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Selection of an appropriate planting time (between the last and the first frost)

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Key words: Spring frost, Autumn frost, Smada, Zonation, Arc GIS

Abstract

Yearly frost and freezing, especially during the spring season often causes heavy damages to fruit trees in Chaharmahal and Bakhtiari province, Iran. Therefore, to reduce the effects of this natural event hazard, approaches should be developed to minimize the damages. One of the long run methods to prevent frost and freezing is the selection of an appropriate planting time. So, a proper comprehensive task is essential to find when the first and last frost occurs. In this research, the yearly first and last frost event dates of Chaharmahal and Bakhtiari Province were determined using available climate data records and then the spatial continuous distribution map of frost was obtained using Arc GIS software. On this basis, the first and the last frost dates with different return periods for various part of the province were determined. According to this research, for instance, with the probability of 50% (return period= 2 years), the first frost dates alter from 17 October (for Shahrekord) to 15 November (for Lordegan) and the last frost dates alter from 29 March (for Lordegan) to 29 April (for Dezak).

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Introduction

Predicting of the time of the first frost of autumn and the last frost of spring in planning of agricultural, economic, social, services and etc. issues has great importance. For example, in the housing and road construction industry, the activity of this part depends on the suitable temperature and is stagnated in below zero. Requisite of social activities in different fields such as tourism and touring is a proper temperature without frost.In agriculture, plants are able to grow in a certain temperature range. If any comparatively severe temperature fluctuations in the three stages of planting, growing and harvesting occur, often severe damages get to farms and farmers.

There is phenomenon of frost and freezing and damages resulting from it in most countries and each year imposes huge economic losses to producers in the agricultural sector. And because it happens suddenly and cause great losses, it is regarded as a natural disaster.Damages from frost and freezing in most years, on sensitive products, especially, almond, apricot, pistachio, peach, etc. are more than 40%.

Awaya *et al.* reported a spring frost occurred in April 21, 2001 (Day111, Julian day) that ruined about 80% of the fresh leaves on a 40-year-old Siebold's beech (Faguscrenata Blume) stand in Morioka, Japan and in some years in an area, the last spring frost may kill the product thoroughly.

In the spring, freezing later than normal (spring frost) caused a kind of damage which frost damage depends on the stage of development of fruit trees.The last spring frost damages newly awakened buds of fruit trees, also the newly formed flowers and fruits will suffer.Fruitful buds are resistant to cold in stagnation but their resistance decreases when awake.

In autumn, freezing earlier than normal (autumn frost) damages to products that are actively during the final stages of their growth.In order to minimize the damages caused by frost in many areas, it is required knowing of the occurrence time of frost.

Tomand Shaw investigated the date of early autumn and late spring frosts in Iowa and showed it follows the normal distribution. In addition, they determined that the date of the last spring frost and the first autumn frostare independently of one another, and thus estimation of the duration of growth period for each specific probability is possible.

Rabbani and karamis howed that the number of frost days in Northern Khorasan province (Iran) has a descending trend during the mentioned statistical period and also mean of annual temperature has ascending trend.In order to assess the risk of frost, recorded data of minimum temperature in weather station were used.

Lakatos *et al.* showed the delay of blooming by 5 days, may reduce the risk of frost damage by 4-20%.Whereas the 10-days delay diminishes the risk by 37-85 percent. To deal with frost in the short term program such as chemical methods including the use of chemical hormones, Polymeric chemical and physical methods such as sprinkler irrigation, use of appliances such as horticultural heaters, stir the air in the garden using a helicopter and a wind generator machine (large fans) and finally a combination of them are recommended. However, these methods are not still widely used in gardens and fields, except developed countries.

It is not attractive for Iranian farmers, due to the high initial investment, Low level of education and negligible income of horticultural products.There is a huge gap for accomplishment of operations confronting with frost to development of new horticultural industry in public. However, numerous works was conducted, either theoretical or statistical methods, to investigation and analysis of the first and the last frost in autumn and spring.

The appropriate growing season and harvest is the best solutions to deal with frost In the long run.It also requires a long-term data on the beginning and end of the cold. This study aims to predict the time of the first frost in the autumn and the last frost in the spring in Chaharmahal and Bakhtiari Province, Iran.

Materials and methods:

Study area

Chaharmahal and bakhtiari province with an area of 16,532 square kilometers, located between latitude of 31°9' to32°48' N and longitude of 49°28' to51°25' E.

Procedure

To predict the first autumn and the last spring frost dates, long-term data from meteorological stations of the province were used.Some of the stations due to lack of sufficient data were excluded .Time criterion to extracting of last spring frost data from 20 February and of first autumn frost data, number of days remaining until 21 March (the end of year in Persian calendar) was considered.According to Table 1, the threshold was considered 0°C. The critical temperatures of some fruits and vegetables are presented in the table.

Table 1. The critical temperature of some fruits and vegetables (6), as quoted by Snyder and de Melo-Abreu

Name	Sugar beet	Tomato	Cucumber	Corn	Strawberry
Critical Temperature	-0.4	-0.5	-0.5	-0.6	-0.8
Name	Potato	Peach	Walnuts	Apple	Almonds
Critical Temperature	-0.8	-0.9	-1	-1.5	-1.7

Date of the first autumn frost and the last spring frost in defined threshold by the minimum daily temperature data was extracted from the stations of province.In Table 2, the existing statistical years and adequacy of data has been shown for different stations.

Table 2. The existing statistical years for different stations and adequacy of data.

Station	Shahrekord	Polzamankhan	Avergan	Lordegan	Koohrang
The existing statistical years	1982-2010	1997-2010	1997-2010	1994-2010	1988-2010
Adequacy ofdata	Yes	Yes	Yes	Yes	Yes
Dezak	Borojen	Emam-gheis	Saman	Boldaji	Malekhalifa
1997-2010	1989-2010	1997-2010	2002-2010	2001-2010	2001-2010
Yes	Yes	Yes	No	No	No

Analysis

To predict the occurrence time of yearly frost, at first, every year the minimum temperature was recorded in Excel for further processing.Then test of the adequacy of the data was carried out. Smada software was used in order to fit with the best statistical distribution .For this purpose, each of the stations studied separately. And the date of first frost in fall and last frost in spring in different years was estimated by available distributions in software and then for each of the distributions, SSR index was used to determine the best distribution function.

Afterward the probabilities of occurrence in the different return periods were estimated in the same distribution function and spatial continuous distribution map of frosts were drawn using Arc GIS software in the return periods of 2, 5, 10, 25 years for study region.

Results and discussion

Adequacy test of data

Generally, the minimum period of statistics data required is dependent on the acceptable Statistics level. This minimum is calculated by the following equation (1). $y = [(4.30\,t)\log R]^2 + 6$ (1)

Where y is minimum acceptable statistical analysis, t Student's t value at the 90% confidence level for each degree of freedom (y-6), R is ratio of the return period of 100 years to the 2 years based on the amount of available data. Adequate statistical years are shown in Table2. According to the table, 8 stations from11 stations were accepted for analysis.

The best distribution function

Because of the random nature of meteorological parameters, the probability of their occurrence can

only be expressed by a probability distribution function. To determine the best distribution function Smada software and SSR (the sum of squared residuals) test was used. The results are shown in Tables 3 and 4.

Table 3. Selection of the best distribution function for the first autumn frost data for different stations.

Station	Distributions				Best distribution
	Log Pearson	Pearson	Gumbel	Normal	
Shahrekord	1.42	1.32	1.68	1.42	Pearson
Boroujen	2.58	2.44	2.23	2.56	Gumbel
kohrang	1.07	1.23	1.48	1.23	Log Pearson
Lordegan	1.47	1.39	1.18	1.43	Gumbel
Polzamankhan	1.35	1.56	1.58	1.5	Log Pearson
Avergan	2.36	2.25	1.99	2.23	Gumbel
Emam-gheis	1.2	1.55	2.19	1.54	Log Pearson
Dezak	2.78	2.6	2.37	2.57	Gumbel

Table 4. Selection of the best distribution function for the last spring frost data for different stations.

Station	Distributions					Best Distribution
	Log Pearson	Pearson	Gumbel	Log Normal	Normal	
Shahrekord	1.72	1.96	2.32	1.98	2.21	Log Pearson
Boroujen	2.46	2.63	3.22	2.91	2.55	Log Pearson
kohrang	1.29	1.51	1.5	1.49	1.71	Log Pearson
Lordegan	3.52	2.76	2.64	3.02	2.71	Gumbel
Polzamankhan	1.99	2.28	3.03	2.93	2.26	Log Pearson
Avergan	2.48	2.47	3.15	2.76	2.43	Normal
Emam-gheis	1.3	1.73	2.75	2.28	1.83	Log Pearson
Dezak	2.56	2.9	3.89	3.35	2.9	Log Pearson

The earliest autumn frost

Due to the best distribution function for each station using statistical data when the probability of freezing curves for different returns period of days remaining. Until the end of the year were plotted. The results for the different stations are given in Fig. 1 to 8 and Table 5. Using these Fig. can be the time of earliest autumn frost predicted for different stations in the province.

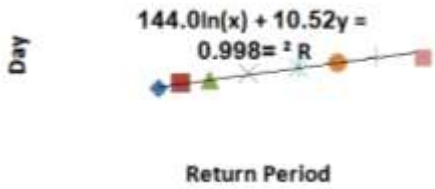


Fig. 2. The first autumn frost in Boroujen

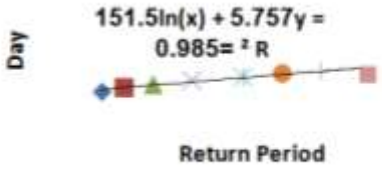
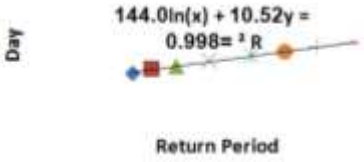


Fig. 1. The first autumn frost in Shahrekord

Fig. 4. The first autumn frost in Avergan

Fig. 3. The first autumn frost in Pol-zamankan



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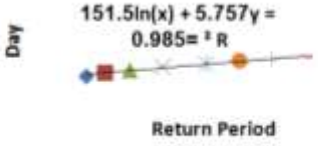

Fig. 1. The first autumn frost in Shahrekord

Fig. 4. The first autumn frost in Avergan

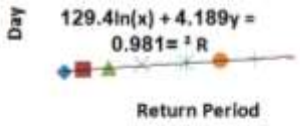

Fig. 3. The first autumn frost in Pol-zamankan

Fig. 8. The first autumn frost in Emam-gheis

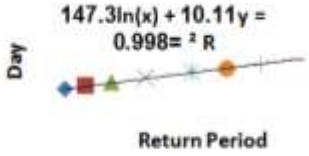

Fig. 7. The first autumn frost in Dezak

Table 5. Prediction of the first autumn frost in different stations and return periods of 2, 5, 10, 2.5

Return Period	Shahrekord	Boroujen	Dezak	Emamgheis	Lordegan	Polzamankhan	Avergan	kohrang
2 Years	154	150	153	140	125	131	137	140
	16 Oct.	20 Oct.	17Oct.	30 Oct.	14 Nov.	8 Nov.	2 Nov.	30 Oct.
5 Years	162	161	164	147	131	137	145	147
	8 Oct.	9 Oct.	6 Oct.	23 Oct.	8 Nov.	2 Nov.	25Oct.	23 Oct.
10	166	169	171	150	135	140	150	150
Years	4 Oct.	1 Oct.	29 Sep.	20 Oct.	4 Nov.	30 Oct.	20Oct.	20 Oct.
25	171	178	180	154	140	144	157	154
Years	29 Sep.	22 Sep.	21 Sep.	16 Oct.	30 Oct.	26 Oct.	13Oct.	16 Oct.

As observed in Table 5 for a period of 2 years in Shahrekord first frost of autumn on 25 October (154 days remaining until the end of the year) and for the period of 10 years on 13 October (166 days remaining until the end of the year) will take fell off. In addition, the observation that for a period of 5 years Borojen first frost on 18 October (161 days remaining until the end of the year) will happen.

The latest spring frost

Due to the best distribution function for each station using statistical data when the probability of freezing curves for different return periods of days remaining until the end of the year were plotted. The results for the different stations are given in Fig. 9 to 16 and Table 6. Using these Fig., can be the time of the latest spring frost predicted for different stations in the province.

As shown in Table 6, in Shahrekord, The latest spring frost for 2 years and 10 years returns period at 67 and 87 days after the first day of March will happen, respectively.

In addition, in borojen. The latest spring frost for 5yearreturn period at76daysafterthe first day of March will happen.

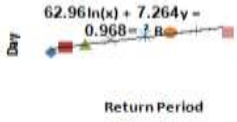

Fig. 10. The last spring frost in Boroujen

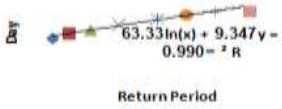

Fig. 9. The last spring frost in Shahrekord

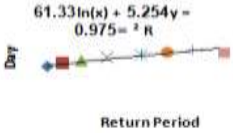

Fig. 12. The last spring frost in Avergan

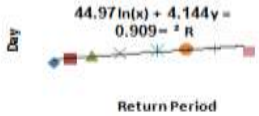

Fig. 11. The last spring frost in Pol-zamankhan

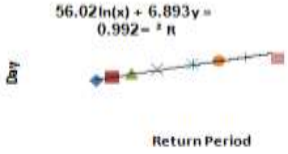

Fig. 14. The last spring frost in Kohreng

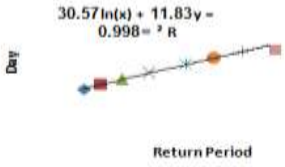

Fig. 13. The last spring frost in Lordegan

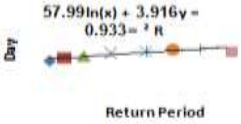

Fig. 16. The last spring frost in Emam-gheis

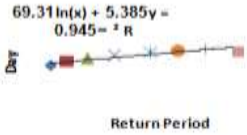

Fig. 15. The last spring frost in Dezak

Table 6. Prediction of the last spring frost in different stations and return periods of 2, 5, 10, 25.

Return Period	Shahrekord	Boroujen	Dezak	Emamgheis	Lordegan	Polzamankhan	Avergan	kohrang
2 Years	67	64	69	58	38	44	63	59
	26 Apr.	23 Apr.	28 Apr.	17 Apr.	28 Mar.	3 Apr.	22 Apr.	18 Apr.
5 Years	79	76	80	66	50	53	71	68
	8 May	5 May	9 May	25 Apr.	9 Apr.	12 Apr.	30 Apr.	27 Apr.
10	87	82	84	69	59	57	75	73
Years	16 May	11 May	13 May	28 Apr.	18 Apr.	16 Apr.	4 May	2 May
25	95	88	89	72	69	60	80	79
Years	24May	17 May	18 May	1 May	28 Apr.	19 Apr.	9 May	8 May

Length of the frost-free period

The length of the frost-free period (FFP) is a very important agro-climatological variable, in that it is most often used to indicate the length of the viable growing season. In its simplest form, the FFP is the number of consecutive days in the spring/summer/fall period on which the daily minimum.

Temperatures do not fall below 0°C. Length of the frost-free period, depending on the latest spring frost and the earliest autumn frost. Accordingly, the distance between the latest spring frost and the earliest autumn frost as a non-frost-year period considered. For each period, the various possibilities of this period were identified. The results are shown in Table 7.

Table 7. Frost-free period (day) in different station and return period of 2, 5, 10 and 25 years.

Return Period	Shahrekord	Boroujen	Dezak	Emamgheis	Lordegan	Polzamankhan	Avergan	kohrang
2 Years	173	180	172	196	231	219	194	195
5 Years	153	157	150	181	213	204	178	179
10 Years	141	143	139	175	200	197	169	171
25 Years	128	128	125	168	185	190	157	161

Zoning maps of dates

To zoning, date of the latest spring frost and the earliest autumn frost as point file were entered into the Arc GIS software. The results for the earliest autumn frost and the latest spring frost in Fig. 17 to 20 and 21 to 24 are shown, respectively. According to the Zoning Map, the earliest autumn frost in Central and East of the province happens and in the southerner gionsoccurslater.

The latest spring frost in areas with a belt stretched from North West to East of the province occurs. In the south of the province, the latest spring frostoccursearlier. According to Table 7, the minimum and maximum length of the frost-free period is Dezak, and Lordegan, respectively. So Lordegan for crops that require more degree-days and Dezak for crops that require less degree-daysare recommended.

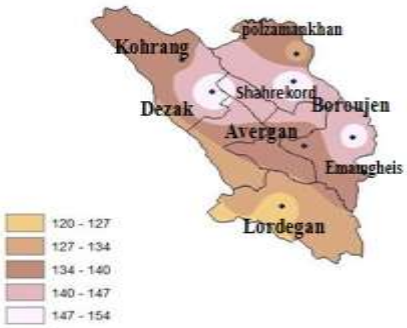

Fig. 17. Map of the first autumn frost with return period of 2 years

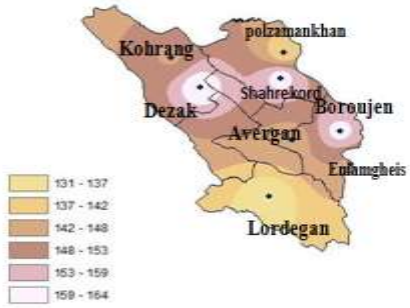

Fig. 18. Map of the first autumn frost with return period of 5 years

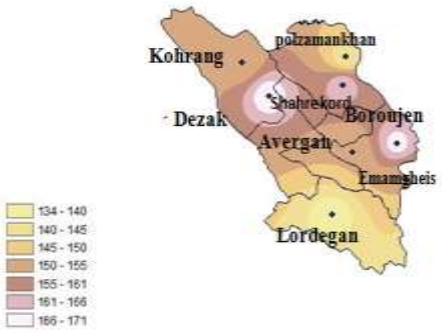

Fig. 19. Map of the first autumn frost with return period of 10 years

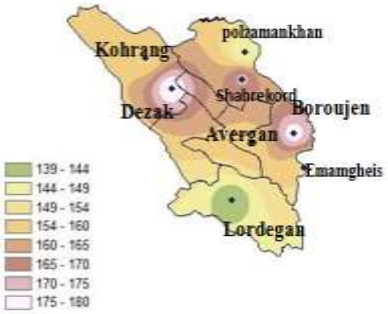

Fig. 20. Map of the first autumn frost with return period of 25 years

Fig. 22. Map of the last spring frost with return period of 2 years

Fig. 21. Map of the last spring frost with return period of 5 years

Fig. 24. Map of the last spring frost with return period of 10 years

Fig. 23. Map of the last spring frost with return period of 25 years

Conclusion

The results showed that due to the different micro climates in the Chaharmahal and Bakhtiari province, the time of the earliest autumn and the latest spring freezing is different in different places. The time of occurrence of the earliest and the latest freezing with different return periods are different in different parts of the province. For example, in Shahrekord station in the return periods of 5, 10 and 25, the time of the latest spring frost, 19, 27 May and 4 June and the earliest autumn frost 17, 13 and 8 October predictable, respectively. Based on this research, planting and harvesting operations can be adjusted to the desired probability. You can also use other methods such as sprinkler irrigation and frost tolerant varieties used. Zoning maps also show that frost period begins in Dezak, shahre Kord and Borojen earlier than other regions and areas Lordegan, polzamankhan begins later than other regions. In addition, the frost period ends in Lorde ganpolzaman khan earlier than other regions and Dezak, Shahrekord and Borojen ends later than other regions.

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