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8.1. INTRODUCTION: TASKS AND AMOUNT OF INVESTIGATIONS

In analysing the effect of atmospheric pollution and climatic changes on biota the forest ecosystems are of a paramount importance. Forests are distributed in the whole regional ecosystem "Lietuva", and from this point of view they may characterize the state of the environment in the whole region. In its turn a comparison of the state-of-art of forests in Lithuania with that of other countries of Europe enable environmental changes occurring here to be more reliably assessed. Because of a spatial crown structure of trees, forests can better contact air masses above the ground, affect penetration and dispersion of pollutants transported by the wind in the ecosystems. Species diversity accumulated in forests permits us to select the most sensitive species for determining the consequences of this or that effect.

In order to investigate the response elicited by the forest ecosystems to atmospheric pollution and environmental changes, the physiological, morphological and dendrochronological parameters of trees submitted to stress as well as changes in crown defoliation and the increment have been analysed. A response of the forest ecosystems to the noticeable sudden environmental changes primarily reveals itself by a stress reaction in the physiological-biochemical system of trees. In needles of trees affected by adaptation mechanisms the concentration of amino acids (proline) varies, and the perturbation of bud twig growth gradually occurs in crowns. The regularities of the height and diameter increment forming change, too. Eventually, these regularities are generated by a succession of the annual tree rings, which is expressed by the diameter increment and its dendrochronological indexes.

This year two hypotheses were raised for investigations. The first one: in the mechanism of the tree increment one has to search for the inner index regulating the increment according to which it would be possible to determine the basic process of the standardized increment independent of anthropogenic pollution or anomalous climatic changes. It is expected that in case the expression of the basic line increment is found, and the standard of the increment is set, it would be possible to compare the deviation of the growth of a concrete tree from the standard and, thus, to assess the effect of environmental changes on trees and forests. The second one: to search for a direct determination of the effect of anthropogenic pollution on the radial increment of trees. In the series of tree rings it is necessary to determine the initial time when atmospheric pollution starts affecting the increment adversely. It is hoped that the establishment of a reliable correlation between the quantity of proline in needles and current crown defoliation of trees on the one hand, and the real tree ring increment in retrospect on the other, would allow us to ascertain the absolute deviation of the increments from the standard in the period searched. By realizing the above hypotheses the investigation has been conducted on the height increment of trees and a tree ring increment over the last 160 years. A total of 167 permanent and temporal plots, a great deal of analyses of dendrochronologies and chemical analyses of needles as well as the data on the analysis of increments of 2179 trees have been applied.

In order to assess the ecological state-of-art in Lithuania the chemical compounds in needles of pine and spruce have been analysed. This analysis is characterized as methodical. Limiting values of chemical elements have been defined and intercalibration in the corresponding laboratories of 24 European states performed. The investigation of determining physiological markers of tree degradation has been carried out. Regional monitoring has been conducted on the state-of-art of forests growing in Lithuania in the international screen of 16X16 km and in the national screen of 8X8 km. Crown defoliation, health, changes in the state-of-art of 5,915 trees and possible trends have been assessed. Complex expeditions have been additionally organized for taking samples of air, soil, etc. in the screen monitoring. For the ecological state of biological systems the favourable and critical zones have been clarified throughout Lithuania.

8.2. A SYSTEM OF STANDARDIZING TREE INCREMENT AND ITS APPLICATION TO ASSESS THE EFFECT OF ATMOSPHERIC POLLUTION AND CLIMATIC CHANGES ON FORESTS

A tree and stand increment is dynamic and quickly responds to changes in the conditions of the growth. For instance, the onset air pollution may be regarded as fertilization. However, later it causes crown defoliation and a significant decrease in the increment or even forest die-off. In case the standard of the natural increment of a tree is known, it would be possible to assess a variation in the increment, which is caused by environmental changes.

While developing a system of standardizing the increment (SSI), basic regularities conditioning the increment have been established. As the radial increment reflects best the conditions of stand growth, the indexes of the mean culminating diameter increment have been applied for standardizing it. This is a new index of expressing the growth. It can be calculated by the following formula:

$k_d = D_{Zr}/(A_{1.3}+n)$, when $k_d = max$; cm/year;

where k_d - the mean culminating diameter increment cm/year;

D_{Zr} - diameter k_d is maximum, cm;

$A_{1.3}$ - the number of years during which a tree grows up to 1.3 m high;

n - the number of tree rings, when k_d is maximum.

In case k_d is maximum, $A_{1.3}+n$ indicates the age of culminating of the mean diameter increment, and k_d - the absolute increment value. Therefore, k_d is used for standardizing the radial increment and culminating age for classifying the initial data. The investigations have shown that culminating age of the mean diameter of dominating trees in pine stands may be from 10 to 90 years. Culminating age of the mean increment in different stands may differ 2-6 times.

It has been determined that index k_d characterizes the potential of the growth of each tree and implies further process (Fig. 8.1) of its growth. Larger mean diameter increment and k_d are typical of trees with a larger diameter. As mentioned above, k_d expresses further growth: in case k_d are identic, the growth of trees and stands with the same culminating ages is identic, too.

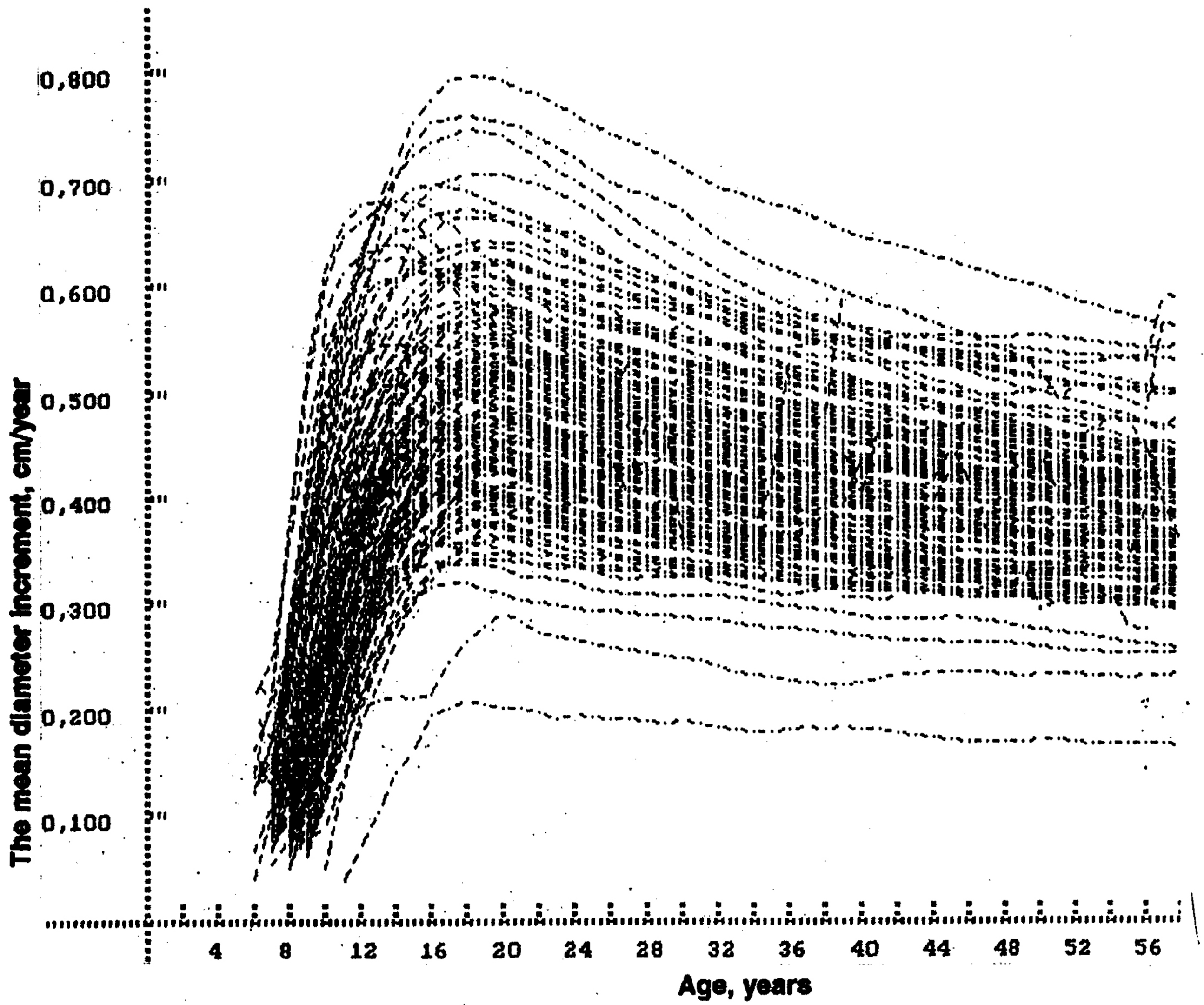

Fig. 8.1. Distribution of the mean values of the mean diameter increments of the dominating trees in different pine stands in different periods of age. Culminating age Ak=6-20 years. The data are unsmoothed

The analysis of factors affecting the growth has indicated that the dynamics of the increment is standardized best by k_d. The coefficient of the correlation between k_d and the diameter of dominating trees in stands aged 70 years is 0.95. A similar correlation is between the mean culminating height (k_h) increments and a further process of the growth of the whole family of curves. At the age of 25 years this relationship is characterized by the coefficient of the correlation $r_{kh}=0.963\pm0.009$ while at the age of 70 years $r_{kh}=0.927\pm0.028$. Thus, the peculiarities of both k_h and k_d are the same and they show that the mean culminating increment is appropriate for standardizing the current increment.

Atmospheric pollution changes both parts of k_d and k_h: culminating diameter or height and culminating age. It is seen from the data in Table 8.1. Due to atmospheric pollution the indexes regulating k_d values vary rather adequately. Therefore, k_d remains relatively stabile. Its major peculiarity is to reflect the process of the growth in normal conditions. Besides, it has a supplementary meaning attributed to its stability. In case k_d is stabile, in future it is possible to assess the changes in tree growth while comparing standardized increments with the increments of stands changed to any extent. However, the law (in case k_d or k_h are identical,the growth of trees and stands is identical) found is not in effect for damaged trees. Their growth changes due to variation in the components of these indexes. Stand changes natural growth because pollution or drastic climatic changes induce the process of forced early aging (Maurin, 1986). In comparison to the height and diameter growth of undamaged stands, that of (with similar k_d values) damaged stands by pollutants was growing poorer. In damaged stands a forced change in the culminating age of the increment and in the culminating diameter perturbs natural process of the growth. The stands growing nearer the pollution source are sooner and stronger damaged while in these growing further the effect of fertilization is observed for a long time.

As a result of investigations, the system of standardizing the increments has been created. It is expressed by the function:

$$Z_r=f(A, k_d, I_{zr}),$$

where A - age, years; k_d - the mean culminating diameter increment cm/year; I_{Zr} - an index of the radial increment, %.

The data on the increments of individual trees have been systematized observing the regularities established during investigations. With the help of computer the radial increments have been systematized by groups A, k_d and I_{Zr} of indexes (group values A=1 year, k_d=0.1 cm/year, I_{zr}=4%). Distribution (Fig. 8.2) of the mean values of the radial increments of the corresponding groups is completely regular. With increasing age the increment diminishes, and with improving climatic conditions the increment enlarges. All k_d values are typical of such a regularity. Distribution of the mean increments is related with the values of the mean culminating increments. In groups of increment indexes of trees of the same age the current diameter increment augments due to an increase in the mean culminating increment. The mean values of the radial increments regularly distribute in all ages and in their limits in all k_d. It demonstrates that the theoretical fundamentals of the system of standardizing the current increment are significant and the structure of the standard is appropriate for a practical use. For some ages unsmoothed mean radial increments of groups A, k_d and I_{zr} are presented in Table 8.2.

Table 8.1. The stability of the mean culmination diameter (k_d) increment and variation in the indexes of age (A_{zrmax}) and diameter (D_{zrmax}), which regulate it, in the conditions of atmospheric pollution. Pine stand has grown in plot 4L (2 km from plant "Achema") affected by pollution and control stands are unaffected by pollution.

№ of sample plot	The mean culmination increment (k_d), m/year	The mean culmination age (A_{zrmax}), year	The mean culmination diameter (D_{zrmax}), cm	Differences in %. Indexes of unpolluted stands=100%		
				A_{zrmax}	D_{zrmax}	k_d
4L	0,463	8,47	3,92	-	-	-
2030	0.419	10.08	4.22	16.0	7.2	-10.5
1740	0.471	10.03	4.87	15.5	19.5	1.7
107	0.485	10.72	5.20	21.0	24.8	4.5
114	0.479	11.28	5.41	25.0	27.6	3.3
127	0.422	13.72	5.79	38.3	32.3	-9.7
1735	0.493	9.98	5.09	15.1	23.0	6.1
6	0.397	11.04	4.39	23.3	10.6	-16.6
14	0.485	10.38	5.04	18.4	22.2	4.5
1731	0.487	11.74	5.72	27.9	31.5	4.9
365	0.434	8.83	3.86	4.1	-1.3	-6.6
366	0.443	8.39	3.76	-4.2	-1.0	-4.5
367	0.447	9.32	4.17	9.1	6.0	-3.6

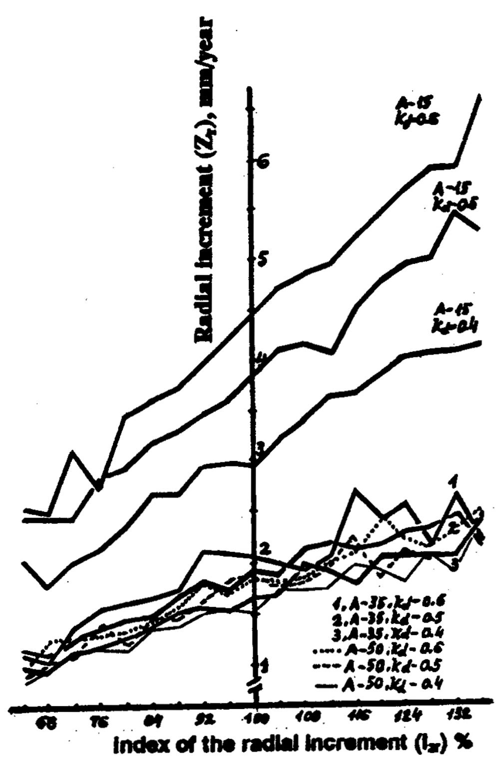

Fig. 8.2. Distribution of radial increments (Zr) in a different group of the mean culminating diameter increment (kd=0.4; 0.5; 0.6 cm/y) in all groups I_{zr} in relation with age (A). The mean values are unsmoothed.

Table 8.2. The mean standard radial increments (Z_r) of the dominating trees of Lithuanian pine stands in groups of age (A), the mean culminating diameter (k_d) increment and index I_{Zr} of the radial increment. The mean values of Z_r are unsmoothed. Fragment.

Age, A (year)	k_d, cm/year	The indexes radial increment (I_{zr}), %.																		
		64	68	72	76	80	84	88	92	96	100	104	108	112	116	120	124	128	132	136
		Radial increments (Z_r), mm/year																		
15	0,3	3 1.400	- -	2 1.650	1 2.000	3 1.400	8 2.025	4 2.275	4 2.375	6 2.367	3 2.367	5 2.400	4 2.950	5 2.460	6 2.833	6 2.800	2 3.350	3 3.300	1 4.100	- -
	0.4	9 2.067	11 1.791	12 2.017	21 2.195	30 2.370	18 2.678	26 2.654	16 2.950	34 2.953	29 2.907	27 3.174	27 3.356	32 3.597	28 3.646	17 3.835	17 4.000	18 4.061	9 4.056	11 4.127
	0.5	6 2.450	8 2.450	21 2.448	10 2.840	24 2.917	28 3.189	30 3.287	33 3.452	47 3.570	40 3.840	40 4.070	44 4.143	42 4.024	38 4.484	32 4.778	23 4.922	27 4.978	10 5.430	10 5.220
	0.6	6 2.533	8 2.475	9 3.089	9 2.744	10 3.430	20 3.570	21 3.657	21 3.962	19 4.184	24 4.458	17 4.700	22 4.814	27 4.881	23 5.109	12 5.442	12 5.608	11 5.891	7 5.871	5 6.600
	0.7	3 2.833	1 1.900	2 2.450	2 3.100	3 4.233	9 3.944	11 4.236	7 4.257	9 4.700	10 4.700	16 5.056	13 5.385	7 5.171	6 5.450	4 5.975	7 6.886	7 6.643	1 7.800	3 6.700
25	0.3	21 0.700	3 1.267	3 1.233	3 1.367	7 1.000	2 1.300	9 1.467	4 1.350	3 1.333	5 1.520	6 1.683	2 1.850	5 1.680	2 1.750	7 2.029	5 1.720	2 2.150	3 1.700	1 1.300
	0.4	8 1.163	9 1.211	11 1.318	14 1.371	19 1.747	25 1.568	25 1.628	28 1.818	37 1.876	29 2.169	24 1.988	31 2.135	28 2.307	24 2.267	20 2.265	21 2.410	9 2.256	5 2.400	8 2.375
	0.5	15 1.360	14 1.440	22 1.586	20 1.595	31 1.606	39 1.869	41 2.034	42 2.129	40 2.295	46 2.233	40 2.458	28 2.439	28 2.629	24 3.004	29 2.572	14 3.000	11 2.745	13 2.500	5 2.860
	0.6	5 1.620	9 1.356	16 1.531	19 1.916	21 1.843	21 2.229	18 2.117	30 2.553	20 2.630	20 2.470	32 2.606	28 2.975	8 2.112	13 3.415	11 2.873	13 3.331	10 4.060	4 2.500	4 3.050
	0.7	2 1.500	4 1.525	4 1.450	7 1.914	11 2.327	14 2.079	15 2.453	6 2.650	8 2.338	9 2.667	11 2.845	12 2.908	4 2.750	2 3.250	5 2.560	4 2.550	3 2.800	- -	2 3.000
35	0.3	4 0.825	2 0.700	2 0.800	6 0.933	3 1.133	6 1.017	4 1.300	8 1.175	6 1.100	4 1.475	6 1.167	5 1.440	4 1.550	4 1.775	4 1.650	3 1.667	1 1.600	2 1.950	1 1.800
	0.4	8 1.000	17 1.047	18 1.106	23 1.209	26 1.285	29 1.390	25 1.524	28 1.579	30 1.530	30 1.693	35 1.689	22 1.977	23 1.939	12 1.800	10 2.060	17 2.076	7 2.071	5 2.040	5 2.440
	0.5	7 1.186	9 1.133	20 1.290	15 1.373	31 1.465	41 1.490	31 1.706	43 1.851	43 1.763	46 1.957	46 1.896	40 2.160	33 2.224	32 2.128	20 2.190	16 2.325	13 2.323	13 2.469	8 2.125
	0.6	5 1.140	8 1.125	11 1.400	11 1.591	15 1.647	19 1.689	20 1.785	17 2.135	23 2.109	21 2.090	18 2.000	19 1.916	19 2.084	14 2.721	15 2.427	16 2.588	6 2.183	10 2.660	6 2.167
	0.7	1 1.400	1 1.200	5 1.660	5 1.480	6 1.433	6 1.817	4 1.425	10 2.090	7 2.086	11 1.945	7 2.229	7 2.471	6 2.033	4 2.500	3 2.933	9 2.733	6 2.517	5 2.380	4 3.050
45	0.3	3 0.967	3 0.633	2 0.700	2 0.800	7 1.000	3 1.000	8 1.225	4 1.275	3 1.300	2 1.350	9 1.467	5 1.560	3 1.633	6 1.483	3 1.300	4 1.825	1 1.300	2 1.800	1 1.200
	0.4	11 1.045	12 1.025	20 1.080	11 1.318	19 1.258	22 1.423	25 1.428	39 1.426	20 1.510	31 1.610	29 1.641	22 1.736	20 1.745	17 1.865	19 1.911	7 2.000	14 1.993	5 2.120	5 2.040
	0.5	10 1.140	13 1.108	17 1.182	22 1.418	23 1.378	37 1.397	39 1.605	35 1.691	33 1.785	45 1.884	38 1.818	37 1.868	37 2.000	24 2.188	26 2.277	8 2.738	15 2.140	6 1.817	7 1.957
	0.6	4 1.150	4 1.000	8 1.275	12 1.425	10 1.520	18 1.567	24 1.550	15 1.713	12 1.812	14 1.814	28 2.246	19 1.889	15 1.840	16 2.119	11 2.082	9 1.967	12 2.308	9 2.389	4 2.600
55	0.3	1 1.000	2 0.700	2 0.900	3 0.967	5 1.020	7 1.300	3 1.100	2 1.350	5 1.360	8 1.238	5 1.480	11 1.473	4 1.475	6 1.483	3 1.800	2 1.450	2 2.350	3 1.533	- -
	0.4	6 1.017	12 1.042	11 1.145	16 1.163	19 1.189	18 1.239	24 1.421	28 1.496	26 1.465	23 1.396	31 1.581	18 1.850	19 1.716	24 1.817	20 1.645	12 1.767	10 1.770	4 1.800	5 2.220
	0.5	12 1.067	13 1.015	9 1.067	19 1.258	17 1.412	23 1.348	23 1.557	29 1.534	31 1.645	32 1.647	34 1.738	27 1.856	26 1.765	31 1.810	26 1.912	15 1.873	10 1.670	10 2.580	9 2.144
	0.6	10 0.990	5 1.180	8 1.100	3 1.333	14 1.029	10 1.230	5 1.520	15 1.313	11 1.436	13 1.923	16 1.700	9 1.667	11 1.900	9 1.711	10 1.990	10 2.070	5 2.800	4 2.350	4 2.700

In the standard the mean values of Z_r have been calculated at the accuracy of 2-7%. The total accuracy of calculating the increment is indicated by the errors of the mean values. By applying formula $Z_r=a_0+a_1 I_{Zr}+a_2/I_{Zr}$, the following reliable intervals have been calculated: S'=0.211 (I_{zr}=64%); S'y=0.196 mm (I_{zr}=100%); S'y=0.207 mm (I_{zr}=136%); r=0.943 for the whole series of I_{zr}. The correlation between age (A=15-50 m) and Z_r is very close (r=0.804). The error ($y_{f(x)}$=0.165) of the mean value is small. It shows that function $Z_r=f(I_{zr}$, A=const., k_d=const.) permits us to assess the dynamics of the radial increment by the coefficient of high determination: R^2=0.88.

The system of standardizing the dynamics of the current increment favours the construction of models of the dynamics of the increments for the main tree species. The models can be used for assessing anthropogenic impact on a broad scale. Computer has been used for processing the data and for comparing the increments. It covers the calculation of index k_d of every tree and every tree ring I_{Zr}, determination of the character of the growth by A_k, Z_r distribution by groups of standardizing, elimination of "information noise" as well as calculation of determining the essence of the difference in statistics, regression and criteria.

8.3. DENDROCHRONOLOGICAL SEARCH FOR CLIMATIC CHANGES

The tree increment affected by climatic fluctuations over time significantly varies. In their turn climatic changes reflect themselves in the dimensions and structure of tree rings. Analysis has been conducted on fluctuation of dendrochronological indexes over the last 166 years. There has been revealed the variability of an effect of climate on forests and a cyclic character of this variability.

The objective of investigations was to analyse the dynamics of parameters of a cyclic fluctuation in dendroscales and to determine whether variation in these parameters is cyclic and whether the length of variation cycles reflects ecoclimatic changes. For the investigation of dendroscales of *Picea abies* (1870-1995), *Pinus sylvestris* (1830-1995) growing on dry and moist *carico-sphagnosa* sites as well as these of *Alnus glutinosa* stands (1880-1995) have been applied. As shown in Figure 8.3, fluctuations of 9-12 and 22-25-year cycles are noted in the dendroscales. Also a recurrent decrease and an increase in the amplitudes of these fluctuations are observed.

Dynamics z(f) of typical dendroscales investigated for the forests of Lithuania is reflected by the model:

$$z(t)=a+\sum_{j=1}^{n} A_j(t)\varphi_j(t)+\varepsilon_t, \qquad (1)$$

where ε_t is a steady-state random process, $\varphi_j(t)$ - a cyclic component $\cos(2\pi t/T_{2j}+\psi_j)$or the process of autoregression-sliding mean, (T_{2j} - period, ψ_j - fluctuation phase), $A_j(t)$ - the function describing variation in amplitude $\varphi_j(t)$. Function $A_j(t)$ may be periodic:

$$A_j(t)=\alpha_j(1+\cos(2\pi t/T_{1j})), \qquad A_j(t)=\alpha_j|\cos(2\pi t/T_{1j})|, \qquad (2)$$

where $T_{1j} >> T_{2j}$ (the period of amplitude fluctuation is by far larger than the length of a cyclic fluctuation),

$$A_j(t)=\alpha_j\cos(\pi t/T_{1j}), \qquad (3)$$

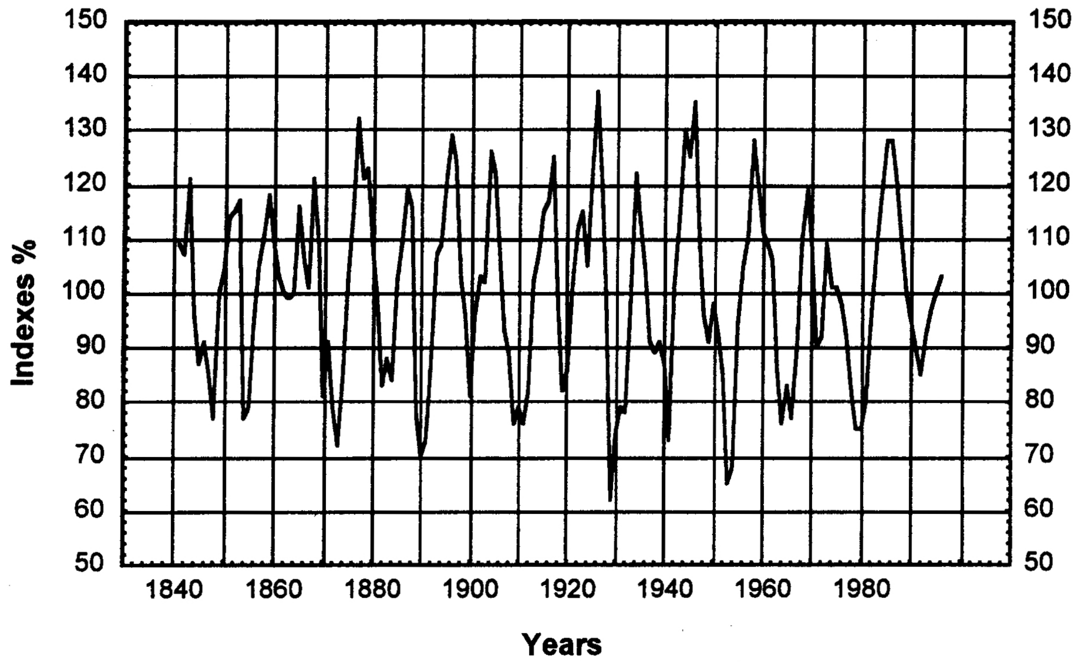

Fig. 8.3. The indexes of standard chronologies of the annual tree rings of pine stands of *Caricosus* type

where $T_{1j} >> T_{2j}$. In this case both the amplitude and the phase of a cyclic fluctuation vary periodically.

$$y(t) = 4.5\cos(\pi t / 60)\cos(2\pi t / 11 + 2.1) \quad (4)$$

$t = 1,...,350$, variation graph (function $z(t)$ where $A_j(t)$ defined by formula(3) as a separate case).

It is noted that in functions (1-3) it is infeasible to catch directly fluctuation periods T_{1j} of amplitudes by the methods of the sliding mean or spectral analysis. Spectral density of function

$$A_j(t)\cos(2\pi t / T_{2j} + \psi_j) \quad (5)$$

where $A_j(t)$ is defined by formulae (2-3), and $T_{1j} >> T_{2j}$ possesses several peaks in narrow frequency $1/T_{2j}$ (or period T_{2j}) bands. This spectral density is insignificant for the periods which are close to T_{1j} (or low frequencies).

Spectral density of function (4) depends upon the frequency and length of the period. Frequency and the period are inverse variables. We see that spectral density of this function possesses two peaks in frequencies 0.083 and 0.101 or in periods 12 and 9.94. For frequencies less than 0.75 or for the periods larger than 20 spectral density of this function is insignificant.

Giving the expression of function (5) and having frequencies V_1 and V_2 in which there are spectral density peaks, we can calculate the values of $T_{1,1}$ and $T_{2,1}$. In case series of time investigated is the sum of several cyclic components and random noise a problem arises in determining the cycles of variation in amplitudes according to the spectral density peaks. In order to reveal fluctuations of function $A_j(t)$ instead of analysing function $A_j(t)\,\varphi_j(t)$, the function $(A_j(t)\,\varphi_j(t))$ - an absolute deviation of this function from fluctuation centres - has been studied. The graphs of function (4) $y(t)$ indicate periods the length of which is 60. They can be defected using the sliding mean of 11 years. Spectral density peaks of the function are distinct in frequencies 0.017 and 0.18 or in periods 58 and 5.5. By applying harmonic analysis it has been determined that peak 58 corresponds to a period of 60 years.

In all investigated dendroscales the fluctuation of 9-12 and 22-25-year old cycles have been found. They recur every 100 years. In order to determine cycles of this length we analysed series formed of the absolute deviation from the mean values of these series: $\bar{\bar{z}}_t = |z_t - \bar{z}_t|$, i.e. transformed indexes. It has been found that in spectral densities of series $\bar{\bar{z}}_t$ of dendroscales, the peaks appear which correspond to low frequencies <0.025. However, the values of spectral density of series Z_t in these points did not differ from the values of white noise. The values of spectral density of series Z_t, which correspond to the periods longer than 40, were insignificant whilst these of series $\bar{\bar{z}}_t$ were significant. It corroborated the assumption that in series $\bar{\bar{z}}_t$ the long cycles, which are longer than half length of the series, hide. The series of dendroscales investigated were too short for evaluating these cycles reliably by the methods of harmonic and spectral analysis. We will assess them with the aid of the method of the sliding mean and the sliding of 11 years.

As a result (Fig. 8.4) of investigations, it has been ascertained that the slightest fluctuation of the increments in pine, spruce and black alder stands investigated were at the turn of this century (in 1895-1910). Next minimum of increment fluctuation is observed currently, i.e. in the period 1990-2000. Thus, the amplitude of fluctuation of indexes indicates that an ecoclimatic 90-92-year old cycle of fluctuation of the increment exists in nature. The presence of such a cycle (in the general form) in the eastern part of the northern hemisphere was stated earlier (Kairiūkštis, Dubinskaitė, 1990) in analysing longterm chronologies of the northern hemisphere (USA, Canada, the former USSR). Currently, it has been proved by the difference in the diapason of fluctuation of amplitudes. At the turn of next century a cyclic variation in the increments can be expected, which can be a concomitant of an increase in fluctuation of the amplitudes of indexes. Consequently, changeable fluctuation of the ecoclimatic background is feasible.

8.4. ASSESSMENT OF ENVIRONMENTAL POLLUTION BY ANALYSIS OF CHEMICAL COMPOUNDS IN NEEDLES OF PINE AND SPRUCE

In forest monitoring the chemical analysis of leaves and needles is a widely applied diagnostic method in studying the interaction between environmental pollution and forest. Previous results of investigation have shown that conifers - spruce and pine - are more sensitive to chemical effect as compared to broad-leaved species. There have been inferred by comparing the findings of investigations conducted on several physiological functions the following: qualitative and quantitative changes in proteins, the content of photosynthetizing pigments, exchange of some nutrients (starch and sugar) and variation in the energetics of a cell through the function of K^+ions (Skuodienė, 1987).

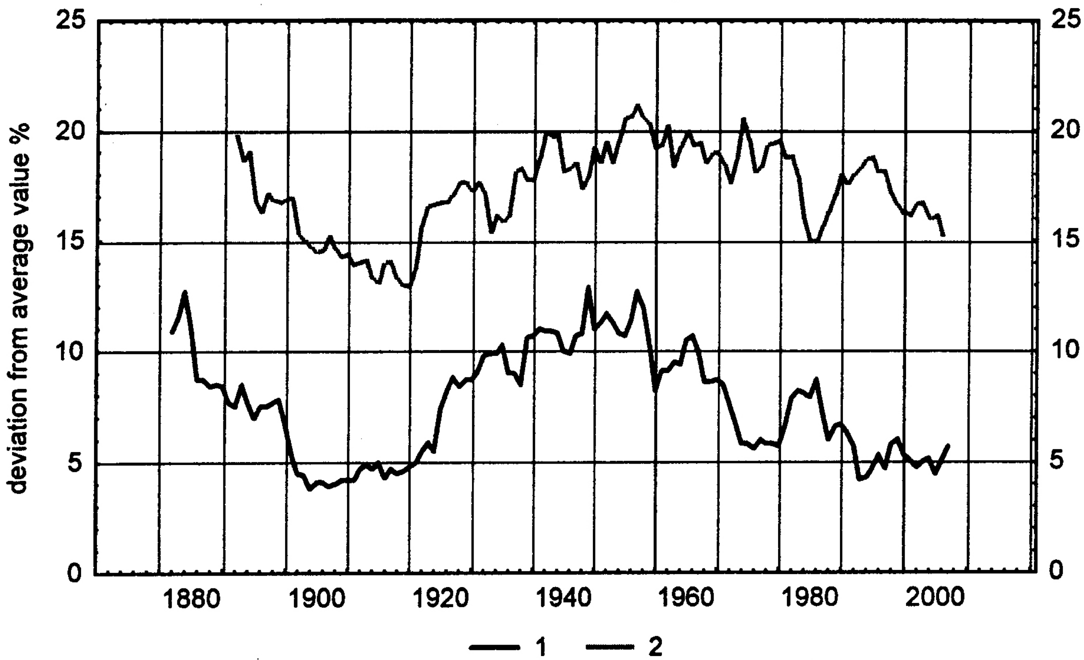

Fig. 8.4. The sliding of transformed indexes of annual rings of standard chronologies (1 - Picea abies; 2 - Alnus glutinosa)

In accordance with the recommendations of the European Coordinating Centre a chemical analysis has been conducted on needles of pine and spruce for determining 6 compulsory (N, S, P, Ca, Mg, K) and 8 freely chosen (Na, Zn, Mn, Fe, Pl, Al, B) elements. The standard methods have been applied in cooperation with the Centre of Agrochemical Studies and the screen of European monitoring.

In comparison to the results of 24 European corresponding laboratories, our data appeared to be good and not limited.

Our data show (Table 8.3) that nearly all mean digital values of nutrients do not exceed the highest values of these elements determined in forest monitoring of Europe. Manganese (Mg) is an exception. Its quantity in Lithuania comprises even 20% more, as compared to the highest value of this element according to data of the European Centre. Larger quantities of manganese may be attributed to the admixture of dolomite in the soil. It has been also found that the quantities of S and N are intangibly related to forest degradation and background air pollution.

8.5. STATE-OF-ART OF FORESTS AND PERFECTION OF MONITORING

Along with experimental studies the forest monitoring is conducted and the information on the extent of crown defoliation and health of different tree species in the conditions of atmospheric pollution is accumulated. In the system of monitoring permanent observation plots (POP) are distributed by means of mathematical statistics (4X4 km). In Lithuania they number 960 and 3840 including satellites with more than 23 thousand inventory trees. The methods of this observation allows the crown defoliation of trees to be reliably assessed and regions of conditional ecological risk delineated.

Table 8.3. The mean, minimum and maximum values of the main nutrient chemical elements in needles of pine and spruce in the screen (16X16 km) of forest monitoring of Lithuania

	The number of PIP on the territory of Lithuania	N	P	K	Ca	Mg	S
Spruce							
The mean value (mg/g)	28	10.5±0.65	1.20±0.10	5.36±0.39	5.57±0.39	1.94±0.16	0.91±0.06
The minimum value (mg/g)	28	4.2	0.4	1.4	1.5	0.9	0.4
The maximum value (mg/g)	28	18.0	3.5	9.0	9.0	3.9	1.7
Pine							
The mean value (mg/g)	36	11.9±0.45	1.25±0.04	3.81±0.36	4.63±0.29	1.54±0.10	1.04±0.06
The minimum value (mg/g)	36	8.0	0.6	0.9	2.0	0.9	0.5
The maximum value (mg/g)	36	17.8	1.6	7.4	8.0	3.0	2.0

In order to assess forest damage complexly, the dynamics of wood and other forest resources as well as real state-of-art of the forest ecosystems experimental national forest inventory (NFI) has been carried out in the forestry of Kazlų Rūda. In accordance with more than 20 different indications trees have been measured in circular permanent inventory plots (PIP) of 400 m^2 size, which are distributed in a systematic way. The investigation of damaged trees and measurement of their dendrometric indexes enabled us to determine the relationship between the quantitative indexes of stand (the number of trees, their volume and increment per area unit, etc). After evaluating distribution of trees in each plot with the aid of regression analysis it has been possible to determine stand productivity by using only the data of forest monitoring. The investigations have shown that in order to perfect the control of wood resources it is expedient to use the screen of regional monitoring of forests and forest soils by expanding it up to the level of NFI. Thus, the information already accumulated on the state-of-art of forests and forest soils would be applied. The new system of control would completely reflect changes in forest resources and their state-of-art, serve the requirements of the European Community.

8.6. THE CURRENT STATE-OF-ART OF FORESTS IN LITHUANIA AND TENDENCIES OF ITS CHANGE

The state-of-art has been assessed according to the international methods and programme of the effect of polluted air on forests (Manual ..., 1994) by supplementing and applying it to the conditions of Lithuania. The investigations have been carried out applying intercalibration data of forest monitoring training. A close inverse correlation (r=-0.8 - 0.9) has been found between the mass of needles of model trees and defoliation of visually assessed crowns. Therefore, the average deviation of assessment by most experts is ±1% [3].

In 1996 the investigations on the state-of-art of forests were conducted on 12,112 trees (POP) including satellites in the screen of 8X8 km and 16X16 km. A total of 5,915 trees including 2,612 pines (44.2%), 1,301 (22.0%) spruces, 1,111 birches (18.8%), 297 asps (5.0%), 216 ashes (3.7%), 175 black alders (3.0%) and other trees were investigated. Additionally, the state-of-art of forests was investigated in 9 permanent plots where 1,408 trees has been investigated.

In accordance with crown defoliation the trees have been grouped into 5 defoliation classes: 0 class - healthy trees (defoliation comprises 0-10%), I class - slightly damaged trees (15-25%), II class - moderately damaged trees (30-60%), III class - significantly damaged trees (over 60%) and IV class - killed trees.

The investigations have shown that healthy trees constitute 29.1% of all trees (Table 8.4), slightly defoliated trees 58.3%, trees which have lost over 60% of needles or leaves less than 1% and killed trees 2.0%. Thus, in 1996 the improvement of the state-of-art of forests was noted. Such a tendency was revealed already in 1995. However, due to considerably damaged spruce stands by *Ips typographus* the number of killed trees was great. It negatively affected the average crown defoliation of trees.

A comparison of the average crown defoliation of all tree species demonstrates that in 1996 it diminished more than 5% and was 19.1±0.2%. The average crown defoliation of conifers remained more significant (19.9±0.3%) than that of broad-leaved trees (17.5±0.3%). Crown defoliation of the main tree species was the following: black alders - 16.1±1.1%, birches - 16.6±0.4%, ashes - 18.1±1.3%, pines 19.3±0.2%, oaks - 19.5±1.5%, asps and grey alders - 20.3±1.1%, spruces 21.2±0.6%. In comparison to the average crown defoliation of undamaged trees, that of damaged trees was found to be more than 13% more significant.

Crown defoliation to a certain extent determines ecological situation of one region. In accordance to the average crown defoliation of all trees the zones have been delineated in Lithuania (Fig. 8.5). The best state-of-art of forests has been assessed in West-South-West Lithuania and in the North-Eastern part. In North Žemaitija and South Lithuania the forests are damaged more considerably. In general, in 1993-1995 in Lithuania the average crown defoliation was similar to that in neighbouring countries (Latvia, Byelorus). In Poland, Czechia and Slovakia it was more significant while in Estonia, Finland and Sweden less. Such a state-of-art of forests may be attributed to changes in air pollution in different European countries and climatic factors. In Estonia, Latvia and Denmark the average crown defoliation of trees tended to decrease several years while in Lithuania two years. It may be associated with the maximum of 11- year dendrochronological cycles.

Table 8.4. The dynamics of distribution of trees in defoliation classes

Years	The number of trees	The number of POP	Defoliation class 0	1	2	3	4
1987	3816	159	41.5	43.7	10.9	3.9	0.0
1988	23136	964	79.0	18.0	3.0	0.0	0.0
1989	23016	963	37.7	41.4	19.1	1.7	0.1
1990	23042	958	31.5	48.1	18.8	1.4	0.2
1991	22836	952	24.6	51.5	22.1	1.5	0.3
1992	1807	74	16.3	66.1	15.9	0.8	0.8
1993	5654	235	21.1	51.4	23.9	3.0	0.6
1994	1761	73	14.8	59.8	23.5	1.5	0.4
1995	7774	320	19.4	55.7	20.3	1.2	3.4
1996	5915	253	29.1	58.3	9.7	0.9	2.0

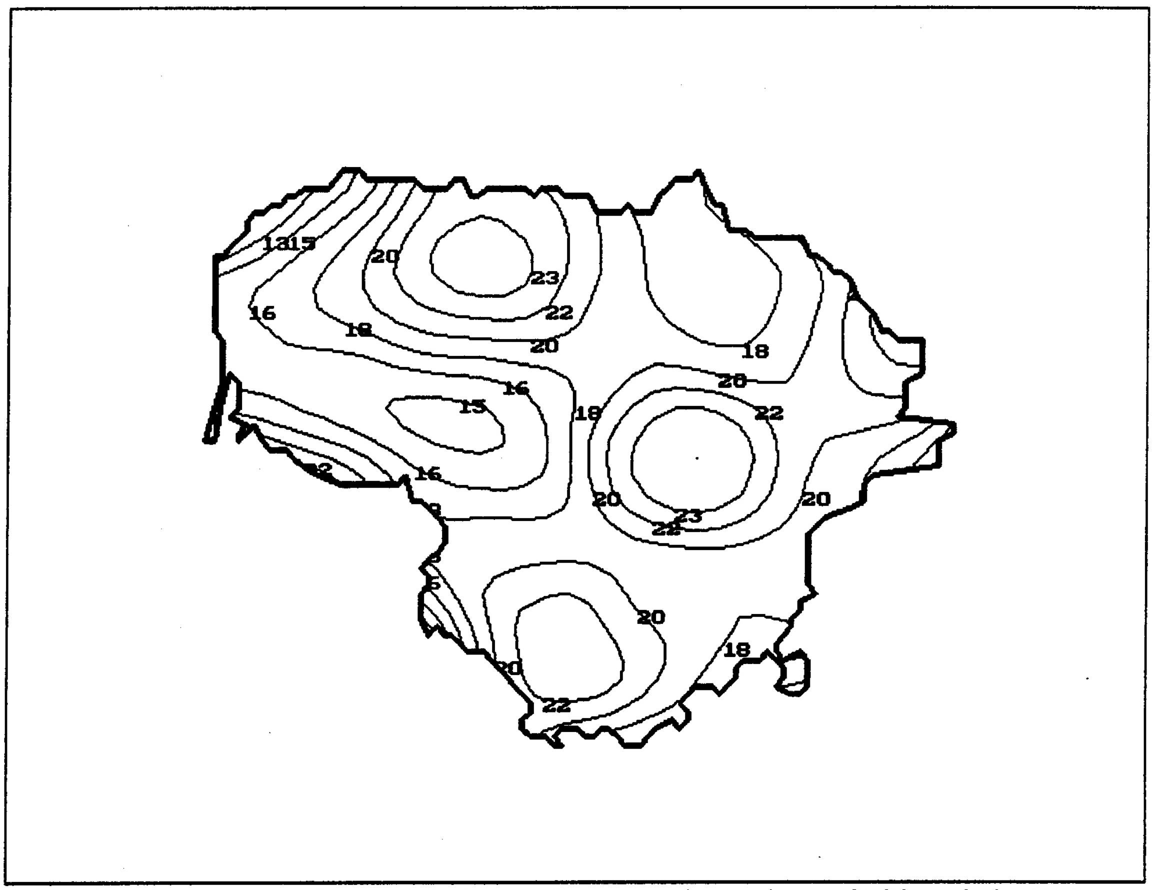

Fig. 8.5. Changes in moderate defoliation of trees on the territory of Lithuania in 1996

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