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Climate modeling and zoning for autumn sugar beet cultivation

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ABSTRACT

This study was conducted to evaluate the potential of suitable sites for autumn sowing of sugar beet in Ardabil. In this study, to evaluate agricultural climate autumn sugar beet cultivation in the province of Ardabil daily temperature data were used in a 10-year period. To calculate the degree of active days, and deviation from optimal thermal gradient agro-climate analysis methods are applied. In this study, the synoptic meteorological stations daily, monthly and annual Ardabil Province of Iran Meteorological Organization received. The research is a descriptive statistic and data were analyzed using phenology indices growth day degree (GDD) based on the temperature threshold in the area of climate phenological calendar beet crops harvested in late November and it is early July. The conclusions showed that prone areas for the cultivation of autumn sugar beet during the year include the northern and northeastern regions of the province. The region according to the characteristics of their environment and living conditions for the cultivation of autumn sugar beet plants are suitable, while other regions such as central, southern, East province are not suitable for cultivation.

1. Introduction

Sugar beet one of the major industrial plants, in addition to primary production, one of the basic needs of society, is another valuable byproduct of the sugar produced. Rapid population growth in the world and the growing need for food and efficient use of agricultural land requires calls for the potential and capabilities with emphasis on areas known climatic elements. Swift et al. (1979) in a research for the impact of climate on the sugar beet crops in West Montana showed that since middle of October until September, there is a close relationship between the average daily temperature records & beet crops. Whereupon every change of the degree causes almost one ton difference in the crops per annum. The highest average temperature causes the lowest percent of sucrose. Ulrich (1952) in research on the impact of weather on sugar beet grown under standard conditions examined at 17 locations sugar beet growing regions of the United States. He achieved that there is the unit of the sugar in the beet which have grown under the standard conditions less than the local beet. Ohki and Ulrich (1973) in a research about the growth of sugar beet under controlled climate conditions; during the night temperature, achieved that plants grown better in this condition. The density of the sucrose increased when the night temperature decreased. The maximum density of sucrose was in 2 °C and the maximum crops of sucrose took place during the 17th week. Petkeviciene (2009) in a study on the impact of climatic factors examined in the initial sugar beet planting time and came to the conclusion that when the average daily temperature for three days (10 °C) and soil moisture at planting depth of 16 to 3 and root yield of 4.7 tons per hectare production rate decreases. Poulsen et al. (2007) in a study on water consumption for sugar beet crop and predict product performance under changing weather conditions in North Africa discussed and came to the conclusion that seasonal changes in weather conditions will increase evaporation and transpiration and reduces the yield of sugar beet.

Al-Sayed et al. (2012) in a study on the effects of harvest date on the yield and quality of sugar beet studied and concluded that no significant difference between the sugar beet variety than soluble solids, sodium, and sugar-amino N is lost. Jones et al. (2003) in a study on the impact of future climate productivity in sugar beet (*Beta vulgaris L.*) in Europe with a general circulation model (GCM) concluded that climate change increases the

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performance in northern Europe from about 1 / T per hectare and the amount of sugar similar in northern France, Belgium and West Poland, for the period 2021- 2050. This research conducted for the zoning and the introduction of suitable areas for autumn sowing of sugar beet in Ardabil

2. Materials and methods

In this research daily minimum and maximum temperature parameters related to the period 2001-2011 has been used from synoptic station of Ardabil as shown in Table 1 and Fig. 1.

Table 1: Characteristics of the weather station Ardabil Province

Station name	Type of station	Longitude	latitude	Above sea level	Statistical period
Ardabil	The main synoptic	48-17-02	38-13-51	1365	2000-2009
Pars abad	The main synoptic	47-55-18	39-39-08	75	2000-2009
Khalkhal	The main synoptic	48-30-59	37-38-08	1806	2000-2009
Meshkin shahr	synoptic	47-40-02	38-23-55	1485	2000-2009

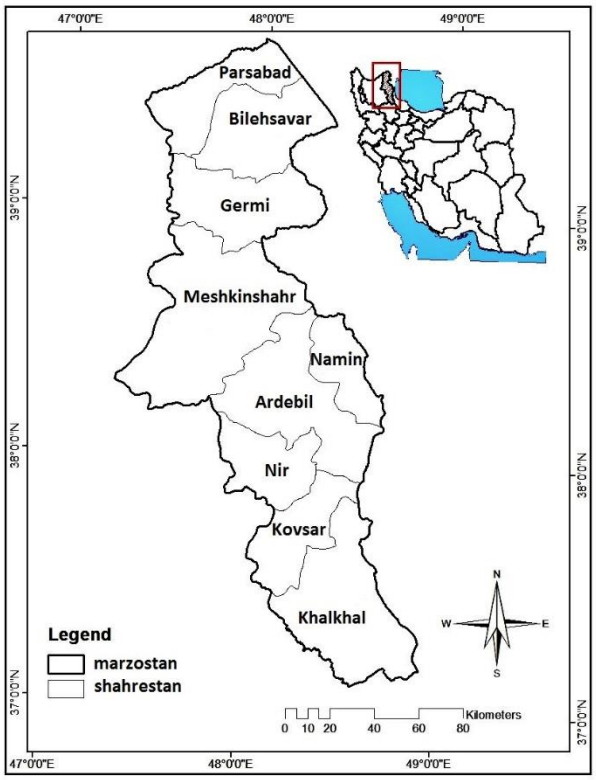

Fig. 1: Location of this study

3. Thermal gradient method

To evaluate the studied area in terms of temperature in relation to the deviation from optimal conditions at different altitudes or optimal time based on height we should make sure that the temperature at ground levels without measuring station is used. To obtain this temperature linear regression method was used.

Using linear regression, coefficients of variation of temperature with altitude for months and the whole year are calculated. To calculate the equivalent line the following equation is used:

$$Y = ax + b$$

where,
y is used for the expected amount (the dependent variable),
x is the most important variable upon which accomplish the prediction for (independent variable)
a is a constant as the intercept read and
b is thermal gradient slope of the line that displays fall of the heat with height. To calculate a and b the following equations are used:

$$a = \frac{\sum(y)\sum(X^2) - \sum(x)\sum(xy)}{N\sum X^2 - (\sum(x))} \quad (1)$$

$$b = \frac{N\sum XY - (\sum X)(\sum Y)}{N\sum X^2 - (\sum X^2)} \quad (2)$$

The first table of elements solidarity for selected locations and times established for the study, which will be mentioned monthly and annually for reaching the above conclusion.

4. The method of deviation from optimal conditions

It is very important to determine the optimal time in each area, according to meteorological stations and daily temperature growth. There are 3 phenological stages for sugar beet and each stage has an optimum temperature that the maximum growth is in the optimum temperature. There can be specified by identifying this items for each phenological stages and the average daily temperature monitoring of minimum and maximum daily: in fact time can be optimized at different times in particular months of the year revealed when the slightest deviation from optimal conditions, be regarded as the optimum time. The procedure for obtaining optimum different times; first item or optimal temperature is determined and then considering the average daily statistics. For this purpose, each month divided into three different decades and then calculates the average of each of the decades; totally an average of 36 decades is calculated for each station. Next, the results of optimum calculated and thus the deviation from the optimal conditions achieve for high levels and its results is determined in a table.

4.1. The thermal coefficient of active or total degree days

Most biological changes such as the growth of plants and some hydrological phenomena is the power of function of ambient temperature. For this purpose the index of degree - day used as thermal needs. Each process has a certain temperature threshold and the amount of growth is activated depends on the number of degree - day above the

threshold. If the number of degree - days is zero or negative growth will have no effect on that day. Each plant to grow well in a region requires a certain degree - days that the area should provide it during the growing season. Otherwise, even if there is a water plant should not be recommended for planting in agricultural projects. The beginner course is the longest growing season in each region where the number of degree - days were required plant will be provided. To determine the need for effective thermal plants is used by a total temperature. It summed up the work in effective temperature is the temperature above zero. The temperature depends on the type of plant. 4°C for sugar beet is calculated by the following relationship:

$$H_U = \sum_i^n \left[\frac{T_M+T_m}{2} - T_t\right] \quad (3)$$

where,
H_U- Thermal units (degree - days) which were collected during the day
T_M- Maximum daily temperature
T_m- Daily minimum temperature
T_t- Basic temperature
N-Number of days in a specified time

The sum of positive temperatures has given that since the beginning of awakening of the harvest and we intend to cultivate sugar beet to 2900 degree - day. So this method is used to calculate degree days. In this study, the most common way is used to estimate the thermal units' active method. To summarize temperature there are two main methods that are effective and the total sum is active in the research of active use.

4.2. Total degree days live

To summarize temperature, all daily temperature values (without subtracting the base temperature) during the active growing season will be gathered together. The relationship is calculated as follows:

$$\frac{T_{Min}+T_{Max}}{2} \quad if\ the \quad \frac{T_{Min}+T_{Max}}{2} \geqq T_t \quad (4)$$

where,
t_{min}, t_{max} are minimum daily temperature and daily maximum temperature
T_t is a biological relationship.

Live temperatures in the way that used in this research is the sum of daily temperatures used with positive values. But, only for the days when the average temperature of the verge of ecological or biological effects is zero, all values greater than 4 ° C will be calculated and all the calculated values shall not be less than 4 ° C.

5. Results and discussion

5.1. Ardabil climate classification

Ardabil province due to the complexity of natural conditions, geological and geomorphological diversity and the variety of factors affecting the climate of the region has various climates. This climatic variation based on the bioclimatic map Ghosn method is as follows:

1. Semi-arid moderate temperate climates, includes the areas of the half eastern and northern plains, plateaus post Moghan, long and dry land, hills and foothills of the border of Iran and Azerbaijan. The main part of the annual precipitation was in the early autumn and spring and low rainfall in summer and it is a bit that leads to drought in some years; hot summers and cold winter mainly. Snow and rain in winter is observed in the early spring and part of it spent on agriculture. The number of months of the dry season in the region of three or four months. The maximum temperature in this area is 40 c & the minimum is 8 °C. Moghan height above the sea level is 100 meters and an average rainfall is 260 mm per year.
2. Steppe climate cold: this zone encompasses areas of West and South-West Province. This climate is, included foothills and the hills between Sabalan and Sareyn clause. Distribution of rainfall in the rainy seasons have been pretty good and generally occur in some seasons seem to have enough dry land for farming, and approximately the growth period of plants. Plant available water is located in the summer. There are more or less rains than other seasons, freezing winters area and about 5-4 months of the year is dry.
3. Humid cold weather: including high mountains, especially in the West of Ardabil city. Mount Sabalan was covered with snow in most seasons. There is foggy and humid climate without dry season.
4. According to the weather division of the province, it has three kinds of weather as follows:
5. Semi-humid cold climate; this region province includes Bagher va Talesh height, Ardabil plain and plateau around the Khalkhal as moderate as Mediterranean climate based on the Ghosn method. In this area, rainfall and relative humidity is higher in the warm months with precipitation.
6. Cold semi-arid climate; Mount Sabalan that surrounded Sabalan like a belt have this type of climate. Maximum rainfall in Ardabil city, which is an average of 350 mm. This climate includes the large part of the Ardabil, Meshkin shahr, Garmi and Khalkhals. The distribution of the rainfall is in the cold season and rainfall decreases in the warm weather. In the summer rainfall in this area is rare.
7. Wet and cold regions; includes, volcanic mountain Sabalan.

The common feature of the region is cold weather despite the variation of the climate, even there can be seem frigid 50 days of year averagely, in the

northern part of the province that is plain & because of that it is moderate and forest increases in areas with more than 2000 meters up to 170 days per year. Ardabil climate type map can be seen in Fig. 2.

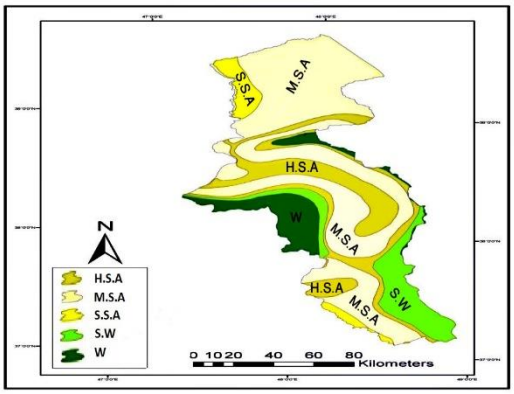

Fig. 2: Climate type map Ardabil province based on Ghosn

In this section, by using the empirical formulas, we do the classification of climatic stations by using Hyetograph, Demarton, Emberger, Ivanov and Kaimi.

5.2. Demarton's classification

In this method for determining climate empirical relationship (I=P/(T+10) presented between the temperature and precipitation values. In which P average annual rainfall in millimeters, T the average temperature annually in c and I will dryness index. Based on the values of I distinguished six types of climate (Table 2).

Table 2: A variety of climate types based on Demarton at selected stations

Station name	semi-arid	Mediterranean	Type of climate
	10-19.9	20-24.9	
Ardabil	17.8		semi-arid
Khalkhal		22.6	Mediterranean
Pars abad	15.3		semi-arid
Meshkin shahr	18.8		semi-arid

5.3. Emberger's classification

In emberger classification is used from the following factors for climate determining the averages of the minimum temperature in degree Kelvin in the hottest months and the average of the rainfall annually in (mm). Emberger based on his experience provided a climagram that of two orthogonal axises.

Emberger classification according to climatic conditions in selected stations of the province is organized as below. Ardabil cold semi-arid, temperate Pars abad half dry, half wet and cold, Khalkhal and Meshkin shahr is cold semi-arid.

5.4. Ivanov's classification

Ivanov, provided a formula, for the climate classification, where the air temperature and relative humidity are used. Thus, it is necessary to achieve the annual evaporate with the sum up the evaporation of each month by the following equation; then he calculated the corresponding coefficient in the name of climate index or known coefficient Ivanov moisture. Table 3 shows Ivanov water coefficients range of climate types and kinds at selected stations.

$$E = 0.0018(2.5 + T_2)(100 - r) \quad (5)$$

Ivanov coefficient equal to E / P = I is
I= Ivanov moisture factor
R= The average monthly relative humidity in%
P= The annual rainfall in cm
T= Average monthly temperature in Celsius
E= Monthly evaporation in cm
E_ε = Total evaporation months of the year in cm

5.5. Karimi's classification

This index is an adaptation from Demarton method. Karimi method is emphasized to 3 index (heat, cold and moisture) and noted that the moisture index for dry condition and heat the heat index determines the warm condition in the warm months of a year and cold index determines the cold intensity in the winter. Karimi method comes from this relevance I=5T/P. Classification results in Table 4 shows Karimi METHOD for selected stations in the province.

Table 3: Pose a variety of climatic and humidity coefficients based on the selected stations Ivanov

Coefficients	0.99> i > 0.6	0.29 > i > 0.13	Type of climate
Type of climate	Forest steppe	Wilderness	
Ardabil	0.67		Forest steppe
Khalkhal	0.65		Forest steppe
Pars abad		0.20	Wilderness
Meshkin shahr	0.68		Forest steppe

Table 4: A variety of climate types based on Karimi at selected stations

Coefficients	1<i<3	3<i<6	Type of climate
Type of climate	Sub-humid	semi-arid	
Ardabil		4.40	Forest steppe
Khalkhal	1.20		Forest steppe
Pars abad		4.80	Wilderness
Meshkin shahr		3.67	Forest steppe

5.6. Hyetograph charts

Hyetograph graph is a graph similar to Figure Theront White which the monthly changes of the air temperature compared with the changes monthly rainfall during the year; the average monthly in this method the average monthly temperature & rainfall is drawn on a vertical axis in which; the horizontal axis due to months & left vertical axis due to the average monthly temperature in C and monthly rainfall is assigned on the right vertical axis in (mm).

Hyetograph charts are provided to identify dry months in the study of climate stations. The basis of this diagram is based on the relationship between temperature and monthly heat temperature. Sections on the basis of the above variables into two categories: dry (lack of water) and wet excess water are divided.

5.7. Ardabil station's Hyetograph diagram

According to the chart, months when the temperature is under the curve, the months of June to October is the dry period. Humid period, this stations in the cold months is since October to middle of spring. So Ardabil station, since October to middle of spring has humid & cold weather & since late spring to late summer has hot and dry weather. As it is observed humid months are longer and it is includes almost all months. Hyetograph graph of Ardabil station is shown in Fig. 3.

5.8. Hyetograph graph Pars abad

As can be seen in Pars abad figure, since the middle of May to the middle of September rainfall's curve is below the temperature's curve. Thus this is considered as dry months. Temperature curve has increased since May, reaching its peak in the month of August. Since mid-September decreases again. Humid period is from October to May. The late spring (May) and early autumn (October) is hot and dry conditions. Hyetograph graphs of Pars abad and Khalhal are shown in Fig. 4 and Fig. 5.

5.9. Hyetograph graph of Meshkin shahr

As can be seen in Meshkin shahr figure, since the middle of September rainfall's curve is below the temperature's curve; thus this is considered as dry months. Hyetograph graph of Meshkin shahr is shown in Fig. 6.

6. Results phenology

The use of temperature coefficient in agricultural issues and agricultural calendar in different areas is important. According to conclusion, Moghan, Pars abad has less departure from the optimum conditions in all of the phase & it means that it has the good situation for sugar beet cultivation.

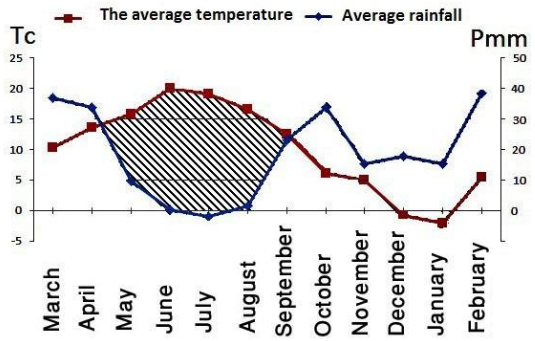

Fig. 3: Hyetograph charts synoptic stations Ardabil (1985-2005)

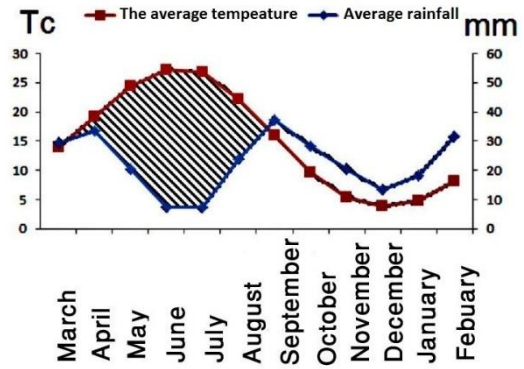

Fig. 4: Hyetograph graph Pars abad synoptic station (1985-2005)

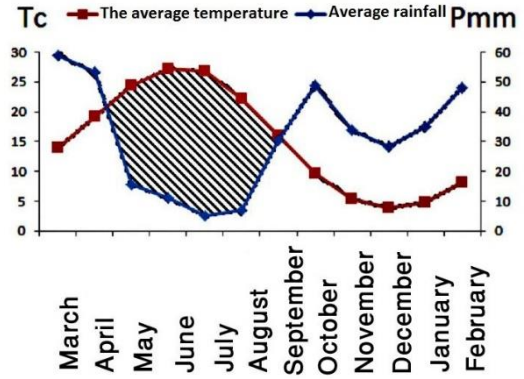

Fig. 5: Hyetograph charts synoptic stations khalkhal (1985-2005)

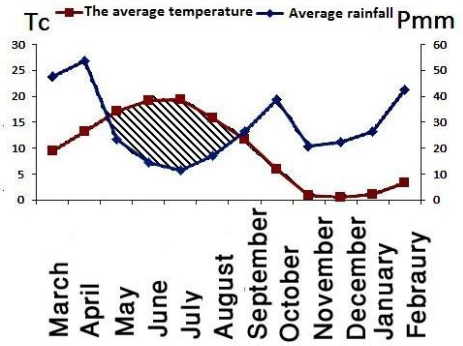

Fig. 6: Hyetograph graph climatological stations Meshkin shahr (1985-2005)

6.1. The optimal time based on active degree method

Another method of agricultural climate on the last event on the threshold of the minimum sugar beet in each phenological stage, the temperature active was used in this study. Total daily temperatures used with positive values but only for the days when the average temperature in the biological or physiological activity is zero. In this study, the basis for calculating the thermal coefficients is active, both based on sugar beet minimum thresholds in each phenological stage and the zero °C. Table 5 shows thermal thresholds sugar beet plants in different phenological stages.

Table 5: shows the temperature threshold sugar beet phenological stages

Phenological stages	Lowest ° C	The optimum temperature
Germinate	-5 To -7	20-25
Youth (developmental)	-1 To -2	27-30
Full ripening	-	16-20

One of the climatic agricultural methods to determine the optimized time for the minimum phenological phase of sugar beet is the daily temperature that has been used in this research. The sum of daily temperatures is positive, but only when the temperature exceeds the normal biological limit. In this study, the active thermic factors are colculated in two ways: based on the minimum threshold of the sugar beet plant in every phenological phase & based on the 0 c as the temperature. Table 4 shows the minimum thermic thresholds of the plant in phenological phases. To obtain a complete history of phenological stages of sugar beet crop at germination stage 125, in the primary stage (growth) in 1000, it reaches the final stage of full sugar beet 2900 thermal units. According to the Table 6 the earliest date and date budding young (development) and arriving at Pars abad station is full of sugar beet, respectively and in the rest of the stations due to harsh winter conditions has not been possible fall planting sugar beet.

Table 6: Completion date phenological stages of sugar in the selected stations

Station	Height	On the eve of the event at least	Germinate date	Youth (developmental) date	Full ripening date
Pars abad	75	26 October	15 November	16 April	28 June
Ardabil	1365	No Preference culture	No Preference culture	No Preference culture	No Preference culture
Meshkin shahr	1485	No Preference culture	No Preference culture	No Preference culture	No Preference culture
Khalkhal	1806	No Preference culture	No Preference culture	No Preference culture	No Preference culture

6.2. Deviation from optimal conditions

Three phenological stages have been studied in the sugar beet; each stage has an optimum temperature that the maximum growth takes place in this temperature. To study the sugar beet plant species, according to a survey conducted early varieties of this plant are suitable for intermediate products. Table 7 shows the deviation from the optimum conditions for each sugar beet plant phenological stage based on the average daily temperature at selected stations according to the results obtained during seed germination, cultivation of sugar beet, Pars abad station has a deviation for Pars abad station is less than optimal conditions & more than other stations. In the juvenile stage (developmental) Pars abad station deviations are less than other stations. Since, all stages of Pars abad station has less deviation than optimal condition. This station has the optimal conditions for the cultivation of sugar beet.

Table 7: To determine deviations from optimal conditions phenological stages of sugar beet in selected stations

Station	Germination		Youth (developmental)		Full ripening		Total departures
	Optimized	Standard deviation	Optimized	Standard deviation	Optimized	Standard deviation	
Ardabil	0	0	0	0	0	0	0
Pars abad	20-25	-6.85	27-30	-15.86	16.20	-9.85	-32.56
Meshkin shahr	0	0	0	0	0	0	0
Khalkhal	0	0	0	0	0	0	0

6.3. The deviation from the optimum conditions based on height

6.3.1. Thermal gradient

In order to evaluate the deviation from optimal conditions at different altitudes or optimum location based on height on height, at first, linear regression was used for the coefficient of variation for month & years. To reach this results and calculate correlation between elements and time periods selected stations have been established; the results are summarized in Table 8 are listed on the annual correlation of selected stations.

6.3.2. Areas suitable for cultivation of sugar beet

Based on the analysis of climatic conditions for the cultivation of sugar beet through the methods listed favorable and unfavorable areas for the

cultivation of sugar beet (autumn) at time of the study follows the Moore area. The best time for planting sugar beet is in early November in Ardabil. According to the map shapes (2) favorable areas for sugar beet cultivation in the north and north-eastern areas of the province during the year involved; the region according to the characteristics of their environment and living conditions for the cultivation of sugar beet plants are suitable; while other regions such as central, southern, East province are not suitable for cultivation (Fig 7).

Table 8: The annual correlation of Ardabil province in terms of phenological stations (thermal gradient)

Coefficients	Germination	Youth (developmental)	Full ripening of sugar beet
B	-0.0087	-0.0006	0.001
A	27.78	15.95	-0.28
R	0.29	0.0015	0.41

7. Conclusion

The environment that we live in, is a set of various factors, such as climatic phenomenon related to atmospheric condition. One of the determinative factors for farming is the climate. There is a close relation between the farming activities & natural factors, climate & environment situations. At the top natural factors affecting agricultural activities are weather conditions. The elements of each alone, or a combination of several elements affect agriculture. Iran todays provides a good situation for producing species strategic agricultural crops.

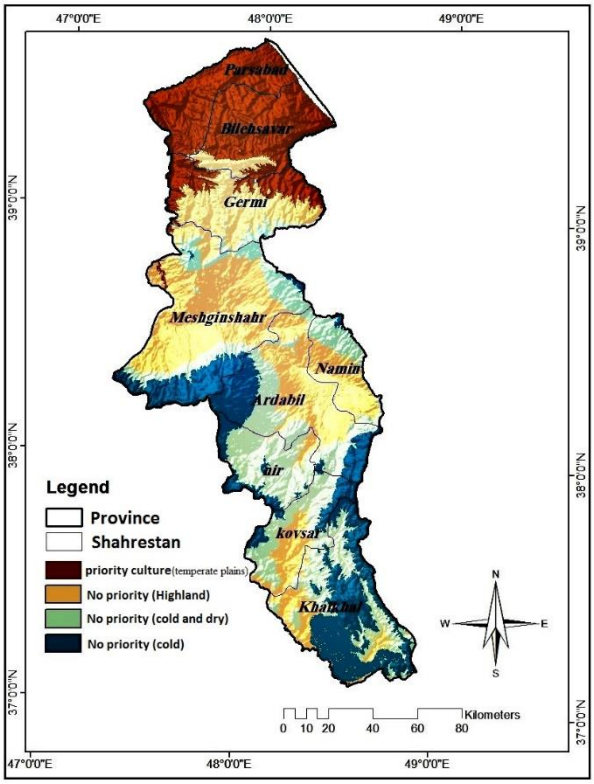

Fig. 7: The total deviation from the optimum conditions for sugar beet autumn due to climate factors

Optimum location suitable for planting sugar beet autumn in the northern regions with high potential. In fact Pars abad station has less deviation from optimal conditions and therefore favorable conditions for sugar beet cultivation are compared to other stations.

The final phenological stages of sugar beet at Pars abad station occurs earlier in comparison to other station. The cropping calendar based on agro climatic analysis for sugar beet cultivation is in early November at Pars abad station. The calendar for sugar-beet harvest to Pars abad station is by early July. Based on the analysis, thermal gradient and deviation from optimal conditions for Pars abad station stands in better conditions for planting compared to other stations. It is important to determine the time of cultivation and commercial production prone areas for the cultivation of sugar beet during the year in the northern and northeastern regions of the province; this region according to the characteristics of their environment and living conditions for the cultivation of sugar beet plants are suitable while other regions such as central, southern, East province are not suitable for cultivation.

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