Tree-Ring Chronology of Scots Pine (*Pinus sylvestris* L.) for Lithuania

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Abstract

The long-term Scots pine tree-ring chronology developed from historical timber and living trees from Lithuania is presented. The chronology involves dated 65 tree-ring width series (33 timber samples and 32 living trees) and runs for 516 years between 1487 and 2002. Constructed chronology shows strong trans-regional signal – high similarity to centennial pine chronologies developed for Poland, Latvia and Estonia. Pointer year analysis has revealed that colds in winter-spring and droughts in summer are the main causes for the sharp decrease in the radial growth. Five negative pointer years cannot be linked to climate events because of the lack of historical records in the pre-meteorological period.

Key words: climate, dating, pointer years, Scots pine, tree-ring chronology

Introduction

Development of dendrochronology is closely related to construction of long-term chronologies (Hughes *et al*. 1982). The chronologies have been used as a tool for dating timber from historical buildings and reconstructions of the past environmental conditions (Eronen *et al*. 2002, Grudd *et al*. 2002, Helama *et al*. 2004).

Scots pine timber was the commonly used species for building activities for the last centuries in Lithuania (Vitas 2005), except small amount of Norway spruce (Vitas 2007) in central Lithuania and English oak, found in Klaipėda (Vitas and Zunde 2008). This was determined not only by climate conditions, but also by timber export to West Europe. On the other hand, due to devastating historical events (wars, fires *etc.*) in Baltic countries (Läänelaid 2002) the original timber from building time only seldom could be found, while wood from the later restoration works usually predominate (Vitas 2005). Therefore, in contrast to West Europe, construction of the long-term centennial chronologies in Lithuania and other Baltic States is more complicated.

The biggest number of previous chronologies (Karpavičius *et al*. 1998, Pukienė 2002) is constructed by using tree-ring series from single objects-buildings. Therefore, such chronologies did not reach present times. The 500-years chronology of Scots pine using living trees and reaching present times in Lithuania was compiled for the first time. The aim of the study was to construct the long-term centennial Scots pine chronology by using tree-ring series of archaeological timber and living trees.

Materials and methods

81 samples (cross-sections) from Scots pine (*Pinus sylvestris* L.) timber taken from historical buildings were investigated. Samples are from old houses (churches, monasteries and estates) located in Kaunas (The Jėzuitai Church, Karmelitai Church, St. Mikalojus Church, Skaruliai Church, Zapyškis Church, City Hall, Aukštoji Freda Estate, Ilguva Estate, Veliuona Estate) and Vilnius regions of Lithuania (The Benediktinai Church, Benediktinai Monastery, Cathedral, Evangelikai Reformatai Church, St. Jonas Church, St. Mykolas Church, Trinitoriai Monastery, Trakai old houses, City Hall and Kairėnai Estate) (Figure 1).

Investigations of living pines were conducted at two oldest parks of Lithuania. 24 samples from oldest pines growing in Vingis Park (Vilnius) were cored. One core was taken from each tree. Eight pines were sampled in Panemunė Šilas (Kaunas) (Figure 1). Four cores in perpendicular radii were taken from each tree.

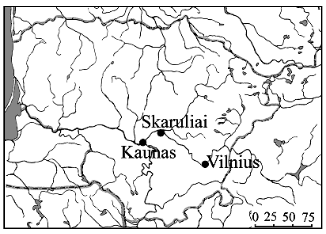

Figure 1. Location of sampling sites for living pines and historical timber in Lithuania

Surface of cores from living trees was prepared by cutting with razor blade. Surface of timber disks were sanded with progressively finer grades of sand paper (40 to 400 grid). The tree-ring widths were measured to the nearest 0.001 mm. Cross-sections were measured in at least two radii. For this purpose, LINTAB tree-ring measuring table and TSAPWin 0.30 computer program (F. Rinn Engineering Office and Distribution, Heidelberg) were used. Tree-ring-series from living trees were synchronised against each other by using Cofecha 3.00P (R.L. Holmes, Tucson). Synchronisation of timber samples was carried out by visual comparison (Eckstein 1987) of ring-width graphs.

For the dating of younger samples (from the last 200-300 years) tree-ring series of living pines (Vingis Park and Panemunė Šilas) were used, while for the dating of older material two long-term pine chronologies were successfully applied: Dannenstern House, Latvia (Zunde 1998) and Polpinus-5, Poland (Zielski 1992). The compiled chronology was compared to other available pine chronologies from the Baltic region: Polpinus (Poland, Zielski 1992), Polskane (Poland, Zielski 1997), Kujawpom (Poland, Zielski and Krąpiec 2004), Estonia (Läänelaid and Eckstein 2003) and Gotland (Bartholin 1987). For this purpose t-values were counted (TSAPWin 0.30, Formula 1) and cluster analysis was performed (Statistica 6, Statsoft Inc., Tulsa). For the analysis of clustering the following statistical methods were adopted: joining (tree clustering) with linkage rule (Ward's method) and distance measure (1-Person r).

$$t = \frac{r^2 * \sqrt{n-2}}{1-r^2} \qquad (1)$$

where, t – t-value, r^2 – cross-correlation, n – number of overlapping points.

Standardisation of the series was carried out using CHRONOL 6.00P program (R.L. Holmes, Tucson). Each tree ring width series belonging to individual tree was indexed separately. Tree-ring growth depressions were analysed by using negative pointer year analysis (Schweingruber 1990, Schweingruber 1993, Schweingruber *et al*. 1990). Calculations were accomplished by using WEISER 1.0 computer program (I.G. Gonzales, Lugo) (Gonzales 2001). The threshold level for pointer years was set at 80% of event years for the period of chronology covered by ten or more trees and at 90% of event years for the period covered by five-nine trees. Interpretation of negative pointer years was carried out by using meteorological data of Vilnius meteorological station (temperature from 1777, precipitation from 1887) and for older period by using historical records of extraordinary weather events compiled by Bukantis (1998).

Results

Crossdating of tree-ring series from archaeological timber was carried out and tree-ring width series from 33 timber samples and 32 from living trees were averaged into Litpinus-1 chronology (Table 1, Figure 2). The number of successfully dated samples was higher, but only series characterized by significant correlation coefficients among others were included into the chronology to enhance the common signal.

Table 1. Tree-ring-widths (upper - mm and lower - indices) of Litpinus-1 Scots pine chronology

Decades	Years									
	0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
148	–	–	–	–	–	–	–	3.53	3.72	3.37
	–	–	–	–	–	–	–	96	105	98
149	3.36	3.10	3.12	2.79	2.23	2.89	2.34	3.10	2.98	3.20
	102	98	102	95	79	107	91	126	128	146
150	1.72	1.89	1.21	1.86	1.46	1.67	2.54	2.53	2.04	1.30
	84	99	68	114	96	84	121	121	106	69
151	1.52	1.69	1.83	1.50	1.58	1.81	2.06	1.73	1.59	1.78
	85	88	90	88	95	106	118	102	100	111
152	1.92	1.60	1.49	1.48	1.68	1.75	1.63	1.80	1.47	1.23
	118	102	98	83	106	108	138	112	94	117
153	0.98	1.10	1.26	1.21	1.46	1.62	1.84	2.03	2.06	1.83
	81	58	80	76	88	101	112	108	106	105
154	1.61	1.75	1.53	1.66	1.38	1.41	1.89	1.66	1.63	1.42
	94	104	102	106	118	101	102	89	106	93
155	1.83	1.96	2.22	2.37	2.05	2.20	2.42	1.66	1.37	1.59
	109	96	103	102	100	109	104	80	72	114
156	1.80	2.05	1.97	1.65	1.65	1.05	1.41	1.32	1.68	1.59
	99	116	115	98	103	76	101	112	102	98
157	1.62	1.63	1.43	1.27	1.33	1.21	1.67	1.73	1.61	1.77
	100	103	95	83	88	80	107	117	113	116
158	1.64	1.43	1.23	1.24	1.07	1.16	1.13	1.03	1.45	1.00
	121	112	94	89	88	104	99	87	97	88
159	1.14	1.17	1.17	1.15	1.44	1.34	1.45	1.09	1.28	0.98
	101	106	109	93	113	99	105	79	103	80
160	1.26	1.34	1.68	1.27	1.11	0.93	0.89	1.00	0.79	0.76
	106	113	142	116	106	90	81	93	81	78
161	0.95	1.28	1.13	1.11	1.24	1.16	1.44	1.55	1.25	1.28
	92	123	105	93	103	107	109	123	109	80
162	1.65	1.40	1.33	1.45	1.26	1.62	1.57	1.39	1.00	0.93
	103	91	101	105	89	112	117	103	101	80
163	1.31	1.13	1.13	0.99	0.83	0.99	1.13	1.06	1.05	1.26
	105	93	91	91	82	90	101	112	111	116
164	1.16	1.12	1.19	1.04	0.95	0.97	0.80	0.95	0.86	0.73
	117	97	107	93	103	122	95	96	84	78
165	0.86	0.83	0.74	0.86	0.73	0.98	1.41	1.13	0.79	0.66
	97	105	83	97	89	110	154	105	93	73
166	0.77	0.87	0.95	0.94	1.02	0.84	1.06	0.83	0.83	1.00
	88	92	98	108	118	108	118	104	108	109
167	0.76	0.70	0.78	1.05	0.76	0.82	1.57	1.42	1.65	1.81
	104	93	92	87	76	89	99	91	105	90
168	2.20	1.77	1.71	1.69	1.67	2.36	2.20	2.07	2.00	1.85
	111	94	97	99	103	111	122	113	105	98

Table 1. (Continued)

Decades	*Years*									
	0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
169	1.65	2.00	1.87	1.80	2.15	1.95	1.97	1.70	1.45	1.42
	88	104	96	87	105	101	108	101	91	94
170	1.32	1.66	1.69	1.26	1.39	1.62	1.72	1.78	1.91	1.73
	88	109	111	82	89	100	96	103	111	100
171	2.09	1.89	1.77	1.80	1.59	1.79	1.59	1.55	1.91	1.67
	114	102	101	109	96	100	90	101	115	100
172	1.59	1.47	1.56	1.86	1.59	1.45	1.23	1.42	1.52	1.48
	96	89	99	117	104	93	81	90	100	100
173	1.59	1.43	1.57	1.69	1.63	1.02	0.80	0.87	0.99	1.15
	109	102	118	130	129	81	72	76	101	104
174	0.87	1.09	1.15	1.29	1.15	1.08	1.14	0.75	0.70	0.72
	81	93	101	117	105	109	114	77	66	75
175	1.15	1.07	1.26	1.48	1.44	1.29	1.29	1.28	0.92	0.99
	103	102	111	126	123	111	112	117	87	96
176	0.88	1.12	0.76	1.11	1.23	1.26	1.06	1.00	1.03	1.13
	83	104	73	97	111	115	95	93	98	101
177	1.12	0.87	1.04	1.05	1.08	1.05	1.10	1.11	1.28	1.42
	103	83	101	99	101	96	103	97	117	132
178	1.10	0.99	0.97	1.05	1.04	1.02	1.25	1.13	1.18	0.93
	103	90	93	102	99	88	105	104	107	81
179	1.07	1.53	1.30	1.20	1.43	1.53	1.56	1.56	1.54	1.51
	78	105	95	86	101	103	102	104	102	105
180	1.48	1.77	1.90	1.42	1.29	1.50	1.43	1.51	1.41	1.50
	101	117	126	96	91	100	97	105	90	96
181	1.60	1.18	1.41	1.83	1.65	1.64	1.61	1.89	1.76	1.47
	101	74	94	122	99	96	98	114	103	82
182	1.64	1.87	1.98	1.71	2.11	1.81	1.54	1.43	1.72	1.58
	93	105	114	102	126	107	93	86	105	96
183	1.55	1.46	1.42	1.35	1.58	1.75	1.66	1.78	1.60	1.25
	97	94	91	85	100	113	102	113	106	85
184	1.56	1.74	1.67	1.32	1.29	1.30	1.52	1.47	1.68	1.74
	96	108	108	86	88	90	106	99	118	128
185	1.44	1.59	1.28	0.87	0.90	1.37	1.54	1.28	1.08	1.15
	109	113	92	73	76	104	116	98	77	85
186	1.35	1.36	1.58	1.77	1.61	1.30	1.95	1.57	1.36	1.79
	104	99	107	114	105	87	126	104	94	119
187	1.64	1.23	1.40	1.43	1.29	1.13	1.22	1.00	1.27	1.46
	109	85	100	104	94	83	92	80	101	114
188	1.37	1.29	1.39	1.15	1.52	1.46	1.26	1.36	1.05	0.75
	105	100	107	91	115	113	96	108	88	63
189	1.09	1.22	1.38	1.52	1.49	1.21	0.93	1.18	1.24	1.22
	90	100	118	119	119	101	82	99	106	104
190	0.98	1.06	1.04	1.08	1.22	1.13	1.04	1.07	1.03	1.09
	88	94	96	100	112	104	94	99	97	104
191	1.33	1.02	1.03	1.15	0.71	0.71	0.94	0.89	1.01	0.98
	128	98	100	114	73	72	96	89	101	98
192	0.92	0.95	1.11	1.20	1.24	1.29	0.86	0.91	0.92	0.91
	91	97	117	118	122	126	89	99	104	111
193	0.92	0.59	0.51	0.57	0.61	0.71	0.67	0.68	0.77	0.70
	110	78	71	85	89	107	98	106	120	104
194	0.37	0.52	0.53	0.71	0.70	0.87	0.89	0.74	0.95	0.82
	59	81	80	102	100	111	118	98	119	105
195	0.94	0.91	0.71	0.66	0.62	0.60	0.53	0.66	0.53	0.62
	122	120	100	97	93	94	85	104	89	104

Table 1. (Continued)

Decades	*Years*									
	0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
196	0.57	0.68	0.42	0.40	0.47	0.53	0.63	0.68	0.63	0.55
	101	116	78	75	85	98	109	112	100	88
197	0.71	0.61	0.79	0.80	0.89	0.81	0.61	0.84	1.00	0.52
	104	89	111	112	120	106	86	106	124	64
198	0.52	0.69	0.93	0.84	0.74	0.94	0.77	0.66	0.95	0.91
	70	96	125	104	94	110	88	81	109	102
199	0.84	0.76	0.75	0.73	0.74	0.89	0.73	0.76	0.75	0.68
	107	109	102	96	101	112	98	99	100	93
2000	0.82	0.89	0.79	–	–	–	–	–	–	–
	107	108	93	–	–	–	–	–	–	–

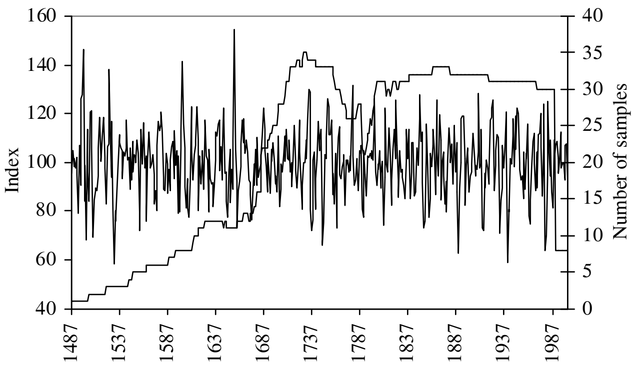

Figure 2. Litpinus-1 chronology in indices and number of samples (secondary axes)

The age of living trees, which series were included into Litpinus-1 chronology varied from 128 to 311 years (on average – 212 years) (Figure 3), the average

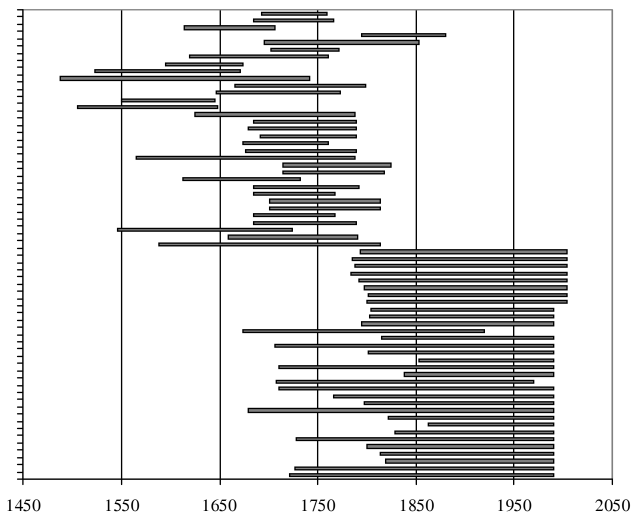

Figure 3. Bar diagram of cross-dated tree ring sequences used to construct Lithuanian pine chronology Litpinus-1

tree-ring width from 0.80 to 1.88 mm (on average – 1.31 mm) and mean sensitivity from 0.16 to 0.33 (on average – 0.24). The tree-ring number of timber samples fluctuated from 66 to 254 (on average – 123), the average tree-ring width from 0.68 to 2.15 mm (on average – 1.41 mm) and mean sensitivity from 0.14 to 0.27 (on average – 0.20). Compiled chronology includes 65 tree-ring series and runs for 516 years between 1487 and 2002. The mean sensitivity of Litpinus-1 chronology is 0.13 (standardised).

The constructed Litpinus-1 chronology was compared to other Scots pine (*Pinus sylvestris* L.) chronologies available for Baltic region (see methods) by using t-values (Table 2) and cluster analysis (Figure 4). The chronology shows strong trans-regional signal. High t-values were obtained between Litpinus-1 chronology and majority chronologies for Latvia, Estonia and Poland (t-value ranges from 6.5 to 9.9), while the link between Gotland and Polpinus chronologies is weaker (t-value – 3.9-5.6).

Table 2. T-values between chronology Litpinus-1 and other pine chronologies for Baltic region

	Lithpinus-1	*Polpinus*	*Polpinus-5*	*Polskane*	*Kujawpom*	*Dannenstern House*	*Estonia*	*Gotland*
Lithpinus-1	X							
Polpinus	3.9	X						
Polpinus-5	6.5	31.1	X					
Polskane	8.1	28.1	61.3	X				
Kujawpom	8.0	19.7	31.0	36.2	X			
Dannenstern House	7.9	1.3	2.3	2.9	3.7	X		
Estonia	9.9	5.6	7.8	8.3	8.9	4.3	X	
Gotland	5.6	4.1	6.1	7.8	7.6	2.4	8.6	X

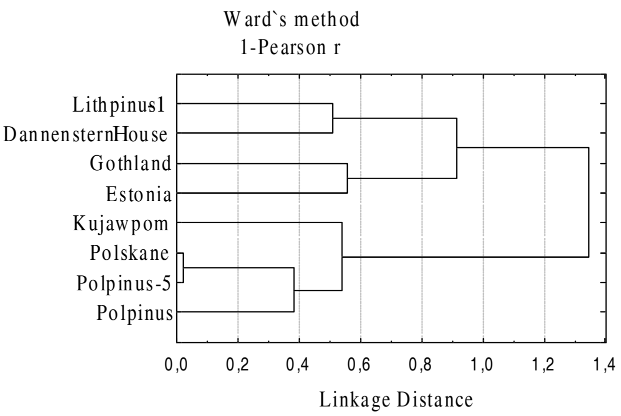

Figure 4. Cluster analysis among Scots pine chronologies for the Baltic region

Cluster analyses among Scots pine chronologies from the Baltic region (Figure 4) have revealed that Litpinus-1 chronology has the greatest similarity to Dannenstern House (Latvia) chronology. The second sub-cluster is formed by Gotland and Estonian chronologies, which are closest to mentioned above chronologies. Four chronologies from Poland form the second big group.

Fifteen negative pointer years have been ascertained. The causes for the growth reduction are presented in Table 3. There are no recorded climate extremes in historical records for five years (1599, 1629, 1659, 1736 and 1762). These years are before the meteorological observations have started. Six pointer years probably were induced by droughts in spring and summer (1748, 1811, 1889, 1896, 1914 and 1915). Three pointer years (1619, 1932 and 1980) could be connected to winter and spring colds and in 1940 both events (droughts and colds) took place.

Table 3. Negative pointer years of the radial growth of Scots pine and possible causes, Δ – indicates deviation from the long-term average

Pointer year	*Possible cause*
1599	There are no recorded climate extremes of this year.
1619	Cold May. The snow was still lying on 5th of May. Frosts during summer were observed Famine year (Борисенков и Пасецкий 1988).
1629	There are no recorded climate extremes of this year.
1659	There are no recorded climate extremes of this year. However, famine and epidemics took place (Bukantis 1998).
1736	There are no recorded climate extremes for this year.
1748	Drought, crop failure (Борисенков & Пасецкий 1988). Climate extremes were recorded also in Estonia – winter lasted from Christmas to the end of March (Wahtre 1970).
1762	There are no recorded climate extremes for this year.
1811	Summer was very hot. The incredible heat lasted from 21st June till 7th July. The average daily temperature recorded was 25-27°C and on 2nd July reached 29.2°C. Severe drought in May-August. At the end of May there was severe fire in the Bialowieza forest. The fire lasted for four months until 1st October (Kirkoras 1995).
1889	Hot May: Δt=+4.6°C in Vilnius. The autumn was dry: only 53% of usual amount in Vilnius.
1896	Hot and rainless summer. June was the warmest during all period of observations in Vilnius: Δt=+3.9°C. Rivers abated.
1914	Dry July: in Vilnius Δt=+3.4°C. Rivers abated.
1915	Spring and summer were dry: 42% of usual amount in Vilnius with temperature little higher than the average (0.3°C) in Vilnius.
1932	Very warm January (Δt=+4.8°C) followed very cold February and March (Δt=-4.2°C).
1940	Very cold winter: in Vilnius Δt=–5.7°C. The Baltic Sea was frozen. The frosts have blasted fruit trees and crops were damaged. The lowest temperature in Varėna (south-eastern Lithuania) for 17th of January was –40.5°C. The beginning of summer was rainless: a lot of forest fires registered.
1980	Cold May: in Vilnius Δt=–4.2°C. Frosts lasted till 23rd of May. The average temperature of spring was lower than average for 2.6°C (in Vilnius).

Discussion and conclusions

Dating in intermediate climate zone usually is complicated because there are no climatic factors, which permanently limits the growth (Lamb 1995). This is reflected in the age of successfully dated timber samples. The average age of dated samples is 123 years, while only a few samples containing less than 80-100 rings were successfully dated (Figure 3). Dating results showed that the pine timber found in the constructions of Lithuanian historical buildings is from the middle of 17th century up to the middle of 19th centuries (Vitas 2005). This indicates that the material from older periods is quite almost lost during the war fires and the biggest amount of taken samples is representatives of the reconstruction works. This is in agreement with Läänelaid (2002) observations from dating in Estonia.

The dating of timber was successful mainly due to available pine chronologies for Baltic region. Chronologies from Latvia and Poland (Dannenstern House and Polpinus-5) have shown the highest similarity to dated samples. Litpinus-1 chronology also shows high similarity to new Polish chronologies – Polskane and Kujawpom. Cluster analysis of all Baltic chronologies (Fig. 4) has revealed that the constructed pine chronology has the highest similarity to Dannenstern House chronology.

The results indicate that pine timber from historical buildings of Kaunas and Vilnius regions of Lithuania are datable between each other. The area of the common signal of Scots pine involves wide neighbouring regions (Latvia, Estonia and partially northern Poland). This validation is very important for the future dating of pine timber from this region, describing more precisely the area in which pine tree-rings contain similar climatic information. The constructed Litpinus-1 chronology was already applied successfully for dating floating chronology Elderslie House (Great Britain) of Baltic origin (A. Croone, personal communication).

The main causes for the sharp reduction of the radial growth revealed by pointer year analysis are connected to droughts, winter colds and spring frosts. Growth depressions are very easily attributed to negative climate events in the period, when meteorological observations are available. To assess tree-growth – climate relationships when only indirect observations (historical chronicles) are available is more complicated. Perhaps, this is connected to the fact that only strong climatic extremes have been recorded, by missing long-lasting climate events of not extreme character. The frequency of negative pointer years is similar for 17-19th centuries (3 events), while increases in 20th century (5 events). This could be outcome of bigger fluctuations in climate during the last century compared to previous centuries. For the validation of this hypothesis further studies with different tree species are necessary.

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ХРОНОЛОГИЯ ГОДИЧНЫХ КОЛЕЦ СОСНЫ ОБЫКНОВЕННОЙ (*PINUS SYLVESTRIS* L.) В ЛИТВЕ

А. Витас

Резюме

В статье представлена многовековая хронология годичных колец сосны обыкновенной, образованная из исторической древесины и растущих деревьев Литвы. Хронология охватывает 65 датированных серий годичных колец (33 из древесины и 32 из живых деревьев). Составленная хронология показывает тесную транс-региональную связь с многовековыми хронологиями Польши, Латвии и Эстонии. Анализ особых реперных лет показал, что зимние и весенние морозы, а также летние засухи являются главной причиной для резкого понижения радиального прироста. Пять негативных реперных лет не могут быть объяснены климатическими условиями из-за отсутствия данных в исторических летописей до-метеорологического периода.

Ключевые слова: датирование, климат, реперной год, сосна обыкновенная, хронология годичных колец