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Development of forest stands condition and its monitoring in the Czech Republic

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ABSTRACT: In 1986, the UN ECE established the *International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests* (hereinafter ICP Forests) to respond on the growing concern about forest damage caused since the beginning of eighties by air pollution load. Pan-European grid of the (ICP Forests) monitoring plots represents one of the most important systems of forest ecosystems assessing and checking. The Czech Republic is unfortunately well known due to this problem and so the country joined ICP Forest Programme since the very beginning. The paper presents general information on Czech forest stand condition that gained through various methods in the past as well as in the frame of ICP Forests. The participation in the *International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests* (ICP Forests) represents a contribution of the EU candidate country to the fulfillment of the Reg. (EEC) No. 3528/86. However it seems that effects and importance of air pollution are decreasing, a lot of new stress situations exists and there is a need for continuing the programme.

Keywords: forests ecosystems; monitoring; international cooperation; UN/ECE; forests condition; defoliation; abiotic and biotic factors; air pollution; remote sensing

Forests in the Central European region have been considerably damaged during the industrial development history. Effects of air pollution and forest decline symptoms were described already in mid of the 19th century. But only 100 years later really serious damages begun in the neighborhood of pollution sources (STEFAN et al. 1997). Czech Republic has regions of this type in the northwest of Bohemia and northern Moravia. Both of those localities have been industrialized together with the long lasting coal mining. The area of Krušné hory Mts. (Ore Mts.) belongs to the "black triangle". In this specific region the forest decline triggered by air pollution is considered to be one of the most important threats facing the forest ecosystem. Energy production via burning of brown coal of low quality and chemical industry is the worst emissions source in this area. Enormous concentration of pollutants, originally mostly SO_2 and NO_x, caused the loss of about 50,000 ha of forests in the mountain ridges. Interactions between air pollution and other stresses, having mostly synergistic effects, occurred also in other regions. A combination with other abiotic (frost, wind) and, usually secondary, biotic factors (insects, fungi), resulted particularly in fragile mountain ecosystems to the ecological catastrophe. Dynamic disintegration of forest, decreases in its production functions, failure of its ecological functions and tree species genetic resources disappearance have immense ecological and social consequences.

During the long-term pressure of pollutants, a nutrient leaching process from forest soils continued, resulting to the soil degradation and site productivity decrease. Thus stability of forests declines and forestry problems continued in contrary to the fact that total forested area has continuously increased already since the beginning of 20th century. In the end of 80ies more than 60% of total forested area has been damaged at some level. Air pollution becomes an important political topic, thus some of research results could not be published in that time. Nevertheless, research results from this "lab" were interesting and broadly accepted by research community and several international meetings took place in Czechia. Particularly IUFRO conferences in 1974 and 1984 should be mentioned. The IUFRO cooperation was important and many field trials have been set up in the border area of former Czechoslovakia, East Germany and Poland.

In this milieu it is quite understandable that Czechia has been involved in the monitoring of forest stands condition.

As mentioned above, mostly mountain forests have been exposed to air pollution. There are areas where the shortening of spruce stands survival shows a relatively similar trend under the influence of air pollutants, climatic, site conditions and genetic characteristics of forest stands. Forests Risk Zones have been determined according to the expected lifetime of mature spruce stands. They represent

a complex means to express potential effects of air pollution not only in mountain forests. There are 4 zones as follows: A: less than 20 years – 6.3%; B: 21 to 40 years – 28.1%; C: 41 to 60 years – 65.6%; D: 61 to 80 years – 0% of mountain forests.

Damaged mountain forests were frequently situated in rock fields exposed to intro-skeletal erosion (removal of organic and inorganic soil into deeper layers of the mantle rock). Accompanying phenomena are drying and withering of original ground vegetation, its decomposition, and faster mineralization of forest litter and subsequently surface stoniness.

Construction and forest road network use, regeneration method, logging and skidding technology, and soil preparation technology for reforestation influenced the production capacity of sites and water quality in streams through erosion in the conditions of air-pollution disaster. Fear of floods increased because mountain regions are crucial areas for their origin. Also great changes in the groundwater level and water regime of soils occurred.

Impacts of global climate changes on the stability of mountain forests ecosystems represent still an open question. The inputs of particular factors and harmful agents into the ecosystems and their synergistic relations and dynamics of their development are not precisely known up to data.

Nevertheless, it is supposed that mixed autochthonous stands composed of local tree species ecotypes (beech, silver fir, spruce, sycamore, mountain ash, birch, etc.) should adapt themselves much better than allochthonous spruce monocultures. A long-term priority is to increase the proportion of broadleaved, particularly of European beech and sycamore.

Monitoring of forest condition

Investigation of forest status was provided, except of forestry research, in long term perspective by Forestry Management Institute on so called "permanent sample plots". This activity on assessment of forests health development began in fifties, when the first sample plots was created mostly for monitoring of SO_2 effect on forest stands. These plots were later used for the creation of the supranational grid of ICP Forests. In consecutive years another stresses and damages agents has been shown, unfortunately mostly in the interactive synergy. The identification of the extent and priority causes of these stress factors was not easy and thus, it was, and is, not possible to divide the immission effect from other stresses affecting forests. There was necessary to monitor the entire changes in forest ecosystems. Květoň Čermák, director of Forestry Research Institute introduced this idea of very first endeavour for the ecosystem approach in the beginning of 50ies.

A monitoring of the forest stands damage level covered the whole country in the beginning of 80ies. Except of investigation of forest stand state, also soil conditions, forest stands nourishment, growth characteristics and air quality have been assessed (cf. UN/ECE, EC 1997, 2003).

Czech Republic joined the Programme since very beginning – in 1986 there were together 61 monitoring plots in the grid 16 × 16 km.

In 1991, a denser grid of 8 × 8 km with another 334 plots was created and except of it so called regional studies in the grid 1 × 1 km in the natural forest regions Šumava, Brdy and Krkonoše. Later the similar study was realized in the Beskydy Mts. Results from these plots brought mainly detailed and representative information on forest condition in particular regions and compare health condition of forest stands with their nourishment.

Currently the assessment of 291 sample plots with 14,432 trees is provided in the regular 16 × 16 km transnational grid according methods corresponding to those of the ICP Forests Manual and the relevant EU/EC Regulations. It represents 24 forest tree species in elevations from 150 to 1,300 m above sea level. In a long-term trend the main indicator – defoliation – has an increasing tendency, in particular by older coniferous trees. Nevertheless, a dynamics of this development was considerably decreased in 90ies. Also latest development of the decrease of the total emission is mentioned, particularly of sulphur oxides, description of influence of other pollutants and effect of weather conditions.

Regular national investigation in Level I, is provided also on selected 8 × 8 km network. Both the networks comprise 300 plots regularly distributed according to the forest percentage over the whole territory of the Czech Republic. Plots are situated into the forest stands so that they could well characterize the defined site and stand conditions.

So called Coordinating Centre East existed in the beginning of 90ies in the Forestry and Game Management Research Institute at Jíloviště-Strnady aimed to the extension of the ICP Forests to the Eastern European countries in transition (CEEC/CIT). There were organized coordination meetings, inter-calibration training courses and short study visits of foreign participants in the FGMRI with the financial support of the UN ECE (cf. UN/ECE 1998). Also Task Force Meetings of ICP Forests were organized twice in the Czech Republic.

At the same time closer collaboration with CEECs has been also supported when EC "claimed" the programme through the financial support and creation of respective legislation.

Czech Republic signed the Strasbourg Resolution No. 1 and obligations of the Programme fulfilled the decision confirming that ICP Forests will represent follow-up of this resolution.

From the viewpoint of the long-term development the defoliation, as a main sign used, has an increasing trend. This is typical mostly in the case of old coniferous trees even though the dynamics of this trend has been significantly declined in beginning of the 90ies. Defoliation development of broadleaved has been slightly different. There was decline in 1998 but in following years the consecutive worsening has been recorded.

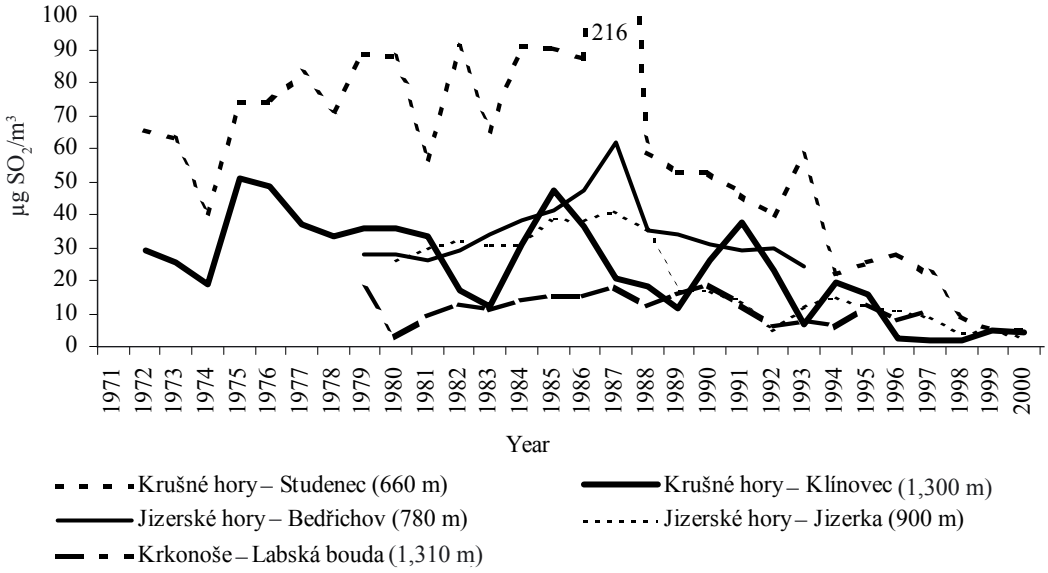

Fig. 1. Average annual SO_2 concentrations at selected mountain forests stations (1973–2001)

Decrease of total emission has occurred in the last years (particularly of SO_2 – Fig. 1 – and solid particulates), the emission of other pollutants has remained approximately at the same level since 1995. Of course, reviewing of development is possible after some time, as forest stands usually reacted on site change and changes of emission situation with certain delay.

Since 1995 also the monitoring on so called "Level II plots" has been performed. Investigation of some of those plots is carried out in the frame of the projects solved by the Ministry of Environment. This intensive evaluation of health state is currently carried out on 14 plots, eight of them are in Norway spruce stands, two are in mixed stands and four are representing broadleaved. All together 918 trees of 14 species were assessed according the common methodology. Crown condition – defoliation, increment, number of needle year classes, phytocoenological observations, foliage, soil and tree ring analyses, deposition, both bulk and throughfall, were observed and measured and also meteorological parameters are continuously assessed at several plots.

Quality, quantity and time dynamics of air-pollution stress have been monitored to describe the type and extent of damage to forest ecosystems that have crucial consequences for the choice of tree species composition in regeneration targets and setting up the fundamental principles of tending and regeneration. Again, fragile mountain forest ecosystems have been a subject of special interest.

Maximum 30-minute SO_2 concentration in the air amounted to about 2,500 μ/m^3 in the Ore Mts. in 1997. The air pollution load is relatively lowest in Šumava, Novohradské hory and Jeseníky Mts.

Enormous problems brought the winter season of 1995 to 1996 to the Ore Mts. Acute injury occurred caused by long-term extreme conditions, high concentrations of SO_2 and unfavourable climatic conditions. A combination of high concentrations of phytotoxic substances and persistent rime presence was on behind and resulted to the loss of about 3,000 ha of mostly young stands.

Recently, damage to forest stands caused by ozone has increased in mountain regions (particularly in Šumava, Slavkovský les, Ore Mts., Jizerské hory and Krkonoše Mts.).

In the last decade when SO_2 and NO_x concentrations significantly decreased, acid atmospheric deposition started to be a serious health hazard for mountain forests in the Czech Republic. It is monitored i.a. in mountain forest watersheds under BIOGEOMON project.

Also remote sensing using the Landsat satellite images of is considered as very important. The Forestry and Game Management Research Institute collaborates with the company Stoklasa Tech., involved in this defoliation and mortality assessment method already since 1994. Information evaluated from satellite images is possible to verify on the basis of terrestrial investigation – and ICP Forests having plots throughout the whole country represents a good source for such verification (Fig. 2).

Average damage and mortality degree is observed and their trend is assessed with the aim to forecast the future development. A terrestrial defoliation assessment is burdened by certain error due to the observer's subjectivity during the whole observation period. The statistical counterbalancing of such assessment based on two alternative models (ICP1 and ICP2) represents an attempt to eliminate this subjective influence. Such adjustment is practised on all monitoring plots (in the picture below presented in a chosen plot No. G240 representing spruce stands of highlands). The visual observation (ICP) and its balancing models are compared with results of remote sensing observation of defoliation using the Landsat TM (LTM) images.

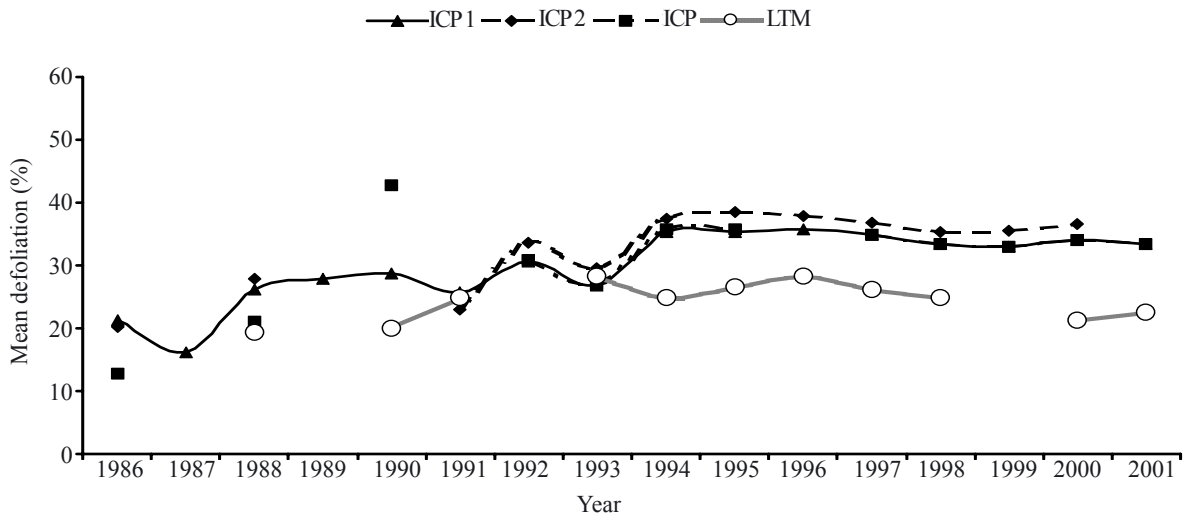

Fig. 2. Development of spruce defoliation on the monitoring plot No. G240 – Horní Benešov according to the ICP (statistical model ICP1 and 2) and Landsat TM

Relation to criteria and indicators of sustainable forest management

Monitoring of forest condition is also important as internationally accepted tool for investigation and assessment of criteria and indicators of sustainable forest management. The Czech Republic has adopted the complete set of Helsinki Criteria and Indicators and also because of problems mentioned, another complementary national indicators have been added (share of salvage fellings, share of broadleaved in reforestation and in total forest area). Regularly are monitored for example depositions of air pollutants (Table 1) and changes in nutrient balance and acidity (Table 2).

CONCLUSIONS

Since the beginning of nineties, changes have been occurred in the composition of pollution and their total amount was downsized also due to the lower industrial production in the beginning of transition stage.

The ICP Forests Programme represents only one activity that covers the whole territory of the country and offers information in the harmony with the precise European methodology. It has, of course, great importance from the point of view of the long-term character of investigated problem and its Pan-European extent. ICP methodology became a unifying element of the whole scale of monitoring systems and its manual is broadly used in national level. If we understand that the cross-sectoral approach to forestry issues is needed, this programme and its system provide a multifunctional monitoring approach.

Unfortunately, the knowledge of different ecosystems responses to progressive civilization pressures is currently poor. Changes in ecological conditions will likely bring changes in ecosystems structure, in their function and production. Conditions of particular forest vegetation zones will certainly change to some extent, but no greater shift is expected, as forest ecosystems are relatively conservative objects. Particularly changes in the soil are very slow, especially in comparison with climate changes.

Trend of defoliation of all species in the last decade gives the general overview on situation in the Czech Republic (Table 3).

Forest inventory programme (2001–2004) supposes various measurements referring to biodiversity. The same methodology should be used in ICP Forests plots. Ground vegetation diversity assessment should continue e.g. in nuclear power plants surroundings (interrupted in 1990). ICP plots with broadly distributed species should serve also to investigate possible global change. Because of climatic extremes there is a need to compare the health status of forest stands with meteorological figures, e.g. Lang's rain factor. Meteodata are considered as important.

A project of forest ecosystems complex monitoring is currently performed. Aim of the project is to sort

Table 1. Total amount and change in depositions of air pollutants (assessed in permanent plots)

Locality	Year	H^+	NO_3, P^-, Cl^-, SO_4^{2-}	Na^+, Mg^{2+}, Ca^{2+}, K^+	NH_4^+
Moldava Erzgebirge/Ore Mts.	stand 1991	0.220	3.066	2.570	1.336
	stand 1996	0.072	3.026	2.324	0.590
Želivka Bohemian-Moravian Uplands	stand 1991	0.715	5.722	2.906	1.816
	stand 1996	0.140	3.422	2.253	0.561

Table 2. Changes in nutrient balance and acidity (pH and CEC); level of saturation of CEC on plots of the European network or of an equivalent national network

Assessment of ICP Forests Plots

pH $CaCl_2$	O horizon			M 01 horizon			M 12 horizon		
Year of investigation	1986–1988	1991	1995	1986–1988	1991	1995	1986–1988	1991	1995
Number of plots	53	206	108	53	206	108	53	206	108
Max. frequency	3.2	3.1–3.5	3.1–3.5	3.2–3.4	3.3–3.5	3.3–3.5	3.6–3.8	3.6-3.8	3.6-3.8
Min.	2.9	2.9	2.9	2.7	2.9	2.9	3.1	3.0	3.0
Max.	4.8	4.7	4.7	4.3	4.1	4.1	4.1	4.2	4.2

pH H_2O	M 01 horizon			M 12 horizon		
Year of investigation	1986–1988	1991	1995	1986–1988	1991	1995
Number of plots	53	206	108	53	206	108
Max. frequency	3.7–3.9	3.8–4.2	3.9–4.2	4.2–4.4	4.0–4.2	4.0–4.2
Min.	3.4	3.5	3.5	3.8	3.4	3.6
Max.	4.9	4.7	4.7	4.7	5.0	5.0

CEC	M 01 horizon			M 12 horizon		
Year of investigation	1986–1988	1991	1995	1986–1988	1991	1995
Number of plots	53	206	108	53	206	108
Average	15.02	11.00	8.10	6.92	7.23	6.07
Min.	3.96	1.60	1.36	3.95	1.00	1.13
Max.	30.78	32.20	14.11	17.58	21.10	16.37

O – organic horizon, M01 – mineral horizon enriched by humus ca. 0–10 cm, M12 – mineral horizon ca. 10–20 cm, CEC – cation exchangeable capacity, Max. frequency = variable or span of variables with maximal frequency

Table 3. Trend of defoliation of all species in 1991–2002 (ICP defoliation classess 2–4)

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
%	45.3	56.1	51.8	57.7	58.5	71.9	68.6	48.8	50.4	51.7	52.2	53.4

out the existing activities carried out at the sector level in monitoring of forest health and its causes, to unify methods, and to reach unique interpretation of results at national and regional levels. Another target is to include possible new projects into the system, to avoid duplicity, and to offer synoptical data and well-arranged materials for the next evaluation of data available. The optimization of current network is very important, as the lack of communication among various subjects dealing with monitoring activities, e.g. on the regional level still exists. Also the harmonization of sampling, analyses of foliage and soil samples, registration and record keeping unification of samples, as well as accessibility of results and unification of laboratory methods are pursued.

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Vývoj stavu lesních porostů a jejich monitoring v České republice

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ABSTRAKT: V roce 1986 ustanovila Ekonomická komise Spojených národů pro Evropu (UN ECE) *Mezinárodní program ochrany lesů před imisemi* (International Cooperative Programme on Assessment and Monitoring of Air Pollution Effect on Forests – ICP Forests) jako reakci na vzrůstající zájem o poškozování lesů, způsobené nárůstem imisí na začátku osmdesátých let. Panevropská síť monitorovacích ploch ICP Forests představuje jednu z nejdůležitějších soustav sledovaných a hodnocených ekosystémů. Problém imisí je v České republice bohužel dlouhodobě aktuální, země se proto k tomuto programu připojila již v jeho začátcích. Příspěvek přináší obecné informace o vývoji porostních poměrů v České republice, které byly získány jak rozličnou metodikou v minulosti, tak v rámci programu ICP Forests. Účast na mezinárodním programu ICP Forests představuje příspěvek kandidátů Evropské unie, nutný k plnění nařízení EEC č. 3528/86. I když se zdá, že síla a význam imisí klesá, objevuje se mnoho nových stresujících faktorů, které zdůrazňují nutnost pokračovat v programu ICP Forests.

Klíčová slova: lesní ekosystémy; monitoring; mezinárodní spolupráce; Ekonomická komise Spojených národů pro Evropu (UN ECE); porostní poměry; defoliace; abiotické a biotické faktory; znečištění ovzduší; dálkový průzkum Země

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