

ARTICLES

Ciclicity in Fluctuations of the Tree Increment as an Expression of the Ecoclimatic Background

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In the paper recurrence of the fluctuations of the tree increment in the Euroasian region over the last millennium is analysed. Four master dendrochronologies (*Quercus robur*, *Picea abies*, *Larix sibirica*) covering 133–867 years, which are created by different authors, have been studied. By using different limiting values of indices deviated from mean values the new series of numbers of outliers has been created and a distinct group of cycles (21–27, 36–45, 92–93, 174–178 and 697 years) of “good” and “bad” increment singled out. It has been found that the last ecoclimatic minimum for tree growth was around the year 1500 (so called short glacial period) and the next minimum is expected around the year 2150. For the concrete tree species and site conditions the current tree increment fluctuations (11, 22 etc. years) may be more reliably assessed and predicted only allowing for long term ecoclimatic fluctuations.

Key words: dendroscales, increment, indices, cyclicity, ecoclimatic, background.

Introduction

Scientific Community of the World and leaders of States are concerned about global changes occurring in the environment. It is hoped that human activity considerably changing the global landscape and chemical content of the atmosphere induces changes in the global climate. It may result in catastrophic consequences for the whole humanity.

The research conducted in developing World Climate Programme (WCP), Climate Changes Programme (CCP), United Nations Environmental Programme (UNEP), Global Habitat (GH), Global Changes (GC), UNESCO Programme “Man and the Biosphere” (MAB), Permanent Monitoring of Global Emergencies (PMPGE) which is conducted by World Federation of Scientists (WFS) witnesses the phenomena occurring in the environment. They already exceed the limits of fluctuation of environmental processes. The report (Eds. Houghton J.T., et al., 1996) by the intergovernmental Commission of Climate Changes corroborates it. Analogical conclusion has been drawn (in 1999) in the US programme (Ed. Rick Piltz., 1999) of investigation of global changes.

Attention should be focused on the fact that the changes are crucially affected not only by anthropogenic activity-related consequences but also by natural processes. The natural processes, particularly these

which occurred in the past are yet insufficiently studied. In a different interval of time the effect of both mentioned vectors on forest growth may coincide or not. Therefore, difficulties arise in singling out the changes caused by anthropogenic consequences and these induced by the fluctuations of natural processes subjected to global processes.

Dendrochronology as well as retrospective chronology of sedimentation, peatland formation, coral growth, glacier formation offer unique possibilities to reveal and perceive the processes which occurred in the past and which occur in the environment currently.

Thus, for determination of the effect of anthropogenic activity (atmospheric air pollution etc.) on forests first natural fluctuation of the tree increment caused by ecoclimatic changes in the remote past must be assessed. Well dated chronological series of the annual rings of long-lived trees serve for perceiving such fluctuation. In the sequence of the annual rings trees accumulate ecoclimatic variations and keep it for a long unlimited time (Fritts, 1987).

In the paper recurrence of the fluctuations of the tree increment in three part of the Eurasia region (Lithuania, Poland, Russia) over the last millennium is analysed. An attempt was made to determine regularly recurring fluctuations of the ecoclimatic background, which exclusively had predetermined “good” and “bad” incre-

ments of trees. To reveal a long term cyclicity of "favourable" and "unfavourable" years for tree growth the time series from the numbers of outliers found in dendroscales was created. It is hoped that perception of the ecoclimatic background will enable us (1) to ascertain the limits of fluctuations of the tree increments; (2) to clarify the regularities of fluctuation of the ecoclimatic background; (3) to assess the effect of the ecoclimatic background on vegetation over a concrete time span; (4) to predict possible effect of the ecoclimatic background on trees; (5) to assess reliably the reasons for forest degradation occurring in recent years.

Material and methods

A great deal of authors have analysed the cycles in the series of dendrochronological indexes and their relationship with the processes occurring in the environment. It has been stated (Mazepa, 1986; Shijatov, Mazepa, 1987) that the cycles found in the dendroscales are not precise periodic functions. Over time the length, phases and amplitudes of cycles fluctuate. Therefore, it is feasible to state the presence of a certain group of cycles in the dendroscales. In the dendroscales usually cycles of short duration (10-12, 21-24, 34-43, 54-60 years) are stated. In order to determine

century-long (72-76, 90-93, 110-114 years) and very long (170-180, 300-350 years) cycles long series of the tree increments are needed. Several authors (Berri, et. Al., 1979; Kairiūkštis, Dubinskaitė, 1986; Lovelius, 1997; Mazepa, 1986; Stravinskienė, Vencloviene, 1998) have stated that the dynamics of dendrochronological indexes z_t , $t=1, 2, \dots, m$, where m is dendroscale duration, is rather well reflected by the cyclic model

$$z_t = A_0 + \sum_{j=1}^n A_j \cos(2\pi t / T_j + \varphi_j) + \varepsilon_t$$

where ε_t is a stationary random process, A_0 – the mean value of indexes, A_j , φ_j – the amplitude and phase of j -th periodic fluctuation with period T_j , n – the number of periodic components. With the aid of this model the prediction of fluctuations of the current increments which cyclicly recur every 10-12, 21-24 years as well as that of ecoclimatic fluctuations (39-45, 50-54, 72-79, 90-93 years) which recur rarer are made. This model has been applied for analysing the peculiarities of the dynamics of cyclic fluctuations of increment indexes in the dendroscales of Lithuania and Poland (52°-56° parallel).

For the analysis of the dynamics of short cycles two dendroscales of oak (*Quercus robur* L.) and one dendroscale of spruce (*Picea abies* Karst.) have been used (Fig. 1). For oak the dendroscale covering 260 years has been constructed by J. Kairaitis (Kairaitis,

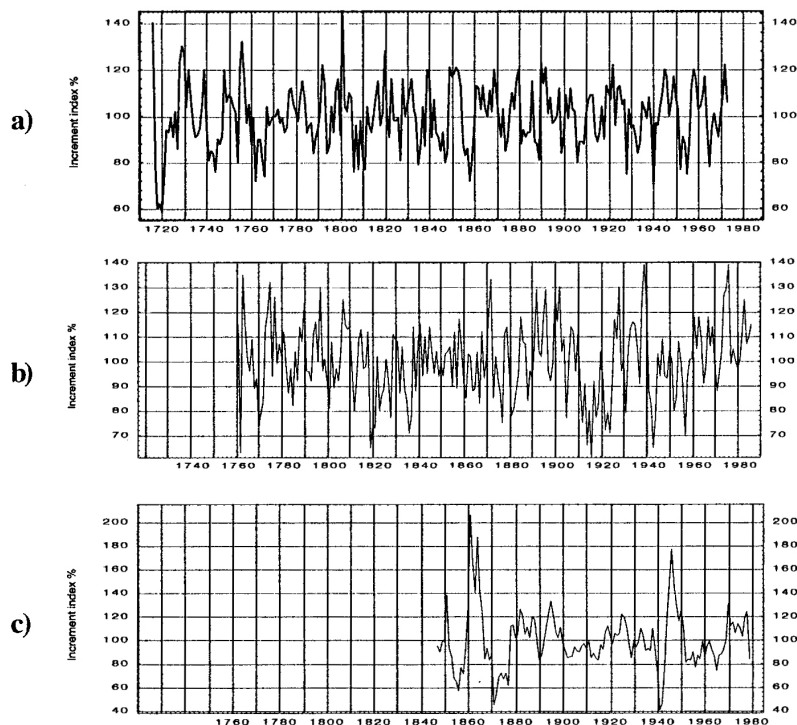


Figure 1. The standard oak (*Q. robur*) chronology - a (Kairaitis, 1979), - b (Bednarz, 1987) and the standard spruce (*P. abies*) chronology - c (Bitvinskas, Brukštus, 1987)

1979) and that covering 225 years by Z. Bednarz (Bednarz, 1987). For spruce stands the dendroscale of 133 years in duration has been constructed by V. Brukštus, T. Bitvinskas (Bitvinskas, Brukštus, 1987). In order to predict the increments we have applied the dendroscale of spruce (*Picea abies* Karst.) growing in the soil of normal moisture. This dendroscale covering 166 years has been constructed by V. Stravinskienė (Stravinskienė, 1998). For assessment of the general ecological background we used the masterchronology of larch (*Larix sibirica* Ledeb.), which had been constructed by Shijatov (Shijatov, 1975). It spans the period AD 1103-1960.

The lengths of cycles in a series of indexes are usually determined by the methods of spectral or harmonic analysis. In order to clarify the cycles longer than $2M+1$, when $M=5, 10, \dots$, shorter cycles in series z_i of indexes are filtered by the moving average of $2M+1$ years. New series $z_i^M = \sum_{j=-M}^M w_j z_{i+j}$, $\sum_{j=-M}^M w_j = 1$ (Cook, Briffa, 1990) are constructed.

It is noted that series z_i of indexes is frequently obtained by standardizing series y_i of the actual radial increments with the help of multiplicative model $z_i = y_i / f_i$. Here f_i is the function reflecting the general process of a change in the increment. It is the influence of tree age, anthropogenic effect and a long term climatic change on the annual increment. In case the length of a series of increment indexes is shorter than cycle length the climatic background fluctuations of very long cycles may get into f_i and not into z_i and z_i^M . However, it is hoped that in case the climatic background is favourable for the growth in indexes series there will be more values considerably exceeding the average. The conditions for the growth will be held "favourable" in case an index of the increment exceeds the largest limiting value x^+ of the increment. In case an index of the increment is less than certain least limiting value x^- of the increment the conditions are characterized as "unfavourable". Largest limiting value x^+ of indexes may be $\bar{x} + \sigma, \bar{x} + 1,5\sigma, \bar{x} + 2\sigma, x_{(85\%)}, x_{(75\%)}, med + H, med + 1,5H$ whilst least limiting value x^- of indexes may be $\bar{x} - \sigma, \bar{x} - 1,5\sigma, \bar{x} - 2\sigma, x_{(15\%)}, x_{(25\%)}, med - H, med - 1,5H$, where \bar{x} is the mean value of indexes series, σ - the standard deviation, med - median of a series, $H = x_{(75\%)} - x_{(25\%)}$ - interquartile range, $x_{(p\%)}$ - percentile of row p of indexes series. The values of indices which do not get into interval (x^+, x^-) will be called outliers. It is clear that the number of outliers in the series of indexes or in its

segment depends upon the choosing of limiting values. It is expected that ecoclimatic background fluctuations may be expressed by outliers of the radial increments. Therefore, for determination of the cycles longer than $(2M+1)$ years, which affect the tree increment, we will create time series from a number of outliers. Outliers of indexes are taken in interval $[t-M, t+M]$. In interval $t \pm M$ years, the numbers of outliers $n_+(t)$ and $n_-(t)$ of years of "favourable" and "unfavourable" conditions for the growth are held random. However, they are associated with certain processes in nature. It is expected that numbers $n_+(t)$ and $n_-(t)$ of seldom occurring events vary according to the Poisson law (Rozanov, 1971):

$$P\{n_+(t)=k\} = (\lambda_+(t))^k \exp\{-\lambda_+(t)\} / k!,$$

$$P\{n_-(t)=k\} = (\lambda_-(t))^k \exp\{-\lambda_-(t)\} / k!,$$

with intensities $\lambda_+(t)$ and $\lambda_-(t)$. In accordance with this law which is called the law of rare events other natural phenomena such as the number of earthquakes over a certain period are explained. The dynamics of numbers $n_+(t)$ and $n_-(t)$ of favourable and unfavourable conditions throughout a century may be held the Poisson processes with intensities $\lambda_+(t)$ and $\lambda_-(t)$. Difference $n_+(t) - n_-(t)$ of intensities will reflect the general ecoclimatic background.

For assessment and prediction of century-long fluctuations of the ecoclimatic background indexes series have been filtered by moving average ($M=50$) of 101 years (filter of low frequency). After that with the aid of the methods of harmonic and spectral analysis cyclic components in the series of indexes have been determined. By applying the obtained parameters the prediction of the ecoclimatic background has been made. The ecoclimatic background has been assessed by function $n_+(t) - n_-(t)$ composed from the numbers of outliers of indexes in series. This function appeared to be very applicable because it allowed us to leave considerably different values of indexes in analysed series $n_+(t) - n_-(t)$, which appear due to significant fluctuation of the ecoclimatic background.

Results and discussion

Descriptive statistics (Table 1) of indexes series of all dendroscales analysed have been calculated. In the dendroscales presented in Table 1 numbers $n_+(t)$ and $n_-(t)$ of recurrence of "favourable" and "unfavourable" conditions in interval $t \pm 5$ for above mentioned limiting values $x^+ (\bar{x} + \sigma, \bar{x} + 1,5\sigma, \bar{x} + 2\sigma, x_{(85\%)}, x_{(75\%)}$,

Table 1. Descriptive statistics indexes of dendroscales

	N	mean	standard deviation	median	Quartile Range	Lower Quartile	Upper Quartile	15 th percentile	85 th percentile
<i>Q. robur</i>	226	100	15,5	100	21	90	111	84	115
<i>Q. robur</i>	260	100	14,4	100	18	91	109	86	115
<i>P. abies</i>	133	100	25	97	24	86	110	83	121

$med + H$) and $x'(\bar{x} - \sigma, \bar{x} - 1,5\sigma, \bar{x} - 2\sigma, x_{(15\%)}, x_{(25\%)}, med - H)$ have been determined. Also resultants of fluctuations of 20-24 years and longer ones $n_+(t) - n_-(t)$ have been calculated. For dendroscales of *Q. robur* and *P. abies* new index series with the moving average of 11 years have been constructed, in which there are fluctuations of 20-24 years and longer ones. After that cyclic components in series $n_+(t) - n_-(t)$ of outliers and cyclic components in the series of indexes with the moving average of 11 years have been calculated with the aid of the methods of harmonic analysis (Anderson, 1971; Berri, et. al., 1974). For every possible cycle which is not longer than half series length the parameters of cyclic components have been calculated. Also for every possible cycle determination coefficients have been calculated and series of cyclic components constructed. The difference has been determined between the series of cyclic components analysed and assessed. In order to evaluate the significance of cycles in a series for every newly singled out cycle we have calculated coefficient (R-square) of determination when the influence (adjusted R-square) of the number of parameters is eliminated. Also coefficient AIC_1 corresponding to the Akaike information criterion (Akaike, 1974). * $AIC_1 = n * \log S_w^2 + 3k$, here k - the number of parameters of cyclic component (amplitude, phase and cycle length) in function AIC_1 criterion of the sum of cyclic components the weight of parameter number is augmented. The singling out of cyclic components was stopped when AIC_1 started increasing or when adjusted R-square started diminishing. It has been determined that in indexes series of the increments of *Q. robur* cyclic components condition not less than 86% and 80% of series variance whilst in these of *P. abies* not less than 94%. In Table 2 we present the results of harmonic analysis of series $n_+(t) - n_-(t)$ constructed using the largest and least limiting values as well as these of the series of indexes moving average. In the Table the cycles and per cent of variance conditioning them in the total dispersion of the series are presented.

* The Akaike criterion is applied for identification of autoregressive moving average model ($AIC = n * \log S_w^2 + 2k$, here k is the number of parameters in the function being approximated)

Table 2. The cycles and their significance (%) in the dendroscales series constructed according to index deviation from the largest and least limiting value and in the sliding of 11 years (S^2 is the variance of series)

<i>Quercus robur</i> , Poland, Niepolomice									
The sliding of 11 years:									
$n_+(t) - n_-(t)$		$n_+(t) - n_-(t)$		$n_+(t) - n_-(t)$		$n_+(t) - n_-(t)$		$n_+(t) - n_-(t)$	
$x' = \bar{x} + \sigma = x_{(85\%)}$		$x' = \bar{x} + 1,5\sigma$		$x' = \bar{x} + 2\sigma$		$x' = \bar{x} + 2\sigma$		$x' = med + H$	
$x'' = \bar{x} - \sigma = x_{(15\%)}$		$x'' = \bar{x} - 1,5\sigma$		$x'' = \bar{x} - 2\sigma$		$x'' = \bar{x} - 2\sigma$		$x'' = med - H$	
$S^2=43,5\%$		$S^2=6,7$ cases		$S^2=3,2$ cases		$S^2=0,43$ cases		$S^2=3,8$ cases	
cycle length, y	the part of variance(%) attributed to this cycle	cycle length, y	the part of variance(%) attributed to this cycle	cycle length, y	the part of variance(%) attributed to this cycle	cycle length, y	the part of variance(%) attributed to this cycle	cycle length, y	the part of variance(%) attributed to this cycle
43	28,2	93	27,4	44	34,1	102	34,5	92	30,8
93	21,3	44	21,5	93	26,6	32	15,6	45	28,7
30	15,0	36	20,0	38	12,2	50	11,4	38	15,6
36	14,4	30	11,0	31	11,6	25	7,9	31	8,6
63	2,6	26	2,5	49	2,3	16	3,5	21	2,3
19	2,3	59	2,1	18	1,9	43	3,7	18	2,0
25	2,3	16	1,4	25	1,3	19	2,5	16	1,0
16	1,7	17	1,3			60	2,4		
46	1,1					28	1,5		
						17	1,1		
						20	1,1		
All cycles 88,9		All cycles 87,2		All cycles 90,0		All cycles 85,2		All cycles 89,0	
Conditioned by cycles 93,1		Conditioned by cycles 91,7		Conditioned by cycles 92,1		Conditioned by cycles 86,1		Conditioned by cycles 91,7	

Continued of the Table 2

<i>Quercus robur</i> (Lithuania, masterchronology)									
The sliding of 11 years:									
$n_+(t) - n_-(t)$		$n_+(t) - n_-(t)$		$n_+(t) - n_-(t)$		$n_+(t) - n_-(t)$		$n_+(t) - n_-(t)$	
$x' = x_{(85\%)}$		$x' = x_{(75\%)}$		$x' = \bar{x} + 1,5\sigma$		$x' = \bar{x} + 1,5\sigma$		$x' = med + H$	
$x'' = x_{(15\%)}$		$x'' = x_{(25\%)}$		$x'' = \bar{x} - 1,5\sigma$		$x'' = \bar{x} - 1,5\sigma$		$x'' = med - H$	
$S^2=19,3\%$		$S^2=3,5$ cases		$S^2=6,2$ cases		$S^2=1,4$ cases		$S^2=2,3$ cases	
cycle length, y	the part of variance(%) attributed to this cycle	cycle length, y	the part of variance(%) attributed to this cycle	cycle length, y	the part of variance(%) attributed to this cycle	cycle length, y	the part of variance(%) attributed to this cycle	cycle length, y	the part of variance(%) attributed to this cycle
24	37,5	23	22,6	24	37,7	23	18,8	24	21,7
22	9,5	32	17,3	21	9,9	48	16,3	49	11,5
21	7,2	21	12,6	44	7,7	31	13,9	31	9,0
43	6,4	52	6,4	33	5,7	22	10,6	58	8,8
32	4,9	18	5,3	16	4,8	87	5,2	28	7,6
26	4,5	43	4,0	81	3,1	117	5,0	23	6,3
18	3,3	20	3,5	22	2,9	28	4,4	124	4,4
16	3,3	16	2,7	26	2,8	25	3,1	21	4,1
22	1,5	124	2,4	19	1,4	58	2,4	25	2,1
19	1,3	17	2,1	112	1,4	15	1,7	36	2,0
15	1,1	25	1,8	17	1,0	39	1,5	18	1,9
80	1,0	66	1,6			18	1,4	16	1,9
		37	1,2			33	1,2	20	1,7
		15	1,1			21	1,1	15	1,4
All cycles 81,4		All cycles 84,6		All cycles 78,4		All cycles 87,7		All cycles 84,4	
Conditioned by cycles 84,2		Conditioned by cycles 87,9		Conditioned by cycles 80,2		Conditioned by cycles 90,1		Conditioned by cycles 84,4	

<i>Picea abies</i> , Lithuania, the Ignalina region									
The sliding of 11 years:									
$n_+(t) - n_-(t)$		$n_+(t) - n_-(t)$		$n_+(t) - n_-(t)$		$n_+(t) - n_-(t)$		$n_+(t) - n_-(t)$	
$x' = \bar{x} + \sigma$		$x' = x_{(85\%)}$		$x' = x_{(75\%)}$		$x' = x_{(25\%)}$		$x' = med + H$	
$x'' = \bar{x} - \sigma$		$x'' = x_{(15\%)}$		$x'' = x_{(25\%)}$		$x'' = x_{(25\%)}$		$x'' = med - H$	
$S^2=140,1\%$		$S^2=5,7$ cases		$S^2=6,9$ cases		$S^2=12,7$ cases		$S^2=6,8$ cases	
cycle length, y	the part of variance(%) attributed to this cycle	cycle length, y	the part of variance(%) attributed to this cycle	cycle length, y	the part of variance(%) attributed to this cycle	cycle length, y	the part of variance(%) attributed to this cycle	cycle length, y	the part of variance(%) attributed to this cycle
29	50,5	29	35,8	21	37,2	28	40,9	29	41,0
21	23,0	22	21,8	29	22,5	22	22,6	21	21,6
17	8,3	17	11,7	37	10,0	46	16,7	55	9,4
38	6,4	56	11,3	16	9,1	16	7,2	17	9,3
19	3,1	19	5,8	14	4,9	14	3,4	24	4,6
14	1,9	36	4,4	19	4,9	32	1,8	37	3,6
22	1,6	14	1,7	59	4,0	60	1,7	14	1,7
		23	1,5	24	1,8	18	1,6	15	1,7

- 1) The chronology constructed by Z.Bednarsz;
- 2) The chronology constructed by J.Kairaitis;
- 3) The chronology constructed by V.Brukštis and T.Bitvinskis

In dendroscale *Q. robur*, (Poland), group cycles of 36-45 and 92-93 years are distinct in series $n_+(t)-n_-(t)$ constructed using different limiting values, excluding $x^+ = \bar{x} + 2\sigma$, $x^- = \bar{x} - 2\sigma$, and in the series of indexes moving average of 11 years. Density spectra (Fig. 2) of these series also corroborate it. In all series $n_+(t)-n_-(t)$ the part of variance conditioned by the cycle of 92-93 years is larger (27-31%) than in the moving average (21%). For instance, the cycle of 102 years in series $n_+(t)-n_-(t)$ with limiting values $x^+ = \bar{x} + 2\sigma$, $x^- = \bar{x} - 2\sigma$ accounts for 34.5% of series variance whilst in the moving average the corresponding long cycle of 93 years accounts only for 21.3%. Density spectra (Fig. 3) of these series corroborate it too. In above series $n_+(t)-n_-(t)$ the major peak of density spectrum corresponds to the cycle of 107 years where as in the moving average to the cycle (Fig. 2) of 42 years.

In dendroscale *Q. robur* (Lithuania): in the series of indexes moving average of 11 years, group cycles of 21-24 years prevail and 60% of series variance is attributed to them. With the aid of harmonic analysis it has been stated that 6.4% and 4.9% of the variance of the values of series are attributed to the cycles of 43 and 42 years, respectively. The peak corresponding to the cycle of 43 years is also observed in density (Fig. 2) spectrum of the series. The 80-year-long cycle in the moving average conditions only 1.0% of its variance. The dynamics of cycles of series $n_+(t)-n_-(t)$ with limiting values $x^+ = x_{(75\%)}$, $x^- = x_{(25\%)}$ is similar to that of the moving average (Table 2). A total of 3.1% of the variance is attributed only to the cycle of 81 year and the stated cycle of 112 years accounts for 1.4% of the variance of the values of series. In remaining series $n_+(t)-n_-(t)$ constructed using other limiting values more dis-

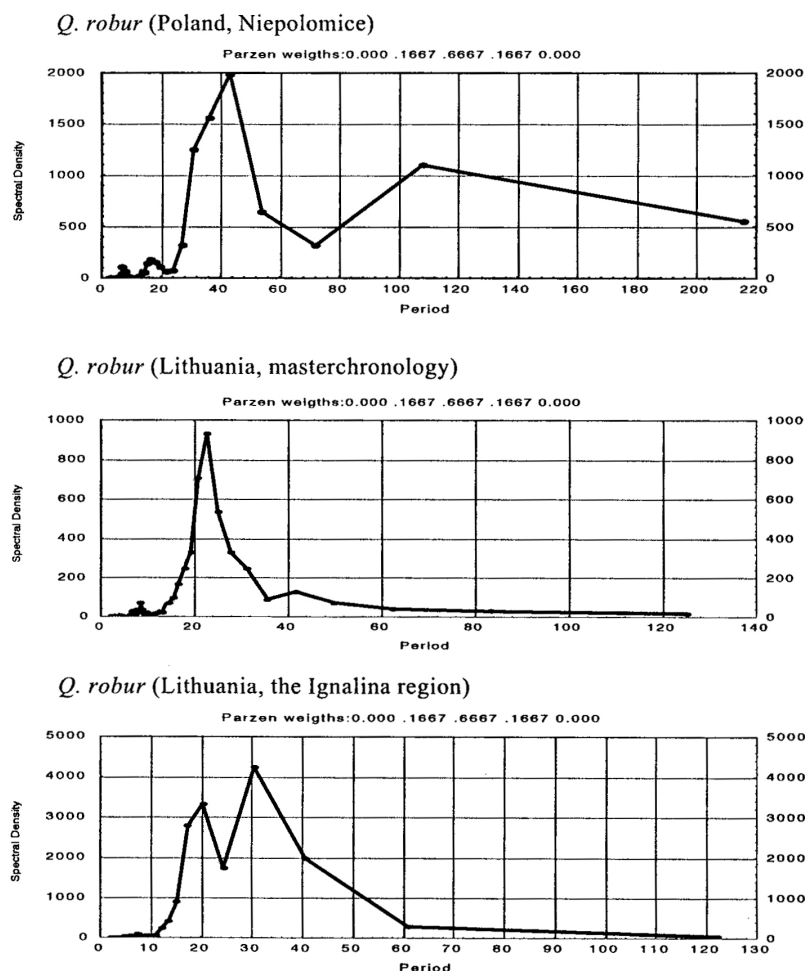


Figure 2. Density spectra of the slidings of 11 years in the chronologies of oak and spruce

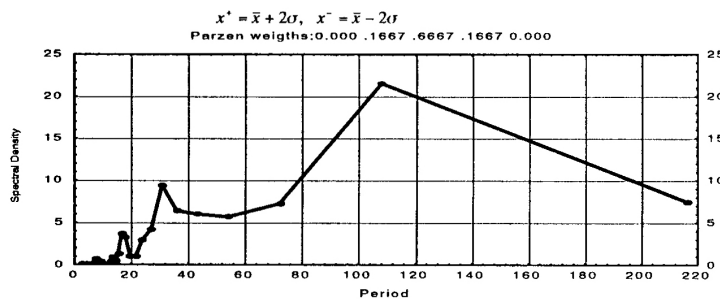
tinct cycles of 31-31, 43-52 and 112-124 years are observed (Table 2). In some series also cycles of 58, 76-87 years are detected. In series $n_+(t)-n_-(t)$ with values $x^+ = \bar{x} + 1.5\sigma$, $x^- = \bar{x} - 1.5\sigma$ 16.3% of variance of the values of series is attributed to the cycle of 31-32 years and 2.4%, 5.2% and 5% of variance of the series to the cycles of 58, 76-87 and 117 years, respectively. Spectral analysis (Fig. 3) confirms it. In density spectrum of above series distinct peaks correspond to the cycles of 23, 31 and 50 years. Moreover, the value of density spectrum corresponding to the cycles of 123 years differs from that of white noise.

In the dendroscale of *P.abies* (Lithuania, the Ignalina region) both in series $n_+(t)-n_-(t)$ constructed using different limiting values and in the series of indexes of the moving average the 11 years, group cycles of

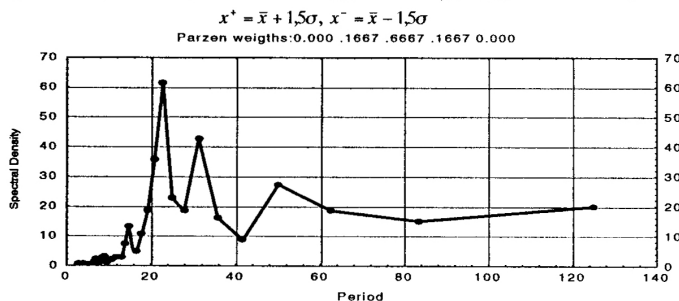
21-22 and 28-29 years prevail. The cycle of group of 36-46 years is pronounced less. This is corroborated by density (Fig. 2, 3) spectra of these series. Besides, with the aid of harmonic analysis in series $n_+(t)-n_-(t)$ the cycle of 55-60 years has been determined. In series with limiting values $x^+ = \bar{x} + \sigma$, $x^- = \bar{x} - \sigma$ 11.3% of variance of the series is attributed to this cycle. The value of density spectrum of above series, which corresponds to the cycle of 60 years differs from that of white noise. However, the value of density spectrum of the moving average is close to zero (Fig. 2, 3) in this point.

In order to determine the influence of climatic background fluctuations of very long duration on the above analysed fluctuations of the cyclic increments the standard chronology of 867 years, which had been con-

Q. robur (Poland) series $n_+(t)-n_-(t)$ with limiting values



Q. robur (Lithuania, masterchronology) series $n_+(t)-n_-(t)$ with limiting values



P. abies series $n_+(t)-n_-(t)$ with limiting values

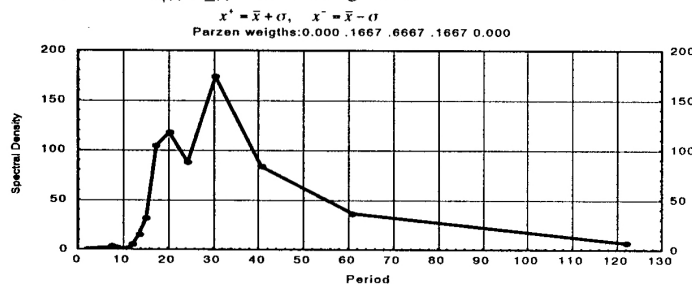


Figure 3. Density spectra of $n_+(t)-n_-(t)$ of the standard oak and spruce chronologies

structed for larch (*Larix sibirica*) by Shijatov, (West Siberia, the limit of polar forest), was applied. The values only considerably differed from the mean values of indexes of the last 780 years have been used. By applying above limiting values x^+ and x^- functions $n_+(t)$ and $n_-(t)$ of the number of "favourable" and "unfavourable" conditions for the growth in century-long interval ± 50 have been elaborated. Also variants of the resultants of the climatic background which have been worked out by the moving average of 101 years are calculated. The expression of functions $n_+(t) - n_-(t)$ with different limiting values is illustrated in Figure 4. With the aid of spectral and harmonic analyses the study on

Table 3. The cycles and their significance (%) in the moving average of 101 year and in series $n_+(t) - n_-(t)$ according to the deviation of indexes from the largest and least limiting value (S^2 is the variance of series)

The sliding of 101 years $S^2=44,2\%$		$n_+(t) - n_-(t)$ $x^+ = \bar{x} + \sigma$ $x^- = \bar{x} - \sigma$ $S^2=88,5$ cases		$n_+(t) - n_-(t)$ $x^+ = x_{(85\%)}$ $x^- = x_{(15\%)}$ $S^2=79,2$ cases		$n_+(t) - n_-(t)$ $x^+ = x_{(75\%)}$ $x^- = x_{(25\%)}$ $S^2=156,2$ cases	
cycle length, y	the part of variance (%) attributed to this cycle	cycle length, y	the part of variance (%) attributed to this cycle	cycle length, y	the part of variance (%) attributed to this cycle	cycle length, y	the part of variance (%) attributed to this cycle
719	52,7	174	41,4	703	45,9	697	56,7
176	30,3	612	37,2	178	33,5	178	28,0
307	4,0	310	4,4	308	5,7	65	4,3
65	3,6	66	3,6	65	3,4	80	2,2
All 4 cycles 90,6		All 4 cycles 86,5		All 4 cycles 88,5		All 4 cycles 91,2	

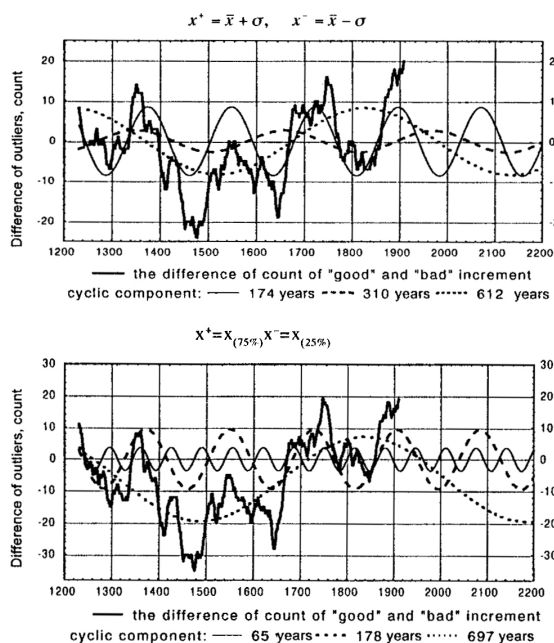


Figure 4. Cyclic fluctuations of the climatic background created from the larch dendroscales starting from 1230 with possible prediction by the year 2100

cyclic components of these functions has been conducted (Table 3, Figure 4). By applying three trigonometric components the approximation and prediction of the difference of "good" and "bad" increment over period $(n_+(t) - n_-(t))$ of 101 year have been derived (Figure 5). The parameters of the trigonometric components have been evaluated by the method of the least squares.

The data of the analysis enables us to infer that the largest part of variance of nearly all series of the increment investigated is conditioned by the cycle of

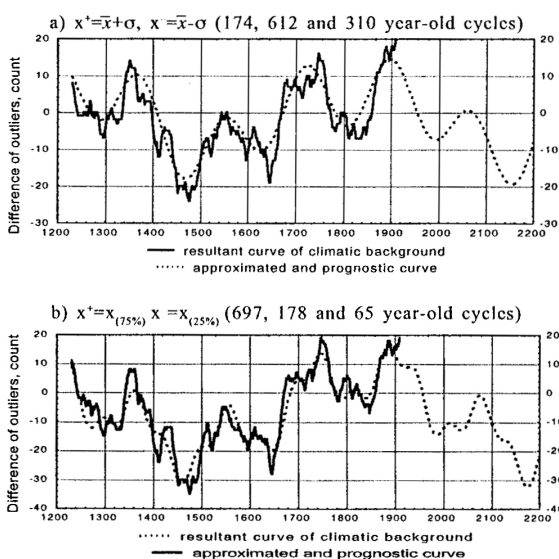


Figure 5. Approximation and prognostic curve of the eco-climatic background, which have been calculated using the differencing count of "good" and "bad" increment $n_+(t) - n_-(t)$ of above mentioned larch, constructed by S. Shijatov

about 700 years, the minimum of which was around the year 1500. It corresponds to the little glacial period. Prior to it the minimum of the 700-year cycle was in AD 760-800. The nearest maximum of this cycle was in the past approximately in 1830. Next minimum of this cycle is expected in 2150. It is feasible to find the corresponding fluctuations of early summer temperature to these years in the dendroscale spanning 2,000 years, which has been used by Nazarabajev and Vaganov (1999) according to the data on the increments of larch (*Larix sibirica*) in the Taimyr peninsula.

In all series $n_+(t)-n_-(t)$ the longterm cycle of 174-178 years (Fig. 4) is seen even visually and has been stated by many authors (Berri, et al., 1979; Shijatov, Mazepa, 1987; Kairiukštis, Dubinskaitė, 1986). The minima of the cycles of 174-178 years in all series investigated are stated around the years 1810 and 1990 while the maxima around the year 1900. Next maximum is expected around the year 2080. These two cyclic components condition even three quarters of series variance (Table 3).

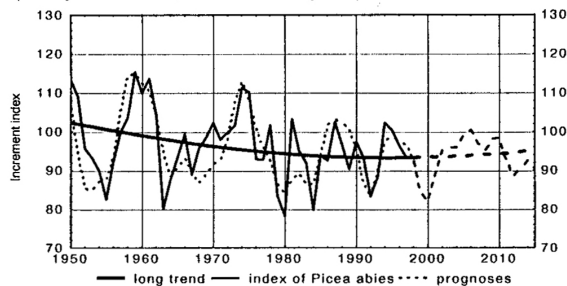
By using approximation of function $n_+(t)-n_-(t)$ with $x^+=\bar{x}+\sigma$, $x^-=\bar{x}-\sigma$ and the resultant (Fig. 5a) of the cycles of 174, 612 and 310 years as well as function $n_+(t)-n_-(t)$ with $x^+=x_{(75\%)}$, $x^-=x_{(25\%)}$ and the resultant (Fig. 5b) of the cycles of 65, 178 and 697 years two general approximating curves reflecting the general ecoclimatic background have been derived. Therefore, we can reliably state and predict the general minimum of the ecoclimatic background in the period 1990-2020.

On the basis of the calculation presented above the minimum of the ecoclimatic background is observed at the turn of this century. Improvement of the climatic background is expected at the onset of the next century. It must be noted that precise prediction of the minima and maxima of the ecoclimatic background as well as the real values of the maxima and minima entail difficulties. The reason for it is that the dynamics of the cycles is not constant and the deviation of the increment values from the mean value in case of the minimum and maximum of the cycle is not constant either. It is hoped that these instabilities appear due to the effect of the cycles which are shorter or longer than the analysed ones. In certain periods of time they coincide or are in the opposite phase. Such possibilities can be illustrated by an example (Fig. 4) when the minimum of cyclic increment fluctuations of 174 and 612 years at the end of this century is softened by recent (about 1960) maximum of the cycle of 310 years and by approaching (2010) maximum of the increment in the 65 year-old cycle.

As to short ecoclimatic fluctuations, the 11 and 22-year-old cycles of the tree increments, which are readily observed and express well perceptible current climatic changes, occur in the background of long cyclic fluctuations. By using the corresponding functions and limiting values, actual and approximated fluctuations of spruce increment and their predicted variants in the background of long term ecoclimatic changes are presented in Figure 6. The data have indicated that at the end of this century the expected minimum of the spruce

increment which recurs every 11 years may be more distinct (Fig. 6). As shown in Figure 6, the minimum of the increment of short cycles will be adversely affected by the resultant of long ecoclimatic fluctuations.

a) a century-long trend assessed using limits $x^+=\bar{x}+\sigma$, $x^-=\bar{x}-\sigma$ (the cycles of 174, 612 and 310 years)



b) the century-long trend assessed applying limiting values $x^+=x_{(75\%)}$, $x^-=x_{(25\%)}$ (the cycles of 697, 178 and 65 years)

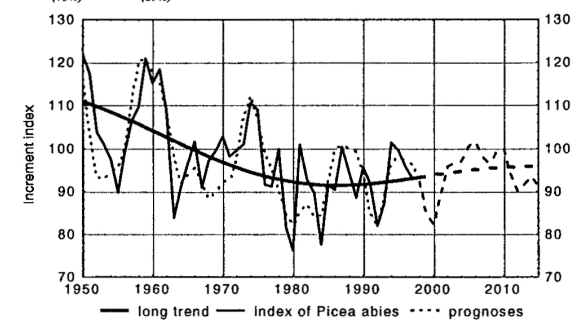


Figure 6. Fluctuation of the increment of spruce (*P. abies*) at the second half of this century and expected prognoses

Conclusions

1. In the paper four chronologies of 133-867 years in duration, which are constructed for Oak (*Quercus robur*, Lithuania, Poland), spruce (*Picea abies*, Lithuania) and larch (*Larix sibirica*, Russia) have been analysed. While using different limiting values the series of outliers numbers have been constructed. The number of outliers may be interpreted as random values distributed according to the Poisson law with varying intensities. It has been determined that in the analysed dendroscales (spanning 133-867 years) the number of outliers better reflects the long cycles of fluctuation of the tree increment, comparing with series of the moving average.

2. By using different limiting values deviated from the mean values in increment series of *Q. robur* and *P. sylvestris*, recurrence of "good" and "bad" growth has

been singled out. They illustrate ecoclimatic conditions and their cyclic components conditioned not less than 80-94% of series variance. Distinct group cycles of 21-24, 36-45 and 92-93 years (comprise 27-31% of the variance of series) have been singled out. Also less distinct group cycles of 31-32, 43-52, 58, 78-87 and 117 years (comprise from 2.1 to 16.3% of the variance of series) have been singled out.

3. While analysing the *Larix sibirica* (West Siberia, the limit of polar forest) chronology it has been found that the largest part of variance of "good" and "bad" increments is conditioned by the cycle of 697 years; the minimum of which was around the year 1500 and maximum around the year 1830. Next minimum is expected around the year 2150. A distinct group cycle of 174-178 years attains its minimum currently at the turn of the century. The maximum of this cycles may be expected only in the second half of the next century.

4. The analysis conducted on long cyclic fluctuations of "good" and "bad" tree increments, which considerably differ from the mean value, has indicated that unfavourable ecoclimatic background for forest growth on the Northtimber line of Eurasia having achieved the minimum at the turn of the century may remain approximately by the year 2020. However, the influence of the climatic background as well as accurate date of its minimum entail difficulties in prediction due to possible (unrevealed) longer and above mentioned shorter cycles being in the opposite phase.

For a concrete tree species and site conditions the current tree increment fluctuations of 11-22 years may be more reliably assessed and predicted only allowing for long term (century - long and longer) ecoclimatic fluctuations.

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ЦИКЛИЧЕСКОЕ КОЛЕБАНИЕ ДРЕВЕСНОГО ПРИРОСТА КАК ВЫРАЖЕНИЕ ЭКОКЛИМАТИЧЕСКОГО ФОНА

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Резюме

Для выявления обусловленных поведением эоклиматического фона циклических составляющих, накопленных в древесных кольцах, использовались четыре дендрошкалы (*Quercus robur*, *Picea abies*, *Larix sibirica*) продолжительности 133-867 лет, составленными разными авторами.

Для выявления циклов использовались спектральный и гармонический анализ. Анализировалось число значений индексов, выходящих за определенные верхние и нижние пределы, в заданном интервале времени. Данные сравнивались с колебаниями выявленными методом средней скользящей. Оказалось, что 90-100 и сверх долголетние циклические колебания лучше отражаются в рядах составленных по числам значений выходящих за определенные пределы (outliers) чем в рядах 11 летней скользящей.

Найдено проявление циклического колебания глобального эоклиматического фона с проявлением циклов 697 и 174 лет. Последний минимум 697 летнего цикла приходится примерно на 1500 годы (малый ледниковый период) и следующий минимум ожидается около 2150 годы, тогда как минимум цикла 174 года на смене веков (в настоящее время).

Предложено коротковременные (11, 22 и т.п. лет) колебания эоклиматического фона оценивать с учетом интегрального тренда сверх долгосрочных циклических колебаний.

Ключевые слова: дендрохронологические индексы, циклы, прогноз, эоклиматический фон.