Drought of 1992 in Lithuania and Consequences to Norway Spruce

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The impact of the summer drought of 1992 on tree rings of Norway spruce (*Picea abies* (L.) Karsten) has been discussed in this publication. The dendroclimatological research has been conducted in 1995-2000. The radial increment from 45 research plots was used. The research plots were selected in *Piceetum vaccinio-myrtillosum*, *Piceetum hepatico-oxalidosum*, *Piceetum myrtillosum*, *Piceetum myrtillo-oxalidosum* forest types. The data of the annual radial increment also includes early and latewood widths. The severe drought of 1992 influenced the increment of Norway spruce, especially latewood, greatly negatively.

Key words: Norway spruce, climate, air temperature, precipitation, radial increment, drought

Introduction

Tree rings accumulate the information about the state of the surrounding environment and are excellent indicators of its changes (Eckstein, 1989; Schweingruber, 1993; Stravinskienė, 1997; Битвинскас, 1974).

Owing to the long-life and anatomical structure of the annual radial increment, conifers are one of the most important objects of the dendroclimatological research in Lithuania (Bitvinskas, 1995).

Norway spruce (*Picea abies* (L.) Karsten) is the second conifer species widespread in the forests of Lithuania. According to the data of the forest inventory in 1996, spruce occupies 24% of the total forest area (Ozolinčius 1998).

Due to Scots pine (*Pinus sylvestris* L.) domination in the forests of Lithuania, the main part of dendrochronological research was concentrated on pine and only a smaller part on spruce. Consequently, Norway spruce was less investigated than Scots pine (Karpavichius, Yadav, Kairaitis 1996).

The aim of the research was to study the impact of the summer drought in 1992 on tree rings of Norway spruce in different regions of Lithuania.

Materials and methods

Research plots in mature stands of Norway spruce (*Picea abies* (L.) Karsten) in Lithuania were selected. On dry sites (forest types: *Piceetum vaccinio-myrtillosum*, *Piceetum hepatico-oxalidosum*) the majority of research plots (31) were selected. Fourteen research plots represent moderately wet sites (*Piceetum myrtillosum* and *Piceetum myrtillo-oxalidosum* forest types) (Table 1). During the field-work, using „Suunto" increment borer, samples were taken at breast height (130 cm). Aiming to the reliable material, samples from 20 to 30 trees in each plot were taken (Fritts, Shatz 1975; Huber 1978; Битвинскас 1974). Using GPS (geographical position system) unit „MAGELLAN 315" geographical co-ordinates for each research plot were established.

Tree ring widths (early and latewood separately) were measured within 0.01 mm accuracy. For this purpose, the „LINTAB" tree-ring measuring table and „TSAP" 3.14 computer program, developed by F. Rinn and S. Jäkel in Heidelberg were used.

During the dating quality control double and false rings, formed due to unfavourable growth conditions (Eckstein 1987; Lovelius 1997; Wendland 1975; Kienast 1985), were detected. For this purpose, the „COFECHA" 3.00P computer program, developed by R. Holmes was used. Tree ring series with possible dating problems or of dissimilar growth were not used for the further analysis.

For the elimination of the age trend, the indexing procedure was performed. The „CHRONOL" computer program developed by E. R. Cook was used. Each tree-ring series obtained from individual tree were indexed independently. The indexing was carried out at two stages, - according to the methods, proposed by Holmes et al. in 1986. At first negative exponential curve or linear regression and after the spline, preserving 67% of variance at wavelength 21 years, were used.

After the dating quality control and indexing, all tree-ring series were averaged into a local chronology of the research plot. The bi-weight robust mean for this purpose was used.

Table 1. Characteristics of research plots: name, geographical co-ordinates, established using GPS, forest type (*Piceetum vaccinio-myrtillosum* (*Pc. v.-m.*), *Piceetum myrtillo-oxalidosum* (*Pc. m.-ox.*), *Piceetum hepatico-oxalidosum* (*Pc. h.-ox.*), *Piceetum myrtillosum* (*Pc. m.*)), soil type

Research plot	Geographical co-ordinates		Forest type	Soil
	Latitude (North)	Longitude (East)		
Alytus	54° 25' 59"	24° 03' 11"	*Pc. v.-m.*	sand
Ąžuolų Būda	54° 41' 35"	23° 32' 30"	*Pc. m.-ox.*	sand
Bebrujai	55° 44' 90"	23° 37' 59"	*Pc. h.-ox.*	sand
Dubrava II	54° 49' 86"	24° 03' 83"	*Pc. m.*	sand
Dumsiai	55° 00' 91"	24° 15' 77"	*Pc. v.-m.*	sand
Eičiai s	55° 11' 12"	22° 27' 28"	*Pc. m.-ox.*	sand
Ežerėlis I	54° 53' 09"	23° 31' 79"	*Pc. v.-m.*	sand
Ežerėlis II	54° 54' 08"	23° 35' 84"	*Pc. v.-m.*	sand
Gerdžiai	54° 57' 99"	23° 19' 15"	*Pc. v.-m.*	sand
Germantas k	55° 59' 07"	22° 07' 94"	*Pc. h.-ox.*	loam with gravel
Germantas p	55° 58' 99"	22° 07' 87"	*Pc. m.*	sand
Geruliai	55° 58' 32"	22° 24' 45"	*Pc. v.-m.*	sand
Jankai	54° 49' 50"	23° 21' 91"	*Pc. m.-ox.*	sand
Juodkrantė	55° 32' 80"	21° 06' 89"	*Pc. h.-ox.*	sand
Jurbarkas	55° 03' 83"	22° 40' 33"	*Pc. m.*	sand
Jūrava	55° 07' 07"	22° 18' 44"	*Pc. v.-m.*	sand
Jūrė ne	54° 44' 91"	23° 35' 71"	*Pc. v.-m.*	sand
Jūrė nu	54° 45' 03"	23° 35' 64"	*Pc. m.*	sand
Kajackai k	54° 48' 24"	23° 35' 38"	*Pc. v.-m.*	sand
Kajackai p	54° 48' 20"	23° 35' 42"	*Pc. m.*	sand
Kalniškė	54° 20' 30"	23° 32' 83"	*Pc. h.-ox.*	sand
Katutiškės	54° 30' 15"	25° 26' 38"	*Pc. m.-ox.*	potter's clay with sandy loam
Kazlų Rūda	54° 44' 63"	23° 28' 40"	*Pc. v.-m.*	sand
Klimbalė	55° 51' 30"	24° 27' 53"	*Pc. v.-m.*	sand
Krepštai	55° 54' 41"	22° 12' 24"	*Pc. v.-m.*	loam with gravel
Lentvaris	54° 35' 97"	25° 05' 77"	*Pc. h.-ox.*	loam with gravel
Margiai-I	55° 51' 25"	24° 29' 71"	*Pc. m.*	sand
Margiai-II	55° 52' 75"	24° 27' 75"	*Pc. m.-ox.*	sand
Mickūnai	54° 42' 40'	25° 34' 94"	*Pc. h.-ox.*	loam
Paštuva	55° 00' 98"	23° 36' 94"	*Pc. v.-m.*	sand
Pikeliškės	54° 51' 85"	25° 13' 11"	*Pc. h.-ox.*	clay
Rietavas-II	55° 41' 26"	21° 57' 47"	*Pc. h.-ox.*	loam with potter's clay
Ringuva	55° 03' 32"	23° 30' 65"	*Pc. h.-ox.*	sand
Stumbriškis	55° 51' 81"	24° 33' 67"	*Pc. m.*	sand
Šališkės	54° 48' 00"	23° 38' 43"	*Pc. m.-ox.*	sand
Šiluva k	55° 31' 75"	23° 12' 60"	*Pc. h.-ox.*	gravel
Šiluva s	55° 31' 73"	23° 12' 38"	*Pc. h.-ox.*	gravel
Šimonys	55° 40' 08"	25° 12' 80"	*Pc. h.-ox.*	sand
Šventoji-II	56° 03' 42"	21° 08' 50"	*Pc. v.-m.*	sand
Vaišnoriškė I	55° 25' 94"	26° 00' 85"	*Pc. v.-m.*	sand with gravel and loam
Vaišnoriškė II k	55° 25' 67"	26° 02' 19"	*Pc. v.-m.*	gravel
Vaišnoriškė II s	55° 25' 62"	26° 02' 30"	*Pc. h.-ox.*	gravel
Vaišnoriškė III	55° 26' 14"	26° 02' 62"	*Pc. v.-m.*	gravel
Veiviržėnai	55° 35' 67"	21° 31' 97"	*Pc. m.*	sand
Višakio Rūda	54° 48' 50"	23° 27' 49"	*Pc. v.-m.*	sand

Results

The results of the research conducted on spruce forests showed that the increment of spruce growing on dry forest sites decreased more than on moderately wet sites (Table 2). From Table 2, it could be seen that the latewood widths decreased most of all (smallest indexes). The smallest decrease was among earlywood widths. In spite of the most significant reduction of the radial increment of spruce on dry sites, spruce on moderately wet sites suffered also very much.

Table 2. Indices of the latewood, earlywood and annual radial increment of the local chronologies of Norway spruce in 1992 (max – highest index, min – lowest index)

Forest types	Latewood		Earlywood		Annual ring	
	max	min	max	min	max	min
Pc. v.-m., Pc. h.-ox.	70	16	92	39	85	32
Pc. m., Pc. m.-ox.	79	26	83	54	83	51

Latewood. The increment of the latewood on dry sites reduced especially (the smallest index values) (Fig. 1). The increment of spruce on moderately wet forest sites also reduced significantly, although not so severely than on dry sites. The most significant decrease of the latewood radial increment in 1992 was in East and South East Lithuania. The smallest decrease (bigger index values) was in North and West Lithuania (Fig. 1). The most significant increment losses were recorded in the research plot, located in the central part of Lithuania, near Jonava district.

Earlywood and annual ring. A decrease in the increment of earlywood on wet sites (Table 1) was slightest. Carrying out the analysis of the earlywood increment losses in 1992, it could be seen that the most significant decrease in the increment was already not in the eastern or south-eastern parts of Lithuania as with latewood case, but in the Central part of Lithuania: in the eastern part of the Kazlų Rūda forests with an extend towards the eastern districts (Fig. 2). The dynamics of a decrease in the increment of the annual ring in 1992 is similar to that of earlywood.

Discussion

The dependence of the increment of tree rings on ecological factors firstly was observed by Leonardo da Vinci, K. Linne and F. Schvedov (Baillie 1982, Битвинскас 1974). Many scientists admitted that extreme climate conditions limit the radial increment of trees (Битвинскас 1965 and 1974). Different reaction

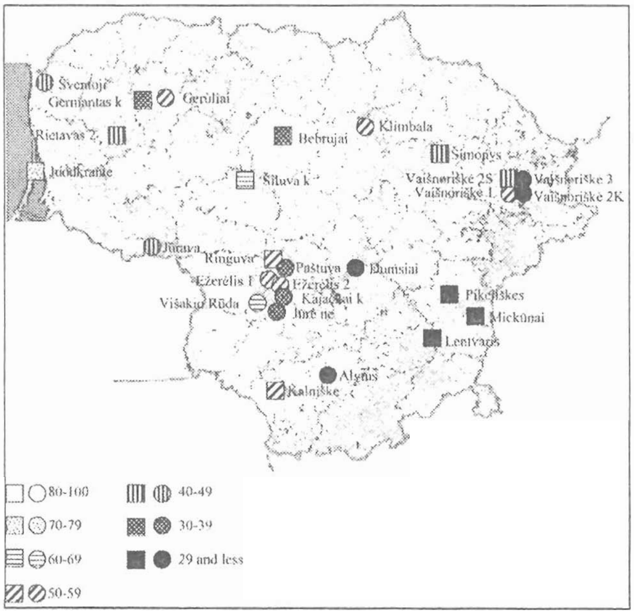

Figure 1. A decrease in the latewood widths (in indices) of Norway spruce in *Piceetum vaccinio-myrtillosum* (circle) and *Piceetum vaccinio-oxalidosum* (square) forest types in 1992

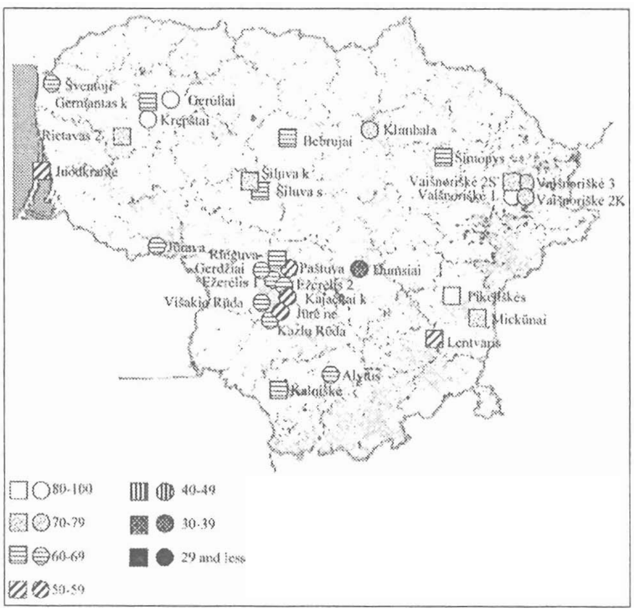

Figure 2. A decrease in the earlywood widths (in indices) of Norway spruce in *Piceetum vaccinio-myrtillosum* (circle) and *Piceetum vaccinio-oxalidosum* (square) forest types in 1992

of trees to the changes of climate also depends on the genetic characteristics of a tree and endogenous factors. It is supposed that there exist certain ecotypes resistant to drought (Lingg 1986).

Summarising the results of his own research and the research carried out by other scientists F. H. Schweingruber had stated, that there are two main methods to research the climate impact on the radial increment of trees: the long-term analysis, encompassing correlation and regression analysis and the short-term analysis – analysis of pointer years (extreme narrow or wide rings). Analyse of the correlation and multiple regression have shown that with a model of air temperature or precipitation it is possible to explain only up to 40% variations of the radial increment in Europe. Due to it, the bigger amount of the research carried out in Europe, deals with the analysis of the radial increment in extreme years also with the analysis of the conditions of vegetation in these years (Schweingruber 1990 and 1993).

Due to a surface root system, Norway spruce is a sensitive indicator of the climate changes, especially sensitively responding to the summer droughts, because sufficient moisture of the soil is necessary for the vegetation of spruce (Eckstein 1989; Ozolinčius 1998; Schweingruber 1993; Stravinskienė 1997; Битвинскас 1974).

Drought of 1992. Drought begins, when the evaporation rate is high and the amount of precipitation is very small or there is no precipitation at all. During the drought the ground water level abates, soils dry and the roots are not supplied with an enough amount of water (Bukantis 1998). The most severe droughts in Lithuania in the period 1961-1996 were in 1971, 1992 and 1994 years (Buitkuviene 1998). Meteorologists of Lithuania name the drought of 1992 as the biggest longest and the most considerable damages has been caused. The drought of the similar intensity was in Southeast Lithuania only in 1887 and 1964 (Bukantis 1993).

The negative impact of the drought of 1992 on the spruce forests was also because from the beginning of the vegetation and until the end the air temperature gradually increased: July and August were warmest from all the months of 1992 summer. The average air temperature of these months was 17.0-19.2°C (the average in July in Vilnius is 17.0 and in August – 16.2 and in Klaipeda – 16.7 and 16.7, respectively). The amount of precipitation during summer remained small. The strong impact of drought was also because it coincided with the beginning of vegetation (Fig. 3, 4). Only in August in some places more significant amount of precipitation fell, which was still less than the average (the average long-term mean of precipitation for July in Vilnius is 87 mm and in August – 83 mm (in Klaipėda 65 mm and 82 mm, respectively). Unfavourable droughty period finished in the middle of August (Agrometeorologinis biuletenis 1992; Bukantis 1993).

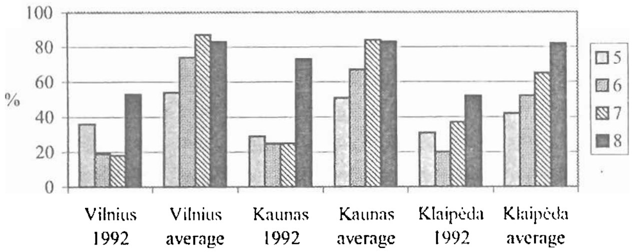

Figure 3. The amount of precipitation of Vilnius, Kaunas and Klaipėda meteorological stations in the May-August (months 5-8) of 1992 and the long-term average during the XX century

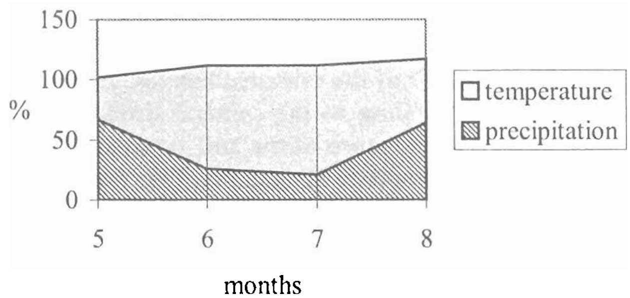

Figure 4. The dynamic of the air temperature and precipitation during the May-August of 1992 (data of Vilnius meteorological station). Amount of the air temperature and precipitation are shown as deviation from the long-term average

Latewood. A more significant decrease in the latewood under the impact of 1992 drought could be explained by the drying up of moisture reserves under the impact of the long-lasting drought. The latewood of Norway spruce suffered more, because the period of its formation is the end of summer and autumn. More significant losses of the radial increment on dry and also in moderately wet forest sites in the East districts of Lithuania could be attributed to the small amount of precipitation in July in East Lithuania and the highest air temperature, the isotherm of which 19°C covered Vilnius, Šalčininkai and Švenčionys districts (Agrometeorologinis biuletenis 1992).

Peculiarities of the impact of climate ascertained in this research, corresponds with the conclusions of the researchers of dendroclimatology in other countries of Europe, e.g. Prof. D. Eckstein affirms that spruce is sensitive to summer droughts and positively responds to wet and cool summer (Schweingruber 1993).

Earlywood. The smaller decrease in the increment in North and Northwest Lithuania (Telšiai, Panevėžys, and Radviliškis districts) coincides with regions where larger amounts of precipitation fell in May – June. Significant differences were observed in three research plots located in the eastern part of Lithuania near Vilnius. The forest types of these research plots are identical, but the decrease in the earlywood differs very much.

A more considerable decrease of the radial increment in the central part of Lithuania coincides with a region of a small amount of precipitation in May and July.

Walter Lingg stated that the increment on moderately wet and fertile sites could reduce less than on dry and infertile sites due to the impact of severe droughts (Lingg 1986). This conclusion corresponds absolutely to the results obtained in my research (Table 1).

Scientists also admit that during the period of droughts, the biochemical composition of the tree cells changes: the amount of resin, tannins, phenols and other substances toxic to insects decreases and the reliability of the severe spreading of tree pests and diseases increases (Bitvinskas, Vitas 1999; Горышина et al. 1975).

Not all differences in the pointer year analysis could be related to climate, because individual site conditions also influence the impact of climatic factors (Schweingruber 1993).

It is difficult to explain the significant differences of the radial increment between two research plots located near the seaside of the Baltic Sea. In the northern part of the seaside, near Latvia (research plot Šventoji) the increment decreased even more significantly than in Kuršių Nerija (plot Juodkrantė). Only local differences of precipitation or the ground water level could help explain this phenomenon. The problem is that the nearest meteorological stations are several tens of kilometres away from these research plots.

The climate of the Earth is under the increasing impact of the human activity, which results in climate warming and forests decline. The resistance of ecosystems to the unfavourable growing conditions reduces (Lamb 1995). The scientists of Lithuania explain more frequent and especial droughts in Lithuania with the climate changes. The severe drying of spruce forests in Lithuania has been attributed to the end of flourishing of Norway spruce in Lithuania due to climate warming or to a temporary climate fluctuation (Ozolinčius 1998).

The biggest decrease of the increment of spruce in Dumsiai research plot near Jonava could be explained with two reasons: the small amount of precipitation in the neighbouring Kaišiadorys district (this area of small precipitation during July perhaps reached the location of the research plot) or with a decline of forests under the influence of the Joint Stock company "ACHEMA" fertiliser plant, negative impact of which is observed already from 1979-1980 (Stravinskienė 1997). Since 1975, the reduction tendency of amplitudes of the cycles in the annual radial increment of spruce has been established. Since 1981 the gradual tendency of the reduction of the annual radial increment of spruce, depending not only on negative climate phenomena, but also on constantly increasing pollution of the environment is observed (Stravinskienė 1997).

Scientists from Poland: A. Zielski, G. Wojcik, R. Przybylak, K. Marciniak and M. Koprowski in the International Dendrochronological Conference "Eurodendro – 2001", held in Martuljek (Slovenia) in June 6-10, 2001, presented interesting results about the research of Norway spruce. Their research was carried out in the North East of Poland and deals with the analysis of pointer years. They also found the big reduction of the latewood increment of Norway spruce (*Picea abies* (L.) Karsten) in 1992 and stated that during the last decades of the XX century, there were only negative years of the increment of spruce in the North East of Poland (Zielski et al. 2001).

Conclusions

1. Under the impact of the summer drought of 1992, the indices of the radial increment of Norway spruce, growing on dry forest sites reduced very significantly. The increment on moderately wet and fertile sites decreased less than on dry sites.

2. Due to a long lasting and beginning of drought already from May, a decrease in the increment of latewood is considerably stronger than that in earlywood or annual ring.

3. Most of regional differences of the radial increment in Lithuania in 1992 could be easily explained by the peculiarities of the falling of precipitation.

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ЗАСУХА 1992 ГОДА В ЛИТВЕ И ПОСЛЕДСТВИЕ НА ОБЫКНОВЕННУЮ ЕЛЬ

А. Витас

Резюме

В статье анализируется влияние засухи 1992 года на формирование годичных колец обыкновенной ели (*Picea abies* (L.) Karsten). Дендроклиматологические исследование были проведены в 1995-2000 года и охватывают данные радиального прироста 45 пробных площадей. Пробные площади были заложены в *Piceetum vaccinio-myrtillosum*, *Piceetum hepatico-oxalidosum*, *Piceetum myrtillosum*, *Piceetum myrtillo-oxalidosum* типах леса. В месте с данными годичного радиального прироста также были использованы данные прироста ранней и поздней древесины. Стихиная засуха 1992 года очень негативно повлияла на радиальный прирост, особенно поздней древесины, обыкновенной ели.

Ключевые слова: ель обыкновенная, климат, температура воздуха, осадки, радиальный прирост, засуха