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Disclosing the effect of climatic factors on the growth and yield of sugar beet in province Azerbaijan East

Amir Hossein Halabian[1], Alireza Dehghanpoor Farashah[1], Mohsen Azizi*[2], Jafar Ganjali[1]

[1] *Department of Geography, Payam Noor University, Tehran, Iran*

[3] *Geography, Payam Noor University, Tehran, Iran*

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Abstract

Climatic condition, is one of the determining factors of crop type which could be cultivated and developed in an area. The amount of sunlight, heat and rainfall and their incidence type are major factors in this determination. In this study, daily temperature data over a period of 10 years were used to evaluate the agricultural climate of sugar beet cultivation in East-Azerbaijan province. Calculation and agro-climatic analysis was performed making use of Papadakis method, active days degree index, thermal gradient and deviation from optimal conditions methods. In this study, data of the synoptic meteorological stations in East-Azarbaijan (daily and monthly and annual reports) were received from National Meteorological Organization.This research is descriptive statistic. Data analysis is performed using phenological index (GDD) and Papadakis method via GIS software. The results show that based on analysis of thermal gradients and deviations from optimal conditions at different heights, Ahar station, amongst all selected stations, has more suitable conditions for cultivation. Based on the temperature thresholds of phenological stages of sugar beet, climatic calendar would be in form of sugar beet sowing season in early April and crop harvest season in mid-September to early October. Evaluation of agro-climate of the area, based on Papadakis thresholds, show that northern and central parts of the province have similar conditions in terms of winter and summer cultivation, which means oat in winter type and cotton in summer type. Southern and eastern parts of the province have identical condition, as well; meaning corn in summer type and wheat in winter type.

***Corresponding Author:** Mohsen Azizi ✉ Azizimohsen3@gmail.com

Introduction

While modelling sugar beet technological processes, a focus should be placed on agro climatic parameters, soil physical maturity, crop growth stages, and physiological needs (Romaneckas *et al.,* 2003).

When spring is early, sugar beet is sown earlier, which provides a longer period of sunshine interception for crops (Petkeviciene, 2002).

but does not always mean an early beginning of vegetation. The lowest base air temperature at the sugar beet field was recorded to be +3–5°C (Durr & Boiffin, 1995; Siddique *et al.*, 2002; Mavi & Tupper, 2004).

Sugar beet sowing time also depends on the cultivation technology chosen (Romaneckas etal., 2003) and is influenced by soil moisture. Some authors indicate that soil surface can be loosened when the soil moisture is 20.0–25.0% (Uhlir *et al.*,2006).

For most plants, phenological development is strongly related to the. accumulation of heat or temperature units above a threshold or base temperature below which little growth occurs. This lower threshold temperature varies with plant species (Ash,1999; Bellin *et al.*, 2007).

Growing degree days have proven useful for scientists, crop consultants, and producers who use them to predict plant development rate and growth stage (Lu & Saylan, 2001; Derscheid & Lytle, 2002).

Sugar beets emerge the fastest when the soil moisture in the seedbed is 20–23 %, and air and soil temperature ranges between 15–25°C (Khan, 1992; Copeland *et al.*, 2001; Sroller I. & Svachula V. 1990; Spaar *et al.*, 2004).

In Europe, sugar beets are sown from March 20 to May 1 (Sugar beet, 2004).

Depending on the geographical region of sugar beet cultivation, the yield potential can range from 11–40 % (Pidgeon *et al.*, 2001).

A delay in sowing by on average one day results in a root yield loss of 300 kg ha-1, and 50 kg ha-1 of white sugar (Abracham *et al.* 1987; Kolbe & Petzold, 2002).

In Lithuania, during the period 1934–1975, the early-sown sugar beet crops produced 22.3–8.1% of bolters, which deteriorated technological crop properties (Lazauskas, 1998).

Root biomass potential of sugar beet varieties ranged from 35 t ha-1 [until 1989) to 50 t ha-1 (during 1991–2000) (Kaunas, 1998; Petkeviciene, 2008).

Early sown sugar beets always have enough time to mature, therefore their technological properties are better (Povilaitis & Grigiene, 1995).

Sugar beet varietal disease resistance increases their biopotential (Petkeviciene, 2002; Petkeviciene & Kaunas, 2004; Gaurilcikiene *et al.*, 2006).

Sugar beet biomass potential is influenced by crop stand density or seed germination (Siuliauskiene *et al.*, 2005).

This study was conducted to evaluate the agro-climate of cultivation of sugar beet in Azerbaijan East province

Materials and methods

Data gathering

In this study, the mini and maxi daily temperature during the period of 2001-2011 and the average monthly temperature data over the period of 1986-2011 from synoptic stations of East-Azerbaijan province have been used. (East Azerbaijan Province Meteorological Bureau, 1986-2011) Table (1).

Table 1. Characteristic of East-Azerbaijan Province Meteorological Stations.

Altitude, m	Longitude		Latitude		Station
minute	degree	minute	degree	minute	
06	Tabriz	17	38	06	Tabriz
26	Ahar	04	38	26	Ahar
15	Haris	06	38	15	Haris
09	Malekan	05	37	09	Malekan

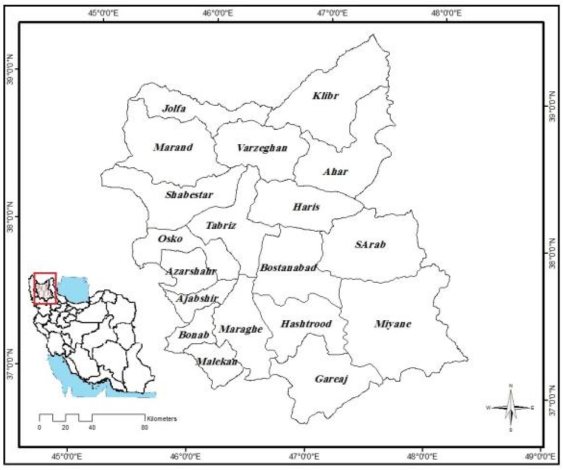

Fig. 1. Study area.

1- Papadakis classification method

In order to classify the agricultural climate of studied area using Papadakis method, data of selected stations in the study area throughout the statistical period of 26-year (1986-2011) was used; including the average minimum and maximum monthly temperature, the absolute maximum and minimum monthly temperatures, monthly and annual average temperature and precipitation.

To evaluate this method, first, based on thermal thresholds defined in related tables, winter and summer types were determined for each station. Then, having the winter and summer conditions, temperature regime for each station was extracted from the appropriate table.To determine the amount of humidity regime for each station, first, monthly potential evapotranspiration according to equation (1) are calculated. The simplest method for calculating evapotranspiration is a relation that is provided by Papadakis. This equation is as follows.

E=0.5625 (ema- emi-2) eee   Eq (1)

In this equation, emi-2 and ema are the saturation vapor pressure according to the maximum and minimum monthly temperatures, respectively, which could be obtained from Papadakis table. Papadakis constant is 0.5625. Then, Humidity Index (HI) is determined based on the ratio of

monthly and annual precipitation to potential evapotranspiration (R/E). In stations which have a humid period (R<E), leaching index (LN) was calculated in order to determine the humidity conditions of months. Months of a year were categorized based on the relationship between precipitation, evaporation, and water stored in the soil into three types (wet, dry, and middle) that can be obtained from the following equations:

R+WS<50% pet dry   Eq(2)

R+WS<500% middle pet   Eq(3)

R> PET wet   Eq(4)

In the above equations, precipitation, soil stored water and potential evapotranspiration are introduced with R, WS and pet, respectively. Leaching index is calculated according to equation (5) and equation (6):

middle period E- (ws+R)= Ln   Eq (5)

Ln =Σ(R-E) wet period   Eq (6)

Next, using the defined indices and thresholds, the type of humidity regime for each station is determined.

Details of the parameters used in this method with the climatic characteristics of various types of climate in selected stations with corresponding codes are presented in related table.

Table 2. Main climate groups in Papadakis method.

Humidity Regime	Thermal Regime	Main Groups
HU, Hu, MO, Mo, mo	EQ, Eq, TR, Tr, tr, Tt, tt	1 - Tropical
HU, Hu, MO, Mo, mo	TF, Tf, tf, An, an, aP, ap, aF	2- Tirafria
da, de, di, do	No limitation, with emphasis on humidity regime	3- Desert
HU, Hu, MO, Mo, mo	Ts, SU, Su	4 - Subtropical
St, Si, Mo, mo	PA, Pa, pa, TE, MA, Ma, ma, SU, Su	5- Pampin
ME, Me, me	No limitation, with emphasis on humidity regime	6- Mediterranean
HU, Hu	Mm, MA, Ma, ma, TE, Te, te, Pa, pa	7- Marine
HU, Hu, Mo	Co, Co, Co	8- Continental humid
St, Si, Mo, mo	Co, Co, Co, Po, Te, te	9- Steppe
Thermal regime governs	Po, Po, Fr, fr, AL, al	10- Polar

Table 3. Different types of Mediterranean and desert climate in Papadakis Method.

Humidity Regime	Thermal Regime	Climate Type
		6- Mediterranean
ME, Me	SU, SU	6-1. Subtropical
ME, Me	MA, Mm	6-2. Marine
ME	Ma	6-3. Marine Cold
ME, Me	Tr	6-4. Tropical
ME, Me	TE	6-5. Moderate
ME, Me	Te, te, Po, Pa	6-6. Moderate cold
ME, Me	Co, Co, Co	6-7. Continental
Me	SU, SU, Tr, tr, MA	6-8. Semi-arid subtropical
Me	Co, Co, Co, TE, Te, te	6-9. - Semiarid continental
		3- Arid
Da, de, di, do	EQ, TR, tr	3-1. Tropical hot
Da, de, di, do	TS, Su	3-2. Subtropical hot
Da, de, di, do	Eq, Tr, tr	3-3. Tropical cool
Da, de, di, do	SU, MA, Mm	3-4. Subtropical cool
Da, do	Tt, tt, TF, tf, An, an	3-5. Continental Antarctic
Da, de, di, do	Co, Co, Co, te	3-7- Continental
Da, de, di, do	PA, TE	3-8. Pampin
Da, de, di, do	Pa, pa	3-9. Patagoni

2- Thermal Gradient Method

In order to study the relationship of temperature of study area with deviation from optimal condition in different heights or time optimal conditions, it was necessary to use the thermal gradient to obtain the temperature of heights points where there was no station. To obtain the temperatures, the linear regression method was used.

Using linear regression, coefficients of variation of temperature with heights, were calculated for the months of the year and the whole year. Following equation was used to calculate the curve equation: (b +ax =y).

In this equation, (y) the expected value (dependent variable), (x) the most important variable which predictions will be based on that (the independent variable), (a) constant coefficient known as Show principle and (b) line slope or thermal gradient showing the thermal decrease with height.

Following equations are used to calculate a and b:

$$a=\frac{\sum(y)\sum(X^2)-\sum(x)\sum(xy)}{N\sum X^2-(\sum X)} \qquad \text{Eq (7)}$$

$$b=\frac{N\sum XY-(\sum X)(\sum Y)}{N\sum X^2-(\sum X^2)} \qquad \text{Eq (8)}$$

To achieve results and calculate the above equations, first, table of correlation variables for selected stations and time intervals was formed; that will be mentioned as the monthly and annual correlation variables of selected stations.

3- Method of deviation from the optimal conditions

Determination of the optimal time for each region, based on meteorology stations' data and daily temperature of crop growth is important. There are three phenological stages for sugar beet plant and each stage has an optimal temperature, at which the maximum growth rate occurs at this temperature. Identifying and determining the optimal point for each phenological stage and the mean daily temperature resulted from monitoring minimum and maximum daily temperatures; one can determine various optimal times, particularly months of a year, and actually, the time which has the least deviation from the optimal condition, would be considered as the optimal time. In this method, to obtain the optimal of different time intervals, optimal points or optimal temperatures were first determined and then, considering the average of daily data, deviations from the optimal conditions were calculated for 3 decades of each month. For this reason, first, each month was divided into three different decades, and then, the average of each decade was calculated, that in total, the averages of 36 decades are calculated for each station. Next, the deviations of the averages from the optimal points are calculated; consequently, the deviations from the optimal conditions are obtained for the above time intervals and the results are tabulated.

4- Method of thermal coefficient or total degrees of active days

Most biological changes such as the growth of plants and some hydrological phenomena are a function of the ambient temperature. For this purpose, the index of degree - days will be used as thermal need. Each process is activated from a certain temperature threshold, and the growth value depends on the number of degree - days more than this threshold. If the number of degree – days is zero or a negative value, that day would have no effect on growth. In order to grow in a specific area, each plant requires a certain number of degree-days that the area must be able to supply throughout the growth period. Otherwise, even if water is available in the area, the plant should not be recommended for planting in agricultural projects. Therefore, growth season in each area is defined as the longest continual period in which the number of degrees - days required to supply the plant is provided. To determine the thermal need of plants, method of the total of effective temperatures is implemented. The principle of this method is to calculate the total summation of effective temperatures, i.e. temperatures above the base zero biological zero of a plant. This temperature depends on the type of the plant. 4 ° C for sugar beet is calculated by the following equation.

$$H_U = \sum_i^n \left[\frac{T_M + T_m}{2} - T_t \right] \quad \text{Eq (9)}$$

H_U : Thermal unit (degree-days) accumulated in N days.

T_M : Maximum daily temperature

T_m : Minimum daily temperature

T_t : Base temperature

N: Number of days in a selected period

In order to cultivate sugar beets must positive total the temperature of 2900C° awakening to harvesting - arrives the degree-days. Therefore, in this study we have used the method of calculating degree-days. In this study, the active method, amongst the most common methods to estimate thermal units, is used. To calculate the summation of temperature, there are two main methods including effective total and active total, and active sum method is used in this study.

A – total of degrees of active days

To total up the temperature, the values of all daily temperatures (without subtracting the base temperature) and during the period of active growth, are added together.

Computational equation is as follows.

Eq (10)

$$\frac{TMin + Tmax}{2} \quad \text{If the} \quad \frac{TMin + TMax}{2} >= Tt$$

In this equation, tmin, tmax are the mini and maxi daily temperature, respectively, and Tt is a biological temperature.

In active temperatures method that has been used in this research, the total total of positive daily temperature is used; but only for the days when the average temperature is greater than the biological threshold or biological zero point. All values more than 5C° will be considered and values less than 5 C° will not.

Discussion

1- Phenology results

Application of thermal coefficients in agricultural problems and the regulation of agricultural calendars in different areas is of significance.

In spite of lack of the extensive phenological studies, using agricultural meteorological studies conducted by Quanta engineers with cooperation of Romanian consultants an applying their methods, active days degree and determination of length of phenological stages were studied according to various thresholds.

2- Optimal time, based on active days degree method

Another method to determine the optimal time for agricultural climate, based on the latest incidence of mini thresholds at each phenological stage of sugar beet, is active temperatures' method is that it is used in this study.

The total daily temperatures with positive values are used, but only for the days when the temperature is greater than the average of biological thresholds or zero point The physiological Activity.

In this research, the basis for calculating the thermal coefficients has two types: one based on a mini threshold of sugar beet plants at each stage, and the other is zero C° Celsius. Thermal thresholds of sugar in different phenological stages are illustrated in table 4.

Table 4. Temperature thresholds of sugar beet in phonological stages.

Desired temperature	Lowest degrees Celsius	Phonological stages
20-25	-5 to -7	germination
27-30	-1 to -2	growing
16-20	-	fully ripen

Meteorological Organization of Ardabil (2013)

Since plant species are highly dependent on temperature, the monitored daily mini temperature is used for phenology of the sugar beet plan. By specifying thresholds of phenological stages of sugar beet and accurate daily temperatures, completion date of each stage is calculated. For all stations, occurance date of mini threshold of sugar beet cultivation at 4C° is considered.

In order to obtain the completion date of phenological stages of sugar beet in germination stage 125, the juvenile stage (growth) 1000, fully ripen stage of sugar beet, 2900 thermal units is necessary. According to Table 5, the earliest date of germination and growth and ripening of sugar beet occurs in Ahar, Harris, Malekan and Tabriz stations, respectively.

Completion dates of phenological stages of sugar beet in selected stations are shown in Table 5.

Table 5. Completion date phenological stages of sugar beet.

Fully ripening date	Growth date	Germi-nation date	Minimum threshold incidence date	Altitude	Station
7 October	13 June	30 April	7 April	2142	Tabriz
6 September	2 June	9 April	26 March	1522	Ahar
17 September	6 June	12 April	29 March	1373	Haris
20 September	13 June	19 April	31 March	1883	Malekan

Completion date of each phenological stage is also considered a suitable method for determining the best time for sowing of sugar beet, based on its critical threshold. Obtained dates are consistent with their optimal time.

3- Deviation from optimal conditions

Three phenological stages have been considered in beet plant; each stage has an optimum temperature, in which, the maxi growth rate occurs._In order to study the sugar beet plant species, according to this study, plant varieties are suitable for mid-mature product. Table 6 shows the deviation from the optimal conditions for each phenological stage of sugar beet based on the average daily temperature at selected stations. According to the results of germination stage of sugar beet cultivation, Ahar station has less deviation and more optimal conditions than the other stations. In the early stages (growth), Ahar and Harris station have less deviation than the other stations; however, there are not significant differences in terms of deviations from optimal conditions. The fully ripening stages of sugarbeet, Harris and Ahar Stations have lower deviations; consequently, in all stages, Ahar station has least deviation from optimal condition, this means that this station has the optimum conditions for the cultivation of sugar beet.

Table 6. Determining the deviation from optimal condition of sugar beet phenological stages in selected stations.

Total deviations	Fully ripening		growth		germination		Growth stages / station
	Deviation from condition	optimum	Deviation from condition	optimum	Deviation from condition	optimum	
-54.43	-11.66	16-20	-20.53	27-30	-11.33	20-25	Tabriz
-31.67	-9.56	16-20	-13.67	27-30	-8.33	20-25	Ahar
-35.24	-11.98	16-20	-13.09	27-30	-9.17	20-25	Haris
-37.21	-11.67	16-20	-13.67	27-30	-10.87	20-25	Malekan

4- Deviation from optimal conditions based on height Thermal gradient

In order to evaluate the deviation from optimal conditions at different height, or the optimal spatial position based on the height,_first, using the linear regression, coefficients for changes in daily temperature as a function of height are calculated for months and whole year. To achieve results, and calculate the above relationships, first, table of correlation elements for selected stations and all time periods of study, were formed, that results are summarized in Table (7) as the annual correlation of the selected stations.

Table 7. The annual elements of correlation of selected stations in East-Azerbaijan province in phenological stages (thermal gradient).

Sugar beet ripening	growth	germ-ination	stage / coefficients
0.027	-18.02	-0.001	B
-0.045	0.008	-0.001	A
0.13	10.98	-0.002	R

5- Evaluation of agro-climatic potentials of the region with Papadakis method

In order to study the diversity and agro-climatic classification of the region, Papadakis method has significant capabilities. Therefore, according to the selected station's data and the defined threshold in Papadakis method, agro-climatic potentials of study area is evaluated and calculated.

6- Winter Conditions

In this method, based on winter temperature and sensitivity and stability of plants to coldness, six different thermal categories is considered, including: equatorial products, tropical products, tropical products, citrus, oats, wheat and spring crops.

Thermal conditions in equatorial class are desired for growing oil palm and caoutchouc. But although the tropical class has no frost season and is in possible frost citrus class and finally in the last thermal class, winters are too severe that all products are cultivated in springs. Table (8) shows winter types and their temperature ranges, according to their ecological characteristics.

To determine the temperature classes, some climatic variables such as absolute average, maxi and mini temperature of the coldest month are used. In fact, these variables determine the temperature drop threshold.

According to Papadakis method thresholds and climate data, stations of Tabriz, Harris belong to oat class (cooler AV) and Ahar and Malekan belong to wheat (TI hotter) class.

Table 8. Temperature condition of selected stations for their winter type according to ecological characteristics.

Ecological Characteristics	Average maximum temperature of the coldest month of the year	Average minimum temperature of the coldest month of the year	The minimum temperature of the coldest month of the year	Winter type	Station
Winter, ideal for crops such as barley, but not appropriate for citrus.	-18.92	-7.96	2.95	Oat, av	Tabriz
Winter, ideal for crops such as barley, but not appropriate for citrus.	-6.31	-0.65	8.31	Oat, av	Haris
Warm enough for winter wheat, but not good for the barely	-20.77	-8.67	1.17	Wheat, TI	Ahar
Warm enough for winter wheat, but not good for the barely	-16.12	-6.88	2.48	Wheat, TI	Malekan

7- Summer conditions

According to summer temperature conditions,9 thermal classes in Papadakis method are considered. Based on the thermal potentials and climatic conditions, these classes are as follows: cotton, coffee, rice, corn, wheat, taiga, tundra, etc. The required criteria for defining the summer conditions include: the length of the frost-free season, the average maxi temperature in the warmest month of the year and the warmer months.

Frost-free season length is classified to three modes: mini, available and n average of maxi average temperature. This classification is based on monthly average of absolute mini temperatures. The basis for mini, available and average is 7, 2 and 0C°, respectively. These indices and thresholds of determination of summer type are set for the following reasons: various thermal requirements of crops and natural vegetation to yield and grow in response to ecological and physiological characteristics.

Table (9) shows the types of summer and their thermal range (inC°) The results of study of summer conditions based on thresholds and thermal ranges of Papadakis method for stations within the province is as follows. Harris Station belongs to cotton (G) warmer class and Tabriz station in cotton (g) cooler class._Ahar and Malekan stations are placed in the class of corn (m). According to climatic data and thresholds of Papadakis in summer conditions, all stations have the suitable agro-climatic conditions for the cultivation of crops such as cotton and corn (type G , g and m) and other crops that require hot and dry weather.

Table 9. Temperature condition of selected stations for their summer type according to ecological characteristics.

Ecological Characteristics	Average maxi temperature of the hottest month of the year	Average maxi temperature id n hottest months	Frost-free season, Months	Summer type	Station
Sufficiently long hot summer for cotton	24.54	N=6>25	Min 5 >4.5	Cotton g	Tabriz
Sufficiently long hot summer for cotton	33.85	N=6>25	Min 5 >4.5	Cotton g	Haris
Rice is not the main crop	25.23	N=6>21	Available >4.5	Corn m	Ahar
Rice is not the main crop	25.11	N=6>21	Available >4.5	Corn m	Malekan

8- Temperature and humidity regime

Study of the thermal regime for all selected stations in East-Azarbaijan Province is as follows.

The yeitherbelong to continental (co) class and in terms of humidity, Haris and Ahar stations belong to humid Mediterranean class and Tabriz and Malekan stations to the dry Mediterranean class.

Table 10. The calculated indices in Papadakis method.

Humidity regime	Thermal regime	Winter type	Summer type	Frost-free season	Evapotranspiration	Annual temperature	Annual precipitation	station
Me	Co1	Av	g	n>4.5	455.63	15.12	286.34	Tabriz
ME	Co1	Av	G	n>4.5	576	20.52	270.92	Haris
ME	CO2	TI	M	n>4.5	454.5	14.33	375.21	Ahar
Me	CO2	TI	M	n>4.5	421.88	14.79	344.84	Malekan
Climatic class	Leaching	Humidity index		Dry months	Mild months	Humid months		station
6-9	25.25	10.39		June to October	May	November to March		Tabriz
6-7	391.05	7.89		-	March to October, January and February	November, October, /March		Haris
6-9	146.50	16.09		June to October	-	November to April		Ahar
6-7	86.17	13.10		June to October	-	November to April		Malekan

9- Areas suitable for cultivation of sugar beet

Based on the analysis of climatic factors for the cultivation of sugar beet, and agro-climatic conditions according to mentioned methods, favorable and unfavorable areas for a variety of sugar beet cultivation (springtime) in different months of study area are as follows. Early spring is the best time for sowing of sugar beet in East Azerbaijan province. According to fig (2), suitable areas for sugar beet cultivation in this province includes the south and northeast regions. These areas are suitable due to their environmental characteristics and living conditions for sugar beet plant; while other areas such as the western regions are not suitable for cultivation of this crop.

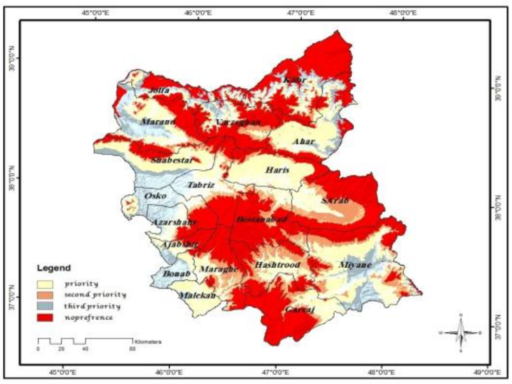

Fig. 2. The total deviation from the optimal conditions for sugar beet.

Conclusions

On a global scale, the beet is an important source of sugar. Nearly seven million hectares of arable land every year, are allocated to sugar beet; Historically, because of its economic consequences in agriculture, industry and commerce, the sugar industry have always been important in organization of the country's economic system. This industry, relying on its positive outcomes and proper function in the employment, food security, sustainable agriculture and savings in foreign currency and having a strong and independent role in achieving an ideal society, has constantly had a considerable portion of production systems. In Iran, due to wrong policies on agriculture, crop yields are very low, insignificant low quality.

The purpose of of this research is to identify and determine suitable regions for the cultivation sugar beet due to the climatically parameters in the the Eastern Azerbaijan province. In fact, this region requires to be with knowledge of the potential agro-climatic Such a study the region relation to cultivate sugar beets shows took place. The results are as follows. Optimal a place for cultivate sugar beet, which is north eastern parts of the study region is very potential. In fact, Ahar station has a lower deviation from the optimal conditions, resulting in favorable conditions for the cultivation of sugar beet in comparison with the other stations. Completion date of phenological stages in sugar beet ripening time, occurs earlier in Ahar station than other stations. In total, Ahar station experiences supplementary phenological stages of other phenological periods, earlier, as well. Best calendar for sugar beet cultivation by agro-climatic analysis, in late April, is for Ahar, Haris, Malekan and Tabriz stations, respectively. Best calendar for sugar beet harvesting is late September for Ahar, Harris, Malekan stations and early October for Tabriz station. Based on analysis of thermal gradients and deviations from optimal conditions at different altitudes of the stations, Ahar station has better conditions for planting, among selected stations. This is important in terms of the timing of sowing and commercial crops cultivation. Total regionssuitable for sugarbeet cultivation in the province are northeast and southern regions. Mentioned areas include Ahar, Harris and Malekan.

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