

# Scots Pine (*Pinus sylvestris* L.) Health Condition in Kaunas City Forests

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## Abstract

This article reviews the dynamics of Scots pine (*Pinus sylvestris* L.) health condition in different Kaunas city districts in 1994–2003. Health condition of Scots pine trees was estimated according to morphological indicator parameters: tree crown defoliation, foliage discoloration, amount of dead branches, needle retention, fruiting, state of tops and visual damages. It was found, that health condition of pine trees was worsening reliably in 1994–1998, except Kleboniškis-2 and Lampėdžiai sample plots, and in 2001–2003 – except Raudondvaris-2 sample plot. The mean crown defoliation of all sample stands in 1994 was  $29.0 \pm 1.9$  %, in 1995 –  $28.8 \pm 2.1$  %, in 1996 –  $30.4 \pm 2.2$  %, in 1997 –  $32.1 \pm 1.9$  %, in 1998 –  $33.5 \pm 2.0$  %, in 2001 –  $25.9 \pm 3.6$  %, in 2002 –  $29.2 \pm 3.2$  %, in 2003 –  $34.3 \pm 2.5$  %. According to tree crown defoliation the best health condition of Scots pine forests was estimated in Botanikos sodas sample plot, small defoliation was found in Kleboniškis-2 and Eiguliai sample plots. The worst state of Scots pine was defined in Raudondvaris-2 sample plot, also great defoliation was defined in Kleboniškis-1, Palemonas-1, Palemonas-2, Panemunė-1, Petrašiūnai-1, Petrašiūnai-2 and Mčiūnai sample plots. The greatest Scots pine crown defoliation ( $34.3 \pm 2.5$  %) in Kaunas city districts during our research period (1994–2003) was found in 2003.

**Key words:** Scots pine, air pollution, indicator parameters, health condition, city environment

## Introduction

Kaunas city environment is affected by various environmental factors, including anthropogenic ones (air, soil pollution, soil pressure, compaction, land use activities, excavation and trenching, mechanical tree injuries – that contribute to overall tree decline). The environs of Kaunas city are covered mostly by Scots pine (*Pinus sylvestris* L.) forests.

Forests cover almost one third of the earth and their environmental and economic value is extremely high. Ecosystems in the urban environment are exposed to a variety of natural and anthropogenic factors. City trees are affected more by factors having negative impact on tree growth and condition than trees in natural forest ecosystems. While assessing the impact of urban environment on trees, it is important to estimate the condition of pine forests near Kaunas city and its dynamics considering the dynamics of air pollution in different Kaunas city districts.

Polluted air is one of the main reasons for forest decline (Manion and Lachance 1992, Juknys *et al.* 2003, 2003, Stravinskienė 2002). Vegetation is affected by polluted air directly through assimilation apparatus and indirectly – polluted precipitation and soil.

Air pollution intensifies the processes of tree ageing (Ozolincius 1996, Ozolincius *et al.* 2005). Emissions and deposition of acid compounds in Europe started to decrease since the mid-1980s, however more intense decrease in tree crown defoliation in many countries including Lithuania, was registered only from 1994–1995 (Hendriks *et al.* 1997; Klap *et al.* 1997; Ozolincius and Stakenas 1999). Many symptoms of air pollution impact can be estimated visually by noticeable symptoms: changes in needle colour, decreased needle retention, increased amount of dead branches, increased crown defoliation and others (Momen *et al.* 2002).

The aim of this investigation is to estimate the health condition of Scots pine trees growing in Kaunas city parks and forest parks.

## Material and methods

There are 10 city parks, 3 city forest parks, 3 landscape conservation areas near Kaunas city. Forests cover 2,842.9 hectares. Conifer stands are dominating – they cover 41 % of the total forest area in the city (where pine forests comprise 34%). Mean forest cover of Kaunas city is approximately 18 %. The charac-

ter of tree reaction towards environment pollution depends on their sensitivity and resistance to polluted air. Conifers are more sensitive to air pollution than deciduous and therefore are better indicators (Stravinskienė 1997). Pine forests were selected for several reasons: Scots pine is dominant species and it is one of the most sensitive indicators of environment condition.

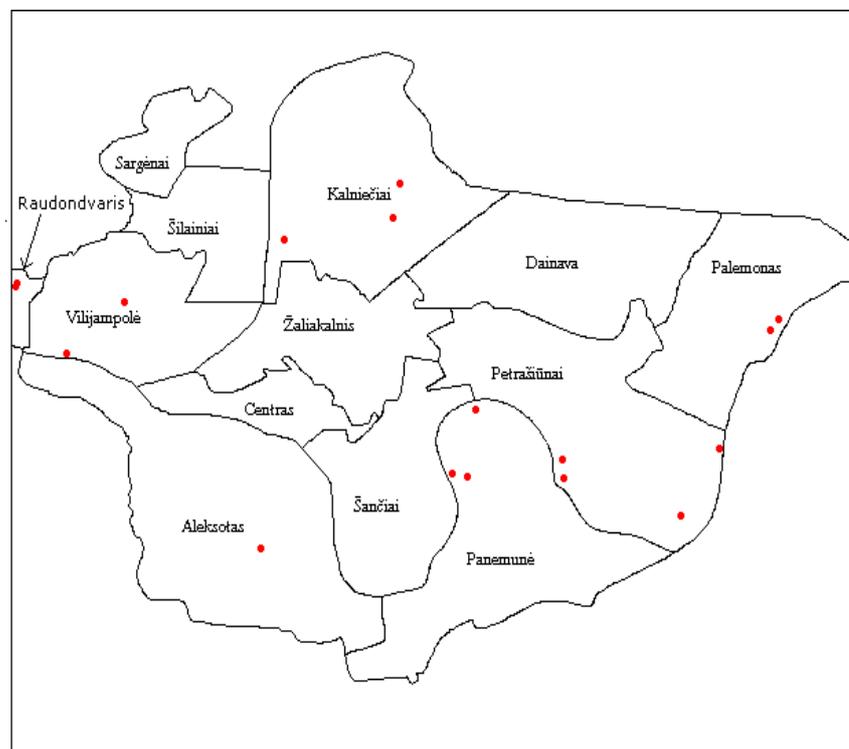
Main task of this research was to assess the health condition of Kaunas pine forests. 17 sample plots were selected in Aleksotas, Kalniečiai, Palemonas, Panemunė, Petrašiūnai, Raudondvaris and Vilijampolė city districts. The distribution of sample plots in city districts is presented in Figure 1. The characteristics of sample plots are described in Table 1. All sample plots were divided into groups according to sample tree age: up to 70 year old pine stands – Botanikos sodas, Eiguliai, Kleboniškis-1, Petrašiūnai-1, Petrašiūnai-2, Raudondvaris-1; 71-90 year old pine stands – Kleboniškis-2, Jachtklubas, Lampėdžiai, Palemonas-1, Palemonas-2, Romainiai; more than 91 year old pine stands – Panemunė-1, Panemunė-2, Pažaislis, Raudondvaris-2, Vičiūnai.

The morphological indicatory parameters (crown defoliation, foliage discoloration, amount of dead branches, state of tops, needle retention, fruiting and damages) of 310 sample trees were assessed each summer (July–August) of 1994-2003 for the whole crown from East-West sides by using a visual estima-

tion method. Crown defoliation, foliage discoloration and the amount of dead branches were assessed by 5 % gradation according to international forest monitoring methods (Manual on methods... 1994). Dead branches under a live crown are not included.

Crown defoliation and foliage discoloration are the most important biological diagnostic tests for tree health condition assessment. Crown defoliation is not only the loss of existing foliage, but also that part of the foliage, which is able to form in normal conditions, but did not form in the existing ones. The natural fall of leaves during autumn is not considered. In other words, defoliation means the loss of compared to the reference tree whose crown defoliation does not exceed 10 % (Ozolincius 1996). The reference tree is usually a tree of the same growth, social class as the sample tree, belongs to the same type of branching, grows in the vicinity of the sample tree. The photo of the reference tree corresponding to a sample tree according to special atlases can be used. We used special atlases with the photos of reference trees (Muller and Stierlin 1990).

Other morphological indicators: the tree top state (healthy, broken, dried or damaged), the amount of dead branches in the crown (%), needle retention (0.1 year accuracy), fruiting level (no fruiting, weak fruiting, average fruiting or good fruiting) and tree damages (from animals, insects, fungi and diseases, abiotic factors, direct human activities and other) were



**Figure 1.** Distribution of sample plots in Kaunas city districts

Table 1. Characteristics of sample plots in Kaunas city pine forests

Sample plot	Sample plot characteristics
<b>Botanikos sodas</b>	Sample plot is located in the territory of Vytautas Magnus university Botanical garden, on a slope 200 m east from the glasshouse. Average age of sample trees is 60 years. It is a small group of pines in a deciduous stand (a mixed stand of <i>Acer platanoides</i> L., <i>Quercus robur</i> L. and <i>Tilia cordata</i> Mill.). Herbal species: <i>Hepatica nobilis</i> Mill., <i>Oxalis acetosella</i> L., <i>Ajuga reptans</i> L.; site landscape indicate Sc (normal moisture loamy slope) forest site type.
<b>Eiguliai</b>	Sample plot is located in the district of Eiguliai cemetery, about 400-500 m south from the northern Kaunas circuit, 100 m. from the Neris river. Average age of the sample trees is 65-70 years. Characteristics of the stand: species composition of stand trees – 100 % pine, solitary spruce ( <i>Picea abies</i> (L.) H. Karst.) trees; stocking level – 0.7; volume (1 ha) – 260 m <sup>3</sup> ; bonitet class – III; forest site type – Ncl (normal moisture light loamy soil); forest type – <i>Pinetum oxalidosum</i> .
<b>Jachtklubas</b>	Sample plot is located at the entrance of yacht club, on both sides of the road, at the distance of 10-30 m from the road. Average age of the sample trees is 80 years. Characteristics of the stand: species composition of stand trees – 90 % pine, 10 % spruce; stocking level – 0.7; volume (1 ha) – 210 m <sup>3</sup> ; bonitet class – IV; forest site type – Nbl (normal moisture light sandy loam soil); forest type – <i>Pinetum vaccinosum</i> .
<b>Kleboniškis-1</b>	Sample plot is located in Kleboniškis forest park at the pedestrian bridge, 30-70 m north from the highway Vilnius-Kaunas. Average age of the sample trees is 65 years. Characteristics of the stand: species composition of stand trees – 100 % pine; stocking level – 0.8; volume (1 ha) – 240 m <sup>3</sup> ; bonitet class – III; forest site type – Nbl; forest type – <i>Pinetum vaccinosum</i> .
<b>Kleboniškis-2</b>	Sample plot is located in Kleboniškis forest park, 1 km west from Kleboniškis-1 sample plot, 300-400 m north from the highway Vilnius-Kaunas. Average age of the sample trees is 80 years. Characteristics of the stand: species composition of stand trees – 80 % pine, 20 % oak ( <i>Quercus robur</i> L.), solitary spruce trees; stocking level – 0.6; volume (1 ha) – 150 m <sup>3</sup> ; bonitet class – III; forest site type – Nbl; forest type – <i>Pinetum vaccinosum</i> .
<b>Lampėdžiai</b>	Sample plot is located at the northern part of Lampėdžiai forest park resort, 100 m from the pool. Average age of the sample trees is 85-90 years. Characteristics of the stand: species composition of stand trees – 100 % pine; stocking level – 0.6; volume (1 ha) – 220 m <sup>3</sup> ; bonitet class – III; forest site type – Ncl; forest type – <i>Pinetum oxalidosum</i> .
<b>Palemonas-1</b>	Sample plot is located on the slope 300-400 m east from stock company „Palemono keramika“ administration building. Average age of the sample trees is 85-90 years. Characteristics of the stand: species composition of stand trees – 100 % pine, stocking level – 0.7; volume (1 ha) – 220 m <sup>3</sup> ; bonitet class – IV; forest site type – Nbp (normal moisture sandy loam soil with double texture – light sand on heavy loam in the upper layer); forest type – <i>Pinetum vaccinosum</i> .
<b>Palemonas-2</b>	Sample plot is located in Palemonas settlement at the end of Parko street, 200-300 m from Kaunas sea shore. Average age of the sample trees is 85-90 years. Characteristics of the stand: species composition of stand trees – 100 % pine; solitary maple ( <i>Acer platanoides</i> L.) and spruce trees; stocking level – 0.7; volume (1 ha) – 200 m <sup>3</sup> ; bonitet class – III; forest site type – Ncp (normal moisture loamy soil with double texture – light sand on heavy loam in the upper layer); forest type – <i>Pinetum oxalidosum</i> .
<b>Panemunė-1</b>	Sample plot is located in front of Panemunė trolleybus circle, 50-150 m north-east from the circle. Average age of the sample trees is 160 years. Characteristics of the stand: species composition of stand trees – 60 % pine, 40 % spruce; stocking level – 0.6; volume (1 ha) – 250 m <sup>3</sup> ; bonitet class – III; forest site type – Ncl; forest type – <i>Pinetum oxalidosum</i> .
<b>Panemunė-2</b>	Sample plot is located in the central part of Panemunė forest park, about 400 m east from the beach. Average age of the sample trees is 170 years. Characteristics of the stand: species composition of stand trees – 60 % pine, 20 % spruce, 10 % oak, 10 % maple; stocking level – 0.6; volume (1 ha) – 240 m <sup>3</sup> ; bonitet class – III; forest site type – Ncs (normal moisture heavy loamy soil); forest type – <i>Pinetum oxalidosum</i> .
<b>Pažaislis</b>	Sample plot is located in the southern part of Pažaislis forest park, at the quay. Average age of the sample trees is 170 years. Characteristics of the stand: species composition of stand trees – 100 % pine, solitary spruce trees; stocking level – 0.4; volume (1 ha) – 120 m <sup>3</sup> ; bonitet class – V; forest site type – Nal (normal moisture light sand); forest type – <i>Pinetum cladoniosum</i> .
<b>Petrašiūnai-1</b>	Sample plot is located 300 m north-west from Kaunas hydroplant, 200 meters from ferroconcrete construction factory. Average age of the sample trees is 60 years. Characteristics of the stand: species composition of stand trees – 100 % pine; stocking level – 0.7; volume (1 ha) – 260 m <sup>3</sup> ; bonitet class – III; forest site type – Nbl; forest type – <i>Pinetum vaccinosum</i> .
<b>Petrašiūnai-2</b>	Sample plot is located 10-50 m north-east from Petrašiūnai trolleybus circle. Average age of the sample trees is 65-70 years. Characteristics of the stand: species composition of stand trees – 100 % pine; stocking level – 0.8; volume (1 ha) – 220 m <sup>3</sup> ; bonitet class – IV; forest site type – Nbl; forest type – <i>Pinetum vaccinosum</i> .
<b>Raudondvaris-1</b>	Sample plot is located at the right side of Raudondvaris road, 30-50 m from the road, 300 m from the Nevėžis river. Average age of the sample trees is 65 years. Characteristics of the stand: species composition of stand trees – 100 % pine; stocking level – 0.7; volume (1 ha) – 240 m <sup>3</sup> ; bonitet class – III; forest site type – Sbl (normal moisture light sandy loam slope); forest type – <i>Pinetum vaccinosum</i> .
<b>Raudondvaris-2</b>	Sample plot is located at the right side of Raudondvaris road, 30 m from the road, 300 m from the Nevėžis river. Average age of sample trees is 180 years. It is a small group of old trees (180 years) in a younger pine stand (65 years). Characteristics of the whole stand: species composition of stand trees – 100 % pine; stocking level – 0.7; volume (1 ha) – 240 m <sup>3</sup> ; bonitet class – III; forest site type – Sbl (normal moisture light sandy loam slope); forest type – <i>Pinetum vaccinosum</i> .
<b>Romainiai</b>	Sample plot is located at the left side of the stairs leading to Romainiai hospital, in the slope 150-300 m from Raudondvaris road and dwelling-houses. Average age of the sample trees is 80 years. Characteristics of the stand: species composition of stand trees – 100 % pine; stocking level – 0.6; volume (1 ha) – 140 m <sup>3</sup> ; bonitet class – IV; forest site type – Sbl, forest type – <i>Pinetum vaccinosum</i> .
<b>Vičiūnai</b>	Sample plot is located at the pedestrian bridge over the river Nemunas, south and south-west 50-150 m from the beach. Average age of the sample trees is 110 years. Characteristics of the stand: species composition of stand trees – 90 % pine, 10 % spruce; stocking level – 0.6; volume (1 ha) – 200 m <sup>3</sup> ; bonitet class – IV; forest site type – Nbl, forest type – <i>Pinetum vaccinosum</i> .

Note: Source of forest valuation parameters data is from Lithuanian State Forest Survey Service inventory database (2003).

estimated. For the evaluation of needle retention, 3-4 model branches in the upper one third of the crown were selected. Age of terminal shoots containing all needles and the ratio of length of the last (the oldest) shoot with remaining needles are evaluated with the help of binoculars.

## Results and discussion

### *Trends of Kaunas city air pollution in 1993-2003*

Air pollution of Kaunas city reduced several times compared to the end of the soviet period, but fast recovery of the transport sector caused an increase in air pollution since 1997. Majority of air pollutants in Kaunas city did not exceed maximal allowable concentrations ( $\text{NO}_2$  – 40.0  $\mu\text{g}/\text{m}^3$ ,  $\text{SO}_2$  – 50.0  $\mu\text{g}/\text{m}^3$ , dust – 150.0  $\mu\text{g}/\text{m}^3$ , formaldehyde – 3.0  $\mu\text{g}/\text{m}^3$ ) in 1994-2003 (Juknys 2004).

The concentration of sulphur dioxide decreased from 30.2  $\mu\text{g}/\text{m}^3$  in 1995 to 1.0  $\mu\text{g}/\text{m}^3$  in 2003 depending on the energetic and industrial sectors depression in 1993-2003. Minimal sulphur  $\text{SO}_2$  concentration was defined in all Kaunas city districts in 1996-1998. In 2003 the greatest  $\text{SO}_2$  concentration (1.5  $\mu\text{g}/\text{m}^3$ ) was observed only in Šilainiai district (Černiauskas 2004, Juknys 2004).

Nitrogen oxides concentration in Kaunas city have reduced just about two times in transition period, because a great part of nitrogen oxides emission was mostly determined by the growing transport sector. During this period  $\text{NO}_2$  concentration was decreasing till 1996 (from 30.2  $\mu\text{g}/\text{m}^3$  down to 5.0  $\mu\text{g}/\text{m}^3$ ). The tendency of an increase in  $\text{NO}_2$  concentration was observed in 1998. Due to economical depression in 1999, caused by Russian economical crisis,  $\text{NO}_2$  concentration reduced again. In 2000-2001 (16.6  $\mu\text{g}/\text{m}^3$  and 26.9  $\mu\text{g}/\text{m}^3$ , respectively)  $\text{NO}_2$  concentration increased in all districts of Kaunas city. A tendency of slight  $\text{NO}_2$  concentration decrease was estimated in 2001-2003 (from 26.9  $\mu\text{g}/\text{m}^3$  down to 20.1  $\mu\text{g}/\text{m}^3$ ), which did not distort  $\text{NO}_2$  concentration increasing tendency in the last several years (Juknys 2004). The greatest  $\text{NO}_2$  concentration in 2003 was observed in the Centre (34.0  $\mu\text{g}/\text{m}^3$ ), Dainava (24.0  $\mu\text{g}/\text{m}^3$ ), Petrašiūnai (23.0  $\mu\text{g}/\text{m}^3$ ) and Šilainiai (22.0  $\mu\text{g}/\text{m}^3$ ) districts, lowest one – in Aleksotas (13.0  $\mu\text{g}/\text{m}^3$ ) (Černiauskas 2004).

The concentration of dust was decreasing since 1995 (108.6  $\mu\text{g}/\text{m}^3$ ) till 1997 (35.8  $\mu\text{g}/\text{m}^3$ ). After that it started signally increasing (up to 154.2  $\mu\text{g}/\text{m}^3$  in 2000). Building trade depression reduced air pollution by dust greatly in Palemonas district. In 2001-2003 dust concentration was lower than in 2000 (56.2  $\mu\text{g}/\text{m}^3$ , 141.4  $\mu\text{g}/\text{m}^3$  and 100.0  $\mu\text{g}/\text{m}^3$ , respectively).

High dust concentration is one of the main Kaunas city air quality problems (Juknys 2004). Great dust concentrations in 2003 were characteristic of the Centre (172.5  $\mu\text{g}/\text{m}^3$ ), Viliampolė (137.0  $\mu\text{g}/\text{m}^3$ ), Sargėnai (124.5  $\mu\text{g}/\text{m}^3$ ) and Petrašiūnai (118.5  $\mu\text{g}/\text{m}^3$ ) districts (Černiauskas 2004).

The concentration of formaldehyde had a tendency of slow decreasing in 1994-1997 (from 2.7  $\mu\text{g}/\text{m}^3$  down to 2.5  $\mu\text{g}/\text{m}^3$ ). An increase of  $\text{CH}_2\text{O}$  concentration was observed in 1998 (2.9  $\mu\text{g}/\text{m}^3$ ). In 1999-2001  $\text{CH}_2\text{O}$  concentration reduced (from 2.3  $\mu\text{g}/\text{m}^3$  down to 1.8  $\mu\text{g}/\text{m}^3$ ). High formaldehyde concentration was estimated in 2002 (3.7  $\mu\text{g}/\text{m}^3$ ) and in 2003 (3.2  $\mu\text{g}/\text{m}^3$ ) – the average annual  $\text{CH}_2\text{O}$  concentrations exceeded the limits of tolerance (Juknys, 2004). Greatest  $\text{CH}_2\text{O}$  concentration in 2003 was observed in Žemieji Šančiai district (4.8  $\mu\text{g}/\text{m}^3$ ) and in the Centre (3.7  $\mu\text{g}/\text{m}^3$ ). High formaldehyde concentrations partially could be explained by a great number of hot and sunny days in 2002 and 2003, as formaldehyde is synthesized during photochemical reactions (Černiauskas 2004; Juknys 2004).

The notable decrease in lead concentration in the air was defined in 1995. Since this year the maximal allowable lead concentration (0.3  $\mu\text{g}/\text{m}^3$ ) has not been exceeding in any district of the city. Lead concentration was highest in Petrašiūnai district and in the Centre (0.12  $\mu\text{g}/\text{m}^3$ ) in 1998-1999. Since the year 2000 lead concentration in Kaunas city districts has been close to analytical zero (Juknys 2004).

The average ground level ozone concentrations in Kaunas city in the period of March-December (according to Dainava air quality monitoring station data) approximately were equal 50  $\mu\text{g}/\text{m}^3$  in 2001-2003, which were similar to these of the largest cities in Sweden (40-60  $\mu\text{g}/\text{m}^3$ ). Ground level ozone concentrations in observed Kaunas city districts did not differ much, but Aleksotas, Dainava, Viliampolė and Palemonas districts could be attributed to the mostly polluted Kaunas city districts ozone. The concentration of PAHs (polycyclic aromatic hydrocarbons) and PCBs (polychlorinated biphenils) in 2000-2002 were higher in more industrialized Kaunas city places with heavier traffic. Phenanthrene (157.0  $\text{ng}/\text{m}^3$ ) was the most abundant PAH. One of most carcinogenic PAH benzo(a)pyrene concentration was lower than 0.1  $\text{ng}/\text{m}^3$ . The most abundant PCBs were TriCB (trichlorobiphenils): in Dainava (4.3  $\text{ng}/\text{m}^3$ ), Laisvės alėja (2.4  $\text{ng}/\text{m}^3$ ), which indicated fresh pollution source (Kaunelienė *et al.* 2003).

### *Trends of Scots pine health condition in 1994-2003*

Mean values of indicator parameters were calculated for each Scots pine sample plot. The dynamics

of Scots pine crown defoliation in different Kaunas city districts in 1994-2003 is presented in Table 2. The mean crown defoliation of all sample stands in 1994 was 29.0±1.9 %, in 1995 – 28.8±2.1 %, in 1996 – 30.4±2.2 %, in 1997 – 32.1±1.9 %, in 1998 – 33.5±2.0 %, in 2001 – 25.9±3.6 %, in 2002 – 29.2±3.2 %, in 2003 – 34.3±2.5 %.

shows that the condition of urban environment and its availability for vegetation is worsening (Stravinskiene 1997, 2002). The greatest defoliation values at all sample plots were determined in 1996-1998. Favourable climatic conditions for vegetation growth and reduced concentrations of some air pollutants (especially formaldehyde) determined the decrease in

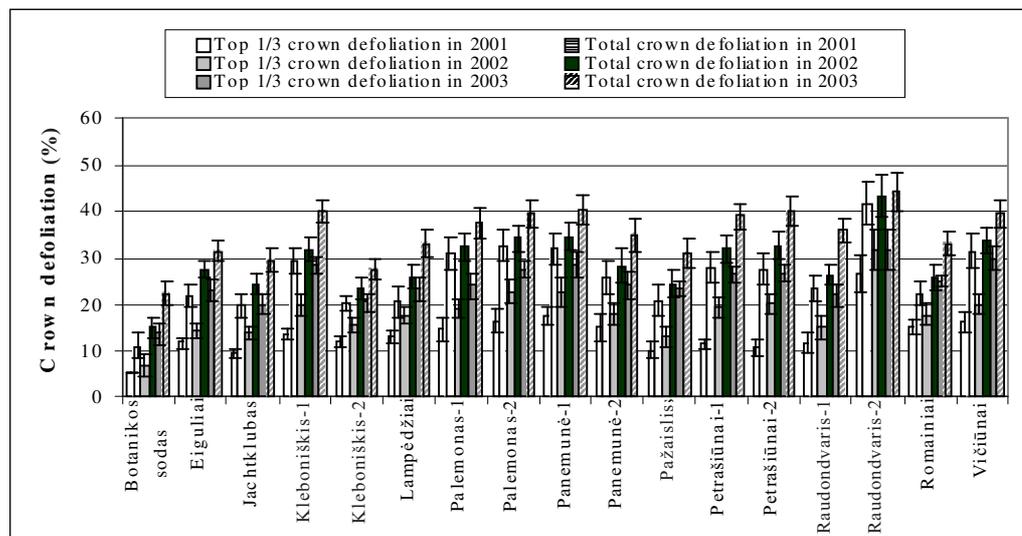
**Table 2.** The dynamics of tree crown defoliation (%) in Kaunas city pine forests

Sample plot	Number of sample trees	Tree crown defoliation (%)					p for F-test	Tree crown defoliation (%)			p for F-test
		1994	1995	1996	1997	1998		2001	2002	2003	
Botanikos sodas	5	9.6±0.8	10.8±1.5	10.8±1.5	12.4±1.7	13.8±1.1	0.006	11.0±2.8	15.0±2.1	20.5±2.5	0.001
Eiguliai	20	21.4±1.4	20.9±1.0	21.7±1.3	22.3±1.1	24.2±1.9	0.006	21.8±2.3	27.5±1.9	31.0±2.1	0.001
Jachtklubas	20	20.1±0.9	21.4±1.4	20.1±0.7	21.5±1.0	22.3±1.4	0.07	19.8±2.3	24.5±2.1	29.5±2.5	0.009
Kleboniškis-1	20	40.2±1.9	39.8±2.6	42.2±2.4	44.5±2.1	46.2±2.0	0.04	29.3±2.7	31.8±2.7	40.0±2.3	0.000
Kleboniškis-2	20	16.2±2.9	15.2±3.8	17.2±3.7	19.3±2.9	20.1±2.5	0.1	20.3±1.6	23.5±2.3	26.0±2.2	0.01
Lampėžiai	20	20.6±1.7	19.9±2.2	23.0±1.7	24.1±1.6	23.4±1.5	0.1	20.5±3.1	26.0±2.6	31.0±2.9	0.000
Palemonas-1	20	35.2±2.7	38.4±1.7	37.1±3.7	38.6±2.7	39.4±2.1	0.05	31.3±3.5	32.5±2.9	36.5±3.4	0.05
Palemonas-2	20	53.1±3.7	45.4±2.9	50.1±3.9	51.5±2.7	54.2±2.8	0.04	32.5±3.4	34.3±2.8	39.0±3.0	0.03
Panemunė-1	20	37.2±2.8	35.0±3.9	39.9±3.7	41.1±2.5	40.8±2.6	0.06	32.0±3.4	34.8±2.9	39.5±3.2	0.009
Panemunė-2	20	29.9±2.3	28.5±2.7	30.5±2.4	30.8±2.2	34.1±2.0	0.04	26.0±3.6	28.3±3.7	34.0±3.4	0.001
Pažaislis	20	22.7±2.3	20.9±1.9	23.1±2.3	25.4±2.2	26.6±3.2	0.03	21.0±3.3	24.5±3.1	31.0±3.0	0.001
Petrašiūnai-1	20	40.1±2.2	42.3±2.4	44.1±3.5	45.2±2.8	45.8±2.5	0.05	28.0±3.3	32.0±3.0	38.5±2.7	0.000
Petrašiūnai-2	20	35.7±2.0	38.2±1.7	40.7±2.4	45.4±2.0	49.6±2.7	0.02	27.5±3.2	32.8±2.9	40.0±3.2	0.000
Raudondvaris-1	20	26.3±1.3	27.7±1.6	28.4±1.6	28.6±1.2	29.8±1.9	0.05	23.5±2.7	26.5±2.1	34.0±2.5	0.000
Raudondvaris-2	5							41.0±4.4	43.0±4.5	43.0±4.2	0.8
Romainiai	20	25.3±1.4	26.0±1.3	26.8±1.7	27.7±1.4	28.0±1.5	0.05	22.5±2.6	25.8±2.7	32.0±2.5	0.001
Vičiūnai	20	30.4±0.9	29.7±1.4	30.2±0.7	35.5±0.9	37.8±1.2	0.04	31.5±3.7	33.8±2.8	37.0±3.0	0.03
Average		29.0±1.9	28.8±2.1	30.4±2.2	32.1±1.9	33.5±2.0		25.9±3.6	29.2±3.2	34.3±2.5	

A tendency of increasing of Scots pine crown defoliation in city pine forests was estimated from 1994 to 1998. Having checked variation reliability of defoliation with the help of F criterion, it was found, that health condition of pine trees was worsening reliably, except Kleboniškis-2 and Lampėžiai sample plots in 1994-1998 and except Raudondvaris-2 sample plot in 2001-2003. An increase in defoliation

Scots pine defoliation in 1998-2001. Hot and dry summer of 2002, favourable conditions for pollutants to accumulate as well as increasing concentrations of emissions determined an increase in tree crown defoliation in 2002 and 2003.

Kaunas city pine forests have characteristic considerably smaller defoliation of the top third crown of a tree than the total crown defoliation (changes in top



**Figure 2.** Defoliation of 1/3 top part and total crown defoliation (%) of Scots pine in Kaunas city pine forests

third and total defoliation in 2001-2003 are presented in Figure 2). The mean top 1/3 crown defoliation was  $13.6 \pm 2.4$  % in 2001,  $18.1 \pm 2.7$  – in 2002,  $24.6 \pm 2.2$  – in 2003. As the condition of Scots pine was worsening, top third crown defoliation increased faster than total crown defoliation.

According to tree crown defoliation the best health condition of Scots pine forests was estimated in Botanikos sodas sample plot. Small defoliation was found in Kleboniškis-2 and Eiguliai sample plots (Figure 3). The worst state of Scots pine was observed in Raudondvaris-2 sample plot, also significant great defoliation was determined in Kleboniškis-1, Palemonas-1, Palemonas-2, Panemunė-1, Petrašiūnai-1, Petrašiūnai-2 and Vičiūnai sample plots. The least crown defoliation was estimated in the youngest sample pine stands (up to 70 year old) and the greatest – in the oldest (more than 91 year old).

niškis-1 sample pine trees are negatively affected not only by transport emissions, but also by spreading of salt on roads in winter. According to our earlier investigations (Stravinskienė 2001a, 2001b) the remains of sodium and calcium chlorides can accumulate even 50–100 metres from the roadside.

For the interpretation of Scots pine defoliation dynamics in Kaunas city districts meteorological factors – the dynamics of the mean annual air temperature, mean April–May air temperature, mean summer (June–August) air temperature, mean winter (December–November) air temperature, mean annual precipitation amount, mean vegetation period (April–September) precipitation amount, mean July–August precipitation amount, mean summer (June–August) precipitation amount, mean winter (December–November) precipitation amount were analysed. Main air pollution parameters: the mean annual nitrogen dioxide

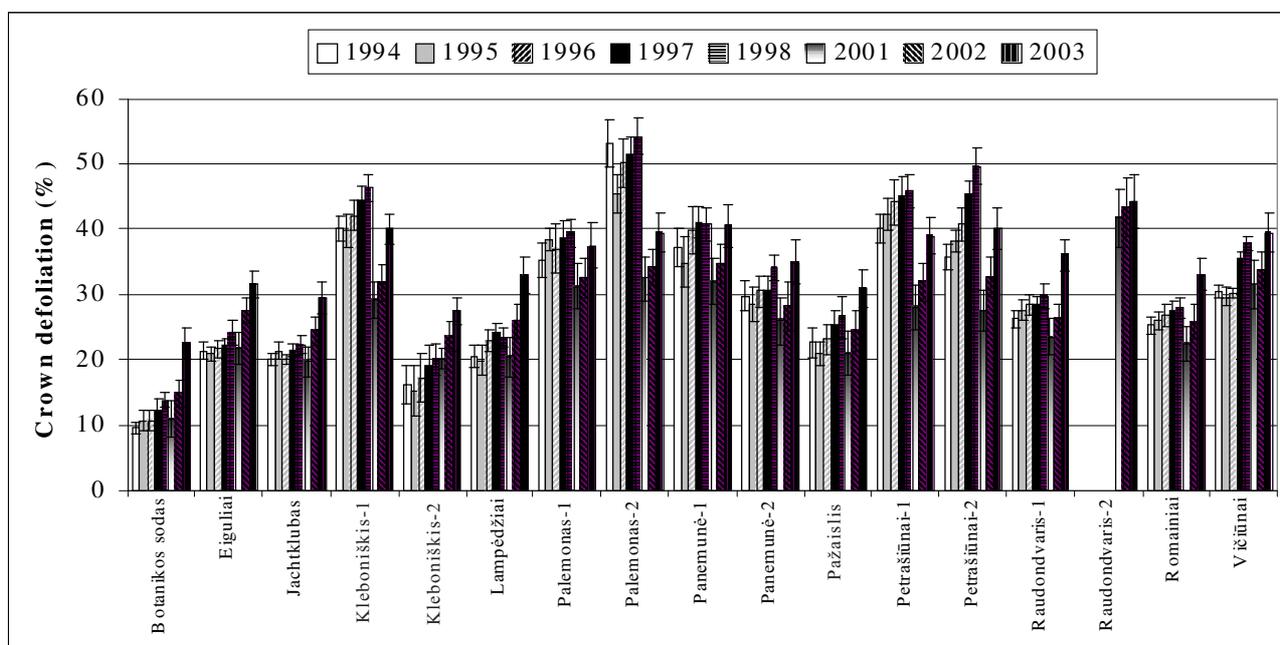


Figure 3. Scots pine (*Pinus sylvestris* L.) crown defoliation in different Kaunas city districts in 1994-2003

The greatest crown defoliation of Scots pine in Raudondvaris-2 sample plot was probably determined for two main reasons – sample trees are very old; sample trees grow near (at the distance of 30 metres from the highroad) Raudondvaris highroad, where the traffic is rather intensive. Pine crown defoliation is more significant than the average for the most polluted Kaunas city districts Palemonas, Panemunė and Petrašiūnai. Higher than the average crown defoliation was also estimated in Kleboniškis-1 sample plot. This sample plot is situated 30-70 metres from Vilnius-Kaunas highway. Raudondvaris-2 and Klebo-

(NO<sub>2</sub>), dust, sulphur dioxide (SO<sub>2</sub>), formaldehyde (CH<sub>2</sub>O) concentrations and the annual integrated air pollution index (which includes a complex of 4 pollutants: SO<sub>2</sub>, NO<sub>2</sub>, CH<sub>2</sub>O and dust) for each sample plot were analysed (Table 3) too.

Each factor separately and in different Kaunas city districts was assessed. Slightly significant correlation values were found. Significant ( $p < 0.05$ ) relationship between crown defoliation and the mean annual air temperature ( $r = -0.51$ ), mean summer air temperature ( $r = -0.52$ ), mean vegetation period precipitation amount ( $r = -0.40$ ), mean summer precipitation amount ( $r = -0.35$ ), mean ni-

**Table 3.** Dynamics of the main environmental factors determining crown defoliation dynamics of Scots pine in Kaunas city

Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Mean annual nitrogen dioxide concentration ( $\mu\text{g}/\text{m}^3$ )	30.2	23.4	5.0	4.9	16.0	10.9	16.6	26.9	25.4	20.1
Mean annual dust concentration ( $\mu\text{g}/\text{m}^3$ )	74.2	108.6	101.9	35.8	75.6	132.0	154.2	56.2	141.4	100.0
Mean annual sulphur dioxide concentration ( $\mu\text{g}/\text{m}^3$ )	2.7	2.5	2.5	2.5	2.9	2.3	2.3	1.8	3.7	3.2
Mean annual formaldehyde concentration ( $\mu\text{g}/\text{m}^3$ )	8.5	30.2	0.0	0.0	0.0	4.8	0.0	0.8	1.5	1.0
Annual integrated air pollution index	2.8	1.9	1.0	1.0	1.6	1.2	1.3	1.0	1.8	1.5
Mean annual air temperature ( $^{\circ}\text{C}$ )	6.8	7.1	5.7	6.9	6.8	7.8	8.3	7.3	8.1	7.5
Mean April–May air temperature ( $^{\circ}\text{C}$ )	9.1	9.3	10.4	8.0	11.0	10.0	12.3	10.5	12.0	9.5
Mean summer (June–August) air temperature ( $^{\circ}\text{C}$ )	17.0	17.6	16.5	17.9	16.0	18.6	15.8	17.7	19.3	17.5
Mean winter (December–November) air temperature ( $^{\circ}\text{C}$ )	-2.3	-1.1	-7.4	-3.6	-0.7	-3.3	-0.7	-0.9	-1.7	-6.3
Mean annual precipitation amount (mm)	759	629	480	634	671	585	571	674	649	573
Mean vegetation period (April–September) precipitation amount (mm)	396	354	299	373	385	274	309	410	264	334
Mean July–August precipitation amount (mm)	44	95	105	109	203	118	164	199	70	172
Mean summer (June–August) precipitation amount (mm)	94	170	169	184	262	171	228	245	163	229
Mean winter (December–November) precipitation amount (mm)	185	167	79	88	144	151	141	110	161	72

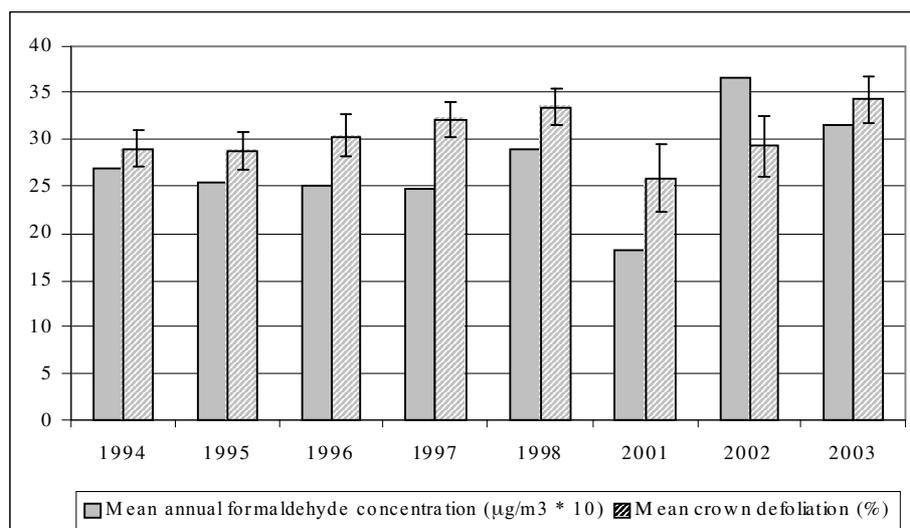
**Note:** Air pollution parameters data source is Kaunas city municipality ecological monitoring program reports (2003, 2004). Air pollution data in separate Kaunas city districts, which are slightly different from mean annual values for the whole city, were used for the estimation of correlations between pine defoliation and air pollution parameters. Kaunas city meteorological station archives are the source of meteorological data.

trogen dioxide concentration ( $r=0.41$ ), mean dust concentration ( $r=0.18$ ), mean formaldehyde concentration ( $r=0.50$ ), annual integrated index ( $r=0.39$ ) were found, when each environmental factor in the whole city was evaluated. In comparison, the correlations between Scots pine defoliation and meteorological factors during the active growing season (May–August), also air pollution parameters in Lithuania (in 1991–2001) according to other research papers (Ozolinčius *et al.* 2005) were insignificant ( $p>0.05$ ):  $r$  (the average temperature)  $=-0.12$ ,  $r$  (amount of precipitation)  $=-0.36$ ,  $r$  ( $\text{SO}_2$ )  $=0.56$ ,  $r$  ( $\text{NO}_2$ )  $=0.59$ . It means that high air temperature and a large amount of precipitation are the main factors, determining good health condition of Scots pine in Kaunas city – smaller crown defoliation. On the contrary, high air pollution is the reason for worse pine condition – larger crown defoliation.

As study data covers 8 years of research period, we made an attempt to evaluate the complex impact

of these factors on Scots pine tree state using the multiple regression method. Regression models (def=58.8-1.9 (summer t,  $^{\circ}\text{C}$ ) -0.006 (annual precipitation, mm) +3371.5 (formaldehyde conc.,  $\mu\text{g}/\text{m}^3$ )  $R^2=0.58$ ; def=23.7-0.5 (winter t,  $^{\circ}\text{C}$ ) +1990.9 (formaldehyde conc.,  $\mu\text{g}/\text{m}^3$ ) +26.6 (sulphur dioxide conc.,  $\mu\text{g}/\text{m}^3$ )  $R^2=0.37$ ; def=69.4-1.8(summer t,  $^{\circ}\text{C}$ )-0.02 (vegetation period precipitation, mm) +0.6 (annual integrated index)  $R^2=0.32$ ) were insignificant ( $p>0.05$ ), it proved that the research period for this method was too short.

It was noticed that the mean annual defoliation dynamics was similar to the mean annual formaldehyde concentration dynamics (Figure 4). The greatest formaldehyde concentration during the research period was found in 1998, 2002 and 2003, which corresponded to the data on crown defoliation. Though mean annual formaldehyde concentration was greatest in 2002, Scots pine crown defoliation was greatest in the year 2003, but at the same time great needle dis-



**Annotation:** the scale used in Figure 4 Y axis is adjusted to both parameters: crown defoliation and formaldehyde concentration. As formaldehyde concentration data source we used Kaunas city municipality ecological monitoring program reports, which present data mean values, therefore standard error bars are not shown on formaldehyde concentration data series.

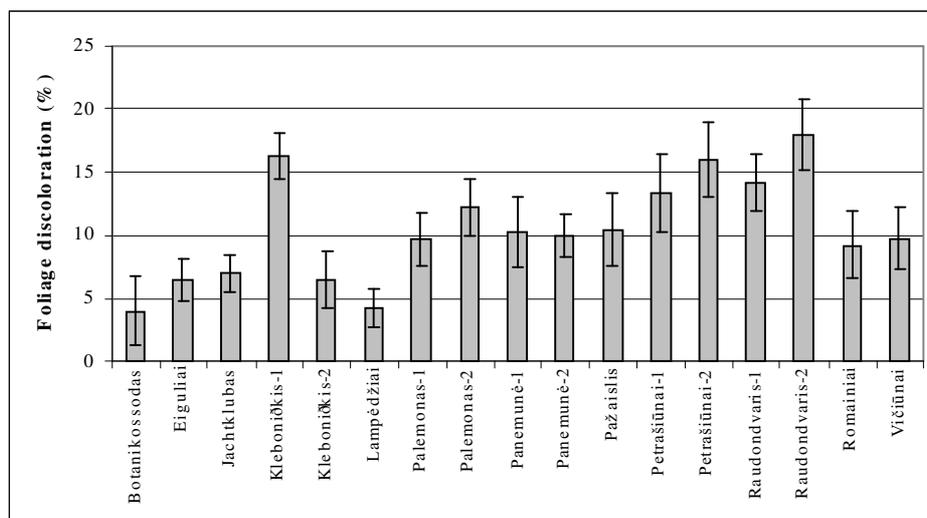
**Figure 4.** Mean annual formaldehyde concentration and mean crown defoliation dynamics

colouration was determined in 2002. Thus in 2002 formaldehyde impact was overdue reflected in 2003, because a part of discoloured needles fell down in the following 2003 and increased the mean defoliation that year.

The greatest Scots pine crown defoliation (34.3±2.5 %) in Kaunas city districts during the research period (1994-2003) was defined in 2003 (Table 3). Very hot and dry summer (the mean air temperature in June–August was +19.3° C, mean amount of precipitation in June–August was 163.0 mm) determined the increase in trees sensitivity to air pollution in 2002. Such great defoliation was determined not only due to high concentration of pollutants but also due to favourable meteorological conditions for

accumulation of pollutants. There were several anti-cyclone periods, which were favourable for pollutants accumulation in the lowest layers of the atmosphere in October 2002 – in March 2003.

Foliage discoloration is a rare phenomenon all over Lithuania, therefore in the majority of Kaunas pine sample stands no signs of discoloration were noticed during the whole research period. Scots pine in Kleboniškis-1 sample plot (which is situated 30-70 metres from Vilnius-Kaunas highway) had visible symptoms of needle discoloration. Indistinctively great needle discoloration was found in 2002 in all sample stands (Figure 5). Mean foliage discoloration was 10.5±2.1 % in 2002.



**Figure 5.** Foliage discoloration of Scots pine in Kaunas city forest stands in 2002

According to foliage discolouration data the best health condition of Kaunas city Scots pine in 2002 was determined in Botanikos sodas and Lampėdžiai sample plots, the worst – Kleboniškis-1, Petrašiūnai-1, Petrašiūnai-2, Raudondvaris-1 and Raudondvaris-2 sample plots. In comparison with crown defoliation data in 2002, foliage discolouration indicated slightly better Scots pine state in Lampėdžiai sample plot and slightly worse – in Kleboniškis – 2 sample plot.

Trees of 1 and 2 defoliation class, indicating slight (crown defoliation 11–25 %) and moderate (defoliation 26–60 %) crown damage are dominant in Kaunas city pine forests. As needle discolouration was not common for Kaunas city pine forests, the majority of sample trees fit in discolouration class 0 – without foliage changes in colour (discolouration 0–10 %). Some sample trees fit in discolouration class 1 – slight discolouration (11–25 %) only in 2002.

The least amount of dead branches was ascertained in Botanikos sodas (4.0±0.2 %), Lampėdžiai (5.9±0.9 %) and Kleboniškis-2 (5.7±0.8 %) sample plots in 1994–1998. More (over 15 %) dead branches were found in Kleboniškis-1, both Palemonas, Petrašiūnai-2, Raudondvaris-1 sample stands. The mean amount of dead branches was: in 2001 – 13.2±2.4 %, in 2002 – 14.1±2.2 %, in 2003 – 16.5±1.7 %. According to the data on dead branches in 2001–2003 the best health condition of Scots pine was estimated in Botanikos sodas, Pažaislis and Kleboniškis-2 sample stands. The greatest amount of dead branches in 2001–2003 was observed in Raudondvaris-2 sample plot and more (over

15 %) dead branches were found in Kleboniškis-1, both Palemonas, Panemunė-1, both Petrašiūnai, Raudondvaris-1 and Vičiūnai sample plots (Table 4).

Short needle retention (2 and less years) shows worsening condition of pine trees: under unfavourable environmental conditions needles die, fall down, crowns become more transparent (Stravinskienė 1998, 2001a, 2002). Needle retention of sample pines in Kaunas city districts oscillated between 2 and 3 years. Short needle retention in 1994–1998 was characteristic of Kleboniškis-1 sample plot, Panemunė, Palemonas, Petrašiūnai and Vičiūnai pine stands. Mean needle retention Scots pine for all sample plots in 2001 was 2.3±0.1 years, in 2002 – 2.1±0.1 years, in 2003 – 1.8±0.1 years. According to needle retention data the best Scots pine state in 2001–2003 was in Botanikos sodas, Kleboniškis-2 and Pažaislis sample plots. Short needle retention (1.6–2.0 years) was estimated in Kleboniškis-1, both Palemonas, both Panemunė, Petrašiūnai-1, Raudondvaris-2 and Vičiūnai sample plots (Table 4).

In the period 2001–2003 out of 310 sample trees 51.3 % had weak fruiting, 27.5 % – middle fruiting, 20.9 % – no fruiting, 0.3 % – good fruiting. Greatest fruiting was determined in Botanikos sodas, Eiguliai, Kleboniškis-2, Pažaislis sample plots, least – in Raudondvaris-2, Kleboniškis-1, Palemonas-1 and Palemonas-2 sample plots.

Healthy tops were characteristic of the most part (96.1 %) of Scots pine sample trees in all Kaunas city districts. Broken tops are typical only of 1.6 %, dried

**Table 4.** The dynamics of dead branches amount and needle retention in Kaunas city pine forests

Sample plot	Number of sample trees	Amount of dead branches (%)			p for F-test	Needle retention (years)			p for F-test
		2001	2002	2003		2001	2002	2003	
Botanikos sodas	5	6.0±2.8	7.0±3.4	11.3±4.3	0.07	2.5±0.4	2.4±0.3	2.3±0.3	0.4
Eiguliai	20	12.0±1.2	14.0±2.1	16.5±2.4	0.005	2.3±0.1	2.1±0.1	2.0±0.2	0.01
Jachtklubas	20	12.0±1.8	13.3±1.9	14.5±1.7	0.13	2.3±0.1	2.2±0.1	1.9±0.2	0.00
Kleboniškis-1	20	17.8±1.2	18.0±1.4	19.0±2.6	0.57	2.2±0.1	2.1±0.1	1.8±0.1	0.00
Kleboniškis-2	20	8.8±1.7	10.5±2.5	14.0±2.1	0.002	2.5±0.1	2.4±0.1	2.1±0.2	0.00
Lampėdžiai	20	10.0±1.7	11.0±2.1	14.5±2.7	0.01	2.4±0.2	2.2±0.1	1.8±0.1	0.00
Palemonas-1	20	13.8±2.4	15.3±2.6	17.5±2.5	0.09	2.2±0.1	2.1±0.1	1.7±0.2	0.00
Palemonas-2	20	16.5±3.3	17.0±3.2	18.5±3.5	0.7	2.1±0.1	1.9±0.1	1.7±0.1	0.00
Panemunė-1	20	14.0±2.2	14.5±2.3	16.5±2.4	0.2	2.2±0.1	2.1±0.2	1.7±0.2	0.00
Panemunė-2	20	13.8±2.3	14.0±2.2	15.0±1.9	0.7	2.2±0.1	2.1±0.1	1.7±0.1	0.00
Pažaislis	20	7.5±1.4	9.3±2.1	13.5±2.4	0.000	2.5±0.1	2.2±0.2	1.9±0.2	0.00
Petrašiūnai-1	20	15.8±2.9	16.0±2.8	17.0±1.9	0.7	2.2±0.1	2.0±0.2	1.8±0.1	0.00
Petrašiūnai-2	20	11.5±2.2	13.3±2.1	17.5±2.3	0.000	2.1±0.1	2.1±0.1	1.7±0.1	0.00
Raudondvaris-1	20	10.8±2.1	12.3±2.1	16.0±2.2	0.001	2.4±0.2	2.1±0.2	1.7±0.1	0.00
Raudondvaris-2	5	26.5±5.5	26.0±5.2	26.7±5.3	0.98	2.0±0.1	1.7±0.2	1.7±0.3	0.1
Romainiai	20	11.5±1.1	13.3±2.1	15.0±2.8	0.06	2.5±0.1	2.2±0.2	2.0±0.2	0.00
Vičiūnai	20	15.3±2.7	16.3±3.4	17.0±2.7	0.7	2.1±0.1	2.1±0.1	1.7±0.1	0.00
Average		13.2±2.4	14.1±2.2	16.5±1.7		2.3±0.1	2.1±0.1	1.8±0.1	

tops – 1.9 % and damaged tops – 0.4 % of the sample trees. A slight increase in dried tops (from 1.0 up to 2.9 %) and damaged tops (from 0.3 % up to 0.5 %) was determined in the period 2001–2003. Most unhealthy tops were found in Palemonas district.

Kaunas city pine stands had common stem fungal and disease (*Peridermium pini*), also mechanical stem damages of anthropogenic origin. Fire damaged stems were found in Panemunė-2 sample plot. Scots pine in Botanikos sodas sample stand did not have any visible damages. Many damaged trees were found in Kleboniškis-1, both Palemonas, both Panemunė, both Petrašiūnai, Pažaislis and Raudondvaris-2 sample stands.

## Conclusions

1. Scots pine crown defoliation in Kaunas city was reliably increasing in 1994–1998 and in 2001–2003. The greatest crown defoliation (34.3±2.5 %) was defined in 2003. According to tree crown defoliation data, best Scots pine health condition was defined in Botanikos sodas, Kleboniškis-2 and Eiguliai sample stands, worst – Raudondvaris-2 sample stand, also significant defoliation was characteristic of both Palemonas and Petrašiūnai, Kleboniškis-1, Panemunė-1 and Vičiūnai sample stands.

2. In 2002, a significant increase in foliage discoloration was estimated in all sample plots (mean foliage discoloration was 10.5±2.1 %) because of favourable meteorological conditions for pollutants accumulation in low atmospheric layers.

3. Amount of dead branches and needle retention showed best health condition in Botanikos sodas, Pažaislis and Kleboniškis-2 sample stands, worst – Kleboniškis-1 and Raudondvaris-2 sample plots, which are situated near intensive traffic roads (Raudondvaris highroad and Vilnius-Kaunas highway) in 2001–2003.

4. Air pollution had negative effect on Kaunas city regions pine forests. It weakened tree resistance to climatic factors. Consequently, in the most polluted Kaunas city districts (Palemonas, Panemunė, Petrašiūnai) and in sample plots near intensive traffic roads (Raudondvaris-1, Raudondvaris-2, Kleboniškis-1) pine health condition is worst.

## References

- Černiauskas, S. 2004. Oro tarša ir triukšmas skirtinguose Kauno mikrorajonuose [Air pollution and noise in different districts of Kaunas city]. In: R. Juknys (Chief editor), Kauno miesto ekologinis monitoringas. Aplinkos tyrimai ir vertinimas 1993–2003. Vytauto Didžiojo universitetas, Kaunas, p. 17–25 (in Lithuanian).
- Hendriks, K., Klap, J., Jong, E., van Leeuwen, E. and Vries, M. 1997. Calculation of natural stress factors. In: Müller-Edzards, C., De Vries, W., Erisman, J.W. (Editors), Ten Years of Monitoring Forest Condition in Europe. Studies on temporal Development, Spatial Distribution and Impacts of Natural and Anthropogenic Stress Factors, Brussels–Geneva, p. 277–307.
- Juknys, R. 2004. Pagrindinės Kauno miesto aplinkos pokyčių tendencijos [Main trends of Kaunas city environmental quality]. In: R. Juknys (Chief editor), Kauno miesto ekologinis monitoringas. Aplinkos tyrimai ir vertinimas 1993–2003. Vytauto Didžiojo universitetas, Kaunas, p. 7–16 (in Lithuanian).
- Juknys, R., Stravinskiene, V. and Vencloviene, J. 2002. Tree-ring analysis for the assessment of anthropogenic changes and trends. *Environmental Monitoring and Assessment*, 77 (1): 81–97.
- Juknys, R., Vencloviene, J., Stravinskiene, V., Augustaitis, A. and Bartkevicius, E. 2003. Scots pine (*Pinus sylvestris* L.) growth and condition in a polluted environment: from decline to recovery. *Environmental pollution*, 125 (2): 205–212.
- Kaunelienė, V., Cicėnaitė, A., Jegorova, I., Žaliauskienė, A. and Bergqvist, P. A. 2003. Tentative Air Concentrations of PAHs and PCBs in Urban Area of Lithuania. *Environmental research, engineering and management*, 2 (24): 39–44.
- Klap, J., Voshaad, J.O., De Vries, W. and Erisman, J.W. 1997. Relationships between crown condition and stress factors. In: Müller-Edzards, C., De Vries, W., Erisman, J.W. (Eds.), Ten Years of Monitoring Forest Condition in Europe. Studies on temporal Development, Spatial Distribution and Impacts of Natural and Anthropogenic Stress Factors, Brussels, Geneva, p. 277–307.
- Manion, P. D. and Lachance, D. 1992. Forest decline concepts: an overview. In: P.D. Manion and D. Lachance (Editors), Forest decline concepts. St. Paul, Minnesota, p. 181–190.
- Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forest. 1994. 3<sup>rd</sup> edition. Edited by the Programme Coordinating Centres Hamburg and Prague. 177 p.
- Momen, B., Anderson, P. D., Houppis, J. L. J. and Helms, J. A. 2002. Growth of ponderosa pine seedlings as affected by air pollution. *Atmospheric Environment*, 36 (11): 1875–1882.
- Muller, E. and Stierlin, R. 1990. Tree crown photos (with percentages of foliage loss). Swiss Federal Institute for Forest, Snow and Landscape Research. 2<sup>nd</sup> Revised and extended edition, 229 p.
- Ozolincius, R. 1996. Хвойные: морфогенез и мониторинг [Conifers: morphogenesis and monitoring]. *Aesti*, Kaunas, 340 p. (in Russian).
- Ozolincius, R. and Stakenas, V. 1999. Regional forest monitoring. In: Ozolincius R. (Chief editor), Monitoring of forest ecosystems in Lithuania. *Lututė*, Kaunas, p. 82–106.
- Ozolincius, R., Stakenas, V. and Serafinavičiute, B. 2005. Meteorological factors and air pollution in Lithuanian forests: Possible effects on tree condition. *Environmental Pollution*, 137: 587–595.
- Stravinskienė, V. 1997. Pušynų dendroekologiniai tyrimai ir jų taikymas gamtinės aplinkos būklės indikacijai [Dendrochronological studies of pine forest and their application for indication of the environmental status]. *Ekologija*, 2: 62–72 (in Lithuanian).
- Stravinskienė, V. and Dičiūnaitė, B. 1999. Health Condition and Dendrochronological Study of the Lime Trees in Kaunas City. *Baltic Forestry*, 5 (2): 37–44.
- Stravinskienė, V. 2001a. Ecological monitoring of Scots pine (*Pinus sylvestris* L.) growing in forest ecosystems at roadsides. *Journal of Forest Science*, 47 (5): 212–219.

Stravinskiene, V. 2001b. Health condition of Scots pine (*Pinus sylvestris* L.) growing at different distances from highway "Vilnius-Kaunas". *Baltic Forestry*, 7 (1): 46-51.

Stravinskienė, V. 2002. Klimato veiksnių ir antropogeninių aplinkos pokyčių dendrochronologinė indikacija [Dendrochronological

Indication of Climatic Factors and Anthropogenic Environmental Trends]. *Lututė*, Kaunas, 172 p. (In Lithuanian, summary in English).

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## СОСТОЯНИЕ ЗДОРОВЬЯ СОСНЫ ОБЫКНОВЕННОЙ (*PINUS SYLVESTRIS* L.) В ЛЕСАХ ГОРОДА КАУНАСА

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Резюме

Руководствуясь методикой экологического мониторинга (ICP Forest, 1994), модифицированной для урбанизированных территорий, определена дефолиация, дехромация крон, состояние их вершин, % сухих ветвей в кроне, возраст хвои, уровень плодоношения, установлены повреждения крон и стволов учетных деревьев сосны обыкновенной (*Pinus sylvestris* L.).

Установлено, что средняя дефолиация крон учетных деревьев в 1994 году составило  $29,0 \pm 1,9$  %, в 1995 –  $28,8 \pm 2,1$  %, в 1996 –  $30,4 \pm 2,2$  %, в 1997 –  $32,1 \pm 1,9$  %, в 1998 –  $33,5 \pm 2,0$  %, в 2001 –  $25,9 \pm 3,6$  %, в 2002 –  $29,2 \pm 3,2$  %, а в 2003 –  $34,3 \pm 2,5$  %.

Исследования показали, что наихудшим состоянием здоровья отличаются деревья сосны обыкновенной (*Pinus sylvestris* L.), произрастающие на объектах Раудондварис-2, Клебонишкис-1, Петрашюнай-1 и Петрашюнай-2, Палемонас-1 и Палемонас-2. Им характерны наивысшие показатели дефолиации и наименьший возраст хвои.

По основным морфологическим индикаторным показателям в наилучшем состоянии находятся деревья, произрастающие в районе Ботанического сада, Яхтклуба, на объектах Клебонишкис-2.

Наибольшая средняя дехромация хвои ( $10,5 \pm 2,1$  %) обнаружена в 2002 году. На объектах Раудондварис-2 и Клебонишкис-1 этот показатель является наибольшим.

В 2003 наибольшим количеством сухих ветвей ( $26,7 \pm 5,3$  %) отличаются сосны, произрастающие на объекте Раудондварис-2, наименьшим ( $11,3 \pm 4,3$  %) – на объекте в районе Ботанического сада. Наименьший возраст хвои ( $1,7 \pm 0,1$  лет) характерен деревьям на объектах. Палемонас-2, Петрашюнай-2 и Вичюнай, наибольший ( $2,3 \pm 0,3$  %) – на объекте в районе Ботанического сада.

**Ключевые слова:** сосна обыкновенная, состояние здоровья, морфологические индикаторы, урбанизированные территории