COMMISSION OF THE EUROPEAN COMMUNITIES

DIRECTORATE-GENERAL
FOR AGRICULTURE

FOREST HEALTH REPORT 1991

Executive report on the 1990 survey

DOCUMENT
CEE: VI/92

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Cataloguing data can be found at the end of this publication.

Luxembourg: Office for Official Publications of the European Communities, 1991

ISBN 92-826-3344-6

Catalogue number: CH-72-91-245-EN-C

Printed in Germany

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Background

This report gives the results of national forest health reports and the European Communities forest damage survey in 1990. The aim of the report is to give an updated overview of the state of forest health in the European Community, and is a follow-up of the Forest Health Reports 1987-1988 and 1989, both prepared by the Commission of the European Communities.

The report is a result of the application for four years of Council Regulation (EEC) no. 3528/86 of 17 November 1986 on protection of the Community's forests against atmospheric pollution. Member States have set up a Community wide forest damage inventory and forwarded annual forest health reports to the Commission since 1987. In this report, forest survey data from five Non-EC countries have been included for the first time.

Under the same Regulation the Commission has granted Community financial aid for the completion of pilot projects and experiments to improve knowledge of air pollution in forests and its effects, to improve methods of observing and measuring damage to forests and to devise methods of maintaining and restoring damaged forests.

For the purpose of making the forest damage survey and national reports, a common methodology was used as laid down by Commission Regulation (EEC) No 1696/87 of 10 June 1987. This methodology is based on guidelines for harmonized sampling and assessment of the health of forests, as adopted by the parties to the Convention on Long-range Transboundary Air Pollution participating in the International Cooperative Programme for Assessment and Monitoring of Air Pollution Effects on Forests.

The Community's forest damage inventory is the first large scale transboundary inventory of its kind to be carried out in accordance with a common method, involving a unified sampling system and centralized data treatment. By 1990, it enabled comparable data to be collected in respect of over 67,000 sample trees throughout the Community, and five Non-EC countries.

The appearance of widespread forest decline, generally attributed to atmospheric pollution in many regions of the Community since the beginning of the 1980's, as well as the rapid spread of forest damage, were at the origin of the Community's action for the protection of forests against atmospheric pollution.

Summary

The European Community (EC) inventory network on forest health covers the entire forest area of the EC-Member States, excluding Sardinia and Sicily. In 1990, the network was further enlarged by the reunion of the two German States. For the first time survey-data from five Non-EC countries, Austria, Czechoslovakia, Hungary, Poland and Switzerland, have been evaluated in this annual report.

The results of the 1990-survey indicate that **a significant proportion of the forests in the Community shows signs of defoliation and/or discolouration.** From year to year this vitality situation of the forests has fluctuated considerably, but **for certain species a pronounced deterioration has been observed**. The large spatial and temporal variability of forest health calls for an increased effort of study on the influence of ecological factors herein.

In the 2005 plots of the 1990 survey in the Community, **a total of 15.1% of the trees showed a clear indication of leaf- or needle loss** (defoliation more than 25%). Trees showing more than 10% **discolouration** represented **14.4% of the tree sample**.
For the most common species groups in the Community, ***Picea*** sp., ***Pinus*** sp., the **deciduous *Quercus*** sp. and ***Fagus*** sp., the percentages of damaged trees were in the order of 10 to 20%. *Eucalyptus* sp. showed the lowest percentage of damaged trees. Symptoms were the most severe among trees of *Quercus suber*.

Considering the changes between 1989 and 1990, **a certain deterioration in forest health occurred over the entire Community**. The overall vitality decreased slightly for all species. Only for *Quercus ilex* the health status remained constant. ***Quercus suber* showed a clear loss in vitality.**

Over the period 1987-1990, the changes in forest vitality are inconsistent for most species. A further **deterioration** was found in ***Picea sitchensis***. This increase in defoliation can be largely attributed to extensive insect damage in the United Kingdom and Ireland, following the mild winters in 1988-1989 and 1989-1990. A deterioration was also observed for *Quercus pubescens*.

In the results of the 1990-survey, **significant relationships were found between the degree of defoliation and the altitude of the plot and the mean stand age**. The percentage of **damaged** trees appeared to decrease with **increasing altitude**, with defoliation being most pronounced in the lowest altitude-classes. Regarding **defoliation and mean stand age** it was found that the total percentage of **not-defoliated** trees clearly **decreased** with increasing age, while at the same time an **increase** could be observed in the percentages of **slightly and moderately/severely defoliated** trees.
The **annual dynamics of defoliation** were found to be **very high**, indicating that many trees, even from relatively healthy stands, switch back and forth one or more classes over the years.
An initial analysis of a limited number of data on soil type showed **large differences in the degree of defoliation among trees on different soil types**.

1 Introduction

1.1 Completion

The network of the Forest Health Inventory, initiated in 1987, reached near-completion in 1989. Since then representative data can be obtained on the state of health of the forests for the entire European Community. The survey of 1990 comprised observations on 48,402 sample trees from a total of 2005 plots, including data collected in the former German Democratic Republic.
In addition to the forests in the EC, the results of the forest health surveys of five other European countries have been included in the evaluations. In Austria, Czechoslovakia, Hungary, Poland and Switzerland a total of 18,933 trees were sampled on 878 plots, using the same common methodology.

1.2 Inventory method

The observation network of the inventory comprises a 16 x 16 km grid which covers the entire forest area (537,000 km^2) of the European Community and the five Non-EC countries. At each grid intersection point falling in a forest, a sample of 20 to 30 trees is selected for assessment according to a stringently defined procedure, as laid down in Commission Regulations No. 1696/87 and No. 2995/89.
Defoliation and **discolouration** of trees are the basic indices of vitality. They are estimated in comparison with a reference tree, being a healthy tree in the vicinity or a photograph of a fully-foliaged and not-discoloured tree, suitable for the region of investigation.

In addition to the vitality of sample trees, data are collected on the parameters describing the general site- and stand characteristics of each sample plot: altitude, aspect (exposition), availability of water to principal species, humus type, mean age of dominant storey and observations of easily identifiable damages. In 1990, information on soil type was included in the survey for the first time on a voluntary basis.
Since 1990 the Member States have been strongly encouraged to present the vitality data in a digital format. For the Non-EC countries participating in the inventory, the submission of data in this format is obligatory.

1.3 Presentation of the survey results

The inventory results are presented in terms of the percentage of the tree sample falling into each of the following defoliation and discolouration classes:

class	Degree of defoliation/ discolouration	Percentage of needle/leaf loss or discolouration
0	not or negligible	0-10%
1	slight	11-25%
2	moderate	26-60%
3	severe	>60%
4	dead	

In this report, trees in **defoliation classes 0 and 1** will be referred to as **'not damaged'**, even though some slight defoliation may have occurred. Defoliation class 1 (slight defoliation) is sometimes considered as a warning class. Trees classified in **defoliation classes 2, 3 or 4** will be considered as **'damaged trees'**. The total percentage of sample trees classified in the defoliation classes 2, 3 and 4 gives an indication of the presence of clearly visible defoliation. The loss of more than 25% of foliage, in relation to the reference tree, is considered to be a clear indication of a loss of health.
In this report, a **sample plot** will be considered **'damaged'** if the weighted average defoliation class of the sample trees in this plot is more than 25%. If, on the other hand, the weighted average of a plot is 25% or less, the sample plot will be considered as **'not damaged'**.

2 1990 survey results

2.1 General results

In 1990 a total of 67,335 trees were sampled in 2883 plots. The mean percentages of defoliation and discolouration in the EC-Member States and in the Non-EC countries are given in Table 1.

TABLE 1 : Total percentages of defoliation and discolouration for all sample trees in the EC and Non-EC countries.

	Defoliation						
	0-10%	11-25%	0-25%	26-60%	>60	dead	No. trees
EC	59.8	25.1	84.9	13.0	1.5	0.6	48402
Non-EC	28.0	36.7	64.7	31.3	3.4	0.6	18933
Total	50.8	28.4	79.2	18.1	2.1	0.6	67335

	Discolouration				
	0-10%	11-25%	26-60%	>60%	No. trees
EC	85.6	10.9	2.3	1.2	48402
Non-EC	87.8	8.2	3.0	1.0	18933
Total	86.2	10.1	2.5	1.2	67335

On the 2005 plots surveyed in the European Community, a total of **15.1% of the trees was classified as damaged** (Figure 1). In 1989 the damage amounted to 9.9% of the trees. This percentage was derived from 1891 plots and 45,572 trees, indicating that the results are not fully comparable. The percentage of damaged trees averaged 35.3% of the total number of trees sampled in the five Non-EC countries. This is considerably higher than in the EC-Member States.
Trees showing more than 10% discolouration represented 14.4% of the tree sample in the Community. In the five Non-EC countries discolouration of more than 10% was on average assessed for 12.2% of the trees.

In order to compare the results of the 1989 and 1990 surveys of the European Community, a subsample was defined including trees that are common to both inventories: the **Common Sample Trees** (CST's). This subsample consists of 40,308 trees, representing 88% of the total tree sample of 1989 and 83% of the total EC-tree sample of 1990.
Within the subsample of Common Sample Trees, **a slight increase in the percentage of damaged trees has occurred** (in 1989 and 1990 respectively 8.2% and 13.4% of the CST's were damaged). The observed deterioration over 1989-1990 in the vitality of the total tree sample was not only due to an increased damage among trees already present in the inventory, but also to the inclusion to the EC-data set of relatively unhealthy trees.

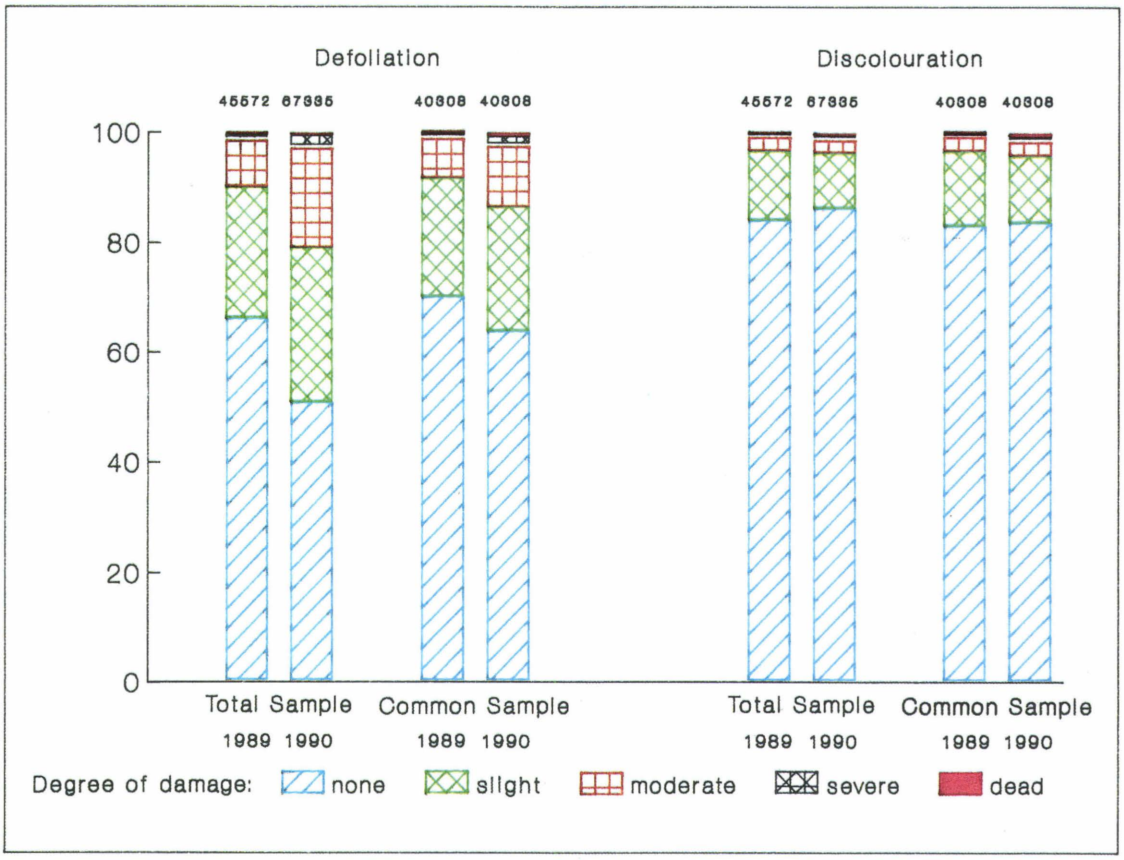

Figure 1: Total percentages of trees in the different defoliation and discolouration classes for the total tree samples and common sample trees of the 1989 and 1990 forest health surveys.

In the Figures 2, 3 and 4, overviews are given of the degree of tree damage, plot defoliation and plot discolouration in the entire survey area. The direct comparison between countries and regions is not fully justified due to differences in the choice of reference trees.

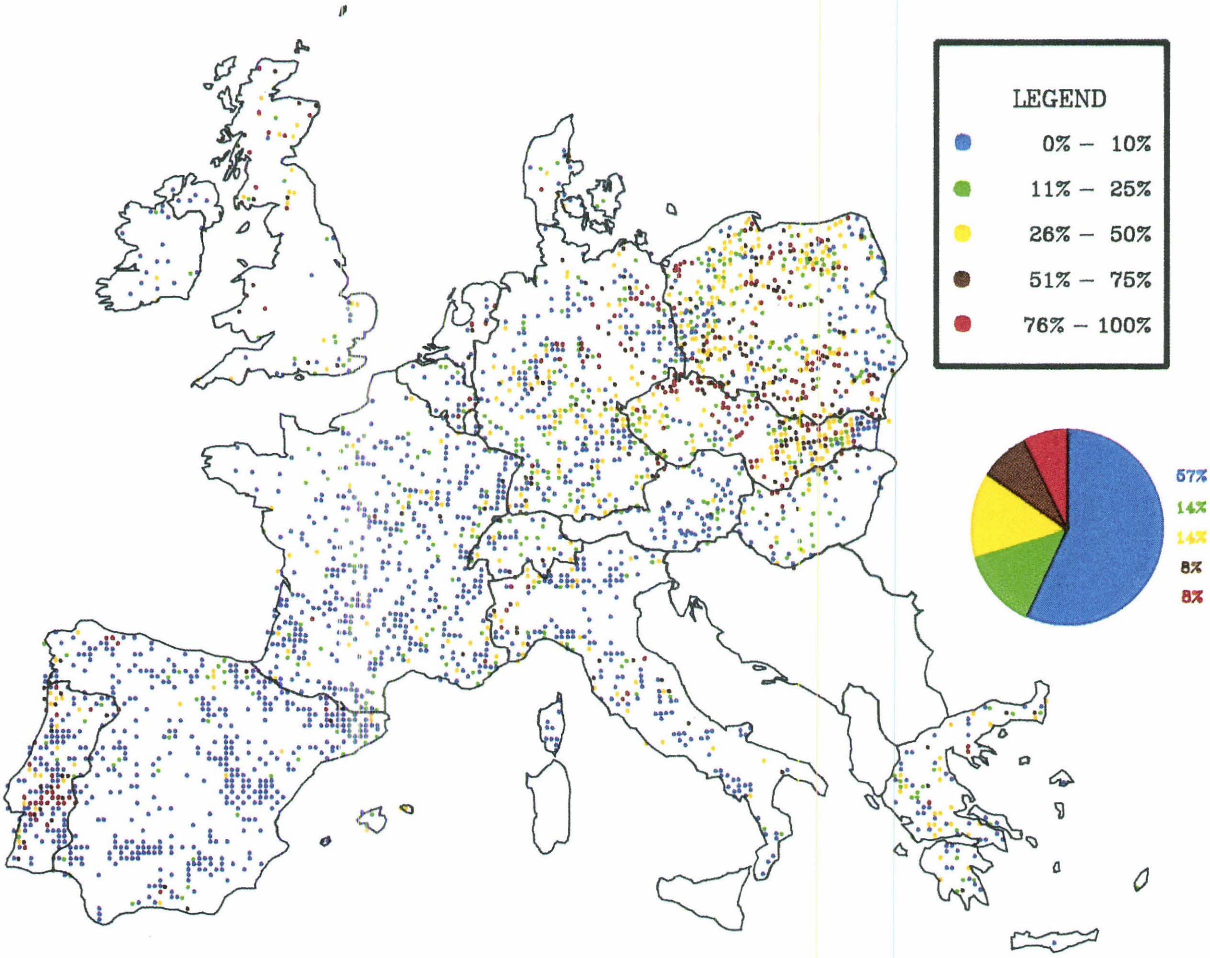

Figure 2: Percentages of trees damaged over the survey area in 1990.

The percentage of trees damaged (>25% defoliation) was relatively high in Scotland, Portugal, Greece and the Federal Republic of Germany (Figure 2). This percentage was very high in Poland and Czechoslovakia.

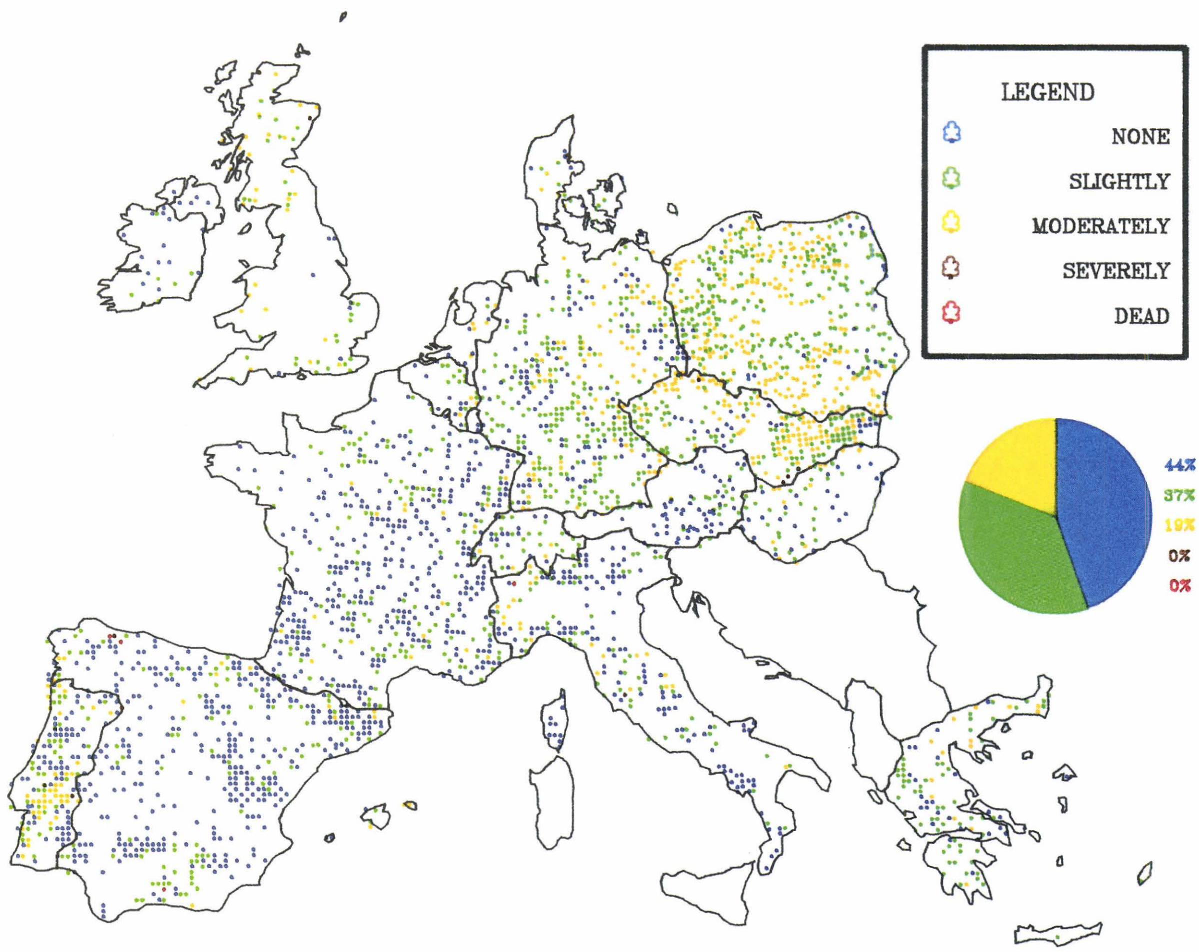

Figure 3: Plot defoliation over the survey area in 1990.

Within the Community, **moderately damaged plots** were found mainly in the United Kingdom, the Federal Republic of Germany, Portugal, and the northwestern part of Italy (Figure 3). Also Greece showed a relatively large number of damaged plots. Among the five Non-EC countries, plot defoliation was notably high in Poland and Czechoslovakia.

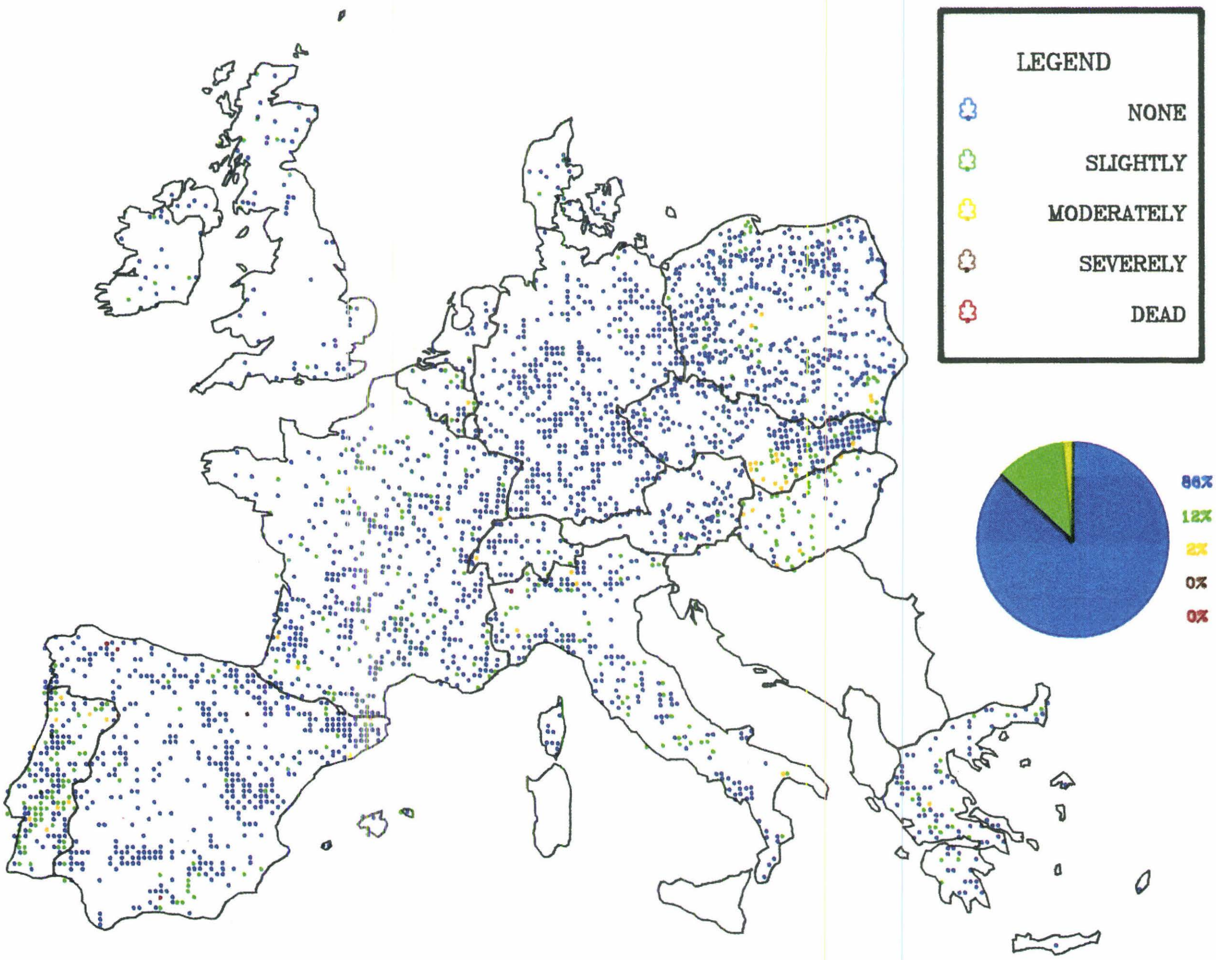

Figure 4: Plot discolouration over the survey area in 1990.

A relatively **high** percentage of **slightly discoloured plots** was found in Portugal, Belgium, Greece, France, and the northwestern part of Italy (Figure 4). Plot discolouration was also pronounced in southern Czechoslovakia and Hungary.

2.2 Vitality by species group

In the 1990 survey 109 different species were identified on the sample plots. The 10 most common species represented over 70% of all observed trees. In the data-set, the proportion of broadleaves and conifers was nearly equal.

Regarding all EC-Member States, broadleaves appear healthier (defoliation class 0+1) than conifers. In terms of discolouration, the reverse is true and conifers appear healthier than broadleaves. For both health-indices, the differences between broadleaves and conifers are in the Non-EC countries more pronounced than in the European Community.

When regarding **defoliation** in the Community by species group, ***Eucalyptus* sp.** and ***Quercus ilex*** show the **lowest** percentages of damaged trees. ***Quercus suber*** and ***Picea*** sp. appeared in the inventory as the species with high percentages of defoliation and discolouration.
The average data for the five Non-EC countries show that the coniferous species *Abies* sp. and *Picea* sp. performed poorly, with more than 40% of the trees damaged. For broadleaves, the mean values in the Non-EC countries showed the highest degree of damage for *Fagus* sp. and the deciduous *Quercus* species, with nearly a quarter of the trees being damaged.

Of all the broadleaves, **most discolouration** was found for ***Quercus suber*** (more than 50% of the trees discoloured). ***Quercus ilex*** **showed the least discolouration** (less than 3% of the trees discoloured). The conifers did not show such a great variation in discolouration. *Abies* sp. and *Pinus* sp. showed relatively high percentages of discoloured trees, up to one fifth of the total number of trees.
The average discolouration in the five Non-EC countries was highest for *Abies* sp., with nearly a quarter of the trees being discoloured.

2.3 Vitality with respect to stand characteristics

In the results of the 1990 survey some **clear relationships could be determined between the degree of defoliation or discolouration** and the parameters describing site conditions **altitude and mean stand age**. Relationships with the other recorded parameters; exposition (aspect), water availability and humus type, could not be detected.

It was found that the **mean defoliation improved with increasing altitude**. The percentages of damaged trees (defoliation > 25%) were highest at lower altitudes, indicating a generally poorer vitality at these heights. A similar, but weaker trend was observed for discolouration.

The relationship between **defoliation and mean stand age** also showed recognizeable trends. With age, the distribution of the trees over the defoliation classes clearly changes. Younger stands appeared to be better foliated than older stands. The percentage of not-defoliated trees (class 0) was found to be high in younger stands, while gradually diminishing with increasing stand age. Concurrently, the percentage of trees in defoliation classes 1 and 2 to 4 gradually increase.
For *Picea abies* the typical relationships between the percentages of trees in the various defoliation classes and mean stand age are shown in Figure 5. The fitted curves suggest that tree vitality worsens with increasing stand age. As the natural decline of the foliation with age is covered by the use of reference trees, the observed pattern reflects the compound influence of an increased sensitivity to damage among older trees, combined with the possible accumulated effects of a longer exposition time of older trees to such sources of damage.
No relationships were found with respect to discolouration.

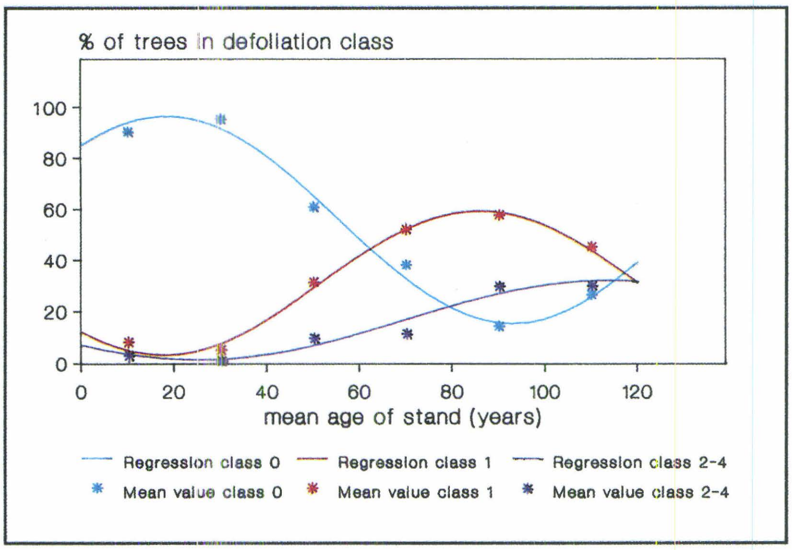

Figure 5: The relationship between mean age and the percentage of not-defoliated (class 0), slightly defoliated (class 1), and moderately defoliated to dead trees (class 2 to 4) for *Picea abies*. The lines are calculated from data of 150 plots, but only the mean values per stand age class are depicted.

2.4 Vitality by easily identifiable damage

Of the total tree sample, nearly a third of the trees showed one or more identifiable causes of damage. The most commonly observed type of damage was caused by **insects**.

All types of damage that were identified had **some negative influence** on foliation and colouration of the trees. However, when regarding all types of damage together, the percentage of damaged trees was only very slightly higher as compared to trees that did not show signs of identifiable damage. With respect to discolouration the trees for which a damage type was observed showed to be considerably more damaged than those trees that did not show any sign of identifiable damage.

The largest effect on the percentage of damaged trees (defoliation class 2+3+4) was observed for trees with **unspecified damage types**. Also, trees affected by **fire**, **the action of man**, **game and grazing** and **local or regional pollution** showed relatively high degrees of defoliation. However, the total number observations for these damage types were small, so no conclusion can be drawn from the figures.

In terms of **discolouration** the most pronounced effect was observed among trees affected by **local or regional pollution**. More than 50% of the trees for which this type of damage was recorded, showed damage in terms of discolouration.

3 Comparison of 1989 and 1990 results

3.1 Changes over the entire Community

Comparisons between the forest health situation in 1989 and 1990 have been based on trees that were common to both surveys (the Common Sample Trees or **CST's**). The percentages of trees in the different defoliation and discolouration classes for the **total tree sample** and the **CST's** of 1989 and 1990 are shown in Figure 1. Among the CST's, the overall percentage of damaged trees increased slightly (5.2%) over the period 1989-1990, indicating that the proportion of undamaged trees has decreased. The change in the total percentage of discoloured trees over this period was negligeable (less than 1%).

The percentage of damaged trees in the total tree sample increased considerably from 9.9% in 1989 to 15.1% in 1990. Comparison with the increase in the percentage of damaged trees among the CST's, shows that the deterioration in the total tree sample was not only due to the deterioration of of trees already present in the inventory, but also to the extension of the grid network in 1990.

Tree health deteriorated most in Portugal and northwestern parts of Italy, where a relatively high number of plots changed from undamaged to damaged in the period 1989-1990. An improvement in tree health was found in several plots spread over the Community (Figure 6).

Regarding the entire subsample of CST's in the Community, a slight deterioration in vitality occurred in the period 1989-1990.

3.2 Changes by species group

The changes in defoliation and discolouration among the CST's in 1989 and 1990 can be specified to account for differences between species groups. Regarding **defoliation** among the CST's of 1989-1990, *Quercus ilex* showed no change in the percentage of damaged trees, whereas all other species showed a worsening in defoliation. *Quercus suber* showed a clear increase in defoliation and discolouration.
As to **discolouration**, some species groups improved while others deteriorated. **The largest improvement in discolouration** occurred for ***Eucalyptus*** sp., which species showed a increase in the total percentage of not- discoloured trees of nearly 10%. For *Quercus suber* the total percentage of not-discoloured trees decreased further to nearly 50% in 1990.

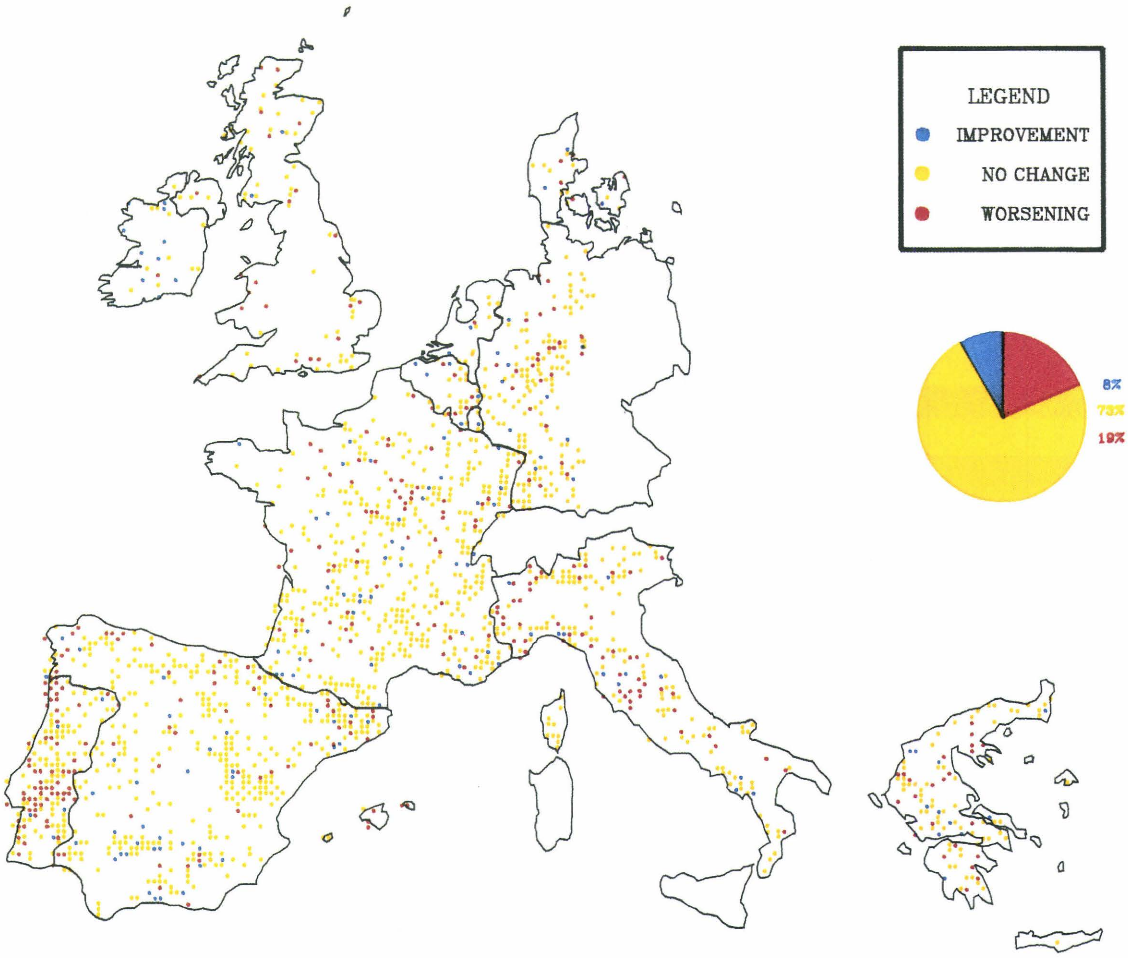

Figure 6: Changes in plot defoliation over the Community in the period 1989-1990.

When defining tree vitality as a combination of defoliation and discolouration, the **overall vitality of *Quercus suber* deteriorated considerably** in the period 1989-1990. **The vitality of *Fagus* sp. and deciduous *Quercus* sp. only worsened slightly**. For the other species groups, changes in both defoliation and discolouration were very small. Most species groups showed changes in defoliation opposite to those in discolouration so no definite statement can be made regarding changes in vitality for these species groups.

The overall vitality of *Quercus ilex* improved slightly. Although the degree of defoliation remained unchanged, the percentage of trees not-discoloured increased over the period 1989-1990.

4 Trends in tree vitality 1987-1988-1989-1990

The Forest Health Inventory of 1990 was the fourth consecutive survey of forest damage. In order to investigate the possible trends in vitality over these four years, a separate **subsample** was defined containing **trees that were common to the 1987, 1988, 1989 and 1990 surveys**. Within this subsample, the changes in vitality were examined for the most common tree species to enable the detection of possible trends in the health condition of the species.

Because of the **incomplete surveys** of 1987 and 1988, the trees in the subsample only represented a part of the total tree sample of the entire network. Changes in vitality that were observed for some species, e.g. *Quercus suber*, could in this analysis not be regarded as conclusive because of the low number of common trees. Future surveys of the completed network will greatly improve this situation.

For **several of the species** included in the investigation, **clear changes in vitality** were found over the four years of the inventory (Table 2). The **vitality of *Quercus ilex* has improved** considerably over the years. For species ***Castanea sativea*, *Picea sitchensis*, and *Quercus pubescens* a clear deteriorating trend** could be observed. The observed loss of vitality for *Picea sitchensis* was reported to be caused by severe attacks of the green spruce aphid (*Elatobium abietinum*), following the mild winters of 1988-1989 and 1989-1990. The effects were still apparent in 1990, although the deterioration was not so marked as in 1989.
In most other cases the **percentages of trees in the different defoliation classes fluctuated considerably**, without showing any consistent trend. The fluctuations may reflect temporal changes in growing conditions such as extreme weather conditions as late frost or drought.

TABLE 2: Changes in defoliation for trees common to 1987-1990 surveys.

Species	Defoliation 0-10%				11-25%				>25%			
year:	'87	'88	'89	'90	'87	'88	'89	'90	'87	'88	'89	'90
Picea abies	64.0	61.5	59.9	56.0	23.5	26.3	26.9	30.0	12.4	12.2	13.2	14.0
Pinus sylvestris	67.3	57.5	58.1	53.0	23.8	32.6	31.8	33.9	8.9	9.9	10.1	13.1
Fagus sylvatica	62.7	66.6	64.0	54.7	24.6	24.3	24.8	27.3	12.8	9.0	11.3	18.0
Quercus ilex	53.9	59.2	64.1	70.8	28.3	33.4	31.0	24.3	17.7	7.4	4.8	5.0
Pinus halepensis	60.9	54.0	65.4	64.1	28.6	37.6	28.9	30.7	10.5	8.3	5.7	5.2
Pinus nigra	73.3	70.9	78.1	60.6	20.7	24.7	19.2	28.6	6.0	4.5	2.7	10.8
Pinus pinaster	65.8	66.8	68.2	69.8	20.2	21.0	22.2	23.3	14.0	12.2	9.7	6.8
Castanea sativa	72.9	78.0	66.7	58.6	21.1	15.4	24.4	22.2	6.0	6.6	9.0	19.2
Picea sitchensis	47.6	39.4	28.4	18.5	31.8	31.4	24.6	27.8	20.6	29.3	46.9	53.7
Quercus robur	48.7	41.4	52.5	60.5	29.8	34.4	33.5	22.2	21.5	24.1	14.1	17.3
Quercus pubescens	88.4	78.0	71.3	62.1	3.9	14.6	20.9	22.2	7.8	7.4	7.8	15.7
Quercus petraea	68.5	70.2	65.4	61.3	25.7	20.5	24.3	29.8	5.8	9.2	10.3	8.9

5 Extended evaluation

5.1 Dynamics in defoliation

Natural fluctuations in annual crown density are suspected to contribute strongly to the observed patterns in defoliation. In a detailed investigation of a sub-sample of the data-set, it was shown that individual trees have **a large annual variation in defoliation**. The percentage of trees with constant crown density was found to be equal for *Pinus sylvestris*, a species with a relatively stable vitality index, and *Picea sitchensis*, which is known to have deteriorated considerably in terms of defoliation over the four years of survey. **Annual dynamics in defoliation are strong and appear independent of long-term trends in vitality.** Further studies into these dynamics in crown density are recommended when data from more annual surveys become available.

5.2 Soil type

Information on soil type was in 1990 for the first time included on a voluntary basis. From the limited number of available data (105 plots), **clear differences in the degree of defoliation between soil types** become apparent. From these initial data, it is important to **include information on soil type in future forest health surveys**.

6 Possible causes of observed damage as reported in the national forest health surveys

6.1 Introduction

National reports on forest health surveys are prepared by each Member State. These reports supply valuable background information on the vitality status of the forests in the Community.
The national surveys are in many cases executed on a denser grid than the 16 x 16 km of the EC-network. The observation grids measure from 0.3 x 0.3 km (in some parts of the Federal Republic of Germany), 1 x 1 km (Netherlands), and 2 x 2 km (Luxemburg), up to 16 x 16 km in other states. As a result of the different grids used in the National surveys, differences may occur when results are compared with results of the 16 x 16 km EC-grid. Due to storm damage, no surveys were carried out in some parts of the Federal Republic of Germany (Bavaria and Saarland) and Luxembourg.
In the National reports a chapter is included, presenting information on the possible causes of observed damage on a regional level. The most important possible causes mentioned are the weather, insects, fungi, forest fires, and air pollution.

6.2 Weather in 1990

For the second consecutive year, the weather in 1990 was in many countries dry, and relatively warm (e.g. Belgium, Federal Republic of Germany, France, Netherlands, and Portugal). In a number of places, late frost was reported as the cause of damage in (young) stands (e.g. the Netherlands, Belgium and Spain).
The dry and relative warm summer months lead to early defoliation and an accelerated discolouration through early-ageing of the leaves in Belgium, Denmark, the Federal Republic of Germany, the Netherlands and the United Kingdom (especially *Fagus* sp.). Damage due to long dry spells over the last years was reported to be severe in Greece.
The storms in the winter of 1989-1990 caused considerable defoliation, windthrow and root damage in Belgium, the Federal Republic of Germany, the United Kingdom and the Netherlands (especially *Picea* sp.).

6.3 Insects

Insects have been recorded in most countries. The attacks of the insects is in many cases less severe than in former years. Insects have been reported in Belgium (*Quercus sp.*), the Federal Republic of Germany (*Quercus sp.*), Spain (*Quercus sp.* and *Pinus*), The Netherlands (*Quercus sp.*, *Fagus sp.* and *Picea abies.*), and the United Kingdom. (*Picea sitchensis.*)

6.4 Fungi

Attacks of fungi have been reported only by The Netherlands (attacks are decreasing as a result of the mild winter and dry periods during the time of infection).

6.5 Forest fires

Severe damage caused by forest fires has been reported by Greece (37000 ha). Forest fires damaged in 1990 also large areas in France (70,000 ha.), Italy (170,000 ha.), Spain (175,000 ha.) and Portugal (122,000 ha.).

6.6 Air pollution

There is a major problem in **separating** changes in crown density or colouration **attributable to pollution from those caused by other factors**. Only a small fraction of the sample trees showed direct damage due to air pollution. However, cause-effect studies indicate that the stresses experienced by forest ecosystems can be divided into three broad categories: predisposing, inciting and contributing. The role of air pollution in forest health clearly varies depending on its nature and concentration. In some parts of Europe, the Central and Eastern European countries, air pollution is considered as an inciting factor and the most important affecting forest health. Elsewhere in Europe, air pollution levels are very low and can only be considered as one of the factors predisposing forests to decline. Several countries emphasised that factors other than air pollution are considered more important in determining forest health, although they regard air pollution as a possible predisposing factor.

6.7 Fructification

Although fructification is not considered to be a cause of damage, excessive fructification could result in a decreased foliation. Excessive fructification has been recorded for in Belgium (*Fagus*), in the United Kingdom (*Fagus*), in the Federal Republic of Germany (*Fagus*), and The Netherlands (*Fagus* and *Pseudotsuga*).

6.8 Other possible causes of observed damage

Greece reported damage caused by overgrazing (especially in the maquis area) and in the near surrounding of population centres (firewood?).
Denmark has reported a complex disorder on Norway spruce, strongly resembling top-dying. The cause of the disorder seems most likely to be a combination of three mild winters in a row, drought, the rather high concentrations of ozone in the forest in 1988-89, and perhaps seasalt deposition.

7 Conclusions and Recommendations

The Forest Health Survey has in 1990 been greatly extended with the participation of five Non-EC countries; Austria, Czechoslovakia, Hungary, Poland and Switzerland, and the reunion of the two German states. The data-set was enlarged by 48% bringing the total number of sample trees to 67,335.

Observations in 1990 showed **15.1%** of the trees in the EC to be considered as **damaged** (defoliation more than 25%). The average damage in the five Non-EC countries amounted to more than twice this figure: 35.3%. The total figures for the defoliation (>25%) in the EC in 1987, 1988 and 1989 were 14.3% (1216 plots), 10.2% (1526 plots) and 9.9% (1891 plots) respectively.

In 1990 a **discolouration of more than 10%** was observed in the Community for **14.4%** of the trees (Non-EC average: 12.2%). For the 1987, 1988 and 1989 surveys in the EC-Member States these figures (from smaller samples) were 13.5%, 13.2% and 16.0% respectively.

In terms of defoliation **conifers** were slightly more damaged than **broadleaves**. In 1990, a defoliation of more than 25% was found for 15.4% of the conifers and 14.9% of the broadleaves (Non-EC averages: 38.4% and 25.5% respectively). The most common species in the Community, ***Picea*** sp., ***Pinus*** sp., the **deciduous *Quercus*** sp. and ***Fagus*** sp., showed percentages of damaged trees (defoliation >25%) in the order of 10 to 20%. ***Quercus suber*** showed the **highest defoliation** with more than 40% of the trees damaged. The ***Eucalyptus*** sp. (3% damaged) showed the **lowest** degree of defoliation in the EC. **Discolouration** was more pronounced among broadleaves (16.2% affected) as compared to conifers (12.5% affected). In the Non-EC countries, discolouration averaged 24.9% among broadleaves and 8.1% among conifers. In the Community the percentage of broadleaved trees with a discolouration of more than 10 % was **highest** for ***Quercus suber*** (nearly 50%). Among conifers the differences in discolouration between species were small, especially in the EC.

Within the subsample of Common Sample Trees 1989-1990, **the percentage of clearly defoliated trees increased** from 8.2% in 1989 to 13.4% in 1990. The largest change in damage occurred in the Mediterranean region for species *Quercus suber*: from less than 10% in 1989 to over 40% in 1990. A reason for this large change has not been reported.

For the majority of the trees common to the surveys of 1987, 1988, 1989 and 1990, no clear changes in vitality were observed over this time-period. A trend of **improvement** in vitality appeared to occur for *Quercus ilex*. A clear **deterioration** is observed for *Quercus pubescens* and *Picea sitchensis*. The increase in defoliation of *Picea sitchensis* is mainly due to attacks by the green spruce aphid (*Elatobium abietinum*) in the United Kingdom and Ireland. For *Quercus pubescens* no reasons for deterioration are known.

There is a major problem in **separating** changes in crown density or colouration **attributable to pollution from those caused by other factors**. Only a small fraction of the sample trees showed direct damage due to air pollution. However, cause-effect studies indicate that the stresses experienced by forest ecosystems can be divided into three broad categories: predisposing, inciting and contributing. The role of air pollution in forest health clearly varies depending on its nature and concentration. In some parts of Europe, the Central and Eastern European countries, air pollution is considered as an inciting factor and the most important affecting forest health. Elsewhere in Europe, air pollution levels are very low and can only be considered as one of the factors predisposing forests to decline. Several countries emphasised that factors other than air pollution are considered more important in determining forest health, although they regard air pollution as a possible predisposing factor.

In an extended evaluation it was shown that there appears to be a general trend for trees to shift to **higher defoliation** classes (higher damage) with increasing **mean stand age**.
The **annual dynamics in defoliation are large**, even among relatively healthy species that remained, on average, unchanged in defoliation. **Most trees show yearly shifts in defoliation classes**. Further studies into these dynamics in crown density are recommended as data from more annual surveys become available.

In the 1990-survey the soil type was for the first time inventoried on a voluntary basis. Given the differences found between the reported soil types, it is strongly recommended **to include information on soil type** in future forest health surveys.

The complete and correct collection of annual data on forest health is of paramount importance to the understanding of the dynamics in tree health. In the future, **time-series of many consecutive years should become available**. In such time-series each annual survey plays an equally important role.

European Communities - Commission

Forest health report 1991 — Executive report on the 1990 survey

Document

Luxembourg: Office for Official Publications of the European Communities

1991 - 26 pp., 6 illus. - 21.0 x 29.7 cm

ISBN 92-826-3344-6

Catalogue number: CH-72-91-245-EN-C