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The assessment of suitable lands for rain-fed safflower (*Carthamus tinctorius* L.) cultivation in Kermanshah province using the Geographic Information System and Analytical Hierarchy Process model

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ABSTRACT

Recognizing potential areas based on agricultural potentials and determining the suitability of land for specific productivity allows for the planning of increased production and sustainable land use, and provides a suitable foundation for human activities and land development. Using the Geographical Information System (GIS) and the Analytical Hierarchy Process (AHP), this study was conducted to identify areas susceptible to autumn safflower cultivation in Kermanshah province. Altitude, maximum, average, and minimum temperature, precipitation, slope, and slope direction were used as parameters. The ecological needs of safflower were extracted from scientific sources in order to determine the areas suitable for safflower cultivation based on the desired parameters. Then, the measurements-related maps were prepared and classified. Using hierarchical analysis, the weight of each variable was determined in the subsequent step. Finally, the safflower zoning map was extracted from the GIS environment by overlapping and combining the obtained maps. The rainfall gauge and then the maximum temperature had the highest coefficients based on the results of the hierarchical analysis procedure (0.295 and 0.219). 52%, 33%, 13%, and 2% of the total arable land in the Kermanshah province are classified as highly suitable, suitable, semi-suitable, and unsuitable, respectively. Based on the investigated climatic and topographical variables, 85% of the cultivated land in the Kermanshah province is suitable for safflower cultivation. They are predominantly regions with moderate and tropical climates, demonstrating the high potential of Kermanshah province for safflower cultivation as a suitable plant for crop rotation.

Highlights

- Recognizing potential agricultural areas and determining land suitability for specific productivity allows for increased production, sustainable land use, and human activities.
- This study identified autumn safflower cultivation areas in Kermanshah province using GIS and AHP.
- The rainfall gauge and maximum temperature had the highest coefficients in hierarchical analysis.
- 52%, 33%, 13%, and 2% of Kermanshah's arable land is highly suitable, suitable, semi-suitable, or unsuitable for safflower.
- As a crop rotation-friendly plant, safflower is well-suited to Kermanshah's temperate and tropical climates.

1. Introduction

Oilseeds are the most important source of edible oil production. The consumption of edible oil in our country is more than one million tons per year. About 90 to 95 percent of this amount is provided through imports, and for this purpose, more than one billion dollars of foreign currency is taken out of the country every year. Safflower (*Carthamus tinctorius* L.) is an annual plant of the citrus family (Asretaceae) with a nut-shaped fruit that stores oil in its cotyledons (Weiss, 2000). It ranks eighth among

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oilseeds (Yari et al., 2004). The content of seed oil in most cultivars is about 30%, and in some cultivars, it reaches 40% under suitable conditions (Yaghobian and Yaghobian, 2016). Having 73-85% of linoleic fatty acid, safflower oil plays an essential role in reducing blood cholesterol and is considered one of the best vegetable oils in terms of quality (Lotfi et al., 2012). In recent years, the area under safflower cultivation has increased in Iran. In this regard, research on this oil plant is expanding to achieve thornless, high-yielding, oil-rich and cold-resistant cultivars.

Safflower is cultivated in more than 60 countries. In Iran, its cultivation started in 1957 (Baghkhani and Farahbakhsh, 2008). This plant is a native plant of Iran (Zeinali, 2008). Due to its adaptability to a wide range of weather conditions, resistance to drought and salinity stresses, early ripening, and the presence of desirable oil with more than 90% of unsaturated linoleic and oleic fatty acids, it has high industrial and food value (Dwivedi et al., 2005). It grows successfully in areas with low temperatures and soils with low fertility (Koutroubas and Papakosta, 2005). Due to its tolerance to cold, drought and salinity, it can be cultivated in the dry Anatolian regions of Turkey and its surroundings that do not have enough rainfall (FAO, 2019).

Optimal use of agricultural lands requires careful assessment of ecological resources. In ecological zoning, a set of environmental information (climate, topography, soil conditions) is examined to determine land use (Bagheri and Asadi, 2019). Identifying suitable areas based on agricultural potential and determining land suitability for specific productivity makes it possible to plan for increased production and sustainable land use (Sokoti-Oskooei, 2001). The diversity of information and the dynamics of natural resources on the one hand and the need for timely information, on the other hand, have caused geoscience experts to abandon manual and traditional data collection, storage, analysis, and processing, and modern systems including geographic information system (GIS = Geographic information system) to replace it. Appropriate spatial analysis, determination of land capabilities, various modelings such as soil erosion, water and air pollution, and preparation of digital maps with appropriate scale are among the facilities of the geographic information system (Bayat et al., 2001; Cengiz and Akbulak, 2009).

Researchers in the Domerk Plain of Turkey conducted a study with the aim of evaluating the appropriateness of land use for agriculture, forest, and pasture with a geographic information system and analytical hierarchy process (AHP). Finally, based on the assigned weights, the western part of the plain was suitable for agriculture, the eastern part for the forest, and the northern and southern parts for pasture (Bobade et al., 2010).

In India, the land use of the Soni Madhya region was investigated using a geographic information system. The results indicated that out of the total 57% of arable land, 24% for sorghum-soybean, 15% for sorghum-cotton, and 18% for rice, citrus fruits, corn, sunflower, and vegetables were suitable (Yasari et al., 2013).

In another study, Isfahan province was zoned in terms of spring safflower planting date using 48-year temperature data of 51 synoptic and climatology stations. Based on the results, Isfahan province was divided into three temperature zones, and in each zone, suitable planting dates were determined, and maps were drawn. Considering the heat requirement of safflower, if this plant is cultivated in different areas on the suggested planting dates, it will not face restrictive temperatures during the growth period (Rafiei et al., 2015). In another study that examined the climatic zoning of Ilam province for safflower cultivation, the researchers stated that the agricultural lands located in the west and southwest of the province (Dahlran county) have more favorable conditions for safflower cultivation than other regions of the province (Dashti et al., 2012).

Other researchers in East Azerbaijan investigated the quantitative and spatial potential of safflower. In terms of planting safflower, Jolfa and Marand regions (1.6%) were found to be very suitable, and East Tabriz and Warzghan (16.4%) were relatively suitable for safflower cultivation (Seyed Shahivandi et al., 2013). In Lorestan province, grain corn climate zoning was done using a geographic information system by hierarchical analysis method. The zoning map of the land suitable for grain corn cultivation was obtained. Based on the results of the role of each of the climatic and land elements in different regions of the province and by combining the effective layers in the GIS environment, it was possible to identify the areas prone to seed corn cultivation. Finally, 299,521 hectares of the province's lands were found to be very suitable for grain corn cultivation, 809,956 hectares were suitable, 1040,944 hectares were of medium capability, 529,535 hectares were unsuitable, and 95,930 hectares were very unsuitable (Kazemi et al., 2012).

As a result of the research in this field, in the zoning of agricultural lands in Golestan province for rapeseed and soybean production, it was found that 21.3% and 27.4% of agricultural lands are highly suitable and semi-suitable for soybeans, respectively. 27.6% and 27.4% of agricultural lands are located in highly suitable and suitable areas (Kazemi et al., 2014). The researchers zoned the lands of Gorgan using the process of hierarchical analysis in terms of the ability to plant sunflowers. After assigning weight to each of the digital layers of environmental factors, the layers were superimposed and combined. The results showed that 71.4% of the agricultural lands of Gorgan County are located in a highly suitable zone for sunflower production (Borna and Alizadeh, 2016).

In research conducted in Khuzestan province, the agroclimatic zoning of citrus cultivation was investigated in the GIS environment using the Hierarchical Analysis Process method. Based on the results, the northern and eastern regions of the province have good to excellent conditions for citrus cultivation. The limited areas of the province with weak potential include the southern, central, and western parts (Alavi Zadeh et al., 2013; Mohammadi et al., 2011). In research on the feasibility of saffron cultivation in different regions of South Khorasan province, according to the results, the northern and northeastern regions of the province had the best position for saffron cultivation in terms of rainfall and relative humidity. The central regions were reported as semi-

suitable and the south of the province as non-suitable (Kouzegaran et al., 2013).

Despite the annual rainfall of more than 300 mm in many areas of Kermanshah province, the production of rainfed crops is limited. The safflower plant has high adaptability to growing in different conditions in a dry state. Identifying areas prone to safflower cultivation in Kermanshah province can provide the basis for the development of safflower cultivation in rainfed lands. In addition, it will create product diversity and increase income in the dry farming sector. Therefore, this study was conducted in order to zoning the rainfed lands of Kermanshah province in terms of safflower cultivation capability using a geographic information system and hierarchical analysis.

2. Materials and methods

2.1. Area of study

Kermanshah province, with an area of about 24435 square kilometers, is located in the middle of the western side of the country between 33 degrees 36 minutes to 35 degrees 15 minutes north latitude and 45 degrees 24 minutes and 48 degrees 30 minutes east longitude from the Greenwich meridian. Kermanshah is one of the western provinces of Iran that share a border with Iraq. This province is bordered by Kurdistan province from the north, Lorestan and Ilam provinces from the south, Hamedan province from the east, and Iraq from the west. Kermanshah city is the capital of Kermanshah province (Figure 1).

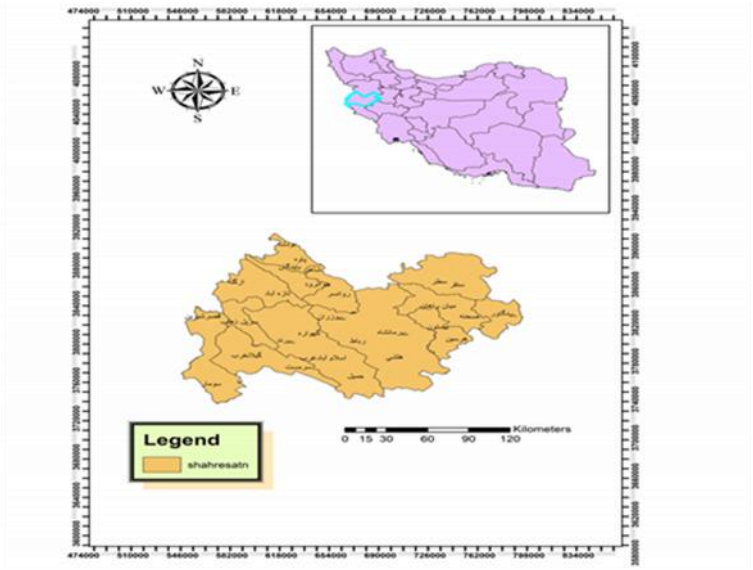

Figure 1. Location of the study area (Kermanshah province)

Kermanshah province has 14 cities, most land belongs to Kermanshah County, with 271,273 hectares, and Paveh County has 874 hectares and the least amount of land. This province with an altitude of 1400 meters above sea level, has an average rainfall of 400 to 500 mm (Eini et al., 2013). The research conducted on the portal of Kermanshah Governorate indicates that more than 1.5 million hectares of natural resource areas of Kermanshah province include forests and pastures, and 942,077 hectares are agricultural lands, of which 210,447 hectares are irrigated lands, and the rest are rainfed. Of course, some statistics indicate that this number is lower than what was mentioned, and they add it to the level of water lands. Because water depends on the amount of annual rainfall, seasonal rivers, and dams in the province and outside the province, so they do not have reliable water and are classified as dry lands.

2.2. Determining the coefficients of the layers using the hierarchical analysis process

The zoning of areas prone to safflower cultivation requires the adaptation of the characteristics and ecological needs of this plant to the environmental conditions of the region. For this purpose, the ecological needs of safflower were determined and graded using available resources (Table 1).

In this way, climatic (rainfall and temperature) and topographical (height, slope and slope direction) requirements of safflower were used as criteria in this experiment.

In order to prepare digital maps, measurements used in the research, plant growth period temperatures and annual rainfall, daily statistics and information from meteorological stations in Kermanshah province were used in the long-term period (10 years). This study was carried out with the assumption of autumn cultivation of safflower.

Since most of the climatic parameters, especially temperature and precipitation, are affected by the geographical conditions of the region (Fatemi Gheiry and Yazdan Panah, 2000). Therefore, in the preparation of maps related to temperature and precipitation, the relationships between these criteria and the geographical features of the region (altitude, longitude and latitude) were used. Therefore, in order to create a multivariable linear relationship, the altitude, longitude, and latitude of meteorological stations were considered independent variables, and temperature and precipitation as dependent

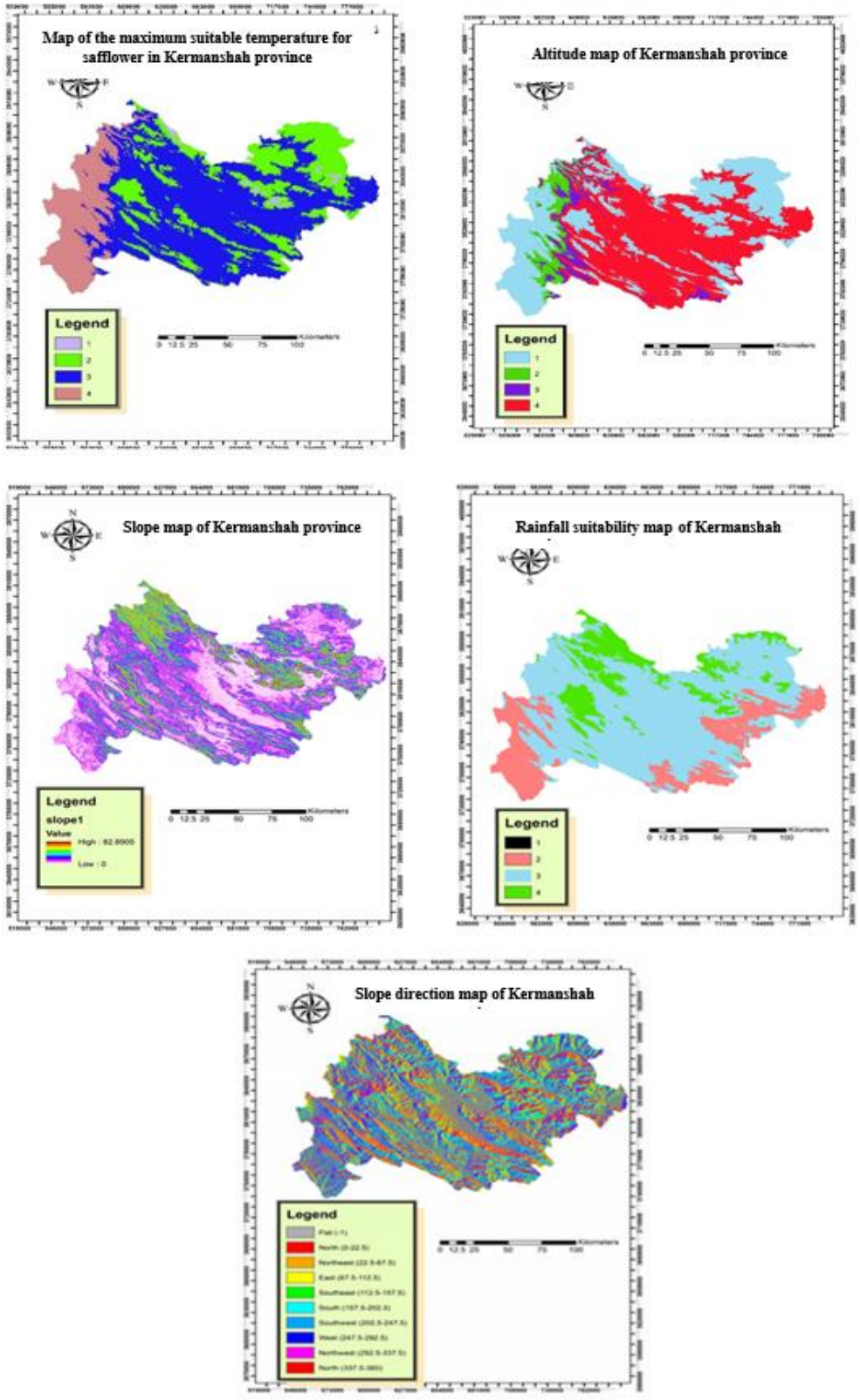

Figure 2. Land suitability map of Kermanshah province based on each of the studied micro-criteria: minimum temperature (a), average temperature (b), maximum temperature (c), altitude (d), rainfall (e), slope (f) and slope direction (g)

variables. In this way, the linear relationship between the height above sea level as well as longitude and latitude as independent variables with temperature (minimum, average and maximum temperatures) and annual precipitation as dependent variables was obtained using SPSS v.20 software. By entering these relations in ArcMap software and using the possibility of Raster Calculator, the same temperature and rainfall raster layers of the studied

area were created. In order to prepare the layers related to the slope measurements and the directions of slope and height, the digital elevation model of Kermanshah province with a spatial accuracy of 30 meters was used in the ArcMap environment (Digital elevation models).
After preparing the layers (raster), classification of the layers (raster classification) was done based on the table of ecological requirements (Table 1), in four classes: high suitable (4), suitable (3), semi-suitable (2), and non-suitable (1) (Figure 2).

2.3. Combine layers

Each of the measures has a different effect on the growth of safflower. A hierarchical analysis process was used to determine the coefficient related to the importance of these measures. Based on the opinions of experts and scientific sources, the gauges were compared in pairs. Then, using Expert Choice software, their importance coefficients were extracted. Moreover, the obtained coefficients were used in the geographic information system to superimpose the raster layers related to each of the gauges (Fathi and Nazari, 2017).

The classified rasters related to each measure were combined using the weighted overlay method in the geographic information system based on the calculated importance coefficient. After combining the layers, the final raster related to all the lands of the province was prepared with four classes: high suitable (4), suitable (3), semi-suitable (2), and non-suitable (1). In order to determine the agricultural lands suitable for the growth of safflower, the final zoning map was cut based on the land use grid related to farms, and all the residential parts, mountains, forests, pastures, and barren lands were removed from the final map. Finally, the area of highly suitable, suitable, semi-suitable and non-suitable for safflower cultivation in agricultural lands was calculated for the province, and important cities were identified.

3. Results and discussion

The results of AHP data analysis showed that according to the weight value and importance of criteria and sub-criteria related to the safflower plant, the importance of climatic variables (rainfall and temperature) was more than other studied variables. Based on the results of the hierarchical process, the rainfall gauge with a coefficient of 0.295, and then the maximum temperature with a coefficient of 0.219 had the highest coefficients (Table 2). After rainfall and maximum temperature, the highest relative importance was observed in slope (0.142), minimum temperature (0.126), height above sea level (0.098), average temperature (0.063), and slope direction (0.057). In research conducted under the title of the effect of temperature and day length on vegetative growth and seed yield in safflower genotypes, the results showed that the maximum temperature, more than any other factor, could affect the growth rate. Moreover, the growth rate in safflower showed a greater response than the maximum temperatures, which can be attributed to the occurrence of moisture and thermal stresses and the reduction in the length of the growth period. (Heydarizadeh et al., 2008). In the study on safflower, the growth rate in the greening to emergence stage was interpreted by the maximum temperature more than other atmospheric variables. The researchers stated that with the increase in temperature, the plant is subjected to thermal and moisture stress, and its growth rate increases greatly (Dadashi and Khajehpour, 2004).

In another study, in field conditions, the growth rate of sunflower cultivars from planting to emergence showed a linear relationship with temperature (Goyne et al., 1990). In autumn safflower planting, planting is done in the cold season, so after the rainfall factor, the temperature gauge is important to ensure the required growth rate. In another study that was conducted among the effective climatic factors of saffron growing in Torbet-Haydriya, rainfall followed by average, maximum, and minimum temperatures were the most important (Sorkh abadi et al., 2015). In Golestan province, the weight of climatic factors was expressed as 0.433 for rapeseed cultivation and 0.269 for soybean cultivation (Kazemi et al., 2012).

In this research, the inconsistency coefficient of the judgments made was less than 0.01, which indicates the coordination of the judgments regarding the criteria and sub-criteria and shows that the comparisons have a very favorable and acceptable consistency. One of the advantages of the hierarchical analysis process is the possibility of evaluating the judgments made in determining the importance coefficients related to criteria and sub-criteria. Thus, by using this method, the possibility of the inconsistency of reviewed judgments and the degree of inconsistency of judgments are shown (Ishizaka and Labib, 2009).

3.1. The potential of safflower cultivation in Kermanshah province by different cities

Highly prone areas (group 4) for safflower cultivation in the province include the cities located in the central region of the province, including Kermanshah (199,273 hectares), Islamabad West (52,825 hectares), Ravansar (42,919 hectares), Dalahu (38,564 hectares), and GilanGharb (33,962 hectares), which includes the plains of Mahidasht, Mian-Darband, and Islamabad. The conditions of the plain, suitable altitude and moderate weather of these areas have provided the necessary conditions for autumn and dry season cultivation of safflower. According to the weather conditions of the province, it is as a suitable cultivar for planting in dry areas such as Faraman thornless red flower variety and Sinai thorny yellow flower variety for these areas (Jabari et al., 2019). According to the results obtained from the long-term study of meteorological data in cold temperate regions, as well as the results of the study in seven provinces, it was shown: Sina cultivar (average yield equal to 1347.2 kg per hectare) has better yield conditions than other safflower cultivars in terms of compatibility. (Poordad, 2017). The best time for autumn sowing of Sina variety is the first decade of November, before the first rain (Pasban Eslam, 2018). According to unreported observations, farmers tend to cultivate thornless cultivars, which can be one of the reasons for the compatibility and proper performance of these cultivars.

According to the report, the Faraman variety, with an average yield of 1079.2 kg per hectare, has a higher yield than the other rainfed safflower varieties after the Sina variety (Poordad, 2017).

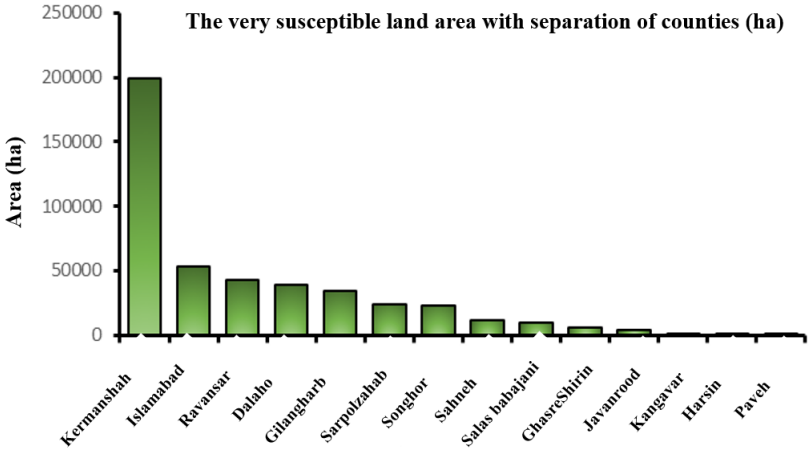

Figure 3. Area and share of highly suitable lands for autumn safflower cultivation in each of the cities

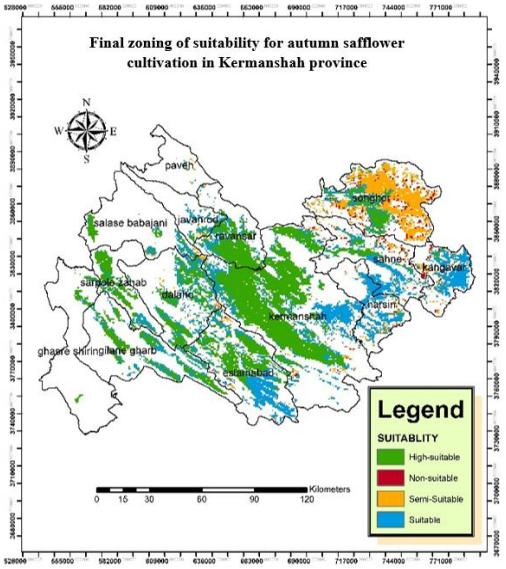

Figure 4. Land suitability map of Kermanshah province for autumn safflower cultivation

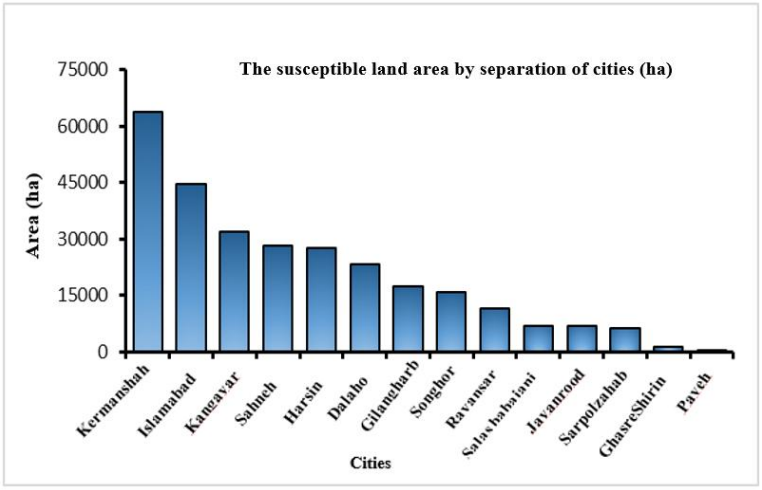

Figure 5. Area and share of suitable lands to autumn safflower cultivation in each of cities

Faraman safflower is a variety resistant to drought stress, early, with an intermediate growth type, thornless, large seeds, with red flowers, with an average plant height of 90 cm and a weight of 1000 seeds of 48 grams, which can be recommended to farmers in these areas. The lowest land classified in the high suitable group of the province was related to Paveh county. Due to its mountainous location, the county of Paveh has a very small amount of total arable land, of which a very small amount is very suitable for safflower cultivation (Figures 3, 4, 5).

Suitable areas (group 3), has a total of 285 thousand hectares of agricultural land in Kermanshah province. Also, it includes the cities located in the center of the province, including the cities of Javanrood, Islamabad and Hamil, Halshi, Bistun, Mian-Rahan, Parts of Kangavar and Dalaho cities, and lands located in the west of Sahne county. In general, 22.5% of the lands of Kermanshah, 15.5% of Islamabad, 11% of Kangavar, 10% of Sahne, 9.5% of Harsin, 8% of Dalahu, and 6.5% of Gilan Gharb were the most suitable areas. Due to having suitable climatic conditions during the safflower growth period, these areas have high performance and can be suitable places to meet the environmental and agricultural requirements of safflower. Similar to the highly suitable group, Paveh County has the least suitable land (1%). As mentioned, due to its mountainous nature, this region has a less cultivated area for agriculture, and its mountainous nature is mostly used for horticulture. After Paveh, Qasr Shirin County has the lowest area of safflower cultivation areas with 2%, which can be attributed to the high air temperature and dryness of the area in the conditions of rainfed cultivation (Figure 6).

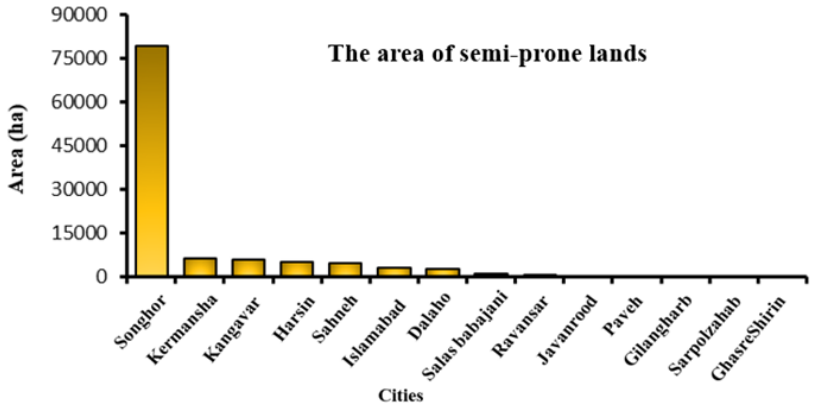

Figure 6. Area and share of semi-suitable lands for autumn safflower cultivation in each county

The semi-suitable areas (group 2) cover about 109 thousand hectares of the province's lands. The most important of which, respectively, included Sanghar counties (72 percent), about 6 percent of the lands of Kermanshah county, and 5 percent of the lands in the west of Kangavar county. The low air temperature in the months of March and April, at the same time as the beginning of the plant's growth period, can lead to a decrease in the proper growth and development of safflower in these areas. On the other hand, the area of this group of lands is small in Qasrshirin Safar county and Sarpol Zahab county (Figure 7). In terms of having suitable ecological conditions, including temperature for safflower cultivation, these areas have weaker conditions than suitable areas.

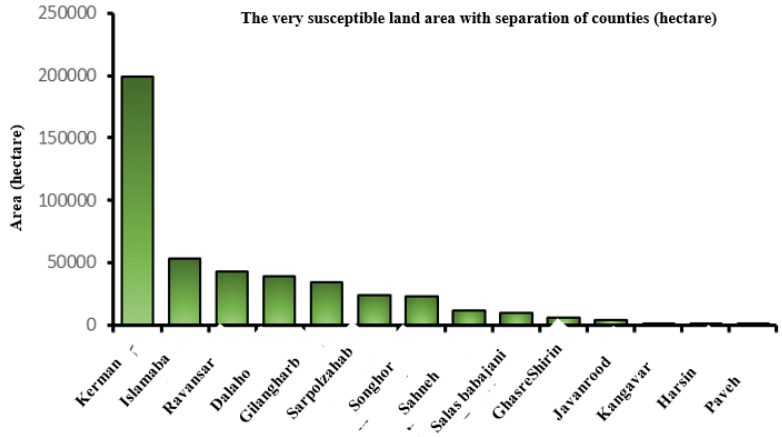

Figure 7. Area and share of semi-suitable lands for autumn safflower cultivation in each county

Regarding the group of non-suitable areas (group 1), 17,885 hectares of the total arable lands of the province are not suitable for safflower cultivation, which includes (2.08) percent of the agricultural lands of the province. Among the cities of the province, Sanghar has the largest area (9849 hectares) of non-suitable areas. Also, 33 hectares of the

land area of Bakhsh-Shahu located in Ravansar county, Setr district located in Sanghar Keliai county, and parts of Nodsheh and Baingan and east of Paveh county were assessed as not suitable for safflower cultivation (Figure 7). As explained in the previous sections, in addition to rainfall and temperature, the slope and direction of slope and height were also examined and evaluated as important. In some areas, the non-standard slope of the land, inappropriate height (the height gauge can affect other gauges such as the maximum, minimum, and average temperature), and the mountainous nature (areas such as Paveh and Bayingan) can be the cause of non-susceptibility. He stated that there is a small amount of land in these cities.

According to the obtained results, 52% of the total agricultural lands of Kermanshah province are highly suitable, and 33% are suitable. Likewise, about 13% of the arable land in the province was identified as semi-suitable and 2% as non-suitable (Figure 8). Therefore, based on the investigated climatic and topographical variables, there are suitable conditions for the cultivation of this crop in 85% of the agricultural lands of the province (areas with moderate and cold weather). These results show the high potential of Kermanshah province in safflower cultivation as a suitable plant in crop rotation.

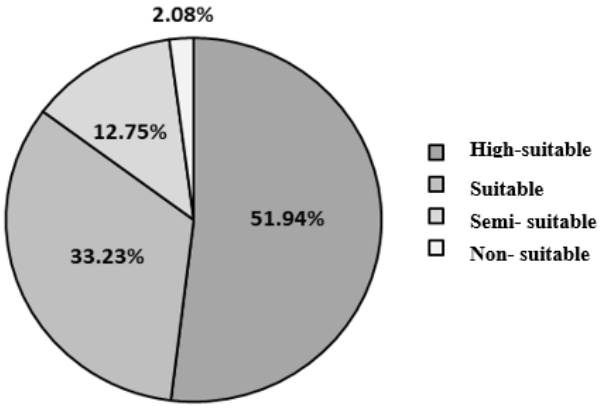

Figure 8. The share of lands in Kermanshah province in terms of ability to autumn safflower cultivation

4. Conclusion

The results of this research showed that by identifying the seven effective environmental layers in the process of safflower cultivation in a GIS environment, it is possible to identify the areas prone to cultivation for this crop in Kermanshah province. The results obtained from the hierarchical process indicated that the rainfall rate is the most important factor in the autumn rainfed cultivation of safflower. The results indicate that Kermanshah province has a high potential for safflower cultivation in terms of climatic and environmental potential and can be included in the periodic program of rainfed crops. This can lead to increasing the variety of rainfed farming systems in the province and benefiting from its benefits. In general, the agroecological zoning method is a suitable method for the qualitative assessment of land suitability in different regions and the quantitative assessment of crop yield. Due to the high potential of this method, it will be possible to evaluate and modify agricultural systems for different crops on a wide scale. This can lead to increasing the productivity of resources and reducing costs in the production of agricultural products.

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