Analysis of the health condition and the abiotic environment of forest stands in the territory of the Jizerské hory Mts, Czech Republic

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Abstract

Hadaš, P. 2012. Analysis of the health condition and the abiotic environment of forest stands in the territory of the Jizerské hory Mts, Czech Republic. *Folia oecol.*, 39: 1–9.

The paper sets out to analyse the causality of the abiotic environment and health condition of forest stands for the territory of the Jizerské hory Mts natural forest region (hereinafter NFR). To reach an understanding of the potential impact of SO_2 and NO_x pollutants and climate stressors on forest ecosystems, a considerable amount of data on the abiotic environment needs to be acquired, also for territory in which such measurements of the data have not been made. This is why the data on temperature conditions, water balance, solar radiation, ozone concentrations and deposition flows of sulphur, nitrogen and hydrogen ions were derived through model applications and interpolation techniques. Geostatistical methods should be used instead based on the application of multidimensional methods. The health condition analysis of the forest stands (as manifested by defoliation) and parameters of the forest stands' abiotic environment is carried out by applying simple and multidimensional regression and correlation analyses. The cluster analysis helped determine spatial distribution of five areas of potential disposition to the damage of forest stands. The results of a multiple correlation and regression for each potential disposition area were put together to form a model explicating the forest stands defoliation status.

Key words

areas of potential disposition to forest stands damage, defoliation, climatic stress, depositions of sulphur, nitrogen and hydrogen ions, regression and cluster analyses

Introduction

The paper sets itself the task of analysing the chain of causation for the abiotic environment and health condition of forest stands in the territory of the NFR Jizerské hory Mts. The analysis rests on the hypothesis asserting that change in health condition is induced by depletion of the resistance potential of forest stands so that even the present air pollution load in the form of atmospheric sulphur and nitrogen depositions combined with climate extremes (changes in temperature and moisture regimes) and the ground (tropospheric) ozone leads to their damage (Hadaš, 2007). The resistance potential of forest stands was defined by way of the critical loads of acidic depositions and depositions of nitrogen. Atmospheric sulphur and nitrogen depositions are still among the accelerators of acidification processes in the forest soil. Acidification is slower but it has not been stopped. Critical doses of sulphur and nitrogen are exceeded on many monitored sites not only in the territory of the Czech Republic. Apart from its acidification, the forest soil is equally subject to eutrophication evoked by the entry of nitrogen.

Direct and indirect influences of the polluted atmosphere on the forest ecosystem depend on a complex of variables, including exposure intensity, conditions of abiotic and biotic environments as well as on the connatural sensitivity of the affected populations, species and societies. In order to reach an understanding of a potential impact of the SO_2 and NO_x pollutants and of climate stressors on forest ecosystems, a considerable amount of data on the abiotic environment has to be acquired also for the territory in which such data measurements do not take place. Data regarding temperature conditions, moisture balance, solar radiation, ozone concentrations, deposition flows of sulphur, nitrogen and hydrogen ions were thus derived by way of model application and interpolation techniques.

It is assumed in the undertaken analysis that the main carrier of air pollution stress inducing forest stand damage are sulphur and nitrogen deposition flows – or potentially their acidic depositions intercepted by the earth surface or by the stand. It is further assumed that extreme climatic conditions and deposition flows within the framework of their synergic effect disturb the course of physiological processes (metabolism, photosynthesis), water balance and balance of substances (Ulrich, 1987), transpiration, phenophase, nutrition uptake by roots (Mauer and Palátová, 2001) etc., which adversely reflect in the health condition of the crown. A change in the health status of trees crowns is assessed according to the loss of the assimilatory organs, i.e. defoliation.

Material and methods

The used methodology compares the derived values of the sulphur and nitrogen deposition flows and acidic depositions both above the forest stand and therein with the values of their critical doses. It also assesses the temperature conditions in terms of frost shock, moisture conditions in respect of water balance and effects of ozone immission load in relation to moisture conditions of the environment and the condition of the ozone layer in the stratosphere. The derived data represent climate and air pollution stress and figure as independent variables in the analysis of the causal relationship between the abiotic environment and forest stands health condition. The analysis simultaneously aims at defining and delimiting the areas of potential disposition to forest stand damage in NFR 21 Jizerské hory Mts.

Common analytical and statistical procedures cannot be applied on processing multidimensional data levels. Geostatistical methods need be used instead based on the application of multidimensional methods (Türk et al., 2001). While analysing relationships or processes in a heterogeneous set of data, the so-called "data levels classification" must be applied in addition to correlation and regression analyses. The classification appears to be an efficient tool for studying internal heterogeneity of data sets while searching for inherent laws of natural processes and phenomena. It makes it possible to process a considerable amount of information and allows for its presentation in a compact and comprehensible form. The classification does not merely provide generalizing information on the surveyed amount of objects and phenomena but it also helps to reveal new, previously hidden patterns.

Forest ecosystem classifications have been used fairly intensively in Germany for over 45 years (Barnes, 1984). In Canada and Australia, classification procedures suitable for extensive areas have been developed and implemented (Hills, 1960; Rowe, 1978). The ecological-climatic classification based on a combination of results from cluster and discriminant analyses was studied by Denton and Barnes (1988). Cluster analysis methods have developed from the needs for analysing and appropriately concentrating the information contained in the multidimensional data characterized by very high heterogeneity. Generally, the cluster analysis situation can be characterized as follows: We have "n" objects. "P" characteristics (properties) are measured or observed on each object so that we acquire "n" p-dimensional vectors X_1, X_2, ... X_n.

Three basic types of cluster construction types can be distinguished with the used cluster methods – parallel, sequential and hierarchic methods (Filáček et al., 1977). In this study, we applied the hierarchic method since there is some previous experience therewith (Hadaš, 1991). In the hierarchic methods of clustering, a sequence $S^{(t)}$ (t = 1, 2, ….. K) is being created of decompositions of the X set of objects with the specification that the S(t) decomposition constitutes a refining of $S^{(t')}$ decompositions for $t < t'$, (t, t' = 1, 2, ...K). When the variables are selected and ordered into a matrix that describes the characteristics of the cluster objects, the first step in the implementation of the cluster algorithm is the evaluation method for the distance or similarity of objects. The calculation of the distance rate between the individual objects can be performed using Minkowski, Hemming, Euclid, Mahalanobis or Chebyshev metrics (Hebák and Hustopecký, 1987). Hemming metric was used to identify and classify larger and smaller units (areas, sub-areas) in terms of similarity rate for the surveyed area of the Jizerské hory Mts by cluster analysis. The clustering process was realized by the method of the furthest neighbour method.

The forest stands health condition (as manifested by defoliation) and the abiotic environment parameters were further analysed by applying the simple and multidimensional regression and correlation analyses to the formed clusters (areas). The aim of this stage of the analysis is to determine the impact rate of the individual factors and to define the regression model.

The potential deposition flows of sulphur and nitrogen, and the acidic depositions of hydrogen ions are calculated based on gaseous concentrations of SO_2, NO_x, (as NO and NO_2) and their dry and wet deposition flows. Calculation of the immission concentrations for SO_2 and NO_x is realized on the basis of Gaussian dispersion model (SYMOS 97, Bubník et al., 1998). The overall 2001 sums of SO_2 and NO_x emissions and the number of emission sources for the individual groups or states that were used in the model calculation of deposition flows of sulphur and nitrogen and of acid H^+ deposition are listed in Table 1. Total SO_2 emissions used in the model calculation reach 9.017 million tons and the total sum of NO_x emissions amounts to 7.016 million tons. The Czech Republic's share accounts for 0.2487 million tons of SO_2, i.e. 2.76% of the overall emission volume of SO_2, and 0.2934 million tons of NO_x, which constitutes 4.18% out of the used NO_x emission amount.

Dry depositions of sulphur and nitrogen are calculated based on the deposition rates acquired by means of the resistance model according to the procedure of Baer and Nester (1988). The calculation of wet deposition of sulphur and nitrogen proceeds from parametrization used in the MESOPUFF II model. The model calculation uses concrete measured data (emissions, technical parameters of the emission sources, concentrations of pollutants, air temperature, atmospheric precipitation, wind direction and velocity) and mathematical approximations of indirect derivation of these parameters for the locations without measurements. Linear multiple regression and interpolation methods are applied (e.g. orographic, Lagrange interpolation). The components of solar radiation and parameters for the water balance calculation were likewise derived using a model calculation. Total precipitation amounts and immission ozone concentrations were inferred on the basis of orographic interpolation and the ozone layer thickness through interpolation grounded on inversion distances. The calculations for 2001 were made in a lattice of 1,642 grids. The location of the Jizerské hory Mts is shown in Fig. 1. For a detailed description of partial methodological procedures refer to dissertation work published by Hadaš (2009).

Table 1. Total SO_2 and NO_x sums used in the dispersion model for the year 2001

Group / Country	SO_2		NO_x	
	Tons a year^{-1}	Number	Tons a year^{-1}	Number
REZZO 1 (CZ)	193,177.2	3,704	145,849.1	3,704
REZZO 2, 3 (CZ)	55,557.0	7,232	18,134.0	7,226
REZZO 4 (CZ)	–	–	129,434.4	4,941
Germany	1,153,519.0	540	1,593,601.9	436
Poland	1,551,132.1	307	871,705.7	308
Slovakia	112,256.1	632	110,597.9	636
Austria	40,629.9	157	190,942.0	157
Hungary	451,372.3	61	194,636.4	61
Other (the Ukraine, Denmark, Belgium, Italy, France etc.)	5,460,155.0	1,521	3,761,159.3	1,519
Total	9,017,798.7	14,154	7,016,060.4	18,988

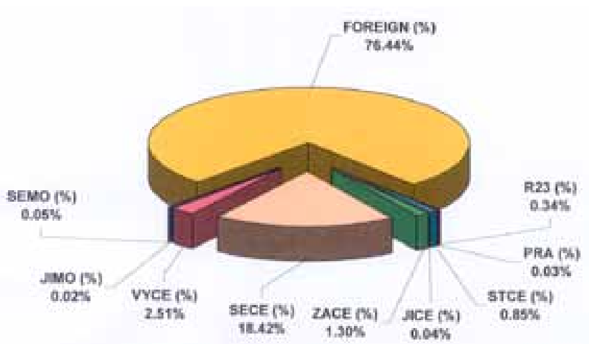
REZZO, Register of Emissions and Air Pollution Sources; 1 – very big, 2 – big; 3 – small; 4 – mobile; CZ, Czech Republic.

Fig. 1. Location of the Natural Forest Region Jizerské hory Mts.

Results and discussion

The total potential sulphur and nitrogen depositions reach values that can still considerably affect and compound the effects of natural acidification of the forest stands and soil. In 2001, the dose of throughfall acidic deposition of 2,000 mol H^+ ha^{-1} per year was exceeded on over 45% of the surveyed area. The results of the VaV /740/4/00 project (Zapletal et al., 2003) were used to assess the deposition flows of acidic depositions. The project evaluated the critical load of acidic deposition for the territory of the NFR Krušné hory Mts at 1,567 mol. H^+ ha^{-1} $year^{-1}$. In the NFR Jizerské hory Mts, the value of this critical dose is exceeded on more than 85% of the territory.

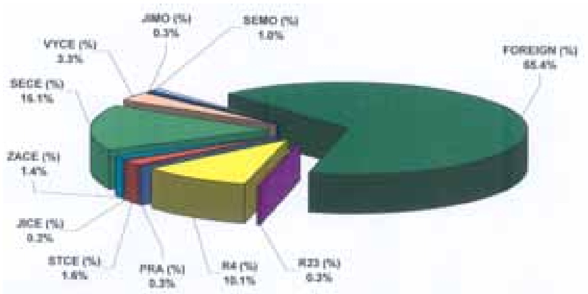
In spite of the decreased production of SO_2 emissions, the impact of both local (average share of Czech emission sources in the deposition of sulphur is 23.6%) and transboundary sulphur pollution (average share of foreign sources in the deposition of sulphur is 76.4%) is still quite noticeable in the air pollution load of the Jizerské hory Mts. The Czech NO_x emission sources contribute to potential nitrogen depositions by on average 34.6%, while the share of foreign NO_x sources is 65.4%. The partial share of the individual groups of emission sources of the Czech and foreign sources in the H^+ deposition (mol. ha^{-1} $year^{-1}$) from dry and wet sulphur depositions above the stand in the territory of the Jizerské hory Mts for 2001 is shown in Fig. 2.



FOREIGN, emissions sources from foreign countries; R23, emissions from big and small sources of Czech republic, emissions from very big sources of regions of Czech republic: PRA, Prague; STCE, central Bohemia; JICE, south Bohemia; ZACE, west Bohemia; SECE, north Bohemia; VYCE, east Bohemia; SEMO, north Moravia; JIMO, south Moravia.

Fig. 2. Average share of emission sources in the potential H^+ deposition (mol. ha^{-1} $year^{-1}$) from dry and wet sulphur depositions above the stand in the territory of the Jizerské hory Mts for 2001.

The share of these emission sources in the H^+ deposition (mol. ha^{-1} $year^{-1}$) from dry and wet nitrogen depositions above the stand in the territory of the Jizerské hory Mts for 2001 is shown in Fig. 3.



FOREIGN – Emissions sources from foreign countries, R23 – Emissions from big and small sources of Czech republic, R4 – Emissions from mobile sources of Czech republic, emissions from very big sources of regions of Czech republic: PRA – Praha, STCE – central Bohemia, JICE – south Bohemia, ZACE – west Bohemia, SECE – north Bohemia, VYCE – east Bohemia, SEMO north Moravia, JIMO – south Moravia.

Fig. 3. Average share of emission sources in the potential H+ deposition (mol. ha^{-1} $year^{-1}$) from dry and wet nitrogen depositions above the stand in the territory of the Jizerské hory Mts for 2001.

The spatial arrangement of five areas with degrees of resistance potential (DRP) to forest stand damage was defined within the scope of partial procedures of the cluster analysis – evaluation of distances between objects using Hemming metric and similarities of objects determined by the furthest neighbour method. The result of the spatial arrangement of the degrees of potential disposition to spruce stands damage is shown in Fig. 4. Table 2 lists the mean values of above-stand deposition flows of sulphur and nitrogen, defoliation, temperature minimums in March 2001 and the proportional distribution of areas in the NFR Jizerské hory Mts.

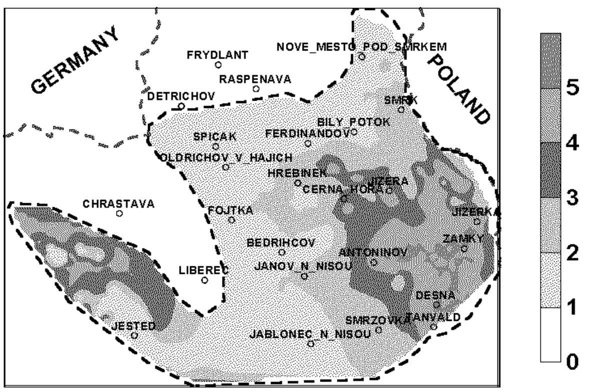


Fig. 4. Spatial distribution of the degrees of resistance potential to forest stands damage in the territory of the NFR Jizerské hory Mts (dashed line) in 2001. The natural neighbour gridding method was used for the depiction (Surfer Demo Version 9, Golden Software, 2009).

Degree 1 of the resistance potential expressing the disposition to spruce stands damage takes up more than

45% of the area of the NFR Jizerské hory Mts, Degree 2 occupies nearly 24%, Degree 3 takes up 16.5%, Degree 4 almost 13% and Degree 5 occupies over 1.5% of the area. The degree of resistance potential is derived on the basis of synergic effects of temperature fluctuations, relative air humidity, water balance condition, ozone concentration, perpendicular global radiation intensity and ozone layer thickness between March and July 2001, length of the growing season and the dose of sulphur and nitrogen deposition flow between January 1, 2001 and August 19, 2001. The date August 19, 2001 is the exposition date of the LANDSAT satellite photograph used to derive the spruce stands health condition through defoliation. The explanation of spruce stands defoliation was made by using all parameters representing the condition of atmosphere above the NFR Jizerské hory Mts. Based on the correlation analysis the parameters with the highest correlation coefficient value were selected for the purposes of setting forth the defoliation values in each degree of potential disposition.

From the results of multiple correlation and regression, a model explicating the spruce stand defoliation status was created for each area defined by the degree of resistance potential. The highest rate of air pollution and climatic stress impact on the forest stands defoliation was reached in area No. 3 (see Fig. 4 brown colour); an extremely low degree of resistance potential disposition to forest stands damage was reached where the coefficient of determination of the derived multiple regression function reaches the value of 64.2%. This means that other unused abiotic factors amount to 35.8% (e.g. soil factors, status of stands nutrition etc.). Table 3 presents parameters of regression model.

The multiple regression model has a following general form:

$$DEFOL = a \cdot ALT + b \cdot MATHN3 + c \cdot ATMI3 + d \cdot WBS58 + e \cdot RMA5 + f \cdot DUD7 + g \cdot OZOC7 + h \cdot PDRS7 + i \cdot S + j \cdot N + k \cdot GSL + \text{constant.} \qquad [1]$$

Table 2. Selected basic characteristics of principal factors applied to define the degrees of resistance potential to forest stands damage in the territory of the NFR Jizerské hory Mts in 2001

Resistance potential degree	Ø Deposition flows above the stand [mol H^+ ha^{-1} $year^{-1}$]		Ø Defoliation of spruce stands [%]	Absolute temperature minimum in March [°C]	Surface area [%]
	Sulphur	Nitrogen			
1 – high	94.9	475.1	29.6	–11.5	45.2
2 – low	134.6	539.9	31.1	–12.7	23.9
3 – extremely low	171.9	593.9	38.2	–12.7	16.5
4 – medium	69.9	418.9	28.7	–9.5	12.8
5 – very low	204.3	683.1	33.6	–13.9	1.6

Table 3. Regression diagnostics of a multiple linear function defining the dependency of the spruce stands defoliation on the abiotic environment factors for the period 1–8/2001 above the NFR Jizerské hory Mts in area of resistance potential degree No. 3

Abiotic environment factors	Factor and unit		Regression coefficient a–k	Partial correlation
Altitude	ALT	[m]	–2.9945	0.0725
Maximum thermal heating of needles in Month 3	MATHN3	[°C]	–95.2748	0.1036
Absolute temperature minimum in Month 3	ATMI3	[°C]	17.8045	0.0227
Water balance sum for Months 5–8	WBS58	[mm]	–0.1389	0.0150
Relative moisture of air Ø Month 5	RMA5	[%]	–3.8584	0.0476
Stage of stratospheric ozone layer Month 7	DUD7	[%]	–65.0530	0.0181
Ozone (tropospheric) concentration Ø Month 7	OZOC7	[μg m^{-3}]	60.9987	0.0561
Perpendicular direct radiation sum for Month 7	PDRS7	[MJ m^{-2}]	–0.3088	0.0723
Sulphur deposition above the stand	S	[mol. H^+ ha^{-1}]	0.3742	0.0057
Nitrogen deposition above the stand	N	[mol. H^+ ha^{-1}]	0.1986	0.0984
Growing season length	GSL	[days]	0.3200	0.0010
Constant	–		–1,381.2137	
R^2	0.6419			
R	0.8012			
SEE	12.2933			

DUD, Dobson unit deviation from the average; R^2, coefficient of determination; R, coefficient of correlation; SEE, Standard error of estimation.

It follows from the partial correlation coefficients that the greatest impact on defoliation have nitrogen depositions and maximum thermal heating of the needles by solar radiation. Some interesting dependences became clear from the values of regression coefficients, e.g. that defoliation of spruce stands increases with the increasing length of the growing season, with the decrease of stratospheric ozone concentrations and the increase of tropospheric ozone in July and with the anticipated growth of sulphur and nitrogen deposition flows. Defoliation is also increased by decreasing absolute temperature minimums in March.

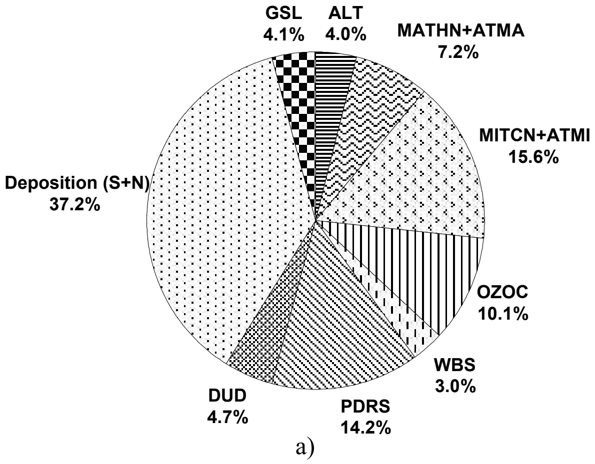
It follows from the development of SO_2 and NO_x emissions that annual SO_2 emissions produced only in the territory of Central Europe have a potential share in the mean annual sulphur deposition flow of 88.7% and that the annual NO_x emissions produced only in Central Europe have a share of 78.1% in the mean nitrogen deposition flow in the territory of the Czech Republic (Hadaš, 2009). The actual proportion is however resulting from a combined effect of many other factors. Despite the obvious decrease of SO_2 and NO_x emissions, the pollutants are still the main factor keeping the forest stands under pressure of deposition stress. A single unexpected emergence of some other abiotic factor (e.g. climate extreme) may become as a triggering factor for local or even large-scale defoliation. The derived multiple regression models clearly show that the impact of abiotic environment factors on stands defoliation is not stable but that it reflects all mutually interconnected positive and negative effects of feedbacks. Table 4 sums up partial significance levels of abiotic factors in the individual areas defined by the degree of resistance potential of the forest stands in NFR 21. The table demonstrates that the deposition flows of acid deposition formed from sulphur and nitrogen depositions show the highest significance in the interval between 13% and 60%. Within the 2–50% interval, the highest significance is shown by changes in temperature conditions (frost damage) between March and May. The influence of tropospheric ozone concentration shows a share in the defoliation change from 0.6% up to almost 29%. Possible damage by ozone is related to July moisture conditions. Conditions supporting the theory of stand damage due to ozone (Šrámek et al., 2006) occur in the areas of resistance potential degrees 1, 2, 3 and 5. In each area, a different significance level (1–21%) of ozone layer reduction was determined.

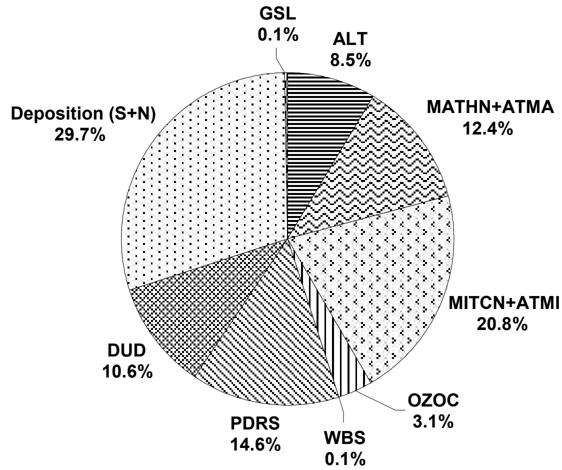
Figure 5 presents an average significance level of the influence of partial abiotic factors on the health condition of forest stands of all tree species and conifers in the territory of NFR 21. The figure clearly shows that defoliation of all forest stands in the NFR 21 Jizerské hory Mts is most affected by the acidic deposition of hydrogen ions – at more than 37% (formed of sulphur and nitrogen deposition flows), by temperature fluctuations (frost shock) – at more than 22%, and by the synergic effect of moisture conditions, ground-level and stratospheric ozone concentrations at nearly 18%. The influence of ozone alone reaches 10%. It is worth noting that the impact of O_3 on the defoliation of all tree species is much higher if the water balance (representing moisture conditions of the forest stands) impact is directly proportionate. The growth of precipitation excess brings about increased defoliation (the regression coefficient is positive). This property of the derived regression models applies for DRP areas 1, 3 and 5 in which the O_3 impact reaches a proportion of more than 28%. Conversely, in the DRP area 2 the water balance shows an indirectly proportionate dependency (defoliation increase resulting from a drop in the precipitation excess) and the share of O_3 in the defoliation falls to

Table 4. Significance of the partial factors of abiotic environment in the regression model used to assess the health condition of forest stands in the NFR 21 Jizerské hory Mts

Factors	Abiotic environment significance – for woody species defoliation [%]						
	All					Conifers	
	DRP-1	DRP-2	DRP-3	DRP-4	DRP-5	DRP-2	DRP-3
Altitude	0	5.11	13.11	1.63	0.15	2.24	14.81
MATHN/ATMA	1.6	21.72	6.28	5.17	1.33	9.71	15.14
MITCN/ATMI	20.12	16.49	40.72	0.18	0.24	6.56	35.08
OZOC	12.69	3.07	5.52	0.62	28.57	0.49	5.79
WBS	2.62	4.87	4.01	0.22	3.32	0.14	0.02
PDRS	3.21	15.7	13.01	6.15	33.04	18.51	10.64
DUD	0.9	4.99	2.7	10.73	3.97	20.66	0.47
Deposition (S + N)	55.24	27.82	13.29	60.3	29.17	41.5	17.96
Growing season length	3.62	0.23	1.36	15	0.21	0.19	0.09

DRP, degrees of resistance potential to forest stands damage; MATHN, maximum thermal heating of needles; ATMA, absolute temperature maximum; MITCN, maximum thermal cooling of needles; ATMI, absolute temperature minimum; OZOC, ozone concentration; WBS, water balance sum; PDRS, perpendicular direct radiation sum; DUD, stage of ozone layer expressed as Dobson unit deviation from the average.





ALT, altitude; MATHN, maximum thermal heating of needles; ATMA, absolute temperature maximum; MITCN, maximum thermal cooling of needles; ATMI, absolute temperature minimum; OZOC, ozone concentration; WBS, water balance sum; PDRS, perpendicular direct radiation sum; DUD, stage of ozone layer expressed as Dobson unit deviation from the average; GSL, growing season length.

Fig. 5. Mean significance levels of the influence of abiotic factors on the health condition of forest stands as manifested by defoliation a) of the stands of all tree species, and b) of coniferous stands.

3%. The derived multiple regression functions thus very aptly simulate an assumption that the forest stands damage by ozone does not occur at every increase of O_3 immission concentrations. As mentioned by Šrámek et al. (2006), the stomatary uptake or ozone dose entering the organism are affected by numerous factors, such as climatic and soil factors (sufficient moisture) that apply in this case.

Defoliation of conifer stands is most impacted (in 33% of cases) by temperature fluctuations (frost shock), by acid deposition of hydrogen ions (at almost 30%) and by the synergic effect of moisture conditions and ground-level and stratospheric ozone (at almost 14%). The impact of ozone alone accounts for 3%. The ozone layer thinning also indicates possible impacts of the UV-AB radiation, which always falls during the daytime perpendicularly on a part of needles or leaves as a component of direct solar radiation with a significance level of ca. 14%. A similar inferential evidence of the possible impact of ozone layer thinning in the stratosphere on the augmentation of UV-AB direct radiation component and ground-level (tropospheric) O_3 concentrations was determined in the Silesian Beskids (Hadaš, 2007).

It appears that the potential of the models of multiple regression functions could reach even higher correlation values between the health condition of forest stands in NFR 21 and abiotic factors. The process of cluster analysis forming clusters (areas) would have to be stopped so that the enclave of Ještědský hřbet Ridge could be singled out separately. The conditions in this enclave disturbed the regression relations in the areas of resistance potential degree 1, 2, 3 and 4. Higher correlation would be probably achieved also if temperature and moisture characteristics, deposition flow and ozone concentrations from the autumn and beginning of winter of 2000 were included too.

Conclusions

The high entry of acidic deposition, the quantity of which exceeds spontaneous regeneration of the soil environment, into the forest soil continues to remain the principal cause for the dieback and damage to stands (trees and individual tree species). The high acidity of the soil environment affects nutrition of the forest stands. The weakened stands become more susceptible to damage provoked by sudden emergence of meteorological factors, namely by increasing or decreasing air temperatures. A triggering factor for large-scale defoliation may become both an extreme temperature increase or prolonged spell of drought or extreme air temperature drop between winter and spring or autumn and winter (winter 2000/2001) and a single acute or synergic damage to soil due to immissions in the form of acidic depositions.

The derived data of the abiotic environment, areas defined by degrees of the potential resistance to forest stands damage in the natural forest region of Jizerské hory Mts, can extend the database of ecological conditions (edaphic-climatic, exposure etc.) and can thus contribute to the evaluation of causes responsible for the forest stands decline, changes in the spruce stands health condition and assessment of the success of revitalization measures.

Acknowledgement

The paper was worked out within the framework of research plan MSM No. 6215648902 “Revitalization of mountain forest ecosystems damaged by air pollution”.

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Analýza zdravotního stavu a abiotického prostředí lesních porostů na území Jizerských hor, Česká republika

Souhrn

Cílem práce bylo analyzovat příčinnou souvislost abiotického prostředí a zdravotního stavu lesních porostů na území přírodní lesní oblasti Jizerské hory. Analýza je založena na hypotéze, že zdravotní stav je vyvolán vyčerpáním odolnostního potenciálu lesních ekosystémů, takže i současná imisní zátěž, ve formě atmosférických depozicí síry a dusíku, v kombinaci s výkyvy klimatu (změny teplotního a vláhového režimu) a stavu přízemního (troposférického) ozónu způsobují jejich poškození. Pro pochopení a porozumění potenciálního vlivu polutantů SO_2 a NO_x a stresorů klimatu na lesní ekosystémy potřebujeme získat značný objem dat o abiotickém prostředí i v území, kde se měření těchto dat neprovádí. Proto údaje o teplotních poměrech, vláhové bilanci, slunečním záření, koncentracích ozónu, depozičních tocích síry, dusíku a iontů vodíku byly odvozeny přes modelové aplikace a interpolační techniky. Změna zdravotního stavu koruny stromů je hodnocena na základě ztráty asimilačních orgánů – defoliací, která byla získána z družicových snímků LANDSAT. V rámci metodického přístupu jsou odvozené hodnoty depozičních toků síry, dusíku, kyselé depozice nad lesním porostem i v porostu, porovnány s hodnotami jejich kritických dávek, teplotní poměry jsou posuzovány z hlediska mrazového šoku, vlhkostní poměry z hlediska vláhové bilance, posuzování vlivu imisní zátěže ozónem z hlediska vlhkostního stavu prostředí a stavu ozónové vrstvy ve stratosféře.

Celkové potenciální depozice síry a dusíku dosahují takových hodnot, že mohou stále významně ovlivňovat a prohlubovat účinky přirozené acidifikace lesních porostů a lesní půdy. Na více jak 45 % studovaného území je překročena kritická dávka kyselé depozice 2 000 mol. H^+ ha^{-1} za rok, v PLO 21 Jizerské hory je kritická dávka překročena na cca 85 % – 90 % území. V rámci dílčích postupů shlukové analýzy – hodnocení vzdálenosti objektů Euklidovou metodou a podobnosti objektů metodou nejvzdálenějšího souseda bylo definováno prostorové rozložení pěti oblastí potenciální dispozice k poškozování lesních porostů. Oblast číslo 1 zaujímá 45,2 % území PLO 21, oblast číslo 2 téměř 24 % území, oblast číslo 3 více jak 16 % území, oblast číslo 4 téměř 19 % území a oblast číslo 5 téměř 2 % území. Z výsledků vícenásobné korelace a regrese byl pro každou oblast potenciální dispozice sestaven model vysvětlující stav defoliace lesních porostů. Nejvyšší míra vlivu imisního a klimatického stresu na defoliaci lesních porostů byla dosažena v oblasti číslo 3, kde koeficient determinace odvozené vícenásobné regresní funkce dosahuje hodnoty 64,2 %. To znamená, že na další abiotické faktory zbývá 35,8 % (např. půdní, stav výživy porostů atd.).

Za hlavní příčinou odumírání a poškozování porostů (respektive stromů, jednotlivých dřevin) stále stojí vysoký vstup kyselé depozice do lesní půdy, jejíž množství přesahuje samovolnou regeneraci půdního prostředí. Vysoká kyselost půdního prostředí ovlivňuje výživu lesních porostů. Oslabené porosty jsou tak více vystaveny poškození vyvolané nenadálým vývojem meteorologických faktorů, zejména vzestupem nebo poklesem teploty vzduchu. Například spouštěcím faktorem velkoplošné defoliace může být jak jednorázové extrémní působení zvýšené teploty nebo prodloužení periody sucha, respektive extrémní snížení teploty vzduchu na přelomu zimy a jara nebo podzimu a zimy (zima 2001/2002), tak jednorázové akutní nebo synergické poškození půdy imisemi ve formě kyselých depozicí.

Received March 24, 2010
Accepted April 5, 2011