Masterchronologies of Norway Spruce (*Picea abies* (L.) Karsten) on Fresh Forest Sites in Lithuania

ADOMAS VITAS
Vytautas Magnus University, Faculty of Natural Sciences
Vileikos g. 8, 3035 Kaunas, Lithuania

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Masterchronologies from living Norway spruce trees (*Picea abies* (L.) Karsten) in *Piceetum vaccinio-myrtillosum* (*Pc. v-m*) and *Piceetum hepatico-oxalidosum* (*Pc. h-ox*) forest types in Lithuania are created for the first time. Masterchronologies for each forest type include data on latewood, earlywood and annual radial growth. Masterchronology in *Pc. v-m* forest type encompasses the data on the radial growth from 18 research plots (464 trees) and in *Pc. h-ox* – from 13 research plots (354 trees). Time span of masterchronology, created using the annual radial growth of living spruce trees in *Pc. v-m* forest type is 132 years and in *Pc. h-ox* – 100 years.

Correlation coefficients and detected event years between created masterchronologies and a regional chronology of spruce from Olsztyn Lake district (Zielski, Koprowski 2001) showed a well enough similarity between their growth dynamics.

Key words: climate, earlywood, event year, latewood, Lithuania, masterchronology, Norway spruce, radial growth

Introduction

Owing to the long-life and anatomical structure of the tree rings, conifers are one of the most important objects of the dendrochronogical research in Lithuania (Bitvinskas 1995). Due to Scots pine (*Pinus sylvestris* L.) domination in Lithuanian conifer forests, 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 (Karpavičius, Kairaitis, Yadav 1996, Vitas, Bitvinskas 1998).

Masterchronology is a chronology averaged from any tree-ring parameter, usually combining site or local chronologies from a given region, and used to date new tree-ring series (Kaennel, Schweinguber 1995).

According to the data of National Forest Exploitation, spruce growing on dry sites – *Piceetum vaccinio-myrtillosum* and *Piceetum hepatico-oxalidosum* occupies more than 6.8% of the total forest area (Ozolinčius 1998) of Norway spruce stands (23.1%) (Kuliešis, Rutkauskas, Butkus 2001).

The aim of the research was to construct masterchronologies for the radial growth of living Norway spruce trees on dry forest sites in Lithuania.

Materials and methods

A total of 33 research plots on dry stands (forest types: *Piceetum vaccinio myrtillosum*, *Piceetum hepatico-oxalidosum*) of Norway spruce (*Picea abies* (L.) Karsten) in Lithuania were selected. During the fieldwork, by using increment borer, samples were taken at the breast height. 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 coordinates for each research plot were established.

Tree ring widths (earlywood and latewood separately) were measured within 0.01 mm accuracy. For this purpose, the LINTAB tree-ring measuring table and TSAP 3.12 computer program, developed by F. Rinn and S. Jäkel in Heidelberg were used.

For the dating quality control (Eckstein 1987, Kienast 1985, Lovelius 1997, Wendland 1975) COFECHA 3.00P computer program, developed by R. Holmes was used. Using CHRONOL 6.00P computer program designed by E.R. Cook, the indexing was performed. 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 was used and after the spline, preserving 67% of variance at wave length 21 years, was fitted (Holmes 1994).

After the dating quality control and indexing, each tree-ring width series was averaged into a site chronology of research plot. The biweight robust mean for this purpose was used. A total of 33 site chronologies were constructed. Totally 31 site chronology were included into compiled masterchronologies. For the masterchronology developed for *Pc. v-m* forest type, site chronologies from 18 research plots (464 trees) were used and for the masterchronology representing *Pc. h-ox* forest type, 13 site chronologies (354 trees) were used. Examination of the localities of research plots and dating quality control between the site chronologies showed that due to a low similarity with others two site chronologies should not be included into masterchronologies. The low similarity of Dubrava 1 (Central Lithuania) site chronology with others could be attributed to a high ground water level because stand is close to a stream. The second site chronology named Kretinga (West Lithuania) was too short (35-40 years old stand) with asynchronous radial growth to include into masterchronologies.

Similarity between chronologies using the coefficient of correlation and Gleichläufigkeit (GLK) coefficient of similarity was evaluated. These calculations were performed using TSAP 3.12 and DPL computer programs.

The constructed masterchronologies were compared with site chronologies, submitted to the ITRDB (http://www.ngdc.noaa.gov/paleo/treering) by E. Feliksik and F.H. Schweingruber named Gasienicowy, Hala Gaslenicowa and Swystowko Wyznig (Southern Poland) and with a regional chronology of Norway spruce constructed for Olsztyn Lake district (Zielski, Koprowski 2001).

Event years were counted from index values: years with indices of 75 and smaller were valuated as negative event years and with indices of 120 and bigger – positive event years.

Results

Several characteristics of research plots and site chronologies, used to develop masterchronologies in Table 1 are presented: name of research plot, geographical coordinates (WGS 84), forest type, span of chronology (years), mean sensitivity of latewood, earlywood and annual ring. Time span of site chronologies varies from the shortest – 66 years to the longest – 162 years. The mean sensitivity of latewood is 0.20 - 0.43, of earlywood – 0.14 - 0.24 and of the annual radial growth – 0.13 - 0.23. The average age of site chronologies is 104 years and the mean sensitivity of the latewood – 0.29, earlywood – 0.18 and the annual radial growth – 0.17.

Nine site chronologies have time span more than 100 years with more than 10 trees and are most valuable. The data of them was submitted to the ITRDB located at Boulder USA (http://www.ngdc.noaa.gov/paleo/treering.html).

Table 1. Characteristics of research plots and site chronologies

Plot	Geographic coordinates		Forest type	Span of chronology	Mean sensitivity		
	North	East			Late wood	Early wood	Annual ring
Alytus	54° 25' 59"	24° 03' 11"	*Pc. v-m*	108	0.38	0.24	0.23
Bebrujai	55° 44' 90"	23° 37' 59"	*Pc. h-ox*	103	0.22	0.16	0.15
Dubrava 1	54° 49' 19"	24° 05' 97"	*Pc. h-ox*	69	0.26	0.17	0.14
Dumsiai	55° 00' 91"	24° 15' 77"	*Pc. v-m*	106	0.28	0.20	0.17
Ežerėlis-I	54° 53' 09"	23° 31' 79"	*Pc. v-m*	74	0.23	0.18	0.16
Ežerėlis-II	54° 54' 08"	23° 35' 84"	*Pc. v-m*	69	0.20	0.16	0.14
Gerdžiai	54° 57' 99"	23° 19' 15"	*Pc. v-m*	85	-	0.20	0.17
Germantas-k	55° 59' 07"	22° 07' 94"	*Pc. h-ox*	76	0.29	0.16	0.15
Geruliai	55° 58' 32"	22° 24' 45"	*Pc. v-m*	145	0.22	0.17	0.16
Juodkrantė	55° 32' 80"	21° 06' 89"	*Pc. h-ox*	113	0.24	0.20	0.17
Jūrava	55° 07' 07"	22° 18' 44"	*Pc. v-m*	91	0.28	0.20	0.17
Jūrė-I	54° 44' 91"	23° 35' 71"	*Pc. v-m*	121	0.27	0.17	0.17
Kajackai-k	54° 48' 24"	23° 35' 38"	*Pc. v-m*	126	0.37	0.23	0.18
Kalniškė	54° 20' 30"	23° 32' 83"	*Pc. h-ox*	96	0.30	0.22	0.18
Kazlų Rūda	54° 44' 63"	23° 28' 40"	*Pc. v-m*	88	-	0.19	0.16
Klimbalė	55° 51' 30"	24° 27' 53"	*Pc. v-m*	151	0.26	0.17	0.15
Krepštai	55° 54' 41"	22° 12' 24"	*Pc. v-m*	130	-	0.17	0.16
Kretinga	55° 51' 44"	21° 11' 59"	*Pc. h-ox*	38	-	0.11	0.10
Lentvaris	54° 35' 97"	25° 05' 77"	*Pc. h-ox*	83	0.37	0.18	0.15
Mickūnai	54° 42' 40'	25° 34' 94"	*Pc. h-ox*	72	0.33	0.17	0.16
Paštuva	55° 00' 98"	23° 36' 94"	*Pc. v-m*	113	0.26	0.18	0.16
Pikeliškės	54° 51' 85"	25° 13' 11"	*Pc. h-ox*	102	0.32	0.22	0.18
Rietavas-II	55° 41' 26"	21° 57' 47"	*Pc. h-ox*	81	0.25	0.15	0.13
Ringuva	55° 03' 32"	23° 30' 65"	*Pc. h-ox*	84	0.30	0.18	0.16
Šiluva-k	55° 31' 75"	23° 12' 60"	*Pc. h-ox*	102	0.30	0.23	0.19
Šiluva s	55° 31' 73"	23° 12' 38"	*Pc. h-ox*	66	-	0.21	0.19
Šimonys	55° 40' 08"	25° 12' 80"	*Pc. h-ox*	147	0.31	0.22	0.20
Šventoji-II	56° 03' 42"	21° 08' 50"	*Pc. v-m*	162	0.26	0.14	0.14
Vaišnoriškė-I	55° 25' 94"	26° 00' 85"	*Pc. v-m*	116	0.31	0.22	0.21
Vaišnoriškė-II	55° 25' 67"	26° 02' 19"	*Pc. v-m*	106	0.43	0.20	0.20
Vaišnoriškė-III	55° 25' 62"	26° 02' 30"	*Pc. h-ox*	98	0.28	0.17	0.16
Vaišnoriškė-IV	55° 26' 14"	26° 02' 62"	*Pc. v-m*	140	0.35	0.20	0.17
Višakio Rūda	54° 48' 50"	23° 27' 49"	*Pc. v-m*	79	0.23	0.17	0.16
Average				**104**	**0.29**	**0.18**	**0.17**

Time span of compiled masterchronology for *Pc. v-m* forest type covered by 10 and more trees is 132 years, and for *Pc. h-ox* – 100 years (Table 2). Mean sensitivity of masterchronologies for the latewood is 0.22-0.23, earlywood – 0.14-0.16 and the annual radial growth – 0.12. So, the most sensitive are series of latewood radial growth and more complacent are series created for the annual radial growth.

Correlation coefficients between two masterchronologies are: +0.80 (latewood), +0.78 (earlywood) and

Table 2. Characteristics of constructed masterchronologies for Norway spruce. Presented time span of masterchronology covered by 10 or more trees

Forest type	Wood	Period (years)	Span of masterchronology (years)	Number of research plots	Number of trees
Pc. v-m	Late	1873-1999	127	14	351
	Early	1869-1999	131	18	449
	Annual	1868-1999	132	18	464
Pc. h-ox	Late	1899-1999	101	12	256
	Early	1894-1999	106	13	345
	Annual	1900-1999	100	13	354

+0.89 (annual radial growth) and coefficients of similarity (GLK) – 71.3, 77.3 and 81.4 respectively. So, the differences between the dynamics of the radial growth of two masterchronologies (forest types *Piceetum vaccinio-myrtillosum* and *Piceetum hepatico-oxalidosum*) are insignificant (Vitas 2002). Graphs of masterchronologies in Figures 1, 2, 3 and indices of the radial growth in Tables 3, 4 are presented.

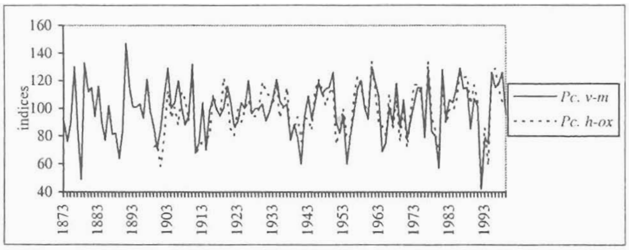

Figure 1. Masterchronologies of Norway spruce latewood radial growth

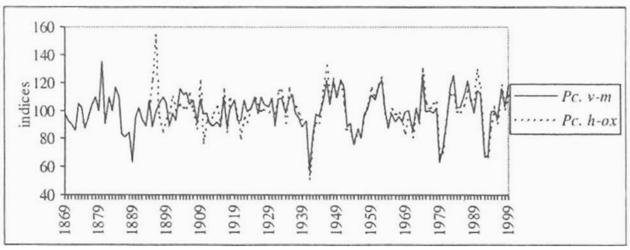

Figure 2. Masterchronologies of Norway spruce earlywood radial growth

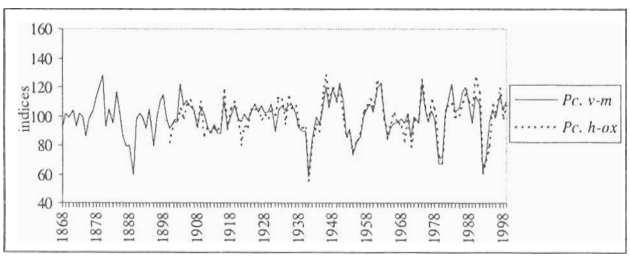

Figure 3. Masterchronologies of Norway spruce annual radial growth

Table 3. Indices of latewood (upper value), earlywood (middle value) and annual radial growth (lower value) masterchronology for Norway spruce in *Pc. v-m* forest type

Decades	*Years* 0	1	2	3	4	5	6	7	8	9
186	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	98
	-	-	-	-	-	-	-	-	92	102
187	-	-	-	91	76	89	130	87	49	133
	93	90	86	105	102	87	94	104	110	100
	99	104	93	102	100	86	98	104	113	121
188	112	115	94	116	90	77	102	81	82	64
	135	90	110	100	117	110	83	81	84	63
	128	93	105	95	117	103	86	79	80	60
189	83	147	115	101	101	103	93	121	98	87
	95	102	94	89	107	88	98	104	110	105
	98	102	99	91	105	79	99	110	115	99
190	71	85	109	129	100	104	120	101	88	94
	89	98	93	116	111	113	104	107	92	108
	91	96	96	122	107	111	107	104	92	105
191	132	68	75	104	70	98	108	99	95	100
	97	98	90	89	92	88	110	88	101	107
	103	94	88	94	88	88	111	92	99	108
192	116	104	87	90	104	100	120	96	100	100
	93	93	107	99	102	110	97	110	104	103
	99	96	102	97	102	109	103	107	103	103
193	103	91	97	107	121	105	101	103	77	88
	109	89	108	109	98	108	111	98	95	88
	109	89	104	107	104	107	109	102	92	90
194	79	60	94	109	92	103	119	110	114	115
	93	57	81	97	96	108	121	104	121	109
	90	58	84	100	94	106	120	106	119	111
195	126	90	82	95	60	80	96	114	120	101
	122	117	88	91	76	87	80	97	101	111
	123	111	86	91	73	84	85	100	105	109
196	92	130	119	109	69	75	101	89	118	86
	107	117	122	102	87	98	92	96	92	99
	103	120	122	104	84	92	95	96	98	95
197	106	78	91	103	115	115	79	127	83	80
	100	86	102	92	126	99	100	98	102	63
	102	85	100	95	123	106	96	104	98	67
198	57	128	92	106	104	115	129	114	115	85
	73	95	117	125	102	102	111	121	109	98
	67	101	112	122	103	106	117	120	109	95
199	107	102	42	78	75	126	115	118	126	96
	114	112	67	68	99	100	94	116	103	118
	114	109	62	71	96	105	99	115	104	111

Discussion

Carrying out the dating quality control was established that the number of trees with dissimilar radial growth or suspected with dating problems on average is 31% of latewood, 19% of earlywood and 16% of annual growth series, the data of which were not used for the further analysis. Poorer dating quality or greater amount of dissimilar tree radial growth was detected among the latewood series, which could be explained with reaction-compression wood. Trees of dissimilar growth are from different age categories: significantly younger or older than the average tree in the stand. Previous researchers have also pointed out that tree number with poor dating quality in plot varies from 15% to 30% (Bitvinskas 1974) and dating of Norway spruce radial growth series between trees are often complicated (Becker 1978).

Similarity between the radial growths of site chronologies could be characterised by high enough coefficients of correlation (average +0.60 - +0.62, lowest +0.26 +- +0.37 and highest +0.82 - +0.84). Similarity slightly decreases with increasing distance between research plots, but even between the farthest plots (Šventoji 2, Juodkrantė and Vaišnoriškė are approximately 300 km in distance), similarity is significant (coefficients of correlation varies from +0.31 to +0.55).

Table 4. Indices of latewood (upper value), earlywood (middle value) and annual radial growth (lower value) masterchronology for Norway spruce in *Pc. h-ox* forest type

Decades	Years 0	1	2	3	4	5	6	7	8	9
189	-	-	-	-	-	-	-	-	-	72
	-	-	-	-	102	123	154	95	85	94
	-	-	-	-	-	-	-	-	-	-
190	74	58	79	113	93	101	88	112	106	91
	98	110	100	104	103	102	112	100	87	121
	82	97	97	105	99	108	111	103	93	110
191	126	67	72	76	78	80	110	100	94	122
	77	93	90	98	103	90	115	85	108	106
	87	92	89	92	91	94	118	91	106	110
192	108	85	80	100	90	98	106	95	94	99
	96	80	95	92	104	109	104	100	101	99
	97	81	93	93	105	105	105	98	101	99
193	119	112	109	102	119	93	101	115	79	85
	102	98	114	114	91	116	107	103	97	94
	105	101	113	112	95	113	106	107	94	93
194	94	76	93	92	84	113	121	113	102	111
	92	52	80	92	91	118	132	109	123	111
	92	56	82	94	90	116	128	111	119	110
195	115	74	84	100	78	80	109	123	115	104
	120	104	87	86	77	85	82	97	105	116
	119	98	86	88	77	84	89	104	108	112
196	94	134	113	88	87	80	110	84	106	76
	110	119	124	98	89	101	97	98	90	84
	106	124	122	98	88	96	102	95	93	83
197	101	72	96	117	117	110	82	134	93	84
	99	81	101	91	130	105	102	105	106	67
	101	79	99	97	125	106	97	111	105	72
198	64	118	89	99	98	104	125	122	123	103
	70	100	112	111	100	99	104	114	107	108
	68	105	107	109	100	101	110	116	110	108
199	117	104	42	86	59	121	129	114	105	104
	129	117	68	67	88	103	91	118	101	111
	126	116	61	70	81	108	103	119	99	107

According to the obtained research results on Norway spruce tree rings, it gives no well-grounded arguments to construct regional masterchronologies for spruce in Lithuania.

A comparison of constructed masterchronologies with the other chronologies was not an easy task. To compare earlywood and latewood series of compiled masterchronologies with previous researchers is quite impossible, because comprehensive analysis on the latewood and earlywood widths of Norway spruce were not performed and published in Lithuania.

Any references on masterchronologies on spruce from the neighbouring regions in the Henri's bibliography pages (http://tree.ltrr.arizona.edu/cgi-bin/bibliosearch.pl) were not found. I found three site chronologies for Norway spruce from upland region of South Poland submitted by E. Feliksik and F. H. Schweingruber to the ITRDB (http://www.ngdc.noaa.gov/paleo/treering). Due to a long distance (approximately 500 km) between the locations of research plots and differences in climate character similarities could not be found (correlation coefficients are -0.03 – -0.14 and coefficients of similarity – 38.5-54.2). Mentioned coefficients indicate dissimilar growth dynamics of compared chronologies.

From Andrzej Zielski and Marcin Koprowski, I received its paper, published in the Journal Sylwan in 2001. A regional chronology of Norway spruce from Olsztyn Lake District (approximately 250 km from the nearest research plots used to compile masterchronologies) in this article is presented. Its chronology has a time span of 160 years, from 1840 until 1999. My masterchronologies with the mentioned regional chronology shows a very good similarity in their growth dynamics (correlation coefficients are +0.68 – +0.70 and coefficients of similarity – 73.8-76.2). These coefficients are significant (p=0.05).

For a more clear view on the similarities and differences of my masterchronologies and a regional chronology of spruce from Olsztyn Lake district, event years of the annual radial growth in Table 5 are presented. From Table 5 it can be seen that the main event years coincide between three chronologies well enough, e.g. in 1889 (-), 1941 (-), 1946 (+), 1961 (+), 1974 (+), 1979 (-), 1980 (-), 1987 (+), 1990 (+) and 1992 (-).

Years	*Master-chronology Pc. v-m*	*Master-chronology Pc. h-ox*	*Olsztyn Lake district*	*Years*	*Master-chronology Pc. v-m*	*Master-chronology Pc. h-ox*	*Olsztyn Lake district*
1870				1958			+
1872			+	1959			+
1878			+	1961	+	+	+
1879	+			1962	+	+	
1880	+			1967			+
1887				1974	+	+	+
1889				1979			
1903	+			1980			
1916			+	1983	+		
1922			-	1986			+
1936			+	1987	+		+
1940				1988			+
1941				1990		+	+
1943			+	1992			
1946	+	+	+	1993			
1950	+		+	1999			+
1954							

Table 5. Established event years of masterchronologies. Minus marks (-) in the table indicate negative events, plus (+) – positive event years

According to the results of my research carried out on the tree rings of Norway spruce in Lithuania, dry spring and summer conditions play the main negative role in the formation of spruce negative pointer years in Lithuania (1941, 1979, 1980 and 1992). Positive pointer years form in the response to warm spring and wet summer conditions (1946 and 1974). The impact of summer droughts is especially powerful after snow-less winter (1941) (Vitas 2002). Main results received during the research of pointer years of Norway spruce corresponds with the results obtained in other countries: spruce is very sensitive to summer droughts and prefers cool and moist weather (Schweingruber 1993).

Summarizing, it could be stated that the radial growth of spruce in Lithuania and in the Olsztyn Lake District (North-east Poland) is favoured by similar climate conditions. While, in the upland of Southern Poland (site chronologies by F.H. Schweingruber and E. Feliksik) Norway spruce is favoured by different climate conditions than in Lithuania and North-eastern Poland.

Conclusions

1. Modern masterchronologies for Norway spruce on dry forest types are created and could be used by scientists in Lithuania and in the neighbouring countries.

2. Coefficients of correlation and similarity, and event years showed that compiled masterchronologies have good similarity in their growth dynamic with the regional chronology for Olsztyn Lake district. It points out to the similar climate conditions in individual years and analogous reaction of Norway spruce radial growth to climate in mentioned regions.

3. Event years of masterchronologies showed that dry spring and summer conditions plays the main negative role in the formation of narrow rings of spruce in Lithuania

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ЭТАЛОННЫЕ ДЕНДРОШКАЛЫ ЕЛИ ОБЫКНОВЕННОЙ (*PICEA ABIES* (L.) KARSTEN) В СВЕЖИХ МЕСТОПРОИЗРОСТАНИЯХ ЛЕСОВ ЛИТВЫ

А. Витас

Резюме

Эталонные дендрошкалы из живых деревьев ели обыкновенной (*Picea abies* (L.) Karsten) в типах леса (*Piceetum vaccinio-myrtillosum* и *Piceetum hepatico-oxalidosum*) созданны в Литве впервые.

Каждая шкала включает в себе данные раннего, позднего и годичного радиального прироста. Шкала в типе леса (*Piceetum vaccinio-myrtilloasum*) включает данные радиального прироста из 18 пробных площадей (464 деревьев) а шкала в ельниках типа *Piceetum hepatico-oxalidosum* – 13 пробных площадей (354 деревьев). Созданные дендрошкалы радиального прироста ели обыкновенной в ельниках типа *Piceetum vaccinio myrtillosum* охватывает 132 года а в типах *Piceetum hepatico-oxalidosum* – 100 лет.

Коефициенты корреляции и выявлянные критические годы радиального прироста созданных дендрошкал показывают близкое сходство с региональной хронологией из Польши.

Ключевые слова: ель обыкновенная, климат, ранная древесина, особый год, поздная древесина, Литва, эталонная дендрошкала, радиальный прирост