THE RISKS ASSOCIATED TO THE HOARFROST PHENOMENON IN THE REGHIN HILLS

J. SZILÁGYI, I. A. IRIMUŞ[1]

Abstract. The risks associated to the hoarfrost phenomenon in the Reghin Hills. Hoarfrost, being a hydrometeor which is produced only in the presence of frost, represents a major risk factor to agriculture especially when it appears early in autumn, 2-3 weeks earlier then the average date of appearance and late in spring, in the second decade of April and the first decade of May.
This paper shows an analysis of the parameters which define the hoarfrost phenomenon in order to highlight the vulnerability of the analysed area regarding this phenomenon.
In a first phase, in order to identify the periods of high vulnerability, we analysed the frequency of the days with minimum temperatures ≤ 0C, and in order to highlight the vulnerability of the studied area regarding the hoarfrost phenomenon we analysed the parameters which define the hoarfrost phenomenon: the medium annual number of days with hoarfrost and their multiannual variation, the frequency of the annual deviations from the multiannual average, the monthly and season variation of the days with hoarfrost, the medium and extreme dates of hoarfrost production and the frequency and degree of assurance of the monthly number of hoarfrost days of different lengths.
The analysis of the parameters which define the hoarfrost phenomenon was realized on the basis of the information recorded at the two metorological stations present in the studied area, the Târgu Mureş Metorological Station and the Batoş Metorological Station and the Eremitu and Gurghiu rainfall stations for the 1978-2008 period.

Key words: frost, frequency of hoarfrost days, vulnerability, risk.

1. General characteristics and genetic causes

Frost is the period of time within a day when the temperature goes below 0 °C. If the temperature remains under 0 °C the whole day, the frost is considered permanent and such a day is called a winter day (Topor, 1958).

N. Topor (1958) shows that both spring and autumn cooling is caused by polar or arctic air masses and they can be advective (determined by the invasion of

[1] "Babeş-Bolyai" University, Faculty of Geography, Cluj-Napoca,
e-mail: irimus@geografie.ubbcluj.ro

polar or arctic air with a temperature lower than 1°C), radiative (determined by the loss of warmth at ground level during the nights with clear sky and calm atmosphere) or advective-radiative (determined by the invasion of polar or arctic air with a temperature higher than 1°C, but which cools down afterwards due to radiation).

Hoarfrost is the deposition of fine ice crystals (with the size between 1-5 mm) on the surface of the ground or ground objects, in the shapes of scales, needles, feathers or fans. The phenomenon occurs during calm nights with clear sky in spring, autumn and winter, by the sublimation of water vapors from the air, on surfaces with temperatures below 0 °C, as a result of radiative night cooling (Ciulache, 2004). Hoarfrost deposition is also influenced by the the colour and smoothness of surfaces on which it occurs (dark or rough surfaces facilitate its occurence) and by the size of the objects (the thinner the objects are, the less hoarfrost forms on them – conductors, leaves of grass).

The optimal conditions for the occurence of hoarfrost are: anticyclonic system (high atmospheric pressure); clear sky and calm atmosphere (or slight wind, under 2m/s); high relative humidity (over 80%); negative air temperatures, the maximum intensity of the depositions can be observed at temperatures of -2 and -3 °C.

Sometimes hoarfrost occurs also in low relative humidity conditions (under 50%),when air temperature is 0 °C, and soil temperature falls below -10 °C. In case of an intense and rapid cooling, hoarfrost may occur on some of the vertical sides of objects as well.

This paper shows an analysis of the parameters which define the hoarfrost phenomenon in order to highlight the vulnerability of the analyzed area regarding this phenomenon.

Taking into account that the air and soil temperatures were not determined at some of the analyzed stations, the analysis of the parameters which define the hoarfrost phenomenon was realized on the basis of the information recorded at the meteorological stations at Târgu Mureş (φ = 46°32', λ=24°32', H =308m), Batoş (φ = 46°54', λ=24°39', H =449m), Eremitu (φ = 46°40', λ=25°00‘,H =510m) and Gurghiu (φ = 46°46', λ=24°51‘, H =415m) for the period 1978-2008.

2. The number of days with minimum temperatures ≤ 0°C

The frosty days (minimum temperatures ≤ 0°C) occur in the period October –May, with the highest frequency during the winter months, when the cold air advections from the polar or arctic regions show a higher frequency.

The multiannual average number of days with frost in the studied area is 113-117 days. Within a year, January shows the highest frequency of frosty days, with a multiannual average of 27 days with frost, followed by December and February with an average of 23 days.

Table 1. The number of days with minimum temperature ≤ 0 °C

Station		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Tg.Mureş	Average nr.	27.0	23.0	17.3	4.3	1.1	-	-	-	-	5.8	15.7	22.9	117.1
	Max. nr.	31	28	27	14	8	-	-	-	-	13	30	31	142
Batoş	Average nr.	26.5	22.9	17.1	4.4	0.9	-	-	-	-	4.5	14.5	23.1	113.9
	Max. nr.	31	28	26	14	6	-	-	-	-	12	30	31	140

Although in transition seasons there are fewer days with temperatures under 0°C, these constitute a risk factor for agriculture, construction and transport activities and last but not least for humans' health.

3. The annual number of days with hoarfrost and their multiannual variation.

The multiannual average number of days with hoarfrost in the Subcarpathians of Reghin varies between 22-47.3 days, but this shows spatio-temporal variations.

The analysis of annual variation of days with hoarfrost, shows a higher frequency of this phenomenon in the Mureş River Corridor and in the northwestern part of the study area, where up to 50 days of hoarfrost per year can be recorded. The annual number of days with hoarfrost varies between 27-58 days per year in Târgu Mureş, between 19-49 days per year in Batoş, between 21-56 days per year in Eremitu and between 0-46 days per year in Gurghiu.

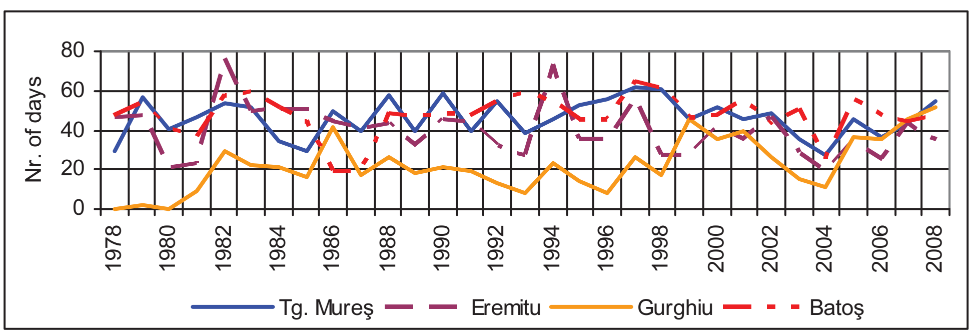

Figure 1. The annual variation in the number of days with hoarfrost, 1978-2008

The maximum number of days with hoarfrost recorded in one year was 62 days, (1997) at the Târgu Mureş Station, 76 days (1982) at Eremitu, 52 days (2008) at Gurghiu and 65 days (1997) at the station in Batoş.

The analysis of annual deviations of the days with hoarfrost from the multiannual average shows a higher number of years with positive deviations at the stations of Eremitu (54.8%) and Batoş (61.3%), which reflects that submontane areas are more vulnerable to this phenomenon.

The positive annual deviations from the multiannual average involve values between 5-35%, the highest values of positive deviations being recorded at the Station of Gurghiu between 2005-2008, when 35-52 days of hoarfrost per year were recorded, which represents a deviation from the annual average of 59.8 to 137.4%.

The number of consecutive years with positive deviations of the number of days with hoarfrost in the range of years analyzed was generally 2-3 years, the maximum being recorded between 1982-1988, with a number of 7 consecutive years at Eremitu and 5 consecutive years at Batoş, recorded between 1990-1994.

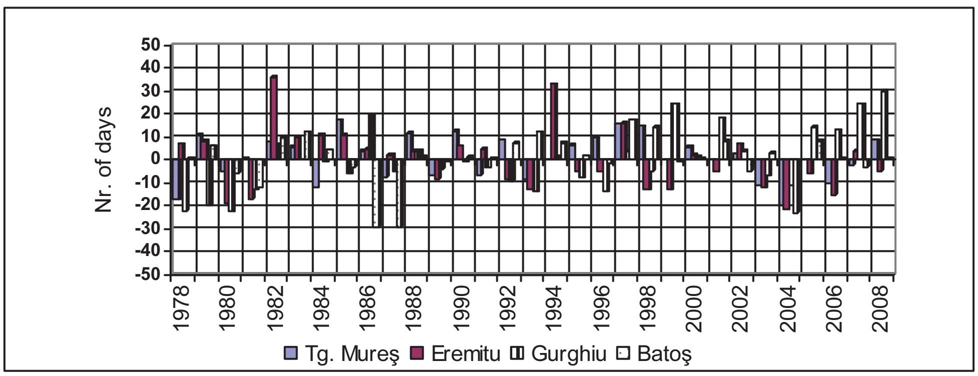

Figure 2. The variation of annual deviation from the multiannual average in the number of days with hoarfrost (1978-2008)

Table 2. The frequency of annual deviations from the multiannual average, (1978-2008)

	Târgu Mureş		**Eremitu**		**Gurghiu**		**Batoş**	
	Nr. of cases	**%**	**Nr. of cases**	**%**	**Nr. of cases**	**%**	**Nr. of cases**	**%**
Positive deviations	15	48.4	17	54.8	14	45.2	19	61.3
Negative deviations	16	51.6	14	45.2	17	54.8	12	38.7

Source: processed data from NMA archive

4. The monthly variation of the days with frost

The analysis of the monthly variation of the days with frost shows that the highest frequency is recorded in late autumn and early spring, when the nocturnal radiative cooling and the high relative air humidity creates optimal conditions for the production of the phenomenon.

The monthly number of days with hoarfrost shows temporal and spatial variations. The highest frequency is recorded in November with an average of 4.9-9.9 days (20.3-23.3%) and in March with an average of 3.2-9.7 days (14.0-20.5%), followed by October with an average number of 4.8-7.5 days.

In the winter months the number of days with hoarfrost presents lower values, the highest number of days with hoarfrost being recorded in December, with an average of 4-7.9 days, which represents a frequency of 16.6 to 18.2% of the cases. The fewest days with hoarfrost is recorded at the beginning and at the end of the potential production period of this phenomenon, so, May has an average of 0.1-0.7 days, and September 0.3-0.9 days, which represents a frequency of 0.5-0.6% respectively 1.4-1.9% of the total number of cases.

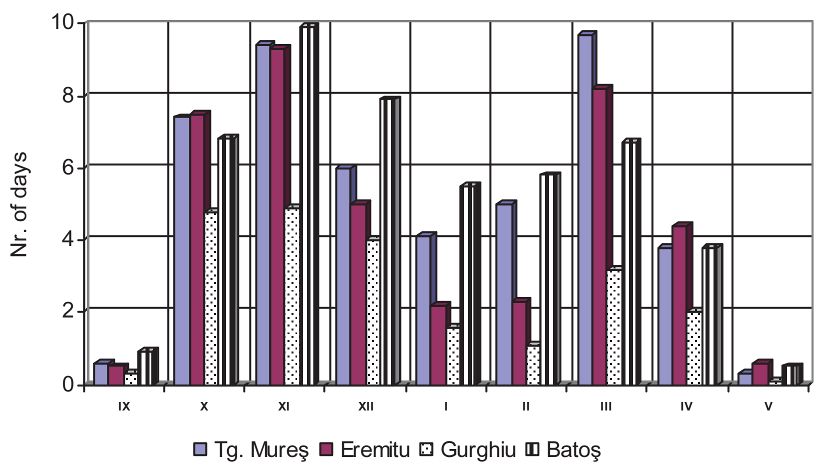

Figure 3. The monthly average number of days with hoarfrost (1978-2008)

Table 3. The monthly average and maximum number of days with hoarfrost (1978-2008)

		IX	X	XI	XII	I	II	III	IV	V	Anual
Tg. Mureş	**Total nr. of days**	21	228	292	184	128	156	299	117	11	1436
	Average nr. of days	0.7	7.4	9.4	5.9	4.1	5.0	9.7	3.8	0.3	46.3
	Maximum nr. of days	**3**	**16**	**18**	**15**	**15**	**16**	**21**	**9**	**2**	**18**
Eremitu	**Total nr. of days**	19	233	289	154	70	71	254	136	20	1242
	Average nr. of days	0.5	7.5	9.3	5.0	2.2	2.3	8.2	4.4	0.6	40
	Maximum nr. of days	**3**	**17**	**21**	**16**	**12**	**13**	**20**	**11**	**3**	**21**
Gurghiu	**Total nr. of days**	10	151	154	126	49	36	99	64	4	693
	Average nr. of days	0.3	4.8	4.9	4.0	1.6	1.1	3.2	2.0	0.1	22
	Maximum nr. of days	**4**	**11**	**15**	**17**	**15**	**14**	**15**	**7**	**2**	**17**
Batoş	**Total nr. of days**	26	210	306	244	171	178	206	115	13	1482
	Average nr. of days	0.9	6.8	9.9	7.9	5.5	5.8	6.7	3.8	0.5	47.8
	Maximum nr. of days	**5**	**14**	**17**	**17**	**17**	**15**	**14**	**14**	**2**	**17**

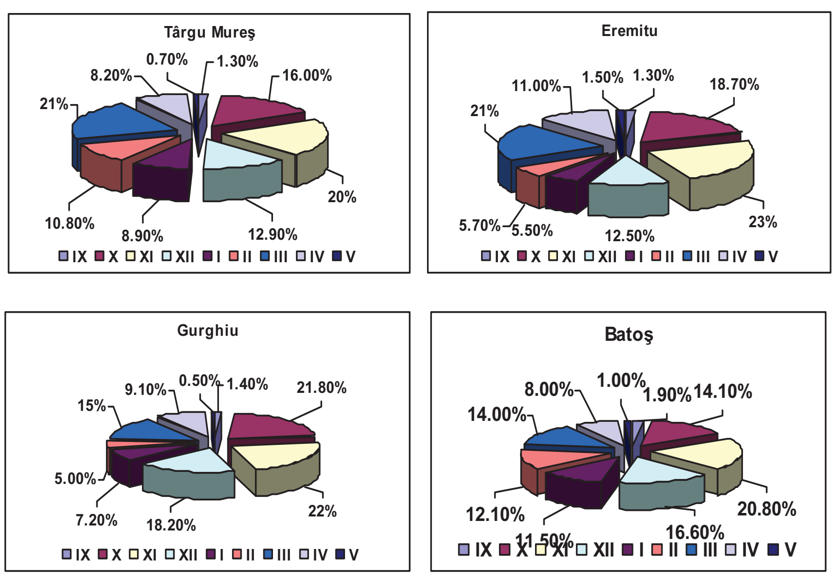

Figure 4. The monthly fequency of the hoarfrost days (1978-2008)

5. The frequency and the assurance degree of the monthly number of hoarfrost days with different duration

In order to quantify the vulnerability degree of the studied area towards this phenomenon, there was calculated the frequency and the assurance degree of the days with hoarfrost with different duration for each month.

The probability of the occurrence of the hoarfrost phenomenon was calculated relying on the number of characteristic cases corresponding to each month within the interval with possibility of occurrence of this phenomenon (September-May), expressed in percent, whereas the assurance was obtained by the summing of frequencies expressed in percents, starting from the last interval.

The evidence of the frequency and the degree of assurance of the monthly numbers of hoarfrost days has been made by relying on the calculation of the number of cases specific for each month within the interval September-May, which subsequently have been grouped into six groups of representative values (0-2 days; 3-5 days; 6-8 days; 9-11 days; 12-15 days; over 15 days).

From the analysis of the frequency of the monthly number of days with hoarfrost and their degree of assurance we can conclude that the study area presents the highest vulnerability towards this phenomenon in the months of October, March and April, when the number of hoarfrost days over 6 days has the highest frequency from the total number of cases and an assurance degree of up to 80%. So, in these months, with the highest percentage and degree of assurance, stand out the groups of values of 6-8 days, with a percentage of 35.4% in October, 29% in November and March, and 38.7% in April; and those of 9-11 days that have a percentage of 16.3% in October, 38.7 in November and 25.8% in March.

In September and in May, the highest frequency and degree of assurance have the groups of values of 0-2 days (90.3% in September and 100% in May) and those of 3-5 days, with a percentage of 9.6%.

The group of values with 12-15 monthly days with hoarfrost records a frequency of 38.7% in November and 25.8 % in May, and represents a degree of assurance of 25.9% and 32.2% respectively. The probability that the number of the days with hoarfrost over 15 days a month is low, this represents a frequency and a degree of assurance of 3.2% for October and 12.6% for November.

In wintertime, the highest number of days with hoarfrost register in December, when the highest frequency registers the group of values of 6-8 days, with 14 such cases in Târgu Mureş and 10 cases at Batoş, that represents a frequency of 45.1% and 32.2% respectively from the total number of cases, and a degree of assurance of 64.6% and 74% respectively. The number of cases with over 15 days with hoarfrost this month is 9.6%, and represents the lowest probability of occurrence 9.6%.

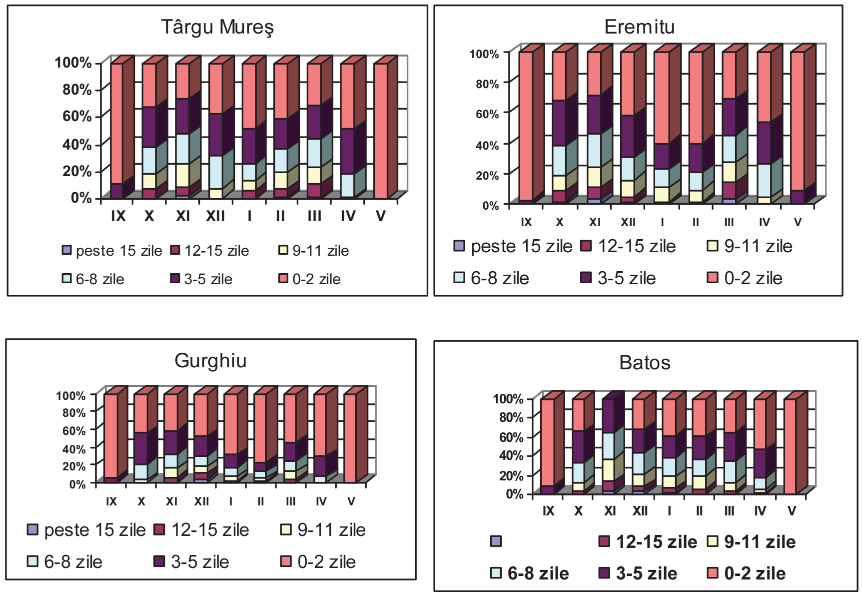

Figure 5. The degree of assurance of the monthly number of hoarfrost days with different durations (1978-2008)

6. The average and the extreme dates and the risk interval for the hoarfrost phenomenon

There are spatio-temporal variations in the average dates of frost and hoarfrost production due to the influence of the air mass circulation, the morphometric characteristics of the landscape and the presence of the Căliman and Gurghiu Mountains. Thereby, the average date of the first frost is moving forward and the date of the last frost lengthens with the altitude.

Compared to the average date of frost production, the hoarfrost may occur in autumn, either together with the frost, or later, but never before because for the production of hoarfrost the air temperature needs to drop below 0°C. In the same way, in spring it can disappear with the frost, or before, but never after the frost (Bogdan, Niculescu, 1999).

The average length of the interval with hoarfrost is placed between the average date of hoarfrost production in autumn and the average date of its disappearance in spring, in this interval the production of hoarfrost being considered a normal meteorologic phenomenon characterizing the cold period of the year.

The hoarfrost being a hydrometeor that occurs only in the presence of frost, it represents a major risk factor for agriculture, especially if it occurs in early autumn, 2-3 weeks earlier than the average date of occurrence and in late spring, in the second decade of April or in the first decade of May.

The risk interval is the period between the average date and the extreme date of frost or hoarfrost production: the interval between the average date of the first frost (hoarfrost) and that of the earliest frost (hoarfrost) is called *the autumn risk interval,* and the interval between the average date of the last frost (hoarfrost) and that of the latest frost (hoarfrost) is called *the spring risk interval.*

Table 4. The average and the extreme dates for hoarfrost production

Station	The average date for hoarfrost production		The extreme dates for hoarfrost production		The average length of the interval with hoarfrost	The risk interval for the hoarfrost phenomenon	
	First	Last	Autumn	Spring		Autumn	Spring
Tg.Mureş	20.10	10.04	27.09	4.05	172	23	24
Eremitu	12.10	21.04	10.09	10.05	191	32	19
Gurghiu	15.10	17.04	12.09	10.05	184	33	23
Batoş	17.10	14.04	16.09	8.05	186	31	24

Source: processed data from NMA archive

7. The risks associated to the hoarfrost phenomenon

The early hoarfrost in autumn causes significant damage to agricultural crops on the fields, the effects being even worse when the plants are hit during the vegetation stage, before the phenological cycle ends. The late hoarfrost in spring causes the most damage to agricultural crops being at the beginning of the vegetation period, not only slowing down plant development and early terminating the growing season, but also causing partial or total death. The most damage occurs in the pomiculture, when the low temperature associated to the hoarfrost phenomenon hits the trees during the vegetation cycle, sometimes destroying all harvest. The vineyards are also affected, especially the early varieties.

8. Preventive, attenuative and control measures against the risks associated to the hoarfrost phenomenon

The control measures against the risks associated to cooling, to early hoarfrost phenomenon in autumn as well as to late hoarfrost phenomenon in spring, from the point of view of the control principle, can be grouped into (Berbecel, O. and collaborators, 1974):

• *Practical measures before planting or sowing:*

- grow frost susceptible plants on slopes with southern or southwestern exposure, ensuring the cold air an easy flowing into the valleys;
- in the case of pomiculture on slopes, avoid the formation of waterproof

selvedges between the trees, which causes cold air stagnation and lower temperature;

- tree density should be chosen in a way as to make cold air flowing easier on the bottom slope;

• *Measures aiming the attenuation of nocturnal radiation, which can be achieved through the following means:*

- fumigation, is a method based on the principle of decreasing the nocturnal radiation effect by the means of an aerosol screen (smoke), generated by a smoke-producing substance, or by the incomplete combustion of plant residues, which reduces heat loss by nocturnal radiation;

- the sheltering of field crops in the risk periods by covering them with mats or with polyethylene sheets;

- creating permanent shelterbelts by planting trees or temporary ones from planks, cane, which are placed perpendicularly in the direction of the prevailing winds, in the case of sloping land these are placed above the cultivated land;

• *Measures for increasing the soil and air temperature*

- soil surface heating, can be done by directing hot water or the unused steam from the heating of greenhouses or from an industrial unit or heating device;

- environment heating, by means of special burners or infrared radiation emittors;

- irrigation of soil surface during the warm noon hours. Since the thermal conductivity of water (0,00150 $cal/cm^2*s*degree$) is higher than that of the air (0,000005 $cal/cm^2*s*degree$), moist soil permits the transmission of the warmth acquired during the daytime more deeply into the lower layers, and during the nighttime, when the radiative balance becomes negative, the heat stored in deeper layers prevents temperature drop. Simultaneously, irrigation creates a heat transfer derived from the added water, but especially from the 80 calories per gramm released by the freezing water.

REFERENCES

1. Berbecel, O. et al., (1974), *Agrometeorologie*, Editura Ceres, Bucureşti.
2. Bogdan, Octavia, Nicolescu, Elena, (1999), *Riscurile climatice din România,* Sega Internaţional, Bucureşti: 280.
3. Cheval, S. et al. (2003), *Indici şi metode cantitative utilizate în climatologie*, Edit.Universităţii din Oradea.
4. Ciulache, S., (2004), *Meteorologie şi climatologie*, Edit. Universitară, Bucureşti.
5. Moldovan, F., (2003), *Fenomene climatice de risc*, Editura Echinocţiu, Cluj-Napoca.
6. Topor, N., (1958), *Bruma şi îngheţul, prevederea şi prevenirea lor*, Editura Agro-Silvică, Bucureşti.
7. * * *Tabele meteorologice*, TM-11 – 1978-2008.