Dynamics of Forest Health Status in Slovakia from 1987 to 1994[1]

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Abstract

*Slovakia is a mountainous and forested country (40.6 percent forest cover) in central Europe and has a large variety of vegetation zones, forest types, and a rich diversity of forest tree species. The most important tree species are beech (*Fagus sylvatica *L.), Norway spruce (*Picea abies *Karst.), oak species (*Quercus *sp.), Scots pine (*Pinus sylvestris *L.), silver fir (*Abies alba *Mill.), European hornbeam (*Carpinus betulus *L.), European larch (*Larix decidua *Mill.), poplars and willows (*Populus *L. sp.,* Salix *L. sp.), and other hardwood broadleaves. On the basis of results of the Forest Health Monitoring System from 1987 to 1994, the scientific information is presented for the following parameters: defoliation, discoloration, percentage of tree number in classes of damage, and percentage of salvage cut in the total annual cut. The percentage of trees in the defoliation classes 0, 1, 2, 3, and 4 were 14.7, 43.5, 36.2, 4.3, and 1.3, respectively (class 0 means healthy trees; class 4 dead trees). The discoloration classes (0, 1, 2, 3, and 4) were represented by 98.0, 1.7, 0.3, 0, and 0 percent for all tree species together. The average defoliation percentage from 1987 to 1994 decreased with time and is expected to further decrease in the following years. However, the percentage of annual salvage cut in the total annual cut increased between 1987 and 1994. Various biotic and abiotic factors influence forest health in Slovakia, such as air pollution, wind and snow, damages by beetles, sucking insects, and game. Global climate change seems to be the most important among them.*

Introduction

Forest health status is a phenomenon studied and monitored in central and eastern Europe, where the natural vegetation cover consists of forests and where forestry is an important part of the economy. Numerous scientific and scientific-technical projects have been involved in the process to describe the main factors influencing the health status of forest trees and to propose measures that could partially solve the problem of forest decline.

Because Slovakia is a mountainous and forested country (about 1.94 million ha. of forest, i.e., 40.6 percent of the total area), it is important to study changes in forest health status. Because of the mountainous character of the country, forested habitats in Slovakia encompass a wide range of environmental conditions and elevations (*table 1*). Trees are subjected to many natural stresses, including those induced by changes in water and nutrient relations, light, temperature, and biotic factors. Because of their longevity, trees usually react to the changes abruptly, and very often they are not able to adapt themselves to the changed growing conditions.

The dominant forest types in Slovakia are the beech (*Fagetum pauer*, *Fagetum typicum*), beech-oak (*Fageto-Quercetum*), and oak-beech (*Querceto-Fageto*m, *Fagetum dealpinum*) types, which together cover about 52 percent of the total forest area. Beech-fir (*Fageto-Abietinum*), fir-beech (*Abieto-Fagetum*), and fir-beech with spruce (*Fagetum abietum - piceosum*) forests cover an additional 25 percent. Other locally important forest types include pine-oak and oak-pine (*Pineto-Quercetum* and *Querceto-Pinetum*, 1.96 percent), Cornel oak forests (*Corneto-Quercetum*, 0.91 percent), oak-ash forests (*Querceto-Fraxinetum*, 0.41 percent), elm-ash forest (*Ulmeto-Fraxinetum populeum* and *Ulmeto-Fraxinetum carpineum*, 1.07 percent), hornbeam-oak forest (*Carpineto-Quercetum*, 6.99 percent), acid oak-beech forest (*Fagetum quercinum*, 2.69 percent), linden-maple forest (*Tilieto-Aceretum*, 0.63 percent), ash-maple forest (*Fraxineto-Aceretum*, 2.28 percent), dealpine pine forest (*Pinetum dealpinum*, 0.96 percent), fir-spruce forest (*Abieto Piceetum*, 2.84 percent), mountain ash-spruce forest

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(1.02 percent), maple-spruce forest (*Acereto-Piceetum*, 0.53 percent), and dwarf pine forest (*Mughetum,* 0.60 percent).

According to the newest forest inventory results (Novotny and others 1994), the tree species percentage in the Slovakian forests include:

Species	*Percent*
Norway spruce (*Picea abies* Karst.)	27.2
European larch (*Larix decidua* Mill.)	2.0
Silver fir (*Abies alba* Mill.)	5.0
Scots pine (*Pinus sylvestris* L.)	7.0
Oaks (*Quercus* L. sp.)	14.3
Beech (*Fagus sylvatica* L.)	29.8
European hornbeam (*Carpinus betulus* L.)	5.6
Other hardwood broadleaves	4.5
Poplars and willows (*Populus* L. sp., *Salix* L. sp.)	3.5

Slovakia is situated in the central European region where prevailing northwest winds bring pollutants from the industrial areas in the Czech Republic, Poland, and Germany. Air pollution effects on forests have become critical in the past decades in Slovakia. Other causal factors affecting forest health in Slovakia include soil pollution, wind damage, snow damage, damage by bark-beetles, damage by wood-destroying beetles, damage by phytophagous and sucking insects, browsing damage, and bark peeling (game) damage.

Like most other European countries, Slovakia began a forest tree health monitoring program, which started in 1987 and continued through summer 1995. The ninth monitoring cycle concentrated on the permanent network of forest health monitoring plots (16 by 16 km grid). According to the methods used in the European forest health monitoring system, the permanent monitoring plots, which have no specific size, contain 15 trees close to the center of the plot and are used for measurement and observations.

This paper discusses the results of the forest health monitoring system in Slovakia that studied these parameters: tree stem circumference at the height of 1.3 m above the soil surface (the diameter at breast height calculated—dbh); biosociological position of trees (Kraft tree classes scale); loss of assimilation apparatus (defoliation); heights of three trees (by Blume-Leiss hypsometer); fertility of trees; mechanical damage on trees; fungi; and insects.

Table 1— *General survey of forested habitats divided into vegetation zones.*

Vegetation zone	Altitude (m a.s.l.)	Mean annual temp. (°C)	Annual precip. (mm)	Vegetation period (days)
Oak	<350	>8.0	<600	>165
Oak beech	350-400	7.5-8.0	600-650	160-165
Beech-oak	400-550	6.5-7.5	650-700	150-160
Beech	550-600	6.0-6.5	700-800	140-150
Fir-beech	600-700	5.5-6.0	800-900	130-140
Spruce-beech	700-800	4.5-5.5	900-1,500	115-130
Beech-spruce	900-1,050	4.0-4.5	1,050-1,200	100-115
Spruce	1,050-1,350	2.5-4.0	1,200-1,500	60-100
Dwarf pine	>1,350	<2.5	>1,500	<60

Methods

The numerous data and information obtained from the network of forest health monitoring plots (monitoring was performed August 11-20) provide excellent material for studies. Results that concentrated on the most visible changes on the forest trees document a more complicated system of causal factors responsible for the health of the forests. The variety of anthropogenic causal factor complexes have interacted with natural events and processes that induce stresses in forests and can be observed as ecological response.

Numerous papers (Lapin and others 1994, Lapin and others 1995, Lapin 1995) give information on trends of means of temperature and precipitation in different parts of Slovakia, starting in the year 1870. Results from localities situated in the lowland of south Slovakia and in the mountains in the north document a positive tendency in mean annual temperature and negative tendency in precipitation totals and in relative air humidity.

Results

Defoliation and discoloration of foliage are considered the best and most significant indicators of the health status of forest trees (*tables 2-6*). Both scientists and forestry managers are convinced that defoliation and discoloration are visible responses of the internal and external influences on the life of the individual tree (Novotny and others 1995).

For the evaluation we used the 5 degree scale of defoliation (Novotny and others 1995) to maintain consistency with data from other European countries. But in the Slovak Republic, narrower defoliation classes (each class is 10 percent) were used because this provides greater precision for the ecological evaluation of forest health and its dynamics in a longer period.

The internationally accepted scale denotes degree of damage (0 to 4) in terms of percent of foliage loss (0 to 100 percent):

0 - healthy trees (without symptoms), 0-10 percent
1 - partially ill trees, 11-25 percent
2 - ill trees, 26-60 percent
3 - very ill trees, 61-95 percent
4 - dead trees, 100 percent.

Table 2 *— Tree species percentage in defoliation degrees (1994) (Novotny and others 1995).*

	Degree of Defoliation						
	0	1	2	3	4	1+2+3+4	2+3+4
	Defoliation (percent)						
Tree species	**0-10**	**11-25**	**26-60**	**61-95**	**100**		
Fagus sylvatica L.	27.5	47.8	23.6	1.0	1.0	72.5	24.7
Quercus sp. L.	1.5	53.9	40.0	2.3	2.3	98.5	44.6
Carpinus betulus L.	30.8	45.7	22.9	0.3	0.3	69.2	23.5
Other broadleaf	3.2	23.0	52.9	16.9	4.0	96.8	73.8
Broadleaf total	19.3	45.1	31.0	3.5	1.1	80.7	35.6
Picea abies Karst.	8.4	41.9	43.6	4.9	1.2	91.6	49.7
Abies alba Mill.	15.6	36.0	37.6	8.6	2.2	84.4	48.4
Pinus sylvestris L.	4.6	40.5	48.1	4.8	2.0	95.4	54.9
Larix decidua Mill.	5.1	57.6	28.8	6.8	1.7	94.9	37.3
Coniferous total	8.2	41.5	43.5	5.3	1.5	91.8	50.3
Total	**14.7**	**43.5**	**36.2**	**4.3**	**1.3**	**85.3**	**41.8**

When the data on defoliation are put into a regression, the negative relationship is obvious. Decrease of defoliation percentage from 1987 to 1994 is related to the changes in the economy of the central European countries: the decrease in industrial activity has resulted in decreased pollution. Air and soil pollution has been responsible for the defoliation and discoloration of trees.

Defoliation is not the only and not the most significant indicator of health state of the forest trees; the salvage cut percentage is also a dynamic indicator. Despite of the fact, that the defoliation has the negative tendency in the studied years, the salvage cut percentage has a positive tendency (*table 7*). There are different causal factors responsible for the salvage cut amount in different years. Among them, the most important are the climate changes that seriously influence the growing conditions at each forest site and subsequently forest health and the stability of forest ecosystems.

The data concerning the degree of defoliation show a trend that is controversial to the trends of forest health status in Slovakia. The salvage cut and its percentage of the total cut is the most appropriate and useful indicator of the forest health status in Slovakia. The salvage cut quantifies the amount of the trees (wood) that had to be cut because of biological and abiological damage. Salvage cut quantifies the ecological instability of part of the forest and the bad health status of the forests. It also signifies the decline of forest health status because the salvage cut percentage is increasing permanently.

The annual cut in Slovakia has been relatively stable (average annual cut from 1991 to 1992 was 4.24 million m^3), but the increasing salvage cut documents the necessity of cutting dead, weakened , and damaged trees in increasing volume (*table 7*).

Discussion and Conclusion

As one of the most forested European countries, Slovakia is characterized by forests containing richness of tree species, ecosystems, habitats, and site diversity. However, the data from the monitoring plots network give us very interesting scientific-technical information that documents the worsening state of forest health, with negative prognosis for the future. Although the importance of the causal factors varies in the respective years, the tendency is clear, and it is negative.

Table 3 *— Tree species percentage in discoloration degrees (1994) (Novotny and others 1995).*

	Degree of discoloration						
	0	1	2	3	4	1+2+3+4	2+3+4
	Discoloration (percent)						
Tree species	**0-10**	**11-25**	**26-60**	**61-95**	**100**		
Fagus sylvatica L.	99.6	0.3	0.0	0.1	0	0.4	0.1
Quercus sp.L.	97.1	1.9	0.6	0.2	0.2	2.9	1.0
Carpinus betulus L.	96.5	3.2	0.3	0	0	3.5	0.3
Other broadleaf	97.1	2.4	0.5	0	0	1.9	0.5
Broadleaf total	98.4	1.3	0.2	0	0.10	1.6	0.3
Picea abies Karst.	99.3	0.3	0.4	0	0	0.7	0.4
Abies alba Mill.	100.0	0	0	0	0	0.0	0.0
Pinus sylvestris L.	90.6	8.9	0.5	0	0	9.4	0.5
Larix decidua Mill.	100.0	0	0	0	0	0.0	0.0
Coniferous total	97.5	2.1	0.4	0	0	2.5	0.4
Total	**98.0**	**1.7**	**0.3**	**0**	**0**	**2.0**	**0.3**

Table 4 — *Tree species percentage in defoliation classes (1994) (Novotny and others 1995).*

Tree species	Defoliation (percent)									
	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100
Fagus sylvatica L.	27.5	28.6	31.9	6.3	3.4	1.3	0.7	0.2	0.0	0.1
Quercus sp. L.	1.5	24.3	52.7	12.8	3.1	1.0	1.3	0.2	0.2	2.9
Carpinus betulus L.	30.8	25.5	37.1	5.7	0.3	0.0	0.3	0.0	0.0	0.3
Other broadleaf	3.2	10.7	26.9	20.1	12.7	5.5	6.9	6.1	3.7	4.2
Broadleaf total	19.3	24.6	35.8	9.5	4.4	1.7	1.7	1.1	0.6	1.3
Picea abies Karst.	8.4	24.8	30.7	16.1	9.2	4.7	2.8	1.3	0.7	1.3
Abies alba Mill.	15.6	25.8	18.8	12.9	10.2	5.9	4.8	2.2	1.1	2.7
Pinus sylvestris L.	4.6	23.7	37.7	18.3	6.1	2.8	1.8	2.0	1.0	2.0
Larix decidua Mill.	5.1	28.7	39.0	11.9	6.8	0.0	3.4	3.4	0.0	1.7
Coniferous total	8.2	24.7	31.3	16.1	8.6	4.3	2.8	1.6	0.8	1.6
Total	**14.7**	**24.6**	**33.9**	**12.3**	**6.1**	**2.8**	**2.2**	**1.3**	**0.7**	**1.4**

Table 5 — *Average defoliation percentage of tree species (1987-1994) (Novotny and others 1995).*

Tree species	Average defoliation (percent)							
	1987	1988	1989	1990	1991	1992	1993	1994
Fagus sylvatica L.	23	19	23	17	13	17	17	21
Quercus sp. L.	24	30	35	31	25	27	27	30
Carpinus betulus L.	18	14	20	18	13	18	25	20
Fraxinus excelsior L.	29	23	29	38	40	38	30	40
Acer sp. L.	39	35	46	39	33	30	29	32
Robinia pseudoacacia L.	32	37	38	74	46	61	51	57
Populus sp. L.	26	40	37	38	45	50	32	36
Broadleaf total	24	23	27	25	19	23	23	26
Picea abies Karst.	34	28	31	29	25	27	29	32
Abies alba Mill.	52	31	39	37	31	33	32	33
Pinus sylvestris L.	40	45	44	44	33	42	29	32
Larix decidua Mill.	24	20	33	33	17	26	27	30
Coniferous total	35	32	35	33	27	29	29	32
Total	**30**	**27**	**30**	**28**	**23**	**26**	**26**	**28**

Defoliation and discoloration are not the only and the most significant indicators of forest health. The tendency of defoliation is negative because the trees lose fewer and fewer leaves by August 15 (their "health state" is getting better), but the other important indicators show the opposite tendencies. For instance, the percentage of the annual salvage cut in the total annual cut is increasing (i.e., the stability of the forest is decreasing).

Among other causal factors, partially influencing the health state are pollution, wind and snow damage, damage by beetles, sucking insects, and game. The most important factor is climate change observed in Slovakia.

To evaluate forest health status, defoliation and discoloration of foliage must be always combined with other parameters, especially the salvage cut percentage, which is the most complete indicator of health of forest trees and of ecological stability of forests.

Table 6 *— Percentage of all tree species in respective damage degrees from 1987 to 1994 in the Slovak Republic (Novotny and others 1995).*

Year and Tree Species		Percentage of tree number in damage degrees							
		0	1	2	3	4	1-4	2-4	3-4
1987	Coniferous	11	36	41	11	1	89	53	12
	Broadleaf	26	47	22	5	0	74	27	5
	Total	**19**	**42**	**32**	**7**	**0**	**81**	**39**	**7**
1988	Coniferous	14	33	43	9	1	86	53	10
	Broadleaf	33	39	23	5	0	67	28	5
	Total	**25**	**36**	**32**	**6**	**1**	**75**	**39**	**7**
1989	Coniferous	9	32	49	9	1	91	59	10
	Broadleaf	20	38	37	4	1	80	42	5
	Total	**15**	**36**	**42**	**6**	**1**	**85**	**49**	**7**
1990	Coniferous	14	30	47	8	1	86	56	9
	Broadleaf	23	45	25	5	2	77	32	7
	Total	**20**	**29**	**34**	**6**	**1**	**80**	**41**	**7**
1991	Coniferous	14	47	34	4	1	86	39	5
	Broadleaf	41	38	17	3	1	59	21	4
	Total	**30**	**42**	**24**	**3**	**1**	**70**	**28**	**4**
1992	Coniferous	15	44	33	7	1	85	41	8
	Broadleaf	31	40	23	5	1	69	29	6
	Total	**24**	**42**	**27**	**6**	**1**	**76**	**34**	**7**
1993	Coniferous	8	42	46	3	1	92	50	4
	Broadleaf	28	43	25	3	1	72	28	4
	Total	**20**	**43**	**33**	**3**	**1**	**80**	**37**	**4**
1994	Coniferous	8	41	44	5	2	92	51	7
	Broadleaf	20	45	31	4	1	80	36	5
	Total	**15**	**43**	**36**	**5**	**1**	**85**	**42**	**6**

Table 7 *— Percentage of the annual salvage cut in the total annual cut in 1985 (Novotny and others 1995).*

Year	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Percent of salvage cut	29.7	31.1	31.9	35.9	41.5	49.2	42.8	43.2	51.7	59.6

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