J. Appl. Environ. Biol. Sci., 5(12S)737-742, 2015

ISSN: 2090-4274
Journal of Applied Environmental and Biological Sciences
www.textroad.com

Statistical Analysis and Development of Probable Frost Atlas Using Meteorological Data (Case Study: Selective Isfahan province Stations)

Amir Hossein Parsamehr[1], * Jahangir Abedi Koupai[2], Zahra Khosravani[3], Abdol Rassoul Zarei[4]

1- Faculty Member of Range and Watershed Management, College of Agriculture, Fasa University, Fasa, Iran
2 - Professor of Water Engineering, College of Agriculture, Isfahan University of Technology, Isfahan, Iran
3 – PhD. Student of de-desertification, faculty of Natural Resources and desert studies, Yazd University, Yazd, Iran.
4-Assistant professor, Department of Range and Watershed Management, College of Agriculture, Fasa University, Fasa, Iran

Received: July24, 2015
Accepted: September 31, 2015

ABSTRACT

Frost is one of important climatic factors which have always caused agriculture productions to be faced with many losses and it is very important to determine the starting and end of frost for using methods of loss reduction. With this in mind, this study is aimed at investigating and determining the types of the early fall and late spring frost and their probability in one part of Isfahan province. To this aim, daily minimum temperature parameters from five synoptic stations during a 20–year period (1995-2014) were used. The data of temperature falling to 0º C (threshold) or lower, for the first time in the fall and last time in the spring, were determined and quantitative values were assigned to the date of frost. Then, their efficiency and homogeneity were estimated for being by using different experiments. The selected numbers of days (dates) were fitted to the distribution functions by SMADA software and the best distribution function was identified using the statistical parameter Residual Sum of Squares. Then, based on the fitted distribution function, occurrence of the first and last frost were determined at 50 and 80% probability levels. Finally, each of these occurrence dates was plotted with Surfer software using the geographical positions of each station (longitude and latitude). Results showed that frost period in study area with probability of 50 percent occurred from November 18 to March 20 and with probability of 80 percent from November 28 to April 1. Based on these plotted maps, the best days of planting and harvesting of the crops can be determined throughout the study area.

KEYWORDS: Probability Distributions, Early Fall Frost, Late Spring Frost, Weather Data, Isfahan province.

INTRODUCTION

One of the important factors of climate in the cold period of the year which occur in most parts of the country is the frost phenomenon. From the viewpoint of climatology, frost term is used when the minimum daily temperature falls below zero degrees Celsius, while in agricultural science; frost refers to temperatures which cause damage of plant tissues [1]. The critical temperature is not necessarily synchronized with zero temperature and may occur at temperatures above or below it. But there is more emphasis on the temperature of zero degree [2]. This phenomenon affects many activities directly or indirectly. But the greatest impacts include the energy, transport and agriculture. The effects of frost in the agricultural sector are more than in the other sectors [3]. Low temperature stress and frost in particular are limiting factors for cultivation in cold climates and cause damage to the growing plants. Protoplasm is able to continue its activities only in a limited range of temperatures. If the temperature approximates frost point, the plant life will be endangered [4]. The reported results in different years show that the cold weather and frost have caused heavy losses for various agricultural products. Therefore study of frost effects and trying to prevent it is fully justified from economic point of view.

In agriculture, the first autumn frost and last spring frosts are considered very important [5]. During the growing season, the possibility of cultivation in the area for each product is specified by the occurrence of autumn and spring frosts. The average date of the first and last frost in the autumn and spring is most appropriate measure for determining the start and end of frost and lent of growth season.

*Corresponding Author: Amir Hossein Parsamehr, Faculty Member of Range and Watershed Management, College of Agriculture, Fasa University, Fasa, Iran. Tel: +98-7153340519. Email: parsamehr@fasau.ac.ir

Frost is a clear example of a stochastic process. By definition, the stochastic process refers to those phenomena which do not definitively reveal their result before occurrence [6]. A stochastic process is a set of random variables showing different values that over time. It is clear that such events will depend on many factors a slight change of which may significantly cause a change in its nature or even prevent it from happening. Although frost, as a random event, cannot be predicted accurately, its observations lead to useful knowledge defined by the laws of probability. Therefore, an important part of understanding the mechanism of frost forecasting likely depends on knowledge about probability of occurrence of this phenomenon [7].

Lindkvist et al. (2000) showed a method to estimate frost in mountain area of Sweden [8]. Snyder [9] notes that finding a way to estimate minimum temperature is usually one of the main factors in predicting frost. Thom and Shaw [10] showed that time of frost is accidental and follows normal distribution function. Hence average and standard deviation are valid statistical indexes for studying. Rosenberg and Myers [11] deduced that time of early autumn frost is independent from late spring frost. Their result is based on statistical distribution and selecting the best distribution function. Watkins [12] specified the best frost distribution function and normal distribution by investigating frost series. Wylen [13] analyzed contingencies of frost specifications, beginning and ending date of frost, coldest temperature and the risk of cold spells in central Florida and predicted the most appropriate probability distribution function [13]. The purpose of this paper is to specify probability of first autumn frost and last spring frost in east of Isfahan province.

METHODS

Investigated area is located in east of Isfahan province and it's more that 70000 km^2. Stations are located between 32^0 $37^/$ to 33^0 $47^/$ of north latitude and 51^0 $54^/$ to 55^0 $5^/$ of east longitude and is in central Iran. It includes Isfahan, Ardestan, Khour-biabanak, Natanz, and Naeen.

To perform this project, minimum daily temperature parameter below zero was used. Therefore data from 5 synoptic stations in east of Isfahan province were selected. They include approximately half of the province area. Specifications of stations and also their geographical situation are shown in Table 1 and Figure 1, respectively.

Table 1-The specifications of studied synoptic situation

Stations	Longitude (E)	Latitude (N)	Elevation	Number of data
Ardestan	52° $23'$	33^0 $23'$	1252	15
Isfahan	51° $40'$	32^0 $37'$	1590	46
Khour-biabanak	55° $05'$	33^0 $47'$	845	21
Naein	53° $05'$	33^0 $51'$	1549	15
Natanz	51° $54'$	33^0 $32'$	1685	15

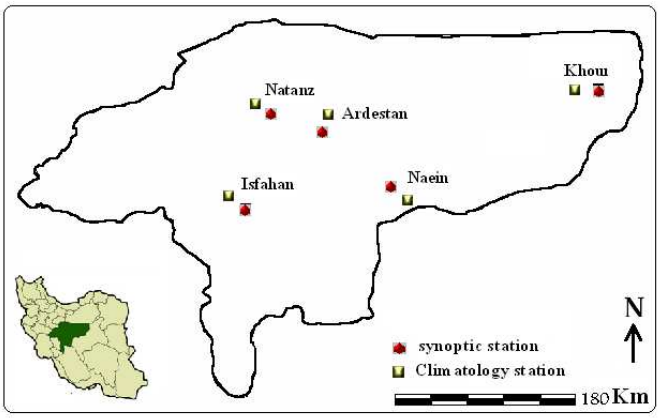

Fig. 1-The map of Isfahan province and distribution of synoptic and climatology stations

Daily minimum temperature of each year was investigated separately to determine the first date in autumn (or winter) which had zero or below zero temperature in each station. Also the same process was performed for last spring frost. In other words minimum daily temperature of each year in each station was investigated and last date in winter (or spring) in which minimum daily temperature was zero or below zero was registered. It was done for all stations and all statistical years in each station.

In this project Julian numbers were used because data of weather stations were based on Christian date. Regarding to Julian days a number should assign to each date. In arbitrary way 1 is assigned to 1st of January and 365 is assigned to last day of December. For example in reviewing data of a station in 2005, if last spring frost has happened on 6th of March (2014/3/6) and first autumn frost has happened on 23rd of December (2014/12/23) Julian numbers relating to them would be 66 and 358 respectively. With this method all dates of previous steps were obtained.

Testing data adequacy:

Data adequacy is an important factor in investigating data and having long period for data; final results would be more accurate.

Mockus equation is used to measure data adequacy and by using it we can get number of required data in level of significance:

$$N = (4.3\ t \log R)^2 + 6 \quad (1)$$

Where:

N: least number of required data

t: t student amount which is obtained by (N-6) of freedom degree.

R: ratio of numeric amount of regarded variable in 100 year return period and amount of 2 year return period.

To get t with trail and error method, different amounts of N is considered then t is put in equation 1 to reach the least difference between two sides of equation (14).

Testing for outliers:

Outliers are data which are much different from the data. Specifying them will make them to be considered and then they are tested to see whether they are false or measured properly or they belong to rare data that has happened in a short period of data. To test for outliers proposed equation from US Water Resources Association could be used:

$$Y_H = \bar{Y} + K_N S_N \quad (2)$$

$$Y_L = \bar{Y} - K_N S_N \quad (3)$$

Where:

$\bar{Y}$: average data logarithm

K_N: coefficient of testing for outlier's method from table introduced by US water Resources Association (USRA) which is calculated for a normal distribution in 10% level of significance and one sided.

S_N: standard deviation of data logarithms

If there is data among existing data which is bigger than Y_H or lesser than Y_L, they belong to outlier data [14].

Testing for normality and homogeneous data

Normality of data was investigated by SPSS program and Kolmogerph-Smirnoff test. Also for specifying homogeneity of data by SPSS program and Runs test homogeneity of data was investigated in 95% level of significance [14].

Selecting the best probability distribution function

In this step data from first autumn frost and last spring frost were analyzed separately by SMADA program in each station. By using mentioned program various distribution functions with various return periods were fit into these data and the best distribution was chosen by drawing method and calculation of residual sum of squares (RSS).

To calculate residual sum of squares equation 4 is used:

$$R.S.S = \left[\frac{\sum_{i=1}^{n} (Q_e - Q_o)^2}{n - m} \right]^{\frac{1}{2}} \quad (4)$$

Where:

RSS: residual sum of squares

Q_e: estimated amount for each data
Q_o: observed amount for each data
N: number of data
M: number of used distribution parameters which is equal 2 in normal distribution, log-normal distribution and Gumbel and is 3 in Pearson and log-Pearson distribution.
The most appropriate distribution has the least RSS and it's chosen to estimate with regarded return period.
First and last data of autumn and spring frost with various contingencies were specified by using the best distribution function. There is no high probability in predicting cold spells because it is an aero phenomenon [15].
To draw contour lines, dates of first autumn frost and last spring frost, latitude and longitude of stations and also probability dates were brought on map of Isfahan province by Surfer program and maps with same amount of probability dates were drawn. Statistical ground networking method by Surfer program is used in this research.

RESULTS AND DISCUSSION

Results obtained from Mockus test to specify the least statistical years on various stations showed that 8 to 11 statistical year (in various stations) with 10% error is required but number of statistical years in investigated stations are 15 to 46. So data have adequacy in 95% level of significance. By performing test for outliers no data were known as outlier. Beside that results of normal and homogeneous data showed in data are normal and homogeneous. Results are shown in Table 3. Results in Table 3 describe this meaning (normality and homogeneous) when amounts are bigger than 0.05.

Table 2-Te results of normal and homogeneous of different station

Stations / Tests	Ardestan		Isfahan		Khour		Naein		Natanz	
	last spring frost	first autumn frost	last spring frost	first autumn frost	last spring frost	first autumn frost	last spring frost	first autumn frost	last spring frost	first autumn frost
Normality	0.72	0.88	0.96	0.30	0.95	0.77	0.74	0.84	0.99	0.47
Homogeneous	0.98	0.57	0.92	0.90	0.17	0.18	0.69	0.60	0.11	0.86

To specify the best distribution function in probability of first autumn frost and last spring frost in each stations data were fitted into distribution functions by using SMADA program and related curves were drawn for each of them.
In analyzing distribution functions, distribution which has less RSS amount is considered as the best distribution in related data series. Results are in Table 3.

Table 3- The selection of best statistical distribution for different data

Stations / Type of distribution	Ardestan		Isfahan		Khour		Naein		Natanz	
	last spring frost	first autumn frost	last spring frost	first autumn frost	last spring frost	first autumn frost	last spring frost	first autumn frost	last spring frost	first autumn frost
Normal	√					√				
Log-normal		√								
Pearson				√	√					
Log- pearson			√						√	
Gumble							√	√		√

First and last probability dates of autumn and spring frost with various contingencies were obtained by using SMADA program. Results were used by Surfer program and maps of probability of first autumn frost and last spring frost were drawn but there are just maps with 50% and 80% probability because cold spells cannot be predicted by high probability.

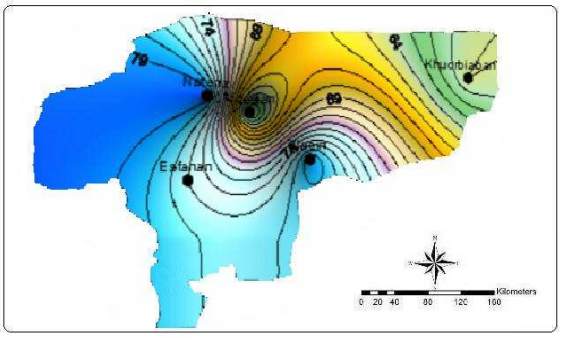

Fig. 2-The contour line of data of last spring frost regarding to1st of January for 50% probability

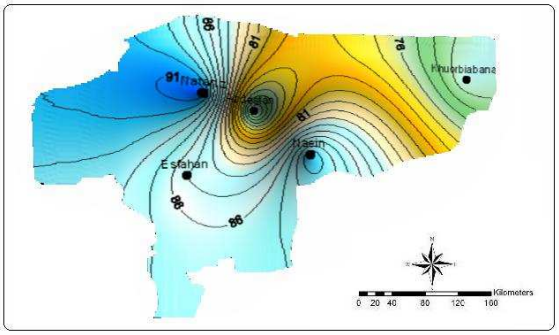

Fig. 3-The contour line of data of last spring frost regarding to1st of January for 80% probability

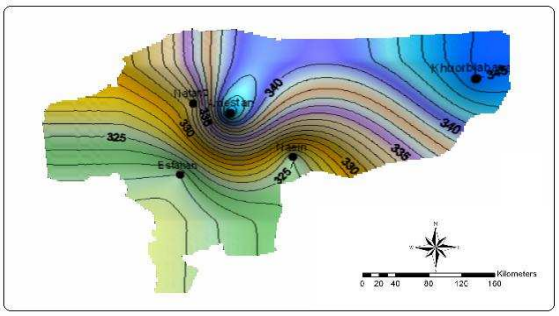

Fig. 4- The contour line of data of first autumn frost regarding to1st of January for 50% probability

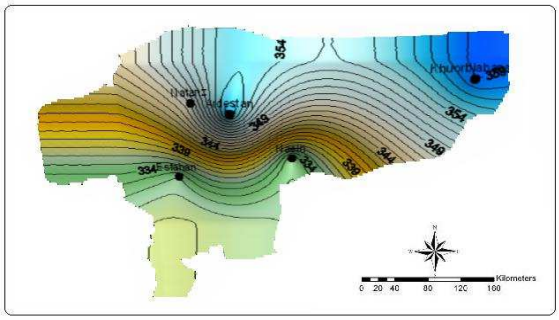

Fig. 5-The contour line of data of first autumn frost regarding to1st of January for 80% probability

Conclusion

It is concluded that from north to south and east to west, first frost happens sooner and last frost happens later. It may be related to the mountain area of west and south west of investigated area. Purpose of drawing maps is to decide to select appropriate time for planting and removing products that are planted in the area. For instance by considering agricultural activities in Natanz, there is 80% probability of having frost lasting to 20th of March, therefore we can decrease the possible damages of cold spells and frost in gardens and farmlands. The same analysis can be performed for different regions and prevent from heavy damages of early autumn frost and last spring frost.

REFERENCES

1. Sari Sarraf, B. B. Haji Mirzayee, and A. Malekiyan, 2010. The Survey of Relation of Annually Freezing Period in Decreasing the Duration of Agricultural Crop Growth Period of Ardebil, Journal of Geography and Planning, 31: 187-208.
2. Kaviani, M. R., S. H. Hosseini Abri, and E. Asadi Broujerdi, 2002. Probability of occurrence and return period of minimal temperature in almond orchards at Saman region during March, April and May. Journal of Agriculture Science and Natural Resources, 9(3): 49-57.
3. Hejazi Zadeh, Z., and M. H. Naser Zadeh, 2005. Calculation and analysis of frost hours continuous using Delphi programming language, Journal of Geographical

Research, 76: 139-150.

4. Khaledi, Sh., 1995. Applied Climatology, Ghoms Publications (in Persian), Tehran, pp. 87-89.
5. Noohi, K. F., Sahraeian, M. Pedram, and A. Sedaghat Kerdar, 2009 ۹. Determination of Frost Free Season by Using Dates of First and Last Advection and Radiation Frosts in Zanjan, Gazvin and Tehran Regions, Journal of Science and Technology of Agriculture and Natural Resources, Water and Soil Science, 12(46): 449-460.
6. MirMousavi. S.H., and M. Hosseinbabai, 2011. Study of frost tempo_spatial probability distribution in Zanjan province, Geography and Environmental Planning Journal, 43(3): 167-184.
7. Mahmoudi, P., M. Khosravi, A. Masoudian, and B. Alijani, 2013. Climatology Atlas of Frosts Statistical Properties of Iran, Geographical Research, 28(111): 55-66.
8. Lindkvist, L., T. Gustavsson and J. Bogren. 2000. A frost assessment method for mountainous areas, Agric. For Meteorol, 102:51-67.
9. Snyder, R. L., 2000. Predicting temperature during freeze nights, Dept. of Land, Air and Water Resources, University of California, Davis, CA 95616. USA.
10. Thom, H. C. S. and R. H. Shaw. 1958. Climatological analysis of freeze date for Iowa, Wea. Rev, 86:251 – 257.
11. Rosenberg. N. J., and R. E., Myers, 1962. The nature of growing season frost, Mon. Wea. Rev, 10: 471–479.
12. Watkins, S. C., 1991. The annual period of frost temperatures in central England, 1850 – 1959. Inter .J. Climatol, 11:889 – 896.
13. Wylen, P. R., 1988. Statistical analysis of cold spells. J. Appl. Meteor, 27:67-76.
14. Kite, G. W., 1985. Frequency Analysis in Hydrology, Water Res. Pub., Colorado USA.
15. Ziaee, A., A. A. Kamgar haghighi, A. Sepaskhah and S. Ranjbar, 2006. Development of Fars province probable minimum temperature Atlas using meteorological data, Journal of Science and Technology of Agriculture and Natural resources, 10(3) : 13-26.