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Statistical Analysis of Early Autumn and Late Spring Frosts in Khorasan Razavi Province

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ABSTRACT

The phenomenon of early and late frosts is an extreme and harmful event which is investigated in various branches of engineering such as various structures, agriculture, horticulture, transport, consumption of gas, insurance services, etc. The probable analysis of this event and applying its results can reduce the damages of the above section. The objective of this research is to analysis the first and last day of frost in all the Synoptic stations and the Khorasan Razavi regional water. Eight normal probability distributions consisting of Gumbel type 1, gamma distribution with two parameters, 2 and 3 parameter lognormal distributions, generalized Pareto and generalized extreme value and Pearson type 3 were fitted to the data and parameters were estimated with seven methods including five different methods of torques, the maximum likelihood and entropy. The best fitting function for each station were selected through K-S test and the first and last days of frost were predicted in different return periods (2 to 100 years) with superior distribution. 3 parameter lognormal distributions and gamma distribution with two parameters are the best fitness functions in different stations respectively for starting the frost period and for the end of the frost period. The most common use of the parameter's estimation method is related to a variety of torques. Therefore, for investigating the phenomenon, a fitting function couldn't be suggested with a specific way of estimating the parameters.

Keywords: *probability distribution, Khorasan Razavi, Extreme event, early and late frosts*

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INTRODUCTION

The number, beginning and the end of the frosty days of the year are among the important meteorological phenomena. The extent of damage caused by frost occurrence in various sectors including the construction industry, structure, insurance services of agricultural products, water supply, production and distribution of fuel, energy, tourism, industrial activities, transportation, including road and bridge construction and road hazards makes it necessary to understand and study this phenomenon precisely to cope with potential losses. Forecasts and analysis of critical temperatures that caused the damage is very important. Sub-zero frosts are among the most common analysis (Alizadeh et al., 2000). The damage of the early autumn and late spring frost occurrence could be reduced by using mathematical analysis and identifying and applying methods to deal with it (Amir Ghasemi, 2002). Destruction caused by frost can mostly be seen in some parts of the building such as the capping, canopies, the seats and the bottom of the windows. Generally, more limestone and dolomitic are under frost attacks compared to sandstone (www.wikipedia). Marble, shale and granite are not affected by frost due to their low porosity. For example, the effect of freezing is discussed on fresh concrete. Concrete gains very little resistance at very low temperatures. As long as the saturation of the concrete, due to dewatering operation, is not reduced enough, it is necessary to protect fresh concrete against the devastating effects of frost. The concrete that has been frozen just once at an early age has a lower resistance against weather conditions compared to a concrete that is not frozen and will not seal. The frost phenomenon creates extensive damage every year in the field of transportation that is more frequent in cold months. Due to the structure of the atmosphere, the role of elevation has a particular importance at the ground level and practically, the logical relationship between height and characteristics of frost in each region could be established and thus, frost and critical temperatures would be organized by using these forecasts. Weather forecast of the frost occurrence is done on the basis of the established order on their occurrence and the natural conditions of the region while the statistical frost forecasting is based on this theory that the occurrence of a certain temperature in a place has a significant process and repetition and follows a specific rule that the behavior of the atmosphere can be predicted by analyzing their data. In agriculture, frostbite

and frost is very important at different stages of growth for agricultural and horticultural crops, because the plant's protoplasm is only able to continue their activities at a limited range of temperature. So its occurrence leads to product restrictions. The amount of damage caused by early frostbite and frost in most years was more than 40 percent, according to the information and statistics received from the provinces of the country on sensitive garden crops especially almonds, pistachio, apricot and peach. The degree of frostbite is different for various plants. In general, frost applies to a condition where the air temperature, at a height of 1.2 meters from the ground level, reaches to zero or below zero degrees Celsius, but from the perspective of agricultural meteorology, frost applies to a condition in which the temperature drops to such an extent that leads to some damages to the plant tissues that this type of frost is different for any product due to the critical temperature. The statistical study about how the harmful or beneficial atmospheric phenomena occur, and calculating their probability in every location, provides the possibility to use favorable atmospheric condition and avoiding the damage of harmful phenomena that in total, over the years, can guarantee a great deal of economic benefits (Faraji, 1999). Exploring this phenomenon with high precision in the thermometer stations of Khorasan Razavi is the subject of this research. For this purpose, the beginning and the end of frost days in these stations were analyzed and evaluated. The raw data was obtained from meteorological organizations and the Department of Energy (Khorasan Regional Water Authority) and the statistics required will be extracted to achieve results. Having this data is one of the characteristics of the random sample under investigation. The fitness of the statistical extreme functions of normal distribution consisting of Gumbel type 1, gamma distribution with two parameters, 2 and 3 parameter lognormal distributions, generalized Pareto and generalized extreme value and Pearson type 3 will be examined on the data. Estimation of parameters can be done through different ways: ordinary torques, maximum likelihood, probability weighted moments, maximum entropy and modified moments. The test of Kolmogorov – Smirnov could be used in order to select the best fittness function and the best method to estimate parameters for the data in each station (Rezai, Pajand and Bozorgnia, 1995; Rezaei Pajand, 2001). Also, it might be possible that critical temperatures be linked to geo-location features, such as latitude and longitude and altitude. The investigation of this relationship and the possibility of presenting a paradigm for this relationship is one of the goals of this research. Transport agencies, insurance services, construction sectors, Agricultural Jihad Organization and farmers can be the beneficiaries. The study area is Khorasan Razavi province. This province is in the northeastern part of Iran with an area of 420.128 square kilometers and is limited to 55.77' to 61 15' Longitude and 30.24' to 38.17' latitude. The present objective is to analyze the frequency of the first and last frost days in the synoptic stations and the Department of Energy (regional water) of Khorasan Razavi with fitting seven probability distributions (Gumbel type 1, gamma 2 parameters, 2 and 3 parameters log-normal, generalized Pareto, Pearson type 3 and generalized extreme with five estimation methods (ordinary torque, trimmed moment, probability weighted moments, maximum likelihood and maximum entropy).

MATERIALS AND METHODS

The study area is Khorasan Razavi province. This province is in the northeastern part of Iran with an area of 420.128 square kilometers and is limited to 55.77' to 61 15' Longitude and 30.24' to 38.17' latitude. This province has 13 synoptic stations and 35 stations of regional water in total. In analyzing the frequency of screening the data, basic tests (including independency, homogeneity, etc.), selecting the appropriate distribution, their fitness and goodness-of-fit tests (Rezai and Rao) has been observed. Most of the plants were harvested in the early autumn frosts or are being harvested. Wheat and rainfed barley are in the stage of emergence and establishment and wheat and water barley are in the tillering stage. Cumin and sesame are not usually coinciding with this frost. Thus, the temperature threshold of zero degrees Celsius was selected for this frost and the frequency analysis was done for it. The frequency analysis of the first and last day of frost in all the synoptic stations of Khorasan Razavi is objective of this study. September was intended to be the beginning of the first year in order to have a better compatibility with agriculture and horticulture. The available data is the daily minimum temperature in all the synoptic stations and Khorasan Razavi regional Water (beginning of October). Initially, the data related to the first and last frost was extracted for each year starting from September. Then, the distance of the first and the last day of frost from September were determined numerically for each station. As a result, the data for the first and last day of frost were obtained per station (beginning of September). Screening the data to verify the authenticity and accuracy of them is the next step. Suspicious and incorrect data was corrected. Some suspicious data in Quchan and several other stations were detected and modified by regression analysis.

All the data related to Synoptic stations and Khorasan Razavi Regional Water were tested by Circulation, Mann-Whitney, Valed Wolfowitz, Grubbs Beck and three sigma tests. The following information shows the final results of basic tests to begin the frost.

1. The data from all stations are considered to be random. 2. Independency and the homogeneity of all stations are confirmed (not rejected). 3. The following stations have a low outlier data: Araye charbagh, Dahaneshore, Darone, Mashhad, Gonabad, Marzian and Senobar. Coefficient of skewness in these stations is negative. These factors indicate that their data are asymmetric and skewed to the left. This means that producing the lower outlier data is one of their intrinsic properties and these outliers do not have a lot of deviation from the body. So it can be part of the intrinsic properties of the sample.

4. The following stations: Baghsngan, Dargaz, Malek Abad, Yengejeh waterfall have a high outlier. Coefficient of skewness is positive in these stations. These factors indicate that their data is asymmetric and skewed to the right. This means that producing the higher outlier data is one of their intrinsic properties and these outliers do not show a large deviation from the body of the data and they can be part of the intrinsic properties of the sample.

The final result of the basic tests for the end of frost has been given below:

1. The data from all stations are considered to be random. 2. The independency and the homogeneity of all stations are confirmed (not rejected). 3. The following stations have low outliers: Bazangan, Dargaz, Gonabad, Kashmar, Manj Shirin, Paul Khatun, Sarakhs. The coefficient of skewness is negative in these stations. These factors indicate that their data is asymmetric or skewed to the left. That means producing the lower outlier data is one of their intrinsic properties and these outliers do not show a large deviation from the body of the data. Therefore, it can be part of the intrinsic properties of the sample.

4. The following stations: Arie Chahar Bagh, Bakavol, Farhadgerd, Layinno, Mozdoran, Senobar, Shamkhal and Yengejeh waterfall have a high outlier. Coefficient of skewness is positive in these stations. These factors indicate that their data is asymmetric and skewed to the right. This means that producing the lower outlier data is one of their intrinsic properties and these outliers do not show a large deviation from

the body of the data therefore, they can be part of the intrinsic properties of the sample.

Analyzing the frequency of data in the stations was carried out after the screening and basic tests. Seven extreme distributions with five estimation methods for T were fitted to the data. The test of Kolmogorov-Smirnov (KS) was used to choose the Premier rule and the goodness of fit. This statistic had a close estimation in few methods for some stations. The characteristics of the sample such as the volume and the behavior of the estimation method were considered in order to select the preferred method. Programming and software packages (Matlab.2006) were used for all the above analysis.

The following items are the result of frequency analysis. The frequency analysis of these stations (Table 1) shows that there is no distinct possible rule to be offered to analyze the first and last day of frost. The distributions of LN3 at 27.5% and GEV at 22.5% were the best distributions at the start of the frost which these states have shown their superiority (Table 1). GAMMA2 at 25% and LN2 at 20% were the best distributions at the end of the frost which these states have shown their superiority. It can be suggested that the distributions of LN3 and GAMMA2 be prioritized in the frost analysis. For example, fitting this function on the data from Golmakan station showed that the occurrence of the first day of frost is with a 2 year return period: the second of November, with a 5-year return period: the fourteenth of November with a10-year return period, the twentieth of November with a 20-year return period: November Twenty-five, with a return period of 50 years: first of August, and so on.

RESULTS

Table 1-analyzing the frequency of occurrence for the first day of frost at different return periods

Return period (year)						**Estimation method**	**Distribution**	**(Station)**
2	5	10	20	50	100			
38.8	57.3	68.9	79.5	92.7	102.1	MOMWRC	PT3	Torbat-e Jam
34.1	48.3	57	65	74.7	81.7	MOMWRC	PT3	Torbat-e Heidarie
68.7	85.5	95.4	104	114.3	121.5	MOM	LN2	Sabzevar
49.7	66.8	78	88.6	102.3	112.6	MML	GEV	Sarakhs
37.6	62.2	82	104.1	138	168	MOdM	GPA	Ghochan
65.9	80.6	89.5	97.6	107.6	114.8	MOM	GAMMA2	Kashmar
31.6	43.4	49.6	54.7	60.5	64.4	PWM	GUMBL1	Golmakan
61.3	71.8	77.7	82.8	88.9	93	MOM	GAMMA2	Gonabad
47.9	63.5	72.8	81.1	91.2	98.3	MOM	LN2	Mashhad
31.1	45.2	50.6	53.6	55.6	56.3	PWM	GUMBL1	Neishabor
34.6	51.2	61.6	71.2	83.1	91.6	MML	GEV	Fadisheh
63.6	65.6	66.1	66.4	66.5	66.6	MOMWRC	PT3	Ardak Band Saroj
27.7	48.7	65.4	83.4	109.7	131.7	MML	GUMBL1	Yengejeh waterfall
52.7	64.2	70.7	76.2	83.4	88.1	MOMWRC	PT3	Senobar
56.5	72	81.1	89.2	98.9	105.7	MOM	GAMMA2	Gonabad Senoptic
47.8	56.1	60.8	64.8	69.6	72.9	MML	GEV	Manj Shirin
52.6	64.7	69.5	72.6	75.3	76.5	MML	GUMBL1	Dahane Shor Meshkan
60.9	71.3	77.4	82.8	89.4	94.1	MOM	LN2	Jannat Abad forest
70.5	93.9	109.9	125.8	146.9	163.2	MOM	GAMMA2	Malekabad
66.3	79.4	87.2	94.2	102.8	109	PWM	GAMMA2	Doruneh
53.6	66.7	74.8	82.2	91.4	98.1	MOM	GAMMA2	Mazinan
33.2	59.5	76.9	93.6	115.2	131.4	MML	GEV	Bakavol
55.7	64.3	70.1	75.6	82.8	88.1	MOM	GAMMA2	Khairabad Taibad
67.6	85.8	97.9	109.5	124.7	136.1	MOM	GAMMA2	Sangan khaf
47.4	65.6	78	90.1	106.2	118.6	PWM	LN2	Torbat-e Jam Baghsngan
53.5	83.7	107.2	132.6	170.4	202.8	MOMWRC	PT3	Zeshk
55	67	73.2	78.3	84	87.9	MML	GUMBL1	Mazdoran
41.4	55.3	62.6	68.6	75.3	79.8	MML	GEV	Olang Asadi
46	65.5	77.6	88.5	101.9	111.6	MML	GAMMA2	Kashafrud's Khatun bridge
36	57.4	71.5	85.1	102.6	115.8	MML	LN2	Kardeh Dam
27.4	49.4	66.4	84.7	111.7	134.9	MML	GEV	Marashk
41.6	57.8	67.7	76.6	87.6	95.4	MOMWRC	PT3	Torogh dam
36.2	49.6	56.6	62.4	68.9	73.3	MOMBOB	PT3	Arie Charbagh
51.9	70.5	82.8	94.6	109.9	121.3	PWM	GAMMA2	Sarakhs synoptic
47.7	70.8	85.3	98.6	115.1	127	PWM	LN2	Bazangan
59.2	75.2	85.7	95.6	108.3	117.7	MOM	LN2	Dargaz
8.1	21.2	31.8	43	58.6	71.2	MOM	GPA	Shamkhal
53.2	64.7	75.7	89.9	100.6	111.3	PWM	GUMBL1	Farhadgerd fariman

30.2	45.6	55.4	64.4	75.6	83.7	PWM	LN2	Qadir Abad
64.7	76.9	83.9	89.9	97	102	MODMBOB	PT3	Labinto

Symbols: GPA generalized Pareto distribution. Gam2, gamma 2 parameters, LN2, lognormal 2 parameters, GEV, generalized extreme. Tr, return period (years), GUMBLE1, Gumbel type 1 distribution. LN3, 3 parameters log normal, PT3, Pearson type 3.

Table 2-analyzing the frequency of occurrence for the last day of frost at different return periods

Return period (year)						Estimation method	Distribution	(Station)
2	5	10	20	50	100			
176.4	187.2	194.7	202	211.4	218.3	MOMWRC	PT3	Torbat-e Jam
185.7	185.7	198.9	202.9	207.7	211	MOMWRC	PT3	Torbat-e Heidarie
171.8	183.6	190.1	195.6	202	206.4	MOM	LN2	Sabzevar
164.5	180.7	189.6	197.1	205.8	211.8	MML	GEV	Sarakhs
188.7	203.4	209.3	212.7	215.1	216.1	MOdM	GPA	Ghochan
169.9	182	188.6	194.1	200.4	204.7	MOM	GAMMA2	Kashmar
186.6	199.9	208.7	217.2	228.1	236.3	PWM	GUMBL1	Golmakan
168.7	182.1	189.4	195.6	202.7	207.5	MOM	GAMMA2	Gonabad
177.3	190.7	198.2	204.5	211.9	217	MOM	LN2	Mashhad
185	198	206.6	214.9	225.6	233.6	PWM	GUMBL1	Neishabor
184.9	193.9	202	212.1	229.5	246.7	MML	GEV	Fadisheh
184.8	197.4	205.7	213.7	224	231.7	MOMWRC	PT3	Ardak Band Saroj
195.4	212.9	224.5	235.6	250	260.8	MML	GUMBL1	Yengejeh waterfall
184	195.5	202.3	208.2	215.4	220.4	MOMWRC	PT3	Senobar
166.2	179.6	186.9	193.1	200.2	205	MOM	GAMMA2	Gonabad Senoptic
189.4	204.3	209.3	212.2	214.3	215.2	MML	GEV	Manj Shirin
180.2	192.4	200.4	208.1	218.1	225.6	MML	GUMBL1	Dahane Shor Meshkan
164.5	180.6	189.7	197.5	206.7	213.1	MOM	LN2	Jannat Abad forest
168.8	180.8	187.3	192.7	199	203.3	MOM	GAMMA2	Malekabad
154.5	174.6	185.8	195.4	206.5	214.2	PWM	GAMMA2	Doruneh
173.2	186.2	193.2	199.2	206	210.7	MOM	GAMMA2	Mazinan
205.3	227.3	245.4	266	298.3	327.7	MML	GEV	Bakavol
166.7	179.8	187	193	200	204.7	MOM	GAMMA2	Khairabad Taibad
161.8	175.1	182.2	188.3	195.4	200.1	MOM	GAMMA2	Sangan khaf
173.8	190	199.1	206.9	216	222.3	PWM	LN2	Torbat-e Jam Baghsngan
190.2	203.8	211.7	218.5	226.7	232.4	MOMWRC	PT3	Zeshk
177.2	190.6	199.5	208	219	227.3	MML	GUMBL1	Mazdoran
180.7	194.5	202.3	209	216.5	221.4	MML	GEV	Olang Asadi
168.2	185.3	194.7	202.6	211.9	218.2	MML	GAMMA2	Kashafrud's Khatun bridge
189.8	200.4	206.2	211.1	216.7	220.6	MML	LN2	Kardeh Dam
207.9	253	291.8	337.4	411.9	481.8	MML	GEV	Marashk
186	199.5	207.6	214.8	223.4	229.5	MOMWRC	PT3	Torogh dam
191.2	202	207.7	212.5	217.9	221.5	MOMBOB	PT3	Arie Charbagh
167.7	180.3	187.1	192.9	199.5	204	PWM	GAMMA2	Sarakhs synoptic
176.6	196.4	207.6	217.4	228.9	236.9	PWM	LN2	Bazangan
167.5	185	194.8	203.3	213.3	220.3	MOM	LN2	Dargaz
251.4	332.1	375.9	408.7	439.9	456.8	MOM	GPA	Shamkhal
192.4	208	218.3	228.2	241	250.6	PWM	GUMBL1	Farhadgerd fariman
187.4	200.4	207.6	213.7	220.8	225.7	PWM	LN2	Qadir Abad
176.5	186.8	194	200.9	209.9	216.5	MODMBOB	PT3	Labinto

Symbols: GPA generalized Pareto distribution. Gam2, gamma 2 parameters, LN2, lognormal 2 parameters, GEV, generalized extreme. Tr, return period (years), GUMBLE1, Gumbel type 1 distribution. LN3, 3 parameters log normal.

Discussion

Statistical analysis of the first and last day of frost can be useful in engineering, transportation and agriculture (especially cultivation of vegetables) and gardening in order to reduce the damage. The current study has analyzed this phenomenon for all the synoptic stations and Razavi Khorasan Regional Water. Screening and basic tests were conducted to accept the data as a sample. Seven probable rules with seven estimation method

were used to analyze the data. The results showed that three rules of LN3, GEV, GAMMA2, LN2 showed the most fitness. MOM (12 cases), PWM (8 cases), MML (11 cases) are the best methods for estimation. The frequency analysis of these stations shows that no specific probable rule could be proposed for analyzing the first and last day of frost. The best distribution at the start of frost is LN3 distribution at 27.5% and GEV at 22.5% which these states have shown their superiority. The best distribution at the end of the frost is GAMMA2 at 25% and LN2 at 20% and these states have shown their superiority. It can be suggested that the distribution of LN3 and GAMMA2 should be prioritized in the analysis of frost. For example, fitting this function on the data related to Golmakan station showed that the occurrence of the first day of frost with a 2-year return period, the second of November with a 5-year return period, the fourteenth of November with a 10 years return period, twentieth of November with a 20-year return period, Twenty-fifth of November with a 50 year return period, first of August and so on.

As can be seen, the frequency Analysis of these stations show that no specific probable rule could be suggested for analyzing the first and last day of frost. Therefore, assuming that the beginning and the end of the frost follows a probable distribution is rejected. Know, by using the zoning conducted by GIS maps and the awareness of the beginning and the end of the early autumn and late spring frosts in stations under study and the probability to predict the first and last day of frost with different probabilities such as 50%, 25%.

REFERENCES

1. Kamali Gh.A. Hajam S. and Khairkhah A. 2008. The Assessment of Relationship between durabiling of the lost spring frost & apple production loss in Tehran. P. 2-17. Workshop frost, frost and ways of dealing with it. 30 April 2008 Administration of Meteorological Semnan province, Iran, Semnan. (In Persian with English abstract)
2. Mianabadi A., Mousavi- Baygi M., Sanai Nejad H. and Nezami A. 2009. Assessment and mapping of early autumn, late spring and winter freezing in Khorasan Razavi province using GIS Journal of Water and Soil, 23(1):79-90. (In Persian with English abstract)
3. Noohi K., Sahraian F., Pedram F. and Sedaghat-kerdar A. 2007. Determination the no frost period by the dates of beginning and end of the advection and radiation frost in the region of Zanjan, Qazvin and Tehran. Journal of Science and Technology of Agriculture and Natural Resources, 46: 449-460.
4. Rahimi M., Hajjam, S., Khalili, A. and Kamali, G. A. 2007. Risk analysis of first and last frost occurrences in the central Alborz region, Iran. International Journal of climatology, 27(3): 349–356.
5. Rao, A., Khaled H. Hamed,Raton, Boca ,2000,"Flood Frequency Analysis", CRC Press LLC, 350 pp.
6. Rezaee-Pajand H. and Bozorgnia A. 2006. The gamma family and derived distributions applied in hydrology. Ferdowsi university press, Mashhad.
7. Rezaee-Pazhand H. 2001. Application of statistics and probability in water resources. Sokhan gostar, Iran, Mashhad.
8. Ricardo A. Maronna, R. Douglas Martin, V´ıctor J. Yohai,2006, " Robust Statistics", Jhon Wiley,417pp
9. Root TJ, Price JT, Hall KR, Schneider SH, Rosenzweig C, Pounds JA, 2003 ," Fingerprints of global warming on wild animals and plants", Nature (Lond) 421: 57–60)
10. Rosenberg NJ, Myers RE, 1962,"The nature of growing season frosting and along the Platte valley of Nebraska", Monthly Weather Review90: 471–478.
11. khaledy, Shahriar. (1995). Practical climatology, First edition, Ghomes publication
12. khalji, Mahdi. (2001). "Predicting the late spring cold and early autumn frosts for some agricultural and horticultural plants in the province of Chahar Mahal Bakhtiari" The University of Shahrekord
13. Stone, R., Nicholls, N., Hammer, G., 1996,"Frost in NE Australia, trends and influence of phases of the Southern Oscillation", Journal of climate 9: 1896-1909.
14. Tavakoli, M., Hosseini, M., 2006, evaluation indicators and the seasonal frost in Iran (Case Study Ekbatan station, Journal of Nivar, the new course No. 61, page 31. (In Persian with English abstract(
15. Thom, H. C. S. and Shaw, R. H., 1958," Climatological analysis of freeze data for Iowa", Monthly Weather Rev.86: 251-257.
16. Vincent LA, Peterson TC, Barros VR, Marino Mb, Rusticucci M, Carrasco G, Ramirez E, Alves LM, Ambrizzi T, Berrlato MA, Grimm AM, Marengo JA, Molion L, Moncunill DF, Rebello E, Anunciacao YMT, Quintana J, Santos JL, Baez J, Coronel G, Garcia J, Trebejo I, Bidegain M, Haylock MR, Karoly D. 2005. "Observed trends in indices of daily temperature extremes in South America "1960–2000. Journal of climate 18: 5011–5023.
17. Rezai Pajand, Hojat. (2001). The application of probability and statistics in water resources, first edition, Mashhad: sokhan Gostar press.
18. Rezai Pajand, H.; Bozorgnia, Abolghasem, (2002), non-linear regression, Mashhad, Mashhad University Press.
19. Alijani, B.. (2000) "Iran's Weather" fourth edition, Tehran: Payam Noor publication. .
20. Alijani, B. and mohammad reza kavyani. (1999). Meteorology, sixth edition, Tehran: Samt publication.
21. Alizadeh, Amin, Avaz Kochaki, (1995). Climate agriculture, first edition, Mashhad, Mashhad publication.
22. kavyani Mohammad Reza. (2007). The Microclimatology, second edition, Tehran: Samt publication.
23. Hozhirpur Gh. and Alijani B. 2007. Frost Synoptic analysing of Ardabil province. Geography and Development, 10: 89-106. (In Persian).