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Agro-climatic zonation for dry farming wheat in Zanjan Province, Iran

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Abstract

Climate knowledge and investigating in climatologic requirements of plants is considered as a most salient factor in cultivation. It can be determined the climatic potential conditions in the various regions and utilize them to a large extent by investigating in agro-meteorology. In this research, it has been applied the Geographic Information System to generate the climatic potential maps for Zanjan Province. To this purpose, the 30-year statistical records of climatology and synoptic stations have been used in the province of Zanjan. It was determined the date of cultivation for each section of the province after obtaining the beginning date of autumn precipitations for each part of the province. In the next step, the rainfall element was used for producing the isohyets climatic maps of annual rainfall, rainfall in the germination, blossoming, and ripe periods. The isotherm climatic maps of germination's suitable temperature, thermal tensions during the blossoming, ripe periods were provided for the whole province. In the long run, the climatic potential regionalization map of dry-farming wheat was produced through overlying the relevant maps by GIS. The outputs showed the major suitable regions for dry-farming of wheat are in the South and Central areas of the province. In contrast, the regions located in the North of the province – upland and sharp steep regions of Alburz mountain chain - hold ordinary and feeble conditions in the light of wheat cultivation.

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Introduction

Inevitably, agriculture is commonly considerate as one of the important sections of economics, as it is claimed that economic progress depends strongly on the agricultural crops. Nowadays, it is applicable to achieve to an improved and scientific agriculture based on doing precise scientific researches and to identify the environmental potentials of each region. To knowledge the climatic parameters and its effects on the farming plants is one of the most important effective factors in increasing performance and also production, and especially such condition is considerate to be more important in the view of dry farming. In relation to being strategic crop, wheat and that, it is contemplated as the most significant agricultural production in the country, and plays a key role in the people sustenance's supplying, it is practically feasible to achieve a higher performance, in which it will automatically boost the economics condition of agriculture and the people's revenue, as well; conditioning that the suitable regions have already recognized for cultivating this crop and also identified the climatic limitations and potentials in the environments according to thermal and humidity requirements of wheat crop.

Since the farming regions separation in our country have been mostly based on a traditionally method and it is currently unclear the agricultural-climatic potentials in most parts of the country, this paper aims to interpolate the regions about wheat production based on climatic potentials of Zanjan province through temperature and precipitation analyses. It is possible to present a crop performance's enhancement and utilizing the climatic condition by identifying the appropriate areas to cultivate. This will end in a proper planning in the agricultural field of the province.

Various researches have been carried out regarding the climatic factors and plant growth in dry-farming. Zang (1994) has been done many researches on the winter wheat' growth to determine the effects of temperature and precipitation changes in China. The results indicated that the temperature's oscillations play a more significant role in seed's performance than those of precipitation. In his research, Norwood (2000) investigated the effects of climatic parameters on the dry-farming wheat cultivation in the Great Plains of Kansas State in the United States, and came to the conclusion that evaporation and precipitation play the most significant role in dry-farming wheat' growth process compared to the other climatic elements. Kamali *et al* (1999) studied the climatic potentials of dry-farming wheat cultivation in the province of Eastern Azerbaijan. They in their researches were identified the proper and improper regions for dry-farming wheat crop by using temperature and precipitation parameters. In the Western Azerbaijan, Zarrin (2000) investigated the effect of climatic parameters on performance amount of dry-farming crops. He finally represented a pattern for the dry-farming wheat crop's forecasting in the region. Din Pajoh and Movahed Danesh (1996), carried out a research which showed that the precipitation's role was more considerable in the regions with a dry-farming regime than other climatic parameters.

Climate knowledge and investigating in climatologic requirements of plants is considered as a most salient factor in cultivation. Therefore, the paper's objectives are to identify the abilities and limitations caused by climate in the region, in other words, are to regionalize agro-climatology of dry-farming wheat using climatic elements by GIS. To do so, the former background studies regarding the climatic potentials of dry-farming wheat's cultivation were investigated first, and then the final agro-climatology map of dry-farming wheat was produced for Zanjan province by using overlying method in GIS.

Material and methods

Zanjan has an area of 22,164 km^2, occupying 1.34% of the Iranian territory. Located northwest of Iran, Zanjan covers joint borders with seven provinces- East Azerbaijan, West Azerbaijan, Hamadan, Kurdistan, Gilan, Ghazvin and Ardabil. Zanjan has a highland climate characterized by cold snowy weather in the mountains and moderate climate in the plains

in wintertime. In the summers, the weather is warm. The average maximum temperature of Zanjan is around 27 °C, whereas the average minimum temperature stands at -19 °C. Meanwhile, the temperature rises to 32 °C on hot days, whereas it drops to -27 °C below zero on icy days. The average annual rainfall in the first month of spring stands at 72 millimeters, while in the second month of summer, it slips to a meager 3.6 mm. The rate of humidity in the morning stands by average at 74% and at noon at 43%. Fig 1 shows the geographic location of Zanjan Province in Iran.

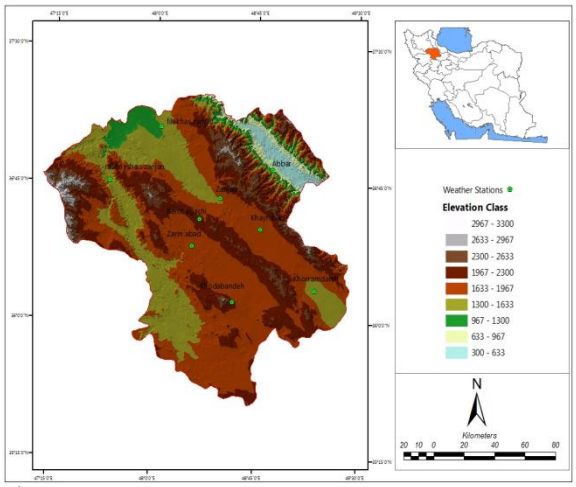

Fig. 1. The geographic position of Zanjan Province along with used stations and the underlying topography.

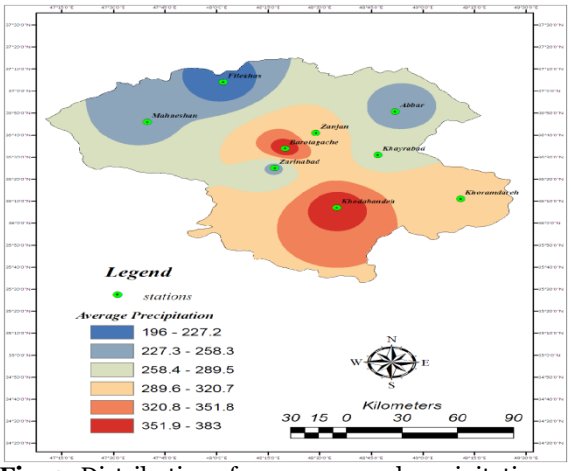

Fig. 2. Distribution of average annual precipitation.

Climatologic data, in the climatic researches, is considered as the most important source of information. In such studies in which are computed in the form of network, the results derived from data analysis would be more accurate in case of existing more stations. In this paper, the daily maximum, minimum and average temperatures, and annual precipitation data records from 9 synoptic and climatology stations existed in the province were applied for a statistical period of 30-years (1976-2005), and subtraction and ratio methods have been used for filling some gaps of temperature and precipitation data records. The meteorological stations characteristics represented in table (1) and distribution of used stations illustrated in Fig (1). At the present research, climatic variables of precipitation and temperature have been applied to investigate the climatic potentials of dry-farming wheat in Zanjan province.

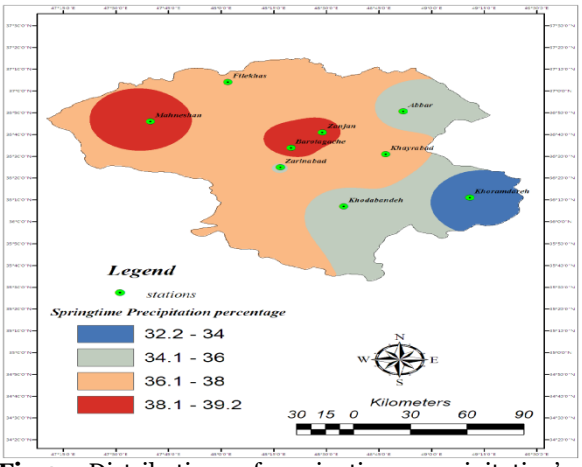

Fig.3. Distribution of springtime precipitation's ratio.

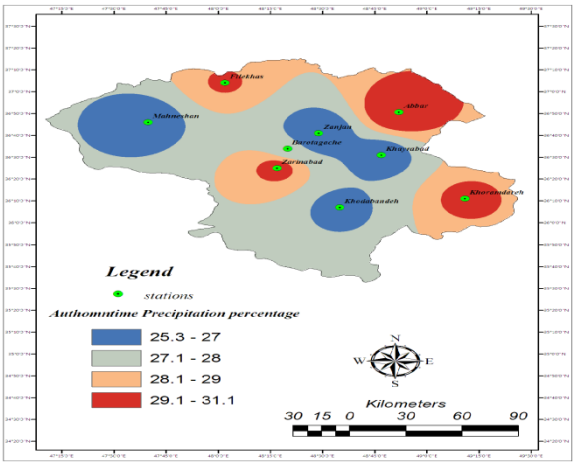

Fig. 4. Distribution of autumn precipitation's ratio.

In the next step, an attempt made to derive the precipitation variables (annual precipitation, autumn/spring/winter and summertime

precipitations, and germinating/blooming/full-grown precipitations), as well as temperature variables (proper temperature of germinating, temperatures less than 9°C in blooming, temperatures more than 25°C in blooming period, and temperatures less than 9 °C in full-grown, and temperatures more than 30°C in full-grown period). Appropriate condition for wintertime wheat cultivation is depending on two variables of precipitation and temperature. Because of being in a good condition the appropriate temperature for germinating, in this paper we mostly emphasize on precipitation element and temperature is considered as a second factor.

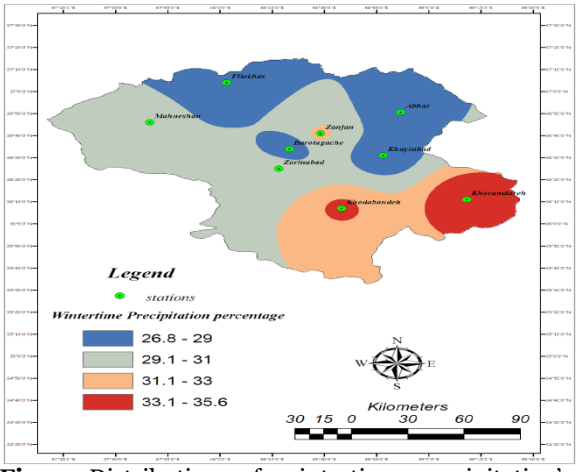

Fig.5. Distribution of wintertime precipitation's ratio.

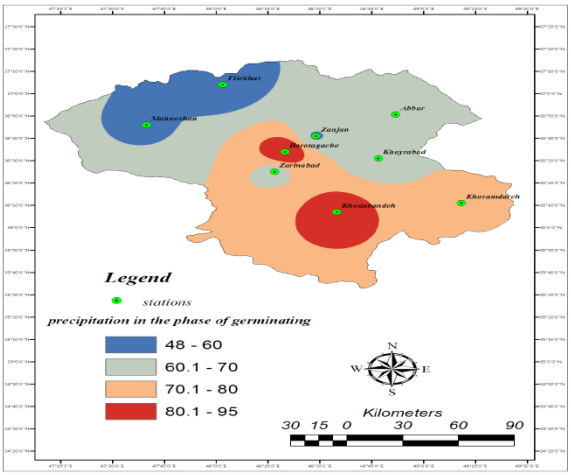

Fig. 6. Average precipitation in the phase of germinating.

At the present research, as regards the region and importance of precipitation in dry-farming, the following definition was applied to compute the date of cultivation: the first date of rainfall occurrence and more than 5mm taken place for one or two consecutive days with a probability of 75% in fall season. As well as, proper temperatures for this period also were determined between 12°C to 20°C. In continuation, concerning the thermal requirements of wheat during various growing phases, it was determined the beginning and ending time of growth sensitive steps (germinating/ blooming/ full-grown). Because the annual precipitation and its distribution is considered as the most important climatic variable in dry-farming wheat, the amount of annual precipitation of the province and its distribution in different seasons and its value during phases of germinating/ blooming/ full-grown in the region was determined by using GIS.

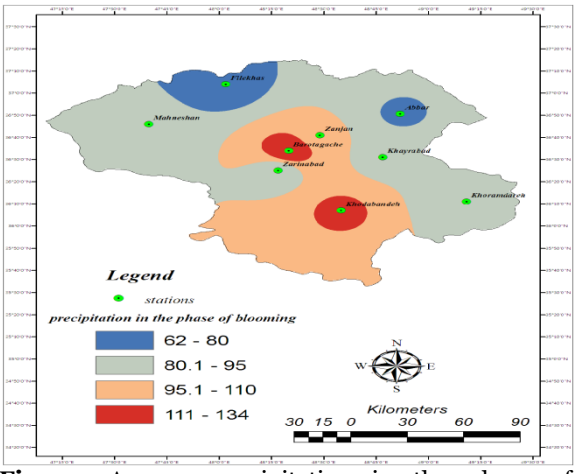

Fig. 7. Average precipitation in the phase of blooming.

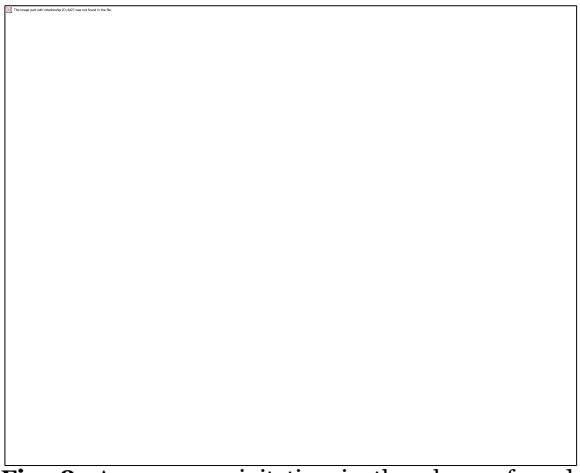

Fig. 8. Average precipitation in the phase of seed full-grown.

Since temperature is a key factor in growth of agrarian plants, and it has been defined a specific

definition of thermal threshold for each plant, in this research therefore, this factor has been analyzed during the growth sensitive phases. It was investigated the daily average temperature condition in germinating period and temperatures between 12°C to 20°C were approved as appropriate temperatures. In the blooming period also based on the climatic condition of the region, it was contemplated 9°C as the occurrence threshold of the cooling tension and 25°C as the occurrence threshold of the thermal tension.

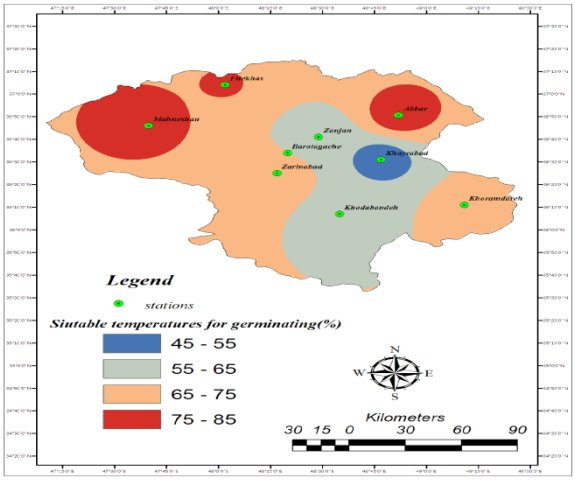

Fig. 9. Appropriate temperatures in the phase of germinating.

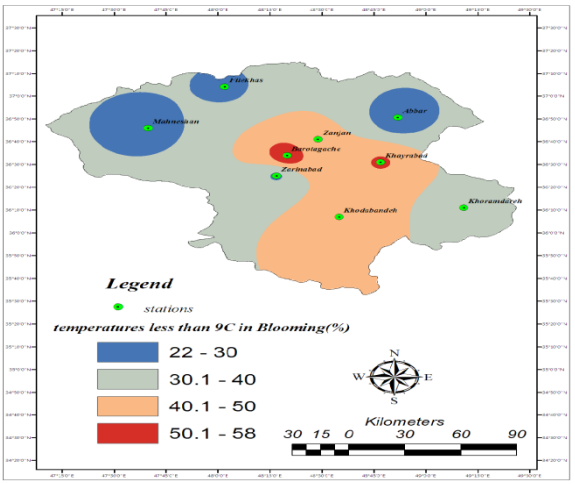

Fig. 10. Temperatures less than 9°C in the phase of germinating.

Correspondingly, in the full-grown period also 9°C taken into account as the occurrence threshold of the cooling tension, and it was considered the temperatures above 30°C the occurrence threshold of the thermal tension. As well as, the interpolation maps related to these parameters were provided and then categorized by using GIS. In the long run, the overlying method (categorized weighting) for data analysis was applied. Overlying of the provided layers parameters carried out based on the following relation:

$$P = W_1 S_1 + W_2 S_2 + W_3 S_3 + \ldots + W_n S_n$$

Where,

P stands for the result derived from overlying the parameters, and W letter is the name of each parameter used in the paper, and as well as S is weighting value of classifies for each parameter. By overlying the relevant layers and using the above relation the agrarian interpolated maps of the province for dry-farming wheat cultivation were produced and then classified into 4 groups of very good, good, mean and poor.

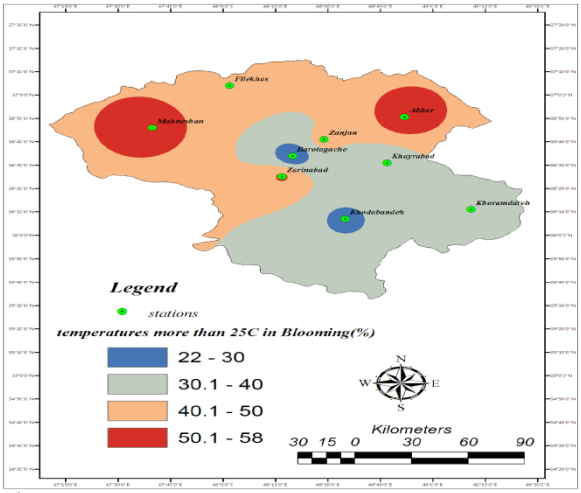

Fig. 11. Temperatures more than 25°C in the phase of germinating.

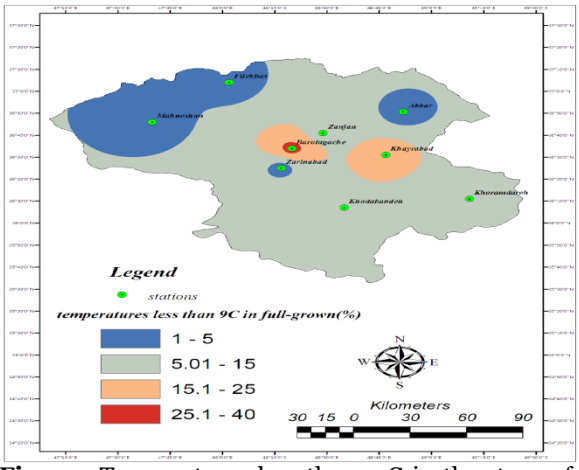

Fig. 12. Temperatures less than 9°C in the stage of full-grown.

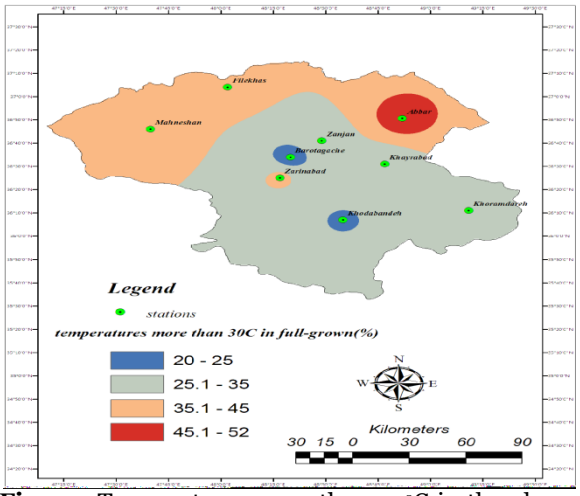

Fig. 13. Temperatures more than 30°C in the phase of full-grown.

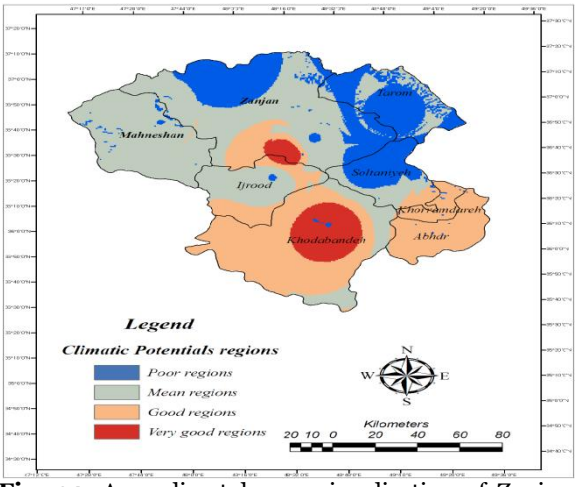

Fig. 14. Agro-climatology regionalization of Zanjan Province based on the climatic potentials of dry-farming wheat cultivation.

Result and discussion

The results of the geographic distribution regionalization of the province's precipitation showed that the amount of precipitation is noticeability in a poor condition (less than 250mm) in a small part of the Northwest and west of the province in which is an obstacle for economical cultivation of dry-farming wheat. In addition, in some parts of West and East province the amount of precipitation is around 250mm to 300mm, and the regions located in the Center and South of the province possess a suitable rainfall for wheat crop (Fig. 2). Through investigating (Fig. 3), it can be concluded that the springtime precipitation's ratio to annual precipitation is rather low in the Eastern and Southeastern parts of the province, and moving northwestwards it is increasing the springtime precipitation's portion so that it is become more than 40 percent at the corner of Northwest. This is because of locating in high latitude and also to be arrived the Caspian's streams into the region. The results obtained from Fig (4) indicate that the amount of autumn's precipitation is more than annual one in the Northeastern and East of the province, and the autumn precipitation's amount is decreasing towards the South and West. Concerning that the Western coasts of Caspian Sea receive the most precipitation in the Fall season, and to be neighboring with such a rainy area, that is the reason why in the Northwest of the Zanjan province receives a highly amount of precipitation in Fall season. Having analyzed the Fig (5), it can be clearly obtained that opposed to the springtime precipitation trend, wintertime precipitation's ratio is more than annual precipitation in the Southeastern regions, and it declining the amount of wintertime precipitation towards the Northwest and Western regions of the province, and it is increased to the amount of springtime precipitation. The summertime precipitation's ratio to the annual precipitation does not have a specific trend due to being erratic and accidentally.

As it is obvious in the Fig (6), the amount of precipitation in the phase of germinating significantly increases from Northwest to the Southeast parts. According to the defined classes, it is determined that the very good regions enjoy a precipitation more than 80mm, good regions possess a precipitation between 70mm to 80mm, and mean areas hold a precipitation between 600mm to 70mm, and finally the poor regions have less than 60mm precipitation. Regarding the precipitation in the phase of blooming, based on Fig. (7) the amount of precipitation in the central and Southern regions of the province are noticeably high, in contrast the Northern and Eastern parts of the province are in a poor condition, in which are classified into four categories.

According to Fig (8), the regions located in the central parts of the province enjoy a high precipitation in the phase of full-grown, while the Northern regions suffer

from a poor rainfall. Therefore, four classes were applied, very good regions hold a precipitation more than 16mm, good regions possess 13mm to 16mm precipitation, and average regions have a precipitation between 10mm to 13mm, and also poor areas only receive less than 10mm precipitation.

Table 1. Meteorological stations characteristics of Zanjan Province.

No.	Station	Longitude	Latitude	Type of Station	Elevation
1	Khodabandeh	48 35	36 07	Synoptic	1887
2	Khoramdareh	49 11	36 11	Synoptic	1575
3	Mahneshan	47 40	36 46	Synoptic	1282
4	Abbar	48 58	36 56	Synoptic	702
5	Zarrinabad	48 37	36 47	Climatology	1548
6	Zanjan	48 29	36 41	Synoptic	1663
7	Kheirabad	48 47	36 31	Synoptic	1770
8	Filehkhas	49 05	36 39	Climatology	1800
9	Barotaghachi	48 41	36 28	Climatology	1721

Temperature is mostly considered as a key factor in the agrarian plants geography. It has been defined a specific thermal thresholds for each plant. Temperature is a very significant element in each phases of the growth, meanwhile there are processes in which are more important due to the plant's sensitivity to the climatic changes. Thus, in this research the thermal conditions of the used stations were investigated based on the thermal requirements of wheat in the phases of germinating, blooming, and seed full-grown (Bazgir 2000). It was used the growth's degree-days to obtain the date required for the above stages. Thermal units required for the plant to pass the aforesaid stages are as follows (Nonhebel 1996):

The whole thermal units from date of the cultivation to germinating .....180^{o}C degree-days.

The whole thermal units from date of the cultivation to blooming ..... 1300^{o}C degree-days.

The whole thermal units from date of the cultivation to seed full-grown..... 2100^{o}C degree days.

Temperature has a remarkable effect on the green plants in the initial phase of plant's growth in particular in the cultivation's period to germinating. At the time of germinating, the appropriate temperature is between 8^{oC} to 14^{o}C conditioning that the daily temperature is not zero (Kamali 1997). The appropriate temperatures percentages for germinating are shown in Fig (9). Most regions situated in the North and West province are in a good condition with a view to occurrence of proper temperature in the germinating stage. In contrast, regions located in the Southeast and center of the province are in a moderate to poor conditions with a view to occurrence of proper temperature in thegerminating stage.

The blooming stage is other sensitive phases of wheat phenology. At this stage of the wheat growth, it causes to drop in the wheat performance as if the daily maximum temperature increases to more than 25^{o}C and/or decreases to less than 9^{o}C (Warrington 1997). To investigate and regionalize the province's temperature at the stage of wheat's blooming, it was computed the growth's degree-days since the date of cultivation to acquire 1300^{oC} degree-days for each stations. According to Fig (10), it has been determined four classes for the geographic distribution of cooling tensions occurrence at the stage of blooming. The lowest occurrence's percentages of temperatures less than 9^{o}C in the phase of blooming are mostly happening in the Northwest and Northeast of the region, in which it is

considered as a good area. And the most occurrences' percentages of temperatures less than 9°C in the phase of blooming are mainly taking place in the central and Southern regions of the province, which it is taken into consideration as an inappropriate area. Based on Fig (11), four classes have been determined for the geographic distribution of thermal tensions occurrence at the stage of blooming, and interpolated. The lowest occurrence's percentages of temperatures more than 25°C are mostly happening in the South and Southeastern of the province, in which it is considered as a good area. As well as the most occurrences' percentages of temperatures more than 25°C are mainly taking place in the North and Northwest regions of the province, which it is taken into account as an inappropriate area.

Table 2. Defined classes and weights dedicated to the layer.

Qualitative Value		Very Good	Good	Mean	Poor
Parameters	Weight Value	4	3	2	1
Annual Precipitation		340<	290-340	240-290	<240
Germination Precipitation		80<	70-80	60-70	<60
Blooming Precipitation		110<	95-110	80-95	<80
Seed Full-Grown Precipitation		16<	13-16	10-13	<10
Germinating Suitable Temperatures		75<	65-75	55-65	<55
Temperatures less than 9°C in Blooming		<30	30-40	40-50	50<
Temperatures more than 25°C in Blooming		<30	30-40	40-50	50<
Temperatures less than 9°C in Seed Full-Grown		<15	15-25	25-35	<35
Temperatures more than 30°C in Seed Full-Grown		<30	30-40	40-50	<50

In the phase of seed full-grown, temperatures 30°C and more, and 9°C and less can cause to dropping in the crop's performance. According to Fig (12), we can say that almost all of the province's regions are in an appropriate condition with the view of occurrence's percentage of temperatures less than 9°C in the phase of seed full-grown, and only a small parts locating in the center of the province are in a poor condition. Fig (13) shows the geographic distribution of percentages of the temperatures more than 30°C in the stage of seed full-grown. Regarding to that, it is clear that the most parts of the province situated in the center and South are in a good condition in the light of occurrence's percentage of the temperatures above 30°C so that the occurrence's percentage of such condition is less than 35% in these areas, meanwhile regions locating in the Northwest and Northeast of the province are in a poor condition with the view of occurrence's percentage of the temperatures more than 30°C and the occurrence's percentage of such condition is above 30°C for these regions.

It was defined four classes for each layer, after deriving the required parameters for all the stations and transferring them to GIS based on the scientific resources as well as the climatic conditions of the study area. In addition, each region was given a digital weight between1 to 4 to make the same scale for the layers for overlying process, based on the climatic proper condition of the dry-farming wheat (table 2).

All of the layers related to the climatic parameters of temperature and precipitation were integrated using GIS by utilizing the overlying method of "classified weight". In the next step, the high steep heights and forest regions as inappropriate regions with the view of wheat cultivation were overlie with the map of obtained from the climatic parameters, and finally the regionalization map of areas for dry-farming wheat was produced for the Zanjan province (Fig. 14).

The final agro-climatology map of dry-farming wheat in Zanjan province including 4 classes as follows:
Very good regions (1st class): have a great performance due to possessing a suitable climatic

condition during the wheat' growth and/or these areas can to have such a performance in case of providing the other required parameters.

Good regions (2nd class): are in a weaker condition with the view of suitable climatic condition for dry-farming wheat as compared to the very good regions. However, we can still expect to harvest a relatively good crop at these areas. These regions are locating mostly in the Southern and central parts including Southern sections of the Zanjan city, the Western sections of the Abhar, and most sections of Khoramdareh and Khodabandeh cities.

Mean regions (3rd class): have a poor climatic condition to cultivate the dry-farming wheat, in which including mostly areas in the North of province such as parts of the Mahneshan and Tarom cities, and Northern sections of the Zanjan city as well.

Poor regions (4th class): dry-farming wheat is not economical and profitable at these areas due to lack of suitable climatic condition, which including some parts of Mahneshan and Tarom cities, as well as high and steep regions of the Alborz mountain range extending northeastwards of the province.

Conclusions

Special geographic situation of Zanjan province and its natural capabilities throughout the history has led to forming a series of agricultural activities. The paper's objectives are to identify the abilities and limitations caused by climate in the region, in other words, are to regionalize agro-climatology of dry-farming wheat using climatic elements by GIS. To do so, the former background studies regarding the climatic potentials of dry-farming wheat's cultivation were investigated first, and then the final agro-climatology map of dry-farming wheat was produced for Zanjan province through applying the precipitation and temperature data and using overlying method by GIS. The results showed that some central parts of the province such as Khodabandeh and Southwest Zanjan city recognized as the best locations to cultivate the dry-farming wheat. Other equivalent important results of the paper is to utilize the capabilities and abilities of Geographic Information System (GIS) in overlying and producing the spatial information with non-spatial data, which can be very useful for managers and planners to access the information.

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