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Short Communication

Feasibility of safflower cultivation based on Analytic Hierarchy Process (AHP) analyses in GIS environment (Case study: Ardabil)

Authors:
Palangi V

Institution:
Department of Animal Sciences, Agricultural Faculty, Ataturk University, 25240, Erzurum, Turkey.

Corresponding author:
Palangi V

ABSTRACT:

The separation of cultivation areas in Iran is mostly based on traditions and agro-climatic potential of most areas of the country is unknown. Considering these the aim of this study is to examine the climatic feasibility of rain-fed cultivation of safflower in Ardabil based on its environmental potential, so that while reducing costs and increasing efficiency of the studied variables, increase the crop yield per unit of area. The present study used climatic and edaphic variables in the form of AHP (Analytic Hierarchy Process) approach to weight the layers. We used geostatistical method and overlapping feature of ArcGIS software to generate final maps of data. Data analysis showed that Ardabil could be divided into four areas regarding safflower cultivation: very suitable, suitable, average and poor. Very suitable and suitable areas for rain-fed cultivation of safflower in the province are mostly in the northern part of the province with total area of about 249290 ha, which is about 61% of the total area of the province. Climatic factors including temperature, sunshine, days of frost in the southern regions of the province have limitations and are not recommended for safflower cultivation.

Keywords:
Ardabil, Safflower, Location, AHP and GIS models.

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INTRODUCTION

Safflower (*Carthamus tinctorius*) is an oilseed crop, derived probably from Iran, Turkey and India originated. (Khajehpour, 2004). Safflower is a plant for growth with a maximum temperature from 20 - 32°C and minimum -7°C and has a good performance at altitudes from 1800 to 2300 m above sea level. The soil for cultivation of this plant should be loamy and sandy, so for suitable growth and development of this plant and production of high quality and good products, fertile lands and drained with loam, limon, clay and sand soil and lime with a pH of 7 to 8.5 (Tabrizi *et al*., 2000). Minimum temperature for germination of safflower is about 5°C (Tabrizi *et al*., 2000). The best growth of safflower is at 15 to 20°C. Safflower is more resistant to frost in early spring compared to oilseeds, such as canola and flax. Proper soil moisture can reduce the effects of high temperatures. Generally, precipitation of about 300 mm before flowering is suitable for safflower growth. The plant is resistant to drought due to developed root system. Its ability to absorb water is more than wheat and barley and has less water use efficiency.

It needs less water in rosette stage due to low evaporation and low temperature, but in stem elongation and heading stages, it needs enough water (Naseri, 1991). Its maximum amount of water consumption is in flowering stage and after this stage its water requirement reduces. Water requirement in irrigated agriculture varies from 6000 to 12,000 cubic meters per hectare. Safflower has low expectations in terms of soil type and fertile and nitrogen-rich soils are not desirable for its growth because they enhance vegetative growth and decrease harvest index (Eslam, 2004). This plant has been considered as a valuable oil plant and its area under cultivation is increasing due to its various applications, such as medical, industrial and nutritional uses and its specific characteristics such high quality oil and having 90% unsaturated fatty acids, especially linoleic and oleic fatty acids, high resistance to drought and salinity and adaptability to high and low temperatures (Vollman and Rajcan, 2010).

On the other hand, severe shortages of primary sources to extract vegetable oil in the country and outflow of foreign currency for its imports have increased the importance of addressing this valuable plant (Eslam, 2004). Two main groups are involved in promoting and developing farming activities: stable and unstable factors. Stable factors are the ones whose changes are low and slow over years, including slope,

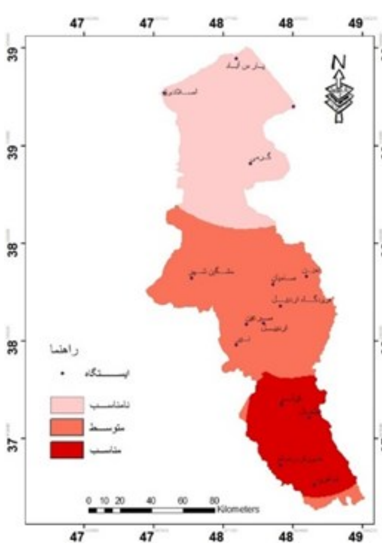

Figure 1. Weighting rainfall for planting safflower (In Persian)

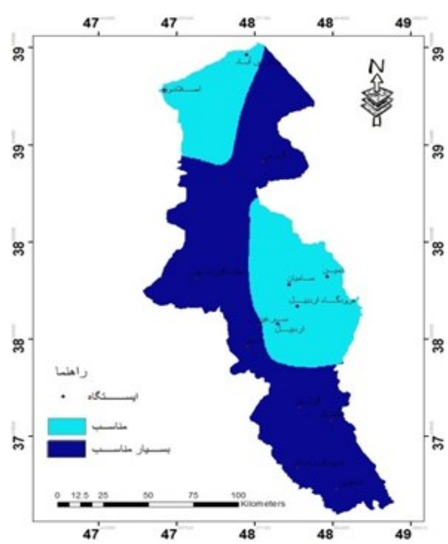

Figure 2. Weighting daily temperature of safflower (In Persian)

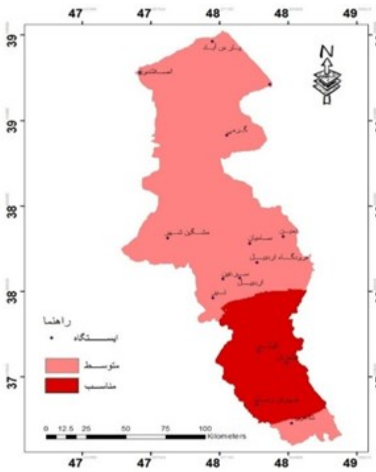

Figure 3. Weighting maximum temperature of Safflower (In Persian)

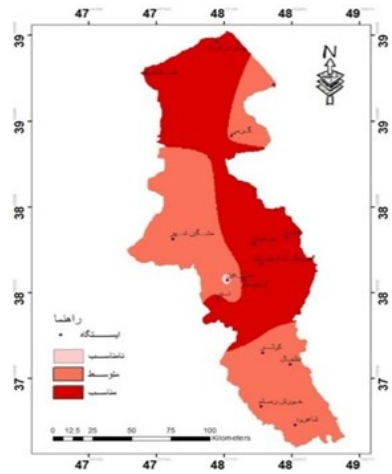

Figure 4. Weighting minimum temperature of Safflower (In Persian)

altitude, direction and type of soil (Naseri, 1991). Unstable factors are the ones that have time changes are factors that have unstable factors, such as rainfall, temperature and humidity. The noteworthy point is that it is possible to modify or change stable factors according to the needs for the creation and development of successful farming activities. However, changing climatic conditions, except under greenhouse conditions, is not possible and even crop condition should be in accordance with climatic conditions (Zainali, 1999). According to climatic and environmental diversity of each region, the crops must be chosen for cultivation, which that leads to economic development. The importance of this issue has made environmental researchers and scientists pay special attention to spatial planning. This issue is more important, especially in rain-fed agricultural conditions, and due to its drought resistance, it is considered as a crop for dry land farming in mountainous areas in the country (Mehraban *et al*., 2005). In this study, agro-climatic zoning of Ardabil is done for safflower cultivation in GIS environment by analyzing of climate and geological data as well as using geostatistical methods such as kriging and cokriging and combination of effective factors using compliance operation of different layers. Research on this plant, especially its fall planting, is limited and few systematic reports have been published in scientific journals of the country. In studying safflower and the effect of environmental factors Esendel *et al*. (1992) stated that the performance

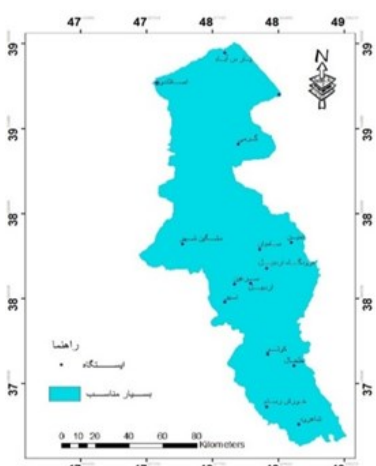

Figure 5. Weighting safflower moisture (In Persian)

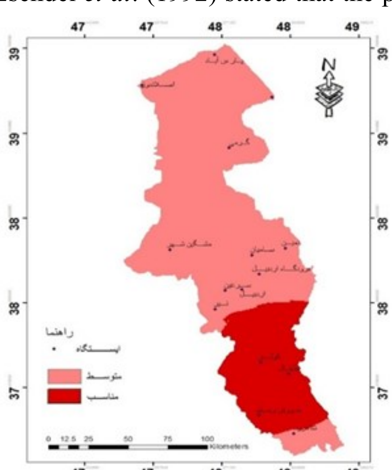

Figure 6. Weighting evaporation of safflower (In Persian)

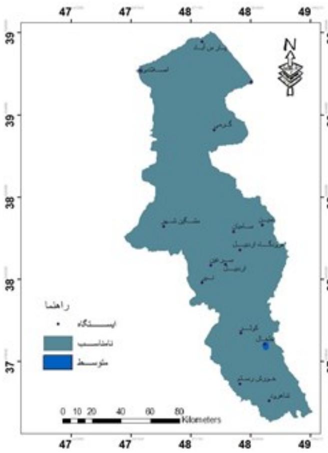

Figure 7. Weighting sunshine for safflower (In Persian)

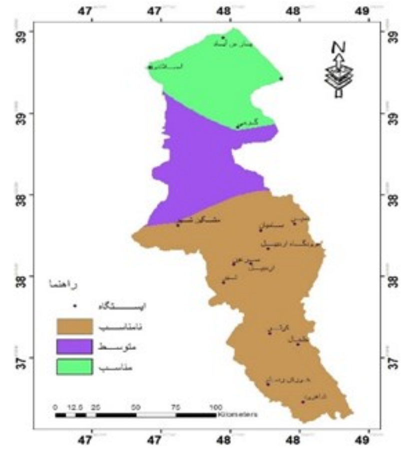

Figure 8. Weighting frost for safflower (In Persian)

of safflower seeds is positively correlated with low rainfall and temperatures from germination to flowering and from flowering to maturity and negatively correlated with high temperature in the above two steps. Zhang (1993) conducted various experiments to determine the effects of temperature and precipitation changes on growth and development of safflower product in China. The results of this study indicated that the effects of changes in temperature on seed performance are more important than precipitation. Makhdum *et al*. (2001) have conducted a study on zoning in GIS environment. This study has measured weighted values of climatic elements and physical factors of land in GIS environment using linear calculated and has zoned agricultural areas. Moreover, climatic zoning of rain-fed wheat in Kordestan (Bazgir, 1999) and sunflower in Gilan (Ramezani and Rad, 2007) can be noted. Finally, the aim of this study is to identify and zone areas suitable for cultivation of safflower in Ardabil province with an emphasis on the use of multi-criteria decision-making methods (MCDM) for evaluation of the capability of lands in GIS environment.

MATERIALS AND METHODS

Ardabil with an area of 17951 square kilometers is located in the North West of the country. The height difference between the peak of Sabalan and Aras river in Moghan plain, which is about 5000 m, is in a short spatial distance from this province. This has caused climate variability of the province that has given it special climatic features. We used library and field

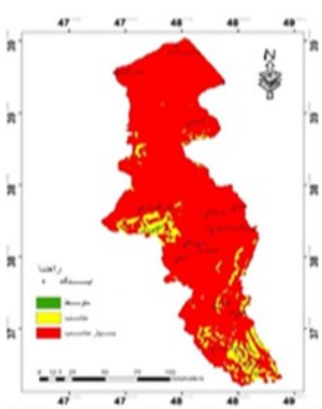

Figure 9. Weighting of elevation for safflower (In Persian)

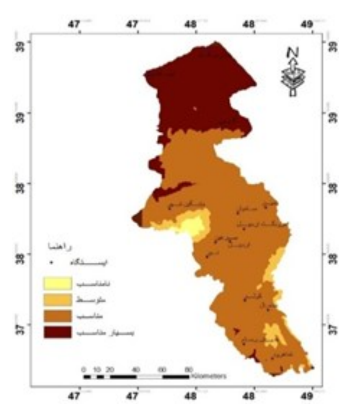

Figure 10. Weighting of slope for safflower (In Persian)

Table 1. Weighing effective parameters in safflower cultivation based on AHP model

Effective parameters in safflower cultivation	Relative weight	Factors	Relative weight	Sub-factors	Relative weight	Final weight
Topography	0.227	Elevation	0.239	Very suitable	0.467	0.
				Suitable	0.315	0.017
				Average	0.139	0.007
				Unsuitable	0.080	0.004
		Slope	0.624	Very suitable	0.520	0.073
				Suitable	0.268	0.037
				Average	0.141	0.019
				Unsuitable	0.071	0.010
		Slope direction	0.137	Very suitable	0.530	0.016
				Suitable	0.289	0.008
				Average	0.124	0.003
				Unsuitable	0.056	0.001
Land and soil cover	0.071	Land type	0.539	Very suitable	0.470	0.017
				Suitable	0.319	0.012
				Average	0.149	0.005
				Unsuitable	0.062	0.002
		pH	0.297	Very suitable	0.555	0.011
				Suitable	0.270	0.005
				Average	0.116	0.002
				Unsuitable	0.059	0.001
		EC	0.163	Very suitable	0.563	0.006
				Suitable	0.233	0.002
				Average	0.139	0.001
				Unsuitable	0.065	0.00
Climate		Daily temperature	0.304	Very suitable	0.492	0.104
				Suitable	0.305	0.065
				Average	0.134	0.028
				Unsuitable	0.070	0.014
		Precipitation	0.210	Very suitable	0.535	0.078
				Suitable	0.263	0.038
				Average	0.138	0.020
				Unsuitable	0.064	0.009
		Sunshine	0.150	Very suitable	0.490	0.051
				Suitable	0.306	0.032
				Average	0.126	0.013
				Unsuitable	0.079	0.008
		Moisture	0.112	Very suitable	0.517	0.040
				Suitable	0.260	0.020
				Average	0.149	0.011
				Unsuitable	0.074	0.005

Continued….

Continued….

Minimum temperature	0.089	Very suitable	0.540	0.033
		Suitable	0.211	0.016
		Average	0.131	0.008
		Unsuitable	0.057	0.003
Maximum temperature	0.068	Very suitable	0.461	0.022
		Suitable	0.311	0.014
		Average	0.155	0.007
		Unsuitable	0.073	0.003
Evaporation	0.041	Very suitable	0.564	0.016
		Suitable	0.251	0.007
		Average	0.125	0.003
		Unsuitable	0.060	0.001
Frost	0.026	Very suitable	0.518	0.009
		Suitable	0.289/0	0.005
		Average	0.133	0.002
		Unsuitable	0.059	0.001

methods to carry out the study and collated the data including climatic elements such as precipitation, maximum, minimum, and average temperature values, relative humidity, sunshine, evapotranspiration and the number of frost days from 15 meteorological stations in the province. In the next step, we calculated interpolation using geostatistical methods.

Moreover, land-use maps, pH and EC of soil, elevation, slope and slope direction were prepared. This study has used the following materials and tools:

1. Collecting basic data required for the studied plants from different sources
2. Collecting climatic data from 15 meteorological stations of the Meteorological Organization
3. Collecting topographic maps at 1:50000 scale from armed forces geographical organization and mapping organization
4. Collecting land use map, pH and EC of soil in 1:50000 scale from soil and water research institute
5. Using statistical software such as SPSS, Excel and GIS to perform statistical calculations and analysis of data and maps

In methodology for determining the power and limitations of the province for planting safflower, first based on AHP model, we clustered and valued effective factors and after calculating the final score of the options and examining the logical consistency of judgments, we created spatial information for each of the factors and options of layers. Moreover, according to the intended criteria, analyses were performed with the help of GIS software and the lands of the province were classified in terms of capability for safflower cultivation. The process of evaluating capability of the land and locating have included the following steps.

Creating hierarchical structure

At this stage, the hierarchical structure related to the subject was determined. This stage is the most important part of AHP (Analytic Hierarch Process). This is because in this part by breakdown of difficult and complex issues, AHP turns them into simple form in compliance with the human mind. In other words, AHP turns complex problems into simpler form through their breakdown to small elements that are hierarchically related and the relationship between the main purpose of the problem with the lowest level of the hierarchy is known (Kunz, 2010).

In the present study, to locate safflower cultivation, first, information about land and soil use,

Table 2. The results of studying compatibility of criteria, sub-criteria, and options of safflower product

	Compatibility Index	Sub-criteria	Compatibility Index	Option	Compatibility Index
Criteria	0.03+6	Topography	0.01	Elevation	0.00
				Slope	0.02
				Slope direction	0.00
		Climate	0.02	Daily temperature	0.04
				Precipitation	0.04
				Sunshine	0.03
				Moisture	0.03
				Minimum temperature	0.02
				Maximum pHtemperature	0.00
				Evaporation	0.00
				Frost	0.02
		Land and soil cover	0.00	pH	0.00
				ec	0.00
				Land type	0.00

topography and climate were chosen as the main factors. To determine the weight of criteria and sub-criteria, we compare them two by two. In order to determine the relative weight of the main parameters, first, we form geometric matrix for each of them and calculate their relative weight (Bazgir, 1999), then start to determine the relative weight of sub-criteria and by combining the mentioned factors, we determine the final score of each option (Braglia, 2006). For this, Saati's principle of hierarchical combining is used, which leads to the creation of a priority vector by taking into consideration all judgments at all levels of hierarchy (Aggarwal, 2003).

Final score (priority) of options

$$j= \sum_{k=1}^{n} \sum_{i=1}^{m} W_k W_j (gij)$$

Where ‘W_k’ is coefficient of importance of ‘k’
‘W_j’ is coefficient of importance of ‘i’; ‘gij’ is the score of option ‘j’ in connection with sub-criteria ‘i’.

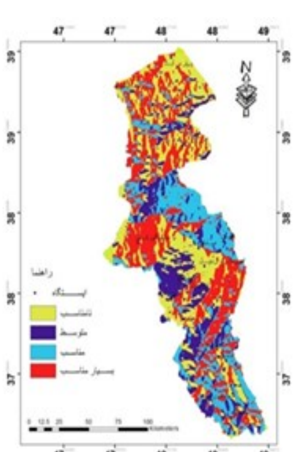

Figure 11. Weighting of slope direction for safflower (In Persian)

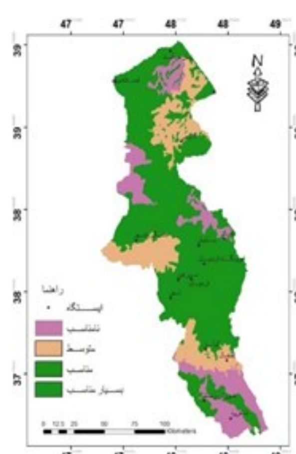

Figure 12. Weighting of land type for safflower (In Persian)

Table 3. General characteristics of the studied parameters

S. No	Variable	N	Minimum	Maximum	Mean	Standard Deviation	Skewness	Kurtosis
1	Annual precipitation	15	239.0	396.7	340.293	53.2151	-0.908	-0.468
2	Annual temperatures	15	8.0	15.6	11.220	2.6072	0.669	-1.086
3	The average minimum temperature	15	1.7	10.1	5.587	2.6508	0.368	-0.932
4	The average maximum temperature	15	14.0	22.0	18.139	2.1444	-0.176	-0.387
5	Sunshine	15	169	236	208.27	16.863	-0.535	0.937
6	Frost	15	36	142	94.80	34.831	-0.526	-1.079
7	Evaporation	15	989	1276	1136.33	89.579	-0.253	-1.202
8	Humidity	15	58	73	67.73	4.399	-0.601	-0.104
9	pH	15	5.4	7.8	6.733	0.7078	-0.465	0.320
10	Ec	15	3.5	6.0	4.500	0.7319	0.473	-0.467

In simple terms, the final score of each option is obtained by multiplying each of the parameters by sub-criteria related to it, and by multiplying the resulting number by the score of the related option.

RESULTS AND DISCUSSION

Relative multiplication of criteria, sub-criteria, options and the final score calculated for each option in conjunction with the herb (safflower) is provided, respectively in Table 1. Then we check the compatibility factor in the judgments of the coefficients above. If this factor is less than or equal to 0.1, compatibility in judgments is accepted; otherwise, judgment should be revised (Kunz, 2010) In the next step, we used interpolation methods to convert the point data to raster layer and in interpolation method, first, climate data must follow a normal distribution, so data normality was analyzed in SPSS environment and frequency distribution graph showed that data follow a normal distribution. Then we measure precision and deviation of the model using validation for each parameter. The result of evaluation of interpolation methods for variables showed that cokriging simple method was more accurate. The general characteristics of the studied parameters and variogram parameters of simple cokriging for the variables studied are shown in Table 2 - 4.

Given that the studied medicinal plants need, on average, 200-300 mm annual rainfall to grow, all the stations studied in the area have the necessary conditions for the cultivation of safflower in respect. Accordingly, it is observed that according to the threshold considered precipitation in whole Ardabil creates no limitation (Figure 1). Temperature is one of

Table 4. Simple variogram cokriging parameters for the studied variables

S. No	Variable	Radius of effect	Threshold	Block effect	R
1	Precipitation	1.30	259255	65702	0.35
2	Annual temperatures	1.36	0.47	0.500	0.64
3	Maximum temperature	1.44	0.44	0.48	0.12
4	Minimum Temperature	1.30	0.56	3.58	0.53
5	Evaporation	1.28	0.38	0.53	0.59
6	Moisture	0.73	11.54	8.77	0.26
7	sunshine	1.24	0.76	1.04	0.63
8	Frost	1.41	0.72	0.39	0.69

Table 5. Group specifications of areas suitable for safflower cultivation in Ardabil

Weight value	Description of the capability	Area (percent)	Hectare
1	Not suitable	1%	2267
3	Average	38%	154727
5	Suitable	55%	224401
7	Very suitable	6%	24890

the main elements in the distribution pattern of crops. Most plants in temperate areas will not grow unless temperature reaches higher than 6°C. In this study, the best temperature for safflower is considered 15-20°C according to theoretical basics and specialists' idea about the ideal temperature for the cultivation of medicinal plants and statistics of synoptic stations in the study area.

Thus, according to the temperature requirements of medicinal plants, we have weighted and provided maps of annual temperature, maximum, and minimum temperature for the intended products in GIS. With an overview to the forms of layers related to temperatures, one can state that the northern parts of the province are suitable for safflower cultivation in terms of daily and maximum temperatures (Figures 2 to 4).

The results of the maps moisture reflected the fact that Ardabil the province has no restrictions for the cultivation of safflower in terms of moisture (Figure 5). Transpiration and soil features play an important role in

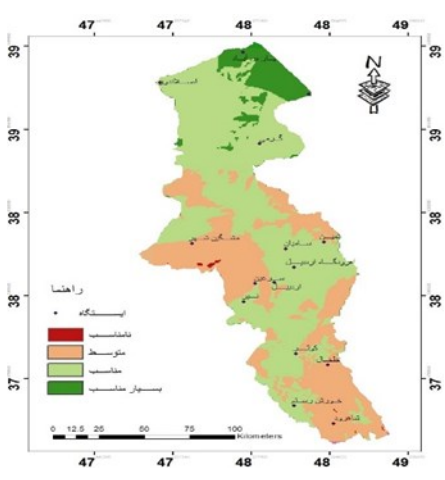

Figure 13. Areas suitable for safflower cultivation in Ardabil based on AHP (In Persian)

retaining water in moisture regime of each region. Precipitation is often compared to potential evapotranspiration. Growth and development periods of medicinal plants are autumn, winter, and early spring, and at these days, regardless of abundant water (rain water) and reduction of evaporation to zero, the need of the studied crops to water and irrigation decreases. Classifying of the need for evapotranspiration of medicinal plants in the studied area is done according to theoretical basics and specialists' opinion. As can be inferred, due to the amount of precipitation in the region, as evapotranspiration reduces, it is better, and as evapotranspiration increases, it is detrimental for medicinal herbs. Thus, very suitable ability is allocated to lower evapotranspiration and unsuitable degrees for cultivation of medicinal plants is dedicated to high evapotranspiration. According to meteorological statistics of Ardabil evaporation rate is high and as is seen in the obtained maps, Ardabil has limitations in terms of evapotranspiration for the cultivation of these products (Figure 6).

Sunshine has a direct relation to day and season, so that by increase in day length and reduction of cloud cover in the area, sunshine increases. Satisfying and economic products safflower are obtained in areas that have more than 250 h of sunshine every month. In the study area, the highest monthly average sunshine is 223-236 h. This is while the sunshine needed for safflower is above 250 according to experts. Thus, the studied area has limitations in terms of sunshine for the cultivation of these crops (Figure 7).

A sharp drop in temperature (minimum temperature) and freezing in different stages of growth are of great importance for agricultural products that in the event of happening lead to restrictions on production and product at different stages and make problems for planting-harvesting or incur losses to farmers. Studying the theoretical principles concerning the number of frost days for safflower showed that the number of frost days should not be more than 90 days. According to the statistics, the number of frost days in Bilesuar, Germi, Pars Abad and Aslanduz stations is 36-49 days in the year, so the northern parts of Ardabil are suitable for cultivation of safflower in terms of the number of frost days (Figure 8).

Height from sea level is one of the factors that affect the quality of atmospheric effects such as temperature, rain, snow and other weather effects effects (Barzgar and Rezaei, 1998). In this study, threshold from 0 to 1000 m is weighted as suitable heights for safflower. Based on the zoning map of digital model, and elevation and the weighting of each of elevation values by using GIS functions in GIS software, weighting map of elevation model was extracted.

Then using the digital maps of slope and slope direction, as secondary processes, land parameters of weighting and their classifications in the study area were dealt with. As we know, the slope of the land affects surface runoff and thus affects the amount of precipitation. Flat lands, compared with sloped lands, retain the ground water for longer time and give the opportunity for more penetration of water. Thus, runoff reduces and penetration rate increases. As a result, rain that is more effective increases that leads to increase of moisture storage of soil. In the studied area, the threshold of slope is considered 0-8 percent for safflower cultivation. Thus, for preparation of weighted layer of slope, using zoning map of slope and digital map of elevation, we have given specific weights to different slopes based on the ability to cultivate the plant. Thus, weighted slope map of the region was extracted. As sunlight and directions prevent cold and enhance the quality of rain-fed and crops, the cultivation of these crops in south and southeast slopes is recommended. Thus, slope is considered as a data layer (Figures 9, 10 and 11).

Available land types were specified through land use map, and based on different talents they were divided into land suitable for planting medicinal herbs. According to examinations conducted in this study, it can be concluded that the soil in the study area is suitable for planting safflower in terms of soil pH and electrical conductivity (EC) (Figure 12 and 13).

Data analysis and concluding references include division of environmental factors into understandable parts and then combining them in a way that the assessor can realize the limitation of land resources for the intended use. In this study, after weighting parameters effective in the cultivation of safflower based on AHP model and modeling and analysis of spatial data using GIS, final map of areas suitable for cultivation of safflower in Ardabil were obtained (Figure 1). In this map, province has been classified into four groups in terms of the potential for cultivation of safflower, and group specifications of areas suitable for safflower cultivation in Ardabil are given in Table 5.

The first group, about 1% of the total area of the province, lacks the required conditions for safflower cultivation. The second group is those areas that have relatively suitable conditions for safflower cultivation, including mountainous regions in central and southern parts of the province. General environmental limitations of these regions are primarily the limitations of climate, especially freezing in the growth and germination stages and in second place are elevation, slope and soil type that include almost 38 percent of the province area. Third and fourth groups include areas where safflower can be cultivated that cover almost 61 percent of the area of the province. This group, mainly including Maghan Plain, is according to the agricultural areas of the province.

To assess the results and ensure the accuracy of the information of the final map, by visiting a number of experimental farms of safflower cultures that work under the auspices of agricultural organization of the province, yield and product quality were compared with the information obtained from zoning map. Considering the scale and accuracy of location information used in the research, the accuracy of the results was confirmed that indicates the effectiveness of MCDM methods, especially AHP model in the assessment of land capability to cultivate safflower.

CONCLUSION

The results showed that almost half of the land area of the province has the capabilities required for the cultivation of safflower and according to the specific characteristics of this product, replacing its cultivation with high water consuming crops can be considered by agricultural experts. This is because its cultivation beside other agricultural products, especially in areas with water shortages, is useful and can reduce the density of farming activities in times of crisis of need for work force.

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