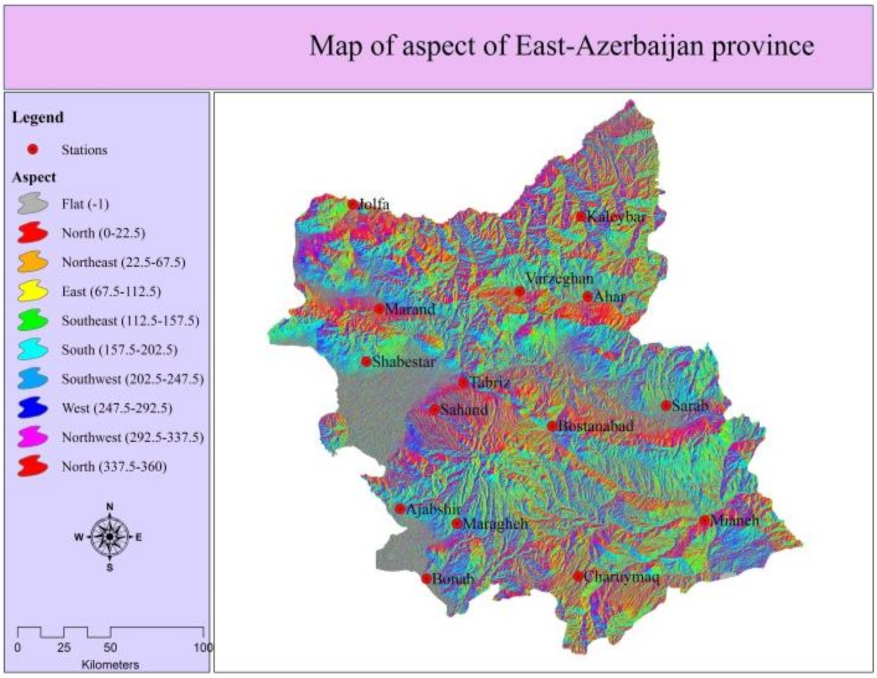

Fig. 12. Map of aspect of East-Azerbaijan province

3.7. Soil Temperature (5 and 10 cm depth)

Soil temperature at 0 -10 centimeter depth is an effective factor in the emergency of the corms which unsuitable temperatures could inhibit the growths of the corms (Sadeghi, *et al*., 2014). In consideration for finding the areas with 12-15 C temperature, results indicated that south-east, north-west and south-west of this studied province were warmest area with about 15-18 centigrade soil 5 cm temperature during the October and November (Fig. 13, 14). According to the table 6, about 27.36 percentage of 5cm soil deep of this region had high suitable temperature and 40.76 percentage of this region had suitable temperature for flowering of saffron. While by increasing of soil depth to the 10 cm, 57.51 percentages of this region had suitable temperature (13.5<x<16.5) (Table 6).

3.8. GDD

Growing degree days (GDD) is a weather-based indicator for assessing crop development. It is a calculation used by crop producers that is a measure of heat accumulation used to predict plant and pest development rates such as the date that a crop reaches maturity. Our results showed that 42.49 percentage of East-Azerbaijan could supply plant requirement for GDD (Table 6). Moreover, in some regions 2 or 3 times more than plant required needs (x≥416 GDD) is supplied. As shown in the figure 15, west and south-east of this province is completely suitable for this purpose. In this way, Mianeh, Jolfa, Maragheh-Bonab-Ajabshir and vicinity of Tabriz had high potential and this followed by Marand, Shabestar and Sahand regions.

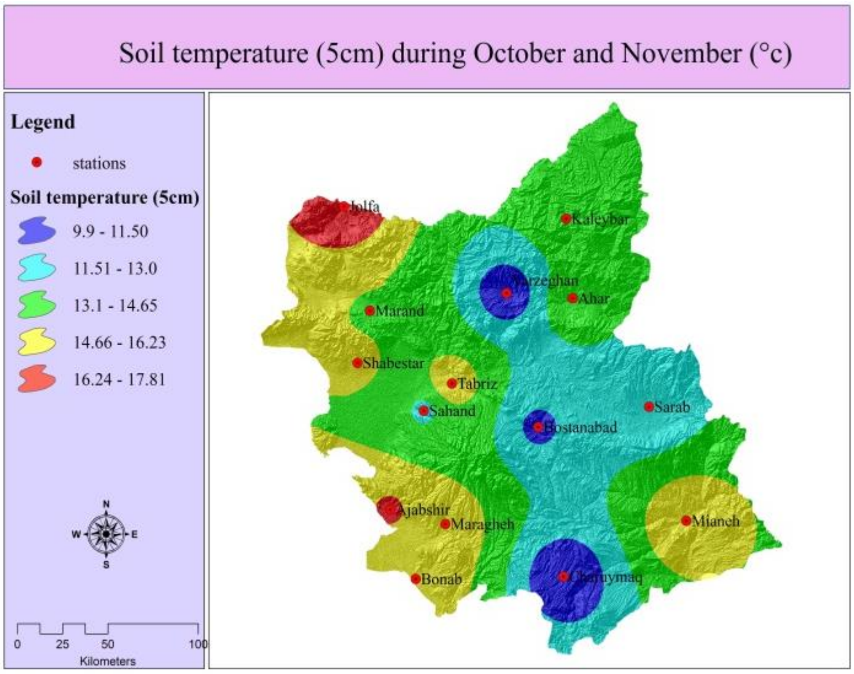

Fig. 13. Map of soil temperature (5cm) during October and November

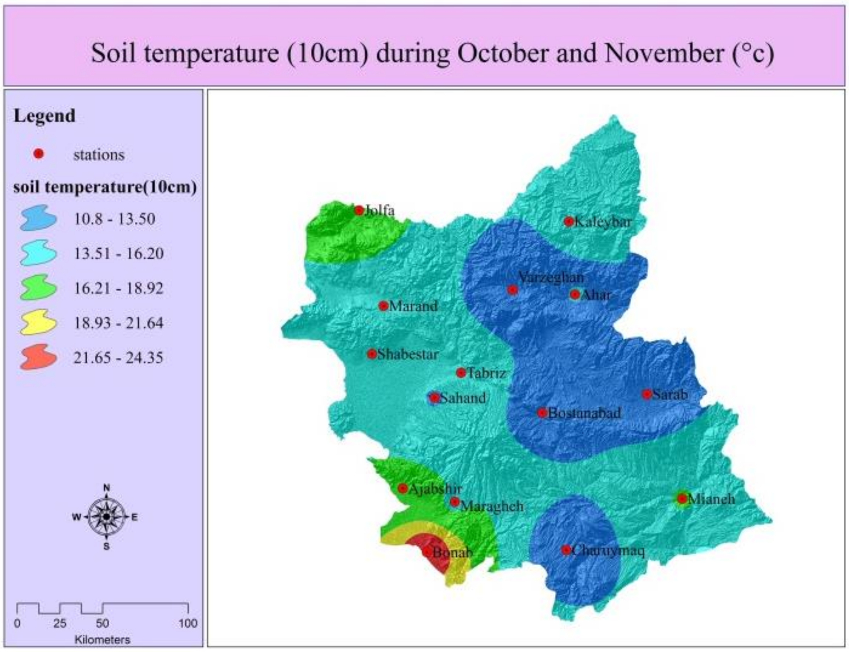

Fig. 14. Map of soil temperature (10cm) during October and November

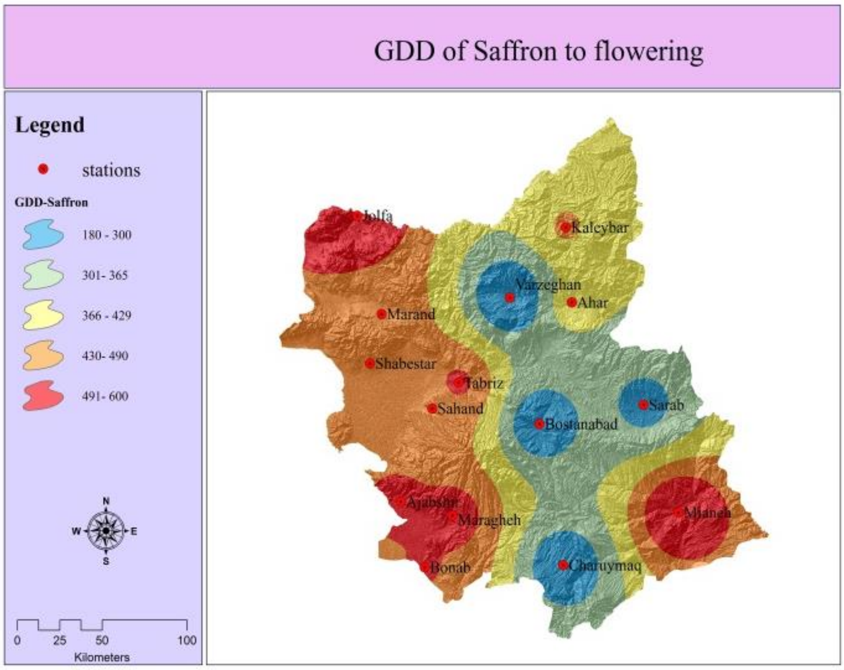

Fig. 15. Map of growth degree days for saffron plant

3.9. AHP

By consideration of important factors influence on plant growth and yield, analytic hierarchy process makes a chance for weighting and finding of the importance of studied factors (Table 5) and finally could suggest the best regions for cultivation of each plant such as saffron medicinal plant. In this way, by using of agricultural scientists' opinions and preparing of a questionnaire final map of saffron plant cultivation feasibility was prepared. According to the Figure 17, Marand, Maragheh, Bonab, Jolfa, Sahand, Sarab, Shabestar, Mianeh and Tabriz regions had high potential in production of Saffron. Although some parts of Varzeghan, Charuymaq, Bostanabad, Kaleybar regions had low potential for this purpose, however, other parts of this province had moderate suitability for cultivation of saffron while there will be a predictable decrease in yield compared to the regions with high susceptibility conditions. At all 42.7 percentage of this province had good suitability (1954416.9 ha), 55.4 percentage had moderate suitability (2537492.0 ha) and 1.8 Percentage had low suitability in cultivation of this plant (84643.2 ha). In this study there was no region that could supply all plant needs to produce the highest possibly yield, moreover, there was no region that been completely unsuitable for cultivation of this plant.

As the main goal of the paper is creating a new attitude and knowledge in term of Saffron cultivation in East-Azerbaijan province, so, for better understanding of this issue, attention and evaluation of the areas under cultivation of Saffron during 2014 could be useful. As shown in figure 18, farmers of Marand and Shabestar regions seems to be well aware of the possibility of cultivating this plant, thereby, the most Saffron planted covered areas are accounted for this regions. The lands of the Maragheh, Tabriz, Bonab, Sarab and Mianeh regions in comparison of Marand and Shabestar regions despite having potential for cultivating this plant (Fig. 17) are less in cultivation of Saffron. Unlike these regions, farmers of Charumaq, Bostanabad and Varzeghan regions seems to be well aware of this fact that these regions have low suitability for cultivating Saffron plant, thereby, the lowest cultivated areas are belonging to these regions.

Also, by consideration of land cover of East-Azerbaijan (Fig. 16) it could be found that Jolfa and Mianeh regions by having high, moderate and low range lands could better use from these natural resources and develop its agricultural products by cultivation of saffron.

In consideration of the factors influencing yield and quality of saffron production, it is resulted that, as length of daylight starts to decrease in autumn, so, sun hours by increasing the differences between day and night temperature could well induce flowering of Saffron plant. Thereby, in among the important factors affected this plant cultivation, sum of sun hours which influence on temperature is the important factor in flowering of Saffron (Table 5). Also, irregular precipitation (rate and distribution) due to the stimulating of vegetation stage could affect the quality and yield of Saffron and supposed as limiting factors in the production of this plant.

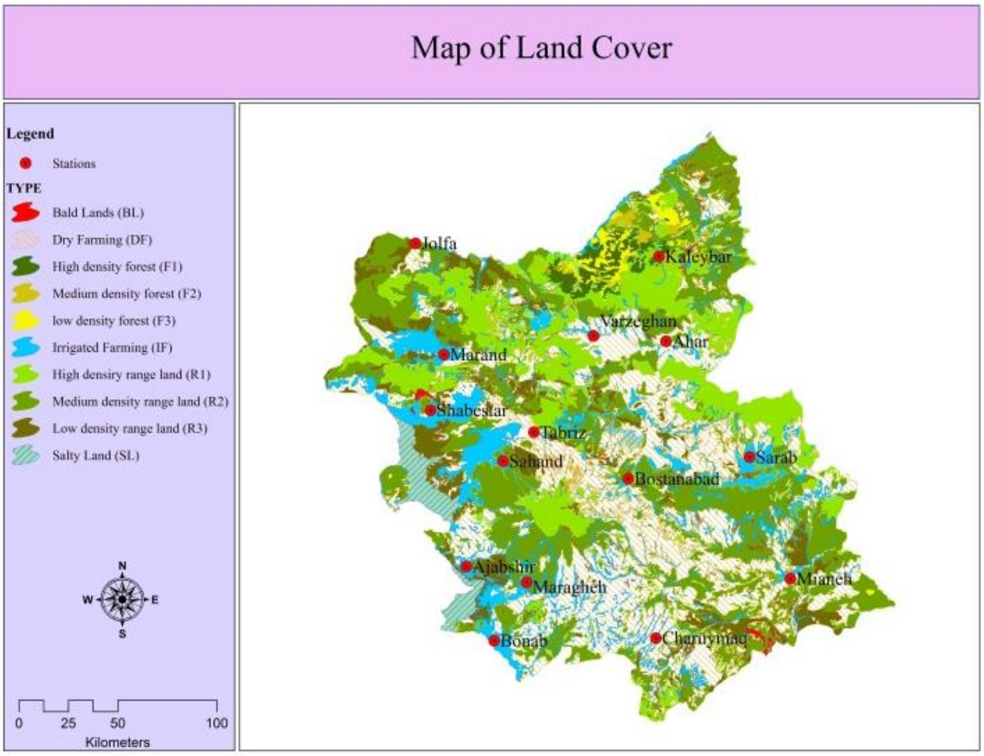

Fig. 16. Map of land cover of East-Azerbaijan

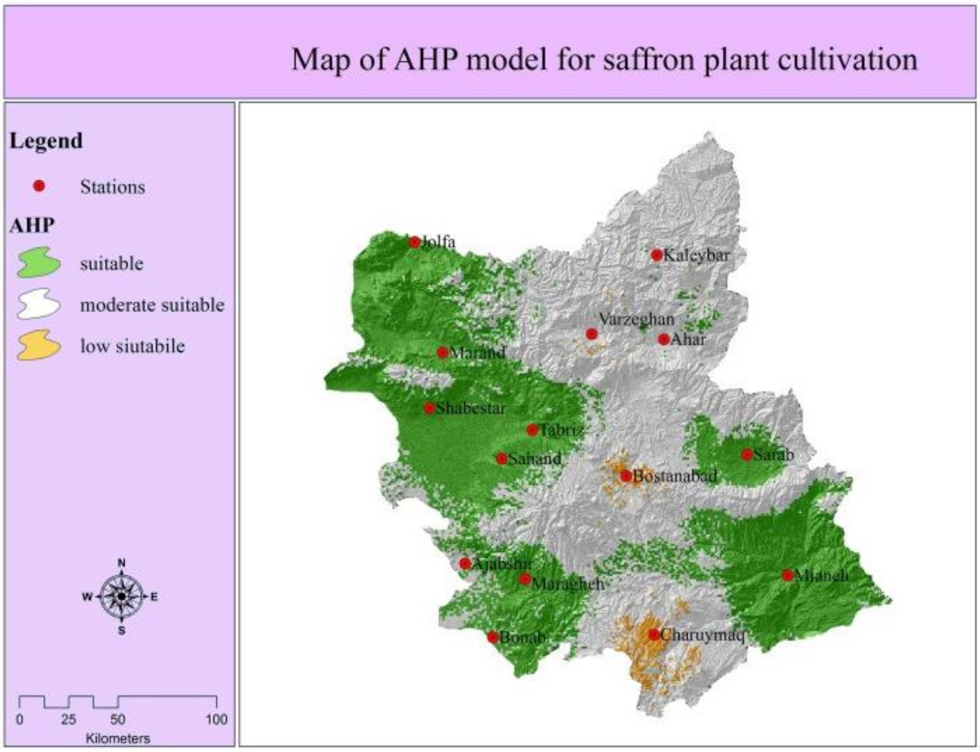

Fig. 17. Suitable areas for cultivation of saffron based on AHP technique

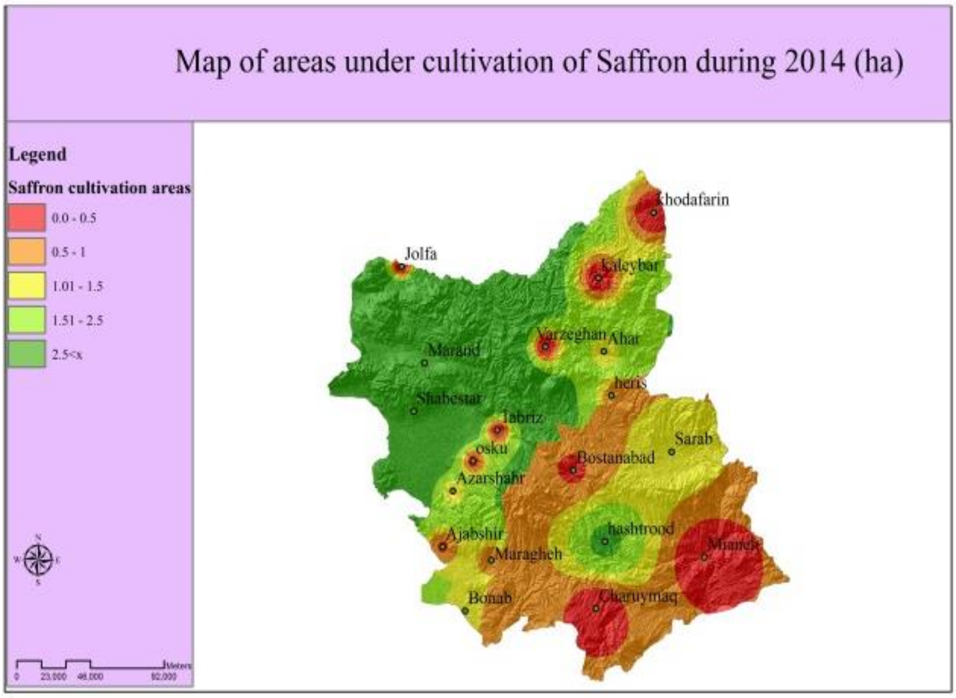

Fig. 18. Map of areas under cultivation of Saffron in 2014

4. Conclusion

Selection of medicinal plant species adapted to the arid and semi-arid areas and better usage of natural resources with high efficiency in these regions is very important toward the sustainable agriculture. As we discussed in introduction section, one of the first steps in cultivation of any plant is consideration of regions and requirements of the plant that is going to be plant there. Analytic hierarchy process by combination of prepared dataset could suggest best regions for cultivation of an individual plant. This study by evaluating of EAP and collecting the important factors that influence on saffron cultivation and matching of these with plant requirements could resulted that this province had high potential in production of saffron plant and Marand, Shabestar, Jolfa, Mianeh, Maragheh, Bonab, Ajabshir, Sarab, Sahand and Tabriz regions are very suitable for this purpose. We also concluded that current research by employing GIS spatial analysis allowed us to identify those areas with high potential to Saffron crop production. However, it is possible that saffron in these areas has been affected by other factors which have not evaluated, such as soil parameters and could make partial contradictory with the reality, thereby, we acknowledge that applying 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 be focus on applying GIS spatial explicit sensitivity and uncertainty analysis for GIS-MCDA based suitability assessment. Applying this approach would leads to assess the reliability of results spatial and measure the accuracy of results in each spot. We concluded that, the results obtained from this research can be used as base of decision plans in managing of water scarcity at this basin and are great of importance for regional planning and decision makers for understanding the physical condition of EAP and its potentiality for cultivating Saffron.

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