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Camelina Zoning for Different Climate Conditions in Kurdistan Province

Houshang Ghamarnia, Meisam Palash*, Babak Dousti

Department of Water Resources Engineering, Faculty of Agricultural Science and Engineering, Razi University, Kermanshah, Iran

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ABSTRACT

Medicinal-oil plant Camelina is a plant that has attracted a lot of attention in recent years. Because its most important advantage is excellent resistance to drought and cold as well. Therefore, in this study, in order to determine the best cultivation areas of Camelina in Kurdistan province based on a number of main parameters affecting the growth of this plant, statistics and daily meteorological information for 19 years in different meteorological stations of the province from 2000 to 2019 were used. Statistics and information from14 stations in neighboring provinces were also used to increase the accuracy of the created zoning maps. To create a spatial database for the study area, the required maps were entered into the ArcGIS 10.3 software and environment and descriptive map information was added to them. Finally, based on the requirements for each of the parameters, the classification of the maps was done according to the resources used. Krigink's method was used to prepare temperature, precipitation and altitude maps. The final results showed that for Camelina cultivation, in 26259 and 7059 square kilometers, equal to 75 and 25% of the total area of the province was suitable and unsuitable respectively. In addition, Camelina susceptible areas were often located in the southern parts of the province.

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1. Introduction

Today, the oil-pressing industry is one of the strategic industries. In Iran, there are large arable lands and favorable fields for cultivating oilseeds, but unfortunately, according to available statistics, more than 95% of the country's oil needs are still supplied from abroad. However, common oilseeds such as soybean, sunflower and Canola, despite their many advantages, have their own limitations in various aspects of cultivation and climatic conditions and have high requirements for water and inputs. Therefore, the strong need for new oil products with more compatibility and less needs (Kahrizi *et al*., 2018).

Camelina (*Camelina sativa*) from the Brassicaceae family is a plant that has attracted a lot of attention, especially in recent years, and its most important advantage is its extraordinary resistance to drought and cold (Hassani Beliani *et al*., 2020). The plant also has a high resistance to common pests in oilseeds such as Meligethes aeneus. The potential for high yield production in the plant has been proven and the possibility of its placement as a suitable option in rotation with fine-grained cereals has been reported (Kahrizi and Ahmadvandi, 2015).

The plant is native to Europe and South Asia and the largest producer of this plant was the Soviet Union in the twentieth century, which 1950 cultivated about 300,000 hectares of its land (Kahrizi *et al*., 2016; Rezaei *et al*., 2016a). Camelina is a plant with a short growth period (85 to 100 days) and grows well in temperate climates (Gholamian *et al*., 2017). The seeds of the plant have 38 to 43% oil and 27 to 32% protein.

The plant used in items such as food, raw materials, pharmaceuticals, and biofuels (Betancor *et al*., 2015; Haslam *et al*., 2016). The use of the plant as a jet fuel has reduced carbon emissions from the jet engine and, given that it is produced in many climates, is less expensive to produce than other oilseeds. Therefore, it is a more suitable option than other oils plant for use as biofuels (Kahrizi and Rostami, 2016).

* Corresponding author.
E-mail address: Meisampalash1371@gmail.com

Various reports on land zoning have been provided, for example, in a study, Agro-ecological zoning of agricultural lands in Golestan province for canola cultivation was examined and reported that 21.34% of farms are highly susceptible to canola cultivation (Kazemi Posht Masari *et al*., 2012). In the study of land suitability of Khorasan province in cumin cultivation, was reported that the southern regions and part of the northern regions have high potential in cumin production and the most important factors limiting the plant cultivation were high temperature, soil slope and slope direction (Kamkar and Meqdadi, 2015). In an investigation, the potential points of saffron in Kermanshah province reported that 20.8% of the area of the province suitable conditions for saffron cultivation (Ghamarnia and Soltani, 2016). In the study of saffron cultivation in Miyaneh city, it was reported that the southeastern and northwestern regions, especially rivers and catchments, are suitable places for saffron cultivation. According to the results, 28 percent of the area was in the appropriate class, 36 percent in the relatively suitable class, and 20 percent in the critical class, and other areas, which covered about 16 percent of the area, were in the inappropriate class (Zamani *et al*., 2022).

Iran is located in the arid region of the world, the cultivation of plants adapted to the climatic conditions of the region, such as Camelina, should be on the agenda (Kahrizi *et al*., 2016). Various reports on Camelina have given different results, for example The results of a study showed that nitrogen and sulfur fertilizers affect the oil content and fatty acid composition of Camelina oil (Sipalova *et al*., 2011). In a study, a modified Camelina cultivar namely Soheil was cultivated in the lands of seven cities in Kermanshah province (Kangavar, Sonqor, Islamabad Gharb, Sarfiroozabad, Kermanshah, Sahneh and Sarpol-e Zahab) and results showed that the yield of Camelina in Sarpol-e-Zahab counties was 1.41 ton/ha and Islamabad Gharb was 1.39 ton/ha . Moreover, the lowest yield was related to Songhor city at the rate of 1.1 ton/ha. Also, the results of this study showed that in all climates of the Kermanshah province, at least 1 ton/ha of Camelina seeds (equivalent to 350 kg of oil/ha) can be produced in dry land conditions (Kahrizi *et al*., 2018).

It was reported that the effect of using biofertilizer in Camelina on plant height and number of seeds per pod and number of silica per plant, 1000-seed weight and harvest index was significant, but the number of branches, seed yield and biological yield were not significant. The best treatment for Camelina fertilizer was a combination of nitrogen + phosphorus + sulfur fertilizer with biofertilizer (Hassani Bliani *et al*., 2019).

A study reported that the amount of Camelina oil seeds, the oil production efficiency and fatty acid composition of this plant can change from one environment to another due to differences in temperature conditions and soil composition (Jiang *et al*., 2014). It was reported that areas with an altitude of more than 1200 meters m above sea level were unsuitable for the cultivation of the plant and areas with an altitude of less than 1200 meters and a temperature range "between" 23.5-28.5° C were suitable (Celian Roman *et al*., 2017). In an investigation on Camelina cultivation in the Black Sea region, it was reported that the growth duration of the plant varies from 179 to 269 days depending on the planting date and climatic conditions (Pashtetskiy *et al*., 2021).

Because of the lack of experts and farmers information on the cultivation of the medicinal-oil plant Camelina and research on the possibility of its planting in different conditions is very limited, therefore this study was conducted to determine areas prone to cultivation of Camelina in Kurdistan province.

2. Materials and methods

Kurdistan province is located between 45° 31' and 48°16' east longitude and 34°44' and 36°30' north latitude. Fig. 1 shows the position of Kurdistan Province in Iran. The area of the province is about 29,000 km^2, which is 1.8% of the total area of the country. The highest rainfall in the western part of the province (Baneh and Marivan cities) is about 800 mm/year and the lowest rainfall in the eastern region is about 400 mm/year. The amount of precipitation in the central part of the province (Saqez and Sanandaj cities) is close to 500 mm/year. The whole territory of the province has a cool and temperate climate in spring and summer.

In this study, 19-year statistics and information of meteorological stations in Kurdistan province in the period 2000 to 2019, obtained from the Applied Meteorological Research Center, were used to determine climatic parameters including average temperature, maximum temperature and minimum temperature. In this research, digital elevation model (DEM), slope direction map and slope map were also prepared. To create a space base for the study area, the required maps were entered into ArcGIS 10.3 software and descriptive map information was added to them. Then, according to the necessary conditions for each of the parameters, according to the sources used, the maps were classified. Krigink's interpolation method was used to prepare both temperature and precipitation maps. Table 1, also shows the characteristics and location of synoptic stations in Kurdistan province along with the average of some meteorological parameters. The specifications of meteorological stations used in this research are also presented in Table 2.

Figure 1. Location of Kurdistan province in Iran.

Table 1. Synoptic meteorological stations of Kurdistan province.

No.	Station	Climate	Latitude (N)	Longitude (E)	Elevation (m)	Rain (mm)	Temperature (◦C)
1	Saqqez	semi-arid	36.2	46.3	1522.8	405.1	11.5
2	Zarineh	semi-arid	36.1	49.9	2142.6	363.5	8.6
3	Sanandaj	semi-arid	35.3	47	1373.4	348.4	14.4
4	Marivan	Very wet	35.5	46.2	1287	829.8	13.7
5	Qorveh	semi-arid	35.2	47.8	1906	321.4	12.6
6	Bijar	semi-arid	35.9	47.6	1883.4	316.1	11.9

Table 2. Details of meteorological stations in Kermanshah, Hamedan, Kurdistan, Zanjan and Azerbaijan-e- Gharbi provinces.

Province	Station	Latitude	Longitude	Elevation
Kermanshah	Sonqor	34.783	47.583	1700
	Ravansar	34.716	46.650	1380
	Javanrud	34.766	46.500	1375.4
Hamedan	Asad Abad	34.766	48.116	1552
	Hamedan (Airport)	34.869	48.534	1740.8
	Hamedan (nojeh)	35.195	48.690	1679.8
Kurdistan	Baneh	1600	45.895	36.006
	Bijar	35.886	47.621	1883.4
	Marivan	35.496	46.151	1287
	Qorveh	35.180	47.786	1906
	Sanandaj	35.254	47.014	1373.4
	Saqqez	36.221	46.311	1522.8
	Zarineh	36.066	46.916	2142.6
	Kamyaran	34.800	46.933	1404
	Hezarkanian	35.750	46.800	1934
Zanjan	khodabande	36.143	48.589	1887
	Garmab	35.849	48.210	1632
	Mahneshan	36.740	47.683	1284.5
Azerbaijan-e- Gharbi	Takab	36.395	47.098	1817.2
	Shahin Dej	36.666	46.733	1395
	Bukan	36.526	46.231	1386.1
	Mahabad	36.753	45.715	1351.8
	Sardasht	36.148	45.485	1556.8

2.1. Climatic and topographic indicators studied for Camelina cultivation

Table 3, which is based on sources (Celian Roman *et al*., 2017) and (Falasca *et al*., 2014), determines and distributes climatic and topographic parameters conditions for Camelina cultivation, as well as weighting based on experts and available sources. The growth period from November to June and TMX (maximum temperature) is also considered in May.

Table 3. Distribution of climatic and topographic parameters for Camelina cultivation.

Values	1	2	3	4	Weight
Parameters		Weak	Medium	Good	
Height (m)	-	>1200	<1200	-	0.14
Rain (mm)	-	<300	300–500	>500	0.26
Sunny hours (year)	<7	-	7 –10	>10	0.3
TMX (◦c)	<21 >31	-	21.5-23.5 28.5-31	23.5-28.5	0.23
Tilt	>12	8-12	4-8	0-4	0.07

TMX: Maximum temperature of the warmest month

2.2. Layer weighting method and preparation of a general map of cultivated areas

At this stage, according to the results obtained from the opinions of experts and previous research and existing scientific sources on the environmental conditions and requirements of the Camelina, the weight and classification of each layer of information were allocated. Whichever factor is more important, the most weight was assigned to that factor. Each layer has been influential in preparing the final map due to its weight. To prepare thematic maps of the study area, slope and elevation maps of the province were obtained and after the effect of climatic parameters affecting plant cultivation in weighting and classification using the weight scoring method, a zoning map of all layers was prepared. For zoning of the maps, Krigink's method was used to mediate the points in GIS and the final map was extracted from the combination of all layers. In this research, for modeling raster parameters, the usual reclassify tool in GIS and the final map have been obtained with the Map Algebra command.

3. Results and discussion

By examining the available sources classification of, the topography map, Isothermal map, isohyetal map, slope and maximum temperature maps for Camelina were introduced as follows.

3.1. Zoning map of height

According to the map presented in Fig. 2, almost the entire province has unfavorable altitude conditions for Camelina cultivation.

Figure 2. Altitude map of Kurdistan province for Camelina cultivation.

3.2. Rainfall zoning map

As can be seen in the map shown in Fig. 3, the western parts of the province were quite favorable in terms of rainfall and the rainfall was more than 500 mm/year and in the eastern parts, the rainfall was between 500-300 mm/year.

Figure 3. Rainfall proportionality map of Kurdistan province for Camelina cultivation.

3.3. Average temperature zoning map

According to the map shown in Fig. 4, except for some parts in the north of the province, the rest of the province in terms of temperature for Camelina cultivation, were in relatively good conditions.

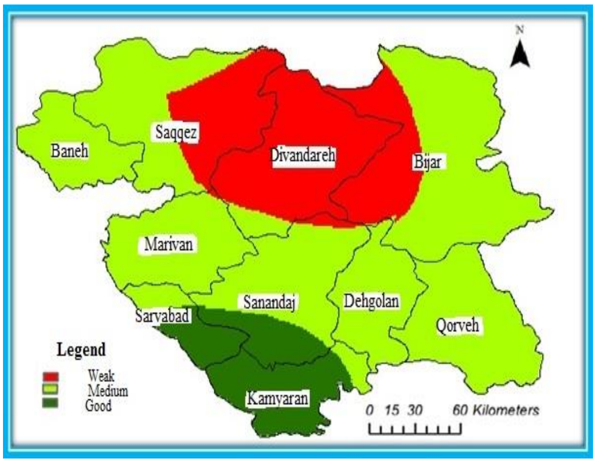

Figure 4. Average temperature map of Kurdistan province for Camelina cultivation.

3.4. Maximum temperature zoning map

The map shown in Fig. 5 shows that most parts of Kurdistan province were suitable for cultivating Camelina in terms of maximum temperature.

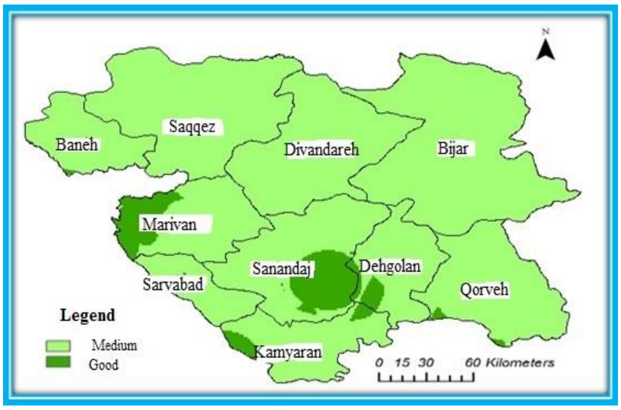

Figure 5. Map of the maximum temperature proportion of Kurdistan province for the cultivation of Camelina.

3.5. Slope zoning map

Fig. 6 also shows the slope map of the province. This figure indicated that all parts of the province were in Optimal to Undesirable slope for cultivating Camelina.

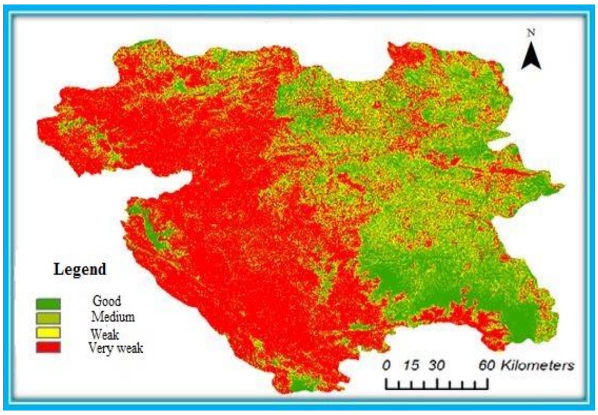

Figure 6. Slope map of Kurdistan province for Camelina cultivation.

3.6. The final map

Table 4 shows the results obtained from the distribution of potentially cultivated areas of Camelina based on area and percentage of the total area in Kurdistan province. As shown in the final map in Fig.7, and considering the resistance of the Camelina plant to cold climate, as well as adaptation to adverse climatic conditions and high resistance to various environmental factors, the cultivation of this plant in Kurdistan province was acceptable and responsive. As shown in Table 4, most parts of the province obtained a score between 2.5 to 3 and favorable conditions were available in this part of Kurdistan province for the cultivation of Camelina. Also, the results showed that different parts of the north of the province received a score less than 2.5 and have no favorable conditions for Camelina cultivation.

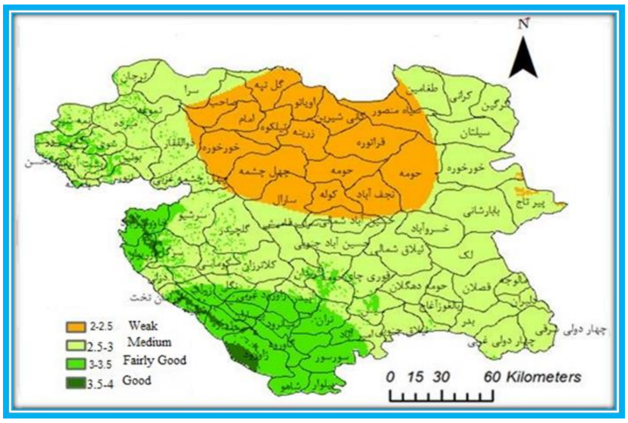

Figure 7. The final map of Camelina cultivation potential areas in Kurdistan province.

Table 4. Distribution of areas prone to Camelina cultivation

Value	Class	Area (km)	Area (%)
Weak	2.5-2	7058.75	25
Medium	3–2.5	16093.95	57
Fairly Good	3.5 -3	4517.6	16
Good	4–3.5	5647	2

In the present study, the zoning of susceptible areas of Kurdistan province for plant and Camelina cultivation were investigated. The studied parameters for preparing the Camelina zoning map were as altitude, rainfall, temperature and slope. Due to the fact that the average altitude of Kurdistan province is 2100 meters above sea level, according to Fig. 2, most parts of the province were unsuitable for cultivation. A study also reported that an altitude above 1200 meters above sea level was unsuitable for the cultivation of Camelina. (Celian Roman *et al*., 2017) Which is consistent with our results.

According to the results obtained based on the distribution of climatic and topographic parameters for Camelina cultivation, areas with rainfall of more than 500 mm/year are in a good category for Camelina cultivation and therefore, based on Fig. 3, most parts of the province had favorable conditions in terms of rainfall, but the cities of Baneh, Marivan and Sarvabad due to higher annual rainfall compare to other parts were in more favorable conditions for Camelina cultivation.

According to Fig. 5, the central parts of Sanandaj city and also the western part of Marivan city were in favorable conditions in terms of maximum temperature conditions for cultivating of Camelina and other parts of the province were in average conditions. One of the reasons for this result is the appropriate temperature of the mentioned parts and the creation of optimal temperature conditions for plant cultivation according to table 3. In research entitled "Study of the effect of climatic conditions on productivity and adaptation of Camelina" over several consecutive years, it was reported that during a year when the average daily temperature was in the optimal category, the performance of Camelina has also improved. (Turina and Prakhova, 2020).

According to Fig. 6, it was observed that the southeastern part of the province, with a slope in the range of 0-4%, was in favorable conditions in terms of Camelina cultivation. However, due to the unsuitable slope, many parts of the province have no the necessary conditions for cultivation. These findings were in agreement with Kamkar and Meqdadi. (2015) who reported that the most limiting factor in cumin cultivation in Khorasan province with soil slope and slope direction.

According to Fig. 7, the northern and southern parts of the province were in the weak and good category for Camelina cultivation, respectively. Although, the other parts of the province, which included most parts, were in the middle category. According to the studied parameters in the zoning of Camelina cultivation, considering that the southern parts of the province were in more ideal conditions in terms of temperature and rainfall, in the final map, these areas were in a fairly good category.

4. Conclusion

According to the study of climatic parameters affecting the cultivation of Camelina and also the production of zoning maps of cultivation of the plant in Kurdistan province, it was observed that 5647 km^2 equivalent to 2 % of the total area of the province for cultivation was perfectly suited. Also, 4517.6 km^2, equivalent to 16% of the total area, was relatively suitable, 16093.95 km^2, equivalent to 57% of the total area medium and 7058.75 km^2, equivalent to 25% of the total area of the province, were weak for cultivation. The results of this study showed that a large part of the regions of Kurdistan province were in the medium category in terms of Camelina cultivation. The main reasons for this result was the unsuitable slope of most places, the amount of rainfall less than 500 mm/year and also the altitude of the Kurdistan province. In addition, suitable areas for cultivating Camelina were often located in the southern part of the province. The final map of Camelina cultivation potential points in Kurdistan province showed a general study based on various parameters such as height, rainfall, temperature and slope. Therefore, it is suggested that appropriate field research be conducted by relevant researchers to determine the true potential for cultivation and development of this medicinal and oil plant in all parts of Kurdistan province.

Conflict of interests

All authors declare no conflict of interest.

Ethics approval and consent to participate

No human or animals were used in the present research.

Consent for publications

All authors read and approved the final manuscript for publication.

Availability of data and material

All the data are embedded in the manuscript.

Authors' contributions

All authors had an equal role in study design, work, statistical analysis and manuscript writing.

Informed consent

The authors declare not to use any patients in this research.

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