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EXTENT OF STORMS IN THE UKRAINIAN CARPATHIANS

Vasyl Lavnyy[1], Reinhard Lässig[2]
[1]Ukrainian State University of Forestry and Wood Technology, Gen. Chuprynka Str. 103, 79057 Lviv, Ukraine
[2]Swiss Federal Institute for Forest, Snow and Landscape Research, Zürcherstrasse 111, 8903 Birmensdorf, Switzerland

Abstract

Using data from 16 meteorological stations we have analysed the frequency and intensity of storms (≥20 m/s) in the Ukrainian Carpathians from 1945 to 1999. 6631 storms were recorded in this region, 60 percent of them at mountain tops. The number of storms at each station varied greatly from one year to the other. In 1996 an annual maximum of 52 storms at one station was recorded. In general, storm frequency fluctuated and showed cyclical character. It did neither increase nor decrease over these years. 60 percent of the storms occurred between October and March. In summer only few storms occurred in this mountain region. 55 percent of the storms showed maximum wind speeds between 20.0 and 24.9 m/s. there was a total of 413 storms (6.2 %) with wind speeds of 40 m/s or more. 88 percent of them occurred in winter. Winter storms usually lasted longer than summer storms.

Key words: Ukrainian Carpathians, storm frequency, storm intensity, climate change, forestry

1. Introduction

Intensive storms are, probably, the most important natural hazard for forestry. In 1990 and 1999, for example, severe cyclones caused extensive windthrow all over Central Europe. More than 300 Million m^3 of timber were thrown or broken by gales which originated in the cyclones «Vivian» and «Wiebke» in 1990 as well as «Lothar» and «Martin» in 1999 (Lässig 2002).

Like in Central Europe (Krapfenbauer und Holtermann 2000), many foresters and scientists in the Ukraine apprehend a further increase of storms in the Ukrainian Carpathians, in connection with the global increase of mean temperature. They fear that severe storms could devastate more forests than ever before. Contrarily, there is no empirical evidence of an increased frequency or magnitude of storms so far, neither in Central Europe (Schiesser et al 1997), in Scandinavia (Alexandersson et al 2000) and above the Northern Atlantic (Lefebvre 2002) nor in the Urals (Lässig and Mocalov 2002). For the Ukraine almost no information on the frequency of severe natural disasters is available at present. Stojko (1965, 1977), at least, reported on particularly extensive storm damage in Carpathian's forests in the Ukraine.

Concerning global climate changes, however, the mean monthly temperature recorded in different countries of the northern hemisphere display a clear upward trend. Russian forest scientists, for example, fear that the global change in climate will result in more frequent storms in Russia and that these will, in the long term, have negative effects on forest structures and forest management. For many meteorological stations in western Russia and western Siberia an upward temperature trend has been documented (Bradley et al. 1985).

Before analysing meteorological data for the Ukrainian Carpathians in detail, we have quickly checked how mean annual temperature has developed there during the last decades. And indeed, the data from all the meteorological stations in the Ukrainian Carpathians checked showed the same trend as the above mentioned stations in the Urals. The result of this pre-study corroborated the apprehension of a changing climate and of an increasing storm activity. Therefore we started a joint project on frequency and characteristics of storms and their consequences on forests in 2001.

The Ukrainian Carpathians, situated in the west of the Ukraine, cover an area of ca. 24'000 km^2. This region, 42 percent covered with forests (Weber and Lavny 1998), is haunted by natural disasters like flooding, landslide and windthrow very often. On the long-term, windthrow is the most important natural event damaging vast forest areas in this region.

In order to estimate the importance of frequent storms for forest dynamics and forest management in the Western Carpathians, the present study mainly deals with the question how often storms actually do occur in this region, and whether the number and intensity of severe storms are actually on the increase.

Fig.1:
Meteorological stations in the Ukrainian Carpathians.

All the meteorological data was compiled by the Central Geophysical Observatory, Ministry of environment and natural resources of Ukraine, Kiev.

2. Methods

Its mainly wind gusts of more than 20 m/s which damage single trees or large forests (Rottmann, M. 1986). Therefore, we investigated extensive meteorological data on the occurrence and characteristics of storms, which happened between 1945 and 1999, from a

region covering an area of more than 24'000 km^2. Data on storms with a (hourly mean) wind speed of 20 m/s or more were collected from 16 stations throughout this most westerly part of the Ukraine (Fig. 1). For the period studied, the date of each storm, its duration, the maximum speed of wind gusts measured and various data of temperature, precipitation and air pressure were recorded.

To describe the frequency and intensity of storms in general which have continuously recorded at more than one meteorological station, just the one storm with the highest wind speed recorded was used. In case of not continuously recorded measures (gaps) - the majority of the stations recorded storm data at an interval of three hours - the data was analysed as it was from two different storms. In case of storms which showed the same wind speed at more than one station the one which have lasted longest was analysed. In the following, storms measured at different stations are bundled in the analyses as one, so called, storm event. The annual number of storm events between 1945 and 1967 was rounded upwards, as, during this period, there were fewer meteorological stations than from 1968 onwards. The method is described in detail in Lässig and Mocalov (2000).

3. Results

3.1 Storm frequency

In the Ukrainian Carpathians storms were very frequent between 1945 and 1999. The weather stations in the study area registered a total of 6631 different storms with wind speeds of at least 20 m/s. The number of storms varied greatly from one year to the other. The meteorological stations with the highest storm frequency are those on the summits of Pozhyzhevs`ka and Plaj mountains. These stations registered 59.0 and 50.3 times per year wind speeds of 20 m/s and more, in the average (Tab.1). The other stations which are less exposed and in lower elevation showed smaller numbers of storms.

Meteorological Station	data period	elevation a.s.l. (m)	total N of storms	average N of storms / year
Plaj summit	1968-1999	1330	1609	50.3
Pozhyzhevs`ka summit	1959-1999	1429	2421	59.0
Dolyna	1945-1999	470	495	9.0
Drohobych	1947-1999	275	251	4.7
Ivano-Frankivs`k	1945-1999	244	155	2.8
Kolomyja	1945-1999	298	122	2.2
Mizhgirja	1961-1999	401	119	3.1
Nyzhni Worota	1949-1999	496	49	1.0
Nyzhnij Studenyy	1946-1999	615	7	0.1
Rahiv	1946-1999	438	45	0.8
Rus`ka Mokra	1946-1966	589	2	0.1
Slavs`ke	1946-1999	592	52	1.0
Stryy	1945-1999	294	430	7.8
Turka	1945-1999	594	537	9.8
Velykyy Beresnyy	1946-1999	205	26	0.5
Yaremcha	1946-1999	531	311	5.8
total			6631	

Tab. 1:
Total number of storms recorded at 16 meteorological stations in the Ukrainian Carpathians

Over all, strong winds mainly came from south-west (Tab. 2). They mainly hit forests on the leeward side of the mountains facing to the north-east, especially in winter. West of the mountain chain in Transcarpathia, where south-westerly exposed slopes predominate, storm

damage in forests was rare. At the meteorological stations Rus`ka-Mokra and Nyzhnij Studennyy, for example, only two and seven storm events took place throughout the whole observation period.

At the summit of Pozhyzhevs`ka mountain 81 percent of the storms recorded, in Yaremcha 73, in Drohobych 55 and, over all the meteorological stations in the Ukrainian Carpathians, 57 percent of the storms blew from south-west. Storms which came from the west predominated in Ivano-Frankivs`k and Drohobych with 46 percent and 27 percent, respectively. But in the whole region investigated, only 14 percent of all storms came from this direction.

Meteorological station	Total N of storms	Wind direction (%)							
		W	SW	S	SE	E	NE	N	NW
Plaj summit	1609	4	53	17	6	3	9	5	3
Pozhyzhevs`ka summit	2421	14	81	1	1	1			2
Dolyna	495	23	54	6	2	1		1	13
Drohobych	251	27	55	6		1			11
Ivano-Frankivs`k	155	46	8	2	3	2			39
Kolomyja	122	29	15		2	2	2	2	48
Mizhgirja	119	2	4	58	7	4	1	10	14
Nyzhni Worota	49	12	18	23	4	2		29	12
Nyzhnij Studenyy	7			72	14				14
Rahiv	45	7	47	38		6	2		
Rus`ka Mokra	2		50				50		
Slavs`ke	52		17	67	4		2	8	2
Stryj	430	23	39	6	2	3	1	1	25
Turka	537	20	15	24	13	1	1	2	24
Velykyj Beresnyj	26	19	4	15	4	4	4	27	23
Yaremcha	311	6	73	19			2		
total	6631	14	57	11	3	1	3	2	9

Tab. 2:
Wind direction of storms (v=20 m/s) at 16 meteorological stations in the Ukrainian Carpathians (in % of total N of storms)

The storm direction in the valleys is heavily influenced by the direction of the valley. The meteorological stations Nyzhnij Studenyy, Mizhgirja and Slavs`ke, for example, are situated in valleys which run from north to south. In these valleys the direction of storms which impinged on the Carpathians from the West and South-west had changed. Therefore more than 50 percent of all storms at these stations blew from the South. Storms coming from the North and the East were rare at most of the stations.

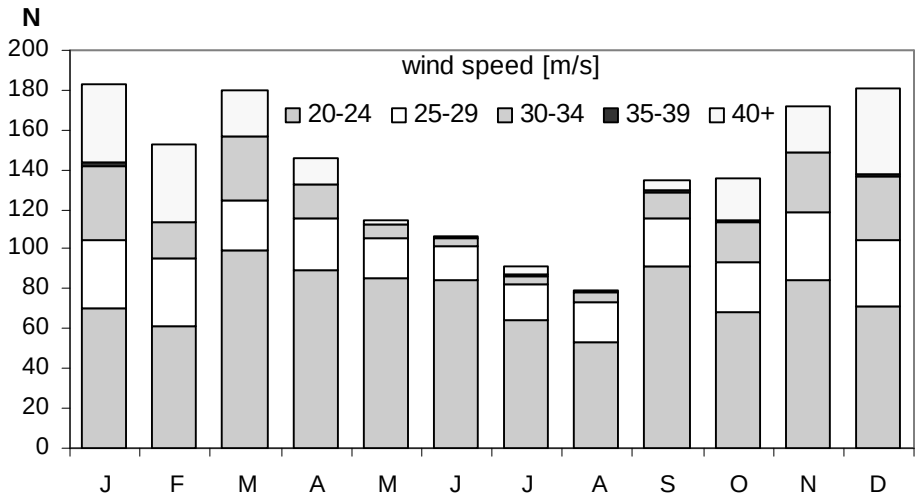

Fig. 2:
Number of storm events (N) at 16 meteorological stations in the Ukrainian Carpathians sorted by month and wind speed (m/s)

60 percent of the storms in the Carpathian mountains occurred between October and March (Fig. 2). In summer, with a minimum in August, only few storms were observed in this region. 55 percent of the storms showed wind speeds between 20.0 and 24.9 m/s. In contrast, there was a total of 413 storms (6.2 %) showing wind speeds of 40 m/s or more. 88 percent of them occurred in winter. These were mainly registered at the summits of Pozhyzhevs`ka and Plaj mountains. At the meteorological stations in Yaremcha, Stryy and Mizhgirja, for example, storms of this velocity were rarely recorded because they are situated in the valley bottom. No other station did show storms with such high wind speeds.

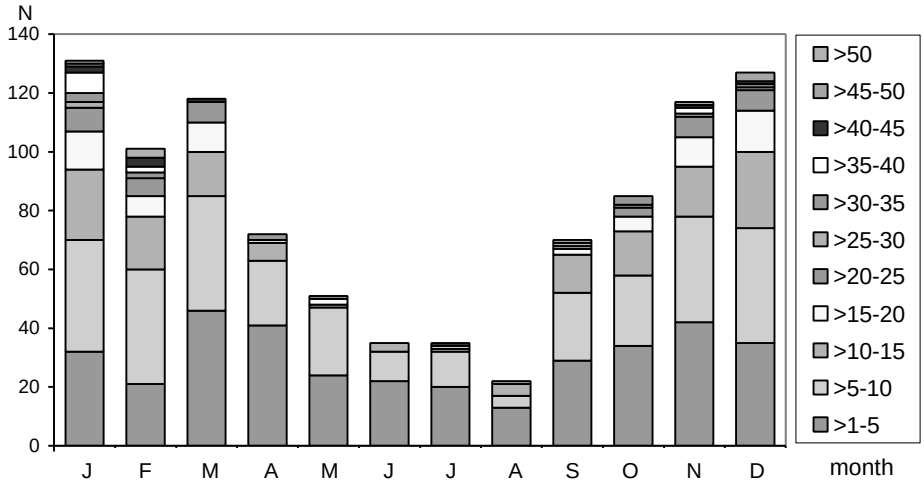

Fig. 3: Number of storm events (N) at 16 meteorological stations in the Ukrainian Carpathians sorted by month and storm duration (h)

Winter storms usually lasted longer than summer storms. The average duration of a storm event was 5.0 hours in winter and 2.4 hours in summer. Over all, 80 percent of the storms lasted between one and ten hours. Only few storms blew longer than 50 hours. In summer, thunder storms with severe gales sometimes occurred, lasting one hour or less. Long lasting storms mainly occur at the mountain summits mentioned above. The majority of the long lasting storms occurred between November and March with a maximum in January (Fig. 3). The most long lasting storm with a total duration of 96 hours was recorded in 1965 between February 25 and 28 at the summit of Pozhyzhevs`ka mountain. The second longest took 92 hours 50 minutes and happened in 1984 between February 11 an 14 at Plaj mountain.

Severe storm events occurred every year almost everywhere in the Carpathians, but their frequency varied clearly from one year to the other (Fig. 4). But not only the number of storms in general, the number of extreme storms with wind speeds of more than 40 m/s also varies greatly. 1996 an annual maximum of 52 storm events was recorded (Fig. 4). The marked difference in the annual number of storm events between the periods 1945-1959 and 1960-1999 is connected with the start of the measurements at the meteorological station on the top of Pozhyzhevs`ka mountain in 1968 as well as the one at Plaj mountain which started its measurements in autumn of 1959.

In general, no significant trend in storm frequency could be stated for the region investigated (Fig. 5). The meteorological stations which had registered the largest number of storms were the two highly elevated stations at the ridges of Pozhyzhevška and Plaj mountains. Despite the high variation from one year to the other at these two mountain stations, the annual storm frequency increased with an annual rate of 0.5 storms. At the 14 lower elevated stations it has slightly decreased.

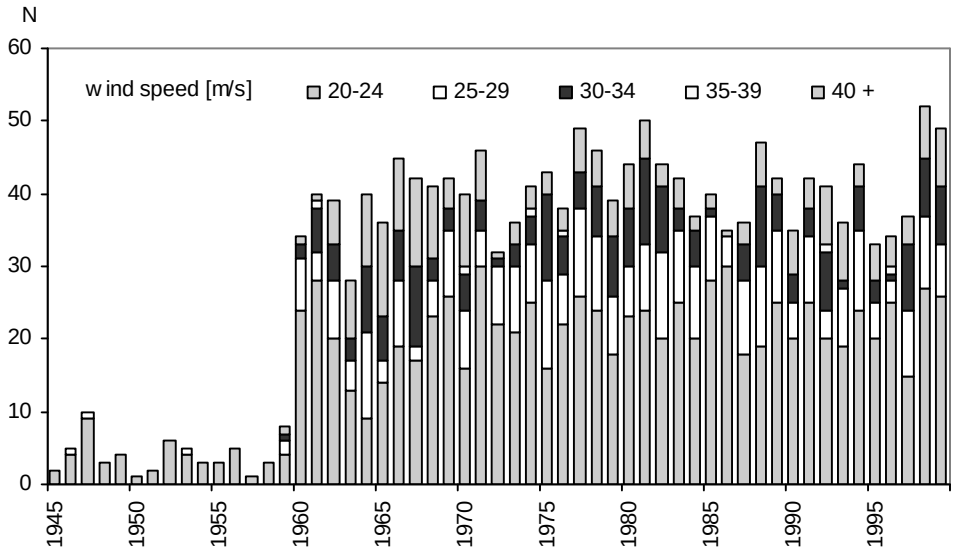

Fig.4: Annual number of storm events in the Ukrainian Carpathians sorted by wind speed (m/s)

Based on these data the annual number of storm events between 1945 and 1967 was rounded upwards, as there were fewer meteorological stations than from 1965 onwards. But, for the period investigated no clear trend is visible (Fig. 5). Storm frequency has, over all, cyclic character (Fig. 5). In the short-term view, the frequency of storms since 1996 is certainly greater, and this explains the fears of the foresters about increasing storm activity.

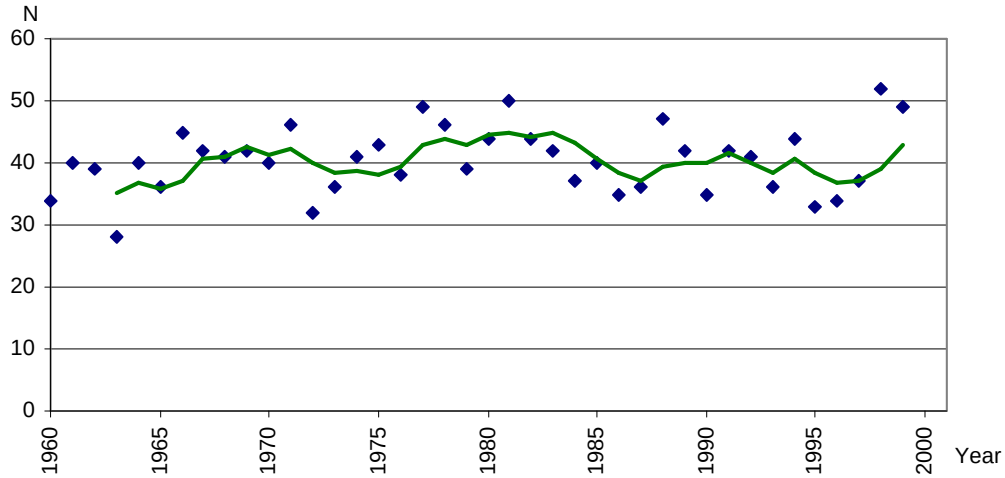

Fig. 5: Annual number of storm events 1960-1999 in the Ukrainian Carpathians (dots) and moving average (fourth degree polynomial)

3.2 Temperature and precipitation

Like in other mountain regions, the mean annual temperature in the Ukrainian Carpathians changes with elevation. In the valley of Tysa (100 m a.s.l.), for example, it is 10° C, at 2000 m a.s.l. in the mountains it is about 0° C. The meteorological data from different stations of different elevation between 1945 and 1999 show an increase of mean annual temperatures in this region of 0.4 to 0.6° C, in general. Data from the meteorological stations at Jaremche, Drohobych, and Rahiv showed a rise of mean January temperatures between 2.0 and 3.5^{o} C between 1947 and 1999, while mean July temperatures changed between -0.3 and +0.4^{o} C. At all three stations the mean temperature showed an clear upward trend of about 0.5^{o} C.

The mean annual precipitation in the Ukrainian Carpathians varies between 600 mm in the foreland and 1600 mm on the mountain tops. On the long-term, there is no clear trend in precipitation development visible. In Drohobych, for example, the precipitation sum slightly decreased during the last 55 years, in Rahiv it was constant and at other meteorological stations, in Turka for example, it increased during this period. Between 70 and 80 percent of

the precipitation fell during the growing season, with a peak in June and July. Once in a while intensive rainfall or fast melting snow causes flooding in the Carpathian region. Recent flooding which caused catastrophic damage happened in the southern foreland in November 1998 and, again, in March 2001.

Severe storm in combination with intensive rainfall is very often causing windthrow in forests. On December 14th, 1964, for example, the daily amount of rainfall totalled 92,9 mm at Rus`ka Mokra, 90,5 mm at Mizhgirja and 59,6 mm at Nyzhnij Studennyy. And on October 29th, 1992, 102,1 mm of rain fell on the summit of Plaj mountain, in combination with gusts of 34 m/s. Both events caused large-scale windthrow. On the long-time, events like those mentioned above are comparatively rare. Usually, when windthrow occurred, daily precipitation rates up to 19,9 mm are predominating.

4. Discussion

The results show that storm frequency in the Ukrainian Carpathians is high. Compared to the Ural region (Lässig and Mocalov 1999 and 2000) storms are much more frequent in the Carpathians. In the Urals an annual maximum of 18 storm events (1965) has been noted, in the Carpathians the maximum was 52 (1998). Like in the Urals there is no upward trend of storm frequency visible. This corresponds with the above mentioned results of Schiesser (1997) and Lefebvre (2002). For the earlier years it corresponds also with the results of Dissescu (1962) found in the North of Romania. A connection of storm activity with the 11-year cycle of solar activity which has been stated by Dissescu (1962) is not obvious in the Ukrainian Carpathians.

Not only the number of storms in general, but also the number of storms with a wind speed of more than 40 m/s was higher in the Carpathian mountains than in the Urals. Another difference in the results between these two regions is the occurrence of storms throughout the year. In the Urals storms mainly occurred in summer, in the Carpathians in winter.

In both regions a slight increase in storm frequency has been noted for the mid and end of the nineties of the 20th century. Kosovets and Shven (2002) have also noted an increase of winds with a speed of more than 25 m/s since 1996 in this region. However, it is too early to talk about a general increase in storm frequency because this increase in the Carpathians still fluctuates within natural boundaries.

The above mentioned findings on temperature development fit to what Mocalov and Lässig (1998) have found for the Urals. At different meteorological stations there, mean January temperatures showed a rise between 1.7 and 3.3^{o} C, while mean July temperatures only showed a rise between 0.3 and 1.1^{o} C between 1888 and 1996. In both the Carpathians as well as the Urals winter temperature is, obviously, much more increasing than summer temperature. Even if no increase in storm frequency was evident a change in temperature - and might be precipitation - regime could result in a higher storm frequency if the reason for this is a change of traction of the Atlantic low pressure areas (Munich Re 1993).

5. Conclusion

Concerning global climate changes it is obvious that the increase of temperature definitely takes place in the Ukrainian Carpathians. But this has not resulted in a higher frequency of storm events, so far. Therefore neither foresters nor forest scientists have to fear, yet, that

severe storms will have more negative effects on forest management than ever before. This on condition that the average stand height (often re-calculated from the stand volume) of the forests persists on the same level. If the stand volume rises there is an increased probability of windthrow. There is no doubt that, in this mountain region, wind is an important site factor which regularly forms the local as well as the regional structure of forests. Especially for higher elevations like on Pozhyzhevs`ka and Plaj mountain wind limits the height growth of trees.

The next step of the study will be to analyse windthrow data in the same region to check whether and where these are increasing or not and to cross-check meteorological and forest data to find correlation between both sets.

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