Forest Health Status in Hungary[1]

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Abstract

Because Hungary has about 18 percent forest area, it is not as densely forested as most of the countries in Europe. Forests are dominated by native species such as oaks, beech, hornbeam, and other broadleaves. As a result of an intensive afforestation in the last 50 years, introduced species, such as black locust, Scots pine, and improved poplars were widely planted and forest area increased by 50 percent — to 18,000 km^2*. Several observations in Hungary from the early 1980's detected an unusual amount and type of forest damage affecting native and introduced species. A shocking observation was the oak decline sweeping through the country with a dieback rate of 10 to 70 percent within a decade. New methods had to be developed to detect and explain changes of forest health status and forest ecosystems. In close cooperation with the International Cooperative Program on the Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests), a national multi-level monitoring and research program was launched in 1986. The first level of the program — large scale monitoring — accepted defoliation and discoloration as key parameters, but a detailed survey of each sample tree was added. On the basis of the annual survey of about 22,000 trees, a significant increase of defoliation was observed. Although 79 percent of the trees were healthy in 1988, only 44 percent were healthy in 1995. Proportion of damaged trees (defoliation greater than 25 percent) seems to have stabilized at about 20 percent in the last 4 years, close to the average of the European survey results ranging from 6 to 60 percent. Oaks, black locust and Scots pine were particularly heavily defoliated, while beech and hornbeam were only lightly affected. The disturbed balance of forest ecosystems is closely related to the lack of water — a result of river regulation since the 18th century and especially the 12-year period of dry and hot weather in the Carpathian Basin. Although* SO_2 *emission has been reduced by 50 percent since 1980 and* NO_x *by 30 percent since 1987, and direct damages have not been observed, air pollution can be a predisposing factor of forest damages. Additional intensive research is necessary to clarify the role of climatic factors and air pollution effects on forest ecosystems, including direct effects, carbon and nutrient cycling at different sites, and damaging biotic factors.*

Introduction

Because Hungary has about 18 percent forest area, it is not as densely forested as most of the countries in Europe. Forests are dominated by native species, such as oaks (35 percent), beech *(Fagus sylvatica* L) (7 percent), and other broadleaves (13 percent). As a result of an intensive afforestation in the last 50 years, introduced species, such as black locust *(Robinia pseudo-acacia* L), Scots pine *(Pinus silvestris* L), and improved poplars were widely planted and forest area increased by 50 percent to 18,000 km^2. Although the total area of the country is only 93,000 km^2, about 150 tree species and subspecies occupy the landscape as a result of diverse site conditions with a variety of different forest types, ranging from the nearly treeless steppe to the mountainous beech forests.

Different Sources of Information about Forest Damage

Forest health has been a major concern of forest scientists and practitioners and has been continually observed. In the last 40 years different systems have been developed to detect or forecast forest damage.

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Local Damage Report

The traditional and most widely used method was based on the damage reports of forest owners that were collected and evaluated by the Forest Research Institute (FRI). This method is still in use and can provide fairly good results for forestry practice, but it cannot be considered as representative. Thus, its role is limited.

Light Traps

Another program, a network of 25 light traps, has been run for 32 years. This monitoring provides reliable information on insect migrations and gradations. The results are collected and evaluated by the FRI and published annually with special focus on forecasts and recommendations.

Monitoring of Oak Decline

Because of the oak decline in the early 1980's, a specific monitoring program was established in 1987 to follow the development of the disease. Although the decline recently reached its peak, the network is still in use. Similar specific monitoring started at the end of the 1980's in beech forests.

Data are collected by the University of Forestry, the Forest Research Institute, and the crews of the Forest Management Planning Service (FMPS). Sample plots are located in selected stands. The data collection is completed by using visual assessments that apply specific codes describing the different stages of the decline. Reports are published annually.

Large Scale Surveys

Several observations in Hungary from the early 1980's detected unusual amount and type of forest damage affecting native and introduced species. In close cooperation with the International Cooperative Program on the Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) — a European program initiated and run by the Economic Commission for Europe (ECE) of the United Nations under the Convention on Long-range Transboundary Air Pollution — a national multi-level monitoring and research program was launched in 1985. With special regard to the site and climatic conditions in Hungary, the priority of air pollution effects of the international program was accepted, but special emphasis was put on all kinds of different damaging factors.

The forest management plans cover the entire forest area, with a 10-year renewal period. The methodology was extended by the FMPS for the collection of more detailed data on health status at the stand level, which was a specific part of the national program in 1985. Results have been evaluated on the national and regional level, and were the basis of the national health condition reports until 1988, when the first survey of the systematic monitoring plots was done. The main goal was to inform forest owners on the health status of the forests and to adjust management practices according to these findings.

The national forest protection program followed the outline initiated by the ICP Forests Manual (1986) and distinguished three different intensity levels:

- **Level I:** Large scale survey of forest condition to follow the spatial and temporal development of damages.
- **Level II:** Intensive monitoring of forest condition to recognize the key factors and processes.
- **Level III:** Special forest ecosystem analysis aimed at gaining a deeper insight into cause-effect relationships.

In the first level of the national program — large scale monitoring run by the FMPS — recommendations of the ECE Manual were accepted, especially defoliation and discoloration as key parameters. A detailed list of all kinds of visible abiotic or biotic symptoms was also added for a better and more detailed description of the sample trees. With the establishment of 1,027 sample plots (24 trees/plot) in a 4 by 4 km grid (1987) and the first survey in 1988, the first forest health status data from a representative sampling became available for decision makers, which was an effective tool to identify the problems and concentrate the efforts to the critical areas.

Air Pollutants

The ICP Forests cooperation is based on a hypothesis that new types of forest damage are closely related to air pollution effects. In the recent ICP Forests report (U.N. Economic Commission for Europe, European Commission 1995) more than half of the participating countries mentioned air pollution in their national reports as possible predisposing, accompanying, or triggering factor of forest damage. A clear advantage of the transitional period in Hungary was the reduction of air pollutants as a result of the recession of heavy industry and the restructuring of the whole economy. In addition, the environment protection authorities became more effective during the last decade and implemented the European air pollution protocols. Therefore, an improvement of the air quality was a result of two substantially different factors.

However, numerous disadvantages of the transitional period, include the lack of an updated and comprehensive traditional statistical system. Consequently, the emission charts show 1992 as the last reliable publicly available data. (According to different sources, the levels have been stabilized or continued to sink since then.)

Sulfur Dioxide

Sulfur dioxide emission is still rather high in Hungary, mainly because of brown coal combustion. The 1.6 million tons/year emitted in 1980 was reduced to 830,000 tons/year in 1992 (*fig. 1*). This reduction corresponded with the Helsinki (Finland) protocol (1985) that targeted 30 percent sulfur dioxide reduction between 1980-1993 in Europe. (All the 20 signatories fulfilled the commitments.)

Nitrogen Oxides

The nitrogen oxides protocol signed in Sofia, Bulgaria in 1988 required that by 1994 the emissions of all signatories did not exceed the 1987 levels. The majority of the 26 signatories fulfilled the commitments, including Hungary with 31 percent reduction. Total emission of nitrogen oxides was reduced from 270,000 tons/year in 1980 to 180,000 tons/year in 1992 (*fig. 2*).

Concentration of Gaseous Compounds

Emission is only one factor; it is more important to follow the changes of concentrations and depositions of pollutants in the forests. Concentration of gaseous pollutants — sulfur dioxide (SO_2) and nitrogen oxides (NO_x) — were considerably lower in 1994 than at the beginning of the observations in 1988 (*fig. 3*). Charts are based on data from the three measuring stations continuously operating since 1988 in the western, northern, and central forested region of Hungary. Reduction of concentrations was unexpectedly fast, not clearly explained, but related to the Europe-wide efforts to reduce the emission of these air pollutants (for instance, neighboring Austria also reduced SO_2 emission to one-fifth within the last 10 years.)

Despite these reductions, there are some areas where clear evidence of local air pollution impact has been observed on forests. The general level of these frequently cited air pollutants seems to be rather low compared to central and western Europe. There is a real danger, however, that the reconstruction of the industry may cause an emission increase.

Figure 1 — Sulfur dioxide (SO_2) emission in Hungary, 1980-1992.

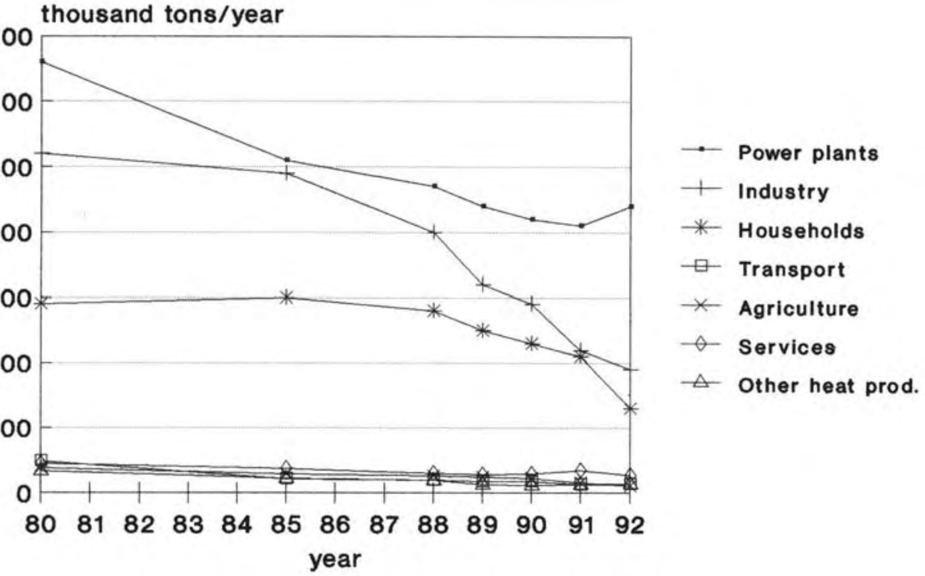


Figure 2 — Nitrogen oxide (NO_x) emission in Hungary, 1980-1992.

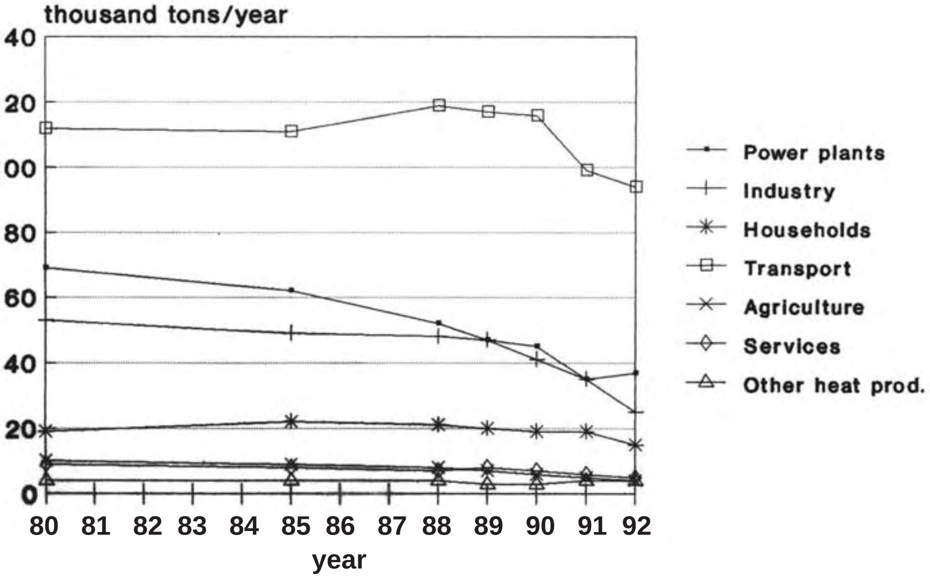
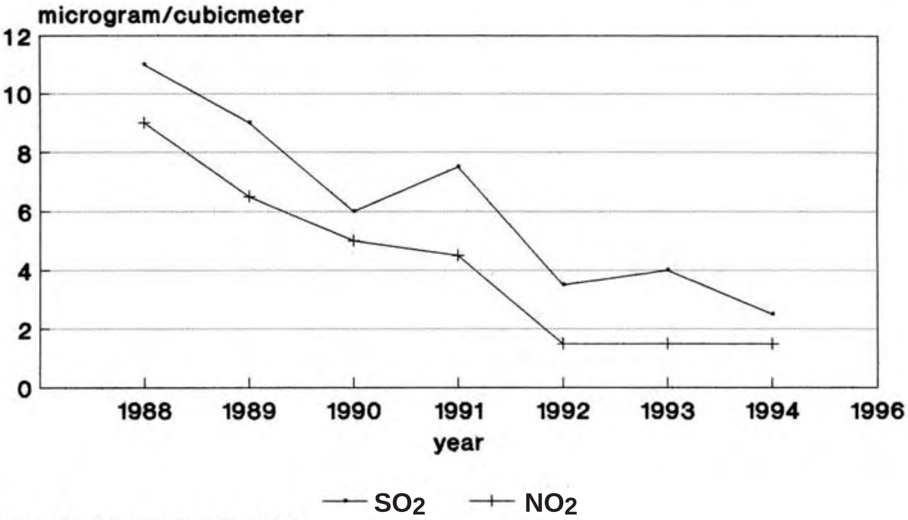


Figure 3 — Sulfur dioxide and nitrogen dioxide concentrations in Hungary's forest area, 1988-1994.



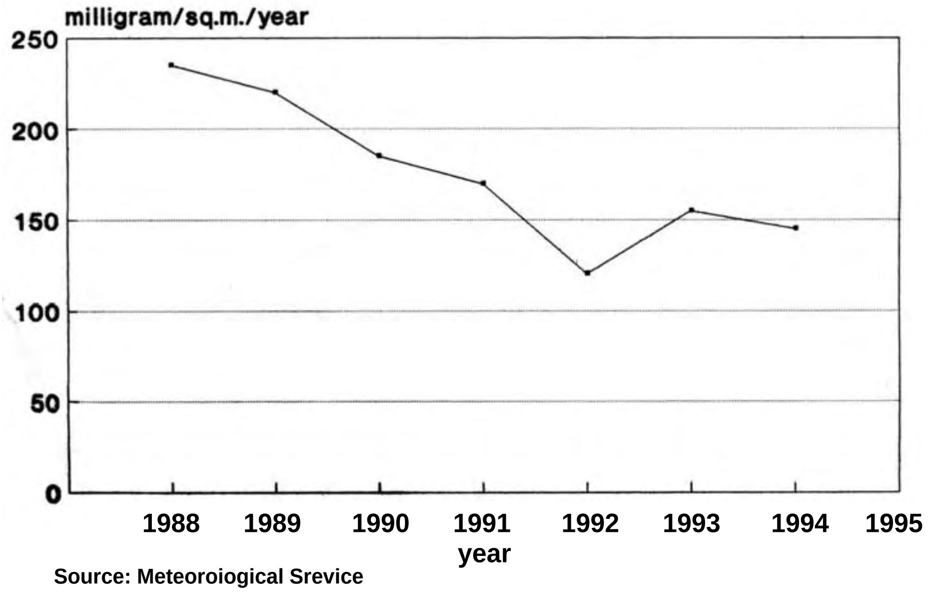
Source: Meteorological Service

Soil Acidification

Acidification of the soil is a real threat and a detected ongoing process in large forest areas of Europe (Germany, Czech and Slovak Republics, Poland). The reduction rate of hydrogen ion deposition is much less than that of the gaseous compounds in the forest area (*fig. 4*). It has also been measured since 1988; however, because the majority of the soils in Hungary are calcareous or well-buffered, the risk of acidification is moderate in general. To detect any kind of acidification may require more time, especially on soils with good buffer capacity. Measurements on research sites have shown that acidic precipitation is neutralized on the leaves in broadleaved forests, which diminishes the effects of acid deposition.

Clear evidence of acidification on agricultural lands was detected in the last two decades, but the main reason was the intensive fertilization and the selection of fertilizers. Role of air pollution was not measured or estimated.

In forested areas resampling of old soil pits and changes of the grass vegetation may indicate the acidification process, but there are not enough reliable data available. A special sampling method was applied with nine subsamples by using a 5- or 10- year resampling period to detect the changes of main soil characteristics quantitatively.



Source: Meteoroiogical Srevice

Figure 4 — Hydrogen ion deposition in Hungary's forest area, 1988-1994.

Climate

Climate change and its possible effects on forests are debated. Hungary lies in the Carpathian Basin and is a meeting point of three main climatic regions: the Atlantic from west, the Mediterranean from the south, and the continental from the east. Even a little shift of the main climatic regions may cause considerably different weather conditions in the country dominated by lowlands.

According to the recent assumptions on climate change, a drier and milder climate is predicted for the Carpathian Basin. Because one-third of the country is already characterized by a continental climate, productive closed forests are not expected without a surplus of ground water. Deterioration of large forest areas and decrease of productivity may occur as a result of drier climate. Foresters did not pay much attention to the climate change scenarios in Hungary because of the uncertainties, but the dry and mild climate of the last 12 years put the issues in the focus of the experts. Abatement strategies, such as the reduction of carbon dioxide were not effective enough, with about 25 percent reduction of the annual emission within the last 15 years. This left the emission on a high level of 65 million tons/

year (*fig. 5*). The increase of the growing stock, including afforestation and better use of the different assortments, has also been calculated as capturing about 10 percent of the carbon dioxide emitted recently.

Precipitation has an outstanding importance in the life of forests in Hungary. The stress of high temperature and lack of water is characterized by a drought index that depends on the precipitation in October to August and on the monthly average temperature in April to August (additional factors, like hot days, rainless periods, and groundwater level are included as well) (*fig. 6*). The index is well-known in agriculture and with some modifications, it can also be informative in forestry. Main categories of the index include:

- Moderate drought 5 - 6
- Medium drought 6 - 7
- Strong drought 7 - 8
- Very strong drought 8 +

Although the level of air pollutants decreased in the last 15 years, the weather conditions became more unfavourable for the forests in general. This statement does not refer necessarily to climate change effect, since the meteorological data are within the natural variation of the long-term observation results, rather, this phenomenon is an indication of the possible causes regarding the health status observed from the large scale damage survey since 1988.

Figure 5 — Carbon dioxide (CO$_2$) emission in Hungary,1980-1992.

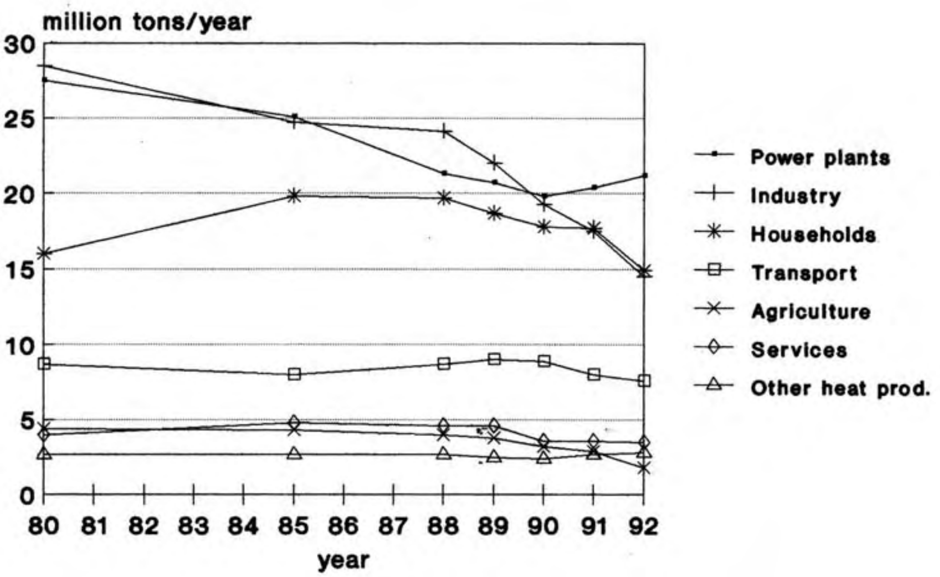
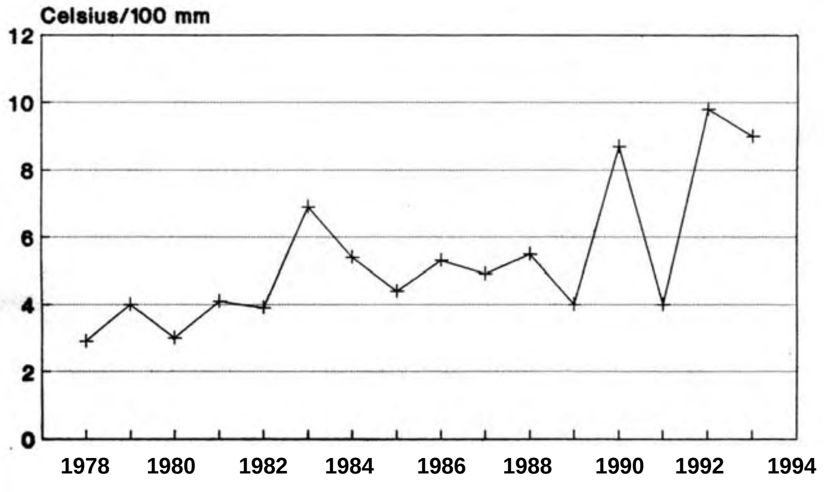


Figure 6 — Drought index in Hungary, 1978-1993.



Source: Meteoroiogical Srevice

Results of the Large Scale Forest Damage Survey

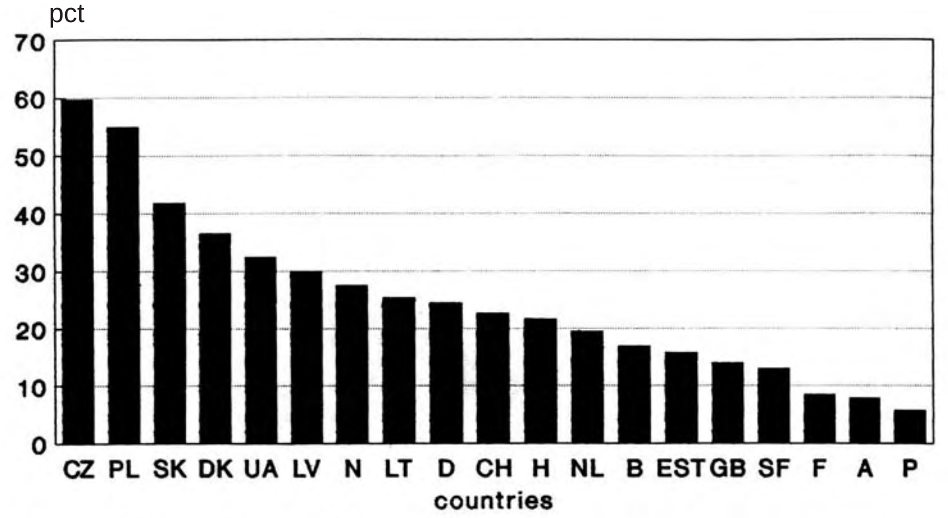
Comprehensive Observations

Defoliation, discoloration and about 44 different symptoms (classified according to the main parts of the tree where they can appear or cause damage) have been assessed by individual sample trees annually since 1988. In 1995 about 1,104 sample plots and 23,000 sample trees were assessed. In 1991-1993 a soil survey was performed based on the national methodology, soil pits, and sampling by genetic horizons. In 1994 additional soil samples were collected with a special sampling design that detected changes of the most important soil characteristics on 67 plots within the 10-year resampling period.

Increment measurements started in 1993, based on 2.83 by 2.83 km net and 200 by 200 m tracts, including all plots of the 4 by 4 km damage survey network. All data collected are important for a detailed and reliable inventory of forest health status and for a scientific interpretation of the observations.

Defoliation in Europe

Defoliation is considered a general indicator of the health status. Despite the common European Manual and the continuous efforts on better harmonization, international comparability is still biased by the differences among the national methods. However, we can compare the forest condition in some European countries to highlight the Hungarian situation. Because about 22 percent of the trees are considerably defoliated (defoliation above 25 percent), Hungary is close to the average defoliation observed in Europe in 1994 (*fig. 7*). The highest damage was observed in the Czech Republic, where 60 percent of the trees were considerably defoliated, while the rate of damaged trees was only 6 percent in Portugal.



Source: Forest Condition in Europe

Figure 7 — Defoliation (greater than 25 percent) in Europe in 1994. Key:
CZ=Czech Republic;
PL=Poland;
SK=Slovak Republic;
DK=Denmark;
UA=Ukraine;
LV=Latvia;
N=Norway;
LT=Lithuania;
D=Germany;
CH=Switzerland;
H=Hungary;
NL=Netherlands;
B=Belgium;
EST=Estonia;
GB=United Kingdom;
SF=Finland;
F=France;
A=Austria;
P=Portugal.

National Results

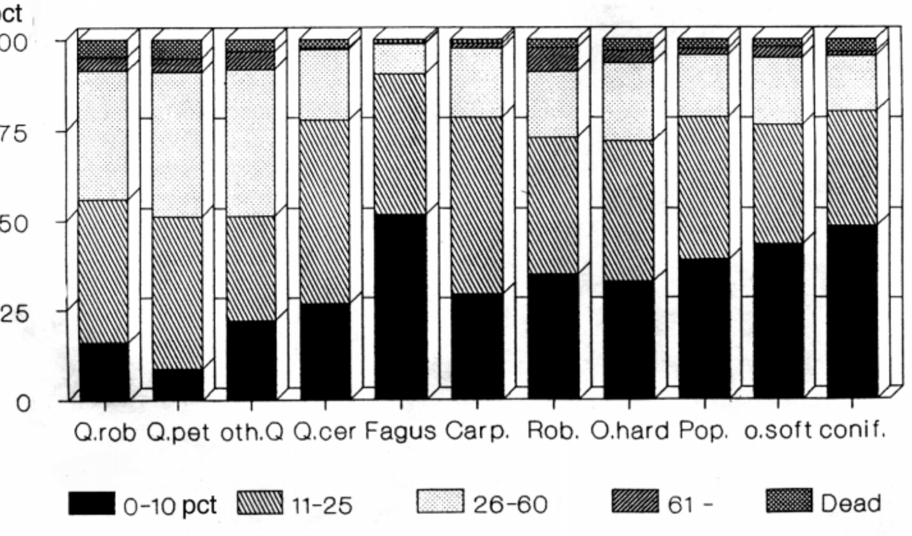
Defoliation

All types of damages are assessed in 10 percent classes, but interpretation is often combined into 5 classes to follow a classification that is accepted internationally. The following classes are used in the charts:

• Not damaged	0 - 10	percent
• Slightly damaged	11 - 25	percent
• Moderately damaged	26 - 60	percent
• Severely damaged, dead	61 -100	percent

Two different categories of defoilations were used in Hungary. The first is 'total defoliation' including all kinds of leaf losses regardless of the reasons of defoliation; and the second is simply 'defoliation', which is the international terminology that excludes clearly identified reasons of defoliation, such as leaf eaters, fungi, or breaks.

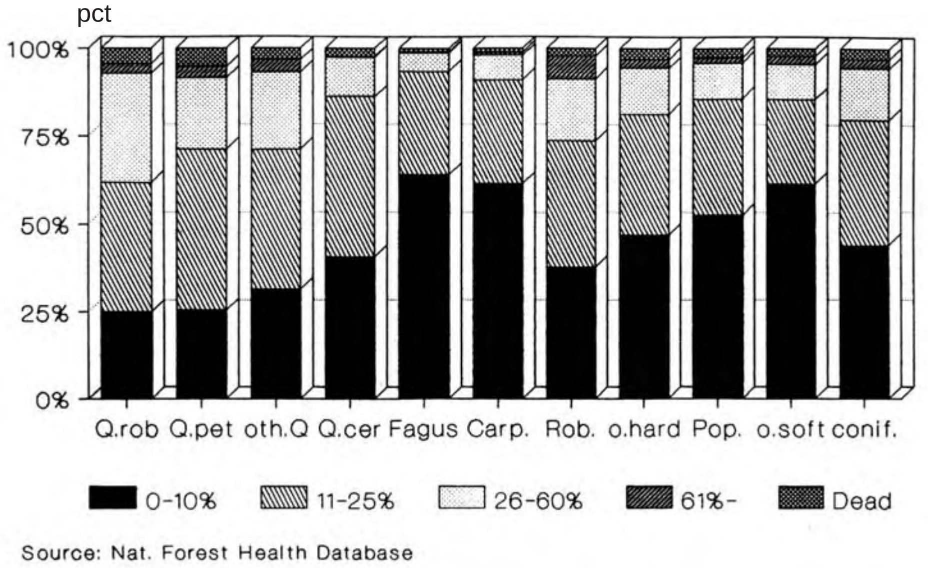
According to the total defoliation category (*fig. 8*), 33 percent of the trees were classified healthy, while 27 percent showed considerable defoliation (above 25 percent leaf loss). Noble oaks (European oak and sessile oak) were in the worst condition with about 50 percent of the trees defoliated considerably. Although clear evidence has not yet been found, oak stands may have been affected by an increment loss because of the intensive reduction of the leaf area. Primary damage factors include foliage insects (mainly caterpillars) and some fungi that attack the native species like oaks or hornbeam (*Carbines beetles* L), while conifers or black locust have been attacked only scarcely and regionally.



Source: Nat. Forest Health Database

Figure 8 — Total defoliation (23,000 sample trees) in Hungary, 1995. Key:
Q. rob = *Quercus robur*;
Q. pet = *Quercus petraea*;
oth. Q = other quercus species;
Q.cer = *Quercus cerris*;
Fagus = *Fagus sylvatica*;
Carp. = *Carpinus betulus*;
Rob. = *Robinia pseudoacacia*;
o. hard = other hard broadleaves;
Pop. = poplars;
o. soft = other soft broadleaves;
conif. = conifers

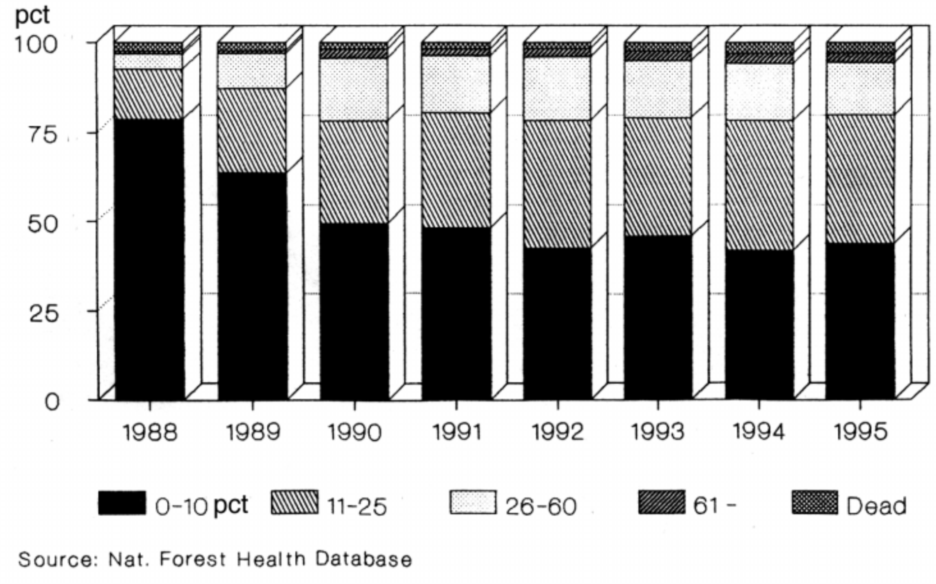
The second category, defoliation (*fig. 9*), had a better relationship to air pollution or drought effects. Oaks and especially hornbeam were more healthy than on the chart of total defoliation, but noble oaks were still in the worst condition. With at least moderate defoliation (above 25 percent) European oak (*Quarks robber* L) (32 percent), sessile oak (*Quarks petard* L) (28 percent), and black locust (26 percent) had the highest defoliation, while beech and hornbeam were the least affected (7 and 9 percent, respectively).



Source: Nat. Forest Health Database

Figure 9 — Defoliation (23,000 sample trees) in 1995.

Defoliation change was alarming in the first 3 years of the survey, showing a rapid increase. But since 1991 the situation seems to have stabilized (*fig. 10*). The proportion of healthy trees decreased from 80 percent to 44 percent and trees with considerable defoliation (class 2-4) increased from 7 percent to 20 percent within the survey period of 1988-1995.

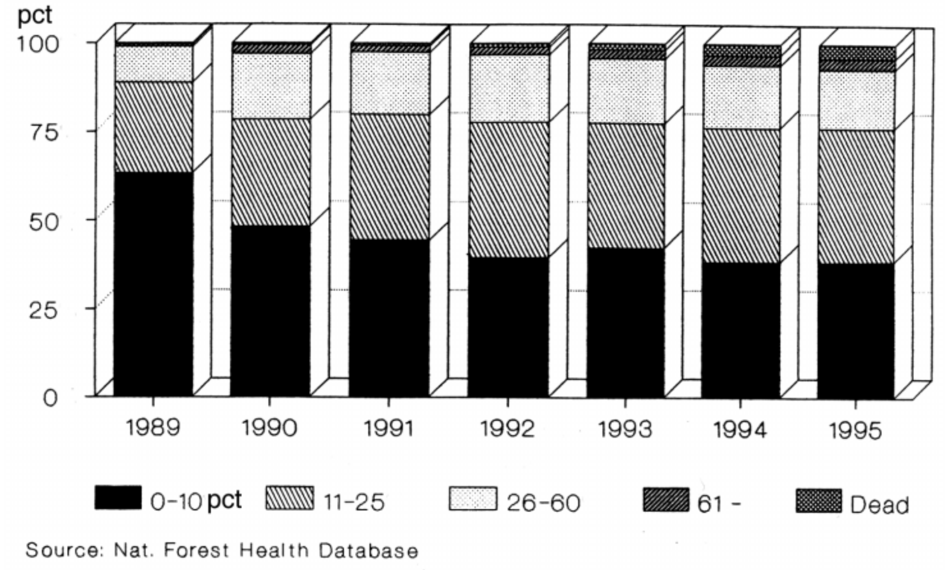


Source: Nat. Forest Health Database

Figure 10 — Defoliation in 1988-95, total sample (17,100 to 23,300 trees).

Mortality is a complex problem in managed forests where the intensity of sanitary fellings and thinning may considerably change the results collected on the permanent plots. In 1995 about 2.9 percent of the sample trees were dead with great differences among the tree species (spruce —12 percent, beech — 1 percent). The mortality rate doubled during the survey period because of the health condition, and the privatization of 40 percent of the forests, in which proper management was not always performed by a responsible owner.

While the results of the total sample are slightly distorted by the replacements and the new sample plots, a comparison was also made for the common sample trees (common trees in 1989-1995) (*fig. 11*). To reduce the possible errors of the first survey, when the staff had only moderate experience, the 1988 data was excluded. Defoliation of the common sample trees was faster than the total sample and the defoliation in 1995 is higher — only 38 percent of the sample trees are classified as healthy, and 25 percent defoliated considerably. Defoliation of the most important



Source: Nat. Forest Health Database

Figure 11 — Defoliation in 1989-95, common sample trees (13,100 trees).

tree species was predetermined by site conditions and annually modified by weather conditions as well as other damaging factors.

The oak decline, affecting sessile oak, peaked in 1988, and on a lower level still exists. Oak stands on shallow soils were severely affected by the long dry period of the last 12 years. In the northern mountainous region, third and fourth generation coppice stands were the most sensitive. High defoliation is not only related to the oak decline; the water reserves in the soil also became exhausted and resistance of the stands to various damages decreased (*fig. 12*).

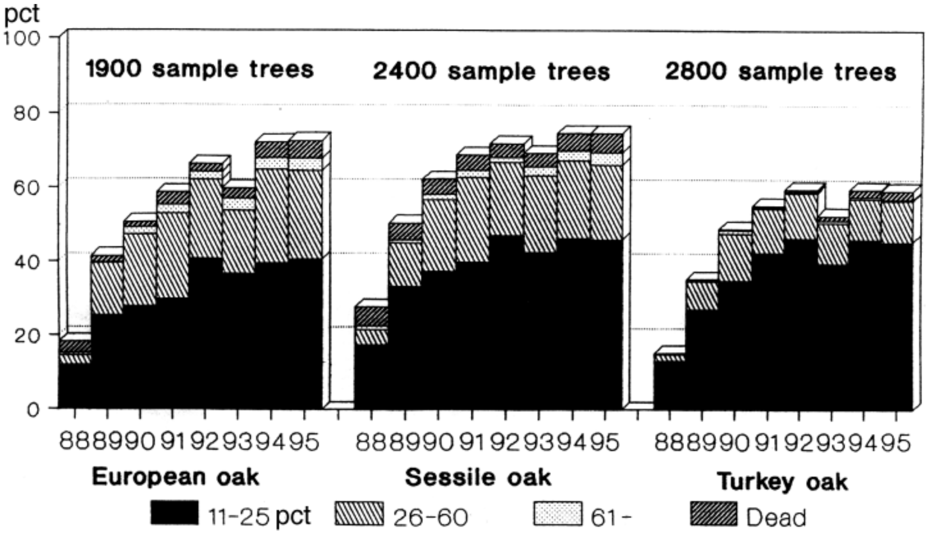
Dieback of European oak started at the beginning of the survey (*fig. 12*) and was closely related to the traditional water management practice, which lead the water out of the Carpathian Basin, an area frequently threatened by floods, that diminished surface waters in springtime on agricultural areas. Roots of middle-aged and older stands were not able to follow the sinking water, while water deficiency and possible uptake disturbances reduced the resistance of the oak. Thus, the trees also became more sensitive to insect (*Tortrix* sp, *Lymantria dispar* L., *Melolontha melolontha* L.) and fungus *(Microsphaera quercina* Schw. Burr., *Armillaria* sp.) attacks.

Turkey oak (*Quercus cerris* L.) is less sensitive to drought (Mediterranean species, but native in Hungary), often growing on shallow soils or on the drier southern or western slopes. Even the increase of slight defoliation (*fig. 12*) to 40 percent (similar to noble oaks) reduced the canopy closure so that dense grass vegetation became an important obstacle of natural regeneration. Unexplained diebacks were reported in some localities of the northern mountainous region.

Natural and artificial regeneration was more difficult in this dry period and frequency of good seed crops decreased (oaks, beech). Moreover, the regeneration areas are to be protected by fences to reduce game damages. In several areas the grass vegetation became a dangerous competitor of the seedlings because in the spring only the upper 10-20 cm of the soil is saturated properly with water.

Beech was the healthiest species (*fig. 13*). Unlike other tree species in Hungary, beech seldom grew out of its ecological niche. In the humid and cool climate, where the 7 percent beech forests are located, effects of drought were less severe. However, local foresters and pathologists have focused on these species for the past 10 years and have recorded various types of damage related to climatic or biotic factors. Higher defoliation in 1994 was connected with high seed production throughout the country, a phenomenon that reduced the amount of leaves, and increased defoliation.

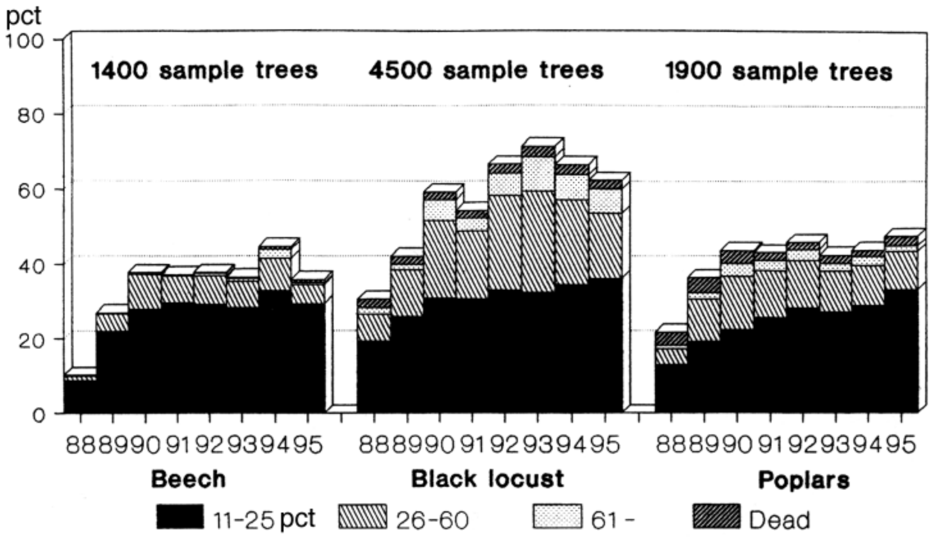
Figure 12 — Defoliation of European oak, sessile oak, and turkey oak in 1988-1995.



Source: Nat. Forest Health Database

Black locust was introduced in the beginning of the 19th century and intensively planted in the country by small owners for fuelwood and later by the cooperatives. Because only a few fungi and insects attacked black locust in Hungary, the species appeared healthy until the mid 1980's, but large scale observations showed rapid deterioration afterwards (*fig. 13*), especially on the sandy and shallow soils. Although the oaks could not respond to the higher precipitation of 1994-1995, the black locust responded, and defoliation in these years decreased. Because black locust was mainly planted close to or on the edges of the villages, resulting in numerous scattered small forest lots, and dead trees have been continuously exploited by local people, the number of dead trees has remained at the same level since 1988 in spite of the increasing mortality.

The group of poplars is heterogeneous, dominated by the improved poplars in plantations (15-30 m^3 annual increment) regularly suffering from specific fungi *(Chryptodiaporthe populea* Sacc. Butin., *Marssonina brunnea* E. et E., Magn.), or the white and black poplar, native in the country. Despite the dominance of the sensitive improved poplars, the health condition of the poplar group has only slightly deteriorated in the last 4 years (*fig. 13*). It is characterized by a high variation of spatial distribution depending on soils and different clones. The stabilized health condition is also attributed to the focus on the selection of sites suitable for new plantations, as well as new more resistant clones.



Source: Nat. Forest Health Database

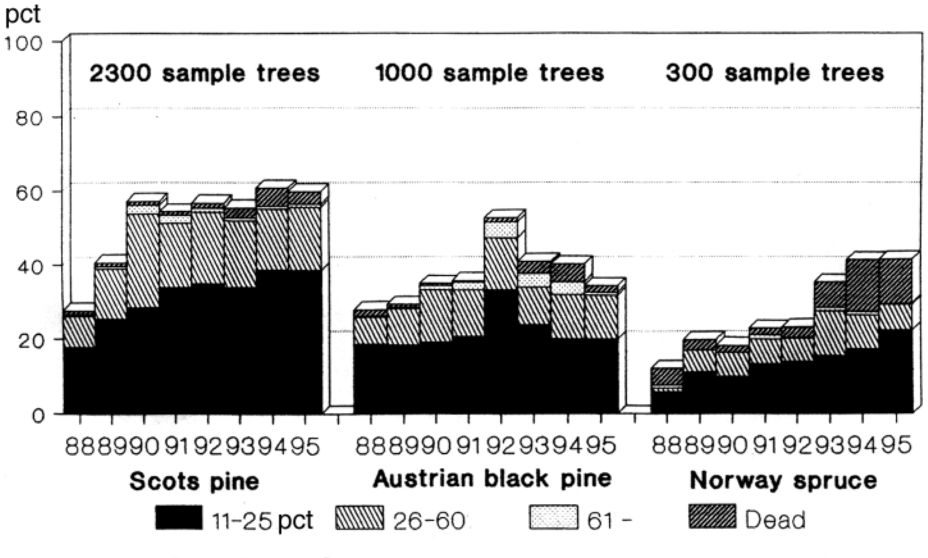
Figure 13 — Defoliation of beech, black locust, and poplars in 1988-1995.

Although 15 percent of the forest area is covered by conifers, they are not native in Hungary. Even spruce that was planted in the humid sites does not receive sufficiently high precipitation and permanently high air humidity. Consequently, rapid and alarming deterioration was observed within the survey period (*fig. 14*) attributed to low precipitation. Although pines dropped only the eldest needle curls in the dry years, spruces lost more and more needles annually. In 1995 about 12 percent of the sample trees were dead, partially because trunks were attacked by root decaying tinder *(Heterobasidion annosum* Fr. Bref.) in several regions where the replanting of conifers required special technologies or they would not be economical any longer. Intensive attack of bark beetles in the weakened stands with dead trees may result in the collapse of the forest within 2-3 years.

The problem is the same in Scots pine stands (about 8 percent of the forests) where defoliation has been rather stable in the last 5 years (*fig. 14*), but the level was constantly high. Trees were more defoliated in the western border region and in higher elevations — within more favourable climatic conditions — than that in the lowlands, where the existence of closed forest is uncertain (there are some different hypotheses, but no clear explanation about the phenomenon). In these dry sandy regions, Scots pine has no deciduous alternative if attacked by root decaying tinder or killed by the lack of water so that replanting of conifers (species already introduced to the country) becomes impossible. The original vegetation — steppe and scattered small groups of trees and bushes — can only be restored within a long period, depending on the weather conditions.

Austrian black pine (*Pinus nigra* Arn.) is very tolerant to drought, so it has been planted in the poor sites where soil protection has primary importance. In addition to the lack of water, new pathogens, like *Diplodia pinea*, native in the Balkan peninsula, attacked the stands and increased the high defoliation attributed to drought — especially in 1992. Since then a definitely higher mortality was observed (*fig. 14*). Despite the unfavorable conditions, Austrian black pine has a relatively low defoliation, but a prolonged dry period or additional fungus attacks may rapidly increase diebacks and deforestation is also possible in some regions.

Figure 14 — Defoliation of Scots pine, Austrian black pine, and Norway spruce in 1988-1995.



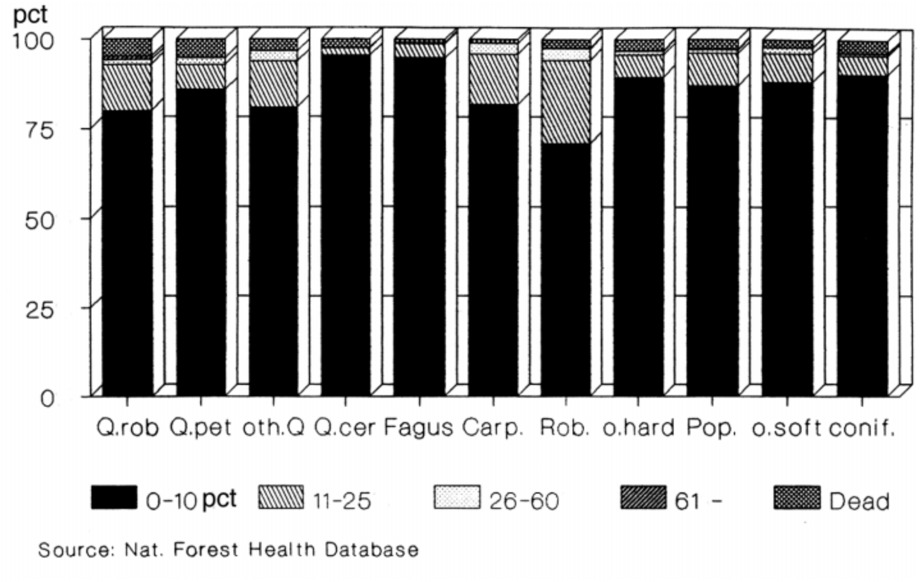
Source: Nat. Forest Health Database

Discoloration

Although discoloration caused by air pollution or disturbed nutrient balance, such as lack of calcium or magnesium, has been described in some European countries, it has not been observed in Hungary. In the dry years or after unusually long hot and dry summer periods early fall of leaves was reported, starting with yellowing in the second half of the survey period (in the first half of August). Discoloration of black locust, hornbeam, and Scots pine have always been high, with outstanding results in 1990 when about 20 percent of the respective tree species were considerably discolored (more than 25 percent discoloration); but only 3 percent was found in 1995 (*figs. 15,16*). While 39 percent of the sample trees were at least slightly discoloured in 1990, less than 12 percent were discolored in 1995. Presence of fungi or insects is another common reason of discoloration observed on oaks, poplars, and conifers. However, decrease of discoloration was not in correlation with the decrease of fungus and insect damage; on the contrary, the frequency of identified crown damage increased gradually within the survey period.

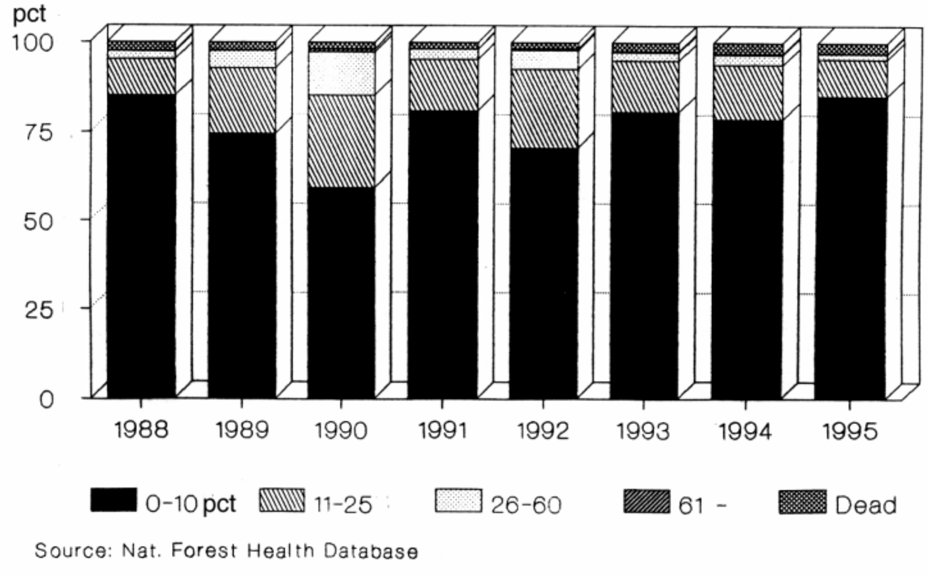
Other Damage

Methodology of the field survey was extended by a detailed list of 44 various biotic and abiotic damage factors or symptoms identified on the tree. The damage factors were grouped according to the main parts of the tree where they appear or cause damage (*fig. 17*). The intensity of the damage is also recorded in 10 percent classes. Some damage was typical to certain tree species during the whole survey period, like foliage insects on European oak and hornbeam, and frost ribs on Turkey



Source: Nat. Forest Health Database

Figure 15 — Discoloration of 23,300 sample trees in 1995.



Source: Nat. Forest Health Database

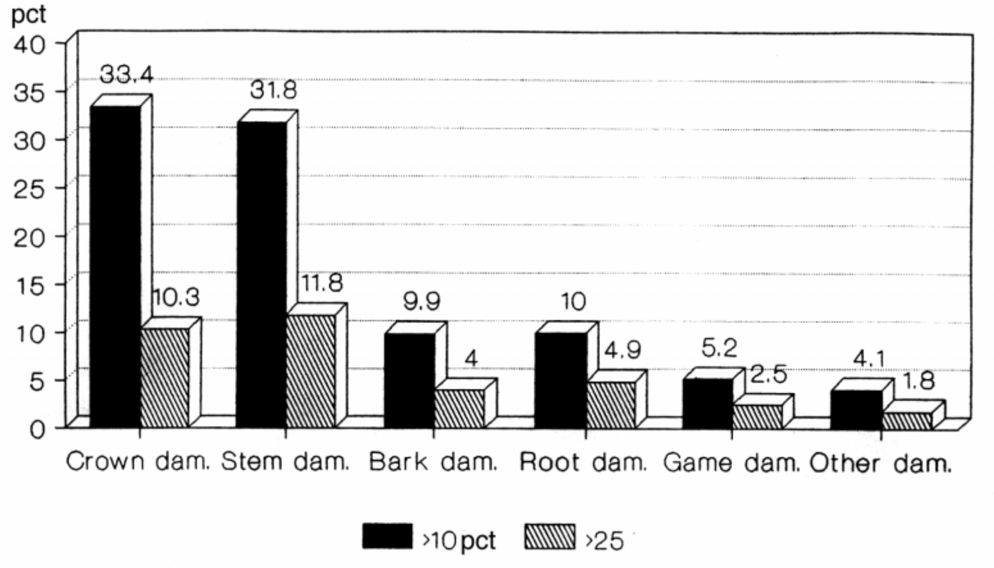
Figure 16 — Discoloration of 17,100 to 23,300 sample trees in 1988-1995.

oak and some improved poplar clones, and bark injuries on beech. Other damage from game and drought affected nearly all tree species and has been more frequently identified recently. It is difficult to clarify the role of damaging factors based on the defoliation and discoloration results that show a general worsening of the condition of forest health. Unfavourable weather conditions and some suspected effects of air pollution might have reduced the resistance of the trees or caused deterioration directly, and these weather conditions may have also resulted in an abundance of various insects and fungi on forest trees.

Future Outlook

Despite the monitoring and research efforts, it is difficult to predict the development of forest damage in Hungary. The large-scale survey highlighted the alarming development and extent of forest damage and encouraged the forest authorities as well as the public to pay more attention to the protection of our forests. The forest protection program is supported by the government, and as a second level of the national implications of the ICP Forests cooperation, 14 intensive monitoring plots were selected and equipped according to the standards of the ECE Manual. The government provided a special fund available for forest owners to diminish forest damages and encourage regeneration.

Figure 17 — Primary damage symptoms of 23,300 sample trees in 1995.



Source: Nat. Forest Health Database

Effective air pollution control may keep emissions on a constant level after the recession, or even further decrease can be expected due to the acceptance of the European Union's air pollution standards. Better cooperation is necessary with water management authorities to keep more water in the Carpathian Basin and ensure the permanent feedback to the ground water without creating new swampy areas.

Additional intensive research is necessary to clarify the role of climatic factors and air pollution effects on forest ecosystems, including direct effects, carbon and nutrient cycling at different sites, and damaging biotic factors.

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