Available online at www.scholarsresearchlibrary.com

Scholars Research Library

Annals of Biological Research, 2012, 3 (5):2307-2317
(http://scholarsresearchlibrary.com/archive.html)

ISSN 0976-1233
CODEN (USA): ABRNBW

Using AHP Modeling and GIS to Evaluate the Suitability of Site with Climatic Potential for Cultivation of Autumn Canola in Ardabil Province

[1]Bashir Beigbabayi and [2]Mohammad Azadi Mobaraki

[1]Islamic Azad University, Malekan Branch, Malekan, Iran
[2]Payame Noor University, Ajabshir Branch, Iran

ABSTRACT

Cultivation and harvest of oil seeds are of high economic value in the world today.Extraction and exportation of oil has a special place in the non-oil exports of Iran. Canolais an economical oil seed and over the last few years many attempts have been made to increase its subculture in different regions of the country. But it must be noted that due to various factors that affect the growth and performance of autumn canola, the process of evaluating suitability of site for cultivation requires comprehensive spatial and descriptive information. GIS technology enablesthe application of these data and facilitates the spatial analysis of data based on relevant models. Thus, in the present research, considering the ecological needs of autumn canola, multi-criteria decision making (MCDM) is applied based on Analytic Hierarchy Process and the modeling and then spatial analysis of the data were carried outusingArcGIS 9.3 software. Finally, the zones favorable to the cultivation of autumn canola in Ardabil Province were evaluated and demarcated. The results of the research show that zones with severe restrictions, relatively high restrictions, moderate restrictions, few restrictions, and now restrictions respectively constitute 38, 21.27, 19.01, 16.27, and 5.45 percent of the entire province.

Keywords: canola, climatic elements, Analytic Hierarchy Process (AHP), multi-criteria decision making (MCDM), Ardabil Province, GIS software.

INTROUDACTION

The flora and fauna are considered as two of the major sources of human nutrition. Fats and proteins are two essential materials in providing energy for the basic needs of the body. Vegetable oils, due to having considerable amounts of vitamins, proteins, and especiallypolyunsaturated fatty acids, play an important role in controlling blood cholesterol andin the health of human societies. Along with the increase in the population of Iran and improvement in the quality of life of people, the consumption of vegetable oils has also increased, and due to the coordinated growth of oil seed production and increase in the demand for vegetable oil, more than 90 percent of the consumption of oil in the country is supplied through import and a considerable amount of foreign currency [1]. Meanwhile, canola is an oil seed with unique economic value throughout the world. Iran has recently experimented with the cultivation of this product in different regions of the country. It must be noted that this venture at times wastes the money and time of farmers and relevant organizations, for like any other agricultural and horticultural product, canola has its own ecological properties and the lack of any such property can result in lack of growth of this productin some of the regions of the country. Therefore, by studying the driving factors in the efficiency of products, one can with more a more comprehensive understandingand provide facilities commensurate to the potentials of the cultivation zone.

Spatial modeling is one of the strategies that allows for scientific evaluation of suitability of site for cultivation of a specific product. Since different factors and criteria must be taken into accountfor evaluation of site suitability in the province, one must use multi-criteria decision making techniques. There are different techniques but the present research uses Analytic Hierarchy Process (AHP). There are many studies based on AHP due to its high accuracy. Faraji (2005) applied AHP to urban planning and finding the location of commercial services, and the results were deemed satisfactory [2]. Beigloo et al. (2008) used AHP model to examine the site suitability for cultivation of saffron in Qazvin Province and the results suggested the efficiency of analytic hierarchy process and the province was accordingly divided into favorable, applied AHP to create a model in GIS software forfinding proper locations for landfill in provincial regions, [3]. Using the same model, Hashempour (2009) determined the potential regions for cultivating citrus throughout Mazandaran Province and classified the regions from very favorable to unfavorable, [4]. Tabatabaei (2009) also carried out a similar research to demarcate the lands of East Azerbaijan Province and find the favorablesites for cultivating sugar beet, [5].

Thus, the purpose of the present research is to determine the favorable regions in Ardabil Province for cultivation of canola oil seeds using AHP and by applying overlapping method in GIS software.

MATERIALS AND METHODS

The studied area is located in north-west Iran (38.2514°N 48.2973°E). The total area of this region is almost 17951 km^2.The area is contiguous with Republic of Azerbaijan from the north, Gilan Province from south-east, Zanjan Province from the south, and East Azerbaijan Province from the east (figure 1).

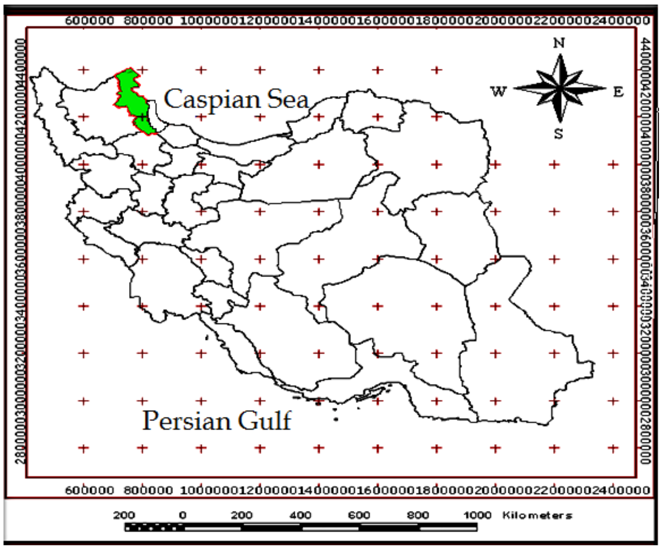

Figure 1 – The location of the studied region

The following procedures were performed in the present research.

1. Library study

In this stage, books, articles, journals, and all the available material that were related to the issue were examined. Many people have researched the phenological stages of canola, including Ayeneband (1993), Veisz et al. (2001), Parker (1998), and Hollinger (2002),[6,7,8,9]. Finally, the phonological table of autumn canola that was presented by Abiri (2007) was used as the basis of study, [10,11].

2. Data collection

Taking into account the parameters in table 1, the required data was collected from Ardabil MeteorologicalOrganization and includes information from 14 synoptic andevaporimetricstations (figure 2).

Table 1 – The climatic requirements of autumn canola (Abiri, 2007)

Category Climatic Properties	No Restrictions (Favorable)	Few Restrictions (Favorable)	Moderate Restrictions (Average)	High Restrictions (Unfavorable)	Severe Restrictions (Unfavorable)
Mean temp	12.5-13.5	12-12.5 13.5-14	11-12 14-15	9-11 15-17	9 > or > 17
Mean max. temp	18-19	17-18 19-20	16-17 20-21	15-16 21-22	15 > or > 22
Mean min. temp	6-7	5-6 7-7.5	4-5 7.5-8	2-4 8-10	2 > or > 10
Precipitation during the growth period	< 500	400-500	300-400	200-300	< 200
Number of frosty days	50-60	40-50 60-70	30-40 70-90	20-30 90-120	20 > or > 120
Relative humidity	70-80	65-70	55-65	40-55	40 > or > 80
Slope	0-2	2-8	8-12	12-16	> 16
Soil depth	> 150	100-150	80-100	60-80	< 60
Landform	Alluvial, fluvial, and flood plain	Plateaus, terraces, and alluvial fans	Hills	Mountains	Salt marsh
Application	Farming	Pasture	Forest	Water source	Acrid land

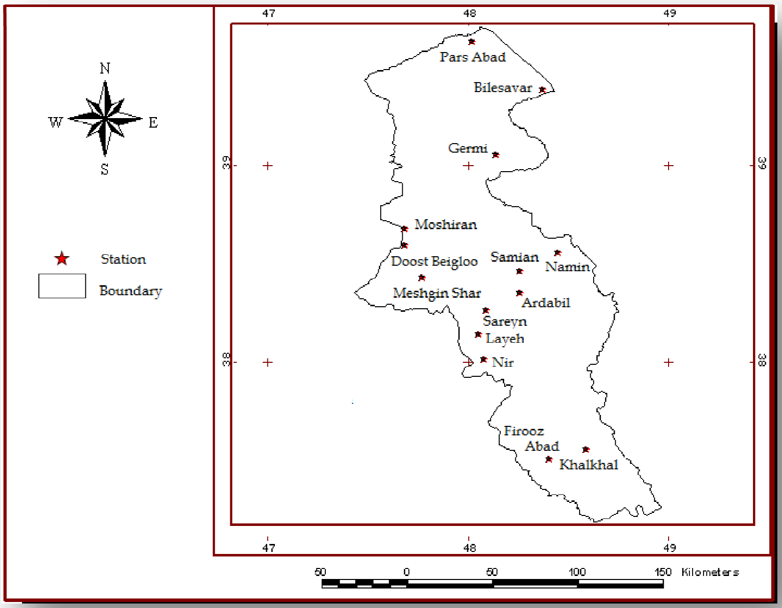

Figure 2 – The location of the studied area and stations

3. Data analysis

Data analysis is the most important stage of any research. In this stage, the descriptive data was collected, the spatial data wasquantified, anda relationship was established between the descriptive data and layers by creating a topological space in GIS software. Then, based on the ecological conditions of autumn canola the criteria were identified and the criteria and sub-criteria were valued using AHP; accordingly, the data were overlapped and analyzed in ArcGIS 9.3 software. Regions with the highest weight were selected as favorable sites for cultivating autumn canola in Ardabil Province.

RESULTS

Suitability of site evaluation and location of autumn canola cultivation

To determine the potential or restriction of different regions of Ardabil Province for cultivation of autumn canola, AHP method was applied to cluster and rate the driving factors. After calculating the final score of the alternatives and examining the logical consistency of the decisions, spatial data was created foreach of the factors and alternatives and analysis was carried out using GIS software. The lands of Ardabil Province were ranked in terms of their potential for cultivation of autumn canola. In general, the process of evaluating the potential of the sites and finding the best locations was as follows:

Analytic Hierarchy Process (AHP)

The model used to incorporate the mentioned data is, in effect, a weight model based on AHP. In this model, the criteria are placed within a hierarchic system and are compared in a pairwise fashion, and each criterion receives a weight ranging from 1 to 9. Then, the final value of the criteria is determined and they are categorized into several groups of interest. Finally, the categorized layers are combined, the final map is obtained in GIS software, and the regions are demarcated based on preference. This method is usually applied when criteria lack structure and when evaluation is based on decision making preferences (Faraji, 2008). In order to increase the accuracy of decisions and to enable data comparisons, the criteria at each level are compared pairwise to the criteria at a higher level and they receive a relative weight. To determine the relative weight of the main parameters, first a geometric mean matrix was created for each parameter and the relative weight of climate was calculated; then, the relative weight of criteria and sub-criteria related to climatic elements was determined and in the end the final weight of each alternative was identified (table 3).

	Climate	Soil	Slope	Landform	Application	Weight
Climate	1	3	5	8	9	$W_1 = 0.496$
Soil	1/3	1	4	5	6	$W_2 = 0.259$
Slope	1/5	1/4	1	4	5	$W_3 = 0.132$
Landform	1/8	1/5	1/4	1	3	$W_4 = 0.061$
Application	1/9	1/6	1/5	1/3	1	$W_5 = 0.030$

The procedures of calculating the weight of the sub-criteria is the same as those used for calculating the weight of the criteria. The climate criterion consists of seven sub-criteria and its matrix is as follows:

	Min. Temp	Mean Temp	Frost	Precipitation	Humidity	Max. Temp	Sunny Hours	Weight
Min. Temp	1	2	3	4	6	7	9	$W_1 = 0.352$
Mean Temp	1/2	1	2	3	5	6	7	$W_2 = 0.237$
Frost	1/3	1/2	1	2	4	5	6	$W_3 = 0.161$
Precipitation	1/4	1/3	1/2	1	3	4	5	$W_4 = 0.111$
Humidity	1/6	1/5	1/4	1/3	1	3	4	$W_5 = 0.081$
Max. Temp	1/7	1/6	1/5	1/4	1/3	1	2	$W_6 = 0.036$
Sunny hours	1/9	1/7	1/6	1/5	1/4	1/2	1	$W_7 = 0.025$

Now the weight of the alternatives is determined.

Annual Temp

	A	B	C	D	E	Annual Temp	Weight
A	1	4	5	7	8	-13.5-12.5	$W_A = 0.514$
B	1/4	1	4	5	6	12-12.5 & 13.5-14	$W_B = 0.257$
C	1/5	1/4	1	3	4	11-12 & 14-15	$W_C = 0.125$
D	1/7	1/5	1/3	1	2	9-11 & 15-17	$W_D = 0.060$
E	1/8	1/6	1/4	1/2	1	> 9 or > 17	$W_E = 0.040$

Minimum Annual Temp

	A	B	C	D	E	Min. AnnualTemp	Weight
A	1	4	5	8	9	6-7	$W_A = 0.533$
B	1/4	1	3	4	5	5-6 & 7-7.5	$W_B = 0.187$
C	1/5	1/3	1	2	3	4-5& 7.5-8	$W_C = 0.111$
D	1/8	1/4	1/2	1	2	2-4&8-10	$W_D = 0.066$
E	1/9	1/5	1/3	1/2	1	>2 or >10	$W_E = 0.042$

Maximum Annual Temp

	A	B	C	D	E	Max. AnnualTemp	Weight
A	1	2	3	5	6	18-19	$W_A = 0.416$
B	1/2	1	2	3	4	17-18 & 19-20	$W_B = 0.291$
C	1/3	1/2	1	2	3	16-17 & 20-21	$W_C = 0.162$
D	1/5	1/3	1/2	1	2	15-16&20-21	$W_D = 0.076$
E	1/6	1/4	1/3	1/2	1	>15 or >22	$W_E = 0.050$

Annual Frost

	A	B	C	D	E	AnnualFrost (Days)	Weight
A	1	2	3	5	6	50-60	$W_A = 0.462$
B	1/2	1	2	3	4	40-50&60-70	$W_B = 0.266$
C	1/3	1/2	1	2	3	30-40&70-90	$W_C = 0.138$
D	1/5	1/3	1/2	1	2	20-30&90-120	$W_D = 0.076$
E	1/6	1/4	1/3	1/2	1	>20 or >120	$W_E = 0.032$

Annual Sunny Hours

	A	B	C	D	E	AnnualSunny Hours	Weight
A	1	2	3	4	5	> 2000	$W_A = 0.410$
B	1/2	1	2	3	4	1500-2000	$W_B = 0.256$
C	1/3	1/2	1	2	3	1000-1500	$W_C = 0.158$
D	1/4	1/3	1/2	1	2	800-1000	$W_D = 0.094$
E	1/5	1/4	1/3	1/2	1	< 800	$W_E = 0.062$

Precipitation

	A	B	C	D	E	Precipitation	Weight
A	1	3	4	5	6	> 500	$W_A = 0.464$
B	1/3	1	3	4	5	400-500	$W_B = 0.260$
C	1/4	1/3	1	3	2	300-400	$W_C = 0.126$
D	1/5	1/4	1/3	1	2	200-300	$W_D = 0.074$
E	1/6	1/5	1/2	1/2	1	< 200	$W_E = 0.052$

Humidity

	A	B	C	D	E	Humidity (%)	Weight
A	1	2	3	5	6	70-80	$W_A = 0.438$
B	1/2	1	2	3	4	65-70	$W_B = 0.257$
C	1/3	1/2	1	2	3	55-65	$W_C = 0.155$
D	1/5	1/3	1/2	1	2	40-50	$W_D = 0.091$
E	1/6	1/4	1/3	1/2	1	> 80 or < 40	$W_E = 0.057$

Examining consistency in decisions

One of the advantages of hierarchic analyses is the ability to examine the consistency of the decisions made for determining the weight of the criteria and sub-criteria.A weighted sum vector is determined for each of the criteria and sub-criteria bymultiplying the weight of the first criterion by the first column of the original pairwise comparison matrix, the weight of the second criterion by the second column, and so forth. Finally, we sum these values over the rows (the same procedures are followed for each of the criteria and sub-criteria).

Table 2 – Consistency ratio

Criterion	First Step	Second Step
Climate	0.496 (1) + 0.259 (3) + 0.132 (5) + 0.061 (8) + 0.030 (9) = 2.688	2.68/0.0496 = 5.42
Soil	0.496 (1/2) + 0.259 (1) + 0.132 (4) + 0.061 (5) + 0.030 (6) = 1.375	1.375/0.259 = 5.31
Slope	0.496 (1/5) + 0.259 (1/4) + 0.132 (1) + 0.061 (4) + 0.030 (5) = 0.680	0.68/0.132 = 5.15
Landform	0.496 (1/8) + 0.259 (1/5) + 0.132 (1/4) + 0.061 (1) + 0.030 (3) = 0.297	0.297/0.03 = 4.86
Application	0.496 (1/9) + 0.259 (1/6) + 0.132 (1/5) + 0.061 (1/3) + 0.030 (1) = 0.171	0.171/0.03 = 5.73

After calculating the consistency vector, two more vectors are needed to complete the calculations: lambda (λ) and consistency index (CI). The value of lambda is the average value of the consistency vector and is calculated as:

$$\lambda = \frac{5.42 + 5.31 + 5.15 + 4.86 + 5.73}{5} = 5.294$$

$$CI = \frac{\lambda - n}{n - 1} = \frac{5.294 - 5}{5 - 1} = 0.0735$$

Table 3 – Random index (RI)

n	RI	n	RI	n	RI
1	0.00	6	1.24	11	1.51
2	0.00	7	1.32	12	1.48
3	0.58	8	1.41	13	1.56
4	0.90	9	1.45	14	1.57
5	1.12	10	1.49	15	1.59

Source: Farajzadeh-Asl (2005)

Finally, the consistency ratio (CR) is obtained from dividing the consistency index (CI) by the random index (RI):

$$CR = \frac{CI}{RI} = \frac{0.0735}{1.12} = 0.065$$

The value of the random index changes with respect to the number of criteria (sub-criteria and alternatives) (table 3). A value of CR less than 0.1 indicates an acceptable level of consistency in pairwise comparisons.In other words, if CR is equal to or greater than 0.1, the weight applied on it must be reconsidered and the pairwise matrix must be reexamined until an acceptable level is reached.

Table 4 –The results of examining the consistency of criteriaand sub-criteria

	CI		CI	Alternative	CI
Criteria	0.1	Climate	0.047	Mean Annual Temp	0.0004
				Mean Min. Temp	0.321
				Mean Max. Temp	0.316
				Precipitation	0.048
				Sunny Hours	0.0138
				Humidity	0.007
				Frost Days	0.0546

Table 5 –Weighting the appropriate parameters (criteria) for cultivation of canola based on AHP

Relative Weight of Climate	Factors	Relative Weight	Secondary Factors	Relative Weight	Final Weight
0.496	Mean Temp	0.237	Severe Restrictions	0.040	0.0094
			High Restrictions	0.060	0.0142
			Moderate Restrictions	0.135	0.0296
			Few Restrictions	0.257	0.0609
			No Restrictions	0.514	0.121
	Mean Max. Temp	0.036	Severe Restrictions	0.050	0.0018
			High Restrictions	0.076	0.0027
			Moderate Restrictions	0.162	0.0058
			Few Restrictions	0.291	0.0104
			No Restrictions	0.416	0.0149
	Mean Min. Temp	0.352	Severe Restrictions	0.042	0.0147
			High Restrictions	0.066	0.0232
			Moderate Restrictions	0.111	0.039
			Few Restrictions	0.187	0.0658
			No Restrictions	0.553	0.1946
	Precipitation	0.111	Severe Restrictions	0.052	0.0057
			High Restrictions	0.074	0.0082
			Moderate Restrictions	0.126	0.0139
			Few Restrictions	0.26	0.0288
			No Restrictions	0.464	0.0515
	Sunny Hours	0.025	Severe Restrictions	0.062	0.0015
			High Restrictions	0.094	0.0023
			Moderate Restrictions	0.158	0.0039
			Few Restrictions	0.256	0.0064
			No Restrictions	0.41	0.0102
	Frosty Days	0.161	Severe Restrictions	0.032	0.0051
			High Restrictions	0.076	0.0122
			Moderate Restrictions	0.138	0.0222
			Few Restrictions	0.266	0.0428
			No Restrictions	0.465	0.0748
	Humidity	0.081	Severe Restrictions	0.057	0.0064
			High Restrictions	0.091	0.0073
			Moderate Restrictions	0.155	0.125
			Few Restrictions	0.254	0.0205
			No Restrictions	0.0351	0.438

After completing the above steps, the layers related to each of the matrices were obtained in GIS software and the results are presented below.

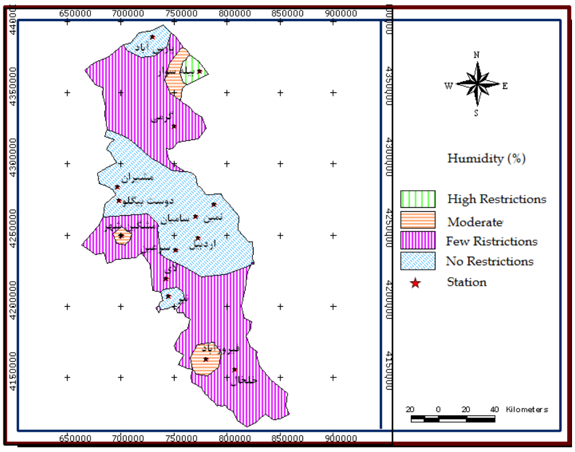

Figure 3 – The favorable sites for cultivation of autumn canola in terms of humidity

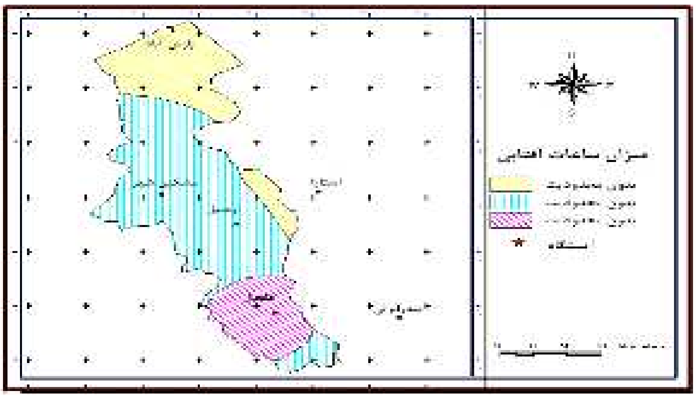

Figure 4 -The favorable sites for cultivation of autumn canola in terms of sunny hours

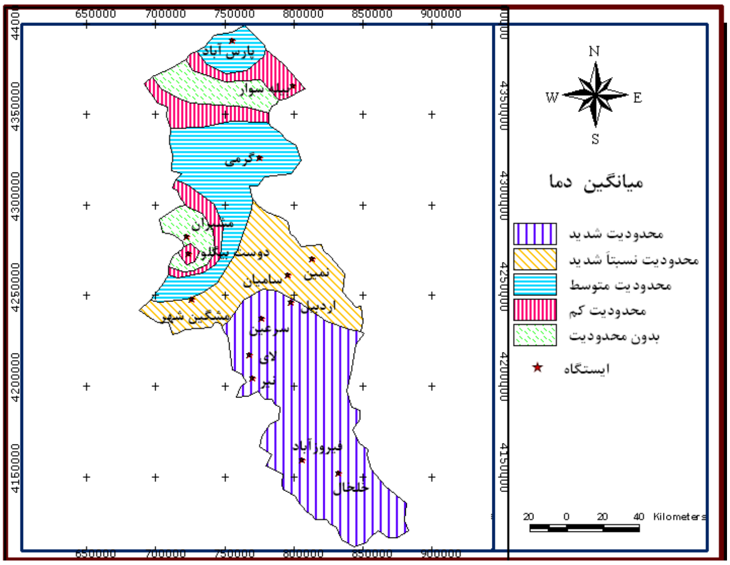

Figure 5 - The favorable sites for cultivation of autumn canola in terms of mean temperature

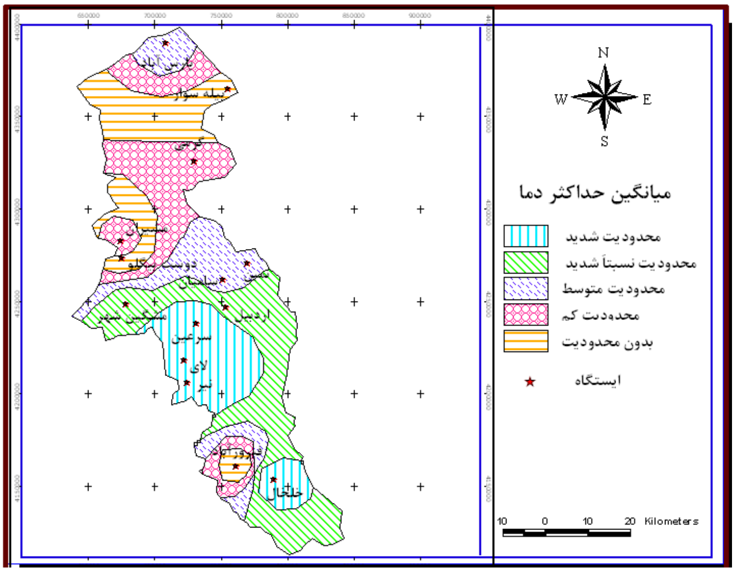

Figure 6 - The favorable sites for cultivation of autumn canola in terms of maximum temperature

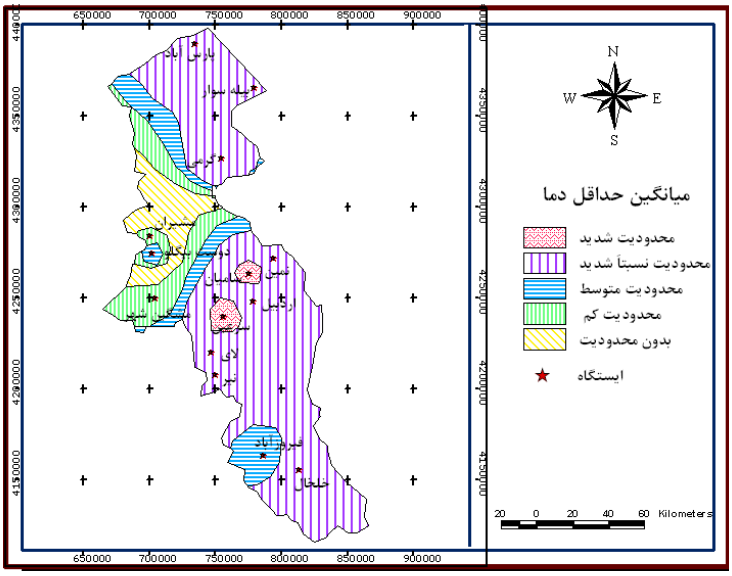

Figure 7 - The favorable sites for cultivation of autumn canola in terms of minimum temperature

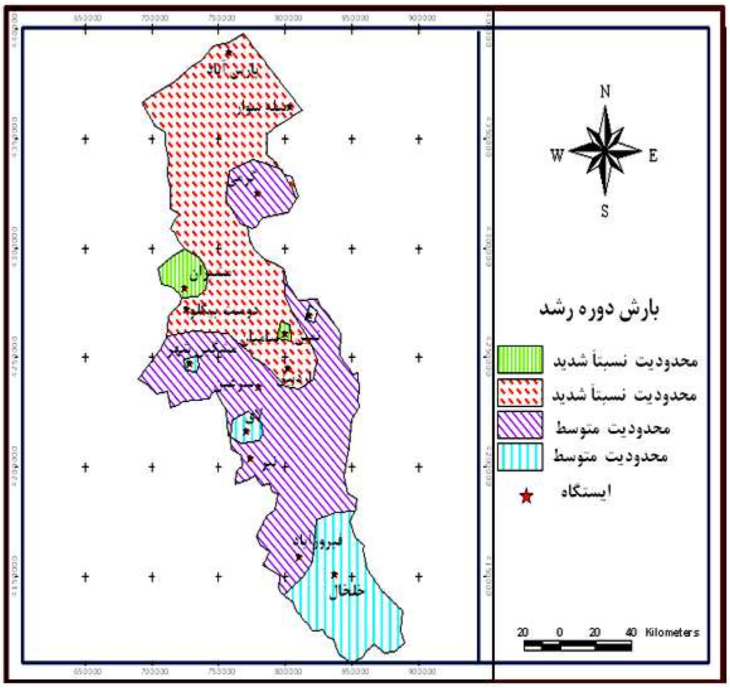

Figure 8 - The favorable sites for cultivation of autumn canola in terms of precipitation

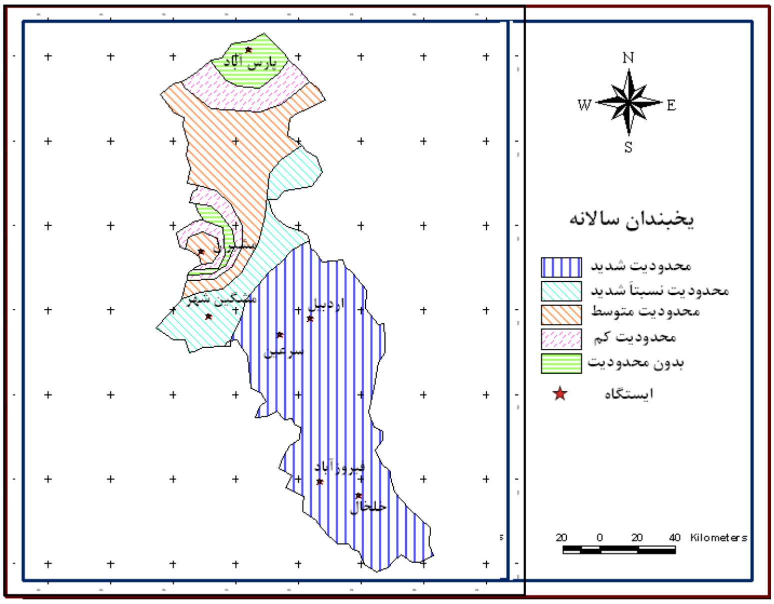

Figure 9 - The favorable sites for cultivation of autumn canola in terms of annual frost

Table 6 – The weight of the layers related to the final map for cultivation of autumn canola

Condition	Area (%)
Severe Restrictions	38
High Restrictions	21.27
Moderate Restrictions	19.01
Few Restrictions	16.27
No Restrictions	5.45

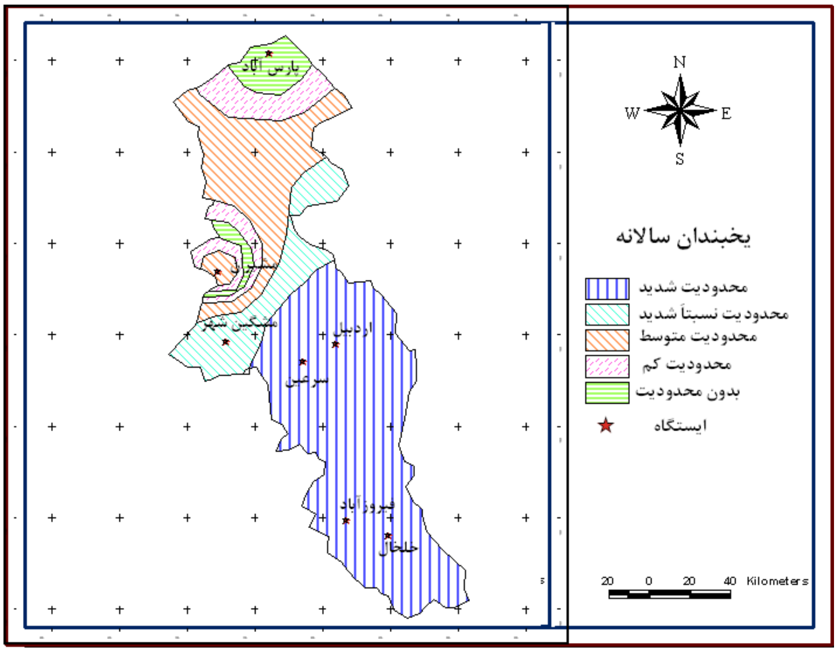

Figure 10 – The favorable sites for cultivation of autumn canola in terms of elements

DISCUSTION AND CONCLUSION

Analysis of the climatic elements that influence the cultivation of autumn canola in Ardabil Province suggested restrictions in various regions of the province.Considering the layers for the amount of precipitation required for cultivation of autumn canola, Ardabil has high to moderate restrictions and proper management is required to compensate for this need by transferring water from water sources to the cultivated areas. Moreover, it must be noted that frost can be the second restricting factor in the cultivation of canola in the studied region. In general, considering the layers obtained for frost, mean temperature, and mean maximum temperature, it can be concluded that the southern half of the province is in worst conditions as compared to the northern half. Among the layers created for climatic elements, only the layer related to sunny hours for which the entire province has no restrictions, while other climatic parameters are faced with a degree of restriction in some areas of the Province and hinder the cultivation of autumn canola [12, 13].

The main purpose of the present research was to examine the role of climatic elements in finding favorable sites for cultivation of autumn canola in Ardabil Province. Thus, the layers related to the climatic elements (annual temperature, annual minimum temperature, annual maximum temperature, precipitation in the growth period, humidity, sunny hours, and the number of frosty days) were analyzed in GIS software and finally, by overlapping the final map, the qualitative evaluation of site suitability for cultivation of autumn canola was provided (figure 10).For cultivation of autumn canola, Ardabil Province can be divided into five categories. According to table 6, sites with severe restrictions constitute 38% of the entire province and examining the map reveals that these regions are located in central and southern regions. Sites with high restrictions, moderate restrictions, and few restrictions respectively make up 21.27, 19.01, and 16.27 percent of the province. The remaining 5.45 percent is in favorable conditions for cultivation of autumn canola and this product can continue its growth in this region. These sites include some regions in the north and some part in the western part of Ardabil. It can be gathered from the analysis of the maps that there are regions in Ardabil Province where cultivating autumn canola is possible.

REFERENCES

[1]. A Arghavani, Master's Thesis, **2009**, pp. 20-25.
[2]. H.A Faraji Sabokbar, *Journal of Geographical Research*, **2005**, 51: 125-138.
[3]. M Beigloo, Z Mobaraki, *Journal of Geographical Research*, **2008**, 66: 102-119.
[4]. F Hashempour, Identifying the favorable areas for cultivation of citrus, **2009**. pp. 35-40.
[5]. B Tabatabaei, Master's Thesis,University of Mohaghegh Ardabili, **2009**, pp. 65-75.
[6]. A Ayeneband, Master's Thesis, Faculty of Agriculture, Tarbiat Modarres University, **1993**, p. 61.
[7]. O Veisz, H.J Braun, Z Bedo, Plant damage after freezing, Euphytica, **2001**, 119:179-183.
[8]. R Parker, Introduction to plant science. **1998**, Albany, NY: Delmar.

[9]. S.E Hollinger, Agricultural climatology, University of Illinois at Urbana-Champaign, **2002**, pp. 1–21.
[10]. S.A Abiri, Master's Thesis, Tarbiat Modarres University, **2007**, p. 21.
[11]. K Vatalis, A two-level multi-criteria DSS for Landfill Site Selection Using, **2002**, 6(1): 49-56.
[12]. M Farajzadeh-Asl, SAMT, Tehran, **2005**, p. 147.
[13]. H.A Faraji Sabokbar, H Karimzadeh, B Sahneh, H Koohestani, *Journal of Geography and Planning*, **1999**, 27: 17-45.