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Assessment of environmental suitability for sugar beet planting in Torbat-e Heydarieh city using Geographic Information System (GIS)

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ABSTRACT

This study aimed at determining the prone areas for sugar beet planting with regard to major factors influencing it. Climate data of 1998-2009 period were obtained from the local stations of Khorasan Razavi Meteorological Bureau. The topographical data including altitude, slope, slope direction, and TIN were extracted from 1:250000 topographic maps of Cartographic Organization, Iran. The land use and vegetation land maps were prepared from 1:250000 maps of National Soil and Water Research Institute. The Geographic Information System (GIS) was used for numerical calculation and map drawing. After the spatial geo-database of the region was developed, the descriptive data of the maps were added to it using the ARCGIS software. Then, with regard to the climate needed for sugar beet crop and based on views of the experts, each layer weight and its importance in Hierarchical Decision making model was determined using EXPERT CHOICE software. Finally, through overlay analysis in GIS system, the potential cultivated areas for sugar beet were classified. Results of the final zoning map showed that 59.61% of Torbat-e Heydarieh area (3745.82 Km^{-2}) has a great potential for sugar beet planting and about 24.49% of the area was found not be suitable. Among the agricultural regions, Rokh plain and Kadkan region (north of Torbat-e Heydarieh) were highly suitable for sugar beet planting followed by Markazi plain.

Keywords: Agro-ecological classification, climatic parameter, environmental factors, geographic information system (GIS), sugar beet

INTRODUCTION

Generally, agricultural programming without considering climate condition is not successful (Alijani and Kaviani 1992). For better understanding of the problems associated with climate and agriculture, region zoning is inevitable (Kenny et al. 2000). Variation in climate condition made unique opportunity for Iran to grow different crops at different seasons. The knowledge of climate condition is a requirement for the establishment of a relative stability in agricultural products distribution into the markets. The knowledge of selecting proper planting and harvest time in different regions and also climate condition, gives a unique opportunity to programmers for making optimal use of natural resources (Nouri 2004). Climate condition is so imimportant for all plant growth stages (Kuchaki et al. 1997). This study aimed to indicate the geography science importance in solving agricultural problems associated with sugar beet planting in terms of climate and ecological points.

Sugar beet is considered as the main sugar crop in arid to semi-arid climates and planted in latitude 35° N and higher. Sugar beet planting began from 100 years ago in Iran. Its planting is distributed in temperate regions, especially Khorasan province. When the number of sunshine hours during the growing season is less than required and the sky is cloudy, sugar content will be re-

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duced.

Sugar beet is a biennial crop originated from annual coastal species and bred to accumulate storage materials, especially sugar. This feature is achieved by planting sugar beet in a long growing season in fertile soil (Peter 2000). The main areas of sugar beet production are arid and semi-arid regions. The optimum temperature for sugar beet growth is 25 ^{o}C (Nuhi 1993). The maximum sugar yield in Czech Republic was achieved in April at 7 ^{o}C. The daily temperature variation in April from 6.8 to 9.3 ^{o}C resulted in yield difference up to 0.2 t ha^{-1}. The effect of low temperatures in September is so important so that the maximum yield was obtained at temperatures lower than 17 ^{o}C (Peter 2000). For germination, sugar beet seed needs water, air, and optimum temperature of 25 ^{o}C and plant growth depends on soil and climate temperature, moisture, seed quality (biological value), and planting depth (Nuhi 1993).

Sugar beet plant communities and climate condition in which plant grows is a complex dynamical system. In this system, plant communities have more variation and balance maintenance. This is not only depends on topography but also on soil and water characteristics, climate variation and human factors. The plant's ability to respond to external factors such as climate condition is genetically governed and can be adjusted by plant breeding and cultural practices (Kudrna 1997).

Sugar beet is a C3, long-day and photoperiod-sensitive plant (Stehlk 1982) which needs 10000-30000 lux light. So, the rate of photorespiration in sugar beet is 3-5 times higher than dark respiration (there is no photorespiration in C4 plants like maize). Net photosynthesis rate is 10-30 mg dry matter per 100 cm^2 leaf area per hour at 25 ^{o}C. Based on Drachovska and Sandera (1959) report, it needs a minimum of 15 hours light per day for photosynthesis which begins from initial root differentiation. According to Torbat-e Heydarieh Sugar Factory Research Department, late planting and delayed establishment resulted in reduction of sugar content. As shown in Table 1, 20 and 39 days delay in planting resulted in 79.5 and 61.2% reduction in sugar yield, respectively.

Compared with other crops, the amount of water required for sugar beet growth is high (8970 m^3 ha^{-1}) (Havlicek 1985; Alizadeh et al. 2003). Sugar beet stomata remains open even at night. Transpiration rate depends on several factors (Buzanov 1979). Buzanov (1979) results confirmed the correlation between transpiration, leaf area index and air temperature. In Iran, sugar beet production relies on irrigation and no dry farming is possible. The water requirement varies according to climate and temperature. For instance, using Blaney Criddle method and sugar beet crop coefficient for irrigation water requirement (IWR) estimation in Khorasan province, the IWR was 14000 m^3 (in flood irrigation method with 30% efficiency).

Table 1. Elevation distribution of the study area

Group	Suitability rate	Elevation (m)	Area (%)	Region area (Km^2)
A	Good	1300-2300	90.5	5691.52
B	Average	<1300	5.4	344.39
C	Inappropriate	>2300	4.1	24.82

Source: Authors' calculation

During a growing season, rainfall distribution is more important than its amount. Drought occurrence in summer has an adverse effect on plant initial development. Rainfall in autumn delays harvest, causing new leaf formation, and reduces sugar content. In a study by Fiedler (1983), drought stress in July and August imposed the highest damage to sugar beet yield. Sugar beet becomes especially susceptible to drought after wet spring when wilting of the developed leaves occur quickly resulting in the plant death. In autumn, when air humidity is high, sugar beet yield increases but the quality decreases. During growth and dry matter production, the optimum temperature for photosynthetic material production is 18-22 ^{o}C. Stehlk (1982) evaluated the effect of climate condition including temperature, rainfall, and light on sugar beet yield and reported rainfall as the main factor. Average and above average rainfall, and also optimal rainfall distribution during the growing season, results in high yield. Rainfall is more important than temperature and radiation for root yield and sugar content. High temperatures are undesirable, especially in late September and October) since they cause leaf fall and growing of the new leaves which decreases root storage. Temperature variation in night may change root yield, sugar content and sugar yield. It can be concluded that soil moisture and water management have major impact on crop quality.

MATERIALS AND METHODS

Introduction of the study area

Torbat-e Heydarieh is located in central region of Khorasan Razavi province in 25´ and 34^{o} to 53´ and 35^{o} N latitude and 1390 m altitude above sea level. The city area is over 6200 km^2, 7.5% of the

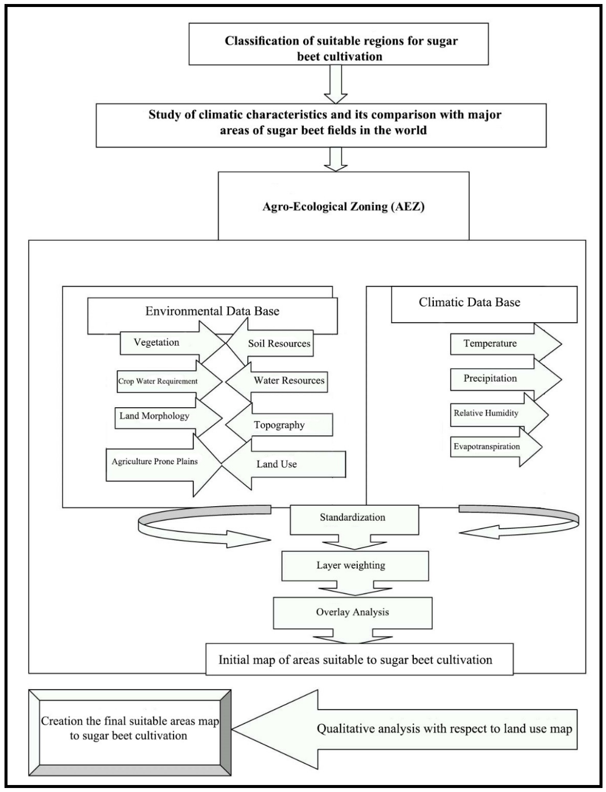

Figure 1. Conceptual model of the study database

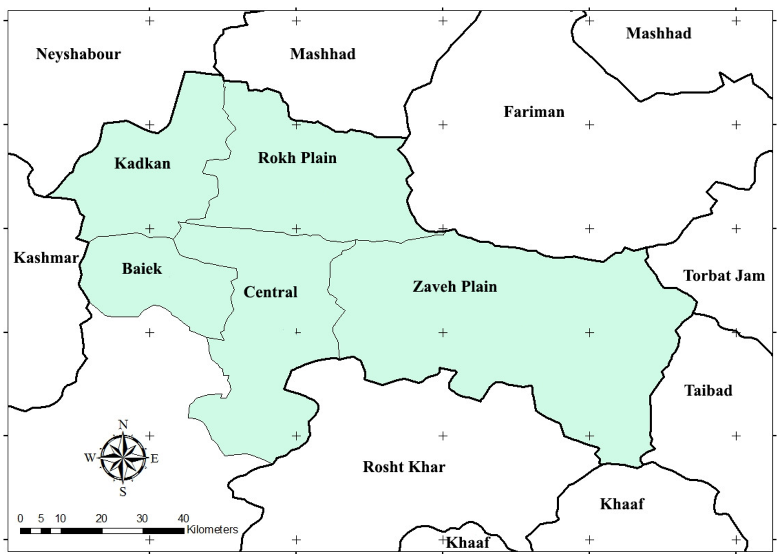

Figure 2. Administrative divisions of Torbat-e Heydarieh city and its surrounding area

province's total area. Position and different parts of the city is depicted in Figure 2. Most of sugar beet production in Khorasan Razavi province belongs to Torbat-e Heydarieh, Sabzevar, and Neishabour cities. From 2005 to 2008, sugar beet planting experienced a dramatic decrease from 8500 hectare in 2004 to 4359 hectare in 2008 in Torbat-e Heydarieh (Torabt-e Heydarieh Sugar Beet factory 2008).

Figure 1 shows the conceptual model of the study process. Based on this graph, for agro-ecological zoning two database containing land climate information were provided. On the basis of field studies and questionnaire forms collection (Delphi method), the importance of each factor for sugar beet growth and yield was evaluated. The final suitability map was developed from overlay weight of information layers in GIS data environment based on hierarchical system (EC software). Finally, by investigating land use maps,

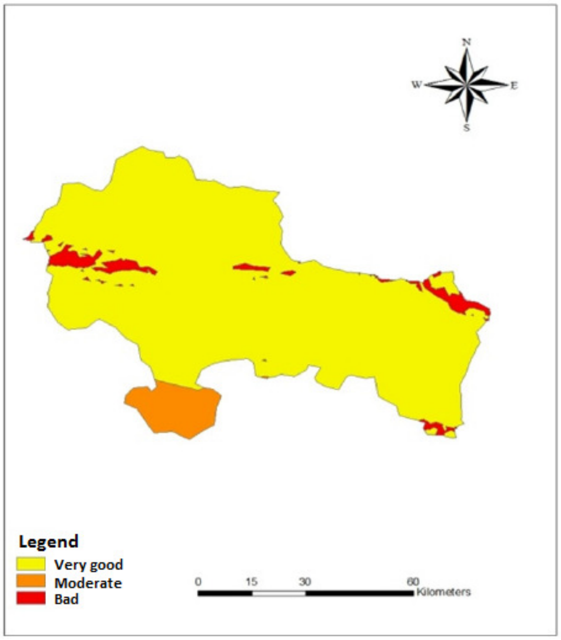

Figure 3. Altitude levels map

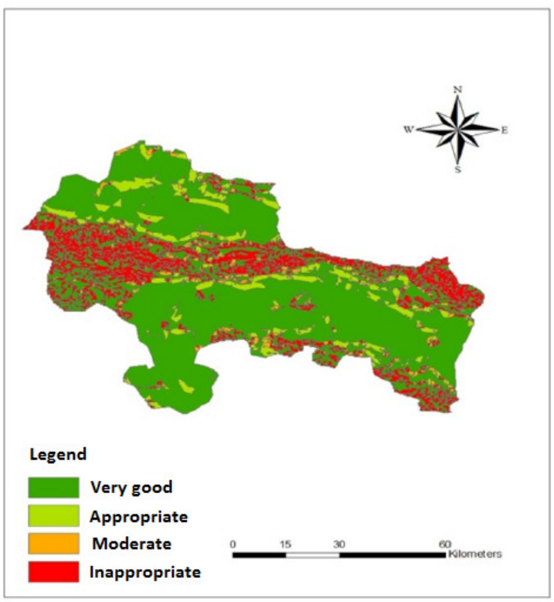

Figure 4. Slopes map

results were compared with suitable agricultural farms and final zoning map was developed.

RESULTS AND DISCUSSION

Altitude map

In this study, altitude means elevation above sea level. Since the plain roughness was in the direction of rainfall system entrance (west to east), therefore, the region map was classified into three categories. As sugar beet prefers cold regions with 1300-2300 m altitude above sea level (Peter 2000) the importance of each group is shown in Table 1. In addition, the classification was divided into three sub-groups including good, average and inappropriate based on sugar beet yield in the studied area. The elevation suitability is shown in Figure 3.

According to Table 1 and Figure 3, 1300-2300 m elevation covered 90.5% (5691.52 Km^2) of the Torbat-e Heydarieh plain area followed by <1300 m and >2300 m elevations, covered 5.4 (344.39 Km^2) and 4.1% (247.72 Km^2) of the area, respectively.

Table 2. Slope status in the study area

Group	Suitability rate	Elevation (m)	Area (%)	Region area (Km^2)
A	Very good	< 4%	67.4	4240
B	Appropriate	4-8%	10.1	636.16
C	Average	8-12%	3.5	220.74
D	Inappropriate	> 12%	18.8	1186.65

lope map

Land slope is one of the main natural factors influencing agricultural crops planting. In northern hemisphere, the south and horizontal surfaces always have a symmetrical energy absorption by sun with maximum absorption at noon. In Equinox, the maximum radiation occurs on south-facing slope at 40 ^{o}N. East-facing slopes receive radiation earlier than south-facing slopes. On west- and east-facing slopes the radiation is symmetrical about afternoon (more than south-facing slopes). Northern walls at Equinox receive no direct sunlight at all and only can use scattered and short period radiation. However, 45´ N latitude is in weak direct sunlight all day. Therefore, using topographical map and determining azimuth angles of slopes, incident radiation can be estimated. With considering pixels dimensions, the slop steepness was determined using 3D Analyzer. Because sugar beet is an irrigated crop and the proper land slope for irrigated farming is about 8% (Makhdoom 1995), therefore steeper incline decreases land suitability for sugar beet planting. Slope map is classified in Table 2 based on four groups with different characteristics.

It was found that more than 67.4% of the land (4240 Km^2) was suitable (slope < 4%) for sugar beet production (Table 2). Figure 4 shows slope direction.

Isoheytal map

The amount of rainfall is measured by data collected from synoptic, climatological and pluviometry stations. Therefore, data collected from

Table 3. Annual rainfall distribution

Group	Suitability rate	Rainfall (mm)	Region area (%)	Area (Km^2)
A	Very good	> 300	30	1823.18
B	Appropriate	200-300	58.9	3763.93
C	Average	100-200	9.8	613.74
D	Inappropriate	< 100	1.3	82.91

Table 4. Annual temperature distribution

Group	Suitability rate	Classification (^oC)	Region area (%)	Area (Km^2)
A	Very good	18-25	6.28	394.91
B	Appropriate	15-18	67.76	4255.62
C	Average	10-15	23.04	1447.19
D	Inappropriate	< 10	2.89	182.044

Table 5. Evapotranspiration, effective rainfall, and net irrigation requirement for sugar beet

Plain	Total growth period evapotranspiration (mm)	Effective rainfall(mm)	Net irrigation requirement (mm)	Drainage basin
Jungle	1125	20	1105	Kale Shur
Rokh	931	34	897	Kale Shur
Zaveh-central	1125	20	1105	Kale Shur
Rashtkhar	1220	14	1206	Kale Shur
Feyzabad mahvelat	1172	15	1157	Kale Shur

Table 6. Effective rainfall distribution in the study area

Group	Suitability rate	Rainfall (mm)	Region area (%)	Area (Km^2)
A	Very good	> 26	11.2	7041.16
B	Appropriate	21-26	13	818.71
C	Average	16-21	58.8	3696.33
D	Inappropriate	< 16	16.9	1064.55

weather stations were interpolated by Kriging. In this study, Kriging spatial interpolation method was used for rainfall data expansion.

Temperature map

As well as rainfall map, temperature map is also drawn based on synoptic and climatological stations data. By using mathematical and statistical models, the results of a point and a place was converted into the same temperature curves and finally expanded to a broad area. The base temperature for sugar beet planting is 5 ^oC. The optimal temperature for most agricultural crops is 25-30 ^oC with a maximum of 35-40 ^oC. Nuhi (1993) reported 4-5 ^oC as the cardinal temperature for sugar beet seed germination (from planting to germination), 25 ^oC as optimum temperature, and 27-30 ^oC as maximum temperature. Therefore, 25 ^oC is considered as optimum temperature for sugar beet planting. In this study, based on theoretical principles and experts' viewpoint, the optimal temperature for sugar beet planting was considered 18-25 ^oC and lower weight was allocated to higher and lower temperatures than this range. It is obvious that based on ranking, weight comparison is relative. Results are shown in Table 4.

Effective rainfall

The relative importance of water in agricultural production is varied based on geographical and climate condition, and in general it depends on the time and amount of rainfall. Thus, evaluation of the rainfall characteristics is important in the identification of each region's suitability for agricultural crops growth (Baily 1979).

Rainfall is the main source of irrigation water for agricultural crops production in most parts of the world. Three main rainfall characteristics are intensity, duration, and frequency which vary from place to place, day to day, month to month, and also year to year (Dustin 1985). Irrespective of high knowledge about weather parameters, some simple concepts such as effective rainfall is not known sufficiently (Ogrosky and Mackus 1964). Effective rainfall is equal to the difference between total rainfall and the quantity of water lost through surface run-off and infiltration from the saturated soil. This definition, however, does not include the water needed for pre-plant and soil preparation stages. Effective rainfall can be calculated directly from the climate parameters and the useable ground reserves. At ground level, water from effective rainfall is split into two fractions: surface run-off and infiltration (Hershfield 1964; Dustin 1985). Effective rainfall values are shown in Table 6. This classification is based on optimal crop planting condition and climate consideration. When effective rainfall is low, plant water requirement should be supplied by irrigation. Studies showed that in northern latitudes, irrigation requirement is low but lower annual rainfall in Mediterranean (< 300-500 mm) and north Africa (< 600 mm), makes irrigation inevitable (Draycott 2006). Therefore, high effective rainfall is considered as a positive score in this Table. Criterion selection is relative according to their ranking.

Table 7. Sugar beet irrigation water requirement in the study area

Table 8. Sugar beet evapotranspiration in the study area

Group	Suitability rate	Category (mm)	Region area (%)	Area (Km^2)
A	Very good	< 960	6.8	430.87
B	Appropriate	960-1060	11.1	699.40
C	Average	1060-1160	60.7	3818.3
D	Inappropriate	> 1160	21.2	1335.1

Group	Suitability rate	Category (mm)	Region area (%)	Area (Km^2)
A	Very good	< 950	7.8	494.28
B	Appropriate	950-1050	8.6	545.42
C	Average	1050-1150	43.7	2746.32
D	Inappropriate	> 1150	39.7	2497.73

Table 9. Land type distribution in the study area

Group	Suitability rate	Types	Region area (%)	Area (Km^2)
A	Very good	Plain range, alluvial plains and river plains	23	1451.5
B	Appropriate	Plateaus and upper layers, plateaus and soil hills, floodplains	61.3	3858.1
C	Average	Hills, fan-shaped debris, tiny stones	13.2	832
D	Inappropriate	Mountain	2.2	142.13

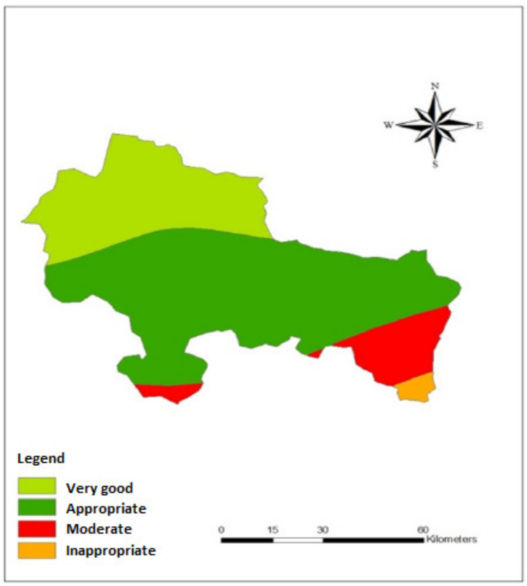

Figure 5. Rainfall distribution map

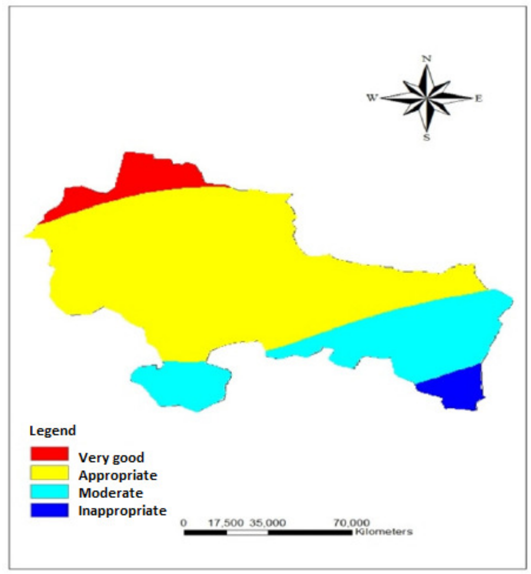

Figure 6. Temperature distribution map

Plant water requirement

NET WAT software (developed for optimization of the agricultural water use pattern) was used for drawing the irrigation water requirement, evapotranspiration and effective rainfall layers. Net irrigation requirement of the agricultural and horticultural crops is one of the water use efficiency optimization projects performed by Meteorological Organization and Ministry of Jihad-e-Agriculture in Iran. In this project, planting and harvest data and also the growth period of agricultural and horticultural crops and crop coefficients were estimated based on field studies conducted on all agricultural plains (620 plains). For water requirement estimation, Penman-Monteith method was used in 10 days and monthly periods (Alizadeh et al. 2003). As a result, evapotranspiration, effective rainfall and net water requirement were estimated in each period, month, and season which is shown in Table 5. Since the average annual rainfall in the study area is less than 300 mm, therefore, regions with low water requirement are more appropriate for sugar beet planting. Although it may decrease crop yield in these regions but it can detect regions with higher suitability (Table 7). The region with a suitability rate of very good covered 6.8% of the area.

Evapotranspiration

In this study, evapotranspiration was measured based on Penman- Monteith method using CROPWAT software. This model requires minimum, maximum, relative humidity, sunshine hours, and wind speed data for evapotranspiration estimation. The classification was carried out based on theoretical factors, experts' viewpoint, and plants evapotranspiration (Table 8). Based on rainfall status, the suitability rates of very good and weak were allocated to regions with low and high evapotranspiration, respectively (Table 9).

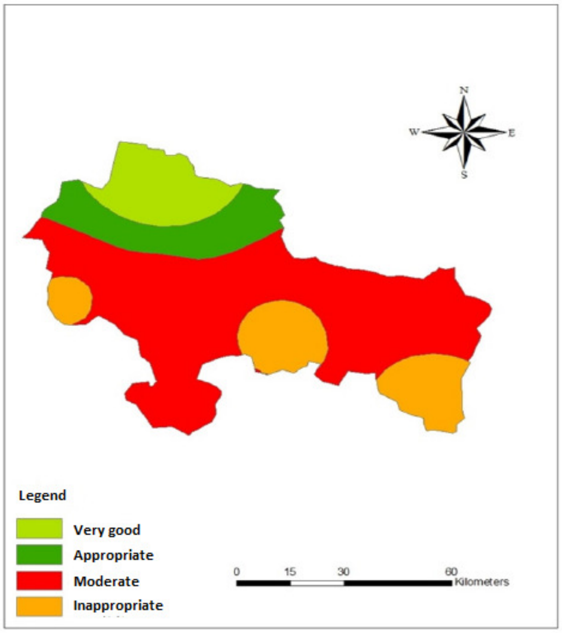

Figure 7. Effective rainfall distribution map

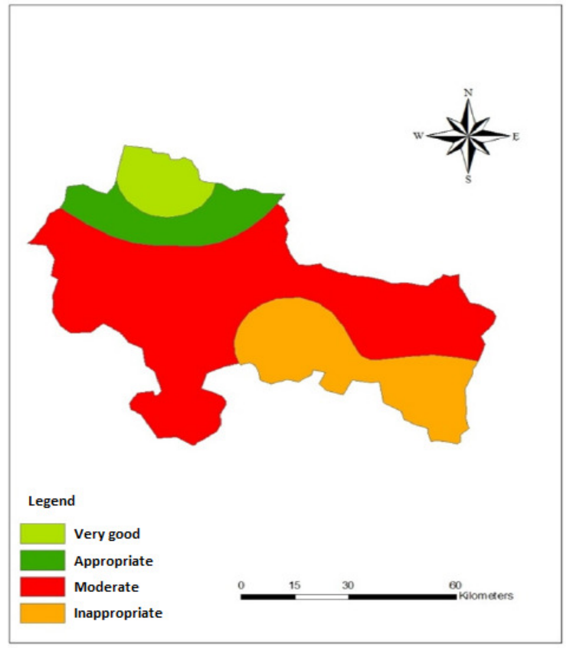

Figure 8. Water requirement map

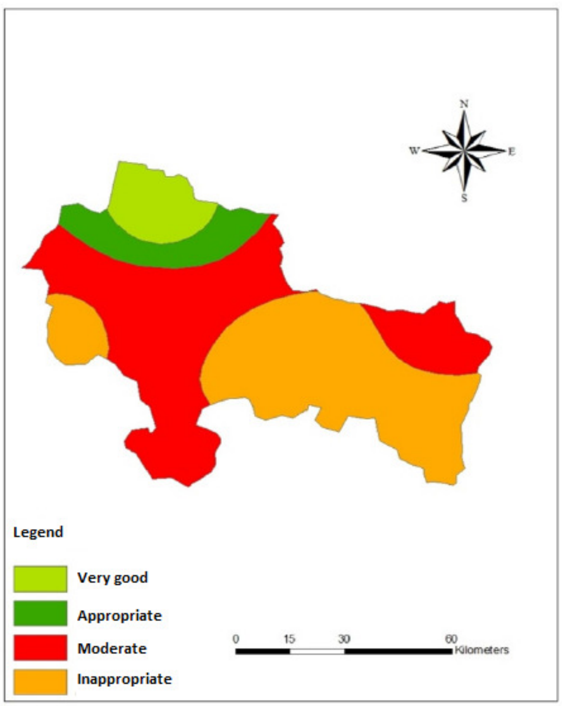

Figure 9. Evapotranspiration map

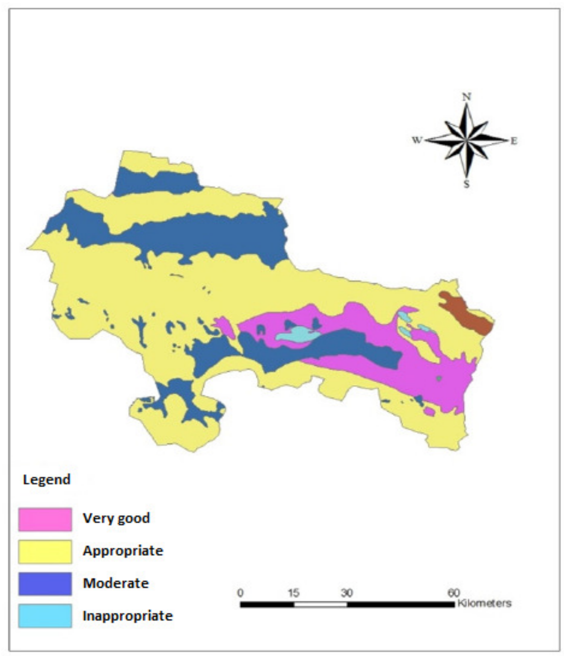

Figure 10. Land type map

Land type

Lands were classified in terms of farming and irrigation suitability according to their permeability, sand percentage, soil texture, soil depth, salinity level, alkalinity, slope, erosion, and drainage. This information was converted to numerical data based on land use maps with 1:250000 scale and descriptive information attached to each map (Figure 10). Through land use map, land type map were determined and classified based on their suitability for sugar beet planting. As shown in Table 9, land types were classified into four groups.

Weighing of maps

At this stage, according to the experts view, weight allocation and classification of the area and vegetative percentage were performed (Table

Table 11. Layer weighing and classification

Layer	Layer weight (from one)	Layer classification	Range	Area (%)	Area (Km^2)
Water requirement	0.33	Very good	< 960	6.8%	430.87
		Appropriate	960-1060	11.1%	699.40
		Average	1060-1160	3818.3%	3818.3
		Weak	> 1160	1335.1%	1335.1
Effective rainfall	0.28	Very good	> 26	11.2%	704.16
		Appropriate	21-26	13%	818.71
		Average	16-21	58.8%	3696.33
		Weak	< 16	16.9%	1064.55
Evapotranspiration	0.053	Very good	< 950	7.8%	494.28
		Appropriate	950-1050	8.6%	454.42
		Average	1050-1150	43.7%	2746.32
		Weak	> 1150	39.7%	2497.73
Soil type	0.19	Very good	alluvial plains	23%	1451.5
		Appropriate	Plateau	61.3%	3858.1
		Average	Fan-shaped debris	13.2%	832
		Weak	Mountain	2.2%	142.13
Rainfall	0.086	Very good	> 300	30%	1823.18
		Appropriate	200-300	58.9%	3763.93
		Average	100-200	9.8%	613.74
		Weak	< 100	1.3%	82.91
Temperature	0.040	Very good	18-25	6.28%	394.91
		Appropriate	15-18	67.76%	4255.62
		Average	10-15	23.04%	1447.19
		Weak	< 10	2.89%	182.044
Topography	0.009	Good	1300-2300	90.5%	5691.52
		Average	< 1300	5.4%	344.39
		Inappropriate	> 2300	4.1%	247.82
Slope	0.012	Very good	< 4´	67.4%	4240
		Appropriate	4-8´	10.1%	636.16
		Average	8-12´	3.5%	220.74
		Weak	> 12´	18.8%	1186.65

2-9). Results showed that the region had no soil limitation for agricultural practices and only in mountain areas (2.2%) the soil quality was poor. 84.3% of the area had sedimentary and alluvial terrace soils and also floodplain which were suitable for sugar beet planting. As pointed out before, the amount of annual rainfall is less than 300 mm in this area, therefore water requirement was considered as the main factor in sugar beet planting. Table 11 shows variable weighing, coverage percentage and their area in ranking scale through Analytical Hierarchy Process (AHP) and by using Expert Choice software. In this Table, each layer weight was listed based on experts' viewpoint. Layer weighing was performed so that factors with high importance in sugar beet planting had more weight in suitable area determination. This means that each layer had an important role in final zoning and the total sum of all weights was equal to one. For example, IWR and topography layer which received 0.33 and 0.009 weight, respectively, had the highest and the lowest influence on suitable area zoning for sugar beet planting (Table 11). These data were prepared based on expert's viewpoint and questionnaire forms.

Final map preparation

Data analysis includes environmental factors breakup into details and their combination in a way that an analyzer can understand the suitability or limitation of each land for its usage. Analysis of geographical information system data has an essential role in presenting a variety of applicable models and without this, large volume of geographical information and the problem of simultaneous analysis of effective parameters, make environmental programming difficult. In this study, after providing initial data including meteorological data, natural resources maps, etc., they were imported as a numerical data into GIS remote sensing and thematic maps of the study area were produced. Using Expert Choice software, weighing was performed based on climate and environmental characteristics and the final map (Figure 11) indicating suitable area for sugar beet planting was developed.

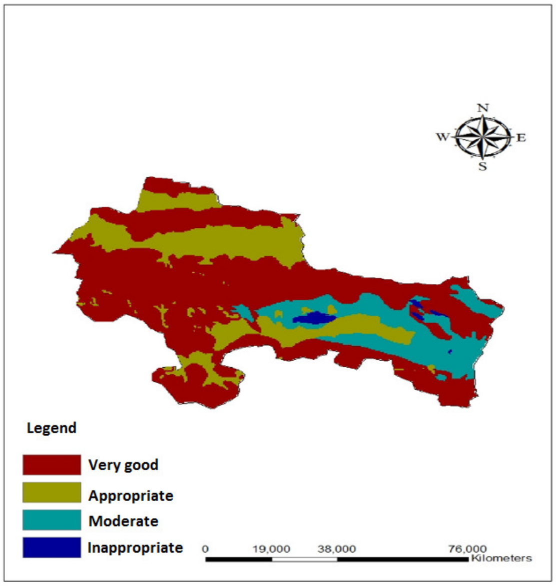

Figure 11. Final map showing suitable area for sugar beet planting

Table 12. Region area status for sugar beet planting using Expert choice software

Group	Suitability rate	Region area (%)	Area (Km^2)
A	Very good	59.61	3745.82
B	Appropriate	19.78	1243.14
C	Average	15.88	998.32
D	Inappropriate	4.71	296.29

Conclusion

According to Table 2 and Figure 3, 1300-2300 m altitude levels covering 90.5% of area (5691.52 Km^2) had the highest plain area, followed by < 1300 m altitude with 5.4% (344.39 Km^2), and > 2300 m altitude with 4.1% area (247.72 Km^2). More than 67.4% (4240 Km^2) of the region's area had slope of 4% which is suitable for sugar beet planting (Table 2). Among the climate parameters, rainfall and temperature with 30% (1823.18 Km^2) and 38% (2391.5 Km^2) area coverage and very good suitability rate had the highest impact. However, water requirement with 6.8% (430.87 Km^2), effective rainfall with 11.2% (704.16 Km^2), and evapotranspiration with 7.8% (494.28 Km^2) and very good suitability rate had the least effect.

As Table 9 shows, plain range, alluvial plains and river plains with 23% area coverage are the best land types for sugar beet planting, and plateaus and upper layers, plateaus and soil hills, floodplains with 61.3% area coverage were also found to be appropriate for sugar beet planting.

Finally, according to Table 12, it is shown that 59.61% (3745.82) of the city area is proper for sugar beet planting which is located in the north and center of the city (Rokh plain and Kadkanoo and zavareh districts). According to the final map, 4.71% (296.29 Km^2) of the city area including mountains and foothills and 19.78% (1243.14 Km^2) including plains were not proper for sugar beet planting.

References

Alijani B, Kaviani MR. The Fundamentals of Climatology. Samt.1992. (In Persian)

Alizadeh A, Kamali Gh A,Mortazavi A. Net irrigation requirement of crops and orchards of Iran, IRIMO, 2003. (in Persian)

Baily HP. Agriculture in Simi-Arid Environmental. Ecological Studies 34. Edited by: A.E.Hall, G.H. Cannel and H.W. Lowton, 1979.

Buzanov IP. Biology and sugar beet breeding. Kolos. Moskva. 1968.

Drachovska H. Sugar beet physiology. Csav, Praha, 1959.

Draycott A. Philip, Sugar Beet, Blackwell Publishing Ltd, 2006.

Dustin IJ. Effective rainfall in irrigated agriculture. Tehran University Press, 1985.

Farajzadeh M, Tkalubighesh A. Agro climatic zoning of hamedan province, using Geographic Information System (GIS). Journal of Geographical Research, 2001; 14: 63-105. (in Persian)

Fiedler J, Technology of sugar beet production. *SZN*, praha, 1975.

Havlicek J, Vivo pocasi N,vysledky. The effect of weather on crop production. Studijni informace, Ovitz praha, 1985.

Hershfield DM. Effective Rainfall and Irrigation Water Requirements; Journal of Irrigation and Drainage Engineering, ASCE 90: IR2, 1964; 3920: 33-47.

Hu Cheng J. Agriculture and Climate, translated by Alizadeh, A. and kuchaki, A, Ferdowsi University of Mashhad. 1978. (in Persian)

Kenny GJ, Warrick RA, Campbell BD, Sims GC, Camilleri M, Jamieson PD, Mitchell ND, McPherson HG, Salinger MJ. Investigating Climate Change Impacts and Thresholds: An Application of the CLIMPACTS Integrated Assessment Model for New Zealand Agriculture, Climate change. 2000; 46(1-2): 91-113

Khorasan Razavi Meteorological Organization, Synoptic stations weather data.

Kuchaki A, khazanedari L. Climate and Agriculture Geography, Geographical Research Quarterly, 1997; 45: 56-71. (in Persian)

Kuchaki A, Dehghanian S, Kolahi A (translation), Author: David G, Introduction to the Geography of Agriculture, Ferdowsi University of Mashhad, 1997. (in Persian)

Kucheki.A, Nasiri M, Agricultural Ecology, Jahad daneshgahi press, Mashhad,1996. (in Persian)

Kudrna k. Agricultural systems. SZN, Praha, 1979.

Kurpelova M,Culic J, Coufal L. Agro climatic condition of CSSR, Hydrometeor logic ustav, priroda, Bratislava, 1975.

Makhdoom M. Infrastructure and land logistics. Tehran University Press.1995. (in Persian)

National Geographical Organization. Iran topographic maps scale 1: 250,000

Nouri M. Agroclimatology of Dehloran region with emphasis on the effects of heat and rainfall on sugar beet cultivation, M.Sc. Thesis, Shahid Beheshti University, Tehran.2004. (in Persian)

Nuhi k. Foundations of Agricultural Meteorology, Publication of Meteorology. 1993. (in Persian).

Ogrosky HO, Mackus V. Hydrology of Agricultural lands; sec. 21 In Hand book Heydrology by V.T. chow; New York. McGraw. 1964.

Peter J. Weather and crop yield, Translated by: Kafi,M,Ganjali A, Nezami A, Shariatmadar F. Jihad Daneshgahi Mashhad publication. 2000. (in Persian)

Soil and Water Research Institute. Iran lands use Maps, Scale1: 250000.

Stehlk V. Biology of the species, varieties and forms of beets of the beta L genus with respect to large– scale production, Academia, praha, 1982.

Torbat Haydariea Sugar beet Factory, Cultivate Unit. 2008. (in Persian).