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Exploring canola planting area using AHP associated with GIS in Meymeh–Zarinabad of Iran

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Abstract Studying physiological needs of plants and their climatic parameters are the main factors to reach optimal productions and reduce the plant injuries such as adverse effects of the harsh environmental conditions. The present study was conducted to evaluate the five main criteria including climate (containing sub criteria of annual minimum temperature, annual mean temperature, annual maximum temperature, annual relative humidity, and annual glacial), soil, slope, land type and land use in locating the capable areas for planting canola in Meymeh–Zarinabad, south west of Iran, using GIS and AHP. For this purpose, meteorological data taken from 26 synoptic stations were used. All criteria were weighted and modeled using AHP and GIS. The results showed the climate and slope with respectively 0.33 and 0.24 are the most important factors for planting canola. Besides, the capability of the case study for this species was classified in four classes of very good, good, medium, and feeble. Results indicated 565,684, 90,586, 63,000 and 51,247 ha were respectively very good, good, medium and feeble. The role of climatic and ground parameters is different in various areas, so with integrating the effective layers, appropriate areas for canola will be obtained.

Keywords Canola · Location · AHP · GIS · Meymeh–Zarinabad

1 Introduction

Today, the potential and capability of geographic information system (GIS) in analyzing temporal and spatial ground data is obvious. Using GIS, providing land suitability maps represents stable distribution of a special product. GIS and remote sensing can be used as proper tools for these purposes. Using both of them together can improve their output twofold [1]. The method of land suitability for specific plants, which is included the quantitative and qualitative evaluation of land suitability, first was proposed by FAO. This system considers effective factors in crop production and determines the land suitability according to land features and crop needs [2]. Each region has some capabilities and limitations in agriculture fields. So, identifying and analyzing these agents can make appropriate effects on the optimized use of the plants based on their requirements [3]. Determining land capability is a suitable way in developing the organic agriculture. Canola, *Brassica Napus* L, is one of the most eminent oilseed crops which is widely being cultivated in temperate regions and has a significant role on producing the edible oils [4]. Canola grows in specific conditions of climate and environment. Many variables affect the growth of plants, including day length, amount of solar energy, rainfall, temperature and amount of nutrients required by plants during growth in soil, altitude, geology etc. [5]. Since evaluating the land suitability needs to consider different factors, Multi-criteria decision analysis

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(MCDA) such as AHP is recommended. In this method, experts do simple paired comparison by hierarchy to reach the priorities [6]. Different authors have investigated various researches on canola. Roger (2000), in a study called "detecting the regions of planting canola in the state of Illinois of Canada, using GIS", provided a model for determining the appropriate areas to plant canola as well as evaluating agricultural products [7]. Pakob used GIS and NDVI index in southeast Mississippi to study the relationship between topographic (slope and aspect) and hydrological factors (length and direction, river water quality) by presenting the Stepwise model to estimate the yield of canola. AHP and GIS have been used by various authors to determine the most appropriate area for planting the best crop [8, 9].

The main purpose of this study is to determine susceptible areas of Meymeh–Zarinabad in Ilam to cultivate oilseeds of Canola by using AHP method as well as overlapping method of the layers in the GIS environment.

2 Materials and methods

2.1 Study area

The present study was conducted in Meymeh–Zarinabad region in Ilam province, south west of Iran, with 46° 44′ to 47° 30′ E and 32° 27′ to 33° 19′ N (Fig. 1). This region covers the altitude ranging from 73 to 2502 m above sea level. The annual rainfall is 421. 8 mm which 84% of it occurs in spring and summer and 308 mm of the precipitation is evaporated due to its high temperature.

2.2 Multispectral image processing

Descriptive-analytical method was used as well as survey method in this study, especially based on practical research. Five criteria including climate (containing sub criteria of annual minimum temperature, annual mean temperature, annual maximum temperature, annual humidity, annual precipitation, and annual glacial), soil, slope, land type and land use which were considered based on expert's decision. Climatic maps were prepared by meteorological data taken from 26 synoptic and climatologic stations based on IDW method (Fig. 2). 1:25,000 topographic map was applied to prepare slope map and also to determine the type of land use in the area, images of Landsat 8, 2014 were selected and categories in five classes of agriculture and horticulture, pasture, forest, dry land and protected areas using maximum likelihood.

2.3 Analytical hierarchy process (AHP)

The criteria were compared and weighted from 1 to 9 using AHP. For reach this purpose, first experts fill in the

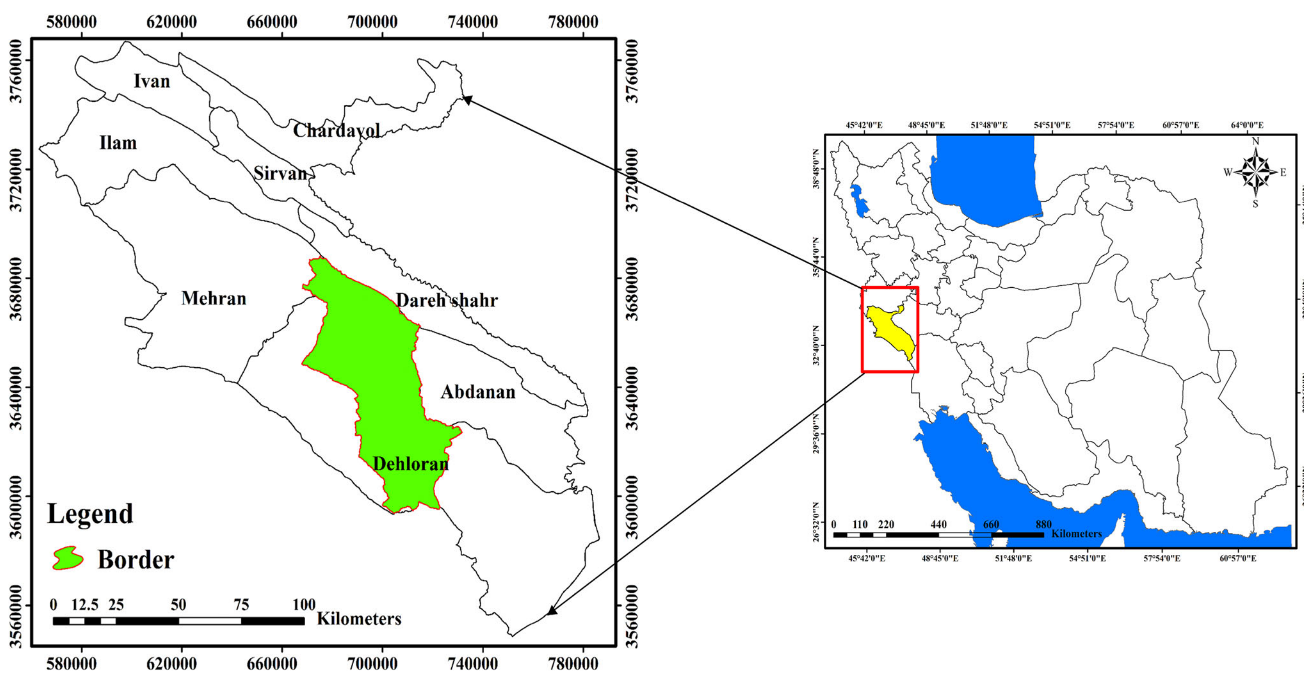

Fig. 1 Location of study area in Ilam province and Iran

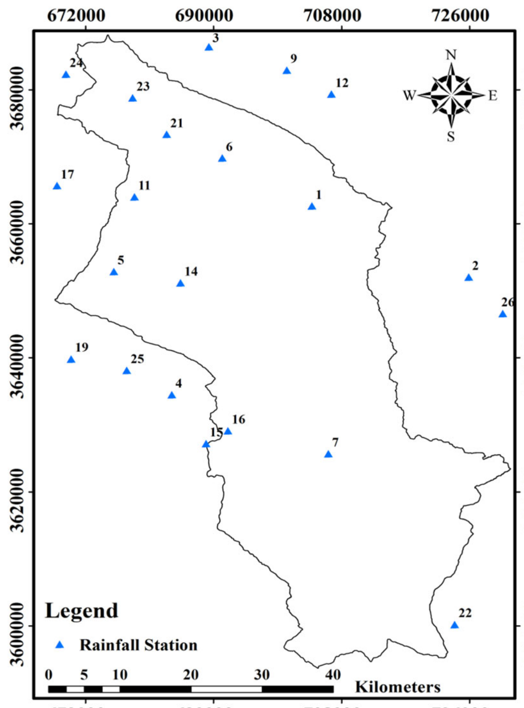

Fig. 2 The stations used in the studied area

questionnaires, then they should compare each paired criteria for decision. This comparison is descriptive, then it will be quantitative in 1–9 according to Table 1 and finally paired matrix comparison will be obtained [10, 11]. The weights of criteria in AHP were presented as a quantitative form by numbers [12]. The main criteria were orally compared by expert's opinions and their weights were measured. After extracting all criteria in the study and preparing the questionnaires for experts, the expert opinions should be evaluated to obtain inconsistency rate by Expert Choice 11 software. If inconsistency rate is less than 0.1, it means that there is a suitable level of consistency in paired comparisons [13–16]. The numbers of participants were 55 people in this study. Figure 3 shows the decision tree of main criteria for locating the land suitability of canola.

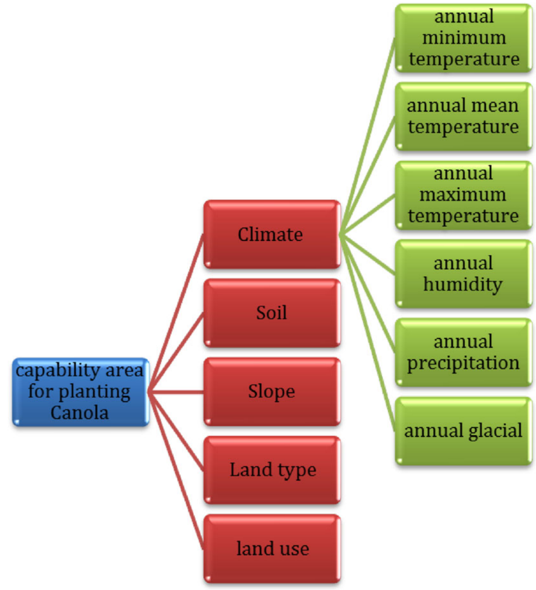

Fig. 3 Decision tree of main criteria for locating the land suitability of canola (Reference: Authors)

The maps were overlaid and finally the map of land suitability for canola was prepared in four classes of very good, good, medium and feeble.

3 Results and discussion

In the present study, five criteria including climate (containing sub criteria of annual minimum temperature, annual mean temperature, annual maximum temperature, annual humidity, annual precipitation and annual glacial), soil, slope, land type and land use were evaluating in Meymeh–Zarinabad using GIS and AHP.

Table 1 Valorization the Criteria Relative to each other by expert's opinions

Explanation	Definition	Intensity of importance
Two factors contribute equally to the objective	Equal importance	1
Experience and judgment slightly favor one over the other.	Somewhat more important	3
Experience and judgement strongly favor one over the other	Much more important	5
Experience and judgment very strongly favor one Over the other. Its importance is demonstrated in practice	Very much more important	7
The evidence favoring one over the other is of the highest possible validity	Absolutely more important	9
When compromise is needed	Intermediate values	2, 4, 8, 9

Table 2 Sub criteria's climate parameter: classes and their relative importance

Class	12.5–13.5	12–12.5 13.5–14	11–12 14–15	9–11 15–17	17< or <9	Geometric mean	Relative importance
Minimum annual temperature							
12.5–13.5	1	2	3	4	5	4.45	0.35
12–12.5 13.5–14	1.2	1	2	3	4	3.30	0.24
11–12 14–15	1.3	1.2	1	2	3	2.41	0.18
9–11 15–17	1.4	1.3	1.2	1	2	1.76	0.13
17 < or < 9	1.5	1.4	1.3	1.2	1	1.30	0.10

Class	18–19	19–20 17–18	20–21 16–17	20–21	20–21 15–16	Geometric mean	Relative importance
Annual mean temperature							
18–19	1	3	5	7	9	3.9362	0.506
19–20 17–18	1.3	1	3	5	7	2.0361	0.257
20–21 16-17	1.5	1.3	1	3	5	1.1846	0.154
20–21 15–16	1.7	1.5	1.5	1	3	0.4088	0.051
20–21 15–16	1.9	1.7	1.7	1.2	1	0.2575	0.032

Class	6–7	5–6 7–7.5	4–5 7.5–8	2–4 8–10	10< or <2	Geometric mean	Relative importance
Annual maximum temperature							
6–7	1	3	5	8	9	4.0428	0.5172
5–6 7–7.5	1.3	1	3	6	7	2.1118	0.2702
4–5 7.5–8	1.5	1.3	1	3	4	0.9564	0.1224
2–4 8–10	1.7	1.6	1.3	1	2	0.4251	0.0544
10 < or < 2	1.9	1.8	1.4	1.2	1	0.2805	0.0359

Class	55–60	50–55	45–50	40–45	60< or <40	Geometric mean	Relative importance
Annual relative							
55–60	1	5	7	8	9	4.7894	0.5498
50–55	1.5	1	5	7	8	2.2369	0.2568
45–50	1.7	1.5	1	6	7	1.0371	0.1190
40–45	1.8	1.7	1.6	1	6	0.4471	0.0513
60 < or < 40	1.9	1.8	1.7	1.6	1	0.2013	0.0231

Class	>500	400–500	300–400	200–300	Geometric mean	Relative importance
Annual precipitation						
>500	1	5	7	9	4.2129	0.6174
400–500	1.5	1	6	8	1.7602	0.2580
300–400	1.7	1.6	1	7	0.6389	0.0936

Table 2 continued

Class	>500	400–500	300–400	200–300	Geometric mean	Relative importance
200–300	1.9	1.8	1.7	1	0.2111	0.0309

Class	50–66	40–50	20–40	<20	Geometric mean	Relative importance
Annual glacial						
50–66	1	2	4	6	4.2129	0.6174
40–50	1.2	1	2	5	1.7602	0.2580
20–40	1.4	1.2	1	3	0.6389	0.0936
<20	1.6	1.5	1.3	1	0.2111	0.0309

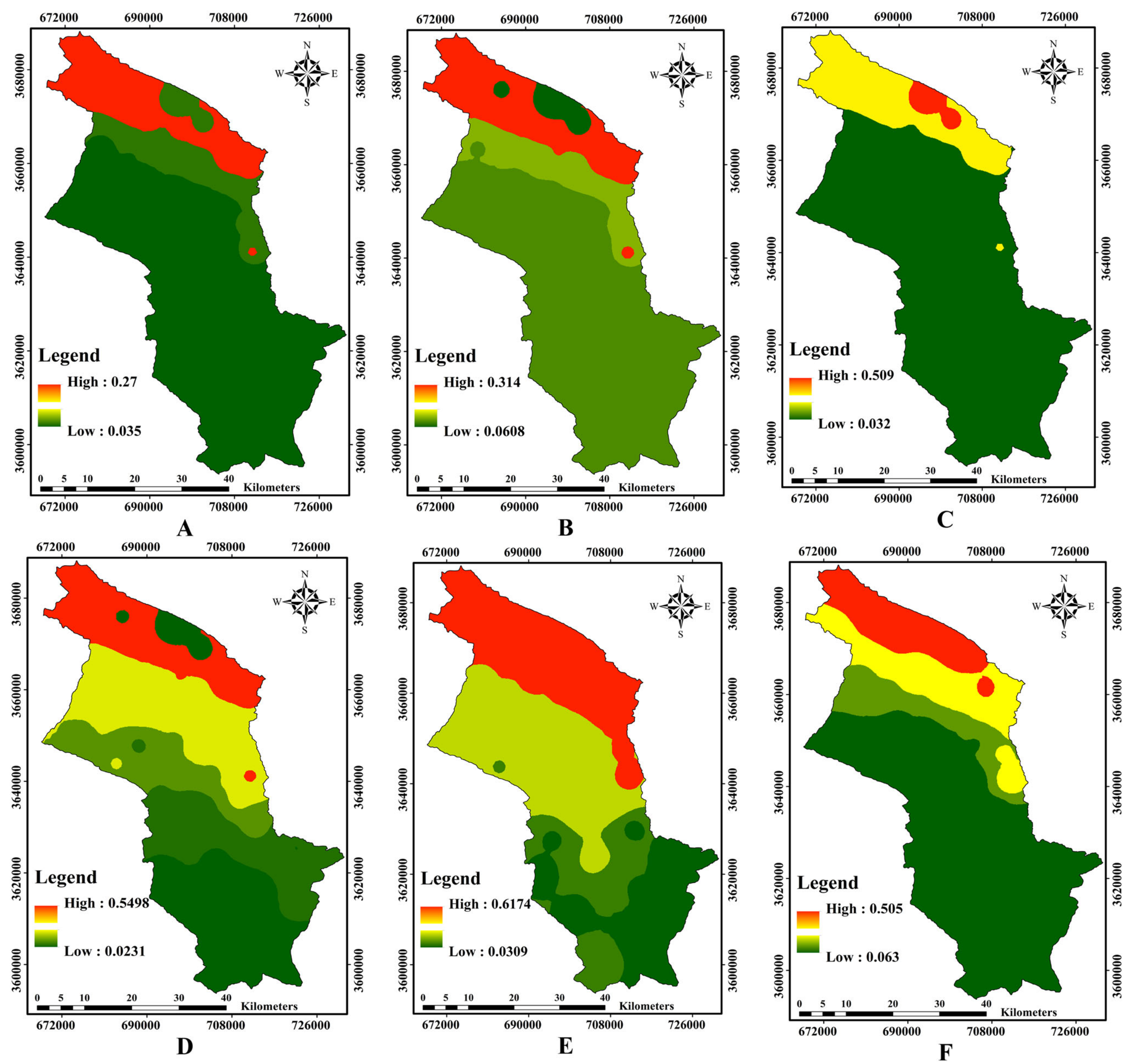

Fig. 4 Criteria Map used for capability of rapeseed cultivation in the Meymeh–Zarinabad region (**a** Annual minimum temperature; **b** Annual temperature; **c** Annual maximum temperature; **d** Annual relative humidity; **e** Annual precipitation; **f** Annual Glacial; **g** Annual climate; **h** Slope; **i** Soil; **j** Land type; **k** Land use)

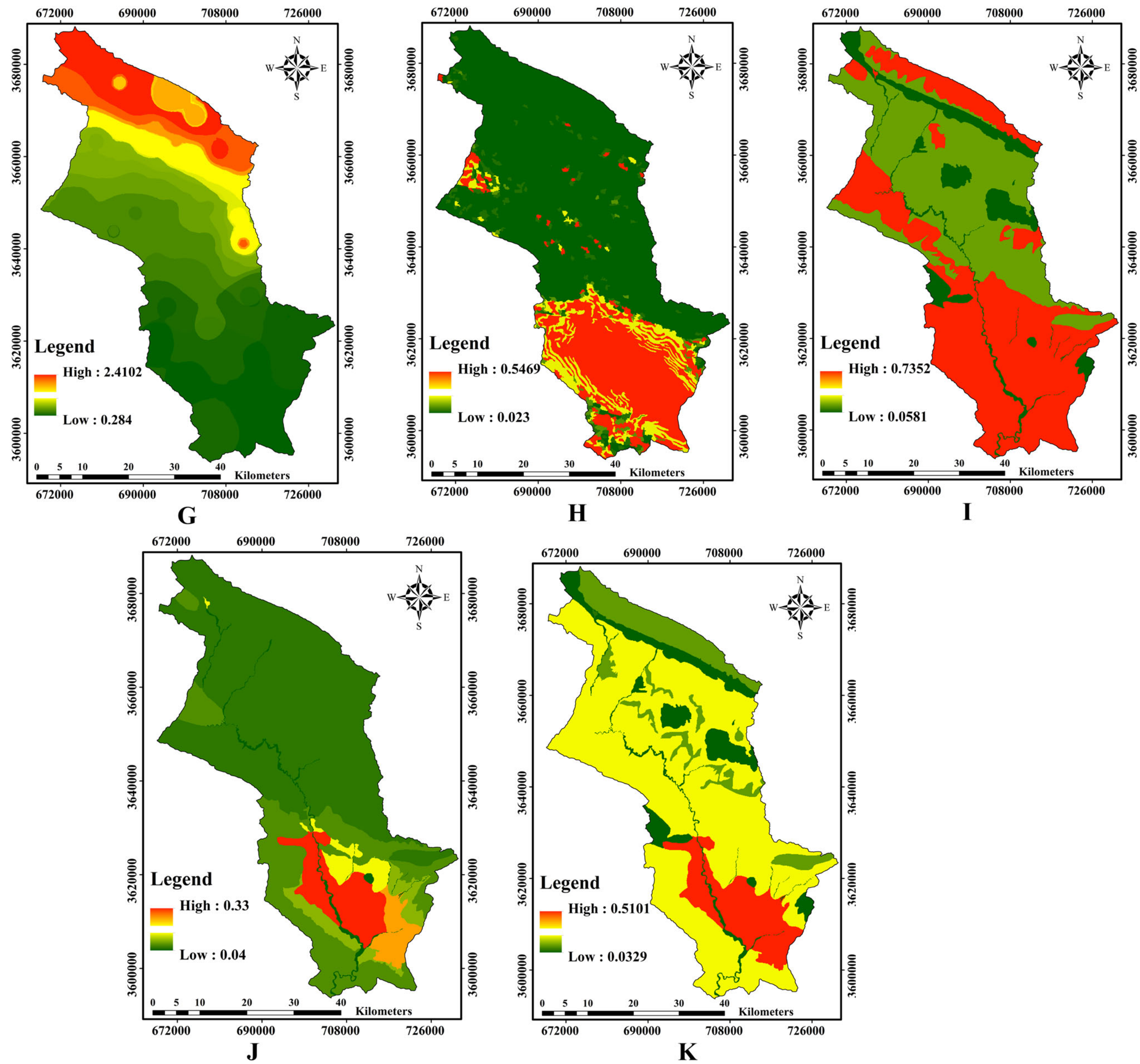

Fig. 4 continued

Table 3 The slope criteria: classes and their relative importance

Relative importance	Geometric mean	>12%	8–12%	5–8%	2–5%	0–2%	Class (%)
0.5469	4.7894	9	8	7	5	1	0–2
0.2649	2.32	8	7	5	1	1.5	2–5
0.1142	1	7	6	1	1.6	1.7	5–8
0.0511	0.4471	6	1	1.6	1.7	1.8	8–12
0.0230	0.2013	1	1.6	1.7	1.8	1.9	>12

3.1 Climate

Temperature is one of the limited factors in agriculture. For each species, the range of certain heat threshold is defined, and there are certain times which are more important due to the sensitivity of plants to climate change. Sub criteria of annual minimum temperature, annual mean temperature and annual maximum temperature have been presented in

Table 4 The soil criteria: classes and their relative importance

Relative importance	Geometric mean	Heavy	Medium	Styles	Class
0.7352	3.5569	9	5	1	Styles
0.2067	1	5	1	1.5	Medium
0.0581	0.2811	1	1.5	1.9	Heavy

Table 5 The land type criteria: classes and their relative importance

Class	Sediment plains river	Domain plains	Plateaus and upper terraces	Debris Fan-shaped gravel	Hills	Mountains	Land other	Geometric mean	Relative importance
Sediment plains river	1	2	3	4	5	6	7	4.18	0.33
Domain plains	1.2	1	2	3	4	5	6	3.03	0.22
Plateaus and upper terraces	1.3	1.2	1	2	3	4	5	2.14	0.16
Debris Fan-shaped gravel	1.4	1.3	1.2	1	2	3	4	1.49	0.11
Hills	1.5	1.4	1.3	1.2	1	2	3	1.03	0.08
Mountains	1.6	1.5	1.4	1.3	1.2	1	2	0.85	0.06
Land other	1.7	1.6	1.5	1.4	1.3	1.2	1	0.5	0.04

Table 6 The land use criteria: classes and their relative importance

Relative importance	Geometric mean	Land protective	Forest	Rangeland	Dry farming agriculture	Agriculture and water garden	Class
0.5101	3.9363	9	7	5	3	1	Agriculture and water garden
0.2638	2.036	7	5	3	1	1.3	Dry farming agriculture
0.1296	1	5	3	1	1.3	1.5	Rangeland
0.0636	0.4911	3	1	1.3	1.5	1.7	Forest
0.329	0.2540	1	1.3	1.5	1.7	1.9	Land protective

Table 7 The main criteria and their relative importance

Relative importance	Geometric mean	Land use	Land type	Soil	Slope	Climate	Class
0.3323	4.529	5	4	3	2	1	Climate
0.2481	3.3818	4	3	2	1	1.2	Slope
0.1830	2.4949	3	2	1	1.2	1.3	Soil
0.1351	1.841	2	1	1.2	1.3	1.4	Land type
0.1104	1.3818	1	1.2	1.3	1.4	1.5	Land use

Table 2 and also the maps of annual minimum temperature, annual mean temperature and annual maximum temperature of weighting have been shown by Fig. 4a, b, c. Canola is very resistant to water scarcity and drought.

High moisture has adverse impacts on the growth of this species. The appropriate moisture should not be more than 60%. Table 2 shows the annual relative sub criterion and its importance, and Fig. 4d indicates the map of annual relative humidity resulted from weighting.

Precipitation is an eminent parameter for culturing. Each species has specific required water. Canola needs more rainfall during growing season to reach the optimal growth. Table 2 shows the annual precipitation sub criterion and its importance, and Fig. 4e indicates the map of annual precipitation obtained from weighting.

If the needed cold is not provided to wake up buds from physiological sleep, opening the buds of leaves and flowers will be delayed in spring. The annual glacial sub criterion

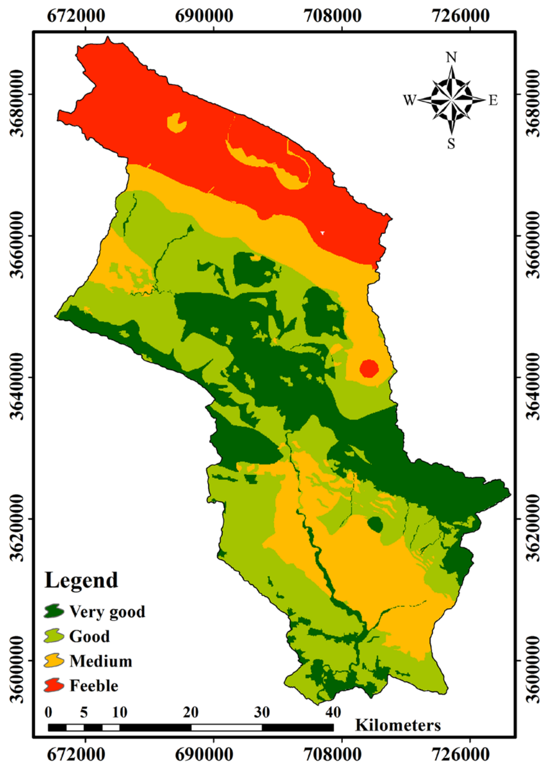

Fig. 5 The final map of capability of rapeseed cultivation in the Meymeh–Zarinabad region

Table 8 Area of each class based on Analytical hierarchy process

Class	Ha	%
Very god	65,684	24.28
Good	90586	33.49
Medium	63000	23.29
Feeble	51247	18.94

and its relative importance and also the map of annual glacial obtained from weighting were presented by Table 2 and Fig. 4f, respectively.

Besides, the final map of six sub criteria of climate has been shown in Fig. 4g.

3.2 Slope

Low slopes have some advantages than high slopes such as maintaining the humidity and soil nutrient. Plants can grow and develop their root systems easily on low slopes. Table 3 shows the slope criterion and its relative importance, and Fig. 4h indicates the map of slope prepared by weighting.

3.3 Soil

Canola can grow in most types of soil, while its maximum growth can be reached in loam soils. It prefers light and well drainage soils. Soil and its relative importance, and its map resulted from weighting have been presented by Table 4 and Fig. 4i, respectively.

3.4 Land type

The best area for growing canola is river plains which have low slope, deep and permeable soils. Table 5 represents land type criterion and its relative importance and Fig. 4j indicated the map of land type prepared by weighting.

Land use shows how to use the land appropriately. If the land use has a suitable capability on growing canola, it can consider as an appropriate area for this species. Table 6 shows the land use criterion and its relative importance and also Fig. 4k represents the land use map of weighting.

The appropriate place for planting canola was different on the map of five main criteria including climate, slope, soil, land type, and land use. Hence, to reach the final location, all criteria were weighted and finally the most appropriate zoning for this species was prepared. Table 7 represents main criteria and their relative importance and Fig. 4j indicated the map of suitable zones by AHP. According to Fig. 5, the case study area was classified to four classes for canola using AHP. Furthermore, the accuracy of classes has been presented in Table 8.

4 Conclusion

In the present study, the appropriate location for planting canola using five main criteria including climate, slope, soil, land type, and land use was conducted in Meymeh–Zarinabad. The results showed the capability of case study for planting canola was classified into four classes of very good, good, medium, and feeble.

Very good class Because it has most appropriate climatic and topographic conditions, the yield is high. The area covered by these regions is 565,684 ha which is 24.28% of total area and covers the center of case study as a layer.

Good class It has appropriate conditions of climate and topography and considered as capable areas for planting canola. It covers 90,586 ha of total areas which is 33.49% of case study and covers all parts except north.

Medium class It is located in southern part of the area due to its low precipitation and temperature limitations. It covers 63,000 ha which is 23.29% of total area.

Feeble class It coves areas with adverse conditions of climate and topography. It covers the north pat of case study with 63,000 ha which is 23.29% of total area.

The center, south west, south east of the case study are the most appropriate areas for planting canola. Generally, the capability of the land is decreased from south to north. According to maps obtained by GIs and AHP, Meymeh–Zarinabad has a good potential for planting canola. The present study tried to use all available climatic parameters to obtain the most appropriate area for canola. It is suggested that the maps of topography, vegetation, and geology of case study will be used to study the comprehensive researches on this species.

References

1. Sarmadian, F., Moravej, K., Mahmoodi, S. H., & Ebrahimi Khomam, S. M. (2003). An investigation of land suitability evaluation for irrigated crop, using remote sensing and geographical information system techniques in parts of Varamin plain. *Iranian Journal of Agriculture Science, 34*, 899–912.
2. FAO. (1976). *A framework for land evaluation. Soils bull, No. 32*. Rome: FAO.
3. York, G. (1979) ABC's of Home-Cured, Green-Ripe Olives. University of California, Agricultural Sciences Publications: Leaflet 21131.
4. Weiss, E. A. (1983). *Oilseed crops longman* (p. 540). New York: Longman Group Ltd.
5. Willer, H., & Sorensen, N. (2008). *The world of organic agriculture: Statistics and emerging trends*. London: Earthscan Publication.
6. Kirti, H.S. (2001). Evaluation of group decision making methods. www.expertchoice.com.
7. Roger, A. (2000). *Determine susceptible areas for planting canola in the state of Illinois Canada*. Toronto: The University of Toronto.
8. Chen, H. S., Liu, G. S., Yang, Y. F., Ye, X. F., & Shi, Z. (2010). Comprehensive evaluation of tobacco ecological suitability of Henan province based on GIS. *Agriculture Sciences in China, 9*, 583–592.
9. Rahman, R., & Saha, S. K. (2008). Remote sensing, spatial multi criteria evaluation (SMCE) and analytical hierarchy process (AHP) in optimal cropping pattern planning for a flood prone area. *Journal of Spatial Science, 53*, 161–177.
10. Saaty, T. L. (1980). *The analytical hierarchy process* (p. 350). New York: McGraw Hill.
11. Saaty, T. L. (2000). *Fundamentals of decision making and priority theory* (2nd ed., p. 11). Pittsburgh, PA: RSW Publications.
12. Kheirkhah Zarkesh, M. (2005). DSS for floodwater site selection in Iran. PhD thesis, p. 273, Wageningen University.
13. Ishizaka, A., & Labib, A. (2009). Analytic hierarchy process and expert choice: Benefits and limitations. *OR Insight, 22*(4), 201–220.
14. Malczewski, J. (2006). GIS-based multicriteria decision analysis: A survey of the literature. *International Journal of Geographical Information Science, 20*(7), 703–726.
15. Oswald, M. (2004). Implementation of the analytical hierarchy process with VBA in ArcGIS. *Computers and Geosciences, 30*, 637–646.
16. Saaty, T. L. (2002). Decision-making with the AHP: Why is the principal eigenvector necessary. *European Journal of Operational Research, 145*, 85–91.