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EVALUATION OF FROST RISK DATES IN ANTALYA AND BURDUR BASIN

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Abstract
The main aim of agriculture is to obtain high quality and healthy products from the unit area by using technology which considers contemporary and sustainability. Climate is the main factor for quality and yield. The number of automatic climate stations used by the public and private sector for early warning purposes has reached to 1000 and the hourly rainfall, temperature, leaf wetness, soil moisture, soil temperature, solar radiation, wind speed values are measured in these climate stations. With this data computers are make a estimation for frost, disease, etc. and send the warning notes to the person's mobile phone. In this regard, the necessary precautions for frost are taken immediately, the problem of plant harms and diseases can be used at the right time and at the right dosage without the problem growing too much. Thus, both labor and economic savings are achieved. In this study carried out in Antalya and Burdur Basins risk dates of frost have been determined. The days when frost formation is expected are determined at different probability levels by different geostatistical methods by using daily minimum temperature of climate stations values in spring and autumn. Inverse Distance Weighted (IDW) and Radial Basic Functions (RBF) methods gave proper results. The frost risk maps for the IDW method for 80%, 50%, 20% probability levels in spring and autumn are given with the digital terrain model of the basins.

Keywords: agrometeorology, climatology, frost, geostatistic, probability.

1. INTRODUCTION

The main target of agriculture is; to produce high quality and healthy products by using agricultural technology which takes contemporary and sustainability into account. Climate is the main factor for quality and yield. Today the number of automatic climate stations that are used for early warning purposes by the public and private sector in Turkey reaches about 1000 and they are measuring rainfall, temperature, leaf wetness, soil moisture, soil temperature, solar radiation and wind speed hourly values.

Antalya province agricultural areas suffer significant damage from disasters such as hail, frost, snow, extreme rainfall, storm, hose, flood, drought, fire caused by climatic factors in every period of the year. Although the lowest loss in recent years was realized in 2002, the economic loss is about 11 million dollars. Frost causes many barriers especially in fruit and vegetable breeding, preventing the plants from continuing their life when temperatures drop very low values. It is not possible for the physiological events that occur in the plant after freeze of the water in the plant. This usually causes the plants to die or the yield to be low.

A multi-regression equation was established between daily minimum temperatures and geographical coordinates and topographical data (elevation, slope, view) using 23 meteorological stations data in a study in Marne area of France. The freeze-sensitive zones were determined with

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the help of the daily minimum temperature map created and the frost damage areas observed in the spring of 2003 were compared with the predicted map, indicating that the observed and predicted areas are compatible (Madelin and Beltrando, 2005).

2. MATERIALS AND METHODS

The study area is Antalya and Burdur Basin, where Turkey is heavily produced primarily apple, fruit and vegetable farming region. Within the boundaries of these 2 basins are mainly 3 provinces: Antalya, Burdur and Isparta. A significant part of the lakes area, which has a very good agroecology for apple farming, is within the boundaries of these basins. The study area and basin boundaries are given in Figure 2.1.

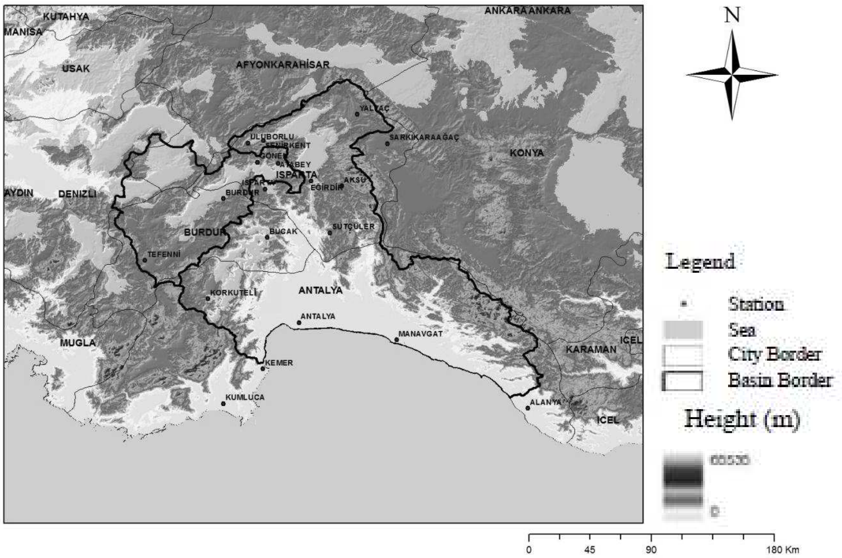

Figure 2.1 Digital terrain model of stations and Antalya and Burdur basins

2.1 Climate Characteristics of the Research Site

Although the climate of Antalya is generally accepted in the Mediterranean climate, which is expressed as hot and dry in summers and warm and rainy in winters, there are three climate types that vary considerably in terms of the meteorological element values.

a. Coastal Climate: It is a warm and dry climate in summer, warm and dry in summer, and warm and rainy in winter.

b. Inner West Segment Climate: The climatic type seen in the inner western part of the province is not very warm and dry as it is in coastal area, it is not warm in winter and it is quite cold and very heavy rainfall is seen in this area.

c. Inner East Cutting Climate: The climate of the inner eastern part of the province shows privileges from the coastal side in terms of all meteorological element values and from the inner western regions in terms of precipitation.

Burdur climate has a different character because of being a gateway area between Aegean, Mediterranean and Central Anatolia. Mountains rising in the southwest and west prevent the warm and humid air from the seas for entering the interior. Due to the fact that the provincial lands are far away from the influence of the Mediterranean climate and the present elevations in the southwest, the winters are cold and the summers are hot. In terms of precipitation it resembles the Mediterranean climate.

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Isparta province is in the transition zone between Mediterranean temperate climate and Central Anatolia continental climate. For this reason, more terrestrial climate prevails in the region (summers are hot and arid, winters are cold and snowy). However, the temperate Mediterranean climate is seen in the pit areas to the south of the Taurus Mountains (summers are arid and warm, winters are warm and rainy).

2.2 Data Used In The Research

In this study, which is the evaluation of frost risk dates in Antalya and Burdur basins, the main material is the minimum temperature values measured daily at the environmental meteorological stations. The location of the meteorological stations is given in ***Figure 2.1***.

In this study, the daily minimum temperatures obtained from studies conducted by the General Directorate of State Meteorology (GDSM) and the frost dates obtained from these temperatures were used. The data of the stations in ***Figure 2.1*** between 1975-2006 are taken as basis. The many years minimum temperature averages are used for instead of the missing data.

2.3 Method

The flow chart for the steps taken in the survey is given in ***Figure 2.2***.

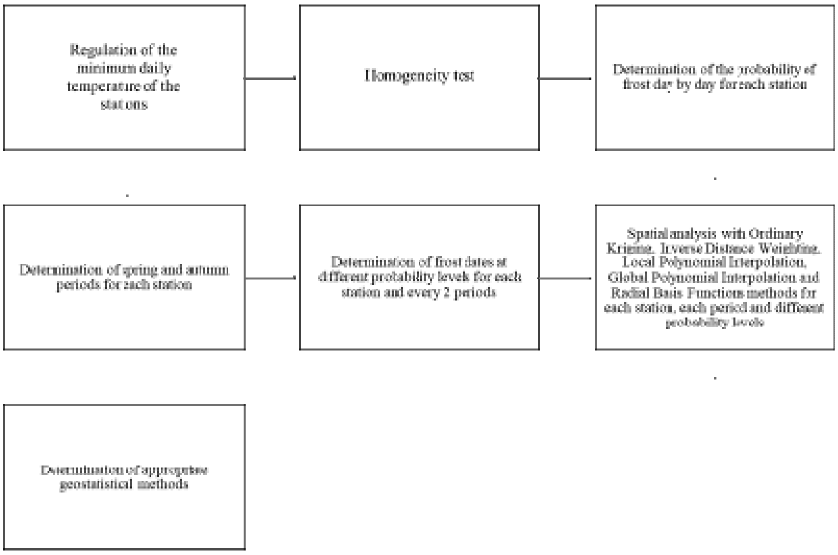

Figure 2.2 Flow diagram of the flow of the cycle in the study

2.3.1 Regulation of daily minimum temperature data

The daily minimum temperature values for the 19 stations taken from GDSM in 1975-2006 are combined in the same file and placed in the date order. For the determination of the average of long years, the day of the year (1-365), if there is no frost, it is set to zero (0). If there is frost, one (1) value is entered.

2.3.2 Determination of frost formation possibilities

In each case, the probability of frost day by day is obtained by the ratio of the number of frost days in each year to the total number of years in a 28-year period.

$$P_d = {N_d}/{N_t}$$

Equality:

P_d : Probability of freezing

N_d : Number of years in which the frost occurred in the period studied,

N_t : Total number of years in the period under review

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2.3.3 Determination of Spring and Autumn Periods

Since the frost event has to be examined for two periods, these two periods have to be determined for each station first. As mentioned earlier, if the standard January 1 - July 1 date was used, some stations encountered an error. For this reason, minimum temperature of ten days averages was taken at each station, and a graph was prepared from these values and it was determined which day was the lowest and which was the highest during the year. These dates were used to make two rounds in spring and autumn for the one year period.

2.3.4 Determination of frost dates for different probability levels

In each station, the probability of frost, obtained based on days, is divided into 2 groups, namely spring frosts and autumn frosts according to the dates obtained in the previous phase. Then, day-frost likelihood charts were prepared for each group and the days (ie, dates) corresponding to the probability levels of 20%, 50% and 80% of these charts were determined.

2.3.5 Determination of spatial distribution of frost dates

The following geostatistical methods have been used in spatial analysis of the basins of frost dates obtained for each probability level at each station in each period:

a) Inverse Distance Weighting (IDW)
b) Global Polynomial Interpolation (GPI)
c) Local Polynomial Interpolation (LPI)
d) Radial Basis Function (RBF)
e) Ordinary Kriging (KO)

Geostatistics is an applied field of statistics and was first used to solve estimation problems in earth sciences. By using geostatistical methods, unbiased and minimum variance estimates can be made by taking into consideration the positions of the points where the observations are made and the correlation between the observations (Olea 1982, Çetin ve Tülcü 1997, Başkan 2004).

2.3.6 Determination of appropriate geostatistical method

It has been determined which geostatistical method yields better results by comparing the estimated frost dates and the actual frost dates from the obtained maps. Statistical comparison t-test was used (Yurtsever 1984).

3. RESULTS AND DISCUSSIONS

3.1 Daily Minimum Temperature Data Regulated

A sample schedule of daily minimum temperature data for each station is given in ***Table 3.1***.

As seen in ***Table 3.1***, no frost occurred at Burdur station on 01.01.1975 (1^{st} day of the year), the frost value was taken as "0". At the Burdur station on 07.01.1975 (7^{th} day of the year) the minimum temperature was -2.6 ^{o}C, so frost occurred and the frost value was taken as "1". These data are calculated for each station and observation period every year, every day.

Table 3.1 Data issued for the Burdur station

Date	Day	Min. Temp. (^{o}C)	Frost Status	Frost Value
01.01.1975	1	5,4	No Frost	0
02.01.1975	2	1,2	No Frost	0
07.01.1975	7	-2,6	Frosty Day	1
08.01.1975	8	3,5	No Frost	0
11.01.1975	11	-6	Frosty Day	1
…	…	…	…	…
30.12.2006	364	-7,2	Frosty Day	1
31.12.2006	365	-3	Frosty Day	1

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3.2 Homogeneity Test Results

The homogeneity test results of the data on the stations evaluated in the study are given in ***Table 3.2***. When the table is examined it is seen that the data related to all stations are homogeneous.

Table 3.2 Single-sample homogeneity test results of Kolmogorov-Smirnov.

Station Name (Code)	Dmax	Dtable		Station Name (Code)	Dmax	Dtable
Aksu (17895)	0,046	4,301		Atabey (17885)	0,055	5,820
Alanya (17310)	0,061	6,607		Eğirdir (17882)	0,045	4,901
Antalya (17300)	0,065	7,063		Gönen (17674)	0,043	4,454
Kemer (17953)	0,072	4,685		Isparta (17240)	0,047	5,073
Korkuteli (17926)	0,059	6,415		Şarkikaraağaç (17863)	0,058	4,321
Kumluca (17951)	0,070	5,566		Senirkent (17826)	0,047	5,123
Manavgat (17954)	0,070	7,574		Sütçüler (17893)	0,067	5,455
Bucak (17887)	0,050	4,608		Uluborlu (17864)	0,057	6,159
Burdur (17238)	0,058	6,234		Yalvaç (17828)	0,046	4,864
Tefenni (17892)	0,060	6,513				

Because of Dmax <Dtable, the distribution of minimum daily temperatures is normal. The results are homogeneous for all stations.

3.3 Frost Risk Probabilties

The probabilities of frost for the days of the year at Burdur station are given in ***Table 3.3***. As seen in ***Table 3.3***, the probability of frost in Burdur on the 20th day of the year (January 20) is 0.72 (72%). This means that in the 1975-2006 period (32 years period) at Burdur station, there are 23 years frost on January 20, so the probability of frost for the 20th day of the year (January 20) is 23/32 = 0,72. The probabilities of frost daily for each station evaluated in the study have been determined.

Table 3.3 Probability of frost for Burdur station

Day	Date	Frost Probability		Day	Date	Frost Probability
1	1 January	0.41		17	17 January	0.78
2	2 January	0.34		18	18 January	0.75
5	5 January	0.56		…	…	…
7	7 January	0.56		…	…	…
13	13 January	0.63		364	29 December	0.38
14	14 January	0.63		365	30 December	0.56
15	15 January	0.59		366	31 December	0.50
16	16 January	0.59				

3.4 Spring and Autumn Periods

The graph of the long-term average daily minimum temperature obtained for the Burdur station is given in ***Figure 3.1***.

As seen, the minimum average daily minimum temperature is 5 February (36th day) and the highest value is 25th July (205th day). These days, Burdur station was used to leave the spring and autumn. For Burdur station, the spring term is between February 5th and July 24th, and the autumn term is between July 25th and February 4th.

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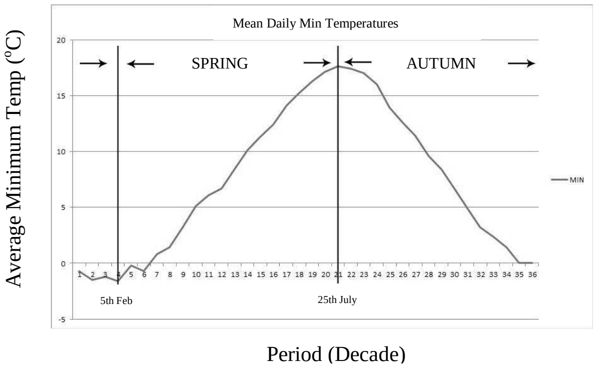


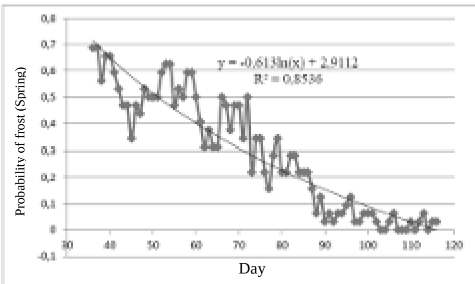
Figure 3.1 Distribution of daily minimum temperature averages at the end station

Table 3.4 Probability of frost during spring and autumn days at Burdur station

Spring Period		**Autumn Period**	
Day	**Frost Probability (Pd)**	**Day**	**Frost Probability (Pd)**
42	0,53	297	0,00
43	0,47	298	0,00
…	…	…	…
206	0	399	0,63
207	0	400	0,72

3.5 Frost Dates for Different Probability Levels

The change graph of the spring frost event obtained for Burdur station on days basis is given in ***Figure 3.2***.



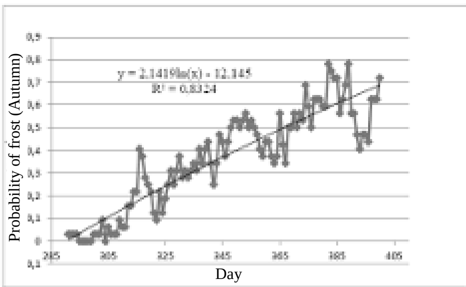


Figure 3.2 Probability of frost during spring and autumn period for Burdur station

By using spring graph, the expected dates of frost formation at Burdur station at 20%, 50% and 80% probability levels are determined. It is not expected to frost at 80% probability. The expected date of frost formation with a probability of 50% is 20th February (Day 51). The expected date for frost formation with 20% probability is 23th March (Day 83). The dates obtained using the autumn graph are November 13 (Day 318) for the 20% probability level and January 1 (Day 1) for the 50% probability level. The chart was not able to determine any day for the 80% probability level.

The frost dates for different probability levels were obtained from the graphs obtained in the spring and autumn period in all the stations evaluated in the study.

3.6 Frost Risk Maps

Frost risk dates maps were obtained with the specified geostatistical methods for different periods and different probability levels are examined in this section.

3.6.1 Frost risk maps obtained by the method of Inverse Distance Weighted (GPI)

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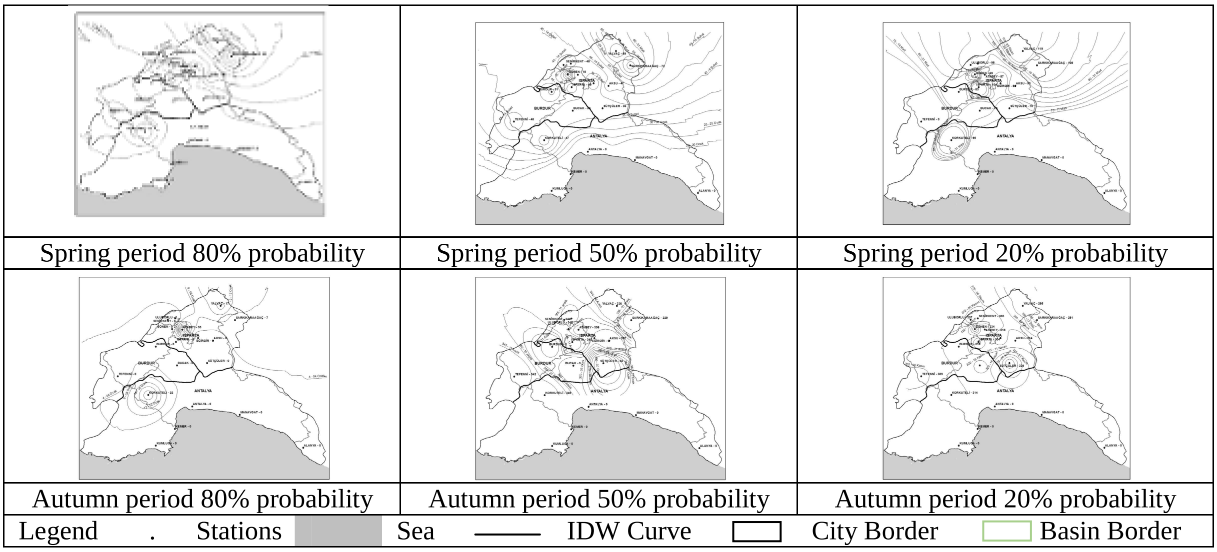

Figure 3.3 Inverse Distance Weighted method

3.6.2 Frost risk maps obtained by the method of Global Polynomial Interpolation (IDW)

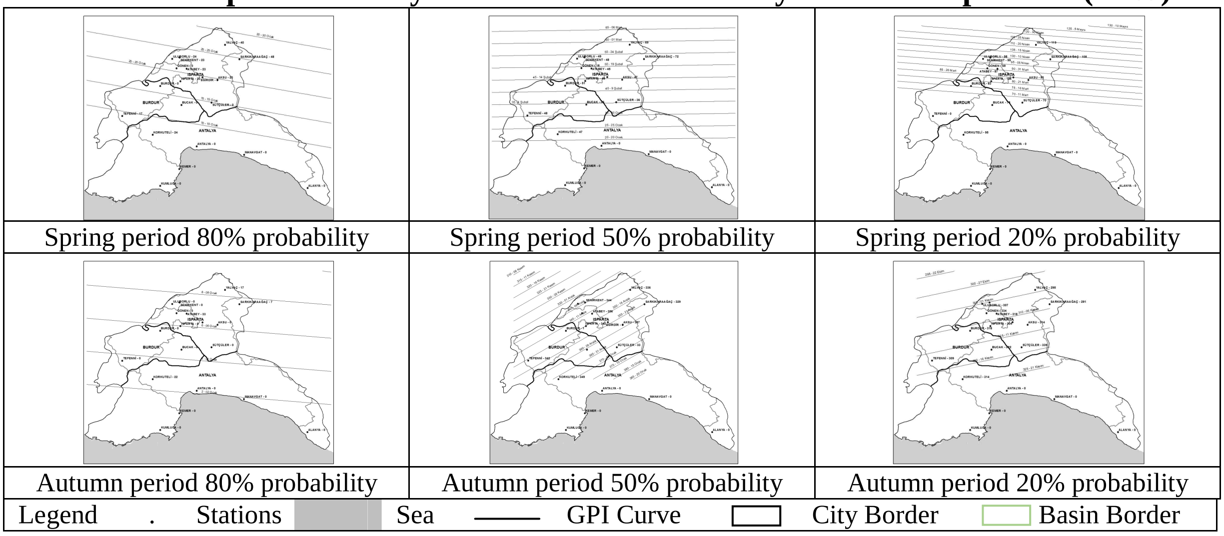

Figure 3.4 Global Polynomial Interpolation method

3.6.3 Frost risk maps obtained by the method of Local Polynomial Interpolation (LPI)

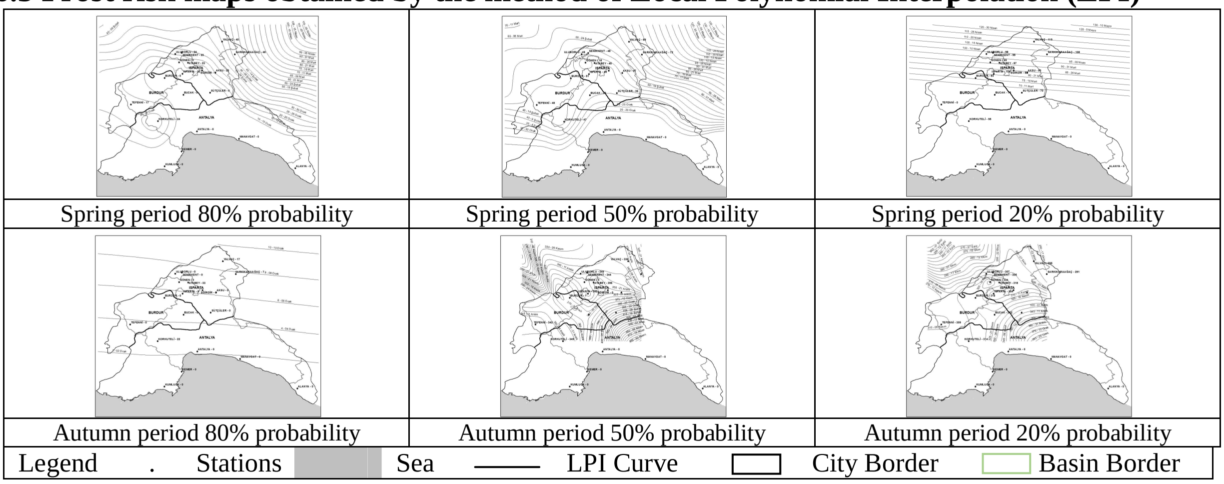

Figure 3.5 Local Polynomial Interpolation method

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3.6.4 Frost risk maps obtained by the method of Radial Basis Function (RBF)

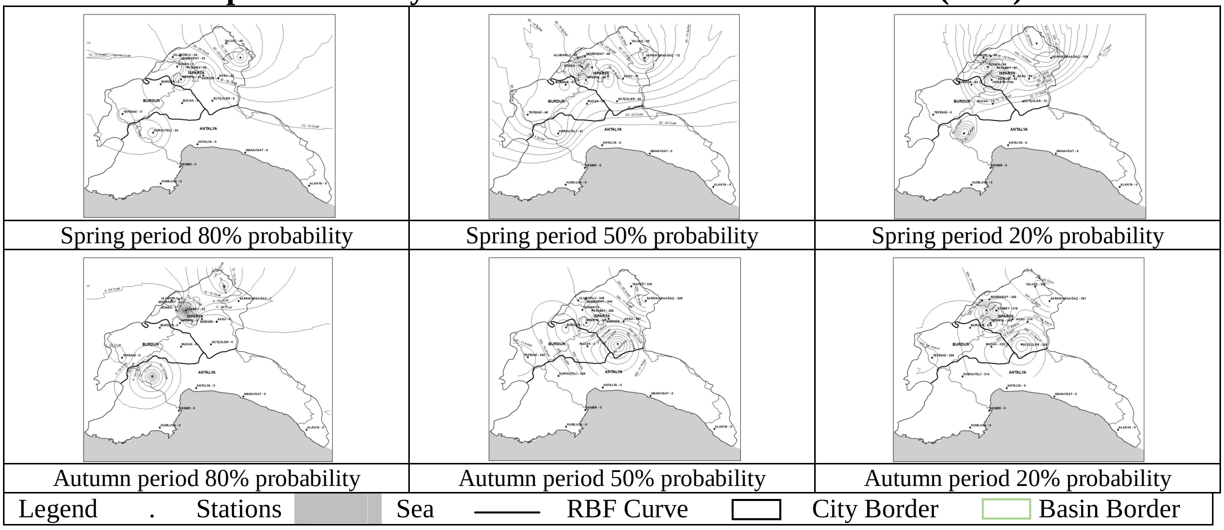

Figure 3.6 Radial Basis Function method

3.6.5 Frost risk maps obtained by the method of Ordinary Kriging (OK)

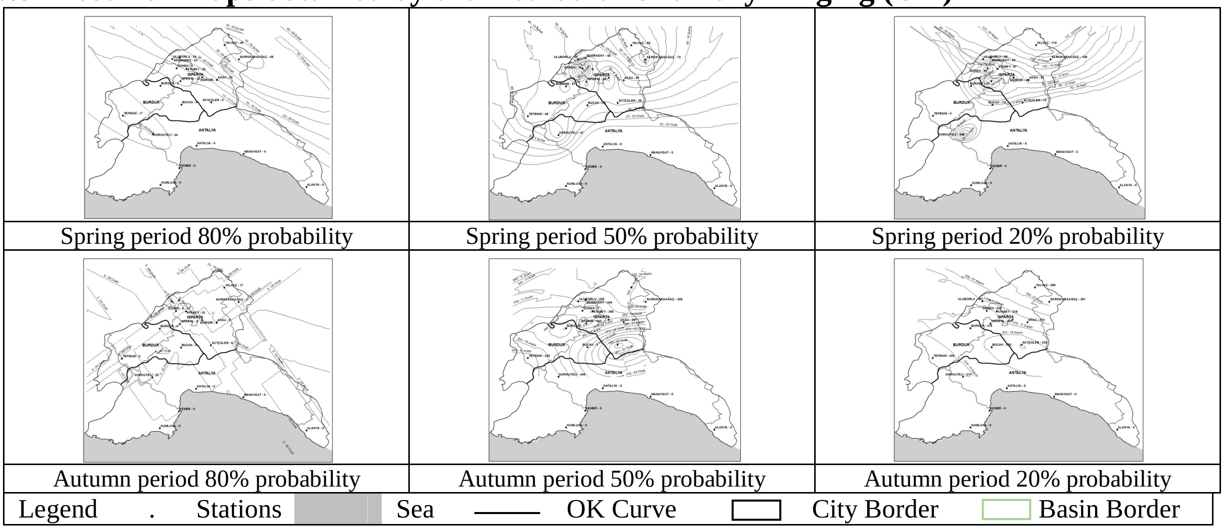

Figure 3.7 Ordinary Kriging method

3.7 Appropriate Geostatistical Method Results

By comparing the freeze risk dates and the actual frost risk dates at different probability levels for the stations, the IDW and RBF methods gave the same results as the real values, using the maps of the frost risk dates obtained with the geostatistical methods obtained in the study. LPI, GPI and OK methods are generally given quite different frost risk dates than real values. The results were compared statistically with the t-test and the values were given in the ***Tables 3.5 – 3.6***.

Table 3.5 Spring t-test results

Period	Method	Observation Number (n)	Mean	Standart Deviation	t	T_{table} (%5)	Conformity
Spring %80	Measured	9	27,222				
	IDW	9	27,222	9,947	0,000	2,306	Appropriate
	GPI	9	19,000	7,071	1,163	2,306	Appropriate
	LPI	9	24,889	11,274	0,207	2,306	Appropriate
	RBF	9	27,222	9,947	0,000	2,306	Appropriate
	KO	9	22,000	10,840	0,482	2,306	Appropriate

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Spring %50	Measured	14	46,071				
	IDW	14	46,071	13,865	0,000	2,160	Appropriate
	GPI	14	43,786	10,562	0,216	2,160	Appropriate
	LPI	14	46,714	11,303	-0,057	2,160	Appropriate
	RBF	14	46,071	13,865	0,000	2,160	Appropriate
	KO	14	46,071	13,697	0,000	2,160	Appropriate
Spring %20	Measured	13	90,923				
	IDW	13	90,923	15,047	0,000	2,179	Appropriate
	GPI	13	83,231	19,816	0,388	2,179	Appropriate
	LPI	13	83,308	19,893	0,383	2,179	Appropriate
	RBF	13	90,923	15,047	0,000	2,179	Appropriate
	KO	13	90,923	14,908	0,000	2,179	Appropriate

Table 3.6 Autumn t-test results

Period	Method	Observation Number (n)	Mean	Standart Deviation	t	T_{table} (%5)	Conformity
Autumn %80	Measured	4	19,750				
	IDW	4	19,750	10,813	0,000	3,182	Appropriate
	GPI	4	6,500	2,380	5,566	3,182	Inappropriate
	LPI	4	6,750	2,630	4,943	3,182	Inappropriate
	RBF	4	19,750	10,813	0,000	3,182	Appropriate
	KO	4	5,750	1,258	11,126	3,182	Inappropriate
Autumn %50	Measured	12	352,667				
	IDW	12	352,667	18,367	0,000	2,201	Appropriate
	GPI	12	352,167	9,476	0,053	2,201	Appropriate
	LPI	12	352,667	18,302	0,000	2,201	Appropriate
	RBF	12	352,667	18,367	0,000	2,201	Appropriate
	KO	12	352,667	18,367	0,000	2,201	Appropriate
Autumn %20	Measured	14	312,500				
	IDW	14	312,500	13,346	0,000	2,160	Appropriate
	GPI	14	311,643	5,865	0,146	2,160	Appropriate
	LPI	14	312,214	12,398	0,023	2,160	Appropriate
	RBF	14	312,500	13,346	0,000	2,160	Appropriate
	KO	14	312,357	7,899	0,018	2,160	Appropriate

4. CONCLUSIONS

The aim of this study is to prepare the frost hazard maps of different probability levels using climate data in Antalya and Burdur basins. In the past years we can clearly see the effects of frost events and to hold a very important place in the agriculture of our country. The IDW and RBF methods were giving statistically satisfactory results in both periods and every 3 probability levels. Estimated day values in both methods are identical to real day values. For this reason, both methods can be interpreted as appropriate.

The results were mapped using the Spline, Inverse Distance Weighted (IDW) and Kriging methods with temperature values of 6 387 km² area in the Arizona region of the United States and 36 meteorological observation stations. As a result; The Kriging method makes the best possible estimation of spatial interpolation. After the Kriging method, the second best estimate is obtained from the results of the IDW method (Anderson, 2003; Keskiner, 2008).

In the study using 11 meteorology observation station data in 31 522 km² area in Bulgaria, the area rainfall was mapped using eight different interpolation techniques using Surfer software. As a result; They emphasize that the selection of the interpolation method depends on the number of spot meteorological data measurements and the knowledge of the climatic characteristics of the area. They have explained that the accuracy rate of the precipitation estimates is obtained with Kriging, Minimum Curvature and Radial Basis Function methods in their investigations (Nikolova and Vassilev, 2006; Keskiner, 2008).

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In Spain, area of 29 750 km² using 121 meteorological station data, it was determined that one method did not comply with the mapping of monthly total rainfall data and that different models gave results compatible with different data sets. It has been explained that the Inverse Distance Weighted technique is better than the other methods in working scale (Miras-Avalos et. al. 2007; Keskiner, 2008).

Tveito and Forland (1999) examined the spatial variation in monthly temperature norms (1961-90) from southern Norway to their study. An approach incorporating linear regression as well as deterministic and geostatistical models has been applied (residual kriging). The reduced temperatures interpolated by applying kriging. Now kriging, better estimates are made without guessing at station-level temperatures. Kriging is now more reliable than the linear regression approach.

Climatic data were entered artificially to determine plant water requirements. The intensity and location of weather stations are important variables for obtaining the necessary weather data. A two-year case study dataset from 17 stations of daily climate data (1989-1990) in Nebraska, Kansas and Colorado states were used to compare alternative network designs and interpolation methods. The root mean square interpolation error (RMSIE) values were the criteria for evaluating Et r estimates and network performance. The Kriging method gives the lowest RMSIE, followed by the inverse square method and the inverse method. Co-kriging has further improved the estimates (Ashraf et. al. 1996).

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