CONVENTION ON LONG-RANGE TRANSBOUNDARY AIR POLLUTION

International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests

United Nations
Economic Commission
for Europe

European Commission

Forest Condition in Europe

Results of the 1993 Survey

1994 Executive Report

Cover photo from M. Lorenz

Printed in Germany

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CONTENTS

PREFACE

With the present report the United Nations Economic Commission for Europe (UN/ECE) and the European Union (EU) continue their series of common Forest Condition Reports. The first of this kind was published in 1992. The report describes the results of both the national and the transnational crown condition surveys, which are conducted annually within the International Cooperative Programme on the Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) of UN/ECE and under EU-Council Regulation (EEC) 3528/86 on the Protection of the Community's Forests against Atmospheric Pollution. These two programmes have the objective to continuously monitor and document the extent and development of recent forest damage in Europe, as well as to contribute to cause-effect studies.

ICP Forests was launched under the Convention on Long-range Transboundary Air Pollution (LRTAP) in 1985, which in the meantime has been signed by 37 Parties. Of these Parties, 32 states and the European Union are participating in ICP Forests. Also participating are Estonia, Latvia and the Republic of Moldova, which are expected to sign the Convention in the near future.

Every year the participating countries submit reports on the results of their national forest damage surveys to the Programme Coordinating Centre West (PCC West) of ICP Forests. Canada and the United States of America also report annually on their research and forest health monitoring programmes in North America.

In 1987, 11 EU-Member States started surveying forest damage annually on the plots of a uniform (16x16 km) large-scale transnational grid, along with a number of site parameters. Since 1988 all 12 EU-Member States have been participating in this survey. Since 1990 this network has been gradually extended, as 15 non-EU countries have joined this survey. These countries are Austria, Croatia, the Czech Republic, Estonia, Finland, Hungary, Lithuania, the Republic of Moldova, Norway, Poland, Romania, the Slovak Republic, Slovenia, Sweden and Switzerland. Altogether there are now 27 European countries participating in the transnational survey. These countries submit their transnational data either to the European Commission or directly to PCC West of ICP Forests. At PCC West the data are evaluated for the preparation of the annual report.

The preparation of the present report was made possible thanks to

- the submission of forest condition data by the participating countries,
- financial support granted by the European Union,
- voluntary financial contributions granted by UN/ECE member states,
- the calculation of geographical coordinates of the inventory grid intersection points by the European Commission, Corine project, DG XI.

SUMMARY

The main objective of the present report is a condensed description of the condition of forests in Europe, as it has been assessed by transnational and national surveys of the United Nations Economic Commission for Europe (UN/ECE) and the European Union (EU). The report presents survey results from 35 European countries, referring to about 26 000 sample plots with about 558 000 sample trees. Of 222 million hectares of forests in Europe as reported by the participating countries, around 181 million hectares have been covered by the surveys (3 million less than in 1992). The results of the 1993 survey indicate that forest damage continues to be a problem in Europe, as a significant proportion of the forests shows signs of defoliation and/or discolouration.

The transnational survey results for 1993 revealed that 22.6% of the total sample of around 102 800 trees had been defoliated by more than 25% and are thus classified as damaged. The respective value in 1992 was 23.5%, which was 0.9 percent points higher than this year.

In 1993 the share of trees with a discolouration of more than 10% was 10.0% of the total tree sample. This change is insignificant (0.1 percent points lower) as compared with the previous year (10.1%).

As regards the two main species groups, 20.4% of the total broadleaves were damaged in 1993. This indicates that the broadleaves are now in a slightly better condition than the conifers, of which 23.9% were damaged. Among the most common species, the most severely affected broadleaved species was *Quercus* spp. (deciduous) with 27.1% damaged trees, followed by Other broadleaves with 22.7% trees damaged. Among the conifers, *Abies* spp. and *Picea* spp. showed the highest percentages of trees classified as damaged (36.7% and 26.5%, respectively).

In the subsample of common trees, the proportion damaged increased between 1988 and 1993 in all of the 12 species analyzed. Among the conifers, *Picea sitchensis* showed the greatest increase, from 4.6% in 1988 to 33.8% in 1993. This was probably due to *Elatobium*. Amongst broadleaved species, there was a dramatic increase in damage in *Quercus suber*, from 0.7% in 1988 to 44.0% in 1991, but the share of damaged trees decreased rapidly from 36.2% in 1992 to 9.5% in 1993. Damage in *Quercus robur* increased remarkably from 12.9% in 1988 to 26.8% in 1993.

In both the national and the transnational survey the most important probable causes for the observed defoliation and discolouration were reported to be adverse weather conditions, insects and fungi, air pollution and forest fires. Very little direct impact from known pollution sources was reported, but this does not exclude the possibility of more widespread effects of air pollution. Particularly in the main damage areas of some countries, but also in several other regions, air pollution is considered as of major concern, because the atmospheric concentrations and the depositions of several air pollutants are thought to exceed the critical levels and loads for forest ecosystems. These countries regard air pollution as the most important factor causing forest damage. The majority of the remaining countries consider air pollution as a predisposing factor leading to the weakening of forest ecosystems.

The great spatial and temporal variation in the survey results emphasizes the importance of continued monitoring of defoliation and discolouration and additional assessments of various ecological data which may contribute to a better understanding of cause-effect relationships. Therefore, within the cooperation between UN/ECE and EU, in addition to the large scale crown condition assessment, an integrated monitoring system is being established. This intensive monitoring aims at the recognition of factors and processes with special regard to the impact of air pollutants on the more common forest ecosystems. This is accomplished by means of a number of subjectively selected permanent monitoring plots, on which a soil inventory, foliar analyses, deposition measurements and increment studies will be conducted.

1. INTRODUCTION

Eight years of continuous monitoring of forest condition and more than a decade of cause-effect research have changed the understanding of forest decline in Europe considerably. In the early 1980s forest decline as diagnosed by means of defoliation and discolouration of trees was mainly tried to be explained by means of several hypotheses involving the effects of air pollution. The reasons for this were the rapid dynamics of forest damage at many locations, the absence of obvious classical damaging agents, an increasing awareness of the impact of air pollution on the environment and the results of cause-effect research on several forest sites. Cause-effect research revealed a multitude of factors and mechanisms, with air pollution being involved to differing extent in certain regions. In the europewide monitoring of forest condition established in the mid 1980s, defoliation and discolouration became the key parameters, because they constituted the most obvious symptoms and were relatively easy to assess. The continuous large-scale monitoring could not contribute to cause-effect research because of the low specificity of these parameters, but reached its objective to document the large scale development of forest condition in Europe. The previous reports on the forest condition assessments in Europe have shown us that air pollution has caused less dramatic damage than feared in the early 1980s at the large scale, but that a general worsening of forest condition is to be observed in many regions. In certain regions the damage is severe and locally catastrophical, particularly at locations where air pollution is high.

The present report documents forest condition in Europe, as it has been assessed in the surveys of UN/ECE and EU in 1993, as well as the development of forest condition since the beginning of the monitoring. The content of the present report has been structured as follows:

Chapter 2 describes the principles of the survey methods. The knowledge of the methodical background is indispensable for the interpretation of the results.

Chapter 3 presents the results of the 1993 surveys. The transnational results (Chapter 3.1) reflect forest condition in Europe as a whole. These results refer to correlations between the symptoms assessed and the site parameters. The national reports (Chapter 3.2) reflect forest condition in particular countries.

Both the transnational and the national survey results are interpreted together in Chapter 4, also with special regard to the effects of air pollution. These interpretations represent the view of the members of the two Programmes of UN/ECE and EU.

Chapter 5 presents the conclusions drawn from the survey results and their interpretation.

The Annex provides tables relevant to the national results and a list of species names in Latin and 11 other languages.

2. METHODS OF THE 1993 SURVEYS

2.1 Transnational survey

The **transnational survey** aims at the documentation of the development of forest condition on the European level. This is achieved by means of a large scale monitoring of tree vitality using uniform survey methods in a systematic way and by assessing a number of site parameters on a 16x16 km transnational grid of sample plots. In several countries the plots of this transnational grid are a subsample of a denser national grid.

2.2 National surveys

The **national surveys** aim at the development of forest condition in the respective country and are therefore conducted on national grids. The densities of these national grids vary between 1x1 km and 32x32 km due to differences in the size of forest area, in the structure of forests and in forest policies. Because of differences in species composition and site conditions and use of different reference trees, comparisons between the two surveys and between different countries should be made with great care.

2.3 Selection of sample trees

Within both the national and transnational surveys, at each sampling point positioned on forest land, 20-30 sample trees are systematically selected according to a statistically sound procedure. The tree sample includes all tree species, provided the trees have a minimum height of 60 cm. Only predominant, dominant, and co-dominant trees (according to the system of KRAFT) without significant mechanical damage qualify as sample trees. Trees removed within management operations or blown over by wind must be replaced by newly selected trees. A special evaluation of the replaced trees has shown that, due to the small percentage of removed trees, this replacement does not distort the assessment results.

2.4 Assessment parameters and presentation of data

On each plot the defoliation and discolouration of the sample trees are assessed in comparison to a reference tree of full foliage. If no reference tree can be found in the vicinity of the sample trees, photo guides suitable for the region under investigation may be used.

In the transnational survey defoliation is reported in general in 5% steps, and discolouration in discoluration classes. The national survey results for defoliation are reported by most countries in 10% steps. This assessment down to the nearest 5 or 10% permits studies of the annual variation of foliage with far greater accuracy than the traditional system of only 5 classes of uneven width. Nevertheless, some countries still report their national results by means of the traditional classification. Discolouration in the national surveys is reported by all countries using the traditional classification. The traditional classification for defoliation and discolouration is shown in Table 2.4-1.

The assessment does not permit separating changes in crown density or discolouration attributable to air pollution from those caused by other factors. As a consequence, defoliation due to any other causes is included, although known causes should be recorded during the assessment.

Table 2.4-1: Defoliation and discolouration classes according to UN/ECE and EU classification

Defoliation class	needle/leaf loss	degree of defoliation
0	up to 10 %	none
1	> 10 - 25 %	slight (warning stage)
2	> 25 - 60 %	moderate
3	> 60 %	severe
4	100 %	dead
Discolouration class	foliage discoloured	degree of discolouration
0	up to 10 %	none
1	> 10 - 25 %	slight
2	> 25 - 60 %	moderate
3	> 60 %	severe
4	100 %	dead

On the plots of the trans-national survey, additional parameters have to be assessed as laid down in Commission Regulation (ECE) 926/93. The following information has to be submitted for each plot: country, plot number, plot coordinates, altitude, aspect, water availability, humus type, soil type (optional), mean age of dominant storey, tree numbers, tree species, observations of easily indentifiable damage, date of observation.

The survey results are expressed mainly in terms of the percentages of the tree sample falling into the traditional 5 defoliation or discolouration classes. This traditional classification reflects to a certain extent the experience gathered in central Europe between 1980 and 1983. At that time, any loss of foliage exceeding 10% was considered as abnormal, indicating an incipient stage of impaired forest health. Furthermore, assumptions based on physiological observations of the vitality of differently defoliated trees led to the establishment of the uneven class widths. Because of these reasons and in order to ensure comparability with previous presentations of survey results the traditional classification of both defoliation and discolouration has been retained for comparative purposes, although it is considered arbitrary by some countries.

In many cases only a distinction has been made between defoliation classes 0 and 1 (0-25% defoliation) on the one hand, and classes 2, 3 and 4 (defoliation > 25%) on the other hand. The reason for this is that trees of a defoliation up to 25% are looked upon as "undamaged", with a defoliation of >10-25% indicating a "warning-stage". Classes 2, 3 and 4 represent considerable defoliation and are thus referred to as "damaged". Similar to the sample trees, the sample points are referred to as "damaged" if the mean defoliation of its trees (expressed as percentages) falls into class 2 or higher. Otherwise the sample point will be considered as "undamaged".

The most important results have been tabulated separately for all countries having participated (called "total Europe") and for the EU-Member States. For those countries, from which suitable data sets of their national survey have been received, the basic results of the national surveys are presented in 10% defoliation classes in order to enhance resolution and thus to be able to study changes in defoliation.

3. RESULTS OF THE 1993 SURVEYS

3.1 Transnational survey results

3.1.1 General results

Of the 102 800 sample trees of 1993, 22.6% of the trees had a **defoliation** of more than 25%, i.e. were in defoliation classes 2-4 and thus considered as damaged. The respective percentage for the EU-Member States was 16.0%. The conifers had a higher proportion of damaged trees (23.9%) than the broadleaves (20.4%). This difference was slightly less pronounced in the EU-Member States (17.0% and 15.1%, respectively, see Table 3.1.1-1). As several non-EU-Member States did not assess discolouration on all of their sample trees, **discolouration** was reported for only 92 943 trees in 1993. 10.0% of this tree sample had a discolouration of more than 10%. In contrast to defoliation, discolouration was higher in the broadleaves than in the conifers. The difference in discolouration between broadleaves and conifers was clearly less pronounced in the EU-Member States (Table 3.1.1-2).

Table 3.1.1-1: Percentages of defoliation for broadleaves, conifers and all species

	Species type	Defoliation							No. trees
		0-10%	>10-25%	0-25%	>25-60%	>60%	dead	>25%	
EU	Broadleaves	51.9	33.0	84.9	12.8	1.5	0.8	15.1	25258
	Conifers	50.1	32.9	83.0	14.8	1.1	1.1	17.0	22913
	All species	51.0	33.0	84.0	13.8	1.3	0.9	16.0	48171
Total Europe	Broadleaves	46.7	32.9	79.6	17.4	2.2	0.8	20.4	40149
	Conifers	41.5	34.6	76.1	21.5	1.7	0.7	23.9	62651
	All species	43.5	33.9	77.4	19.9	1.9	0.8	22.6	102800

Table 3.1.1-2: Percentages of discolouration for broadleaves, conifers and all species

	Species type	Discolouration						No. trees
		0-10%	>10-25%	>25-60%	>60%	dead	>10%	
EU	Broadleaves	87.2	9.3	2.2	0.5	0.8	12.8	25257
	Conifers	88.3	8.7	1.7	0.2	1.1	11.7	22913
	All species	87.7	9.0	2.0	0.4	0.9	12.3	48170
Total Europe	Broadleaves	87.1	9.2	2.3	0.5	0.8	12.9	39584
	Conifers	92.0	5.7	1.2	0.2	0.9	8.0	53359
	All species	90.0	7.2	1.7	0.3	0.8	10.0	92943

In contrast to previous years, the UK data this year are based on an assessment of crown density made with reference to a tree with full foliage growing under the same local conditions as the assessed trees, rather than with reference to photographs of fully-foliated trees growing under ideal conditions. This explains the apparently large change in defoliation since 1992. The change makes possible a better comparison of results with those of other countries.

Figure 3.1.1-1 shows the spatial distribution of the percentages of damaged trees per plot over the entire survey area. The pie diagram in Figure 3.1.1-1 reveals that on 50% of the plots the share of damaged trees is 10% or lower. These plots are mainly located in Scandinavia, in southwestern Europe and in the eastern part of the Alps. On the other hand, the share of damaged trees ranges from 51%-75% on 9% of the plots, and from 76%-100% on 7% of the plots. This means that on 16% of all plots more than half of the trees are damaged. As in previous years, the areas with the highest proportion of damaged trees are located in central Europe.

Maps of the distribution of the mean plot defoliation and plot discolouration over the entire area are shown in Figures 3.1.1-2 and 3.1.1-3. The mean plot defoliation (Fig. 3.1.1-2) is classified according to the five defoliation classes. On 26% of the plots the mean defoliation is larger than 25% (classes 2-4 with 25%, 1% and 0%, respectively). These plots are mainly located in central Europe.

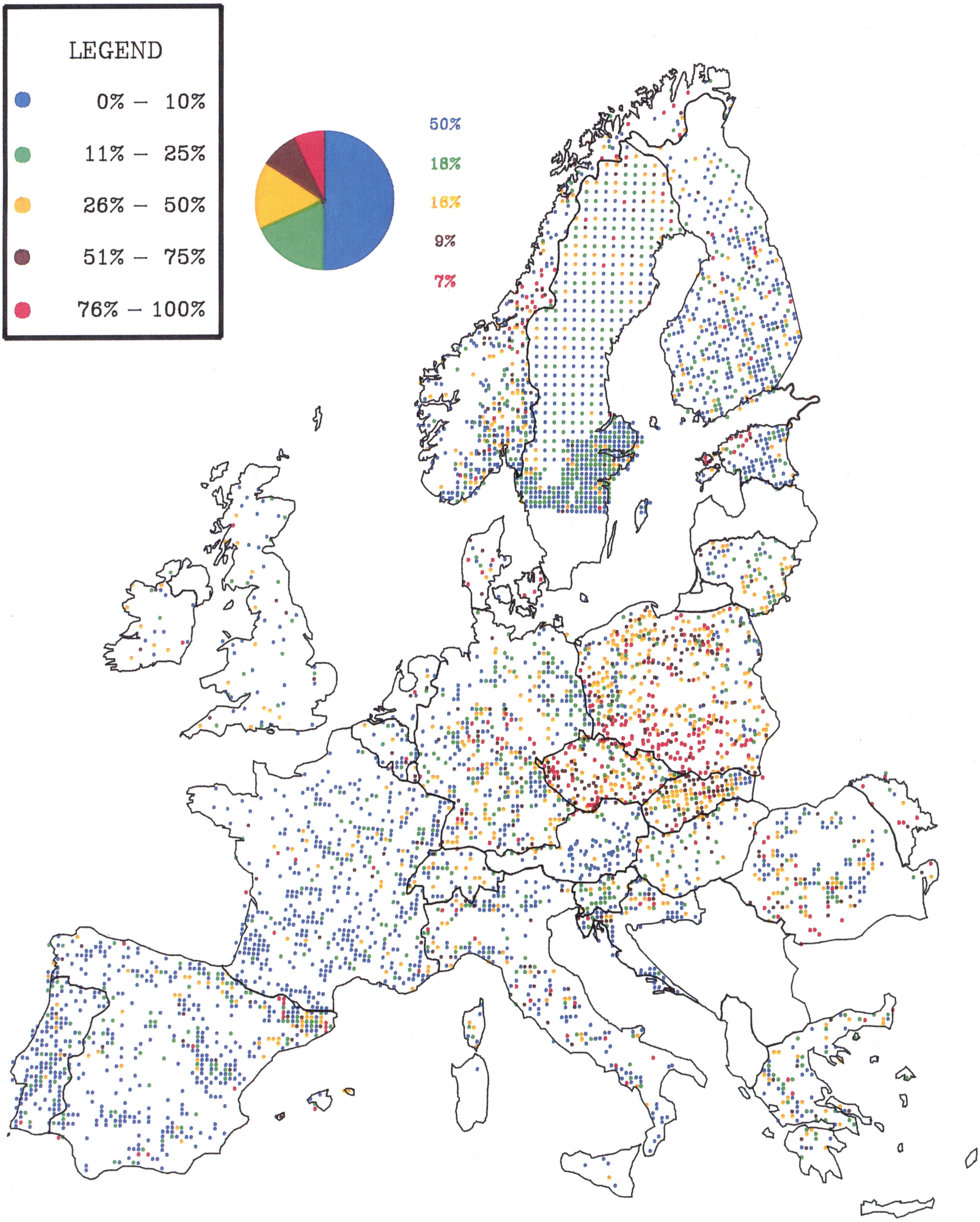

Figure 3.1.1-1: Percentage of trees damaged in 1993. The percentages are the basis for the transnational evaluation and not suitable for comparisons between individual countries.

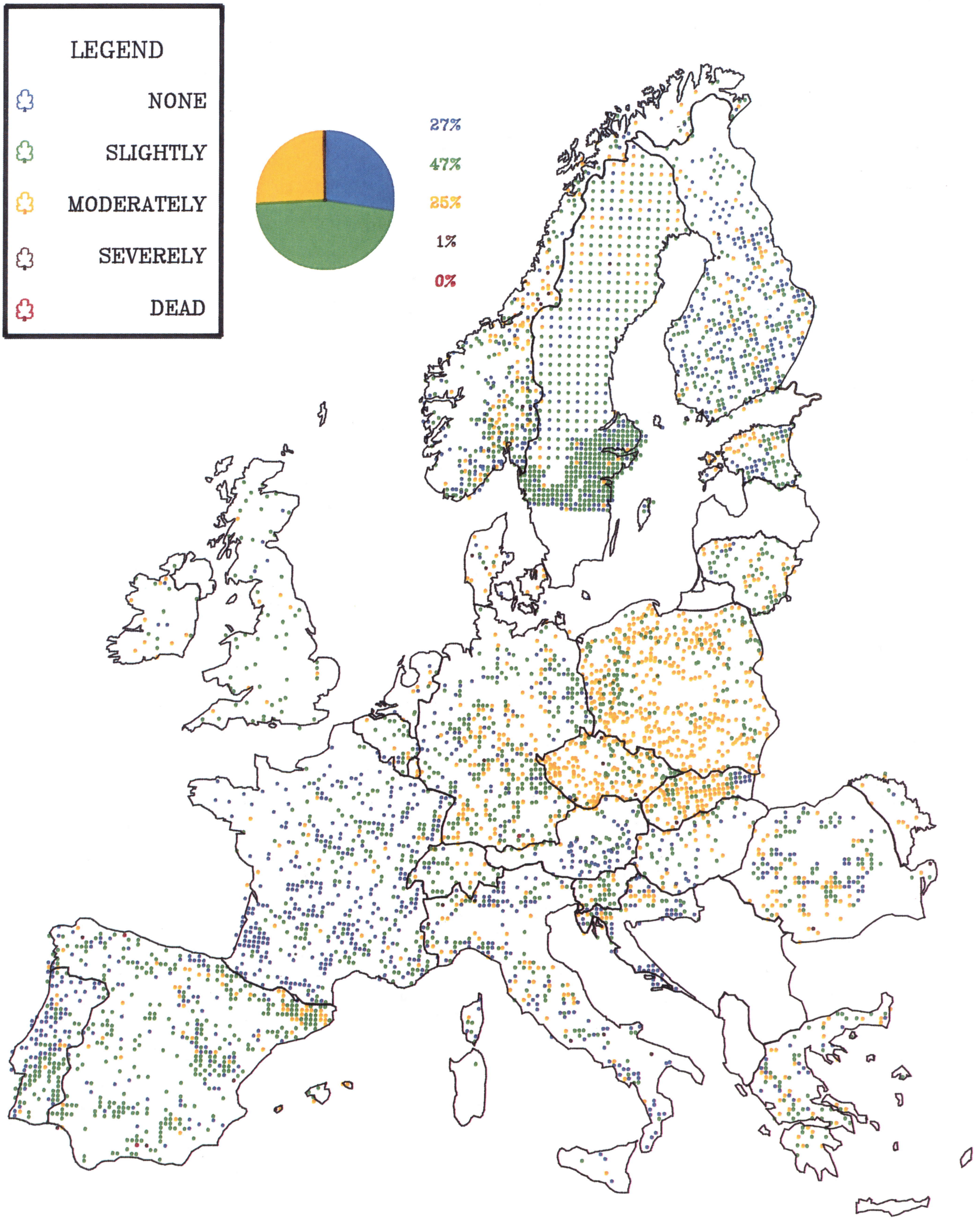

Figure 3.1.1-2: Plot defoliation (1993). The figures for defoliation are the basis for the transnational evaluation and not suitable for comparisons between individual countries.

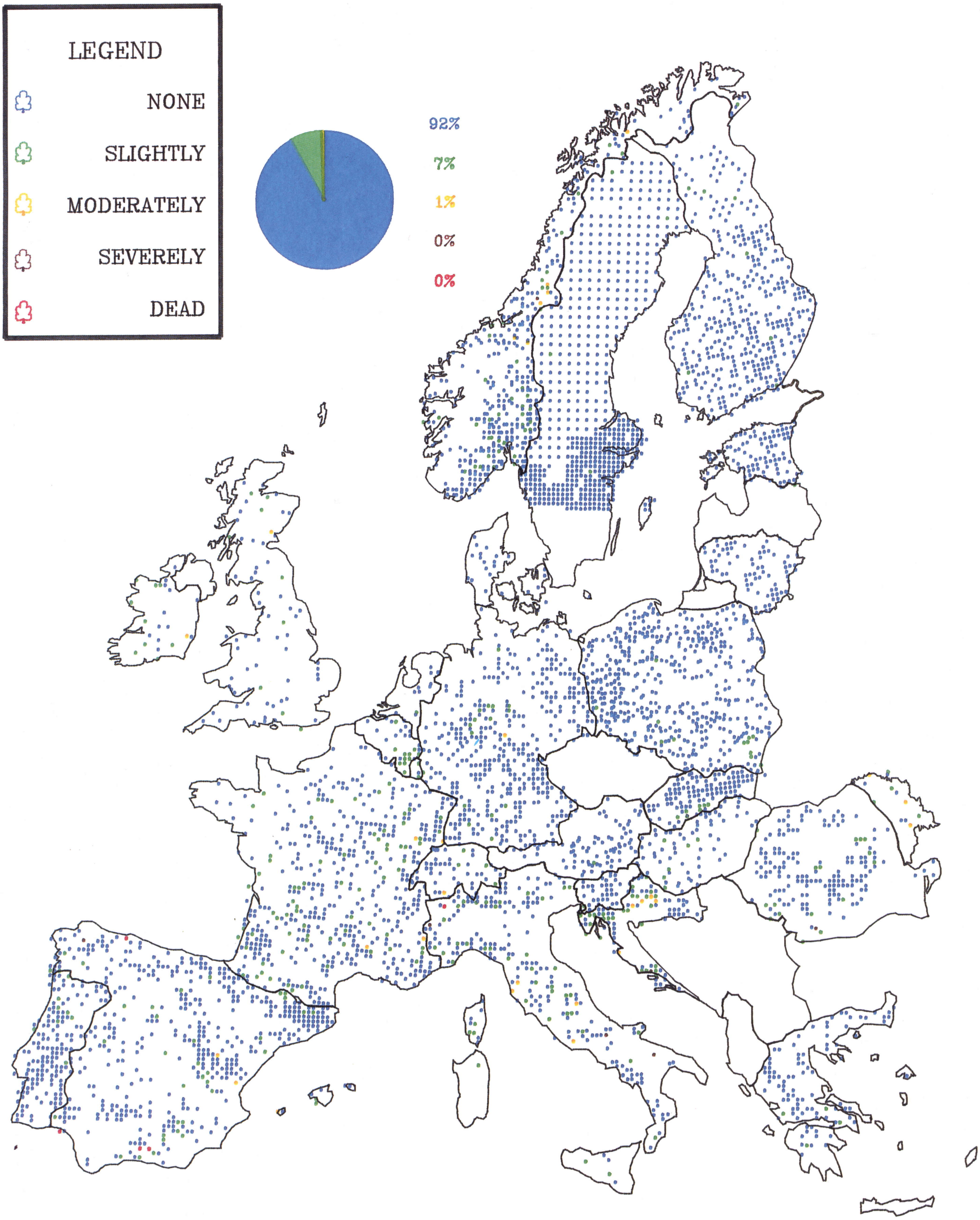

Figure 3.1.1-3: Plot discolouration (1993). The figures for discolouration are the basis for the transnational evaluation and not suitable for comparisons between individual countries.

3.1.2 Forest condition by species groups

In total Europe as well as in the EU-Member States, defoliation among the broadleaved species groups was least severe for *Quercus ilex* and *Eucalyptus* spp. (both 7.1% in classes 2-4). The highest percentage of damage trees was found for *Quercus* spp. (deciduous) (27.1% in classes 2-4). Of all coniferous species groups in total Europe, *Abies* spp. and *Picea* spp. showed the highest percentages of trees in defoliation classes 2-4 (36.7% and 26.5% respectively), suggesting a generally poorer condition. The share of damaged trees was lowest for Other conifers (14.2%).

Discolouration among the broadleaved species groups in total Europe and in the EU-Member States was most prevalent for *Quercus* spp. (decidous) (16.3% of the trees discoloured, i.e. showing discolouration greater than 10%). *Quercus ilex* showed the lowest percentage of trees discoloured (5.5%). Among the conifers, *Abies* spp. was the species group with the highest percentage of trees (17.6%) in discolouration classes 1-4. The least discolouration was found in *Picea* spp. and *Pinus* spp. with 6.2% and 8.3% of the trees being more than 10% discoloured, respectively.

3.1.3 Defoliation and discolouration by mean age

The database of the 1993 survey confirms the strong positive correlation between age and **defoliation** which has been found for slightly smaller data sets already in the previous surveys. For both the EU-Member States and total Europe, Table 3.1.3-1 shows the percentages of trees in each defoliation class for 7 classes of different mean stand age and for a class of irregular age composition.

As in the previous years, the percentage of damaged trees (defoliation >25%) shows a gradual increase with increasing mean age between ages 0-80. With higher ages, however, the percentage of damaged trees remains at approximately the same level. The share of dead and severely defoliated trees is very small compared to the total number of sample trees, but this is partly a result of the conventional classification with only 5 damage classes.

Table 3.1.3-1: Percentages of defoliation of all species by mean age

	Mean age [years]	Defoliation 0-10%	>10-25%	0-25%	>25-60%	>60%	dead	>25%	No. of trees
EU	0 - 20	65.0	25.0	90.0	7.7	0.9	1.4	10.0	7502
	21 - 40	56.8	29.6	86.4	11.2	1.3	1.1	13.6	12528
	41 - 60	49.7	35.8	85.5	12.9	1.1	0.5	14.5	8516
	61 - 80	46.3	37.8	84.1	14.3	1.0	0.6	15.9	5375
	81 -100	39.7	39.7	79.4	18.3	0.9	1.4	20.6	4557
	101-120	34.0	39.9	73.9	23.5	2.3	0.3	26.1	2358
	>120	31.8	35.5	67.3	30.1	2.4	0.2	32.7	2639
	Irregular	51.6	32.6	84.2	12.7	1.9	1.2	15.8	4696
	Total	51.0	33.0	84.0	13.8	1.3	0.9	16.0	48171
Total Europe	0 - 20	63.8	25.3	89.1	8.5	1.1	1.3	10.9	8652
	21 - 40	55.6	29.5	85.1	12.5	1.4	1.0	14.9	16648
	41 - 60	40.1	35.9	76.0	21.0	2.3	0.7	24.0	17945
	61 - 80	34.4	37.0	71.4	25.6	2.3	0.7	28.6	15644
	81 -100	34.4	37.1	71.5	26.0	1.8	0.7	28.5	11540
	101-120	35.2	36.6	71.8	25.5	2.4	0.3	28.2	5326
	>120	39.6	33.4	73.0	23.9	2.7	0.4	27.0	5380
	Irregular	51.2	31.7	82.9	14.0	2.0	1.1	17.1	5056
	Total	43.9	33.6	77.5	19.7	2.0	0.8	22.5	86191

3.1.4 Easily identifiable damage

The eight types of damages that can be easily identified on the sample trees are:

- **game and grazing (damage to trunk, bark etc.)**
- **presence or traces of an excessive number of insects**
- **fungi**
- **abiotic agents (wind, drought, snow etc.)**
- **direct action of man (poor silvicultural practices, logging etc.)**
- **fire**
- **known local or regional pollution (classical smoke damage)**
- **other types of damage**

For these categories, only the **presence** of such damages is indicated. It is presented in Table 3.1.4-1 in terms of the percentage of the total tree or plot sample that is affected. No indication is given of the **intensity** of the damage. It is possible that more than one type of identifiable damage occurs on a single tree. Such trees will therefore be represented more than once in the table. Of the 102 800 trees of the total tree sample, 30 655 trees (29.8%) showed any identifiable damage of one or more causes. These trees were observed on 2 891 plots (60.3%) of the total plot sample. The trees outnumber the plots, as several trees with identifiable damage may occur on the same plot. On the other trees identifiable damage was either not present or not assessed. In the Czech Republic and in Finland (8 779 trees together) easily identifiable damage was not assessed at all.

Table 3.1.4-1: Percentages of trees with defoliation >25% and discolouration >10% by identified damage types, based on a total of 4 791 plots with 102 800 trees

Damage type	Defoliation % in classes 2, 3, 4		Discolouration % in classes 1, 2, 3, 4		Observations (% of total)			
					Total Europe		EU	
	Total Europe	EU	Total Europe	EU	Trees	Plots	Trees	Plots
Game/Grazing	20.4	19.5	16.2	19.2	1.8	5.5	2.7	6.0
Insects	28.3	20.8	14.7	12.4	11.7	25.1	18.0	40.1
Fungi	27.1	19.5	19.0	18.8	6.0	18.9	8.3	25.0
Abiotic agents	31.5	31.4	30.8	35.8	5.2	22.3	5.4	19.6
Action of man	23.2	17.2	15.1	17.2	4.8	20.8	4.9	14.6
Fire	28.4	29.0	28.9	30.9	0.7	1.4	1.3	2.9
Known pollution	29.3	3.0	44.4	56.0	0.3	0.4	0.1	0.2
Other	13.6	11.2	10.6	10.8	9.7	26.3	16.5	27.8
Any ident. damage	24.5	19.3	16.6	16.6	29.8	60.3	39.9	65.8
No ident. damage	21.6	13.7	6.9	9.4	70.2	39.7	60.1	34.2
Total	22.6	16.0	10.0	12.3	102800	4791	48171	1994

Among the trees showing any identifiable damage, the proportions of trees in defoliation classes 2-4 ranged between 13.6% (1349 trees) (**other types of damage**) and 31.5% (1682 trees) (**abiotic agents**) in total Europe. For the damage types **game/grazing**, **fungi** and **fire**, the respective proportions increased in comparison with the 1992 survey results. The most obvious increase occurred in the group of damage caused by **fire** (from 22.9%)(158 trees) in 1992 to 28.4% (200 trees) in 1993). In the respective percentages of trees affected by the other damaging agents there was a decrease in 1993. The largest decrease was reported for the share of trees affected by **known pollution**, namely from 42.9% (97 trees) in 1992 to 29.3% (97 trees) in 1993. These changes should be regarded very carefully because the number of sample trees was too small.

When regarding all trees with **any identifiable damage** together, the percentage of trees in defoliation classes 2-4 (24.5%) is 2.9 percent points higher as compared to trees with **no identifiable damage** (21.6%). In the EU-Member States, 5.6 percent points more trees appear to be damaged (defoliation more than 25%) in the presence of any identifiable damage (19.3%) than when no damage has been identified (13.7%).

As regards discolouration, in total Europe the share of trees of discolouration greater 10% showing any identifiable damage (16.6%) was 9.7 percent points larger than the one without identifiable damage (6.9%). In the EU-Member States, the respective shares of discolouration were 16.6% and 9.4%, yielding a 7.2 percent point difference between the subsamples with any and no identifiable damage types.

The most pronounced negative effect in terms of discolouration was observed for trees affected by **known pollution** with 44.4% of the trees (147 trees) in discolouration classes 1-4 in total Europe. The respective figure for the EU-Member States is 56.0% (37 trees). In comparison to 1992, this represents an increase by 6.8 percent points regarding total Europe and a decrease by 1.8 percent points regarding the EU-Member States. Similar to the defoliation results, these changes in discolouration should be regarded with care because of the small number of sample trees.

Interpretation of the data related to identifiable damage is difficult. The main problem is that some of the damaging agents are more easily identified, or identified with more certainty than others. Moreover, it is not always clear from the data reported if no obvious damage could be identified or if no assessment has been made. Damage types were observed on a low proportion of sample trees (0.3 to 11.7%) only. Therefore, the data presented here only give a general indication of the effect of several damage types.

3.1.5 Changes in defoliation and discolouration from 1992-1993

The results presented under Chapter 3.1.5 are based on differences in the proportions of trees defoliated between the two years. For the climatic regions (Chapter 3.1.5.1) these differences were statistically tested for their significance.

In order to be able to compare the results of 1992 and 1993, a subsample is defined containing all trees that are common to both surveys: the **Common Sample Trees (CSTs)**. This common sample consists of 84 969 trees, representing 89.4% of the total tree sample of 1992 and 82.7% of the total tree sample of 1993. This is 18 828 or 28.5% more CSTs than in the 1992 survey. The reasons for this year's particularly large number of CSTs are the inclusion of Lithuania, Norway and Romania in 1992. Moreover, parts of the Swedish tree sample represenative for identical areas in 1992 and 1993 have been treated as CSTs. In addition, in 1993 the Czech Republic submitted both the 1992 and the 1993 data. The increasing number of CSTs is not only valuable for a more objective calculation of changes in defoliation and discolouration, but also indicates a growing consistency of the datasets in the participating countries. Because of the reasons mentioned in Chapter 3.1.1, the sample trees of the United Kingdom were not included in the CSTs this year.

Table 3.1.5-1 shows the percentages of trees in the different defoliation and discolouration classes for the total tree samples in 1992 and 1993, and the percentages for the trees common to the 1992 and 1993 surveys.

Table 3.1.5-1: Percentages of the total tree sample and the Common Sample Trees in different defoliation and discolouration classes in 1992 and 1993

	Total tree sample		Common Sample Trees	
	1992	1993	1992	1993
Defoliation				
0-10%	43.0	43.5	43.2	43.0
>10-25%	33.5	33.9	33.5	33.9
0-25%	76.5	77.4	76.7	76.9
>25-60%	20.8	19.9	21.1	20.3
>60%	2.1	1.9	1.9	2.0
dead	0.6	0.8	0.3	0.8
>25%	23.5	22.6	23.3	23.1
Discolouration				
0-10%	89.9	90.0	90.3	90.6
>10-25%	7.5	7.2	7.7	6.9
>25-60%	1.6	1.7	1.6	1.4
>60%	0.3	0.3	0.3	0.3
dead	0.7	0.8	0.1	0.8
>10%	10.1	10.0	9.7	9.4
No. of trees	94 699	102 800	84 969	84 969

3.1.5.1 Changes by climatic region

As in the previous years, the total tree sample and the Common Sample Trees (CSTs) were classified into 9 climatic regions in order to consider various climatic site conditions. The selected climatic regions largely match the most important forest vegetation types. Figure 3.1.5.1-1 shows the percentages and distribution of all plots over the climatic regions.

The following descriptions refer to the changes in the percentage of damaged trees, which can be derived from Figure 3.1.5.1-2.

No significant change in the percentage of trees damaged (from 23.3% to 23.1%) was found for the total CSTs of all regions. However, significant increases and significant decreases in the percentage of trees damaged did occur in most of the individual climatic regions.

The most obvious changes occurred in the Boreal (temperate) and the Continental regions, where the percentages of CSTs damaged increased significantly by 4.8 and 4.3 percent points, respectively. Further significant, but less obvious increases were found in the Atlantic (north) region (2.4 percent points), in the Mediterranean (higher) region (1.6 percent points) and in the Atlantic (south) region (1.3 percent points).

Significant decreases of the percentages of trees damaged occurred in the Boreal and Mediterranean (lower) regions with 4.2 percent points and 3.8 percent points, respectively. A significant but very low decrease by 0.2 percent points was found in the Sub-atlantic region.

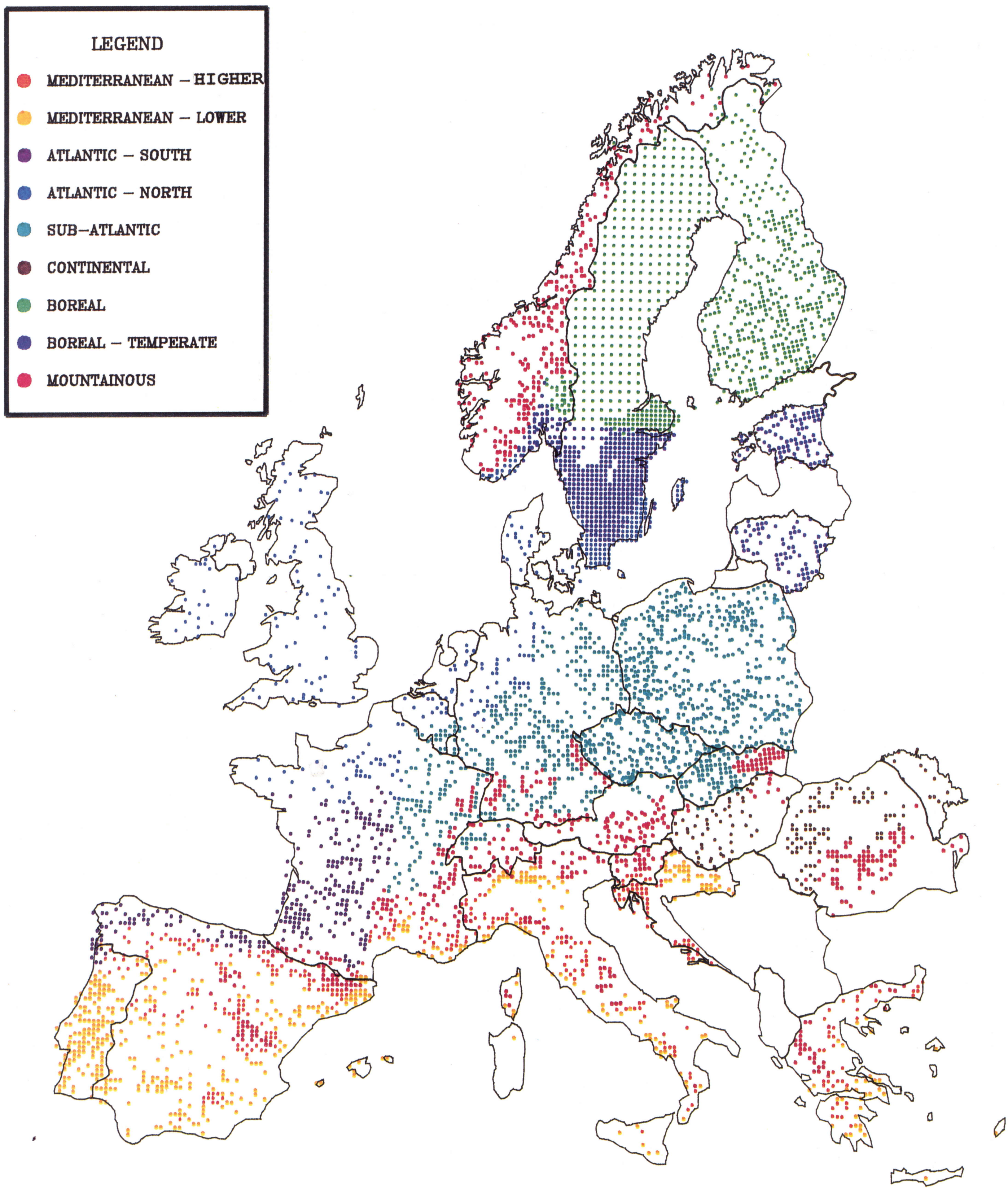

Figure 3.1.5.1-1: Climatic regions

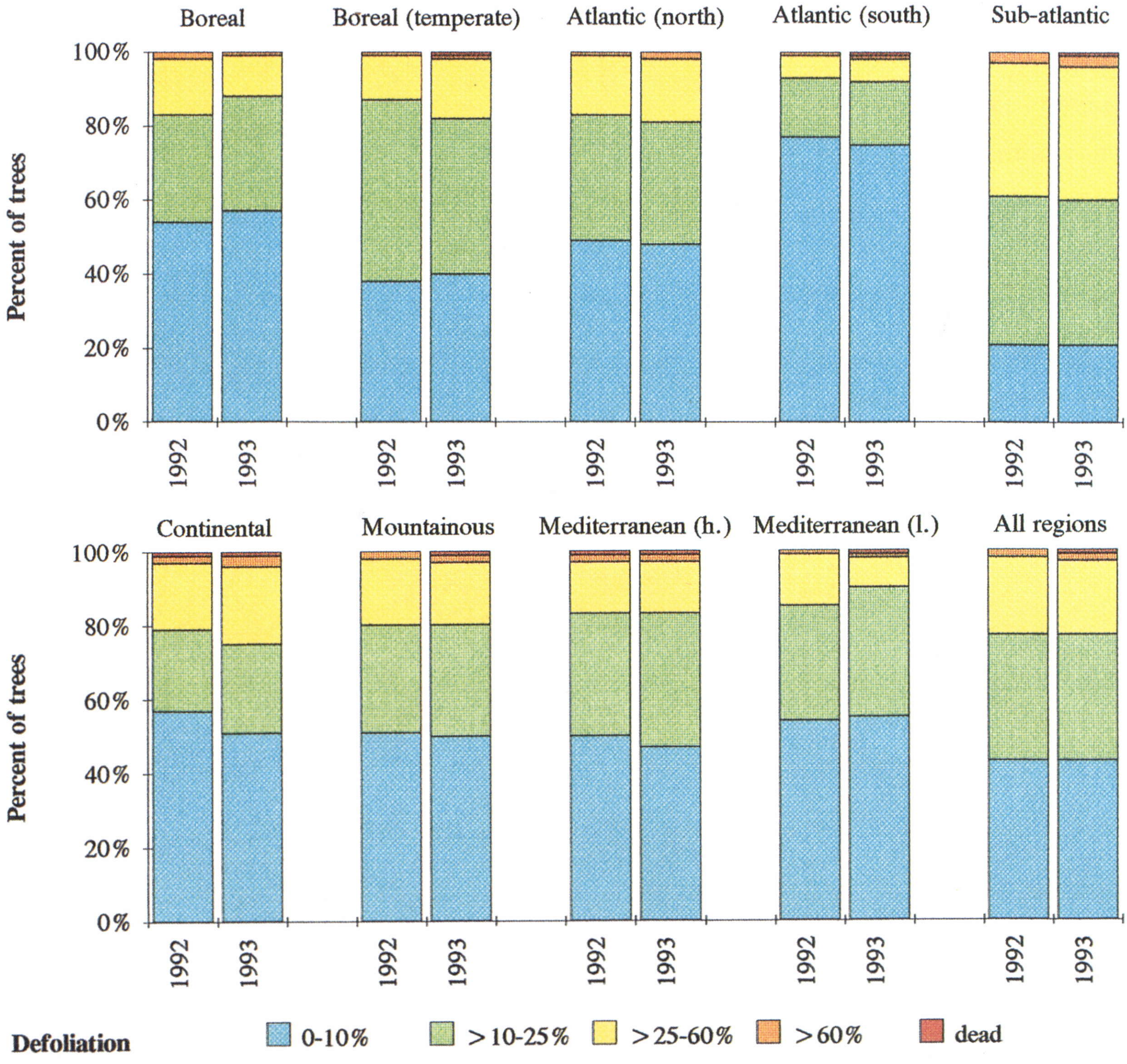

Figure 3.1.5.1-2: Percentages of defoliation of the Common Sample Trees in 1992 and 1993 for each of 9 climatic regions and for the total sample of CSTs

Figure 3.1.5.1-3 visualizes the changes of discolouration between 1992 and 1993. It is striking that the change in the share of discoloured trees in all regions (-0.3 percent points) is nearly as small as the respective change in defoliation (-0.2 percent points), but significant. This is because, in contrast to defoliation, discolouration has significantly changed in climatic regions with relatively high numbers of CSTs, such as the Sub-atlantic, Mountainous and Mediterranean (lower) regions. The highest significant increase in discolouration was found in the Atlantic (south) region (6.1 percent points), the highest significant decrease in the Continental region (5.3 percent points).

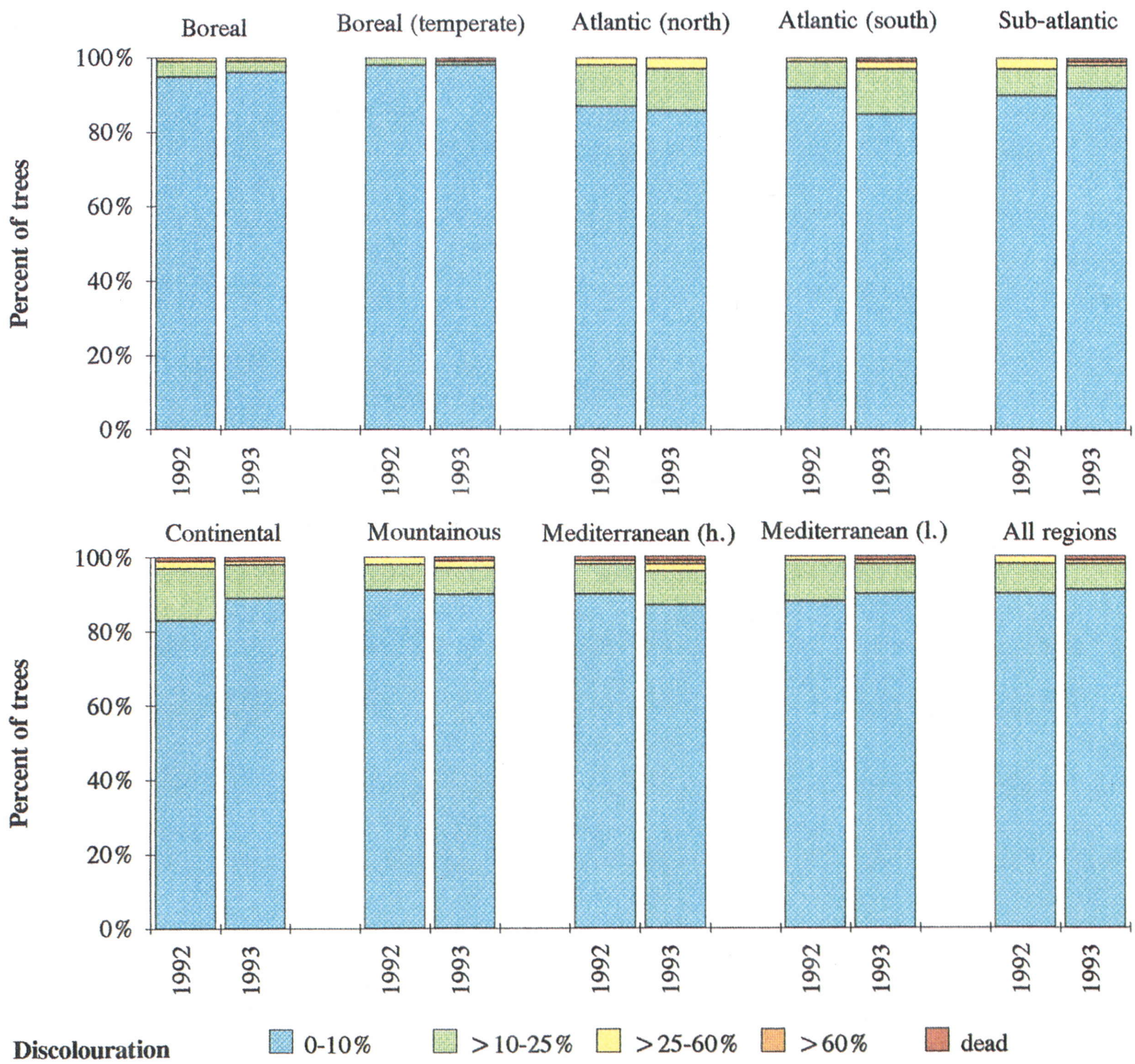

Figure 3.1.5.1-3: Percentages of discolouration of the Common Sample Trees in 1992 and 1993 for each of 9 climatic regions and for the total sample of CSTs

3.1.5.2 Changes by species group

As described in the previous chapter, the CSTs as a whole showed no significant change in **defoliation**. The share of damaged CSTs decreased slightly from 23.3% in 1992 to 23.1% in 1993. In the broadleaved CSTs the proportion of trees showing a defoliation greater than 25% diminished by 0.6 percent points from 20.5% to 19.9%. In the coniferous CSTs the respective proportion remained at its level of 25.2%.

Among the **broadleaved CSTs**, the most conspicuous deterioration, as expressed by the shares of damaged trees, occurred in *Quercus* spp.. The vitality of this species had already decreased in the CSTs of 1991 and 1992. Between 1992 and 1993 the proportion of damaged trees increased from 21.5% by 4.2 percent points to 25.7%. Among *Quercus ilex*, which had shown an obvious increase in defoliation in 1992, the share of damaged trees decreased slightly by 0.2 percent points.

The most remarkable change in defoliation occurred among the CSTs of *Quercus suber*. The proportion of damaged trees decreased from 33.7% by 23.4 percent points to 10.3%. This means, that the number of damaged trees was more than two thirds lower in 1993 than in 1992. There was also a decrease in the proportion of damaged trees in *Castanea sativa*, namely from 20.3% by 3.8 percent points to 16.5%. This species group had shown a prominent increase between 1991 and 1992 by 5.7 percent points.

The largest number of broadleaved CSTs is represented by Other broadleaves (11 060 trees), in which the proportion of damaged trees decreased from 20.5% by 1.5 percent points to 19.9%. The second largest number of CSTs is represented by *Quercus* spp. (9 707 trees).

Of the **coniferous CSTs**, the most species groups experienced only slight changes in defoliation from 1992 to 1993, except *Abies* spp.. The share of damaged *Abies* spp. trees increased from 29.2% by 4.4 percent points to 33.6%. This represented the highest percentage of damaged trees, both among the conifers and the broadleaves in 1993. However, this was of only little influence on the total result, which is dominated mainly by *Pinus* spp. and *Picea* spp..

The largest number of coniferous CSTs was comprised by *Pinus* spp. (27 378), showing a slight decrease in the proportion of damaged trees from 24.1% by 0.3 percent points to 23.8%. *Picea* spp., with 18 747 trees the second largest group of coniferous CSTs, showed a slight increase in the share of damaged trees by 0.3 percent points from 27.4% to 27.7%. As a result, the proportion of damaged coniferous CSTs remained at its level of 25.2%.

As to **discolouration**, some species groups improved over the period 1992-1993, whereas other species groups deteriorated. However, there was an overall higher discolouration in 1993 than in 1992 in the conifers, whereas an improvement occurred on the average in the boadleaves.

Among the **broadleaved CSTs**, the considerable decrease of discolouration observed in *Quercus suber* already last year continued. The proportion of discoloured trees (discolouration classes 1-4) decreased remarkably from 23.9% to 5.6%. Obvious increases in discolouration occurred in *Eucalyptus* spp. (from 3.3% to 6.8% of the trees in classes 1-4), in *Castanea sativa* (from 21.7% to 24.0%) and in *Quercus* spp. (from 11.0% to 12.9%). As regards *Eucalyptus* spp., rapid changes have occurred in recent years. This result may be biased by the comparatively low number (1 033) of CSTs of the latter species group.
In the **coniferous CSTs** a small increase in the proportion of discoloured trees was to be found in all species groups. The most prominent change in discolouration occurred in Other conifers, namely an increase in discoloured trees from 10.1% to 13.8%. This result, however, may also be affected by the small number (900) of CSTs in this species group.

3.1.6 Changes in defoliation since 1988

Similar to the Common Sample Trees (CSTs) of 1992 and 1993 (Chapter 3.1.5) a separate sample of trees common to the years 1988-1993 was defined in order to study the trends in vitality over a longer period. Commencing this time series in 1987 would have resulted into a far lower number of common trees.

Of the total tree sample, 28 656 trees were found with information available for each year between 1988 and 1993. This sample excludes the trees of the United Kingdom, because of the reasons mentioned in Chapter 3.1.1.

The evaluation was confined to the ten most common species, each of which comprised more than 850 common trees. Also evaluated were *Abies alba* and *Picea sitchensis*. These two species had lower tree numbers and were not to be included according to their ranking, but they are of importance in particular regions, especially in the Mountainous and in the Atlantic (north) region. The evaluation was carried out specieswise both for the total number of common trees and for the individual regions. As in the 1992 survey, no evaluation was made for those regions, in which the number of trees of a certain species was lower than 100. No common trees existed in the Boreal, the Boreal (temperate) and the Continental region. The figures 3.1.6-1 and 3.1.6-2 show the changes in defoliation for the most common coniferous and broadleaves species, respectively.

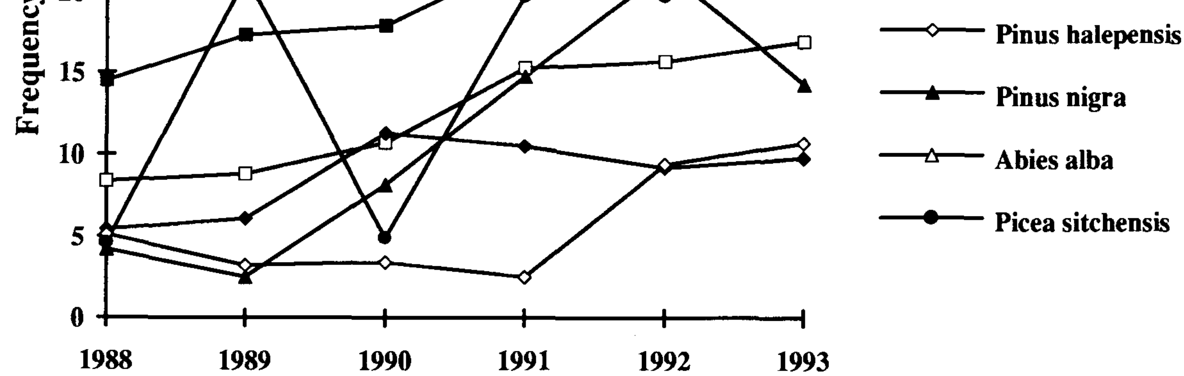

Figure 3.1.6-1: Development of defoliation for coniferous trees (defoliation classes 2-4) common to 1988-1993

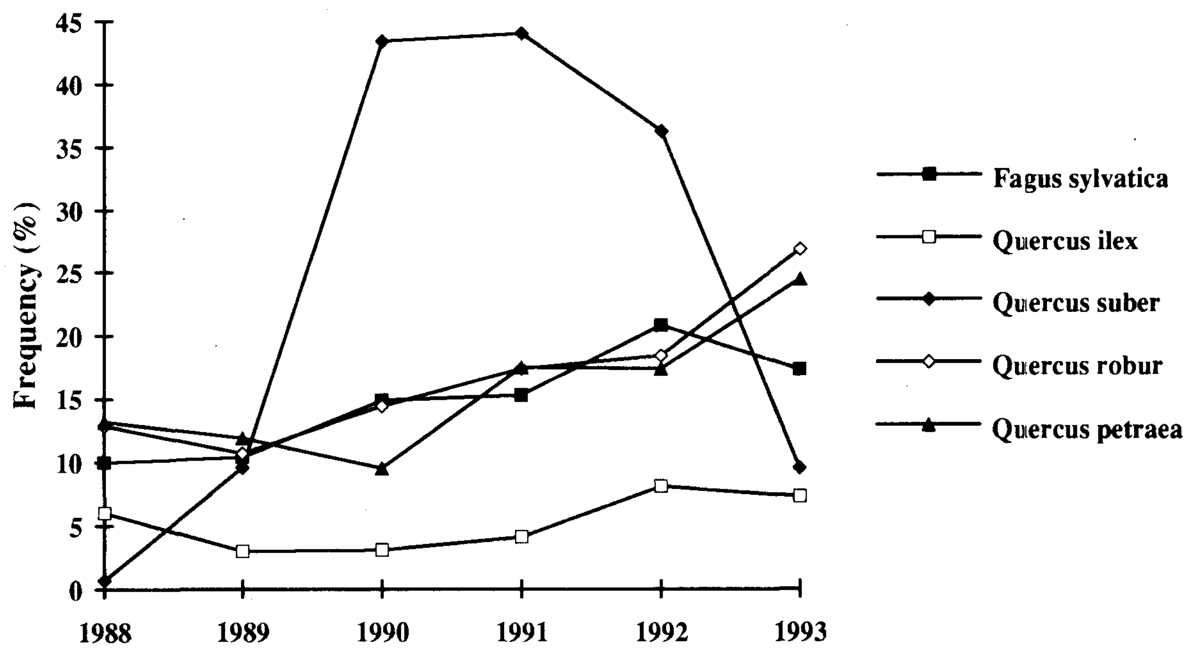

Figure 3.1.6-2: Development of defoliation for broadleaved trees (defoliation classes 2-4) common to 1988-1993

In the subsample of common trees of the period from 1988 to 1993, the proportions of the trees classified as damaged differed considerably between the individual tree species. All of the 12 species analyzed showed a more or less obvious increase in the proportion of damaged trees.

Among the conifers, *Picea sitchensis* had the highest percentage of damaged trees in 1993 and at the same time showed the most obvious increase in this percentage, namely from 4.6% in 1988 to 33.8% in 1993. This was probably due to *Elatobium*. The proportion of damaged *Abies alba* trees was also high, and increased from 25.3% to 30.5% within the six years of observation. The share of damaged *Picea abies* and *Pinus sylvestris* trees showed a gradual increase from 14.5% to 21.9% and from 8.4% to 16.9%, respectively.

As regards the broadleaved species, the sharp increase of the share of damaged trees in *Quercus suber* from 0.7% in 1988 to 44.0% in 1991 was very obvious, but diminished rapidly from 36.2% in 1992 to 9.5% in 1993. Among the other broadleaved species, *Quercus robur* showed also a conspicious increase in this percentage from 12.9% in 1988 to 26.8% in 1993. The proportion of damaged *Fagus sylvatica* and *Quercus petraea* trees increased from 10.0% to 17.3% and from 13.2% to 24.4%, respectively.

3.2 National survey results

Important data from the national surveys are given in the tables in the Annex. Annex I gives an overview of the participating countries, forest areas, density of grids and extent of the monitoring grid. Annexes II-IV contain results for all species, conifers and broadleaves. The changes in the survey results from 1986 on are presented also for all species, conifers and broadleaves in Annexes V-VII.

The national survey results of all species assessed can be summarized as follows:

Although it is not possible to make direct comparisons between different countries because of the way in which the common methodology is applied and because of general differences in climatic and site factors, the data show that countries fall into three groups.

In 1993, 31 countries submitted survey reports, including three countries, namely Ireland, the Russian Federation and Sweden, in which only conifers were assessed. In four of these countries the percentage of sample trees classified as damaged (defoliation classes 2-4) was lower than 10%. These countries are Austria, France, Portugal and the Russian Federation.

In eight of the countries the percentage of sample trees classified as damaged ranged between greater 10% and 20%. These countries are Belgium (including Flanders and Wallonia), Croatia, Finland, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

In another 19 countries, i.e. in more than a half of the member states from which survey results were reported, the percentage of sample trees classified as damaged was greater than 20%, with a maximum of 53.0%. These countries are Belarus, Bulgaria, the Czech Republic, Denmark, Estonia, Germany, Greece, Hungary, Ireland, Latvia, Lithuania, Luxembourg, the Republic of Moldova, the Netherlands, Norway, Poland, Romania, the Slovak Republic and Ukraine. In most of these countries the defoliation was particularly high in coniferous stands. The broadleaved stands were particularly affected in the Czech Republic, Germany, Greece, Luxembourg, the Republic of Moldova , Norway and Poland.

In 16 countries from which survey results were reported, a deterioration has occurred. The following Table 3.2-1 describes the changes of defoliation observed between 1992 and 1993 in classes 2-4. Changes are rated as unimportant if equal to or less than 5.0 percent points, as slight between 5.1 and 10.0 percent points, as moderate between 10.1 and 20.0 percent points and as substantial if exceeding 20.0 percent points from one year to the next.

The figures in Table 3.2-1 refer to only 28 countries by which survey results were submitted. In Slovenia no survey was performed in 1992, and the Republic of Moldova reported survey data for the first time this year. Therefore, no data from both countries were available for the comparison of changes in defoliation from 1992 to 1993.

Table 3.2-1: Changes in defoliation observed between 1992 and 1993 in classes 2-4

	Number of countries						
	No or unimportant change	Increase of defoliation			Decrease of defoliation		
		Slight	Moderate	Substantial	Slight	Moderate	Substantial
All species	17	3	1	-	2	1	1
Conifers	17	5	2	-	3	-	1
Broadleaves	18	2	-	1	-	1	2

As regards all species, a slight increase in defoliation occurred in three countries, whereas a slight decrease was observed in two countries. Changes in defoliation are particularly obvious in the conifers. Concerning this species group, an increase occurred in seven countries, whereas a decrease was observed only in four. In two countries the increases in the conifers were moderate, but no substantial increase was found. In comparison to 1992, the increase of defoliation in the broadleaves is less obvious. However, in one country there was a substantial increase in the broadleaves.

4. INTERPRETATION

With 102 800 trees assessed, the total tree sample of the transnational survey of 1993 was the largest since the beginning of the surveys in 1987. Of these sample trees, 22.6% were considered as damaged. Both the transnational and the national surveys show that losses of needles and leaves exist to different extent in all participating countries. As in the previous years, the areas of highest defoliation are located in central Europe, but defoliation is also high in certain areas of northern and southeastern Europe.

Among all other parameters assessed, **stand age** was found to have the highest correlation with the intensity of defoliation. The proportion of damaged trees increased from 10.9% in age class 0-20 to 27.0% in age class >120 years, as derived from the transnational survey results. The higher defoliation in old stands is confirmed by the national survey results. The strong correlation found, however, largely reflects the well known natural loss of foliage due to ageing, particularly in coniferous trees. The explanation of the correlation between defoliation and stand age was confirmed in a study focusing on severely defoliated and dead trees. Among the severely defoliated and dead trees there is a relatively high proportion of younger trees. The reason for this could be the high degree of competition in younger stands even within canopy classes 1-3, which leads to high natural mortality.

Based on the national survey results, the **weather** is thought to have strong influence on defoliation by many countries. In the national reports, the changes in forest condition observed are ascribed to weather phenomena by more than half of the participating countries. More than one third of the countries mention drought and high temperatures during the vegetation period of 1993 or of several previous years as predisposing or triggering factors for the damage observed. Pests are often looked upon as secondary agents, which were fostered by warm and dry weather conditions. Other weather phenomena ranging among the most important stressors are frost, snow, hail and storm. Whilst drought, heat and subsequent pests are considered as major problems mainly in central, eastern and southeastern Europe, higher precipitation during the vegetation period of 1993 is reported to have caused an improvement of forest condition in northwestern Europe.

As regards the spatial distribution of defoliation, differences in its intensity were found between various **climatic regions**. In the transnational survey, the proportion of damaged trees was highest in the Sub-atlantic region (39.5%) and lowest in the Atlantic (south) region (8.6%).

Easily identifiable damage was reported for 29.8% of all trees of the transnational survey. On these trees the defoliation was higher than on those for which no damage types had been reported. As in recent years, the most frequently observed type of damage was insect attack with 11.7% of the trees for which easily identifiable damage had been reported. Second on the frequency scale (9.7%) were "other types of damage", given evidence of the multitude of factors responsible for the defoliation assessed. Classical smoke damage was reported for a very small number of trees (0.3%). As a consequence, the results for classical smoke were not further interpreted. For 70.2% of the trees no evident source of damage was reported. These trees, however, comprise an unknown proportion of trees on which damage was present but the causes not reported.

The actual **development of forest condition** in Europe is reflected by the Common Sample Trees (CSTs) evaluated for the periods 1992-1993. The statistical evaluation shows that out of the 84 969 CSTs the share of damaged trees did not change significantly between 1992 and 1993 (23.3% and 23.1%, respectively). But there were both significant increases and significant decreases in the shares of damaged CSTs in 7 out of 9 climatic regions. These, however, compensated for each other within the total CSTs.

The largest change occurred in the Boreal (temperate) region where the share of damaged CSTs increased significantly from 12.7% by 4.8 percent points to 17.5%. This is largely due to the increase in defoliation to be observed in Lithuania. From Lithuania an increase in defoliation was reported particularly in the coniferous species.

The second largest change was an increase in the share of damaged CSTs from 20.5% by 4.3 percent points to 24.8% in the Continental region. This increase reflects the deterioration of forest condition in Romania where excessive drought and local air pollution caused an increase in defoliation in many species, particularly in *Abies alba* and *Quercus* spp.. The decline of *Abies alba* in Romania also reveals itself in the change in the share of damaged CSTs of *Abies alba* from 29.2% in 1992 to 33.6% in 1993.

A deterioration of forest vitality can also be inferred for a longer period of time from the evaluation of the trees common to the 1988 to 1993 surveys. All of the 12 species analyzed show a more or less obvious increase in the proportion of damaged trees. This trend is obvious even in individual climatic regions.

More than half of the countries participating in the surveys report air pollution to be a predisposing, accompanying or triggering factor. Air pollution is considered as of concern particularly in northern, central and eastern Europe. The degree to which air pollution has contributed to defoliation and discolouration, however, cannot be quantified as a consequence of the lacking specificity of the symptoms assessed. It must be stated that the trend towards the deterioration of forest condition observed in the common trees from 1988 to 1993 already in earlier years continues. It is this trend which cannot be readily explained by site conditions and natural damaging agents. Although there is no direct evidence of this being an effect of air pollution, this phenomenon deserves special attention because a continuous and large scale weakening of forest health by long-range transboundary air pollution is likely to manifest itself in effects like the ones observed.

5. CONCLUSIONS AND RECOMMENDATIONS

The development of forest condition as assessed in the transnational and national surveys of UN/ECE and EU (Level I) reveals that forest damage in terms of defoliation and discolouration continues to be a problem in Europe. Though at the large scale forest decline has developed less dramatically than feared in the early 1980s, a general worsening of forest condition is to be observed in many parts of Europe. In certain regions the damage is severe and locally catastrophical. There is a concentration of main damage areas in some countries of central Europe (Czech Republic, Germany and Poland) in which many thousand of hectares of forest have died, partly due to classical smoke damage.

According to the opinion of the countries participating in the surveys, the most frequent causes of the symptoms observed are adverse weather conditions, insects, fungi, air pollution and forest fires. Particularly in some of the main damage areas, but also in several other regions, air pollution is considered as of major concern, because the atmospheric concentrations and the depositions of several air pollutants is thought to exceed the critical levels and loads for forest ecosystems. The forest condition monitoring of UN/ECE and EU pays particular attention to the effects of air pollution stress.

Additional information is to be expected from a more complete and correct collection of annual data on the plots of the transnational survey. For example, given the differences in defoliation on the soils currently assessed by only four countries, the soil sampling foreseen in many countries next year will be of particular value.

Furthermore it must be mentioned that despite the intensive monitoring on permanent plots the large-scale assessment (Level I) must be continued. Time series of many consecutive years are expected to give evidence of the potential impact of transboundary air pollution and other factors. Moreover, the large spatial and temporal variation can only be scrutinized by means of time series of observations detached from the constraints of national borders. From the political point of view, evidence of transnational effects is the precondition for common abatement strategies.

Without the large-scale monitoring of forest condition in recent years, today's understanding of recent forest damage can not be imagined. The main benefits received from the monitoring until today are:

- a more accurate knowledge of the extent, dynamics and spatial distribution of crown defoliation and discolouration in Europe

- a database for future time series analyses of defoliation and complex studies in combination with ecological parameters

- impetus to environmental policies and forest damage research.

As the large-scale monitoring does not aim at cause-effect relationships, its results can not be interpreted directly with respect to the impact of air pollution. Instead, the interpretation of the results has often to rely on explanations given in country reports, which in turn are based on research and studies on permanent sample plots.

In order to contribute also to a better understanding of the impact of air pollution on forest ecosystems, UN/ECE and EU have implemented a system of permanent plots for a more intensive and continuous monitoring (Level II). This approach is consistent with the stipulations of the European Ministers of the Ministerial Conference on the Protection of Forests in Europe, in Strasbourg, December 1990. On Level II crown condition assessment, soil analyses, foliar analyses, increment studies and deposition measurements will be carried out, for which four Expert Panels of ICP Forests have developed harmonized methods. These methods are described in the 3rd edition of the ICP-Forests Manual. Further efforts in harmonization are under preparation in the fields of meteorological measurements. Vegetation assessments and crown condition assessments are planned to be developed further. The application of such methods will provide additional important information for a more thorough interpretation of the data.

The synoptical interpretation of the growing database as well as its application to further efforts by the Convention on Long-range Transboundary Air Pollution to develop effects based protocols and to calculate critical loads and levels, will require access by a range of potential users and data exchange with other ICPs under the Convention on Long-range Transboundary Air Pollution. For this reason a common data bank and regulations regarding data ownership, data security and data exchange are being planned by ICP Forests and EU.

In the national reports of many countries the importance of dry conditions in recent years, both in terms of drought stress to trees and increased frequency of forest fires, has been emphasized. Any atmospheric changes that increased the frequency of dry conditions in Europe would have serious consequences for many forests, particularly in the south. ICP Forests and EU therefore support any moves that might help to reduce the rate of global warming and other effects of global climatic change. Due regard should be paid to these impacts within in the future monitoring activities.

As regards abatement strategies, a reduction of the air pollution load could improve the condition of endangered forests. Sulphur dioxide, ammonia, nitrogen oxides (as precursors of ozone and acid deposition) and others may all be important in particular areas.

Annexes

Annex I
FORESTS AND SURVEYS IN EUROPEAN COUNTRIES (1993)

Participating countries	Total area (1000 ha)	Forest area (1000 ha)	Coniferous forest (1000 ha)	Broadleav. forest (1000 ha)	Area surveyed (1000 ha)	Grid size (km x km)	No. of sample plots	No. of sample trees
Austria	8385	3857	2922	935	3857	8.7 x 8.7	218	6551
Belarus	20760	7028	4757	2271	6001	16 x 16	407	9766
Belgium	3057	602	302	300	602	8x8/16x16	104	2453
Bulgaria	11100	3314	1172	2142	3314	16x16/8x8	188	6968
Croatia	5654	2061	321	1740	1175	16 x 16	84	2016
Czech Republic	7886	2630	2051	579	2630	8x8/16x16	184	12659
Denmark	4300	466	308	158	411	7x7/16x16	67	1542
Estonia	4510	1815	1135	680	1135	16 x 16	91	2160
Finland	30464	20059	18484	1575	20059	varying	405	4382
France	54919	14002	5040	8962	13100	16x16 /16x1	506	10120
Germany	35562	10189	6946	3243	10189	4 x 4	3611	85159
Greece a)	13204	2034	954	1080	2034	16 x 16	80	1888
Hungary	9300	1707	267	1440	1684	4 x 4	1063	22200
Ireland	6889	380	334	46	285	16 x 16	22	462
Italy	30126	8675	1735	6940	7154	16 x 16		
Latvia	6450	2797	1633	1164	2797	8 x 8	389	9325
Liechtenstein	16	8	6	2	no survey in 1993			
Lithuania	6520	1823	1073	750	1823	8 x 8	235	5658
Luxembourg	259	84	30	54	88	16x16/4x4	48	1150
Rep. of Moldova	3050	271	6	265	271	2 x 2	550	18280
Netherlands	4147	311	208	103	250	1 x 1	1251	31275
Norway	30686	13700	7000	6700	13700	9x9/18x18	1003	8527
Poland	31270	8654	6895	1759	8654	16 x 16	1493	29860
Portugal	8800	3372	1340	2032	3060	16 x 16	143	4309
Romania	23750	6244	1929	4315	6244	2x2/2x4	8296	235179
Russian Fed. b)	80330	31592	25518	6074	31592	varying	69	1656
Slovak Republic	4901	1885	816	1069	1185	16 x 16	111	4353
Slovenia	2008	1071	500	571	1071	16 x 16	34	816
Spain	50471	11792	5637	6155	11792	16 x 16	460	11040
Sweden	40800	23500	19729	3771	19900	varying	4420	15657
Switzerland	4129	1186	818	368	1186	8 x 8	164	1933
Turkey	77945	20199	9426	10773	no survey in 1993			
Ukraine	60370	6151	2931	3220	2021	16 x 16		1968
United Kingdom	24100	2200	1550	650	2200	random	361	8664
Yugoslavia c)	25600	6100	900	5200	no survey in 1993			
TOTAL	731718	221759	134673	87086	181464	varying	26057	557976

a) Excluding maquis. b) Only St. Petersburg region.
c) Former Yugoslavia excluding Croatia and Slovenia.

Annex II

DEFOLIATION OF ALL SPECIES BY CLASSES AND CLASS AGGREGATES (1993)

Participating countries	Area surveyed (1000 ha)	No. of sample trees	0 none	1 slight	2 moderate	3+4 severe and dead	2+3+4
Austria	3857	6551	54.9	36.9	7.5	0.7	8.2
Belarus	6001	9766	22.3	48.4	27.8	1.5	29.3
Belgium	602	2453	46.6	38.6	13.4	1.4	14.8
Bulgaria	3314	6968	45.7	31.1	19.7	3.5	23.2
Croatia	1175	2016	62.0	18.8	16.6	2.6	19.2
Czech Republic	2630	12659	13.0	34.0	47.2	5.8	53.0
Denmark	411	1542	37.3	29.3	25.4	8.0	33.4
Estonia	1135	2160	43.8	35.9	18.8	1.5	20.3
Finland	20059	4382	60.7	24.1	13.9	1.3	15.2
France	13100	10120	74.8	16.9	7.3	1.0	8.3
Germany	10189	85159	35.9	39.9	22.6	1.6	24.2
Greece a)	2034	1888	37.7	41.1	18.0	3.2	21.2
Hungary	1684	22200	45.8	33.2	16.1	4.9	21.0
Ireland	285	462	only conifers assessed				
Italy	7154						
Latvia	2797	9325	22.0	43.0	33.0	2.0	35.0
Liechtenstein			no survey in 1993				
Lithuania	1823	5658	21.2	51.4	23.8	3.6	27.4
Luxembourg	88	1150	42.2	34.0	20.0	3.8	23.8
Rep. of Moldova	271	18280	26.7	22.5	43.2	7.6	50.8
Netherlands	250	31275	52.6	22.4	20.8	4.2	25.0
Norway	13700	8527	39.4	35.7	20.1	4.8	24.9
Poland	8654	29860	6.3	43.7	47.2	2.8	50.0
Portugal	3060	4309	64.5	28.2	6.5	0.8	7.3
Romania	6244	235179	48.2	31.3	17.9	2.6	20.5
Russian Fed. b)	31592	1656	only conifers assessed				
Slovak Republic	1185	4353	19.8	42.6	33.5	4.1	37.6
Slovenia	1071	816	37.0	44.0	2.0	17.0	19.0
Spain	11792	11040	44.8	42.2	10.0	3.0	13.0
Sweden	19900	15657	only conifers assessed				
Switzerland c)	1186	1933	31.3	50.7	16.0	2.0	18.0
Turkey			no survey in 1993				
Ukraine	2021	1968	27.7	50.8	20.6	0.9	21.5
United Kingdom	2200	8664	38.9	44.2	15.9	1.0	16.9
Yugoslavia d)			no survey in 1993				

a) Excluding maquis. b) Only St. Petersburg Region.
c) Weighted according to diameter breast height (dbh).
d) Former Yugoslavia excluding Croatia and Slovenia.

Annex III
DEFOLIATION OF CONIFERS BY CLASSES AND CLASS AGGREGATES (1993)

Participating countries	Coniferous forest (1000 ha)	No. of sample trees	0 none	1 slight	2 moderate	3+4 severe and dead	2+3+4
Austria a)	2922	5723	56.5	35.3	7.6	0.6	8.2
Belarus	4757	7185	15.9	50.3	32.4	1.4	33.8
Belgium	302	1205	38.0	43.7	16.2	2.1	18.3
Bulgaria	1172	4492	36.2	36.9	23.1	3.8	26.9
Croatia	321	395	55.0	11.1	28.1	5.8	33.9
Czech Republic	2051	11545	13.1	34.1	47.6	5.2	52.8
Denmark	308	975	42.6	20.4	25.6	11.4	37.0
Estonia	1135	2065	41.3	37.5	19.6	1.6	21.2
Finland	18484	3754	60.7	23.7	14.2	1.4	15.6
France	5040	3488	77.9	13.9	7.6	0.6	8.2
Germany	6946	55950	39.4	39.2	19.8	1.6	21.4
Greece b)	954	1015	44.3	41.8	11.6	2.3	13.9
Hungary	267	3591	50.5	29.4	15.4	4.7	20.1
Ireland	334	462	31.4	39	28.6	1.0	29.6
Italy	1735						
Latvia	1633	6854	17.0	42.0	39.0	2.0	41.0
Liechtenstein	6		no survey in 1993				
Lithuania	1073	3787	15.5	55.3	25.7	3.5	29.2
Luxembourg	30	386	63.0	28.0	7.0	2.0	9.0
Rep. of Moldova	6	104	35.6	19.2	45.2	0.0	45.2
Netherlands	165	20675	53.1	16.3	25.8	4.8	30.6
Norway	7000	6904	44.6	34.5	16.8	4.1	20.9
Poland	6895	25260	5.8	43.4	47.9	2.9	50.8
Portugal	1340	1545	71.9	21.0	6.2	0.9	7.1
Romania	1929	47288	53.0	30.4	15.0	1.6	16.6
Russian Fed. c)	25518	1656	56.6	38.9	3.6	0.9	4.5
Slovak Republic	816	1822	7.8	42.3	46.3	3.6	49.9
Slovenia	500	380	24.0	49.0	23.0	4.0	27.0
Spain	5637	5510	50.0	35.4	11.6	3.0	14.6
Sweden	19729	15657	62.4	27.0	8.9	1.7	10.6
Switzerland d)	818	1212	27.6	51.7	18.4	2.3	20.7
Turkey	9426		no survey in 1993				
Ukraine	2931	1348	25.4	53.3	20.9	0.4	21.3
United Kingdom	1550	5376	40.9	42.3	15.7	1.1	16.8
Yugoslavia e)	900		no survey in 1993				

a) Only trees 50 years and older assessed. b) Excluding maquis.
c) Only St. Petersburg Region. d) Weighted according to diameter breast height (dbh).
e) Former Yugoslavia excluding Croatia and Slovenia.

Annex IV
DEFOLIATION OF BROADLEAVES BY CLASSES AND CLASS AGGREGATES (1993)

Participating countries	Broadleav. forest (1000 ha)	No. of sample trees	0 none	1 slight	2 moderate	3+4 severe and dead	2+3+4
Austria a)	935	828	44.3	48.0	6.9	0.8	7.7
Belarus	2271	2581	40.2	43.2	14.9	1.7	16.6
Belgium	300	1248	54.7	33.6	10.9	0.8	11.7
Bulgaria	2142	2476	63.0	20.4	13.5	3.1	16.6
Croatia	1740	1621	63.7	20.7	13.8	1.8	15.6
Czech Republic	579	1114	11.5	33.4	43.6	11.5	55.1
Denmark	158	567	28.4	44.6	24.9	2.1	27.0
Estonia	680	95	97.8	1.1	1.1	0.0	1.1
Finland	1575	627	60.6	26.6	11.8	1.0	12.8
France	8962	6632	73.1	18.5	7.2	1.2	8.4
Germany	3243	29209	28.7	41.4	28.1	1.8	29.9
Greece b)	1080	873	30.0	40.2	25.4	4.4	29.8
Hungary	1440	18609	44.9	33.9	16.2	5.0	21.2
Ireland	46		only conifers assessed				
Italy	6940						
Latvia	1164	2471	36.2	46.0	16.8	1.0	17.8
Liechtenstein	2		no survey in 1993				
Lithuania	750	1871	32.9	43.3	20.0	3.8	23.8
Luxembourg	54	764	32.0	37.0	28.0	3.0	31.0
Rep. of Moldova	265	18176	26.6	22.5	43.2	7.7	50.9
Netherlands	85	10600	52.6	34.3	11.2	1.9	13.1
Norway c)	6700	1623	17.1	40.8	34.4	7.7	42.1
Poland	1759	4600	8.8	45.6	43.0	2.6	45.6
Portugal	2032	2764	60.3	32.2	6.7	0.8	7.5
Romania	4315	187891	47.0	31.6	18.6	2.8	21.4
Russian Fed. d)	6074		only conifers assessed				
Slovak Republic	1069	2531	27.7	43.2	24.7	4.4	29.1
Slovenia	571	436	48.0	41.0	9.0	2.0	11.0
Spain	6155	5530	39.7	48.9	8.3	3.1	11.4
Sweden c)	3771		only conifers assessed				
Switzerland e)	368	721	38.5	48.5	11.4	1.6	13.0
Turkey	10773		no survey in 1993				
Ukraine	3220	620	32.8	45.6	19.6	2.0	21.6
United Kingdom	650	3288	35.6	47.3	16.3	0.8	17.1
Yugoslavia f)	5200		no survey in 1993				

a) Only trees 50 years and older assessed. b) Excluding maquis. c) Special study on birch.
d) Only St. Petersburg Region. e) Weighted according to diameter at breast height (dbh).
f) Former Yugoslavia excluding Croatia and Slovenia.

Annex V
DEFOLIATION OF ALL SPECIES (1986-1993)

Participating countries	All species Defoliation classes 2-4								% change
	1986	1987	1988	1989	1990	1991	1992	1993	1992/1993
Austria				10.8	9.1	7.5	6.9	8.2	1.3
Belarus				67.2	54.0		19.2	29.3	10.1
Belgium				14.6	16.2	17.9	16.9	14.8	-2.1
Bulgaria	8.1	3.6	7.4	24.9	29.1	21.8	23.1	23.2	0.1
Croatia							15.6	19.2	3.6
Czech Republic							56.4	53.0	-3.4
Denmark		23.0	18.0	26.0	21.2	29.9	25.9	33.4	7.5
Estonia			only conifers assessed				28.5	20.3	-8.2
Finland		12.1	16.1	18.0	17.3	16.0	14.5	15.2	0.7
France a)	8.3	9.7	6.9	5.6	7.3	7.1	8.0	8.3	0.3
Germany b)	18.9	17.3	14.9	15.9	15.9	25.2	26.0	24.2	-1.8
Greece c)			17.0	12.0	17.5	16.9	18.1	21.2	3.1
Hungary			7.5	12.7	21.7	19.6	21.5	21.0	-0.5
Ireland			only conifers assessed						
Italy						16.4	18.2		
Latvia					36.0		37.0	35.0	-2.0
Liechtenstein	19.0	19.0	17.0	11.8			16.0		
Lithuania			3.0	21.5	20.4	23.9	17.5	27.4	9.9
Luxembourg	5.1	7.9	10.3	12.3		20.8	20.4	23.8	3.4
Rep. of Moldova								50.8	
Netherlands	23.3	21.4	18.3	16.1	17.8	17.2	33.4	25.0	-8.4
Norway	only conifers assessed				18.2	19.7	26.2	24.9	-1.3
Poland			20.4	31.9	38.4	45.0	48.8	50.0	1.2
Portugal			1.3	9.1	30.7	29.6	22.5	7.3	-15.2
Romania						9.7	16.7	20.5	3.8
Russian Fed.			only conifers assessed						
Slovak Republic			38.8	49.2	41.5	28.5	36.0	37.6	1.6
Slovenia				22.6	18.2	15.9		19.0	
Spain			4.5	4.2	4.8	7.4	12.3	13.0	0.7
Sweden			only conifers assessed						
Switzerland	12.0	15.0	12.0	14.0	17.0	21.0	16.0	18.0	2.0
Turkey									
Ukraine						6.4	16.3	21.5	5.2
United Kingdom d)		22.0	25.0	28.0	39.0	56.7	58.3	16.9	-41.4
Yugoslavia e)						9.8			

a) 16x16 km network after 1988. b) For 1986-1990, only data for former Federal Republic of Germany.
c) Excluding maquis.
d) The difference between 1992 and 1993 is mainly due to a change of assessment method in line with that used in other States. Based on the previous standard the change was - 4,3%.
e) Former Yugoslavia; Croatia and Slovenia excluded from 1991 results.

Annex VI
DEFOLIATION OF CONIFERS (1986-1993)

Participating countries	Conifers								% change
	Defoliation classes 2-4								
	1986	1987	1988	1989	1990	1991	1992	1993	1992/1993
Austria				10.1	8.3	7.0	6.6	8.2	1.6
Belarus				76.0	57.0		33.7	33.8	0.1
Belgium				20.4	23.6	23.4	23.0	18.3	-4.7
Bulgaria	4.7	3.8	7.6	32.9	37.4	26.5	25.5	26.9	1.4
Croatia							26.3	33.9	7.6
Czech Republic							58.4	52.7	-5.7
Denmark		24.0	21.0	24.0	18.8	31.4	28.6	37.0	8.4
Estonia			9.0	28.5	20.0	28.0	29.5	21.2	-8.3
Finland		13.5	17.0	18.7	18.0	17.2	15.2	15.6	0.4
France a)	12.5	12.0	9.1	7.2	6.6	6.7	7.1	8.2	1.1
Germany b)	19.5	15.9	14.0	13.2	15.0	24.8	23.8	21.4	-2.4
Greece			7.7	6.7	10.0	7.2	12.3	13.9	1.6
Hungary			9.4	13.3	23.3	17.8	20.1	20.1	0.0
Ireland		0.0	4.8	13.2	5.4	15.0	15.7	29.6	13.9
Italy						13.8	17.2		
Latvia					43.0		45.0	41.0	-4.0
Liechtenstein	22.0	27.0	23.0	12.4			18.0		
Lithuania			3.0	24.0	22.9	27.8	17.5	29.2	11.7
Luxembourg	4.2	3.8	11.1	9.5			6.3	9.0	2.7
Rep. of Moldova								45.2	
Netherlands	28.9	18.7	14.5	17.7	21.4	21.4	34.7	30.6	-4.1
Norway			20.8	14.8	17.1	19.0	23.4	20.9	-2.5
Poland			24.2	34.5	40.7	46.9	50.3	50.8	0.5
Portugal			1.7	9.8	25.7	19.8	11.3	7.1	-4.2
Romania						6.9	10.9	16.6	5.7
Russian Fed. c)						4.2	5.2	4.5	-0.7
Slovak Republic			52.7	59.1	55.5	38.5	44.0	49.9	5.9
Slovenia					34.6	31.3		27.0	
Spain			7.7	4.7	4.4	7.3	13.5	14.6	1.1
Sweden		5.6	12.3	12.9	16.1	12.3	16.9	10.6	-6.3
Switzerland	14.0	16.0	14.0	18.0	20.0	24.0	19.0	20.0	1.0
Turkey									
Ukraine				1.4	3.0	6.4	13.8	21.3	7.5
United Kingdom d)		23.0	27.0	34.0	45.0	51.5	52.7	16.8	-35.9
Yugoslavia e)	23.0	16.1	17.5	39.1	34.6	15.9			

a) 16x16 km network after 1988. b) For 1986-1990, only data for former Federal Republic of Germany.
c) For 1993, only data for St. Petersburg Region.
d) The difference between 1992 and 1993 is mainly due to a change of assessment method in line with that used in other States. e) Former Yugoslavia; Croatia and Slovenia excluded from 1991 results.

Annex VII
DEFOLIATION OF BROADLEAVES (1986-1993)

Participating countries	Broadleaves								% change
	Defoliation classes 2-4								
	1986	1987	1988	1989	1990	1991	1992	1993	1992/1993
Austria				15.7	14.9	11.1	9.3	7.7	-1.6
Belarus				33.4	45.0		14.8	16.6	1.8
Belgium				8.7	10.0	13.5	11.8	11.7	-0.1
Bulgaria	4.0	3.1	8.8	16.2	17.3	15.3	18.0	16.6	-1.4
Croatia							13.6	15.6	2.0
Czech Republic							31.9	55.1	23.2
Denmark		20.0	14.0	30.0	25.4	27.3	21.2	27.0	5.8
Estonia				only conifers assessed				1.1	
Finland		4.7	7.9	12.6	11.6	7.7	10.1	12.8	2.7
France a)	4.8	6.5	5.3	4.8	7.7	7.4	8.5	8.4	-0.1
Germany b)	16.8	19.2	16.5	20.4	23.8	26.5	32.0	29.9	-2.1
Greece			28.5	18.4	26.5	28.5	25.0	29.8	4.8
Hungary			7.0	12.5	21.5	19.9	21.8	21.2	-0.6
Ireland				only conifers assessed					
Italy		3.6	2.9	9.5	16.7	17.1	18.5		
Latvia					27.0		19.0	17.8	-1.2
Liechtenstein	10.0	7.0	5.0	9.0			8.0		
Lithuania			1.0	16.0	15.8	14.9	17.6	23.8	6.2
Luxembourg	5.6	10.1	12.3	13.9		33.9	30.5	31.0	0.5
Rep. of Moldova								50.9	
Netherlands	13.2	26.5	25.4	13.1	11.5	9.4	31.1	13.1	-18.0
Norway					18.2	25.1	38.9	42.1	3.2
Poland			7.1	17.7	25.6	34.8	40.4	45.6	5.2
Portugal			0.8	8.6	34.1	36.6	29.1	7.5	-21.6
Romania						10.4	18.4	21.4	3.0
Russian Fed. c)				only conifers assessed					
Slovak Republic			28.5	41.8	31.3	21.1	30.0	29.1	-0.9
Slovenia					4.4	5.8		11.0	
Spain			7.4	4.2	4.8	7.4	11.2	11.4	0.2
Sweden				only conifers assessed					
Switzerland	8.0	13.0	6.0	5.0	13.0	15.0	11.0	13.0	2.0
Turkey									
Ukraine				1.4	2.7	6.5	20.2	21.6	1.4
United Kingdom d)		20.0	20.0	21.0	28.8	65.6	67.8	17.1	-50.7
Yugoslavia e)		7.3	9.0	8.2	4.4	8.2			

a) 16x16 km network after 1988. b) For 1986-1990, only data for former Federal Republic of Germany.
c) For 1993, only data for St. Petersburg Region.
d) The difference between 1992 and 1993 is mainly due to a change of assessment method in line with that used in other States. e) Former Yugoslavia; Croatia and Slovenia excluded from 1991 results.

Annex VIII
MAIN SPECIES REFERRED TO IN THE TEXT

Latin	English	German	French	Spanish	Italian
Fagus sylvatica	Common beech	Rotbuche	Hêtre	Haya	Faggio
Quercus petraea	Sessile oak	Traubeneiche	Chêne rouvre	Roble albar	Rovere
Quercus robur	European oak	Stieleiche	Chêne pédonculé	Roble común	Farnia
Quercus ilex	Holm oak	Steineiche	Chêne vert	Encina	Leccio
Quercus suber	Cork oak	Korkeiche	Chêne liège	Alcornoque	Sughera
Pinus sylvestris	Scots pine	Gemeine Kiefer	Pin sylvestre	Pino silvestre	Pino commune
Pinus nigra	Corsican/Austrian black pine	Schwarzkiefer	Pin noir	Pino laricio	Pino nero
Pinus pinaster	Maritime pine	Seestrandkiefer	Pin maritime	Pino negral	Pino marittimo
Pinus halepensis	Aleppo pine	Aleppokiefer	Pin d'Alep	Pino carrasco	Pino d'Aleppo
Picea abies	Norway spruce	Rotfichte	Epicéa commun	Abeto rojo	Picea comune
Picea sitchensis	Sitka spruce	Sitkafichte	Epicéa de Sitka	Picea de Sitka	Picea di Sitka
Abies alba	Silver fir	Weißtanne	Sapin pectiné	Abeto común	Abete bianco
Larix decidua	European larch	Europäische Lärche	Mélèze d'Europe	Alerce	Larice europeo

Annex VIII
MAIN SPECIES REFERRED TO IN THE TEXT

Dutch	Danish	Portuguese	Greek	Finnish	Russian
Beuk	Bøg	Faia	Οξυά δασική	Pyökki	бук лесной
Wintereik	Vintereg	Carvalho branco Americano	Δρυς απόδισκος	Talvitammi	дуб скальный
Zomereik	Stilkeg	Carvalho roble	Δρυς ποδισκοφόρος	Metsätammi	дуб черещатый
Steeneik	Steneg	Azinheira	Αριά	Rautatammi	дуб каменный
Kurkeik	Korkeg	Sobreiro	Φελλοδρύς	Korkkitammi	дуб пробковый
Grove den	Skovfyr	Pinheiro silvestre	Δασική πεύκη	Metsämänty	сосна обыкновенная
Oostenrijkse/ Corsicaanse zwarte den	Østrisk fyr	Pinheiro Austríaco	Μαύρη πεύκη	Euroopanmusta-mänty	сосна чёрная
Zeeden	Strandfyr	Pinheiro bravo	Θαλασσία πεύκη	Rannikkomänty	сосна приморская
Aleppo den	Aleppofyr	Pinheiro de alepo	Χαλέπιος πεύκη	Aleponmänty	сосна алеппская
Fijnspar	Rødgran	Picea	Ερυθρελάτη υψηλή	Metsäkuusi	ель европейская
Sitkaspar	Sitkagran	Picea de Sitka	Ερυθρελάτη	Sitkankuusi	ель ситхинская
Zilverden	Ædelgran	Abeto branco	Λευκή ελάτη	Saksanpihta	пихта белая
Europese lariks	Lærk	Larício Europeu	Λάριξ ευρωπαϊκή	Euroopanlehti-kuusi	лиственница европейская

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