Study and Preparation of Frost Maps for Field and Orchard Crops in West Azarbaijan-Iran

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Received 25 January 2014
Accepted 22 November 2014

1. Introduction

Early frost in the autumn and late spring frost are the most common disasters related to the huge agricultural damages in West Azerbaijan province. Among 39 natural disasters in the world, 7 dominant disasters occur in this region and the frost has the first rank regarding the damage to the public sector and insurance industry in recent years. Based on several reports, early spring frost damage could reach to 25-100% of total production among orchard trees including almond, apricot and walnut. Considering the irregular and unscientific development of orchards in the past, therefor, determining of suitable sites (low frost risk) for crop production based on GIS is necessary. Probability and the risk of causing damage due to temperature differ depending on the time and year as well as plant sensitivity to temperatures below zero. Numerous studies have been done in the country and abroad to determine the probability of occurrence of frost. However, most of these studies have failed to consider the frost threshold temperature at which the plants are damaged. Determining the most probable occurrence of frost with a hypothetical risk in province of west Azerbaijan, which is also known as an agricultural poles in Iran is economically important by applying of the latest tools and geo-statistical methods and preparing spatial patterns of the frost dominated sites in the region are the main objectives of this paper.

2. Study Area

The study area is located in northwestern Iran, western Azerbaijan Province (latitude 44°02' to 47°32' E and 354°58' to 39°46' N). The province has an area of 37,600 square kilometers (without the Urmia Lake) and limited on the north by Turkey, Armenia and the Republic of Nakhichevan, on the west by Turkey and Iraq, and on the south by East Azerbaijan and Kurdistan provinces.

3. Material and Methods

In the previous studies related to frosts, minimum daily temperature records of 34 synoptic, evaporation and climatology stations of the province were collected. The

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critical damage temperature (Tc) from year to-year were extracted from data bank as 0 °C for very sensitive plants, -2 for sensitive plants and -4 °C for approximately resistant plants. Probability and frequency of spring and autumn time series of frost occurred dates were determined with fitting Gumble and non-extreme distributions to the data. A basic program was prepared for fitting normal, log normal, Pearson Type III, log Pearson, and Gumble distributions. Frequency analysis was applied to the data for all 34 stations. Probabilities were calculated using a Gumble extreme value function. To avoid too many frost maps, only 2 seasons, 3 critical temperature thresholds and 10 probability classes, and one common frequency formula were adopted.

IDW (inverse distance weighted), Kriging and Co-Kriging interpolation methods are used for spatial prediction with Geostatistical wizard in ARCGIS10. The IDW is referred to as a deterministic interpolation method because it is directly based on the surrounding measured values or on specified mathematical formulas that determine the smoothness of the resulting surface. However, Kriging, which is based on statistical models, assumes that the distance or direction between sample points reflects a spatial correlation that can be used to explain variation in the surface. The Kriging tool fits a mathematical function to a specified number of points, or all points within a specified radius, to determine the output value for each location. The best spatial prediction method was selected based on cross validation approach with RMSE criteria. The cross validation is based on removing one data location and then predicting the associated data using the data at the rest of the locations and Root Mean Square Error, indicates how closely the model predicts the measured values.

4. Results and Discussion

Based on the results of the interpolation methods, Co-Kriging method showed better results in 67% of cases. In the west Azerbaijan, Co-kriging is dominant with height. The fitting of height, represents a rippling effect of mountains, hills and the effects microclimates. Frost occurrence generally increases by increasing of the height and temperature gradients increase the intensity of the frost. The latitude also could be related to the direction of air masses and frost flow. Higher coefficients (irregular occurrence of frost at a given date) are seen at mountainous area such as north-west and west of Urmia Lake and Tekab and fluctuations of frost are evident in the form of coefficient of variation in the most of maps. Early autumn frosts in the Makoo and Tekab regions occurred much earlier and are rarely seen in the region of Sardasht and the central region and Nazloo from16 October to 15 November. Late spring frost has the same process and lasts from 24 March to 25 February. Coefficient of variations indicating regular or irregular data happened during years. The lower coefficient of variation on the map indicating close frost occurrence time at that point over the years and therefore, the occurrence of the frost could precisely be forecasted. Final frost map of province with 75% probability of occurrence as presented in this paper means that for example among 20 years of history 15 years of frost occurred at this date. Obviously, higher probability levels mean lower risk and vice versa. According to the provided maps, the coefficient of variations was high (0.07-0.09) in central parts as well as in Khoy, Piranshahr, Sardasht and Tekab regions indicating that frost occurs in irregular

patterns. In contrast, lower coefficient of variations (0.06 – 0.045) in northern parts of province and regions surrounded by Urmia Lake indicate a regular frost occurrence at springtime.

5. Conclusion

Preparation of frost maps in every area has a particular importance in reducing the risk of frost damage. In the present study, for mapping the risk of frost in West Azerbaijan Province -Iran, the minimum temperature at different stations were recorded and date of the frost occurrence in the fall and spring for three classes were extracted. Gumble distribution as a dominant regional distribution is proposed for the distribution of frequency analysis. Co-Kriging interpolation method is the dominant method for producing maps related to the frost. Optimized models posing half-angle, resulted in significant improvement in the fit of the model. Frost damage was increased further to the west and mountains regions. By comparing maps a clear trend between the high potential frost and cold masses was detected. These maps can be used for a better field selection for orchards, the development of greenhouses and areas prone to industrial development.

Key Words: Frost, Early autumn frost, Late spring frost, Site selection, Frost maps, Spatial analysis

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