Influence of Sulphur Deposition and Drought Stress on Forest Condition in Lithuania

REMIGIJUS OZOLINČIUS, VIDAS STAKĖNAS

Lithuanian Forest Research Institute
4312, Liepų g. 1, Girionys, Kaunas distr. Lithuania

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Using forest monitoring data and published data on air pollution in European countries as well as calculated hydro-thermal coefficient (HTC), it has been indicated that in the limits of our geographical region - Central Europe-Baltic States-Scandinavia - 75-80% of variations in conifers condition (as the average defoliation for a separate country) can be explained by the different amount of acidic deposition meanwhile HTC had very little influence.

The trend of forest condition improvement in Lithuania is clear since 1996 and can be attributed to the decrease in air pollution. Forest condition improvement was recorded after the significant reduction of sulphur deposition in 1989-1991, i.e. 5-6 years later. The changes in number of healthy trees (defoliation 0-10%) in association with HTC changes during the period 1990-2000 were not very significant ($r=0.59$, $p=0.074$) (droughts were observed in 1992 and 1994). More significant correlation was recorded between the number of healthy Scots pine trees and HTC ($r=0.74$, $p=0.025$). Average defoliation of trees on soils of normal humidity increases along with the decreasing of HTC, although the correlation was not statistically significant ($p>0.05$).

Since 1995, when symptoms of forest condition improvement were recorded, about 15% of the annual variation of crown defoliation can be explained by sulphur depositions and HTC changes.

Key woods: defoliation, drought, hydro-thermal coefficient, sulphur deposition

Introduction

Over 180 hypotheses were proposed to explain the occurrence of forest decline (Vaičys 1991). According to the most of them, air pollution might cause defoliation and yellowing of leaves and needles. For example, some authors (Manion, Lachance 1992; Evans 1984) 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. W. H. Smith (1981) discussed SO_2 and NO_x as responsible for affecting biochemical pathways and so damaging foliage.

Other authors consider 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 solution, responsible for recent forest decline since Al^{3-} is very likely to be toxic to plant roots (Ulrich et al. 1980).

All the hypotheses, in one or another way treated pollutants as one of the main factors causing forest condition decline can be assigned to 6 main groups (Shutt, Cowling 1985; Hain 1987):

1. Soil acidification (SO_2 and NO_x emissions are transformed to the sulphur and nitrogen acids and precipitate as "acid rains") and associated increase of aluminum ions (Al^{3-});

2. Negative impact of high ozone concentrations on the foliage;

3. Magnesium hypothesis, where the cuticle and membranes of the cells are damaged by ozone and frosts and cannot "catch" magnesium; it causes a needle yellowing phenomenon, which is widely spread in some European countries;

4. Surplus of nitrogen. Due to pollution by nitrogen and its compounds: a) increases growth and need for main nutrition elements causes a disbalance and nutrition deficiency; b) negative effects to mycorrhizae; c) increased sensitivity to frosts; d) disbalance in growth processes and in nitrification, de-nitrification and nitrogen fixation system of plant. This increases a sensitivity of plant to diseases;

5. Disbalance of growth regulators;

6. Common stress hypothesis. Pollutants affect energetic status of the tree that increases its sensitivity to stress factors.

Besides the hypothesis mentioned above unfavorable weather conditions, especially drought or relative transpiration, could also be added to the factors influencing forest condition (Auclair et al. 1992; Strand

1997; Klap et al. 1997). Some authors suggested that pest infestations or fungi attacks following drought periods cause the overall deterioration of forest health (Houston 1992).

Some authors (Kandler 1990; Skelly 1992) referring to historical data and photography, state that the decline of foliage is not a new symptom. O.Kandler (1992) argues that in the paintings of the 16th century trees have symptoms similar to ones described as "new type of forest decline". In other words, the forest decline, monitored in the present, is not a new phenomenon and has no relation to the air pollution. Anyway, the most recent studies have proven that changes, before described earlier as "new type of forest decline" can not be transferred from plant to plant (as a virus), but is a result of polluted air or environmental changes (Mekne-Jakobs 1990). Air pollution is considered as one of the predisposing and inciting factors (Manion, Lachance 1992).

Air pollution from a global point of view is an important factor that can influence forest condition. Therefore the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests, has initiated the research of air pollution effects on forest ecosystems.

The largest amounts of pollutants are found in Central Europe. It should be stressed that tree defoliation is highest in this region as well. The lowest defoliation is in Northern Europe. After the air pollution analysis in Europe was carried out in 1986-1995, pollution distribution maps for Europe were completed and the loads for each Pan-European (transnational) permanent observation plot (POP) within the forest monitoring network were calculated. It was indicated that critical SO_2 levels (20 g/m^3) were exceeded in over 20% of all the POPs. Meanwhile, critical NO_2 and NH_3 concentrations (correspondingly 30 and 8 g/m^3) were not exceeded (Van Leuwen et al. 1997). Most of the POPs, where critical concentrations of SO_2 were exceeded, are located in Germany, Poland, Czech and Slovak Republics. SO_2 concentrations in these areas have reached levels of 50 g/m^3. Sometimes critical pollution levels were exceeded also in Hungary, Romania, Bulgaria, The Netherlands, United Kingdom and Spain. The highest NO_2 concentrations were found in The Netherlands, Germany, and the highest concentrations of NH_3 - in The Netherlands, Belgium, Germany and Northern Italy.

Similar situations can be found when analysing deposition levels. Nitrogen loads (NO_x and NH_x) during the period 1986-1995 have exceeded 1000 mol_c/ha*y in about 20% of the POPs and 1500 mol_c/ha*y - in 5% of the POPs. Sum acidic depositions (sulphur and nitrogen loads) "exceed" 2000 mol_c/ha*y levels in the majority of forest monitoring plots. This value was exceeded in 40% of the POPs, where coniferous tree species (Scots pine and Norway spruce) can be found (Van Leuwen et al. 1997).

On the European scale Lithuania occupies an intermediate position between central Europe where the highest air pollution concentrations and deposition are recorded and Scandinavian countries where air pollution is one of the lowest in Europe.

This fact allows us to establish a gradient of decreasing pollutants crossing our country: Central Europe - Lithuania - Scandinavia. After pollutant loads are compared with other forest monitoring data, we are expecting to clarify their impact on forest condition. The aim of this study was to estimate the influence of sulphur deposition and hydro-thermal coefficient (drought stress) on forest condition in Lithuania.

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 of air pollution on forests (UN/ECE, 1998). The regional forest monitoring system in Lithuania is based on systematically selected permanent observation plots (POP). The 24 sample trees were selected for assessment in each POP. Condition of up to 23000 trees were annually evaluated (Ozolinčius, Stakėnas 1999). Selected sample trees represent forest species composition, i.e. 37-42% *Pinus sylvestris L.*, 23-25% - *Picea abies L.*, 16-19% - *Betula pendula* and *B. pubescens*, 4-5% - *Populus tremula*, 3-4% - *Alnus glutinosa*, etc.

The most important tree condition indicators are crown defoliation and foliage discolouration. Defoliation means the loss of foliage compared to the reference tree, which has full foliage. The reference tree is usually a tree of the similar growth, social class and with the same branching pattern, growing in the vicinity or relative tree picture, or the same tree with full foliage imagined (UN/ECE 1998). According to defoliation degree trees are grouped into 5 defoliation classes: 0 - without remarkable signs of defoliation (defoliation 0-10%); 1 - slight defoliation (11-25%), 2 - moderate defoliation (26-60%), 3 - severe defoliation (60-99%), 4 - dead trees (100%). Earlier investigation indicates a close inverse correlation (r=-0.8 - -0.9) between the foliage mass and crown defoliation (Ozolinčius, Stakėnas 1999).

Foliage discolouration is a part of needles or leaves (%), which has changed the colour due to negative external factors. Discolouration, as well as defoliation, is evaluated at least by two experts who have participated in the training and have passed the test.

Changes of air pollution in Lithuania were defined by the use of primary energy sources. In the period 1988-1991 consumption of fuel was at the maximum, and in 1994-1996 the stabilization of the amounts consumed was followed by a sudden decrease in fuel consumption (Žukauskas et al., 1997).

Levels of air pollution in European countries were calculated using data published in the EC-UN/ECE reports (Van Leuwen et al., 1997).

Hydro-thermal coefficient (HTC) of Selianinov (Хромов, Мамонтова, 1974) have been chosen for the evaluation of hydro-thermal conditions:

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

R - the sum of precipitation (mm) during the period when the air temperature is above 10°C, $\sum t$ - the sum of temperatures during the same period.

Average annual HTC values (May-August) were calculated as the average HTC of all the meteostations of Lithuania. HTC values for all POPs were calculated using interpolation method and running the ecological analysis computer programme "Ekožvilgsnis" (prof. L.Sakalauskas).

Results and discussion

Regional forest monitoring data collected during the last 12-13 years and a wide international cooperation (Task Force meetings, intercalibration courses, expert panels, seminars, etc.) create an opportunity for more detailed and objective evaluation of forest condition in Lithuania and neighboring countries.

While analysing changes of forest condition, crown defoliation, tree distribution in defoliation (damage) classes and average defoliation are usually used. Foliage discolouration in Lithuania is not a widely spread phenomenon (there were about 0.2-0.3% of trees in 1-3 discolourations classes and average discolouration does not exceed 1.5-2.0%), crown defoliation generally represents the intensity of tree damage (combined damage class) (UN/ECE 1998).

Evaluation of crown defoliation changes in 1989-2000 (Table 1) had revealed, that the average defoliation of all tree species in Lithuania was increasing until the period 1992-1993. This tendency in forest condition decline was supported by a decreasing number of relatively healthy trees (defoliation class 0) during this period. The tendency of defoliation decrease followed since 1995. Data of 1997-2000 indicate remaining tendencies of forest recovering (condition improvement).

Table 1. Average defoliation and number of trees (%) in different defoliation classes

Year	Number of sample trees	Average defoliation, %	Defoliation class				
			0	1	2	3	4
1989	23016	18,8±0,1	37,7	41,4	19,1	1,7	0,1
1990	23042	19,7±0,1	31,5	47,1	18,8	1,4	0,2
1991	22836	21,3±0,1	24,6	51,5	22,1	1,5	0,3
1992	1807	21,0±0,3	16,3	66,1	15,9	0,8	0,8
1993	5654	23,4±0,6	21,1	51,4	23,9	3,0	0,6
1994	1761	23,0±0,5	14,8	59,8	23,5	1,5	0,4
1995	7774	24,2±0,2	19,4	55,7	20,3	1,2	3,4
1996	5915	19,1+0,2	29,1	58,3	9,7	0,9	2,0
1997	6971	21,1+0,1	15,8	69,7	12,5	0,8	1,1
1998	5328	21,9+0,3	18,2	66,2	13,5	1,3	0,9
1999	7154	19,9±0,2	15,2	73,4	9,7	1,1	0,6
2000	6646	20,8±0,2	16,9	69,2	11,4	1,4	1,1
In the Europe, 2000*	**135839**	**20,0**	**34,8**	**42,4**	**20,3**	**1,5**	**1,0**

* Lorenz M., Seidling W., Mues V., Becher G., Fischer R. 2001. Forest condition in Europe. Results of the 2000 large-scale survey. UN/ECE and EC, Geneva, Brussels, 112p.

Correlation analysis has indicated that within the limits of our geographical region - Central Europe - Baltic States (Lithuania) - Scandinavia 75-80% of variations in conifer condition (an average for separate country) can be explained by the different amount of acidic deposition (Fig. 1). Climatic factors evaluated by the hydro-thermal coefficient had very little influence (influence coefficient has not reached 1%).

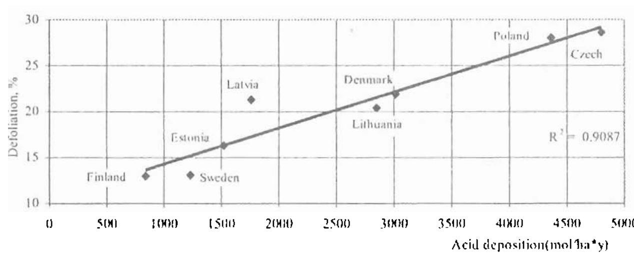

Figure 1. Average defoliation of conifers and acid depositions in some European countries in 1989-1997 (according to EC and UN/ECE 1997)

Bearing in mind the different effects of pollutants on forest ecosystems and their synergistic effects, it is very difficult to discuss the correlation of concentrations of some pollutants with that of tree condition. However, it is clear that the trend of forest condition improvement in Lithuania since 1996 can be related to the decrease in air pollution as well (Fig. 2). Monitoring of sulphur and nitrogen depositions from the atmosphere indicates a clear decrease of sulphate concentrations in precipitation over the last years. This is especially pronounced in a southern and eastern parts of the country where the average concentrations of sulphates have decreased twice (Jasinevičienė, Šopauskienė 1999). The decrease of sulphate concen-

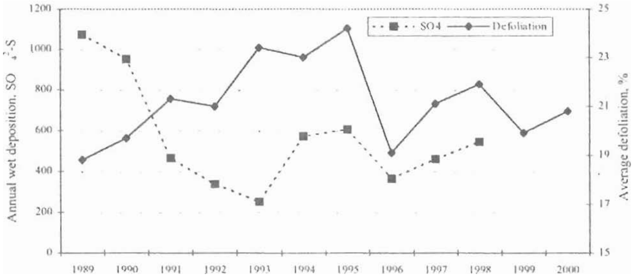

Figure 2. Changes of SO_4^{2-}-S wet deposition (Jasinevičienė, Šopauskienė, 1999) and average defoliation in Lithuania

trations in atmospheric precipitation can be related to the decrease of SO_2 emissions in Western Europe. Meanwhile, NO^{3-} and NH^{4+} concentrations in atmospheric precipitation have changed insignificantly. The improvement of forest condition was not recorded immediately after the reduction of sulphur deposition in Lithuania. It was necessary to take 5-6 years to start forest condition recovering. According to our data in the period 1989-1993 the correlation between average crown defoliation and annual amount of sulphur deposition exceed -0,90. Since 1993 (some symptoms of forest condition improvement were recorded) average defoliation slightly depended on annual amount of sulphur deposition (r=0.32).

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 are made to clarify defoliation changes by the influence of meteorological factors.

Earlier studies have shown, that when HTC>1.5 - the overmoisted climatic conditions are stated, 1.5-1.1 - optimal conditions, 1.0-0.6 - dry conditions, <0.6 - drought (Bukantis, 1994). Based on this gradation territory of Lithuania was divided according to HTC for the period 1991-2000. The results are provided in Figure 3. The droughts were observed in 1992 and 1994. The drought of 1992 was strongest and lasted for 2 months (Buitkuvienė, 1998). This drought covered all Lithuania and total crop productivity decreased by 20-50%. Norway spruce and Scots pine radial increment in 1992 decreased to very low values (Bitvinskas, 1997). The drought of 1994 lasted for 5 weeks, but high air temperature and intensive solar insolation prevailed. In the period 1995-1998, the climatic conditions were optimal or with excess of moisture. The drought and dry conditions in 2000 were in western and northern parts of Lithuania (Fig. 3).

Completed correlation analysis indicated that HTC had no significant influence on the average defoliation and changes in the number of damaged trees (defoliation classes 2-4). The decreasing trends of

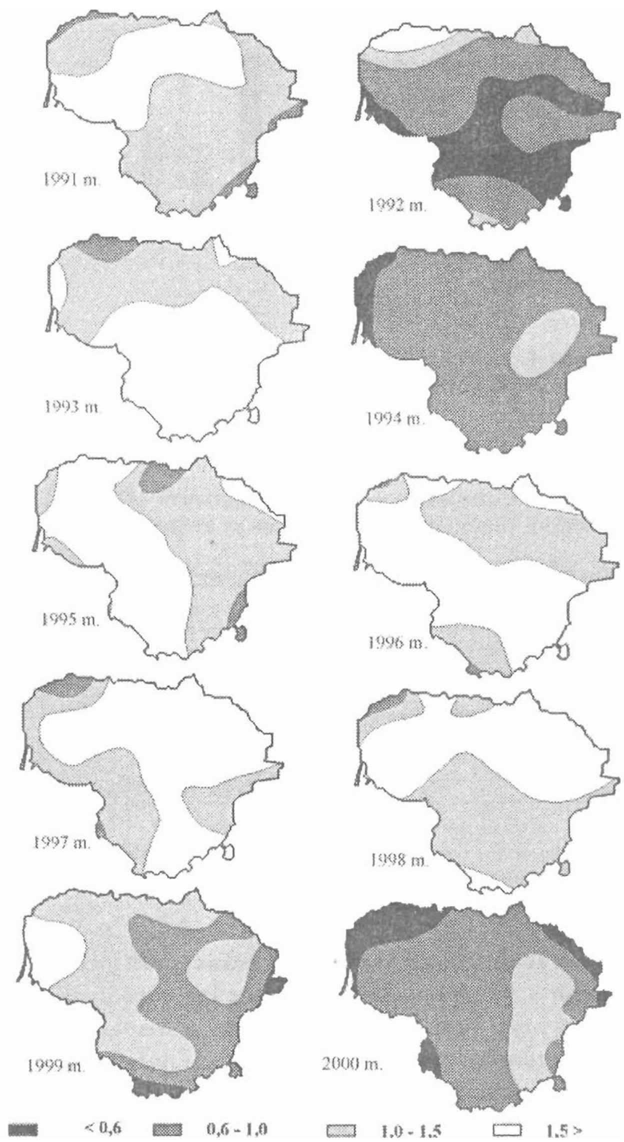

Figure 3. Changes of hydro-thermal coefficient (HTC) in Lithuania in 1991-2000

these indicators can be noticed along with the increases of humidity (HTC). The changes of the number of healthy trees compared to HTC changes were slightly more significant (r=0.59, p=0.074) (Fig. 4). The correlation between the number of healthy Scots pine trees and the HTC on all forest sites is already more statistically reliable (r=0.74, p=0.025). The average defoliation of trees in the soils of normal moisture tends to increase along with the decrease of HTC, although the relationship is not statistically significant (p>0.15) (Table 2). Statistical significance of the relationship between the number of healthy trees (defoliation class 0) in the soils of normal moisture and HTC was higher (r=0.73, p=0.026). From the data provided in Table

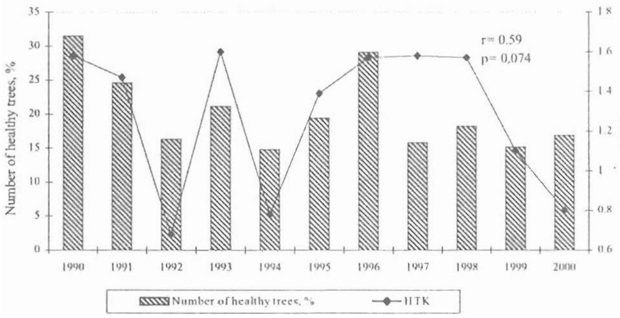

Figure 4. Changes of hydro-thermal coefficient (HTC) and a number of healthy trees (%)

Table 2. Correlation coefficients between HTC and tree condition (defoliation - D; number of healthy trees - H)

Tree species	Site humidity index*							
	N		L		U		P	
	D	H	D	H	D	H	D	H
All species	-0.32	0.73	-0.09	0.23	0.17	0.35	-0.24	-0.18
p-value	0.396	0.026	0.821	0.555	0.665	0.362	0.529	0.639
Pine	-0.29	0.70	-0.03	0.47	-0.45	0.41	-0.32	0.53
p-value	0.451	0.037	0.936	0.206	0.221	0.268	0.407	0.146
Spruce	0.07	0.56	0.34	-0.11	0.39	-	-0.05	-
p-value	0.866	0.115	0.375	0.734	0.299	-	0.899	-
Birch	-0.52	0.64	0.03	0.13	0.41	-0.04	-0.42	-0.26
p-value	0.148	0.065	0.939	0.711	0.278	0.925	0.265	0.508

* N - mineral soils of normal moisture;
L - temporal excess of moistures in mineral (gleyic) soils;
U - permanent excess of moistures in mineral (gley) soils;
P - peatland.

2, weakening of the correlation between defoliation indicators and HTC, along with the increase in site humidity, can be indicated. Along with the decrease of numbers of sample trees due to the lower number of POPs on humid sites, both defoliation indicators and correlation coefficients are less reliable. Defoliation of Scots pine in all hydrotopes is decreasing along with the increase of the HTC, which is reflected by a correlation coefficient between the HTC and the average defoliation.

Therefore, the higher the HTC value is, the smaller the average defoliation and the higher the number of healthy trees. These trends are more clearly expressed in Scots pine and deciduous stands, even though individual species of broadleaves (for example, Black alder), most probably react differently to HTC changes. Our statements (the bigger the amount of precipitation is - the higher density of Scots pine crowns, i.e., lower defoliation) are similar to the research results in Belgium (Callaert, Scheizlink 1996).

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 (Орлов 1980). Assimilation mass of birch stands during individual years fluctuates from 75% to 125% of the average values and 91% of the changes can be explained by the influence of meteorological factors (Mikšys, 1998).

It has been found that the number of dry periods and values of high potential evapotranspiration are positively correlated with defoliation. In general more precipitation leads to decreased defoliation of Scots pine (Callaert, Scheizlink 1996). The relationship between crown defoliation and relative transpiration (drought) were almost linear for *Quercus robur/petraea*. For Scots pine when relative transpiration was below 70%, the correlation between drought and defoliation was almost linear (Klap et al. 1997).

Evaluation of the correlation between the condition of Norway spruce trees and the HTK is more complicated. Most probably, the crown defoliation is also influenced by wind, droughts and bark beetles. Influences of hydro-thermal conditions on spruce trees are perhaps smaller due to the biological particularities of Norway spruce (for example, needle retention, i.e., needles of the current year usually compile not more than 20-25% from the total needle mass). Density of Norway spruce crowns in Norway in 1992, on average have decreased by 1.81% on dry sites and by 2.47% on sites unfavorable for spruce, as compared to the results of 1991 (Strand 1997).

The average defoliation of the broadleaves, positively reacts to the decrease of HTC, but due to the small number of sample trees a more clear expression of this relation was not found. When analysing the influence of sulphur depositions and HTC on the changes of average defoliation (data of 1993-1998 have been used, because since 1993 symptoms of forest condition improvement have been recorded) it was indicated that these two factors could explain about 15% (R^2=0.149, p=0.78) of the variation of annual crown defoliation.

Conclusions

1. In the limits of geographical region - Central Europe-Baltic States-Scandinavia - 75-80% of conifers forest health (average defoliation for the separate country) variation can be explained by the different amount of acidic deposition meanwhile hydro-thermal conditions (hydro-thermal coefficient of Selianinov - HTC) did not have significant influence.

2. Trend of forest condition improvement in Lithuania since 1995 can be related the decrease in sulphur depositions. Forest condition improvement was recorded after reduction of sulphur deposition in 1989-1991, i.e. 5-6 years later. Since 1993 changes in the average defoliation were slightly dependent on the annual amount of sulphur deposition (r=0.32).

3. During the period investigated (1990-2000) the correlation between the number (% from total observed) of healthy trees (crown defoliation 0-10%) and HTC was slightly significant (r=0.59, p=0.074). Decrease in the correlation between defoliation and HTC, along with the increase in site humidity, was indicated.

4. The correlation between the number of healthy Scots pine trees and HTC was more statistically significant (r=0.74, p=0.025).

5. Since 1995, when symptoms of forest condition improvement were recorded, about 15% of the annual variation of crown defoliation can be explained by sulphur depositions and HTC changes.

References

Auclair A.N.D., Worrest R.C., Lachance D., Martin H.C. 1992. Climatic perturbation as a general mechanism of forest dieback. In: Forest decline concepts (eds. Manion P.D., Lachance D.). St. Paul, Minnesota, p. 38-58.

Bitvinskas T. 1997. Modelinių rūšių - Pinus sylvestris L. ir Picea excelsa Link. tvarumo ir išsilaikymo perspektyvos. [Perspective of sustainability and preservation of model species Pinus sylvestris L. ir Picea excelsa Link.]. In: Rūšių tyrimai areale (1). Ekologinio tvarumo zonos. [Investigations of species in areal. (1) Zones of ecological sustainability]. Vilnius, p. 9-11.

Buitkuvienė S. 1998. Sausros Lietuvoje. [Droughts in Lithuania]. In: Lietuvos meteorologijos ir hidrologijos problemos XXI a. išvakarėse. [The problems of meteorology and hidrology in Lithuania on the eve XXI century]. Vilnius, p. 75-79. (In Lithuanian).

Bukantis A. 1994. Lietuvos klimatas. [The climate of Lithuania]. Vilnius, 187 p. (In Lithuanian).

Callaert G., Scheizlink H. 1996. Influence of weather conditions on the vitality of beech and Scots pine. Annex 5 to Minutes "Meteo-Level II". Freising, Germany. 12 p.

Evans L.S. 1984. Botanical aspects of precipitation. Bot. Rev.; 50: 449-489.

Hain R.P. 1987. Interactions of insects, trees and air pollutants. Tree physiology; 3: 93-102.

Houston D.R. 1992. A host-stress-saprogen model for forest dieback-decline diseases. In: Forest decline concepts (eds. Manion P.D., Lachance D.). St.Paul, Minnesota, p. 3-25.

Jasinevičienė D., Šopauskienė D. 1999. Sulfatų koncentracijos pokyčiai atmosferos krituliuose Lietuvoje. [Time trends of sulfate concentrations in atmospheric precipitation in Lithuania]. Aplinkos inžinerija [Environmental Engineering], VII tomas, 4: 187-193. (In Lithuanian).

Kandler O. 1990. Epidemiological evaluation of the development of Waldsterben in Germany. Plant Disease, 74, 1: 4-11.

Kandler O. 1992. The German forest decline situation: a complex disease or a complex of deseases. In: Forest decline concepts (ed. P.D.Manion, D.Lachance). St.Paul, Minnesota, p. 59-84.

Klap J., Voshaar J.O., De Vries W., Erisman J.W. 1997. Relationships between crown condition and stress factors. In: Ten years of monitoring forest condition in Europe (ed. C. Muller-Edzards, W. De Vries, J.W. Erisman). EC and UN/ECE, Brussels, Geneva, p. 277-302.

Manion P.D., Lachance D. 1992. Forest decline concepts. APS Press, St. Paul, Minnesota, USA, 249 p.

Mekne-Jakobs B.M. 1990. Untersuchungen zur Überprüfung der Epidemiehypothese als Erklärungsansatz zu den 'neuartigen' Waldschäden. Allgemeine Forst-und Jagdfeitung, 161(12): 231-239.

Mikšys V. 1998. Meteorologinių faktorių įtaka beržynų asimiliacinei masei. [Influence of meteorological factors on birch stands assimilation mass]. Miškininkystė [Silviculture], 2(40): 22-29. (in Lithuanian).

Ozolinčius R., Stakėnas V. 1999. Regional forest monitoring. In: Monitoring of forest ecosystems in Lithuania. Kaunas, "Lututė": p. 82-121.

Shutt P., Cowling E.B. 1985. Waldsterben - a general decline of forest in Central Europe: symptoms, development and possible cause. Plant Desease, 67: 548-558.

Skelly Y.M. 1992. A closer look at forest decline: a need for more accurate diagnostic. Forest decline concepts (ed. P.D.Manion, D.Lachance). S.Paul, Minnesota, p. 85-107.

Smith W.H. 1981. Air pollution and forests. Interactions between air contaminants and forest ecosystems. New York, Heiduberg, Berlin.

Strand G.-H. 1997. Effects of early summer drought on the crown density of Norway spruce. Forestry, 2(70): 157-160.

Ulrich B., Mayer R., Khanna P.K. 1980. Chemical changes due to acid precipitation in a loess-derived soil in Central Europe. Soil. Sci., 130: 193-199.

UN/ECE. 1998. Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests (4 th edition). Hamburg, Germany.

Van Leeuwen E., Lovbland G., Simpson D., de Vries W., de Jong E., Erisman J.W. 1997. Calculation of anthropogenic stress factors. In: Ten years of Monitoring forest condition in Europe (ed. C. Muller-Edzards, W. De Vries, J.W. Erisman). EC and UN/ECE, Brussels, Geneva, p. 241-260.

Vaičys M. 1991. Rūgštieji lietūs ir jų poveikis įvairiems gamtos komponentams. [Acid rains and its influence on different components of nature]. Vilnius, 48 p. (in Lithuanian).

Žukauskas A., Jaskelevičius B., Žiugžda J.O., Stumbras A. 1997. Anthropogenic pollution of the atmosphere in Lithuania. Ecological sustainability of Lithuania (ECOSLIT). Vilnius, p. 11-17.

Орлов А.Я. 1980. Динамика массы хвои в сосновых культурах. [The dynamic of needle mass in Scots pine plantations]. Лесоведение, 1: 34-41. (In Russian).

Хромов С.П., Мамонтова Л.И. 1974. Метеорологический словарь [Meteorological dictionary]. Л. Гидрометеоиздат, 568с. (In Russian).

ВЛИЯНИЕ ДЕПОЗИЦИЙ СЕРЫ И ГИДРОТЕРМИЧЕСКИХ УСЛОВИЙ НА СОСТОЯНИЕ ЛЕСОВ В ЛИТВЕ

Р. Озолинчюс, В. Стакенас

Резюме

На основе данных лесного мониторинга, а также литературных данных о загрязнении воздуха в некоторых страннах Европы, установлено, что в пределах нашего географического региона - Центральная Европа - Бальтийские страны - Скандинавия - вариация средней дефолиации деревьев в отдельных государствах в 75-80% зависит от количества кислых осадков, в то время как гидротермические условия, выраженные коэффициентом Селянинова (ГТК) практически не оказывают ощутимого влияния.

Тенденция улучшения состояния лесов в Литве наблюдается с 1995 года и может быть связана с значительным уменьшением фонового загрязнения в 1989-1991 году. Связь между числом относительно здоровых деревьев (дефолиация крон 0-10%) в 1990-2000 г.г. и ГТК была слабая (r=0,59). Более тесная связь отмечена для деревьев сосны (r=0,74). Дефолиация деревьев, произрастающих на почвах с нормальным увлажнением, увеличивалась с уменьшением ГТК (увеличением засушливости), но коэффициенты корреляции небыли статистически достоверными. После появления симптомов улучшения состояния лесов (с 1995 года), депозиции серы и ГТК определяют около 15% вариации средней дефолиации.

Ключевые слова: дефолиация, засуха, гидротермический коэффициент, депозиция серы