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AGRO-ECOLOGICAL ZONATION ASSESSMENT FOR SIMULTANEOUS PLANTING OF SUNFLOWER, AND BERSEEM COVER CROP IN GALUGAH COUNTY FARMLANDS, MAZANDARAN PROVINCE, IRAN

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ABSTRACT

Given the beneficial effects of cover crops, their planting is a good way to improve soil fertility, reduce soil erosion, effectively control weeds, etc. some ecological variables were selected for sunflower and berseem clover land suitability assessment, and thematic maps were developed for each of the parameters in Geographic Information System (GIS). Finally, highly suitable, suitable, moderately suitable and unsuitable areas were detected by analytic hierarchy process (AHP). The findings indicated that the ordinary kriging interpolation model was the best model to evaluate the agricultural land suitability assessment for sunflower and berseem clover production in the region. Also, the climatic variables had a major role in the development of sunflower and berseem cultivation, and soil and topography variables ranked next. The final land suitability map revealed that the most highly suitable areas (3358.4 ha) were located in the north of the region, and the rest was suitable (15257 ha) areas for growing sunflower. Also, northwest and very limited areas from the northeast and southeast of the region showed highly suitable conditions (3534.4 ha), and other areas had suitable (15081 ha) condition in cultivation of berseem clover. Therefore, almost areas were suitable for it.

Keywords: analytic hierarchy process, land suitability assessment, ordinary kriging, sustainable agriculture.

INTRODUCTION

Sustainable agriculture seeks to introduce a range of conservation farming practices that can enhance nutrient use efficiency, reduce nutrient losses, increase the crop production, and decrease the greenhouse gas emissions (Adegbeye et al., 2020). Lack of diversity in crop rotation is one of the main reasons for pest damage and the degradation of soils and the plant environment (Congreves et al., 2015). Introducing cover crops to crop rotations is one of the ways to reduce the uniformity of cultivation in farm levels (Venkatramanan and Shachi, 2020). Cover crops allow covering the soil surface with biomass and/or mulch on the one hand and increase diversity in crop rotations on the other (Büchi et al., 2020). Additionally, cover crops can improve food security, environmental quality (Blanco-Canqui et al., 2015), and eventually the sustainability of crop systems in the long time (Büchi et al., 2020) by providing various services to ecosystems, such as the food production, animal feed, fibers, and fuel. A review of the literature showed that cover crops had such advantages as increasing soil organic carbon in the long time, reducing water erosion (Xiong et al., 2018), reducing wind erosion (Blanco-Canqui et al., 2013), reducing soil compaction (Blanco-Canqui et al., 2015), increasing soil temperature (Kahimba et al., 2008), increasing nutrient use efficiency (Frasier et al., 2017), improving the status of microorganisms in soils (Martínez-García et al., 2018), suppressing weeds (Kadziene et al., 2020; Petcu et al., 2022), retaining soil moisture (DeLaune et al., 2020), and enhancing crop yields (Nouri et al., 2019).

Using Geographic Information System (GIS) to introduce the cultivation of a new

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plant in an area can be useful for reasons such as determining the amount of crop production and conserving the resources requirements in the production (Pramanik, 2016). Mandal et al. (2020) stated that use of integrated geographical information system and AHP approach for analyzing land suitability and crop sequences may add a new dimension in spatial information science. In this respect, various studies have addressed land zoning for the cultivation of different crops. For example, Kamkar et al. (2014) used GIS to determine the suitability of canola-soybean rotation for four basins in Golestan Province, Iran. They reported that the canola-soybean rotation for the eastern lands of the province were categorized to be highly suitable and suitable for soybean and canola production, respectively. Mbugwa et al. (2015) evaluated the land suitability to the cultivation of a certain type of alfalfa in Wyoming, the USA, by GIS and found that although daily temperatures and April-July rainfalls were appropriate for this crop. Also, September-October precipitation would challenge its cultivation. They also stated that the final map would provide producers with the information required to more easily determine the best regions for crop cultivation and high yield. In a study Yaghmaeian Mahabadi et al. (2012) found that the soil texture was a major limiting factor in barley and alfalfa production in Isfahan Province, Iran. They used the Analytic Hierarchy Process (AHP) and reported that the most studied area was more suitable for alfalfa production than barley production.

Most studies on cover crops have focused on determining the efficiency of different cover crops in improving crop yields, enhancing soil fertility, controlling weeds, and so on. But, the study of suitable cultivated lands for cover crops and crops, especially sunflower, based on ecological needs has not been done in many parts of the world, particularly in the study area. Therefore, this study was conducted to determine: 1 - evaluation of the best cover crop; 2 - suitable areas for sunflower and the best cover crop production according to the ecological requirements; 3 - suitable areas for simultaneous intercropping of sunflower and the best cover crop in Galougah farmlands, Mazandaran Province.

MATERIAL AND METHODS

Study area

The study was conducted in Galougah township (53°48' E, 36°45' N, 40 m from sea level) located on the east of Mazandaran Province, Iran.

To conformity the environmental requirements of the crops with the land characteristics, the ecological and agronomic needs of sunflower and berseem clover were first collected from the literature including library documents, articles, final reports of research projects and theses, and consultation with local experts at academic and agricultural research centers of Mazandaran province. After collecting the data, the required information layers were prepared in GIS (ArcGIS 10.0 software). Then, the individual layers were categorized from highly suitable to unsuitable based on the environmental requirements of the crops (Tables 1 and 2). Finally, their categorized raster layers were also prepared. Afterward, the raster layers were overlapped to create the map of land suitability for sunflower and berseem clover cultivation.

Table 1. Criteria for delineating land suitability of sunflower in Galougah Township, Iran

Characteristics	Unit	Highly suitable (s_1)	Suitable (s_2)	Moderately suitable (s_3)	Unsuitable (s_4)
Rainfall	mm	500≤	400-500	300-400	<300
Mean annual temperature	°C	20-24	17-20, 24-27	<17, 24-30	>30
Mean minimum temperature	°C	12-15	10-12	8-10	<8
Mean maximum temperature	°C	20-25	30-25	30-35	>35
EC	dS/m	0-2	2-4	4-8	>8
pH	-	6.5-8	6-6.5	5-6	>8, <5
Soil texture	-	Loam, loam-sandy, loam-silt	Loam-clay-silt, loam-clay-sandy, loam-clay	Sandy-loam, loam-clay, clay-silt, clay	Sandy
Slope	%	0-4	4-8	8-12	>12
Aspect		No-aspect, southern, southwestern	Eastern, northeastern	Southwestern, northwestern	Western, northern
Elevation from sea level	m	0-1000	1000-2000	2000-2500	>2500
Nitrogen	%	1≤	0.7-1	0.5-0.7	<0.5
Phosphorus	mg/kg	15-17	12-15, 17-20	8-12, 20-25	>25, <5
Potassium	mg/kg	200-250	150-200, 250-300	100-150	>300, <100
Organic matter	%	>3	2-3	1-2	<1

Sources: Rastegar (2005), Asadi and Faraji (2008), Makhdoom (2001), Sys et al. (1991).

Table 2. Criteria for delineating land suitability of berseem clover in Galougah Township, Iran

Characteristics	Unit	Highly suitable (s_1)	Suitable (s_2)	Moderately suitable (s_3)	Unsuitable (s_4)
Rainfall	mm	≥600, 600-400	400-350	350-300	<300
Mean annual temperature	°C	20-14	25-20	30-25	>30
Mean minimum temperature	°C	14-10	18-14, 10-5	5-0	>0
Mean maximum temperature	°C	22-18	25-22	30-25	>30
EC	dS/m	3-0	5-3	7-5	>7
pH	-	6.7-5	7-8, 6.5-5.5	5-5.5	>8, <5
Soil texture	-	Loam, loam-sandy, loam-silt	Loam-clay-silt, loam-clay-sandy, loam-clay	Sandy-loam, loam-clay, clay-silt, clay	Sandy
Slope	%	4-0	8-4	12-8	>12
Slope direction		No-direction, southern, southwestern	Eastern, northeastern	Southwestern, northwestern	Western, northern
Elevation from sea level	m	1000-0	1500-1000	2000-1500	>2000
Nitrogen	%	1≤	0.1-7	0.0-5.7	<0.5
Phosphorus	mg/kg	14-10	14-18, 10-8	18-22, 8-5	>22, <5
Potassium	mg/kg	240-200	240-280, 200-150	150-100	>280, <100
Organic matter	%	>3	3-2	2-1	<1

Sources: Rastegar (2005), Asadi and Faraji (2008), Makhdoom (2001), Sys et al. (1991).

The layers used included the amount of rainfall and temperature (mean, minimum, and maximum), the variables of topography such as elevation from sea level, slope and aspect, and soil-related variables such as nitrogen (N), potassium (K), phosphorus (P) macro-elements, soil texture, organic matter (OM), pH, and EC (Figures 1-5). Tables 1 and 2 present the degree of suitability of the input variables.

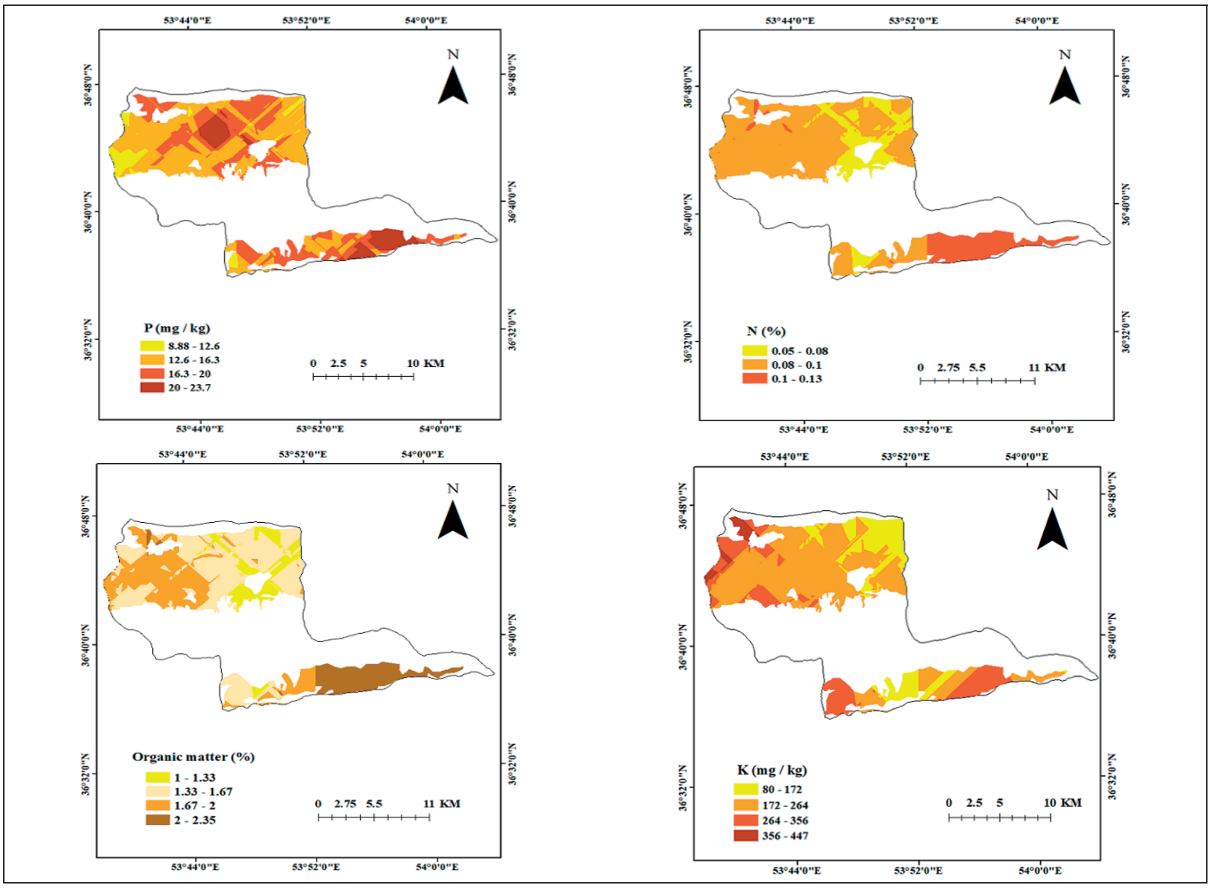

Figure 1. The spatial distribution of N, P, K, and soil OM in the agricultural lands of Galougah Township

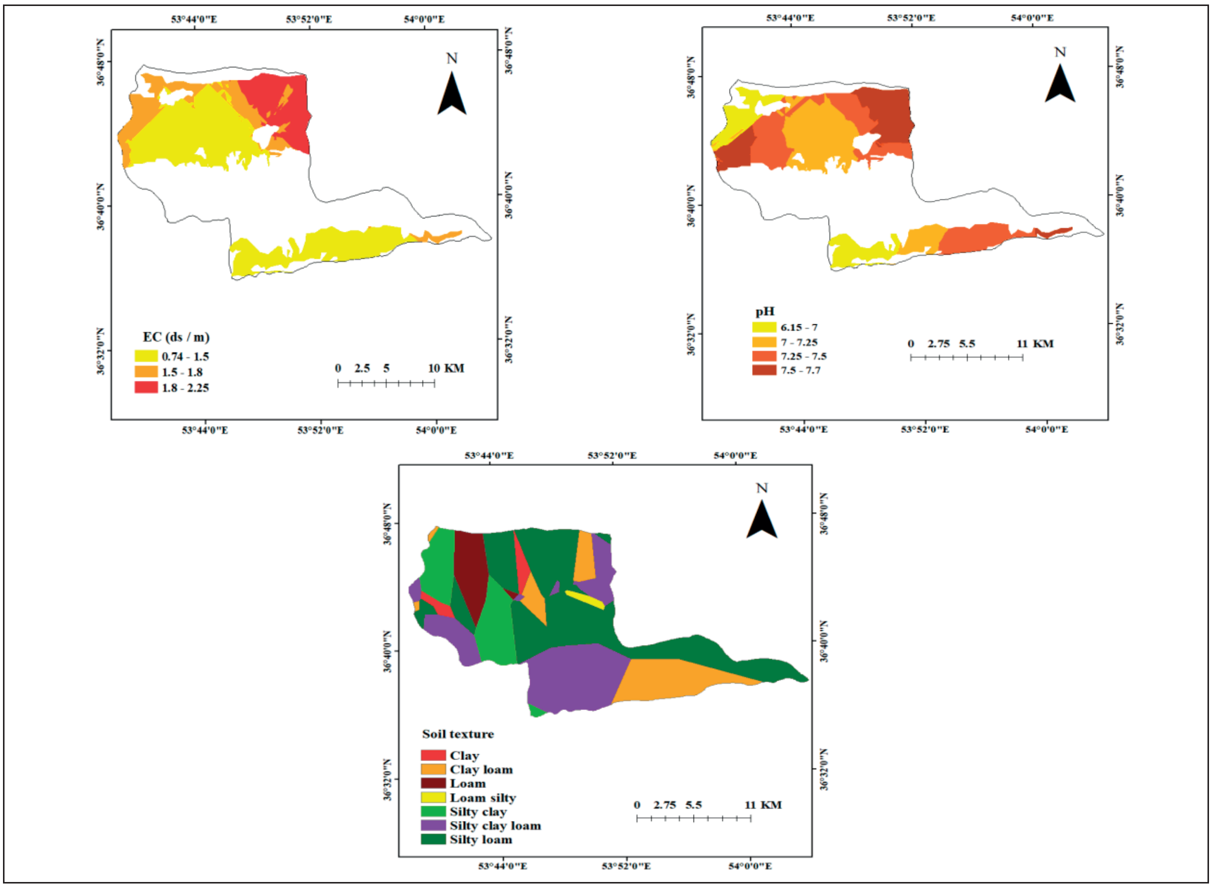

Figure 2. The spatial distribution of EC, pH, and soil texture in the agricultural lands of Galougah Township

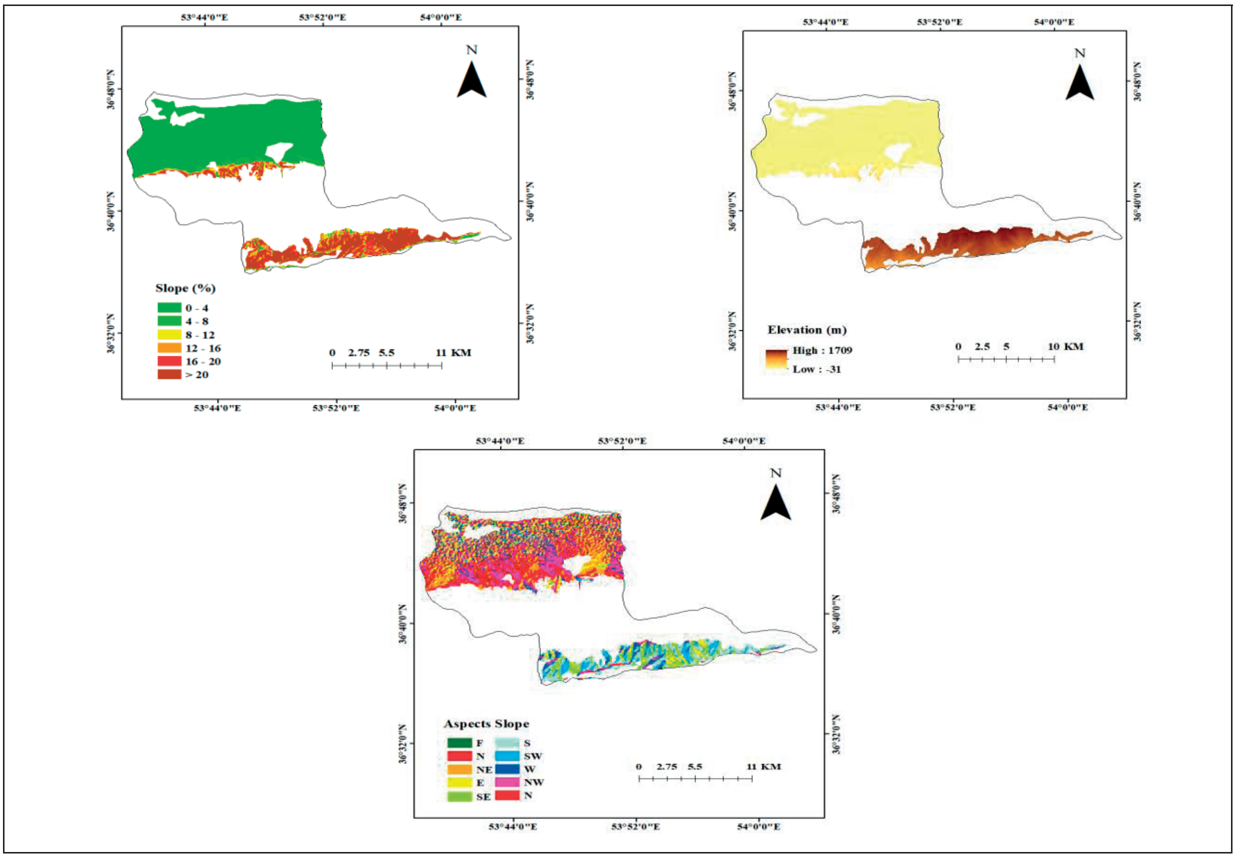

Figure 3. The classified layers of elevation, slope, and aspect in the agricultural lands of Galougah Township

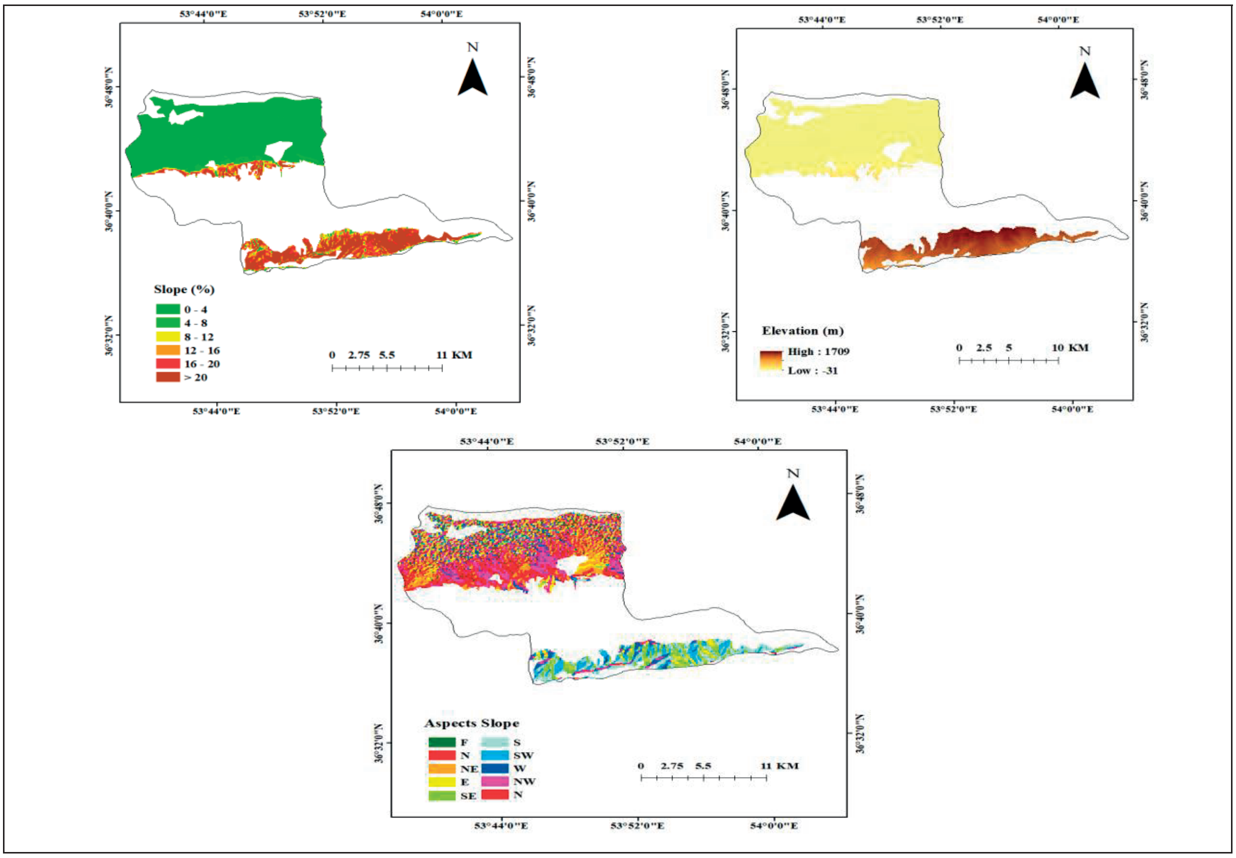

Figure 4. The classified layers of elevation, slope, and aspect in the agricultural lands of Galougah Township

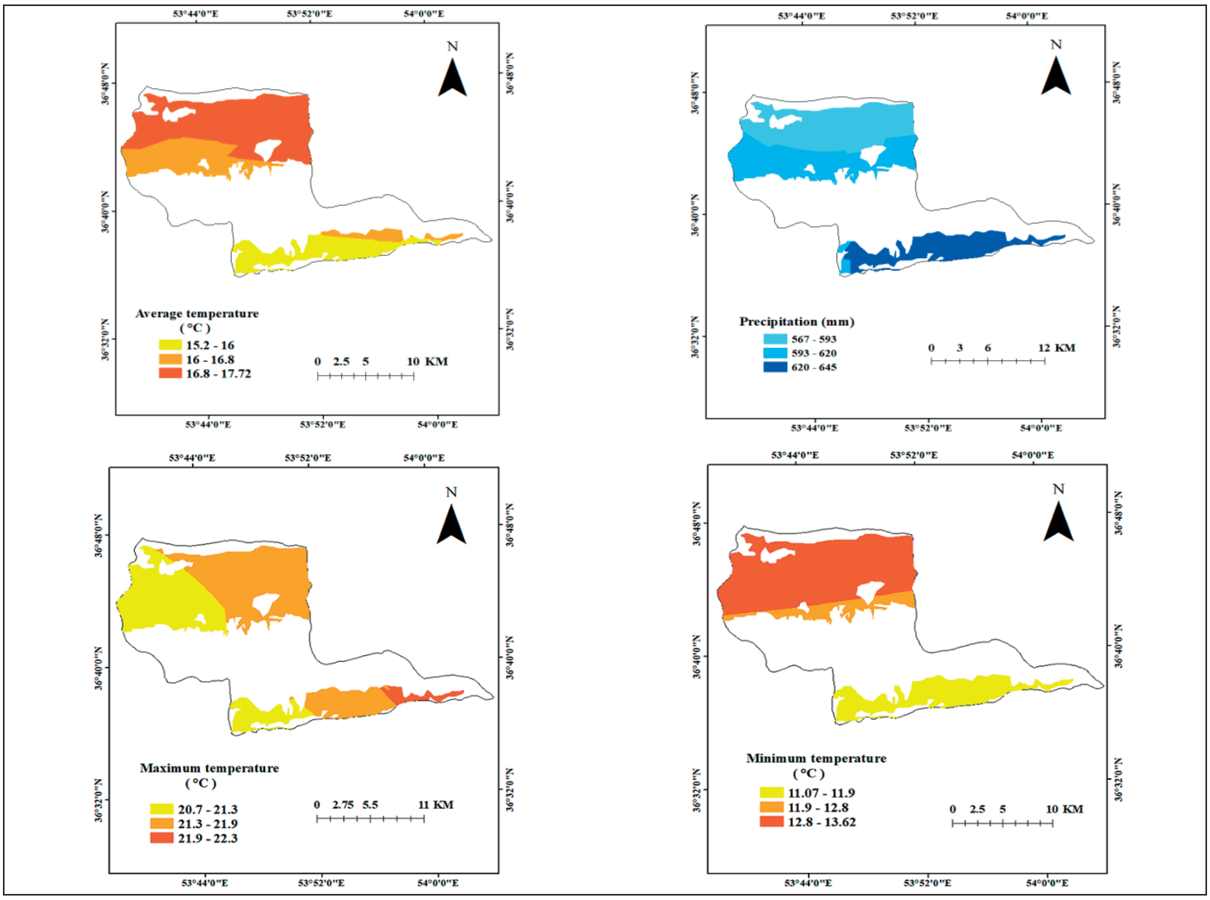

Figure 5. The reclassified layers of precipitation and maximum, average, and minimum temperatures in the agricultural lands of Galougah Township

Evaluation of the best cover crop

A two-year trial was conducted at a farm in Galougah township in two cropping years of 2016-2017 and 2017-2018 as a split-plot experiment based on a randomized complete block design with four replications. The main plot was assigned to the planting time of the cover crop and the sub-plot to the cover crop species. Result showed that among different cover crops, the intercropping of berseem clover with sunflower resulted in the highest sunflower seed yield (2859.06 kg.ha^{-1}). Also, berseem clover was selected to simultaneously cultivate with sunflower in Glougah Township.

Application of analytic hierarchy process (AHP)

The implementation of AHP is performed by forming hierarchy process, making pairwise comparisons, calculating the weight of the structure components, and measuring the inconsistency index (Saaty, 2000). The paired comparisons were made through the pairwise comparison matrices based on a nine-point spectrum (Table 3). The layers used here were created in the GIS and they were overlapped using a raster calculator by considering the weights obtained through AHP. Then, the final maps were obtained in four classified zones according to Table 4.

Table 3. Values of preferences for pairwise comparisons

Weights	Numerical value
Completely suitable and optimal	9
Highly strong suitability	7
Strong suitability	5
Relative suitability	3
Equal suitability	1
Intermediate preferences	8.6-4-2

Table 4. Indicators required for land zoning (Kazemi, 2014)

Zone	Crop production status
Highly suitable	There is 80-100% of the crop production potential in the zone.
Suitable	There is 60-80% of the crop production potential in the zone.
Moderately suitable	There is 40-60% of the crop production potential in the zone.
Unsuitable	There is <40% of the crop production potential in the zone.

RESULTS AND DISCUSSION

The three main factors in crop productions, especially the cultivation of sunflower and berseem clover, based on the AHP model were evaluated. The findings are presented in Table 5. At the next stage, to locate the regions prone to the cultivation of sunflower and berseem clover in Galougah Township, the weights obtained from the AHP results were used to create the final maps.

Table 5. The weight values of the criteria and sub-criteria of the factors effective in agricultural land suitability assessment for sunflower and berseem clover productions in Galougah Township

Criteria and sub-criteria	Sunflower		Berseem clover	
	Value	Rank	Value	Rank
1. Climate	0.461	1	1	0.537
1.1. Precipitation	0.434			0.370
1.2. Mean temperature	0.253			0.320
1.3. Maximum temperature	0.096			0.184
1.4. Minimum temperature	0.217			0.125
2. Topography	0.233	3	3	0.128
2.1. Elevation	0.189			0.198
2.2. Slope	0.417			0.399
2.3. Slope direction	0.394			0.403
3. Soil	0.306	2	2	0.335
3.1. Texture	0.066			0.198
3.2. EC	0.236			0.036
3.3. pH	0.121			0.062
3.4. Nitrogen	0.180			0.133
3.5. Phosphorus	0.123			0.125
3.6. Potassium	0.096			0.102
3.7. Organic matter	0.179			0.344
Inconsistency Ratio (IR)	0.04			0.03

Land suitability assessment for sunflower

The area with highly suitable and suitable degree for sunflower production in the agricultural lands of Galougah Township is presented in Table 6. Figure 8 displays the highly suitable area for sunflower production in the region. It is evident that, based on the results of integrating all studied factors and sub-criteria, the north, particularly the northeast of the region had highly suitable degree for sunflower production. As was already revealed in the results of the previous sections (Table 1), one of the most suitable factors for sunflower production is rainfall above 500 mm, which makes it highly suitable in the north of Galougah Township. Furthermore, low EC, zero or low slope, the elevations less than 1000 m from sea level, loam texture type, and high OM, which were good for sunflower production, making the north of the region highly suitable for the production of this crop. Also, it was also found that the most area was highly suitable and suitable in terms climatic factors. Based on the results, farmers should make plans for sunflower production in the northern area of the region given their suitable conditions. This would improve the regional economy and increase national income. It can also introduce the region as an oilseed production center, especially sunflower, in Iran.

Table 6. The categorized areas for sunflower and berseem clover productions at the agricultural land of Galougah township

Crop	Zone ranking	Area (ha^{-1})	Ratio of zone area to farmland areas of Galougah (%)
Sunflower	Very suitable	3358.4	18
	Suitable	15257	82
Berseem clover	Very suitable	3534.4	19
	Suitable	15081	81

The results of suitable areas for sunflower production showed that if the highly suitable areas are ignored, the other areas including the southern areas had suitable conditions for the production of this crop given all climatic, topographic, and soil factors (Figure 8). For example, 400-500 mm rainfall rate, loam and light texture of the soil, and relatively high fertility at most parts, made the region suitable for sunflower production. Since soil OM has positive impacts on physical, chemical, and biological properties of soils (Six et al., 2000), the decline in soil OM in sunflower fields may reduce seedling germination due to the reduction in soil moisture; a phenomenon that was observed in soils with less than 2 percent (Önemli, 2004). It should be noted that salinity had the highest value among the sub-criteria of the soil factors (Table 5) because, as studies have revealed, the salts of saline soils get into the root system where they disrupt the uptake of nutrients and water and reduce sunflower dry matter and seed yield (Stadler et al., 2015). In a simultaneous study on the effects of salinity and drought stresses on sunflowers, Nasrollahi et al. (2017) revealed that the shortage of soil OM, high soil salinity and inadequate rainfall were the most important reasons for the failure of grain-pasture rotation in the northern regions of Aq-Qala in Golestan Province, Iran.

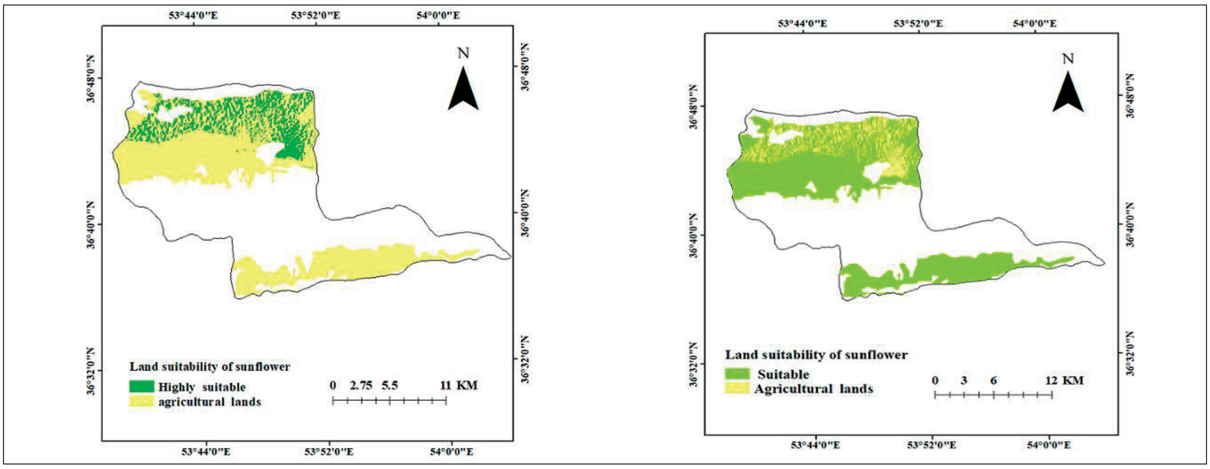

Figure 8. Highly suitable and suitable areas for sunflower production in agricultural lands of Galougah twonship

Land suitability assessment for berseem clover

The maps of highly suitable and suitable areas for berseem clover production are depicted in Figure 8. The results of all criteria and sub-criteria showed that the northwest and southeast, and some limited parts of the northeast of Galougah Township were highly suitable for berseem clover production. According to Table 2, a highly suitable factor is 400-600 mm rainfall for berseem clover production, so the northwest and southeast of the region were highly suitable for berseem clover production owing to their appropriate rainfall rate. As well, the temperature regime in mentioned areas was suitable or highly suitable for berseem clover production. Also, other factors that were good for berseem clover growth, including low EC, zero or low slope, 0-1000 m from sea level elevation, loam texture type, and more soil OM, were found in the northwest and southeast of the region. It was also revealed that the most areas in Galougah Township were climatically suitable or highly suitable for berseem clover production.

Figure 9 displays the final map of the suitable areas for berseem clover production. If highly suitable areas are not considered, other areas had suitable conditions. Some proper conditions for berseem clover production were 350-400 mm rainfall rate and loam-clay or sandy-loam soil texture, which were found in most parts of the region and make it highly suitable for berseem clover production. In fact, rainfall plays a key role in attaining the optimal yield of berseem clover in northwestern and southeastern areas of the region. In a study, Lazaridou and Koutroubas (2004) found that drought stress during the growth stage of berseem clover could reduce the yield than without drought stress condition. Also, soil dryness and lack of adequate rainfall were the most important effective factors in reduction of germination and unfavorable establishment of berseem clover seeds in soil (Daneshnia and Chaichi, 2018). Soil OM was found to be the most important soil sub-criterion in berseem clover production (Table 5) so that higher OM increased the plant height, dry and fresh matter weight, seed yield, raw protein, and fiber of berseem clover (Ismail et al., 2019).

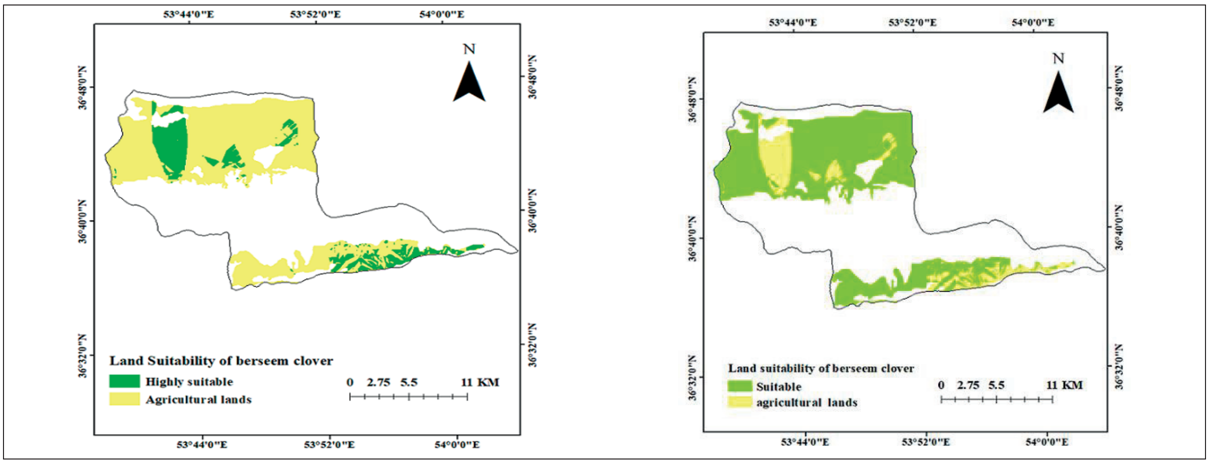

Figure 2. Highly suitable and suitable areas for berseem clover production in agricultural lands of Galougah twonship

Land suitability assessment for simultaneous intercropping of sunflower and berseem clover

As is observed in Figure 10, only limited parts of the north were highly suitable for the simultaneous intercropping of sunflower and berseem clover, but almost all agricultural lands of Galougah Township were suitable for it. The trial site is depicted in Figure 9. It can be observed that this farm had in coordination with the suitable area for the cultivation of sunflower and berseem clover and this confirms that the simultaneous intercropping of berseem clover and sunflower is feasible. Some benefits of the simultaneous intercropping of cover crops and oilseed crops include their capability of biological fixation of N, an increase in soil fertility, the improvement of the physical structure and other soil characteristics, and the capacity to break down the lifecycle of pests (Howieson et al., 2000). The use of the existing and suitable potentials in Galougah Township, including suitable climate conditions, can increase the area under simultaneous intercropping of sunflower and berseem clover. Also, inclusion of these plants in local rotations to be important owing to its nutritional value and economic profitability. This needs the attention of governmental decision-makers to develop this plan. Overall, sunflower in the rotations has the same situation as maize that is cultivated after forage legumes as the first or second crops, although soil moisture storage should also be predicted.

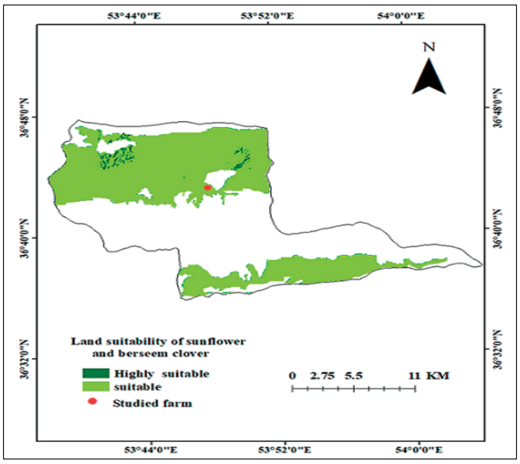

Figure 10. The classified agricultural lands of Galougah twonship for the simultaneous intercropping of sunflower and berseem clover, and the location of the studied fields

CONCLUSIONS

Since berseem clover planting has an effective role in controlling weeds and increasing sunflower seed yield regardless of its planting method and time, the present research assessed the suitable and very suitable regions for growing sunflowers and berseem clover. The map results to find potential sunflower cultivation areas revealed that the northern regions, especially the northeast of Galougah Township, were highly suitable and other regions were only suitable for the sunflower production according to the studied factors. Limited parts of the northeast and southeast of the region had highly suitable conditions for the berseem clover production. So, it is recommended to simultaneously intercropping of sunflower and berseem clover as a cover crop to better control weeds and increase sunflower seed yield in agricultural lands of Galougah.

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