Forest Health Monitoring and Forestry Implications in the Czech Republic[1]

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Abstract

In recent years, a forest monitoring program in the Czech Republic was extended into more detailed monitoring that aimed to describe the extent of changes in forest vitality and identify the nature and the main causes of these changes on local and regional scales. Studies were undertaken in six mountain areas in the Czech Republic. The program of regional forest monitoring is divided into three levels according to the extent of evaluation of the parameters of forest stand health and other components of the forest ecosystem. Level 1 is large scale monitoring in a 1 by 1 km grid of permanent plots. The total number of plots in a single regional study varies from 60 to more than 500. The monitoring at level 1 plots includes a visual assessment of a broad set of features of the health state of individual trees, repeated yearly. Assessment of health includes measurement of tree diameter and height and a basic description of growing conditions. At monitoring level 2 the research assessment is extended to other parameters that characterize the forest stand and environment. The number of plots is usually 5-10 percent of level 1 plots. Monitoring level 3 includes analysis of the processes of nutrient cycling. Detailed analysis of stand structure is done at the plots, including biomass measurements. Results of field measurement are recorded into a database which allows a logical organization of a large amount of data and effective processing of them. Results of monitoring are analyzed using statistical methods and modeling. A geographical information system (GIS) is used for further analyses and for a final interpretation of results. From some studies, 4-5 years of results are now available. The studied regions cover a broad range of conditions, making it possible to assess global trends in the health of Czech forests.

Introduction

Forests in the Czech Republic cover an area of 2,642,064 ha. This corresponds to 33.4 percent of the total area of the Republic. Mean timber volume of forests is 225 m^3/ha and mean annual increment is 6.91 m^3/ha. Conifer species occupy 79 percent of forest area, and the main tree species is Norway spruce, occupying 54 percent of forest area. The primary forest regions of the Czech Republic are mountains located mainly along the mountainous border *(fig. 1)* areas.

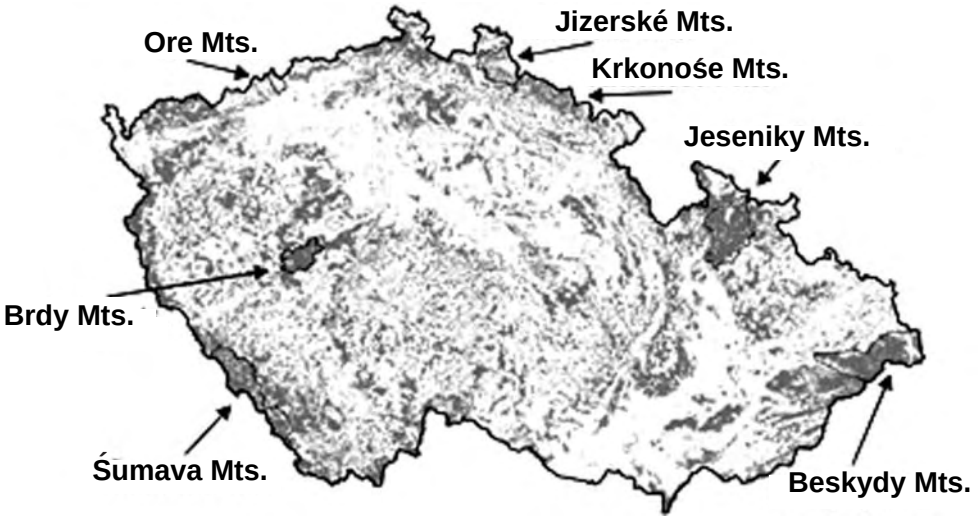

Figure 1 — Forest coverage of the Czech Republic, and location of main mountain ranges (interpretation of LANDSAT TM image done by Stoklasa TECH, Prague).

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The Czech Republic, particularly the north-western part (Ore Mountains) has been strongly influenced by air pollution for the past several decades. A well-known "ecological disaster" began in the Ore Mountains in the 1950's and 1960's. Ten years later severe problems started in the Jizerske Mountains and Krkonose Mountains. The significant decrease of land covered by forests is visible in these previously forested areas *(fig. 1)*; however, almost all deforested areas are now covered by young stands.

At the beginning of the 1980's the symptoms of forest decline were also observed in northern Moravia (Beskydy and Jeseniky Mountains), and by the mid-1980's symptoms were observed in western and southern Bohemia (Brdy Mountains, Sumava Mountains, etc.).

At the same time the forests have been impacted by air pollution in some areas, increased forest increment has been recorded in the Czech Republic based on the data from regular forest inventories and data from permanent research plots. Thus, it has been proved that during the past 100 years, the current height increment of Norway spruce increased from 25 to 35 percent. On the other hand, the clear differentiation of tree growth within individual forest stands related to the symptoms of forest decline has been documented by data of tree ring analyses *(fig. 2):* the diameter increment decreases with increase of health damage symptoms (e.g.,tree defoliation). This example of the contradiction between forest decline and the continuous increase of height increment of Norway Spruce in the mountains of the Czech Republic clearly indicates the need for additional research.

This paper discusses the various forest health monitoring programs implemented in the Czech Republic that provide current data to forest policy makers for the improvement of forest health.

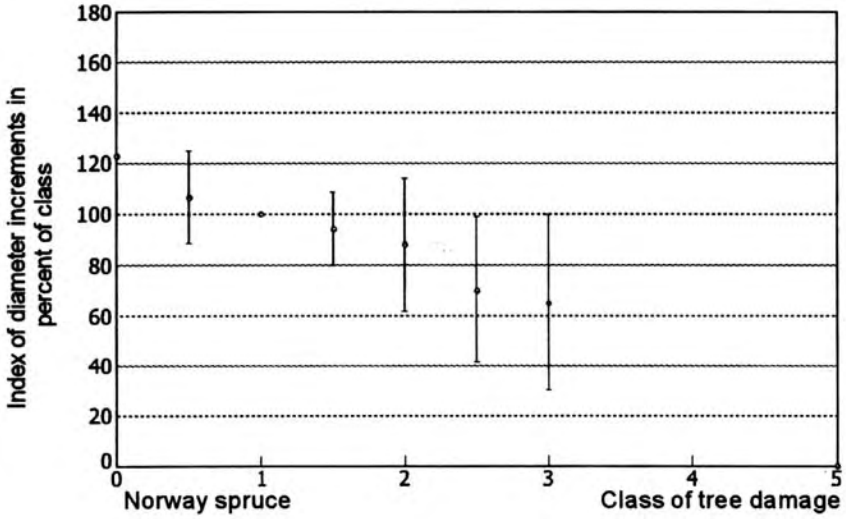

Figure 2 — Relationship between tree damage (classes of tree defoliation) and diameter increment. Index of diameter increment compares the current increment of the past 5 years to the previous 5-year period.

Initial Conditions and Forest Health Monitoring Programs

Forests of the Czech Republic are endangered by the continuous influence of a range of stress factors. These factors disrupt forest ecosystems and cause the forest decline. The significance of potential stress factors is time and area specific. Among the stress factors, sulfur dioxide is still important, although it has gradually decreased over the past years. Ozone, nitrogen oxides, and the influence of potential climatic changes should also be considered. The impacts of complex stress factors have not been sufficiently described.

The pan-European forest monitoring program (ICP Forests) has been implemented in most of the European countries to provide policy makers with basic information on forest health. Within this program a standardized methodology has been developed, and data exchange is supported. The Czech Republic has participated in the ICP Forest program since its establishment in 1986.

However, in the Czech Republic several systems of forest monitoring or research monitoring have been established over the past few decades. These systems have similar scientific aims as the ICP Forest programs, but were designed independently with more or less different methodologies.

In addition to the forest monitoring program, the regular forest inventory is used to estimate forest health status for practical forest management. Forest inventory data describing the whole area of the Czech Republic has been collected every 10 years. A planned national forest inventory program using a regular grid of permanent inventory plots will contribute additional information on forest health. Several other monitoring programs addressing different environmental components (air pollution, agricultural land, etc.) have also been implemented in the Czech Republic under the direction of the Czech Ministry of Agriculture and the Czech Ministry of Environment.

During the past two decades, remote sensing technology has improved significantly. With the support of terrestrial monitoring, remote sensing can serve as a fast and efficient source of information on forests health status. However, because the level of available information is limited to descriptive information on several stand characteristics, it cannot be used to determine causal relationships.

Forest management practice lacks information that is necessary for ecosystem oriented management on local and regional levels. Forest monitoring should serve as a permanent source of continuous information enabling forest managers to evaluate results of management procedures on a regional level and evaluate and reorient forestry policy on the national level.

A system of forest monitoring should be developed to both follow changes in forests, and to identify main potential stress factors. On the basis of the correlative analysis of forest state parameters and characteristics of the growing environment, hypotheses can be derived and then tested by the detailed research on ecosystem mechanisms.

Objectives of Forest Monitoring

Forest monitoring is defined as the long-term investigation of the state of the forest and growing environment by using a set of selected parameters that allow evaluation of forest changes caused by environmental changes and forest management practices.

The primary aims of forest monitoring programs are to clarify the extent of changes in forests in the Czech Republic, describe the character of these changes, and estimate the main causes of changes. The forest monitoring program should also be a unified and internationally compatible system.

Structure of Forest Monitoring

The forest monitoring program in the Czech Republic is differentiated into separate subprograms according to the topics addressed within the program *(table 1)*.

- **Permanent Sample Plots:** The set of permanent sample plots was established in the 1960's to collect data on the growth of stands of the main tree species found in the Czech Republic. These data were collected to develop regional growth and yield tables. Most of the plots are still active and produce valuable information on the development of the forest ecosystem.

- **Regional Forest Monitoring:** Regional forest monitoring is derived from the European program of forest monitoring. For the purposes of local forest managers, and regional authorities in forestry and the environment, the information from the sparse European grid of monitoring plots (16 x 16 km) is not satisfactory. For that reason a dense grid, 1 x 1 km, has been established in selected regions of the Czech Republic. Currently, there are five such regions, and several additional smaller areas are also covered by using this approach.

- **Large Scale Forest Inventory:** Large scale forest inventory by using a terrestrial survey in the grid of permanent inventory plots is one of the main tools for collecting data about forests and forest production. Recent developments in large scale forest inventory methodology allow the evaluation of forest ecosystem status including biodiversity.
- **ICP Forests:** The Czech Republic has participated in the program of European monitoring (ICP Forests) since its beginning in 1986. The data collected in the 16 x 16 km grid are used for the purposes of European forest policy.
- **Remote Sensing:** Satellite imagery from LANDSAT TM data is widely used for the estimation of forest health status.

Forest Monitoring Projects in the Czech Republic

The forest monitoring program in the Czech Republic is coordinated by the Czech Ministry of Agriculture and Ministry of Environment *(table 2)*. Except for ICP Forests, all monitoring projects are funded by grants.

Methodology of Terrestrial Forest Monitoring

The methodology of terrestrial forest monitoring has been derived from European unified methodology for ICP Forests *(table 3)*. The methodology is split into three levels. Level one is applied to all monitoring plots. Level two is used in about 10 percent of the monitoring plots, and separation into level two is defined by the additional cost of methodological procedures.

Table 1 *— Different programs of forest monitoring in the Czech Republic.*

Program	Subject	Characteristics	Size of area unit	Intensity of research	Interval (years)	Application of results
Permanent sample plots.	forest ecosystem.	forest health, environment, production, forest structure.	-	medium to high	1-5	cause-effects studies, modeling, support of decisions on conceptual level.
Regional monitoring.	site, region.	forest health, environment, production.	small	high	1	detailed characteristics of selected region, planning on the regional level, forest improvement measures.
Large scale inventory.	region, country.	structure of forests, production, ownership, quality of management, forest health.	medium to small	medium	5-10	large scale forest inventory, forestry planning, management politics.
ICP Forests.	country.	forest health, environment, production.	large	medium	1	current state of forest health on country level.
Remote sensing.	country, region, site.	forest health, changes in forest coverage.	small	low	1 and more	current information on state of forest.

Table 2 *— Terrestrial forest monitoring network in the Czech Republic.*

Project	Forest area covered, ha	Grid km x km	Number of plots	Level of monitoring	Time of project execution	Run by
National monitoring network						
Permanent sample plots	2,650,000	non regular	900	I, II	1980+	IFER [1]
ICP Forests	2,650,000	16 x 16	126	I, (II)	1986+	FGMRI [2]
Large scale forest inventory	2,650,000	1.41 x 1.41	13,000	I, (II)	([3])	(IFER)[4]
Regional monitoring network						
Brdy Mts.	23,000	1 x 1	220	I, II, III	1989+	IFER
Sumava Mts.	60,000	1 x 1	528	I, II, III	1990+	IFER
Krkonose Mts.	30,000	1 x 1	262	I, II, III	1991+	IFER
Beskydy Mts.	45,000	1 x 1, 4 x 4	176	I, II, III	1992+	IFER
Jizerske Mts.	20,000	1 x 1	120	I	1992-93	IFER
Other local projects	25,000	1 x 1	55	I	1992+	IFER

[1] Institute of Forest Ecosystem Research, Jilove u Prahy

[2] Forestry and Game Management Research Institute, Jiloviste-Strnady

[3] Planned for 1999.

[4] Development of methodology phase

Level three includes procedures that evaluate the ecosystem nutrient cycle and is performed to characterize growing conditions of the forests. The data of field assessments are stored in the MONitoring dataBASE. Version 5 of MONBASE allows efficient computer storage of data as well as implementation of the set of basic processing routines. Pre-processed data are further analyzed and evaluated by using GIS techniques. Point layers of terrestrial monitoring data are combined with interpretation layers (e.g., interpreted satellite images, forest soil maps, forest types maps, and climate maps). By using GIS techniques like co-kriging and multicriteria analysis, the monitoring data are processed and interpreted for further use in forest management practice.

Conclusions

The forest monitoring program in the Czech Republic has significantly developed during the past 5 years. The primary features of the program include a general monitoring approach that is performed in cooperation with other research programs on permanent research plots in the Czech Republic (forest production research plots, forest inventory). Forest monitoring data are interpreted for use by forest managers, and the emphasis is on developing cause-effect relationships.

The unified methodology of the program uses three levels of research monitoring (up to ecosystem level) and extends to cause-effect relationships. The regional forest monitoring network uses permanent research plots (including sites that are less common but important ecologically) and has been extended to several new regions.

The database used for forest monitoring is MONBASE version 5, which is a flexible tool for handling monitoring data. Progressive methods of data processing and evaluation include statistics, GIS, and modeling. Forest damage and production data are interpreted by decision makers and forest policy makers at both national and regional levels. Forests are then zoned according to the level of risk (as a result of multicriteria analysis), and they are managed on the basis of nutrition and species composition. By understanding these forest ecosystem processes, policy makers can apply the monitoring results in forest production research for better management of the Czech forests.

Table 3 *— Methodological elements for different terrestrial forest monitoring levels.*

Level of monitoring	Element of methodology	Extent	Interval
I	**Level one:**		
	basic descriptive data	plot	once
	humus forms	plot	6-12 yrs
	soil chemistry	plot	12 yrs
	needle/leaf chemistry	plot	6 yrs
	phytocenological description	plot	10 yrs
	natural afforestation	plot	3 yrs
	occurrence of lichens	plot	1 yr
	tree species	trees (all)	1 yr
	tree class	trees (all)	1 yr
	mortality of trees	trees (all)	1 yr
	occurrence of crown/stem break	trees (all)	1 yr
	defoliation of whole crown	trees (all)	1 yr
	defoliation of upper third of crown	trees (all)	1 yr
	vitality of the crown tip	trees (all)	1 yr
	occurrence of dead branches	trees (all)	1 yr
	mechanical injury to the stem	trees (all)	1 yr
	type of color changes (discoloration)	trees (all)	1 yr
	intensity of color changes	trees (all)	1 yr
	diameter at breast height	trees (all)	3 yrs
	tree height	trees (10-15)	3 yrs
	occurrence of secondary shoots	trees (5-10)	1 yr
	needle retention	trees (5-10)	1 yr
	occurrence of combs	trees (5-10)	1 yr
	crown ratio	trees (5-10)	1 yr
	angle of branching	trees (5-10)	1 yr
	type of branching	trees (5-10)	1 yr
	injury caused by insects	trees (all)	1 yr
II	**Level one plus:**		
	humus forms	plot	3 yrs
	soil chemistry	plot	6 yrs
	soil profile description & chemistry	plot	12 yrs
	needle/leaf chemistry	plot	3 yrs
	small root vitality	plot	6 yrs
	core analyses	trees (10)	once
	LAI measurement	plot	1 yr
III	**Level two plus:**		
	soil solution chemistry	plot	2 weeks
	wet/dry deposition chemistry	plot	2 weeks
	amount & chemistry of litter	plot	1 month
	air pollution/passive samplers	plot	2 weeks
	cont. measure. of tree diameter incr.	trees (10)	1 month
	detail stand structure description	plot	10 yrs