Effects of air pollution and droughts on forest condition in Lithuania

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Within the limits of our geographical region (Central Europe – Baltic States – Scandinavia) 75–80% of variation in conifer condition of a separate country can be explained by differences in acidic deposition, meanwhile the HTC has a very little influence.

A trend of forest condition improvement in Lithuania is evident since 1996 and can be related with a decrease of air pollution. Changes in the number of healthy trees as compared to HTC changes during the period 1990–1998 were slightly reliable (r = 0.52). A correlation between the number of healthy Scots pine trees and the HTC was statistically more reliable (r = 0.74).

Key woods: defoliation, drought, hydrothermal coefficient, air pollution

INTRODUCTION

Over 180 hypotheses were proposed to explain the reasons of forest decline [1]. According to most of them, air pollution might cause defoliation and yellowing of leaves and needles. For example, Manion [2] and Evans [3] suggested that the oxidation of SO_2 and NO_x to strong acids might directly destroy the leaf cuticle and thus cause damage to trees. Smith [4] discussed SO_2 and NO_x as responsible for affecting biochemical pathways and eventualy damaging the foliage. Other authors considered an indirect effect on tree condition – soil acidification, associated with a decrease in pH and base cation saturation as well as an increase of the concentration of Al^{3+} in the soil, responsible for the recent forest decline, since Al^{3+} is very likely to be toxic to plant roots [5]. To the hypotheses mentioned above, unfavorable weather conditions, especially drought, could also be added [6]. Some authors suggested that pest infestations or fungi attacks following drought periods cause the overall deterioration of forest health [7]. A single factor cannot cause tree health decline. Air pollution is considered as one of the predisposing and inciting factors [2]. Air pollution from a global point of view is an important factor that can influence forest condition.

Considering the spatial distribution of pollutants within the territory of Europe the largest amounts are certainly found in Central Europe. After the air pollution analysis in Europe was carried out in 1986–1995, pollution distribution maps of Europe were compiled and the loads for each Pan-European permanent observation plot (POP) within the forest monitoring network were calculated [7].

MATERIALS AND METHODS

The main investigations were carried out according to the international manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects on air pollution on forests [8]. The regional forest monitoring system in Lithuania is based on systematically selected permanent observation plots (POP). The condition of up to 23000 trees was annually evaluated [9]. Crown defoliation is one of the most important tree condition indicators. Special research indicates a close inverse correlation r = –(0.8–0.9) between the foliage mass and crown defoliation [9].

Changes of air pollution in Lithuania were defined by the use of primary energy sources. During the period of 1988–1991, the consumption of fuel was at its maximum, and in 1994–1996 the stabilization of the amounts consumed was followed by a sudden decrease of fuel consumption [10]. Monitoring of sulphur and nitrogen deposition from the atmosphere indicates that during the last years a clear decrease of sulphate concentrations in precipitation is observed [11]. A decrease of sulphate concentrations in atmospheric precipitation can be related to a decrease of SO_2 emissions in Western Europe. Meanwhile, NO^{3-} and NH^{4+} concentrations

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in atmospheric precipitation have changed insignificantly.

The levels of air pollution in European countries have been calculated using data published in the EC-UN/ECE reports [7].

The hydrothermal coefficient (HTC) of Selianinov has been chosen for evaluation of hydrothermal conditions:

$$HTC = \frac{R*10}{\sum t},$$

were R is the sum of precipitation (mm) during the period when the air temperature is above 10 °C, Σt is the sum of temperatures during the same period.

The average annual HTC values (May–August) were calculated as the average HTC of all meteostations of Lithuania.

RESULTS AND DISCUSSION

A correlation analysis has shown that within the limits of our geographical region (Central Europe–Baltic States (including Lithuania) – Scandinavia) 75–80% of variations in conifer condition of a separate country can be explained by the differences in acid deposition (Figure). Climatic factors evaluated by the hydrothermal coefficient had very little influence (influence coefficient did not reach 1%).

Eevaluation crown defoliation changes in 1989–2000 showed the average defoliation of all tree species in Lithuania was increasing until the period 1992–1993. A tendency of defoliation decrease appeared in 1996. The trend of forest condition improvement in Lithuania since 1996 can be related to a decrease in air pollution as well.

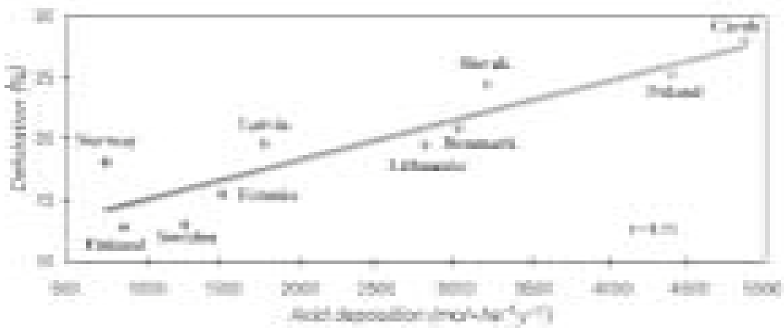

Figure. Average defoliation of conifers and acid deposition in some European countries (1989–1997)

Air pollution does not explain the changes of crown defoliation at certain observation plots or small regions where air pollution is relatively stable (except cases of local pollution). Now attempts to explain defoliation changes by the effect of meteorological factors, invasions of pests and diseases are made [7]. During the first half of the vegetation period soil humidity and precipitation are one of the most important factors in the foliage formation in our region. According to the research data [12], assimilation mass of birch stands during individual years fluctuates from 75% to 125% of the average values, and even 91% of the changes can be explained by the effect of meteorological factors.

Along with the increase of the amounts of precipitation, the Scots pine defoliation is decreasing [13]. The density of Norway spruce crowns in Norway in 1992, compared to the results of 1991, decreased on average by 1.81% in dry sites and by 2.47% in sites unfavourable for spruce [14].

According to our data, changes of the number of healthy trees (defoliation 0–10%) compared to

Table. **Coefficients of correlation between HTC and tree condition (D – defoliation, H – number of healthy trees)**

Tree species	Site humidity index*							
	N		L		U		P	
	D	H	D	H	D	H	D	H
All species	–0.3 ±0.3	0.7** ±0.2	–0.1 ±0.3	0.3 ±0.3	0.2 ±0.3	0.4 ±0.3	–0.2 ±0.3	–0.2 ±0.3
Pine	–0.3 ±0.3	0.7** ±0.2	–0.0 ±0.3	0.5 ±0.3	–0.5 ±0.3	0.4 ±0.3	–0.3 ±0.3	0.5 ±0.2
Spruce	0.1 ±0.3	0.5 ±0.3	0.3 ±0.3	–0.1 ±0.3	0.4 ±0.3	0.0 ±0.3	–0.1 ±0.3	0.3 ±0.3
Birch	–0.5 ±0.2	0.6** ±0.2	0.0 ±0.3	0.1 ±0.3	0.4 ±0.3	–0.0 ±0.3	–0.4 ±0.3	–0.3 ±0.3

* N – mineral soils of normal moisture; L – temporarily overmoistured mineral (gleyic) soils; U – permanently overmoistured mineral (gley) soils; P – peatland.
** Significant at the 0.95 level of probability.

HTC changes were slightly reliable (r = 0.52). A correlation between the number of healthy Scots pine trees and the HTC in all forest sites was statistically more reliable (r = 0.74). The average defoliation of trees on soils of normal moisture increases along with a decrease of the HTC, although the correlation coefficient is not statistically reliable. The increase of the number of healthy trees along with the increase in the coefficient of correlation between the number of healthy trees and the HTC reaches 0.7 ± 0.2. From the data provided in Table, a decrease in the correlation between defoliation indicators and the HTC along with an increase in site humidity can be indicated. Defoliation of Scots pine and broadleaves in all hydrotopes is decreasing along with the increase of the HTC, which is reflected by a negative correlation coefficient between the HTC and the number of healthy trees. Our statements (the bigger the amount of precipitation, the higher the density of Scots pine crowns, *i.e.* the lower defoliation) are similar to the results obtained in Belgium [13].

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R. Ozolinčius, V. Stakėnas

ORO TARŠOS IR SAUSROS POVEIKIS LIETUVOS MIŠKAMS

S a n t r a u k a

Mūsų geografinio regiono (Centrinė Europa–Baltijos šalys–Skandinavija) ribose skirtinga oro tarša (SO_2) galima paaiškinti net 75–80% atskirų valstybių miškų vidutinės defoliacijos kintamumo, tuo tarpu hidroterminis koeficientas (HTC) labai silpnai veikė šį miškų būklės rodiklį.

Lietuvos miškų būklės gerėjimo tendencija, stebima nuo 1996 m., gali būti siejama su foninės oro taršos mažėjimu. Sveikų medžių (lajų defoliacija 0–10%) skaičius 1990–1998 m. (1992 ir 1994 m. Lietuvoje buvo stiprios sausros) šiek tiek priklausė ir nuo HTC (r = 0,52). Stipresnė šių rodiklių koreliacija stebėta pušynuose (r = 0,74). Medžių, augančių normalaus drėkinimo dirvožemiuose, defoliacija didėjo mažėjant HTC, tačiau koreliacijos koeficientai nebuvo statistiškai patikimi.