COMMISSION OF THE EUROPEAN COMMUNITIES

DIRECTORATE-GENERAL
FOR AGRICULTURE

# FOREST HEALTH REPORT 1991

Technical report on the 1990 survey

DOCUMENT

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Cataloguing data can be found at the end of this publication

The preparation of this report was made possible thanks to:

the execution of the forest health surveys by the forest services of the 12 Member States of the European Community and five other European countries;

the entry and processing of the forest inventory data by James Duncan & Associates;

the calculation of the geographical coordinates of the inventory grid intersection points by the Commission of the European Communities, Corine project, DG XI;

the evaluation and reporting of inventory results by the Commission of the European Communities, Unit VI FII 2, Specific actions in rural areas and Oranjewoud International.

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

ISBN 92-826-0549-3

Catalogue number: CH-72-91-237-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 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 **forest damage inventory** programme started in 1987 with a survey of 1216 plots and 26,390 sample trees. By 1989, the network had been enlarged to 1891 plots and 45,572 trees, covering most of the total forest area of the European Community (EC) Member States (approximately 500 000 km$^2$) by a 16x16 km grid. With the reunion of the two German States another 115 plots were added in 1990. The total network in the EC-Member States consists now of 2005 plots with almost 50,000 trees. Besides the analysis and evaluation of the 1990 survey data from these plots, the data from forest health surveys in five Non-EC countries are also included in this Forest Health Report 1991. These data concern the forest vitality of almost 20,000 trees on 878 plots in Austria, Czechoslovakia, Hungary, Poland and Switzerland.

Observations in 1990 showed that in the entire dataset (EC + Non-EC) **20.8%** of the trees were **damaged** (defoliation more than 25%). The figures for the EC-Member States (including the former GDR) and the five Non-EC countries are **15.2%** and **35.2%** respectively. The overall figures for the defoliation in 1987, 1988 and 1989 in the EC (excluding the GDR) were respectively 14.3%, 10.2% and 9.9%.
Similarly **discolouration of more than 10%** was in 1990 observed for **13.8%** of the trees in the entire dataset and for 14.4% and 12.2% of the trees in the EC and Non-EC respectively. In 1987, 1988 and 1989 these figures were 13.5%, 13.2% and 16.0% respectively.

**Conifers** were more damaged than **broadleaves**. In 1990, a defoliation of more than 25% was found for 24.2% of the conifers (EC: 15.6% and Non-EC: 38.4%) and 16.6% of the broadleaves (EC: 14.9% and Non-EC: 25.6%). Of the most common species found in the EC and Non-EC, the coniferous species ***Abies*** sp. and ***Picea*** sp. show the **highest defoliation** with respectively 18.8% and 21.2% of the trees damaged in the EC, while ***Abies*** sp. and ***Pinus*** sp. show the highest defoliation in the Non-EC countries with respectively 57.9% and 40.9% of the trees damaged.

Conifers show less **discolouration** than broadleaves. In 1990, discolouration of more than 10% was found for 10.8% of the conifers (EC: 12.5% and Non-EC: 8.1%) and for 17.5% of the broadleaves (EC: 16.2% and Non-EC: 24.9%). The percentage of trees with a discolouration of more than 10 % was **highest** for ***Quercus suber*** (48.4%). For ***Quercus ilex***, this percentage was **lowest** (2.4%). Among the conifers, *Abies* sp. and *Pinus* sp. showed in the EC and Non-EC the highest percentages of discoloured trees with respectively 19.7% and 32.5% for *Abies*, and 15.0% and 11.0% for *Pinus*.

With regard to the **climatic zones**, the percentage of damaged trees was considerably higher in the Non-EC Sub-atlantic region (36.6%) as compared to the EC Sub-atlantic region (18.2%). For the Mountainous region this difference was less apparent (Non-EC: 15.8% and EC: 7.7%).
The highest percentages for discolouration were found in the Mediterranean region (28.8%). Especially *Quercus suber* and *Abies* sp. show high discolouration figures with 48.4% and 35.0% of the trees discoloured respectively. The lowest discolouration is recorded in the Non-EC Mountainous region where 5.0% shows a discolouration.

For the comparison of the results of the 1989 and 1990 survey, a subsample was defined containing all trees that were **common to both inventories**. As no data are available on the Non-EC countries in 1989, the subsample consists of EC sample trees only. The selected subsample consisted of 40,308 Common Sample Trees (**CST's**). When regarding the entire subsample, an increase in damaged trees of 5.2% was observed from 8.2% in 1989 to 13.4% in 1990, indicating that a **certain deterioration in forest vitality** occurred in the period 1989-1990.

When the CST's are regarded by region, a slight increase in the percentage of damaged trees is found in all regions, with a maximum of 6.9% in the Mediterranean region. Only slight differences in discolouration were observed among the CST's.

For the second consecutive year the overall vitality of ***Quercus suber* has deteriorated severely**. Less than 40% of the trees were in 1990 recorded as not-defoliated, while at the same time the percentage of damaged trees (defoliation >25%) increased from 10% in 1989 to more than 40% in 1990. Most other species groups showed a slight decrease in the percentage of healthy trees, indicating that the vitality situation of the trees has decreased in general. Only *Quercus ilex* showed a slight improvement in defoliation.

From a study on the 12 most common species, executed on a subsample of plots common in 1987, 1988, 1989 and 1990, it appeared that for most species **no improving or deteriorating trends** in the vitality of the sampled trees could be determined when regarding the entire Community.
A clear trend was found only for the species *Quercus ilex*, *Quercus pubescens* and the *Picea sitchensis*. ***Quercus ilex*** seems to be **improving**, while ***Quercus pubescens*** and ***Picea sitchensis*** show a **pronounced deteriorating trend**.

In an extended evaluation of a selection of the available inventory data, some special investigations have been carried out. The correlations between defoliation and mean age were investigated, the dynamics of the trees with respect to defoliation were studied in detail, the reasons for exclusion of a tree in the next year survey were searched, and the first soiltype data were analysed.

Some clear relationships could be determined between **defoliation and the mean age** for the percentages of not- and slightly defoliated trees. It appeared that the total percentage of **not-defoliated** trees clearly **decreases** with increasing age, while at the same time an increase is found in the percentage of **slightly defoliated** trees.

In study of the **dynamics of the trees** with regard to their vitality, it was found that, for the species studied, the dynamics are **very high**, indicating that many trees switch back and forth one or more classes over the years.

# 1 Introduction

## 1.1 Legislative Basis

On November 17, 1986 the Council of Ministers of the EC adopted Regulation (EEC) No. 3528/86 on the protection of the Community's forests against atmospheric pollution, which took effect from January 1, 1987[1]. Within the Regulation, a Community scheme is provided for, establishing a periodic Community inventory of damage to forests and the drawing up by the Member States of a periodic forest health report. It also provides for the development of pilot projects and field experiments in order to improve the understanding of atmospheric pollution in forests and its effects, to improve methods of observing and measuring damage and to establish methods for the restoration of damaged forests.
In Council Regulation (EEC) No. 1613/89 an amendment was adopted in which the provision for pilot projects to maintain damaged forests was included. Also a programme was introduced for the synoptic processing of information on knowledge of atmospheric pollution in woodlands and its effects[2].

With respect to the Community inventory, the scheme in the above Regulation provides for:

- Establishing, on the basis of a common method, a periodic inventory of damage caused to forests in particular by atmospheric pollution;

- Establishing or extending, in a coordinated and harmonious way, the network of observation points required to conduct this inventory.

The Community provides financing of up to 50% of the costs.
Following the inventory, each Member State forwards to the Commission the data gathered at the observation points of the network.

In addition, in accordance with Article 3 of the above Regulation, each Member State draws up and forwards to the Commission a periodic forest health report based in particular on the inventory data referred to in Article 2.

In accordance with the opinion of the Committee on Forest Protection, established by the same Regulation (no. 3528/86), the detailed rules of implementation of the inventory, and in particular the common methodology and format of presentation of the national forest health reports have been adopted and are laid out in Commission Regulation (EEC) no. 1696/87 of June 10, 1987[3]. This common method takes account of the recommendations of the ECE manual (United Nations Economic Commission for Europe, Convention on Long-Range Transboundary Air Pollution - International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests).

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1 OJ no. L 326, 11.21.1986, p. 2
2 OJ no. L 165, 06.15.1989, p. 8
3 OJ no. L 161, 06.22.1987, p. 1

## 1.2 Inclusion of Non-EC countries

In the ICP-forests meeting of May 1990 in Interlaken, Switzerland, the Commission was requested to process the forest health inventory data of a number of Non-EC countries, in addition to the data of the EC-Member States. In December of that year a number of countries supplied the Commission with information on the health situation of their forests. These countries were Switzerland[4], Austria, Hungary, Czechoslovakia and Poland. As the data are applicable to 1990 only, no comparative analysis with other years can be made for these countries.

## 1.3 Inventory method

The common method for establishing a periodic inventory of damage caused to forests is described in Annex 1 of Commission Regulation (EEC) no. 1696/87 and in the Council Regulation (EEC) No. 1613/89. These regulations lay down detailed rules for the implementation of Council Regulation (EEC) no. 3528/86 and apply both to the Community Inventory of forest damage and to the denser grid networks that might be used by the Member States to draw up their forest health reports. The method is also used by the Non-EC countries. Since 1990 the Member States have been encouraged to submit the survey data in a digital format. In the Note[5] introducing this digital format, a complete review is included with the methodology, the parameters, codes, etc. to be used in the survey.

The common inventory methodology requires that a network of observation points should be established following a systematic grid covering the entire forest area. For the inventory, a 16 x 16 km grid is used for which the latitude and longitude coordinates of each point have been provided by the Commission to each Member State and participating European country. Countries are however encouraged to collect additional information from denser networks using the common methodology. Member States are obliged to present in their annual reports the results of forest inventory data collected at national or regional level, as foreseen by Council Regulation (EEC) no. 3528/86.

At each grid intersection point falling in a forest, a sample of 20-30 trees is selected for assessment according to a stringently defined, objective and unbiased statistical procedure. The sample includes all tree species provided the sample trees have a minimum height of 60 cm. Only predominant, dominant and co-dominant trees, according to the system of Kraft, qualify as sample trees.

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4 The data from Switzerland were received in a slightly different format, but were converted to the EC-standard.

5 Note on the submission of the forest vitality inventory data in a digital format

In each observation plot the tree sample is assessed with respect to defoliation and discolouration following the European classification. In the 1987 and 1988 forest damage inventory, **defoliation** was estimated in five classes:

| Class | Degree of defoliation | Percentage of needle/leaf loss |
|---|---|---|
| 0 | not defoliated | 0-10% |
| 1 | slightly defoliated | 11-25% |
| 2 | moderately defoliated | 26-60% |
| 3 | severely defoliated | >60% |
| 4 | dead | |

Since the 1989-inventory, **defoliation** is estimated in 5% increment classes, with class 0 = 0% defoliation, class 5 = 1-5% defoliation, class 10 = 6-10% defoliation, etc.

Defoliation is estimated in comparison to a tree with full foliage, the reference being a healthy tree in the vicinity or a photograph of a tree with full foliage, suitable for the region of investigation.

**Discolouration** is estimated in four (5) classes:

| Class | Degree of discolouration | Percentage of discolouration |
|---|---|---|
| 0 | not discoloured | 0-10% |
| 1 | slightly discoloured | 11-25% |
| 2 | moderately discoloured | 26-60% |
| 3 | severely discoloured | >60% |
| (4) | (dead) | |

Although the discolouration is originally classified in four classes, a fifth class (dead) has been added by many countries. Consequently this class is presented seperately from discolouration class 3 (>60%) in many tables.

Defoliation of trees or crown density is the basic index used in all surveys of forest health carried out throughout Europe within the framework of the Convention on long-range transboundary air pollution. It is influenced by a number of factors, of which pollution is one. The same holds for discolouration of foliage, another index used for evaluating the vitality of trees. 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 addition, for each sample plot data are collected on the following parameters and classified into common categories laid down in Regulation no. 1696/87: country, actual latitude and longitude coordinates, observation plot number, altitude, aspect, availability of water to principal species, humus type, mean age of dominant storey, date of observation, tree number, tree species and observations of easily identifiable damages. For the network these data are collected on common census forms (see Annex V) which are forwarded to the Commission.

Since 1990 it has been strongly encouraged that the vitality data are presented to the Commission in a digital format. Most EC-Member States have submitted the inventory data in such a format, increasing the data input speed considerably. For the Non-EC countries the submission of the data in digital format is obligatory.

# 2 The 1987, 1988, 1989 and 1990 surveys of damage caused to forests

## 2.1 Completion

Under Article 2 of Council Regulation (EEC) no. 3528/86 measures are provided for the establishment of a periodic inventory of the health status of the Community's forests. The inventory is based on a common network of observation points and aims at the collection of representative and comparable data on the developments in forest health.

In the first year of the inventory, 1987, a number of 1216 observation plots of the common network was sampled and a total of 26,389 trees was assessed in terms of defoliation and discolouration. In the subsequent years the network was further expanded and the Commission received information from an increasing number of plots and trees. In 1989 the density of the grid network in the EC reached near-completion.

As a result of the reunion of the two German states, the network was extended with another 115 plots in the former German Democratic Republic. The total inventory network in the EC now consists of 2005 plots with 48,402 trees. In addition to the EC-network, plots were surveyed in a number of other European countries. As requested by the ICP-forests, the data of Switzerland, Austria, Hungary, Czechoslovakia and Poland have been included in this Forest Health Report 1991. The survey results from these countries are in this report referred to as Non-EC countries.
The entire data-set in 1990 consisted of 2883 plots and 67,335 trees inventoried over 17 countries (see Table 1).

In certain parts of the Federal Republic of Germany the forest inventory has not been executed in 1990 because of extensive storm damage (123 plots in Bavaria and Saarland have been destroyed or damaged). As the vitality of the forests in this region is said to have changed little since 1989, it was decided to use the 1989-data for this region again in the 1990-analysis. In this way a total overview of the forest situation in Western Europe could still be prepared.

Table 1 shows the numbers of trees and plots sampled by each country over the period 1987-1990.

## 2.2 Input and screening of data

As stated in the rules of the Council Regulation detailing the inventory of forest damage in the European Communities, the data are collected each summer and forwarded to the Commission by December 15 of the same year.

The information arriving at the Commission is screened. Incomplete and obviously faulty data are excluded from further evaluation. If a single and less vital parameter is missing, the tree and plot-data are excluded only from the detailed evaluation concerning the missing parameter. Due to this screening the total number of trees in some of the detailed analyses is less than the grand total of 67,335 sampled trees.

TABLE 1: Number of plots and sample trees in 1987, 1988, 1989 and 1990.

| Country | Plots | | | | Sample trees | | | |
|---|---|---|---|---|---|---|---|---|
| | 1987 | 1988 | 1989 | 1990 | 1987 | 1988 | 1989 | 1990 |
| France | 75 | 228 | 509 | 514 | 1806 | 4465 | 10192 | 10280 |
| Belgium | 11 | 33 | 33 | 29 | 264 | 792 | 791 | 684 |
| Netherlands | 14 | 14 | 14 | 14 | 280 | 280 | 278 | 279 |
| F. R. Germany | 300 | 299 | 298 | 412 | 8062 | 7919 | 7883 | 10616 |
| Italy | 189 | 208 | 206 | 206 | 5059 | 5536 | 5695 | 5759 |
| United Kingdom | 75 | 75 | 76 | 72 | 1803 | 1791 | 1811 | 1726 |
| Ireland | 22 | 22 | 22 | 22 | 535 | 461 | 462 | 458 |
| Denmark | 20 | 19 | 19 | 19 | 480 | 456 | 456 | 449 |
| Greece | 0 | 84 | 104 | 101 | 0 | 1979 | 2463 | 2392 |
| Portugal | 108 | 154 | 152 | 152 | 2274 | 4621 | 4569 | 4563 |
| Spain | 398 | 386 | 454 | 460 | 5730 | 9211 | 10876 | 11100 |
| Luxemburg | 4 | 4 | 4 | 4 | 96 | 96 | 96 | 96 |
| EC | 1216 | 1526 | 1891 | 2005 | 26389 | 37607 | 45572 | 48402 |
| Switzerland | - | - | - | 45 | - | - | - | 479 |
| Austria | - | - | - | 72 | - | - | - | 2132 |
| Hungary | - | - | - | 67 | - | - | - | 1351 |
| Czechoslovakia | - | - | - | 219 | - | - | - | 5475 |
| Poland | - | - | - | 475 | - | - | - | 9496 |
| Non-EC | - | - | - | 878 | - | - | - | 18933 |
| Grand Total | 1216 | 1526 | 1891 | 2883 | 26389 | 37607 | 45572 | 67335 |

## 2.3 Main characteristics of sample trees in 1990

Of the total of 48,402 trees that were assessed in the EC in 1990, broadleaves accounted for 52.5% of the entire data set and conifers for 47.5%. In the grand total of 67,335 trees these figures are 44.7% and 55.3% for broadleaves and conifers respectively.

For most of the 109 species identified in the 1990-survey, the relative frequency of occurrence was low. Only 12 species showed a presence of over 2%. The 10 most common species represented over 70% of all observed trees, while *Pinus sylvestris* and *Picea abies* accounted for 20.4% and 15.8% of the total number respectively (Table 2, Annex I-1).

With the inclusion of the former German Democratic Republic and the participation of the five Non-EC countries the distribution of the sampled trees over the **climatic zones** has changed considerably.
The majority of the trees (49.5%) showed to be present in the Sub-Atlantic zone. The Mediterranean zone accounted for 30.2% of the trees; the Atlantic zone for 14.8% of the trees; and the Mountainous zone for 5.4% of the trees.

The survey data of 1990 were complete and consistent for the EC-Member States but showed several gaps as far as the results of the five Non-EC countries participating in the Inventory are concerned.

TABLE 2: Presence of most frequent species in the 1990 survey.

| Species | Trees | | | Plots | |
|---|---|---|---|---|---|
| | No. | % | (% cum.) | No. | % |
| *Pinus sylvestris* | 13709 | 20.4 | 20.4 | 814 | 14.5 |
| *Picea abies* | 10668 | 15.8 | 36.2 | 575 | 10.2 |
| *Fagus sylvatica* | 5650 | 8.4 | 44.6 | 485 | 8.6 |
| *Pinus pinaster* | 3761 | 5.6 | 50.2 | 193 | 3.4 |
| *Quercus robur* | 3350 | 5.0 | 55.2 | 337 | 6.0 |
| *Quercus ilex* | 3099 | 4.6 | 59.8 | 202 | 3.6 |
| *Quercus petraea* | 2091 | 3.1 | 62.9 | 235 | 4.2 |
| *Pinus halepensis* | 1871 | 2.8 | 65.7 | 107 | 1.9 |
| *Quercus pubescens* | 1578 | 2.3 | 68.0 | 147 | 2.6 |
| *Pinus nigra* | 1536 | 2.3 | 70.3 | 113 | 2.0 |
| *Quercus suber* | 1470 | 2.2 | 72.5 | 90 | 1.6 |
| *Castanea sativa* | 1338 | 2.0 | 74.5 | 135 | 2.4 |

**Water availability** was not observed for 25.2% of the total number of sample trees, all situated in the Non-EC countries. Of the trees that were surveyed for water availability, a large majority (85.5%) was assessed as sufficiently supplied with water. The classes ‘insufficient’ and ‘excessive’ were attributed 12.8% and 1.7% of the trees respectively.

Concerning **humus type**, 25.3% of the total sample trees lacked information on this parameter. These trees were all found in the Non-EC countries. Of the trees classified for humus type, 36.9% was found on mull humus, 39.6% on moder, 15.4% on mor and only 0.4% and 1.2% on anmor and peat respectively. For 6.4% of the trees other humus types were observed.

For 15.9% of the total sample trees, all situated in the Non-EC countries, no information on **altitude** was made available. Of the trees with information for altitude, 55.1% was situated at less than 500 m, 29.3% between 500 and 1000 m and 15.6% above 1000 m.

With regard to **aspect or exposition** the survey-data were complete for 78.7% of the total number of sample trees. The trees lacking information on this characteristic were all located in the Non-EC countries. Among the trees surveyed with respect to exposition, a fairly equal distribution was observed, with an exception for class 9 (flat) which represented almost a quarter of the sampled trees. A slightly higher proportion of the sample trees was found in north-facing plots.

With regard to **mean age** the 1990-survey was nearly complete, with information lacking for only 2.4% of the total number of sample trees. Of the trees classified for age, 54.4% was located in stands of less than 60 years old and 38.5% in stands of 60 years of age or older. A total of 7.1% of the trees was observed in stands with an irregular age distribution.

## 2.4 Presentation and definitions

The inventory results are expressed in terms of the percentage of the tree sample falling in the defoliation (or discolouration) class. The distinction in classes follows the European classification system; after the initial arrangement of the trees into the 5%-increment classes of defoliation, they are grouped into the 5 major classes of **'not defoliated'** (class 0), **'slightly defoliated'** (class 1), **'moderately defoliated'** (class 2), **'severely defoliated'** (class 3) and **'dead'** (class 4).
Even after this grouping into 5 classes, the question arises whether a qualitative distinction can be made between the first two defoliation classes (0+1). The description 'slightly defoliated' does not necessarily reflect a reduced health status due to external factors, as for example fungal attack or air pollution. It may also be a transient phase of natural variation in crown density.
However, before initially healthy trees reach higher defoliation classes, they must pass the state of defoliation class 1 at a certain phase of development. This class may therefore be interpreted as a 'warning class'. Defoliation classes 2, 3 and 4 represent considerable defoliation (or in other words; the crown density in the trees is less than 75% of that of a fully foliated tree).
The total percentage of sample trees classified in those three defoliation classes gives a reliable indication of the presence of significant damage.
In the report, a **sample tree** in the **defoliation classes 2, 3 or 4** will be referred to as **'damaged'**, while a tree in **defoliation classes 0 or 1** will be classified as **'undamaged'**, even though some defoliation may have occurred.

A **sample plot** will be considered as **'damaged'** if the weighted average defoliation class of the sample trees of this plot is **2, 3 or 4**. If, on the other hand, the weighted average of a plot is **0 or 1**, the sample plot will be considered as **'undamaged'**.

Whenever time trends in defoliation are presented, the mean percentages **per plot** of trees in a certain defoliation class will be considered for individual tree species. These percentages indicate the variation in defoliation between plots. Additionally, when time trends are presented with respect to some environmental variables, only plots will be included that contain at least **10** individuals of the tree species concerned. This way, only stands are included in which the species represents a major stand component. Furthermore, **extreme values** for percentages of trees in the defoliation classes, due to the presence of only a few individuals of the species, will be avoided.

## 2.5 Comparability of 1987, 1988, 1989 and 1990 results

In 1990 a grand total of 67,335 trees was sampled, which is an increase compared to 1989 of 48%. This is explained by the inclusion of the former German Democratic Republic and the participation of the five Non-EC countries. In 1987, 1988 and 1989 the survey area was restricted to EC-Member States only, with a total number of sample trees of 26,390, 37,607 and 45,572 respectively. The results of the 4-year time period are therefore not fully comparable.

In order to allow certain comparisons to be made between results of subsequent years, subsamples have been defined which consist of those sample trees that have been observed over **two or more consecutive years**. For the period 1989-1990 this subsample contains 40,308 trees, that will be referred to as **Common Sample Trees** 1989-1990 (CST's). The comparisons between the

1989 and 1990 observations given hereafter are based on this subsample.

Separate comparisons have been made for the observations on some of the most common tree species in the Inventory. For these species, a separate subsample has been defined for sample trees observed over the entire period of the survey (1987-1990). These comparisons enable the detection of possible trends in the health condition of the species considered over the full time interval of the forest health inventory.

# 3 1990 Survey results

## 3.1 The results of the entire survey

In the 1990 survey, 20.8% of the trees are considered to be damaged (defoliation more than 25%), when the whole dataset is regarded. For the EC and the Non-EC countries these percentages are respectively 15.2% and 35.2%

The total percentages of defoliation and discolouration for all **broadleaves** and **conifers** in the EC-Member States and the five other European countries are shown in Tables 3 and 4. Regarding the entire data-set, broadleaves appear healthier (classes 0+1) in terms of defoliation than conifers. This difference is particularly clear in the Non-EC countries. In terms of discolouration conifers appear most vital, with the differences again being most pronounced in the Non-EC countries.

TABLE 3 : Total percentages of defoliation for all broadleaves, conifers and total sample trees.

| | Defoliation | | | | | | |
|---|---|---|---|---|---|---|---|
| Species type | 0-10% | 11-25% | 0-25% | 26-60% | >60 | dead | No. trees |
| EC | | | | | | | |
| Broadleaves | 61.9 | 23.2 | 85.1 | 12.5 | 1.8 | 0.6 | 25409 |
| Conifers | 57.4 | 27.2 | 84.6 | 13.5 | 1.3 | 0.6 | 22948 |
| All species | 59.8 | 25.1 | 84.9 | 13.0 | 1.5 | 0.6 | 48357 |
| Non–EC | | | | | | | |
| Broadleaves | 37.3 | 37.3 | 74.6 | 21.5 | 3.0 | 0.9 | 4694 |
| Conifers | 25.0 | 36.6 | 61.6 | 34.5 | 3.4 | 0.5 | 14239 |
| All species | 28.0 | 36.7 | 64.7 | 31.3 | 3.4 | 0.6 | 18933 |
| Total | | | | | | | |
| Broadleaves | 58.1 | 25.4 | 83.5 | 13.9 | 2.0 | 0.6 | 30103 |
| Conifers | 45.0 | 30.8 | 75.8 | 21.5 | 2.1 | 0.6 | 37187 |
| All species | 50.8 | 28.4 | 79.2 | 18.1 | 2.0 | 0.6 | 67290 |

In the discussion on **defoliation** and **discolouration** a distinction is made between the EC-Member States and the five other participating European countries. The results in Tables 3 and 4 will be commented on with reference to the detailed lists in Annexes I-3 and I-4.

**Defoliation** among **broadleaved species groups** in the European Community was least severe for *Eucalyptus* sp. (97.0% in classes 0+1). The lowest percentage of undamaged trees was found for *Quercus suber* (only 58.4% in classes 0+1). In the Non-EC countries *Castanea sativa* and the deciduous *Quercus* sp. performed best (84.6% in classes 0+1) and worst (75.2% in classes 0+1) respectively. Other species groups indicated comparable percentages of not- to slightly defoliated trees. (Annex I-3).

Of all **coniferous species groups** in the European Community, *Picea* sp. and *Abies* sp. showed the lowest percentages of not- to slightly defoliated trees (78.8% and 81.2% respectively), suggesting a generally poorer health condition. The share of undamaged trees was highest for *Larix* sp. (87.9%). In the Non-EC countries *Abies* sp. (only 41.9%) and *Pinus* sp. (59.0%) showed the lowest percentages of undamaged trees (classes 0+1, Annex I-3).

TABLE 4: Total percentages of discolouration for all broadleaves, conifers and total sample trees.

| | Discolouration | | | | | |
|---|---|---|---|---|---|---|
| Species type | 0-10% | 11-25% | 26-60% | >60% | dead | No. trees |
| EC | | | | | | |
| Broadleaves | 83.8 | 11.8 | 3.0 | 0.8 | 0.6 | 25409 |
| Conifers | 87.5 | 9.8 | 1.7 | 0.4 | 0.6 | 22948 |
| All species | 85.6 | 10.9 | 2.3 | 0.6 | 0.6 | 48357 |
| Non-EC | | | | | | |
| Broadleaves | 75.1 | 17.4 | 6.0 | 0.6 | 0.9 | 4694 |
| Conifers | 91.9 | 5.2 | 2.0 | 0.4 | 0.5 | 14239 |
| All species | 87.8 | 8.2 | 3.0 | 0.4 | 0.6 | 18933 |
| Total | | | | | | |
| Broadleaves | 82.4 | 12.7 | 3.5 | 0.8 | 0.6 | 30103 |
| Conifers | 89.2 | 8.0 | 1.8 | 0.4 | 0.6 | 37187 |
| All species | 86.2 | 10.1 | 2.5 | 0.6 | 0.6 | 67290 |

**Discolouration** among the **broadleaved species groups** of the European Community was most prevalent for *Quercus suber* (only 51.6% of the trees not-discoloured). Species *Quercus ilex* showed the highest percentage of trees not discoloured (97.6% in class 0). In the five Non-EC countries *Quercus* sp. (76.3% in class 0) appeared less healthy in terms of discolouration than *Fagus* sp. (84.3% in class 0) and *Castanea sativa* (84.6% in class 0, Annex I-4).

For **coniferous species groups** the variation among the species groups is small, especially in the European Community. In the five other European countries most trees of *Picea* sp. showed to be not-discoloured (97.7% in class 0), compared to only 67.5% in discolouration class 0 for *Abies* sp. (Annex I-4).

The distribution over the entire survey area of the percentages of damaged trees per plot is shown in Annex I-5. Annexes I-6 and I-7 show maps of the distribution of the plot defoliation and plot discolouration over the entire area.

## 3.2 Defoliation and discolouration by climatic region

Each sample plot has been attributed a climate type. The climate type assigned is a function of the geographical location, including altitude, of the plot. In order to avoid excessive splitting of the data set, only four large climatic zones have been distinguished (Figure 1).

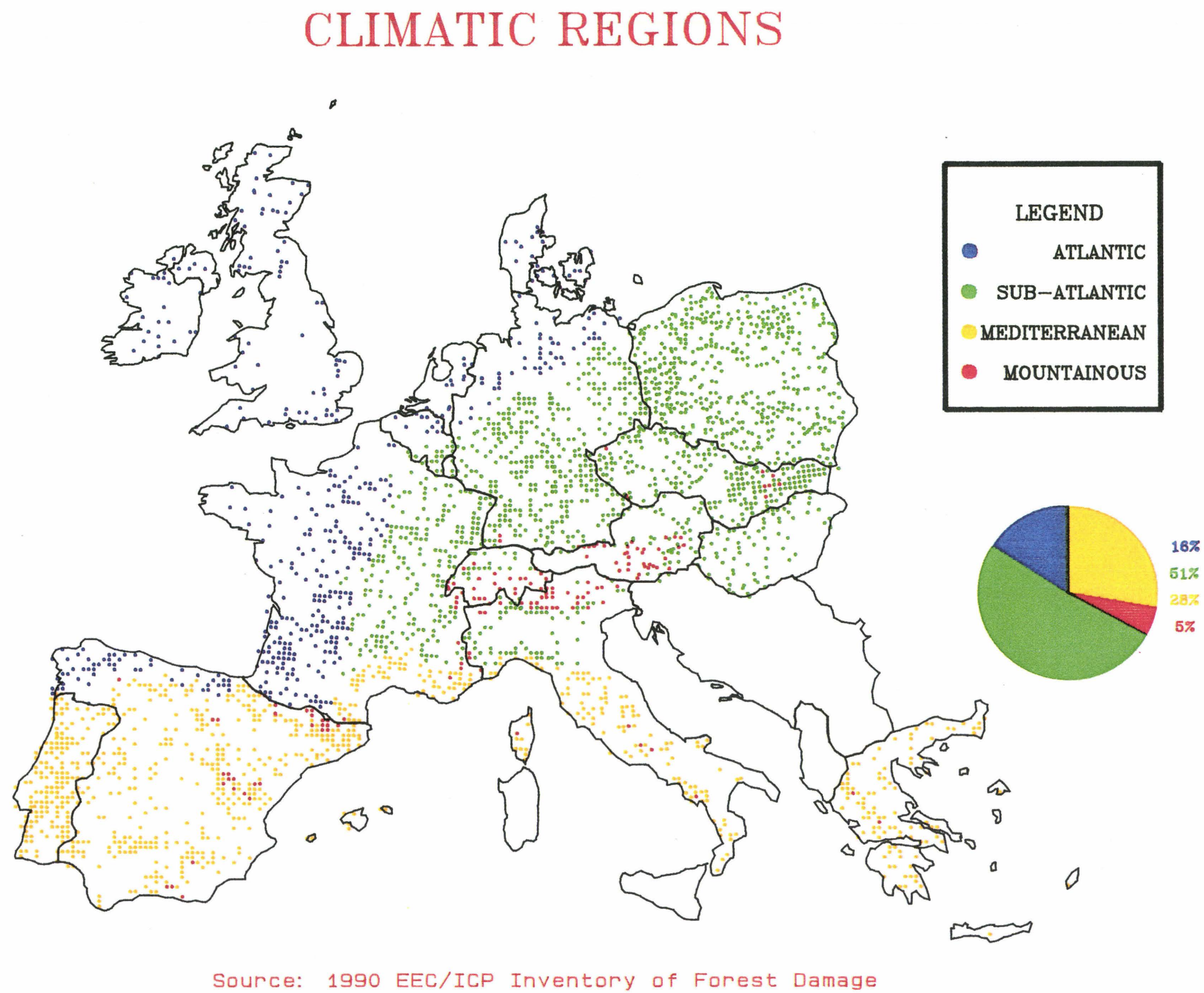



Figure 1: Map of climatic regions.

These are defined as :

* **Atlantic region**
* **Sub-atlantic region**
* **Mediterranean region**
* **Mountainous region**

The **Atlantic** region comprises a broad belt along the Atlantic coast. It starts at the northern border of Portugal, runs across the northern part of Spain and the western part of France and Belgium, and covers all of the Netherlands, Denmark, the United Kingdom and Ireland. The northern part of the Federal Republic of Germany is also included in this region.
The climate in this region is generally moist and windy with moderate temperatures in both summer and winter, and with long transitional seasons. In 1990, nearly a fifth of all the sample trees were located within the Atlantic region.

The **Sub-atlantic** region comprises Luxemburg, Poland, Czechoslovakia, Hungary, the greater part of the Federal Republic of Germany, and parts of Belgium, France, Italy, Switzerland and Austria.
The climate in this region generally shows larger differences between summer and winter temperatures, and has less wind as compared to the Atlantic region. In 1990, half of all the sample trees were located in this region.

The **Mediterranean** region comprises areas with rather dry summers and periods of extensive drought. Rainfall is mainly confined to the winter season. This region covers Greece and Portugal, the greater parts of Italy and Spain, and a small part of France. In 1990, nearly a third of all the sample trees were located within this region.

The **Mountainous** region consists of plots that have been excluded from their original climatic region because of their location at high altitudes. In the south of Europe (up to the latitude running along the southern edge of the Alps and through Lyon) plots situated at more than 1500 m above sea level have been considered mountainous. North of this latitude, plots situated at more than 1000 m. above sea level have been considered mountainous. In 1990, only about 5% of the sample trees were assigned to this region.

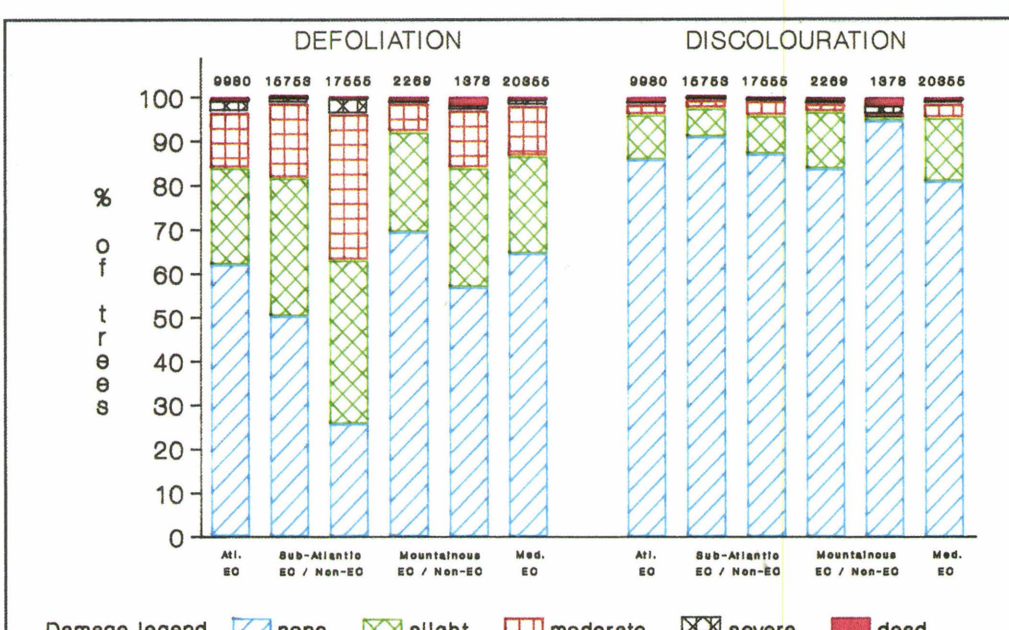



Figure 2: Defoliation and discolouration by climatic region.

The mean percentages of trees of the broadleaved and coniferous species in the five defoliation classes are subdivided by climatic region in Table 5 and Figure 2. Information on the EC and Non-EC countries is included in Annex I-3.

TABLE 5: Total percentages of defoliation for all broadleaves, conifers and total sample trees by climatic region.

| **Climatic region** | **Defoliation** | | | | | | | **No. trees** | |
|---|---|---|---|---|---|---|---|---|---|
| | 0-10% | 11-25% | 0-25% | 26-60% | >60 | dead | Total | EC | Non-EC |
| **Atlantic** | | | | | | | | | |
| Broadleaves | 68.2 | 19.8 | 88.0 | 9.1 | 1.9 | 1.0 | 5233 | 5233 | 0 |
| Conifers | 55.2 | 24.3 | 79.5 | 15.9 | 3.2 | 1.3 | 4747 | 4747 | 0 |
| All species | 62.0 | 21.9 | 84.0 | 12.3 | 2.5 | 1.1 | 9980 | 9980 | 0 |
| **Sub-atlantic** | | | | | | | | | |
| Broadleaves | 49.2 | 30.9 | 80.1 | 17.3 | 2.3 | 0.4 | 11892 | 7245 | 4647 |
| Conifers | 30.9 | 36.7 | 67.6 | 29.6 | 2.7 | 0.2 | 21416 | 8508 | 12908 |
| All species | 37.4 | 34.6 | 72.0 | 25.2 | 2.6 | 0.3 | 33308 | 15753 | 17555 |
| **Mediterranean** | | | | | | | | | |
| Broadleaves | 61.6 | 22.6 | 84.2 | 13.2 | 1.8 | 0.7 | 12384 | 12384 | 0 |
| Conifers | 69.8 | 21.0 | 90.8 | 8.0 | 0.5 | 0.7 | 7971 | 7971 | 0 |
| All species | 64.8 | 22.0 | 86.8 | 11.2 | 1.3 | 0.7 | 20355 | 20355 | 0 |
| **Mountainous** | | | | | | | | | |
| Broadleaves | 71.0 | 23.1 | 94.1 | 5.2 | 0.3 | 0.3 | 594 | 547 | 47 |
| Conifers | 63.7 | 24.5 | 88.2 | 9.4 | 0.7 | 1.6 | 3053 | 1722 | 1331 |
| All species | 64.9 | 24.3 | 89.2 | 8.7 | 0.6 | 1.4 | 3647 | 2269 | 1378 |
| EC + Non-EC | | | | | | | | | |
| Broadleaves | 58.0 | 25.4 | 83.4 | 13.9 | 2.0 | 0.6 | 30103 | 25409 | 4694 |
| Conifers | 45.0 | 30.8 | 75.8 | 21.6 | 2.1 | 0.6 | 37187 | 22948 | 14239 |
| All species | 50.8 | 28.4 | 79.2 | 18.2 | 2.1 | 0.6 | 67290 | 48357 | 18933 |

Considering the total data-set of the EC and Non-EC countries, it can be observed from the table that the lowest frequency of undamaged trees occurred in the Sub-Atlantic zone (only 72.0% in classes 0+1), indicating a generally poorer vitality in this region. The highest percentage of trees without leaf or needle loss was assessed in the Mountainous zone (89.2% in classes 0+1). In all climatic regions except the Mediterranean, and in the total data-set broadleaves were more defoliated than coniferous .

The results of Table 5 can be explained by considering the differences between **species groups** (see for details Annex I-3). These differences are especially large in the **Sub-Atlantic** region. The large number (11,332) of *Pinus* sp. trees and their relatively high percentage of defoliated trees (34.7% in classes 2-4) increased the overall defoliation percentages for conifers and all sample trees in this region.

In the **Atlantic** region defoliation of coniferous species is relatively high due to the impact of a number (1259) of *Picea* sp. trees of which only 69.2% were classified as undamaged (classes 0+1).

In the **Mediterranean** region, *Pinus* sp. is the dominant coniferous species group (6991 trees), showing a relatively high percentage of undamaged trees (90.8% in classes 0+1), whereas the broadleaved species are influenced by *Quercus suber* (1470 trees), with a very low percentage of undamaged trees (only 58.4% in classes 0+1).

In the **Mountainous** region the total percentage of damaged trees for coniferous species is mainly influenced by the relatively low percentage of undamaged trees of *Picea* sp. (84.9% in classes 0+1).

Table 6 and Figure 2 show the **discolouration** for broadleaves, conifers and total sample trees by climatic region. Detailed data for the EC-Member States and the five Non-EC Countries are given in Annex I-4.

The percentage of not-discoloured trees (class 0) is lowest in the **Mediterranean** region (81.2%). Of influence are *Quercus suber* and *Abies* sp. which show low percentages of not-discoloured trees in this region (only 51.6% and 64.9% respectively, see Annex I-4).

TABLE 6: Total percentages of discolouration for all broadleaves, conifers and total sample trees by climatic region.

| Climatic region | Discolouration | | | | | No. trees | | |
|---|---|---|---|---|---|---|---|---|
| | 0-10% | 11-25% | 26-60% | >60% | dead | Total | EC | Non-EC |
| **Atlantic** | | | | | | | | |
| Broadleaves | 86.0 | 9.3 | 2.8 | 0.9 | 1.0 | 5233 | 5233 | 0 |
| Conifers | 86.0 | 11.1 | 1.4 | 0.2 | 1.3 | 4747 | 4747 | 0 |
| All species | 86.0 | 10.2 | 2.1 | 0.6 | 1.1 | 9980 | 9980 | 0 |
| **Sub-atlantic** | | | | | | | | |
| Broadleaves | 83.0 | 12.3 | 3.7 | 0.6 | 0.4 | 11892 | 7245 | 4647 |
| Conifers | 92.5 | 5.2 | 1.8 | 0.3 | 0.2 | 21416 | 8508 | 12908 |
| All species | 89.1 | 7.7 | 2.5 | 0.4 | 0.3 | 33308 | 15753 | 17555 |
| **Mediterranean** | | | | | | | | |
| Broadleaves | 80.5 | 14.4 | 3.4 | 0.9 | 0.7 | 12384 | 12384 | 0 |
| Conifers | 82.2 | 14.2 | 2.5 | 0.5 | 0.7 | 7971 | 7971 | 0 |
| All species | 81.2 | 14.3 | 3.0 | 0.7 | 0.7 | 20355 | 20355 | 0 |
| **Mountainous** | | | | | | | | |
| Broadleaves | 82.0 | 13.6 | 4.0 | 0.0 | 0.3 | 594 | 547 | 47 |
| Conifers | 89.4 | 7.4 | 0.5 | 1.1 | 1.6 | 3053 | 1722 | 1331 |
| All species | 88.2 | 8.4 | 1.1 | 0.9 | 1.4 | 3647 | 2269 | 1378 |
| EC + Non-EC | | | | | | | | |
| Broadleaves | 82.5 | 12.7 | 3.4 | 0.8 | 0.6 | 30103 | 25409 | 4694 |
| Conifers | 89.2 | 8.0 | 1.8 | 0.4 | 0.6 | 37187 | 22948 | 14239 |
| All species | 86.2 | 10.1 | 2.5 | 0.6 | 0.6 | 67290 | 48357 | 18933 |

The **Sub-atlantic** region shows the highest percentage of not-discoloured trees. Conifers appear less discoloured than broadleaves which is mainly due to the influence of *Picea* sp. (97.1% of the trees in class 0). In the **Mountainous** region, conifers are less frequently discoloured than broadleaves. This is largely due to the relatively low percentage of not-discoloured trees of *Fagus* sp. and deciduous *Quercus* species (79.9% and 81.3% in class 0 respectively). In the **Atlantic** region no clear differences between the two species-types can be observed.

## 3.3 Defoliation and discolouration by altitude

Altitude was determined for each sample plot, using 50 m increment classes. In general, the lower altitude classes are most frequent, and the number of plots gradually declines with increasing altitude (Table 7, Annex I-8). Trees in plots at altitudes above 1000 m. are mostly located outside the EC (Switzerland, Austria, Czechoslovakia).

TABLE 7: Defoliation and discolouration by altitude and by climatic region.
Numbers in italics represent less than 250 trees (= approximately 10 plots)

| **Altitude (m)** | **Defoliation (% of trees in classes 0+1)** | | | | | | | | | **Sample trees** |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Region** | | | | | | **EC** | **Non-EC** | **Total** | |
| | **Atl.** | **Sub-atl.** | | **Medit.** | **Moun.** | | | | | |
| | | EC | Non-EC | | EC | Non-EC | | | | |
| 0 - 250 | 83.8 | 79.0 | 69.6 | 74.5 | | - | 80.2 | 69.6 | 79.3 | 16918 |
| 251 - 500 | 80.7 | 82.7 | 63.8 | 85.2 | | - | 83.4 | 63.8 | 80.3 | 14277 |
| 501 - 750 | 85.5 | 80.9 | 67.6 | 89.1 | | - | 85.1 | 67.6 | 81.5 | 9818 |
| 751 - 1000 | 93.6 | 81.8 | 71.9 | 93.7 | | - | 90.9 | 71.9 | 87.1 | 6776 |
| 1001 - 1250 | *95.0* | 89.1 | - | 91.9 | 91.0 | 75.6 | 91.3 | 75.6 | 89.5 | 4416 |
| 1251 - 1500 | *97.7* | 92.3 | - | 93.1 | 80.4 | 87.6 | 91.8 | 87.6 | 91.0 | 2558 |
| >1500 | - | | - | - | 94.5 | 90.8 | 94.5 | 90.8 | 93.7 | 1861 |
| Total | 84.0 | 81.8 | 67.6 | 86.8 | 92.2 | 84.2 | 84.8 | 70.3 | 82.6 | 56624 |

| **Altitude (m)** | **Discolouration (% of trees in class 0)** | | | | | | | | | **Sample trees** |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Region** | | | | | | **EC** | **Non-EC** | **Total** | |
| | **Atl.** | **Sub-atl.** | | **Medit.** | **Moun.** | | | | | |
| | | EC | Non-EC | | EC | Non-EC | | | | |
| 0 - 250 | 85.6 | 94.9 | 51.1 | 67.2 | | - | 82.9 | 51.1 | 80.3 | 16918 |
| 251 - 500 | 87.6 | 91.9 | 77.5 | 80.8 | | - | 87.3 | 77.5 | 85.8 | 14277 |
| 501 - 750 | 88.6 | 90.0 | 95.0 | 84.1 | | - | 87.1 | 95.0 | 88.7 | 9818 |
| 751 - 1000 | 84.1 | 86.4 | 94.9 | 87.0 | | - | 86.7 | 94.9 | 88.3 | 6776 |
| 1001 - 1250 | *10.0* | 88.1 | - | 86.9 | 92.1 | 97.6 | 87.4 | 97.6 | 88.6 | 4416 |
| 1251 - 1500 | *96.6* | 74.7 | - | 87.7 | 74.3 | 94.2 | 92.1 | 94.2 | 92.6 | 2558 |
| >1500 | - | | - | - | 82.3 | 92.7 | 82.3 | 92.7 | 84.6 | 1861 |
| Total | 86.0 | 91.2 | 80.6 | 81.1 | 83.9 | 95.0 | 85.5 | 83.0 | 85.2 | 56624 |

Table 7 shows the total percentages of **not- to slightly defoliated** trees (class 0+1) in the different altitude ranges, subdivided by the climatic regions of the EC and Non-EC countries. For the entire data-set, vitality appears to increase with increasing altitude. In Figure 3 the relationship between altitude and the mean values of defoliation in each of the six altitude classes is shown to approach a straight line. In general, the percentage of undamaged trees (classes 0+1) increases with altitude. The observed trends are similar for the two data-sets of the EC and the Non-EC countries, but in the five Non-EC countries the percentages of undamaged trees are consistently lower than in the EC-countries over the entire altitudinal range.

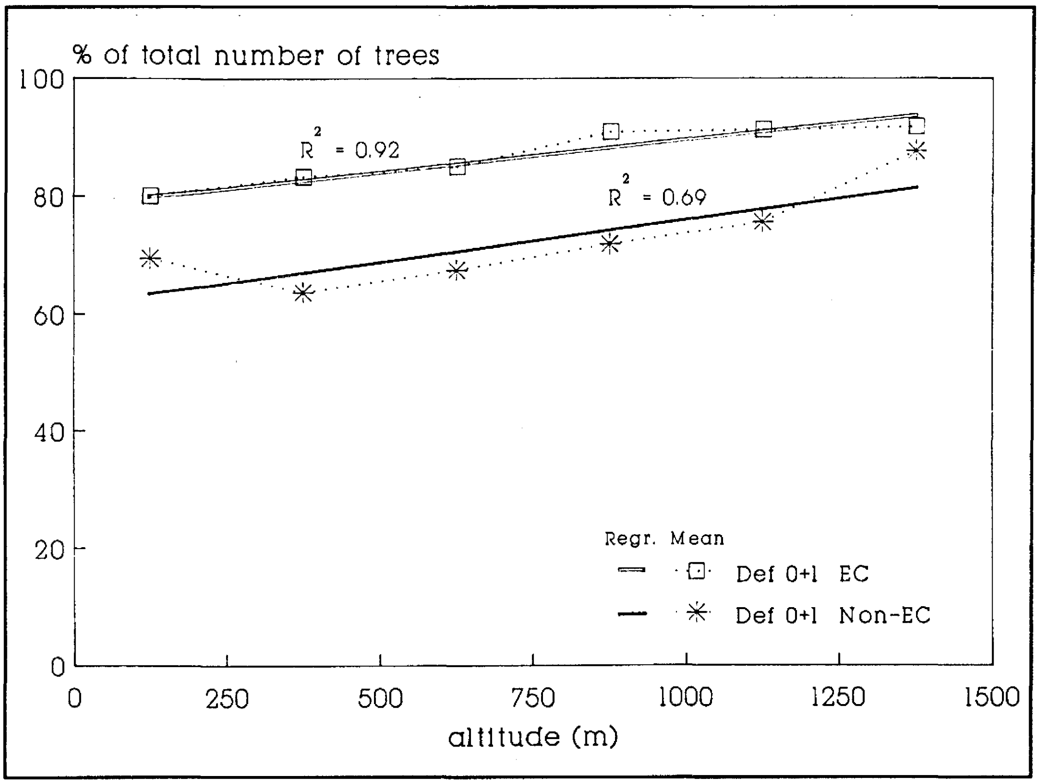



Figure 3: Relation between mean defoliation per altitude class and altitude.

In Table 7, also the total percentages of **not-discoloured** trees are presented by altitude and the climatic regions of the EC and Non-EC countries. For the entire data-set, the proportion of not-discoloured trees is lowest in the lowest altitude-class (only 80.3% in class 0 at 0-250 m.). Up to an altitude of 500 m. discolouration is considerably more frequent in the Non-EC countries as compared to the EC-Member States (Annex I-8).

In the **Atlantic** and **Sub-atlantic** regions,
no clear trends are apparent for discolouration in relation to altitude. Only slight differences in discolouration occur (the 10% for not-discoloured trees at 1001-1250 m. in the Atlantic region refers to only one plot, and is therefore not representative).

In the **Mediterranean** region, the percentages of not-discoloured trees appear to increase with altitude for the first 1000 m. In the lowest 250 m, only 67.2% of the trees are not-discoloured. Climbing to an altitude of 1000 m, this percentage gradually rises to 87.0%. This possible relationship may be caused by several factors, for instance the more favorable site conditions such as temperature and humidity at higher altitudes in this region.

## 3.4 Defoliation and discolouration by exposition (aspect)

The exposition or aspect is determined by the orientation of the sample plot towards a certain compass direction (facing north, southwest, etc.). Differences in terms of defoliation and discolouration between the EC and Non-EC countries occur for most compass directions, but are rather inconsistent (Table 8, Annex I-9). In the Non-EC countries northern, eastern, southern and western directions appear less healthy in terms of defoliation and discolouration than plots with intermediate expositions. This is explained by the fact that in Czechoslovakia such intermediate expositions were not distinguished. Plots situated in flat areas performed considerably worse in the Non-EC countries (23.4% in defoliation classes 0+1, 17.2% in discolouration class 0) than in the EC-countries (82.5% and 87.7% respectively). In Austria no plots on flat areas occur at all.

TABLE 8: Defoliation and discolouration by aspect.
Numbers in italics represent less than 250 trees (= approximately 10 plots)

| Aspect | Defoliation (% class 0+1) | | Discolouration (% class 0) | | Sample trees | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Total | | EC | Non-EC |
| | EC | Non-EC | EC | Non-EC | No. | % | % | % |
| N | 85.9 | 72.6 | 86.0 | 84.1 | 7125 | 13.4 | 12.2 | 25.6 |
| NE | 83.8 | 96.3 | 84.9 | 99.3 | 5102 | 9.6 | 10.0 | 6.2 |
| E | 86.3 | 74.4 | 83.8 | 82.9 | 4276 | 8.1 | 7.7 | 11.4 |
| SE | 85.3 | *85.4* | 83.2 | *97.8* | 4032 | 7.6 | 8.1 | 2.8 |
| S | 85.6 | 73.0 | 83.4 | 87.7 | 5464 | 10.3 | 9.6 | 17.0 |
| SW | 87.1 | 93.0 | 84.7 | 93.9 | 4215 | 8.0 | 8.1 | 6.8 |
| W | 83.9 | 70.2 | 84.6 | 85.9 | 4945 | 9.3 | 8.2 | 20.4 |
| NW | 87.4 | *95.8* | 86.7 | *100.0* | 4973 | 9.4 | 10.0 | 3.0 |
| Flat | 82.5 | 23.4 | 87.7 | 17.2 | 12873 | 24.3 | 26.0 | 6.7 |
| Total | 84.8 | 73.0 | 85.5 | 82.9 | 53005 | 100 | 100 | 100 |

## 3.5 Defoliation and discolouration by water availability

Water availability refers to the relative availability of water to the principal species in a plot, and is determined at the date of observation. Table 8 shows for the entire data-set that in plots with **excessive** water availability relatively lower percentages of undamaged trees (only 79.6% in defoliation classes 0+1) were found. For all other classes no clear differences can be observed with respect to defoliation or discolouration (Table 9, Annex I-10).

TABLE 9: Defoliation and discolouration by water availability.

| Water availability | Defoliation | | | Discolouration | Sample trees | |
|---|---|---|---|---|---|---|
| | 0-10 | 11-25 | 0-25% | 0-10% | No. | % |
| Insufficient | 50.0 | 34.7 | 84.7 | 83.4 | 6435 | 12.8 |
| Sufficient | 61.9 | 23.6 | 85.5 | 86.5 | 43046 | 85.5 |
| Excessive | 59.7 | 19.9 | 79.6 | 84.4 | 863 | 1.7 |
| Total | 60.3 | 25.0 | 85.3 | 86.1 | 50344 | 100 |

## 3.6 Defoliation and discolouration by humus type

An overview of defoliation and discolouration by humus type is presented in Table 10 for the entire data-set (see Annex I-11 for details). Only the humus types **mull**, **moder** and **mor** are well represented in the total sample. In the Non-EC countries the moder humus type was found on the majority of the plots surveyed. There are only slight differences in defoliation and discolouration between these three humus types. The moder humus type shows on average the least damage (88.0% in defoliation classes 0+1). In plots with **peat**, the vitality in terms of defoliation and discolouration was found to be slightly worse (only 73.9% and 72.8% in classes 0+1 and 0 respectively) than in plots with other humus types. However, as the tree sample in this humus type is very small (1.2% of the total sample), no conclusions can be drawn from these figures.

TABLE 10: Defoliation and discolouration by humus type.

| Humus type | Defoliation | Discolouration | Sample trees | | | |
|---|---|---|---|---|---|---|
| | (% class 0+1) | (% class 0) | Total | | EC | Non-EC |
| | | | No. | % | % | % |
| Mull | 84.7 | 81.4 | 18580 | 36.9 | 38.0 | 12.7 |
| Moder | 88.0 | 88.2 | 19941 | 39.6 | 37.8 | 80.3 |
| Mor | 82.6 | 88.5 | 7773 | 15.4 | 15.8 | 7.0 |
| Anmor | 79.1 | 82.7 | 225 | 0.4 | 0.5 | 0.0 |
| Peat | 73.9 | 72.8 | 591 | 1.2 | 1.2 | 0.0 |
| Other | 81.0 | 95.9 | 3206 | 6.4 | 6.7 | 0.0 |
| Total | 85.3 | 86.0 | 50316 | 100 | 100 | 100 |

## 3.7 Defoliation and discolouration by mean age

Table 11 shows the defoliation and discolouration by mean age for all species. A distinction is made between the results for the EC-Member States and the five other European countries. Percentages of not- to slightly defoliated trees (class 0+1) show a gradual decline with increasing mean age. When the defoliation classes 0 and 1 are considered separately, a relatively strong relationship between defoliation and mean stand age becomes apparent; percentages of not-defoliated trees show a rapid decrease with increasing age, whereas an opposite trend is observed for the percentages of slightly defoliated trees. Relationships are stronger for the data-set of the EC as compared to the results of the Non-EC countries (Figure 4, Annex 1-12).

The percentages of trees in the different **discolouration** classes show no trend with increasing age.

In Figure 4 the means of the percentage of trees in defoliation classes 0 and 1 are shown for each of the mean age classes. A distinction is made between the data from the European Community and the results from the other European

TABLE 11: Defoliation and discolouration by mean age.

| Mean age (years) | Defoliation 0-10% EC | Defoliation 0-10% Non-EC | Defoliation 11-25% EC | Defoliation 11-25% Non-EC | Defoliation 0-25% EC | Defoliation 0-25% Non-EC | Defoliation 0-25% Total | Discolouration 0-10% EC | Discolouration 0-10% Non-EC | Discolouration 0-10% Total | Sample Trees |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 20 | 75.8 | 58.4 | 15.3 | 18.9 | 91.1 | 77.3 | 90.3 | 87.9 | 74.7 | 87.2 | 8288 |
| 21 - 40 | 63.5 | 53.1 | 22.9 | 22.7 | 86.4 | 75.8 | 85.9 | 84.7 | 60.5 | 83.6 | 13999 |
| 41 - 60 | 57.1 | 23.6 | 27.6 | 40.3 | 84.7 | 63.9 | 76.9 | 86.2 | 87.6 | 86.7 | 13469 |
| 61 - 80 | 54.7 | 26.0 | 30.4 | 38.4 | 85.1 | 64.4 | 74.4 | 85.8 | 85.4 | 85.6 | 10659 |
| 81 - 100 | 42.7 | 24.6 | 34.2 | 37.9 | 76.9 | 62.5 | 70.3 | 82.6 | 89.6 | 85.8 | 8062 |
| 101 - 120 | 36.9 | 31.7 | 37.4 | 41.1 | 74.3 | 72.8 | 73.8 | 84.7 | 94.9 | 88.5 | 3419 |
| >120 | 31.6 | 42.5 | 33.6 | 34.3 | 65.2 | 76.8 | 68.3 | 82.4 | 95.0 | 85.7 | 3196 |
| Irregular | 72.6 | - | 18.8 | - | 91.4 | - | 91.4 | 87.2 | - | 87.2 | 4645 |
| Total | 59.7 | 28.1 | 25.1 | 37.7 | 84.8 | 65.8 | 79.8 | 85.5 | 86.8 | 85.9 | 65737 |

countries. The data-points in Figure 4 are the means for all species and the regression lines shown refer to these means only. The dotted lines have been added for the purpose of interpretability only.

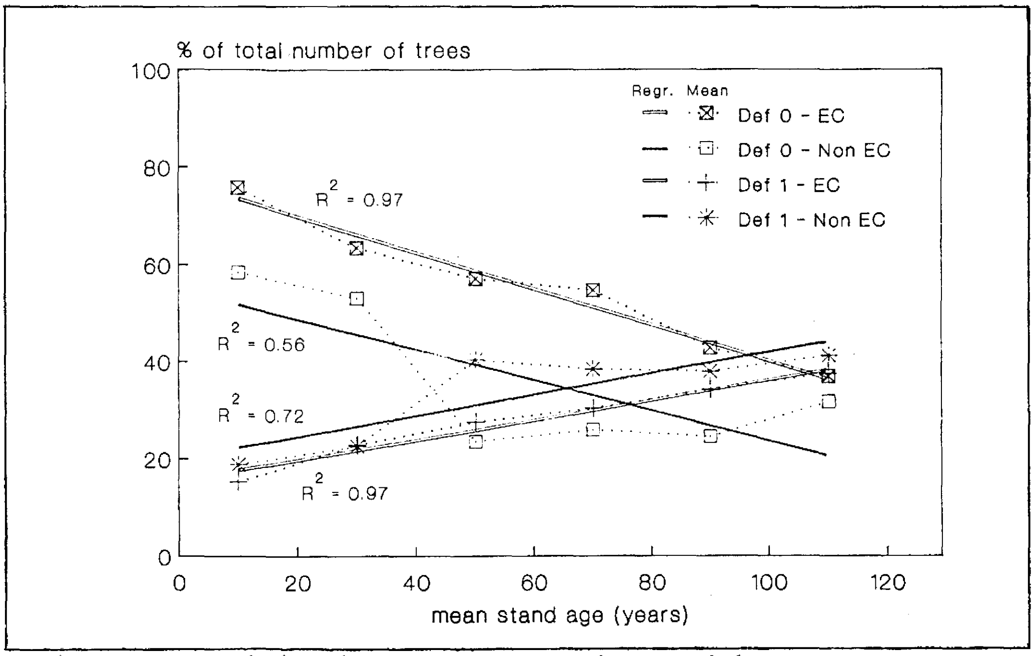



Figure 4: Correlations between mean stand age and the mean percentages of not-defoliated (class 0) and slightly defoliated trees (class 1) for all species in the EC and Non-EC Countries.

The regression coefficients ($R^2$) of the straight (regression) lines drawn in Figure 4 are very high, especially for the EC-data-set (0.97 for defoliation class 0 and class 1). The relationships appear to be nearly linear, with the mean percentage of trees residing in class 0 decreasing with increasing age. Conversely the mean percentage of trees in class 1 shows an increase with age. For the trees in the Non-EC countries these patterns are similar, but the mean percentage of trees in class 0 is consistently lower and the mean percentage of

trees in class 1 is consistently higher than the corresponding percentages in the data-set of the EC.
In section 6.1 the relationship between defoliation and mean stand age will be further discussed for *Picea abies*.

## 3.8 Easily identifiable damage

Types of damage to sample trees that could easily be identified have been divided into eight categories:

* **Game and Grazing** (damage to trunk, bark, etc.)
* **Insects**
* **Fungi**
* **Abiotic agents** (wind, drought, snow, etc.)
* **Direct action of man** (poor sylvicultural practices, logging)
* **Fire**
* **Known local or regional pollution**
* **Other types of damage**

For these categories, only the **presence** of such damage is indicated. It is presented 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 damage table.

TABLE 12: Defoliation and discolouration by identifiable damage type.
Numbers in italics represent less than 250 trees (= approximately 10 plots)

| Damage type | Defoliation | | | Discolouration | | | Observations (% of total) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | (% in 0+1) | | | (% in 0) | | | Total | | EC | Non-EC |
| | EC | Non-EC | Total | EC | Non-EC | Total | trees | plots | trees | trees |
| Game / Grazing | 70.3 | *93.7* | 77.0 | 75.5 | *94.1* | 80.9 | 1.3 | 3.4 | 1.2 | 1.6 |
| Insects | 85.5 | 60.3 | 82.4 | 82.3 | 75.6 | 81.4 | 14.4 | 32.3 | 16.3 | 8.0 |
| Fungi | 84.3 | 59.0 | 80.1 | 82.6 | 70.8 | 80.6 | 6.9 | 22.4 | 7.5 | 5.1 |
| Abiotic agents | 76.1 | 86.9 | 78.0 | 61.7 | 84.7 | 65.7 | 5.9 | 19.4 | 6.3 | 4.5 |
| Action of man | 74.6 | 90.6 | 76.5 | 63.7 | 96.9 | 67.5 | 6.1 | 15.3 | 7.0 | 3.2 |
| Fire | 76.1 | *100.0* | 76.2 | 84.8 | *100.0* | 84.9 | 1.6 | 3.9 | 2.0 | 0.1 |
| Known pollution | *75.5* | *87.5* | *77.0* | *47.2* | *25.0* | *44.3* | 0.1 | 0.4 | 0.1 | 0.1 |
| Other | 73.4 | *79.7* | 74.9 | 72.2 | *92.3* | 77.2 | 1.5 | 6.0 | 1.5 | 1.6 |
| Any ident. damage | 81.0 | 71.6 | 79.6 | 75.4 | 80.7 | 76.2 | 29.6 | 58.4 | 32.7 | 19.3 |
| No ident. damage | 86.9 | 67.9 | 82.0 | 89.3 | 83.3 | 87.8 | 70.4 | 41.6 | 67.3 | 80.7 |
| Multiple damage | 80.2 | 75.6 | 79.6 | 75.4 | 82.7 | 76.3 | 7.3 | 22.1 | 8.2 | 4.0 |
| Total | 85.1 | 68.6 | 81.3 | 85.3 | 82.8 | 84.7 | 59372 | 2513 | 45914 | 13458 |

In both the EC and the other European countries participating, a number of trees (2488 and 5475 respectively) and plots (105 and 219 respectively) had to be excluded from Table 12 as no damage-types were inventoried at all in these countries.

Of the available data-set, 29.6% of the trees showed one or more identifiable causes of damage (Table 12, Annex I-13). These trees are observed in 57.4% of the plots. The most commonly observed type of damage is caused by **insects** (14.4% of the trees, 31.7% of the plots). Damage attributed to **fungi**, **action of man** and **abiotic agents** is observed less frequently, representing respectively 6.9%, 6.1% and 5.9% of the total tree sample. Damage by known pollution was recorded on only 0.1% of the trees in 0.4 % of the plots. Identifiable damage that could not be assigned to any category is observed for 1.5% of the trees and the plots. Of the total sample, 7.3% of the trees suffered damage from more than one damage type (Table 12).

Interpretation of the data related to identifiable damage is difficult, since they only represent trees for which the type of damage has been established conclusively. Trees that are affected as well, but do not show any kind of symptom that can be related to a known damage type are not included. Therefore, the data presented here only give a general indication of the effect of the several damage types. Trees may be affected by some type of damage, but this may not be accounted for. The frequency of observations of the damage types is relatively low (in the range of 0.1 to 16.3%).

The identification of damage types results in slight differences in terms of defoliation. However, when discolouration is considered, these differences are much more pronounced (Table 12).

As expected, most of the damage types identified have some negative influence on foliation and colouration of the trees. However, the effect is small for most types of damage. The percentage of **not- to slightly defoliated** trees (classes 0+1) is lowest for trees affected by unspecified **other types of damage**, closely followed by the influence of **fire**, **the action of man**, **game and grazing**, and **local or regional pollution**. When regarding all types of damage together, the percentage of not- to slightly defoliated trees is only 2.4% higher as compared to trees with no damage identified (Table 12). In the five Non-EC countries more trees appear to be undamaged (defoliation classes 0+1) in the presence of identifiable damage types than when no damage has been identified (71.6% versus 67.9% in classes 0+1 respectively).

This difference between any and no damage type identified is considerably higher for the percentages of **not-discoloured** trees: 11.6% for the total data-set of the EC and Non-EC countries. The most pronounced negative effect in terms of discolouration is observed for trees affected by **known pollution**. Only 44.3% of the trees showing this type of damage was not-discoloured (class 0), with the lowest value (25%) occurring in the data-set for the Non-EC countries (Table 12). These figures however refer a very small sample of only 61 trees.

## 3.9 Defoliation and discolouration by soil type

In 1990 soil type was for the first time included in the survey on a voluntary basis. Information on soil type was reported for 105 plots in the survey area (3.6% of the total of 2883 plots). For these plots, situated in the Federal Republic of Germany and in Austria, the dominant soil type at the site of the plot was determined according to the FAO soil classification system (Soil Map of the European Communities 1985). The percentages of trees in the defoliation and discolouration classes on these soil types are shown in Table 13. More detailed information on soil types is presented in Annex I-14.

TABLE 13: Defoliation and discolouration by soil type

| Soiltype | Total trees | Defoliation 0-10% | Defoliation 11-25% | Defoliation >26% | Discolouration 0-10% | Discolouration >11% |
|---|---|---|---|---|---|---|
| Cambic Arenosol | 168 | 9.5 | 51.8 | 38.7 | 100.0 | 0 |
| Luvic Arenosol | 120 | 40.8 | 33.3 | 25.8 | 100.0 | 0 |
| Orthic Rendzina | 324 | 59.3 | 30.6 | 10.2 | 97.5 | 2.5 |
| Eutric Cambisol | 322 | 74.2 | 22.4 | 3.4 | 96.3 | 3.7 |
| Dystric Cambisol | 379 | 71.5 | 25.9 | 2.7 | 96.6 | 3.4 |
| Gleyic Cambisol | 150 | 86.0 | 12.0 | 2.0 | 100.0 | 0 |
| Calcic Cambisol | 30 | 93.3 | 3.3 | 3.3 | 93.3 | 6.7 |
| Chromic Luvisol | 210 | 53.8 | 36.7 | 9.6 | 98.6 | 1.4 |
| Gleyic Luvisol | 149 | 91.3 | 8.7 | 0 | 100.0 | 0 |
| Orthic Podzol | 90 | 93.3 | 3.3 | 3.3 | 94.4 | 5.6 |
| Leptic Podzol | 550 | 78.4 | 18.4 | 3.3 | 98.5 | 1.5 |
| Humic Podzol | 360 | 53.3 | 40.8 | 5.9 | 100.0 | 0 |
| Eutric Planosol | 24 | 37.5 | 50.0 | 12.5 | 100.0 | 0 |
| Dystric Histosol | 48 | 47.9 | 39.6 | 12.5 | 97.9 | 2.1 |
| Total | 2924 | 65.4 | 26.9 | 7.7 | 98.2 | 1.8 |

On the sandy Arenosols the percentage of **not-defoliated** trees is very low, indicating a generally poorer health condition on these soils. The poorly drained Planosols and the peaty Histosols also appear less favourable to tree vitality. On Cambisols and the more developed Luvisols the percentages of not-defoliated trees are generally higher, which is in line with the commonly more favourable site-conditions on these soil types. On the relatively infertile Podzols the percentages of not-defoliated trees range from 53% to 93%.
The differences in **discolouration** between the soil types are negligible.

The percentages of trees in the five **defoliation** classes on the plots surveyed for soil type are also shown in Figure 5. Clear differences in defoliation appear to exist between the soil types. The chemically richer Eutric Cambisols perform slightly better than the poorer Dystric Cambisols. Surprising are the relatively high percentages of not-defoliated trees on Gleyic Cambisols and Gleyic Luvisols, which are soils with a high groundwater table, limiting the rootable depth. On the relatively suitable Chromic Luvisols the percentage of not-defoliated trees is surprisingly low.
Given the differences in defoliation between the various soil types, it is strongly recommended that the observation on soil type is included in future surveys. In section 6.4 more attention will be given to the influence of soil type on the defoliation of a specific species.

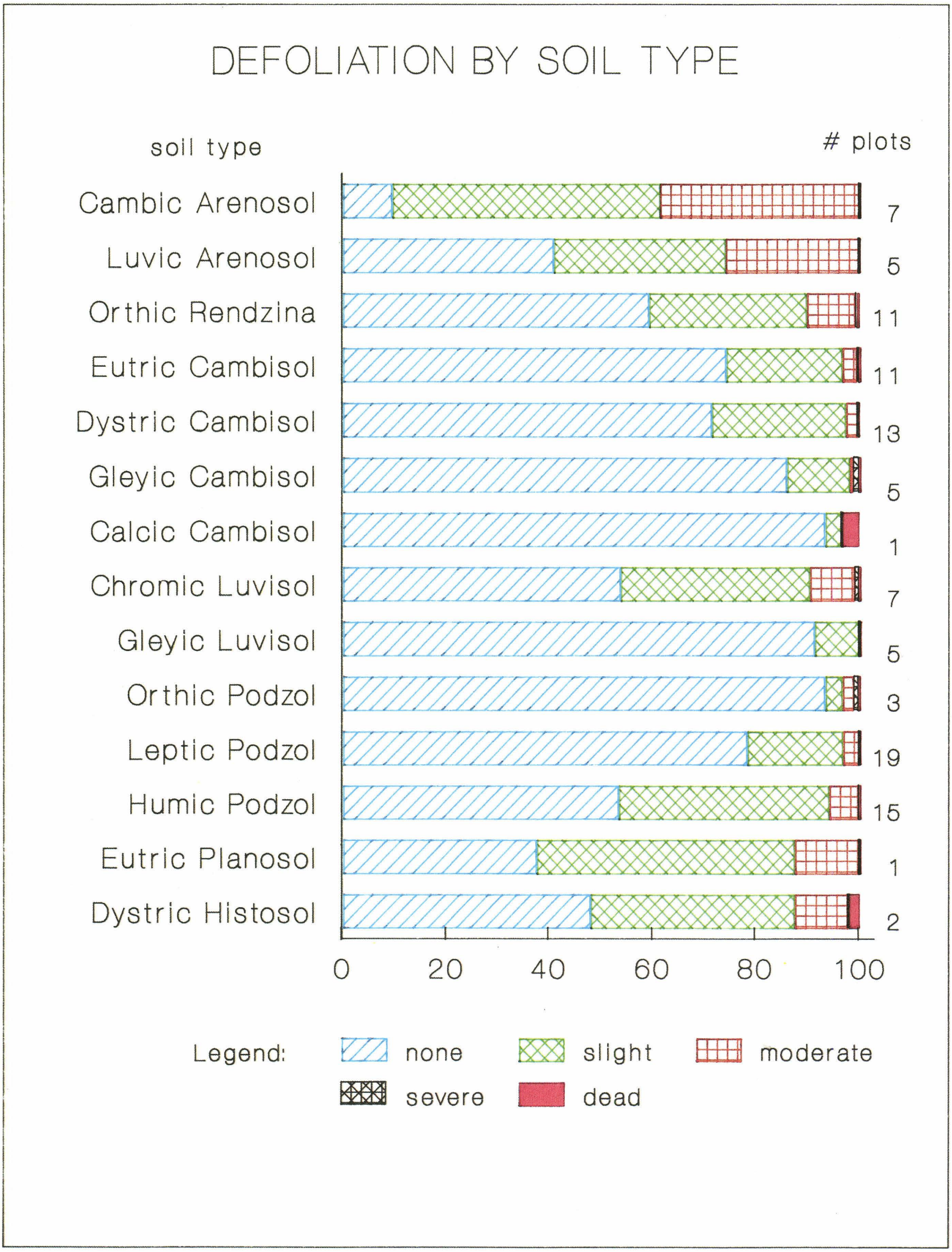



Figure 5. Defoliation by soil type. The mean percentage of trees in defoliation classes none (class 0), slight (class 1), moderate (class 2), severe (class 3), and dead (class 4) for each soil type distinguished in the 1990-survey.
Data from Germany and Austria.

# 4 Comparison of 1989 and 1990 results

Comparison of the total tree samples of 1989 and 1990 may produce biased results since the 1990 survey includes an increased number of observations due to the inclusion of the former German Democratic Republic and the participation of the five Non-EC Countries. Furthermore, some of the plots surveyed in 1989 have not been resurveyed in 1990. In order to be able to compare the results of 1989 and 1990, a subsample is defined containing all trees that are common to both surveys: the **Common Sample Trees (CST's)**. This common sample consists of 40,308 trees, representing 88% of the total tree sample of 1989 and 60% of the total tree sample of 1990 (see Table 14).

## 4.1 Comparison 1989-1990 for the entire Inventory

Table 14 shows the percentages of trees in the different defoliation and discolouration classes for the **total tree sample** in 1989 and 1990, and the percentages for the trees common to the 1989 and 1990 surveys (**CST's**).

TABLE 14 Changes in defoliation and discolouration over 1989-1990 for total sample trees and common sample trees.

DEFOLIATION

| Defoliation | Total tree sample | | Common Sample Trees | |
|---|---|---|---|---|
| classes | 1989 | 1990 | 1989 | 1990 |
| 0 - 10% | 66.1 | 50.8 | 70.1 | 63.8 |
| 11 - 25% | 24.0 | 28.4 | 21.7 | 22.8 |
| 26 - 60% | 8.7 | 18.1 | 7.3 | 11.1 |
| >60% | 0.9 | 2.1 | 0.8 | 1.6 |
| dead | 0.3 | 0.6 | 0.1 | 0.7 |
| No. of trees | 45572 | 67335 | 40308 | 40308 |

DISCOLOURATION

| Discolouration | Total tree sample | | Common Sample Trees | |
|---|---|---|---|---|
| classes | 1989 | 1990 | 1989 | 1990 |
| 0 - 10% | 84.0 | 86.3 | 83.1 | 83.7 |
| 11 - 25% | 12.7 | 10.1 | 13.7 | 12.2 |
| 26 - 60% | 2.6 | 2.5 | 2.7 | 2.7 |
| >60% | 0.4 | 0.6 | 0.4 | 0.7 |
| dead | 0.3 | 0.5 | 0.1 | 0.7 |
| No. of trees | 45572 | 67335 | 40308 | 40308 |

In 1990, the total tree sample was enlarged by 48% (Table 14); 6% within the European Community (mainly the inclusion of the former GDR) and 42% due to the participation of Austria, Czechoslovakia, Hungary, Poland and Switzerland.

The difference between the total sample trees and the common sample trees in 1990 (Table 14) was 13.0% for trees in **defoliation** class 0 and 5.6% for trees in defoliation class 1. As the difference in 1989 was smaller this implies that the extension of the grid network has caused an overall decrease of the total percentage of undamaged trees.
Among the CST's the percentage of not-defoliated trees (class 0) decreased to a lesser extent over the period 1989-1990 than among the total sample trees (6.3% and 15.3% respectively). Defoliation class 1 increased slightly among both samples (1.1% and 4.4% respectively). This implies that for the total tree sample the reduction in the percentage of trees in defoliation classes 0+1 was mainly due to the extension of the grid network with relatively unhealthy trees, and to a lesser degree due to the loss of vitality of trees already present in the Inventory.
Maps showing the changes in defoliation are included in Annex II-4 and II-5. A worsening in plot defoliation was found in Portugal, northern and western Italy, and in parts of Greece.

When regarding the trees common to **three** consecutive years (1988, 1989, and 1990) a similar trend can be recognized (Annex II-6).

The percentage of not-discoloured trees in the total tree sample of 1990 is slightly higher than in the Common Sample; 83.7% of the CST's in 1990 show no **discolouration**, whereas this percentage is 86.3% for the total tree sample (Table 14). This implies that the extension of the grid has caused a relative increase of the percentage of not-discoloured trees. This increase is partly due to the slight improvement among the common sample trees (Table 14).

## 4.2 Comparison of CST's by climatic region

Regarding **defoliation**, differences are present in all climatic regions between the percentages of not- to slightly defoliated trees for the CST's in 1989 and 1990 (Figure 6). On average, the proportion of not-defoliated trees (class 0+1) decreased by 5.2%, with the largest decrease in defoliation (6.9%) taking place in the Mediterranean region (Annex II-1, Figure 6).

Only slight differences in **discolouration** occured among the CST's in 1989 and 1990. The CST's in the Mountainous region show the largest differences in discolouration; the percentage of not-discoloured trees decreased from 85.7% in 1989 to 83.4% in 1990. In the Mediterranean region the CST's slightly improved in terms of discolouration (from 79.9% in 1989 to 81.1% in 1990). In all other climatic regions the changes were negligible (Annex II-1, Figure 6).

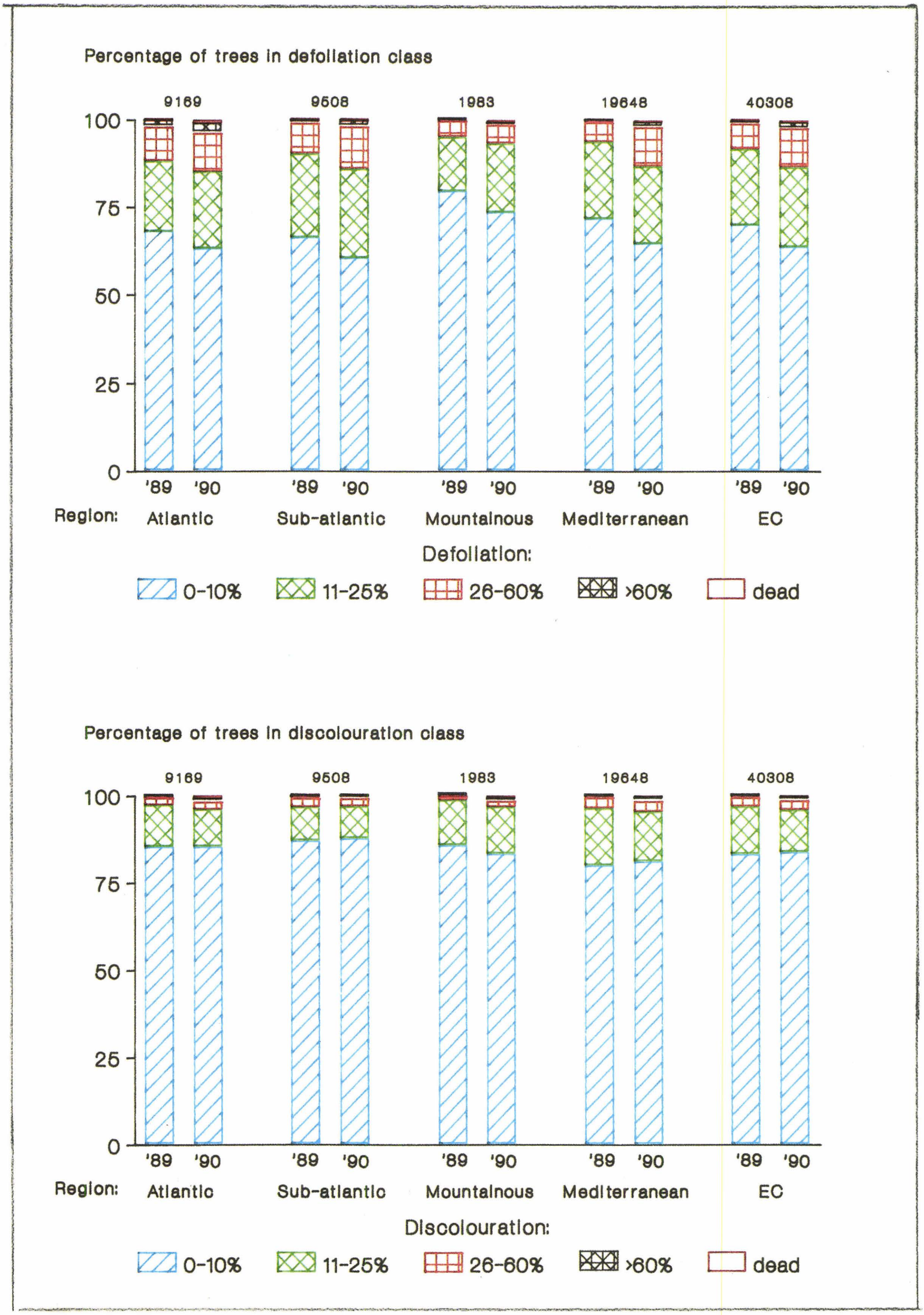



Figure 6: Changes in defoliation and discolouration for Common Sample Trees (CST's) by climatic region.

## 4.3 Comparison of CST's by species group

The differences in defoliation and discolouration between the CST's in 1989 and 1990 are specified according to species groups in Table 15 (Annex II-2 and II-3).

Regarding **defoliation**, *Quercus ilex* showed a general improvement, with percentages of not-defoliated trees increasing from 69.7% in 1989, to 75.7% in 1990. All other species showed a decrease in the percentage of not-defoliated trees. This decrease was largest for *Quercus suber*: in 1989 64.3% of the trees was grouped to class 0, whereas in 1990 this percentage was only 39.9%.

TABLE 15: Changes in defoliation and discolouration for trees common to the 1989 and 1990 sample (CST's), by species group.

| Species group | Defoliation | | | | | | Discolouration | |
|---|---|---|---|---|---|---|---|---|
| | 0-10% | | 11-25% | | 0-25% | | 0-10% | |
| | 1989 | 1990 | 1989 | 1990 | 1989 | 1990 | 1989 | 1990 |
| *Castanea sativa* | 71.8 | 69.3 | 20.4 | 17.6 | 92.2 | 86.9 | 77.4 | 81.7 |
| *Eucalyptus sp.* | 96.3 | 90.9 | 3.1 | 5.9 | 99.4 | 96.8 | 86.5 | 94.7 |
| *Fagus sp.* | 67.5 | 61.8 | 24.3 | 25.9 | 91.8 | 87.7 | 88.4 | 87.8 |
| *Quercus sp.* (deciduous) | 71.7 | 64.0 | 19.8 | 24.0 | 91.5 | 88.1 | 87.9 | 86.2 |
| *Quercus ilex* | 69.7 | 75.7 | 27.0 | 21.0 | 96.7 | 96.7 | 93.2 | 97.6 |
| *Quercus suber* | 64.3 | 39.9 | 26.4 | 18.7 | 90.7 | 58.6 | 54.0 | 51.8 |
| Other broadleaves | 69.9 | 57.6 | 21.4 | 23.8 | 91.2 | 81.5 | 79.0 | 75.8 |
| Total broadleaves | 70.9 | 63.5 | 21.6 | 22.4 | 92.5 | 85.9 | 83.7 | 83.3 |
| *Abies sp.* | 58.8 | 55.5 | 26.4 | 27.6 | 85.2 | 83.1 | 75.1 | 78.6 |
| *Larix sp.* | 69.8 | 68.6 | 23.2 | 22.3 | 93.0 | 90.9 | 88.1 | 91.8 |
| *Picea sp.* | 57.3 | 54.3 | 25.1 | 27.0 | 82.4 | 81.3 | 86.4 | 91.1 |
| *Pinus sp.* | 72.7 | 67.2 | 21.0 | 22.3 | 93.7 | 89.6 | 81.0 | 81.6 |
| Other conifers | 76.1 | 71.1 | 15.5 | 15.8 | 91.6 | 87.0 | 89.6 | 94.7 |
| Total conifers | 68.8 | 64.1 | 22.0 | 23.3 | 90.8 | 87.4 | 82.4 | 84.3 |
| Total species | 70.0 | 63.8 | 21.7 | 22.8 | 91.8 | 86.6 | 83.1 | 83.7 |

Considering the percentages of not- to slightly defoliated trees (class 0+1), the changes are less pronounced for the various species groups. The percentage of *Quercus ilex* trees remained **constant**, while all other species showed a **reduction** in the percentage of undamaged trees over the period 1989-1990 (Table 15). *Quercus suber* showed the largest deterioration in defoliation; in terms of defoliation (class 0+1) a change was observed from 90.7% in 1989 to 58.6% in 1990, representing a decrease of 32.1%.

The changes in the period 1989-1990 in terms of defoliation (classes 0+1) were larger for the **broadleaved** species (6.6%) than for the **coniferous** species (3.4%, Table 15, Annex II-2).

As to **discolouration**, some species groups improved over the period 1989-1990, whereas other species groups deteriorated. A considerable improvement occurred for *Eucalyptus* sp. (86.5% in discolouration class 0 in 1989 to 94.7% in 1990). For *Quercus suber* the observed deterioration in terms of defoliation was accompanied by a comparatively smaller decrease in the percentage of not-discoloured trees (54.0% in 1989 to 51.8% in 1990).

For the **total broadleaves** the percentages of not-discoloured trees decreased only very slightly (0.4%), while for the **total conifers** this percentage showed an increase (1.9%), indicating that no large overall changes took place (Table 15, Annex II-3).

When defining overall tree vitality as a combination of defoliation and discolouration, the **overall vitality** of *Quercus suber* decreased considerably in the period 1989-1990. Approximately 80% of the sampled *Quercus suber* is located in Portugal. In 1990 the Portugese government started a 3 year study on the damage caused to woodlands (*Q. suber*) by air pollution in the southern region of Portugal. This study is co-financed under Article 4 of Council Regulation (EEC) no. 3528/86. In other studies it has been indicated that management may have an important influence.

The overall vitality of *Fagus* sp. and *Quercus* sp. (deciduous) only slightly decreased. All other species groups showed changes in defoliation opposite to those in terms of discolouration, so no definite statement can be made regarding changes in overall vitality for these species groups. The overall vitality of *Quercus ilex* slightly improved; the defoliation remained unchanged while the percentage of not-discoloured trees increased.

Comparing **broadleaves** with **conifers**, broadleaves showed a slight decrease in the overall vitality (a deterioration in terms of both defoliation and discolouration), whereas conifers showed inconclusive changes; a deterioration in terms of defoliation and a slight improvement in terms of discolouration in the period 1989-1990.

## 4.4 The relationship between defoliation and discolouration

It was investigated whether the degree of discolouration in 1989 showed a relationship with the change in defoliation over the period 1989-1990 and, alternatively, whether the degree of defoliation in 1989 showed a correlation with the changes in discolouration over 1989-1990. Table 16 and Figure 7 depict the results of these cross-tabulations. The table shows the numbers and percentages of trees improving, remaining unchanged or worsening in terms of defoliation or discolouration.

The first observation from Table 16 and Figure 17 is that more trees changed over 1989-1990 in terms of defoliation than in terms of discolouration. Also it appears that the proportion of trees changing in terms of **defoliation** over 1989-1990 increases with the degree of discolouration in 1989, except when trees were classified as dead (discolouration class 4). Changes for the worse (to the right in Figure 7) outnumber changes for the better. It is interesting to note that these improvements in defoliation over 1989-1990 tend to be larger (-2 classes) for trees of higher discolouration classes in 1989.

The changes in **discolouration** over 1989-1990 mainly occurred among the trees classified in 1989 as slightly to severely defoliated (classes 1 to 3). As noted before there was an overall improvement in terms of discolouration.

TABLE 16: Changes in defoliation/discolouration over 1989–1990 as a result of the discolouration/defoliation of the tree in 1989.

| | Change in Defoliation 1989–1990 (number of classes) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Discolouration | | | <- improving | | | | unchanged | | worsening -> | | | | | | | | |
| 1989 | −3 | | −2 | | −1 | | 0 | | 1 | | 2 | | 3 | | 4 | | Total |
| | No | % | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % | % |
| None | 5 | 0.0 | 151 | 0.5 | 2534 | 7.6 | 25323 | 75.6 | 4007 | 12.0 | 1176 | 3.5 | 172 | 0.5 | 138 | 0.4 | 100 |
| Slight | 1 | 0.0 | 98 | 1.8 | 833 | 15.1 | 3175 | 57.5 | 1039 | 18.8 | 333 | 6.0 | 43 | 0.8 | 4 | 0.1 | 100 |
| Moderate | 6 | 0.6 | 36 | 3.3 | 187 | 17.3 | 614 | 56.7 | 184 | 17.0 | 52 | 4.8 | 4 | 0.4 | 0 | 0.0 | 100 |
| Severe | 0 | 0.0 | 5 | 3.1 | 31 | 19.4 | 81 | 50.6 | 33 | 20.6 | 6 | 3.8 | 2 | 1.3 | 2 | 1.3 | 100 |
| Dead | 2 | 6.7 | 2 | 6.7 | 2 | 6.7 | 24 | 80.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 100 |
| Total | 14 | 0.0 | 292 | 0.7 | 3587 | 8.9 | 29217 | 72.5 | 5263 | 13.1 | 1567 | 3.9 | 221 | 0.5 | 144 | 0.4 | |

| | Change in Discolouration 1989–1990 (number of classes) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Defoliation | | | <- improving | | | | unchanged | | worsening -> | | | | | | | | |
| 1989 | −3 | | −2 | | −1 | | 0 | | 1 | | 2 | | 3 | | 4 | | Total |
| | No | % | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % | % |
| None | 8 | 0.0 | 93 | 0.3 | 1515 | 5.4 | 24097 | 85.4 | 1971 | 7.0 | 322 | 1.1 | 77 | 0.3 | 138 | 0.5 | 100 |
| Slight | 13 | 0.1 | 125 | 1.4 | 1303 | 14.9 | 6540 | 74.6 | 623 | 7.1 | 84 | 1.0 | 36 | 0.4 | 40 | 0.5 | 100 |
| Moderate | 13 | 0.4 | 145 | 4.9 | 537 | 18.2 | 1919 | 65.1 | 256 | 8.7 | 48 | 1.6 | 21 | 0.7 | 11 | 0.4 | 100 |
| Severe | 11 | 3.2 | 24 | 7.1 | 42 | 12.4 | 202 | 59.4 | 24 | 7.1 | 10 | 2.9 | 9 | 2.6 | 18 | 5.3 | 100 |
| Dead | 2 | 7.1 | 1 | 3.6 | 1 | 3.6 | 24 | 85.7 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 100 |
| Total | 47 | 0.1 | 388 | 1.0 | 3398 | 8.4 | 32782 | 81.3 | 2874 | 7.1 | 464 | 1.2 | 143 | 0.4 | 207 | 0.5 | |

It is also surprising that improvements in discolouration are more pronounced (two classes) among trees classified as more heavily defoliated in 1989.

From Table 16 and Figure 7 it can be deduced that the dynamics in defoliation and discolouration are stronger for trees that were classified as either discoloured or defoliated in the preceding year, than for trees that were not damaged in the year before at all.

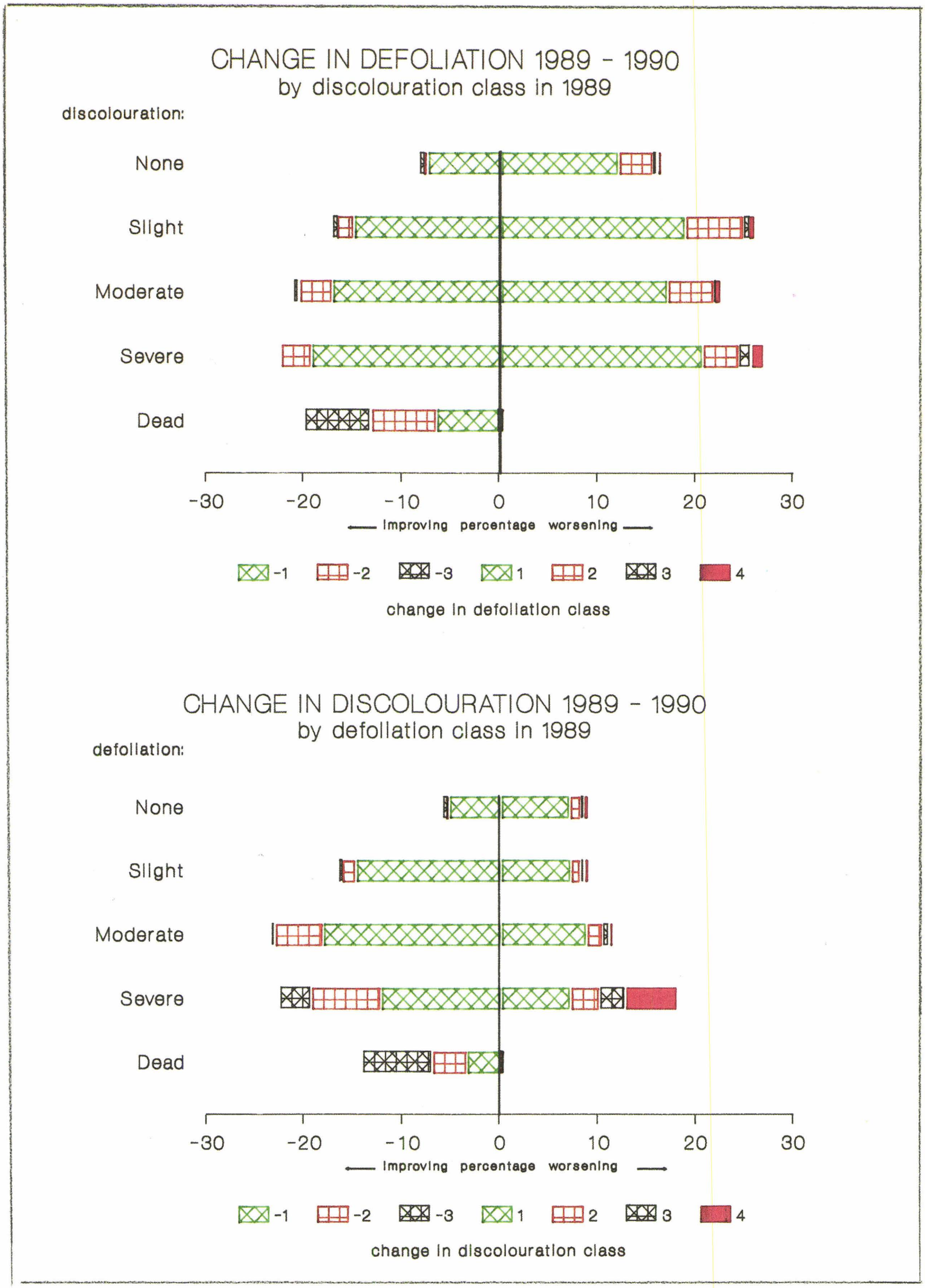



Figure 7: Relationship between defoliation and discolouration for Common Sample Trees (CST's).
Percentages of trees improving (left of y-axis) and worsening (right of y-axis) over 1989-1990 by their classification in 1989.

# 5 Comparison of 1987, 1988, 1989 and 1990 results

In order to investigate the changes in vitality over the first four years of the inventory, a separate subsample was defined, containing trees that are common to the 1987, 1988, 1989 and 1990 inventories. These trees are referred to as Common Trees 87-90. The changes in vitality were examined for the 12 most common species in this subsample. Whenever appropriate, these changes were examined by climatic region.

## 5.1 Investigated species

The 12 most common species in the subsample were investigated regarding changes in defoliation and discolouration over the period 1987, 1988, 1989 and 1990. The investigation was carried out for the entire Community, as well as for the separate climatic regions. The changes by climatic region were only considered when information was available for a species from 10 different stands (plots) or more. This corresponds to approximately 150 - 200 trees. The order and presence of the most frequent species in Table 17 is somewhat different from that of the total inventory of 1990 (Table 2, Chapter 2), since the 1987 and 1988 inventories lacked a great number of plots, particularly in the Mediterranean region. Therefore, *Quercus suber* could not be investigated. In Table 17 an overview is presented of the number of Common Trees 87-90 for the 12 most common species over the various climatic regions.

TABLE 17: Investigated species from plots common to the 1987, 1988, 1989 and 1990 surveys. Numbers of trees by climatic zone.

| Species | Atlantic | Sub-atlantic | Mediterranean | Mountainous | Total |
|---|---|---|---|---|---|
| *Picea abies* | 100 | 1153 | -- | 324 | 1577 |
| *Pinus sylvestris* | 903 | 405 | 289 | 159 | 1756 |
| *Fagus sylvatica* | 159 | 1022 | 331 | 197 | 1709 |
| *Quercus ilex* | 17 | -- | 1207 | -- | 1224 |
| *Pinus halepensis* | -- | -- | 755 | -- | 755 |
| *Pinus nigra* | 54 | 5 | 461 | 64 | 584 |
| *Pinus pinaster* | 188 | -- | 388 | 24 | 600 |
| *Castanea sativa* | 56 | 198 | 292 | -- | 546 |
| *Picea sitchensis* | 472 | 3 | -- | -- | 475 |
| *Quercus robur* | 347 | 174 | 5 | -- | 526 |
| *Quercus pubescens* | -- | 78 | 436 | 27 | 541 |
| *Quercus petraea* | 8 | 261 | 23 | -- | 292 |

Changes in defoliation and discolouration were examined using the percentages of trees in classes 0 (0-10% def./disc.), 1 (11-25% def./disc.) and 2-4 (>25% def./disc. or dead). The percentages of trees in the different classes were calculated over all individuals included in the subsample.

## 5.2 Presentation of the results

The results are presented by species. For each species, a small table is presented showing the general range in the percentages of healthy and damaged trees -including the observed trends- for all trees over the four years in the entire subsample, as well as by climatic region. The percentages of trees in the different defoliation and discolouration classes for the years 1987, 1988, 1989 and 1990 are presented by means of figures. Numerical information on percentages for defoliation and discolouration is presented in Annex III-1 and Annex III-2 respectively.

## 5.3 Changes by species over 1987-1990

### *5.3.1 Picea abies*

| Defoliation | Common | Healthy trees (def. 0–10%) | | Damaged trees (def. >25%) | |
|---|---|---|---|---|---|
| *Picea abies* | trees | range | trend | range | trend |
| Total sample | 1577 | 60% | sl. decrease | 10-15% | sl. increase |
| - Atlantic | 100 | 35-40% | decrease | 20-30% | fluctuating |
| - Sub–atlantic | 1153 | 55-65% | decrease | 14% | constant |
| - Mountainous | 324 | 65% | sl. decrease | 10% | constant |

*Picea abies* was represented most frequently in the Sub-atlantic zone. Unfortunately a considerable part of data for *Picea abies* has been lost for the assessment over the years, as parts of Germany (e.g. Bavaria) were not surveyed in 1990. Therefore, a comparison with the results as presented in the Forest Health Report 1989 is not possible.
Among the remaining common trees in the Sub-atlantic region, a slight decrease in the total percentages of the healthy trees has occurred, while the percentages of the damaged trees has remained fairly constant in the period 1987-1990 (Figure 8). Compared with the Sub-atlantic region, the range of the total of healthy trees was similar in the Mountainous but lower in the Atlantic region.

| Discolouration | Common | Healthy trees (disc. 0–10%) | | Damaged trees (disc. 11–25%) | |
|---|---|---|---|---|---|
| *Picea abies* | trees | range | trend | range | trend |
| Total sample | 1577 | 90-97% | fluctuating | 2-10% | constant |
| - Atlantic | 100 | 95-99% | fluctuating | 1-5% | constant |
| - Sub–atlantic | 1153 | 90-99% | fluctuating | 1-8% | constant |
| - Mountainous | 324 | 80-90% | sl. increase | 9-18% | constant |

The percentage of not-discoloured trees for the entire subsample has remained fairly constant over the last four years (Figure 9). An increase in the percentage of not-discoloured trees occurred in 1990 only. A similar situation is found in the Sub-atlantic region.
The percentage of not-discoloured trees in the Mountainous region is slightly lower than the other regions and showed a gradual increase over the period 1987-1989. This did not continue into 1990.

The overall vitality of *Picea abies* in the Common Trees 87-90 has not changed significantly over the period 1987-1990, although a slight decrease in vitality appears to be present.

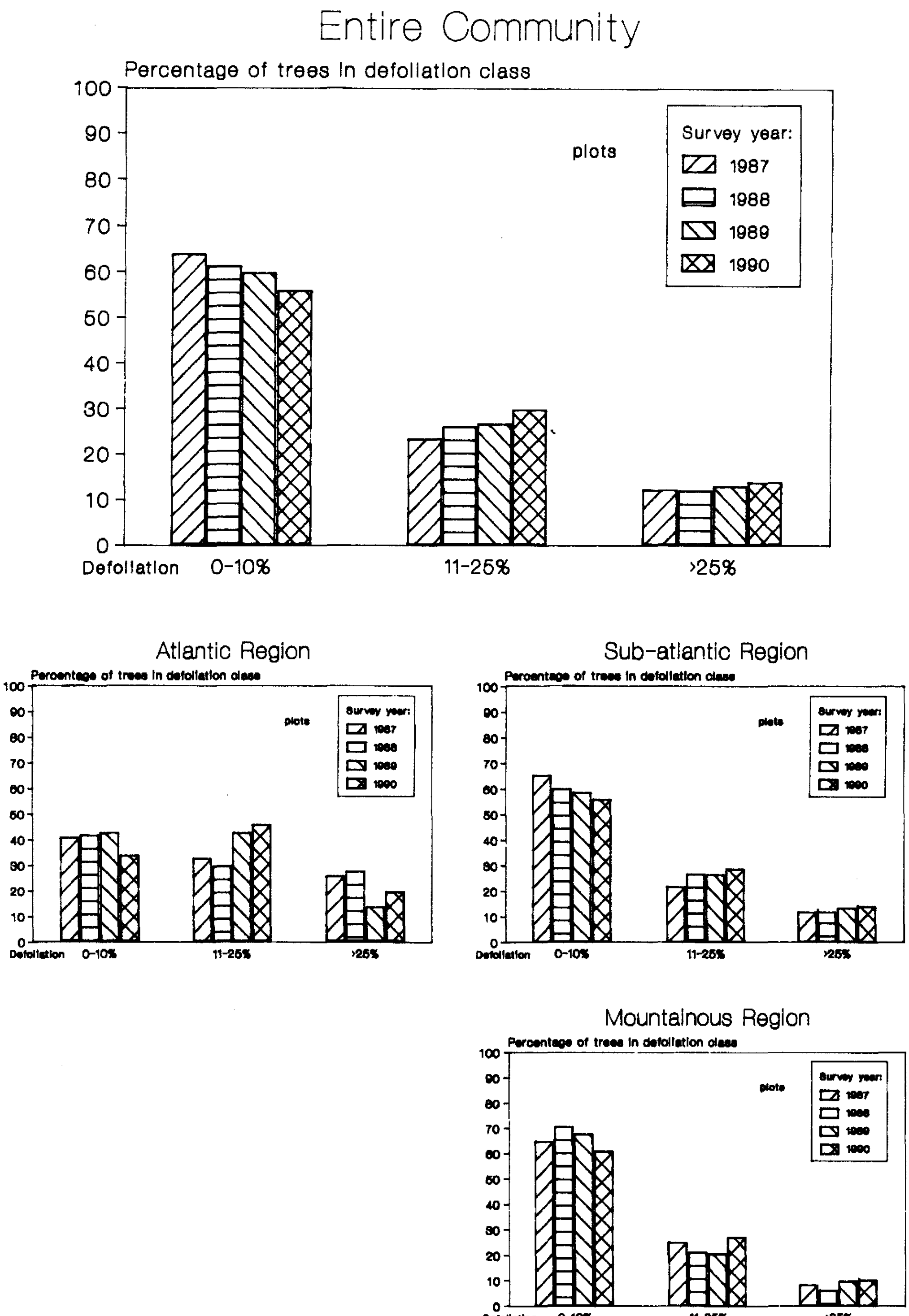



Figure 8 : Changes in defoliation for *Picea abies* in period 1987-1990. Trees common to the 1987, 1988, 1989 and 1990 surveys.

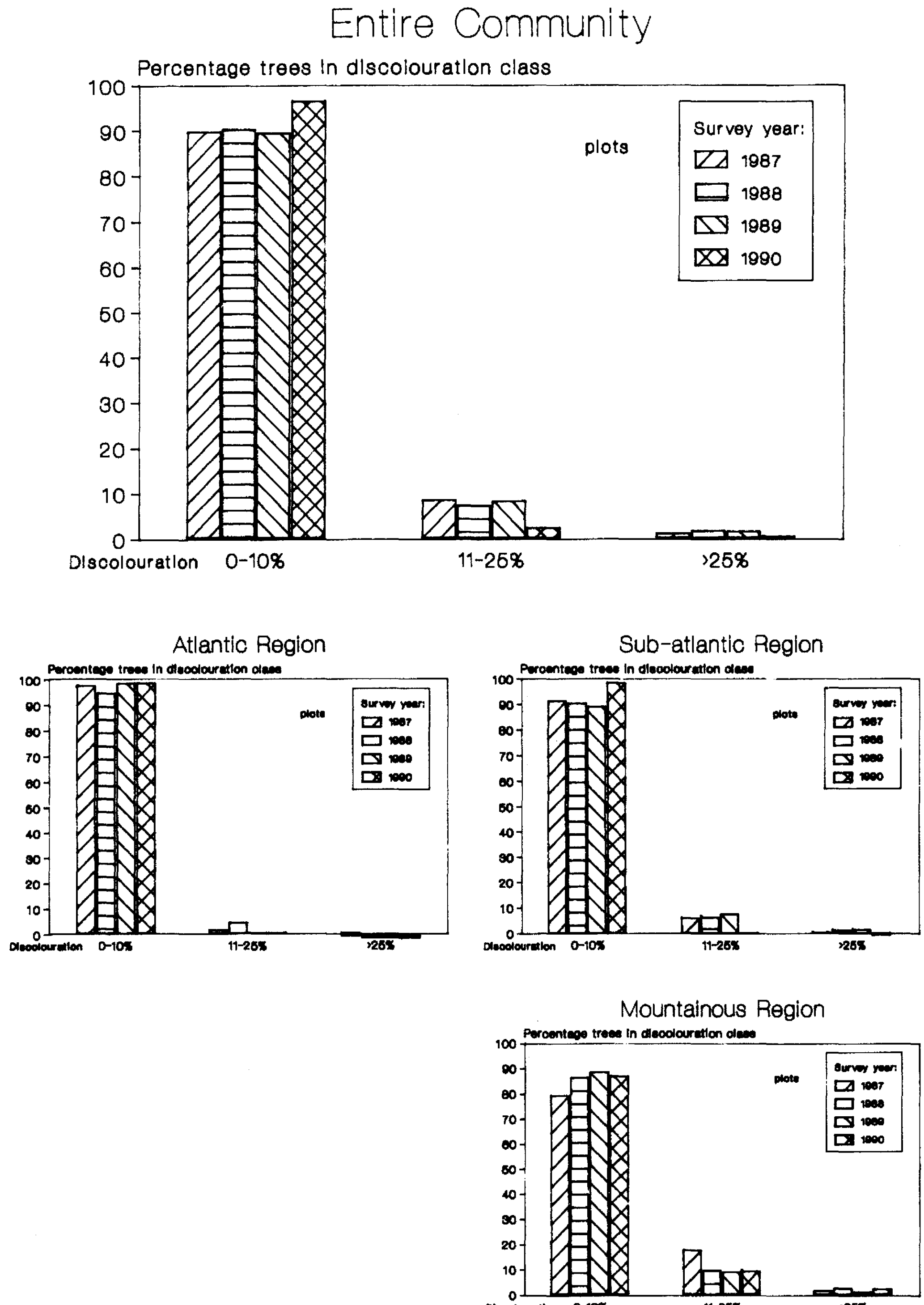



Figure 9 : Changes in discolouration for *Picea abies* in period 1987-1990. Trees common to the 1987, 1988, 1989 and 1990 surveys.

### 5.3.2 *Pinus sylvestris*

| Defoliation<br>*Pinus sylvestris* | Common trees | Healthy trees (def. 0-10%) range | trend | Damaged trees (def. >25%) range | trend |
|---|---|---|---|---|---|
| Total sample | 1756 | 50-70% | decrease | 10% | sl. increase |
| - Atlantic | 903 | 45-70% | decrease | 10% | constant |
| - Sub-atlantic | 405 | 35-50% | decrease | 10-15% | sl. increase |
| - Mediterranean | 289 | 60-85% | fluctuating | 2-8% | fluctuating |

For the entire Community, a slight increase was observed in the total percentages of damaged trees. The percentages of healthy trees decreased (Figure 10).
In all regions a net decrease in the percentage of the healthy trees occurred, while at the same time the percentage of the total damaged trees slightly increased in the Atlantic and Sub-atlantic regions.
In the Mediterranean region the percentages of healthy trees are remarkably high. Within this region *Pinus sylvestris* shows large fluctuations in defoliation. The number of plots is relatively low for this region so the patterns found must be regarded with some restraint.

| Discolouration<br>*Pinus sylvestris* | Common trees | Healthy trees (disc. 0-10%) range | trend | Damaged trees (disc. 11-25%) range | trend |
|---|---|---|---|---|---|
| Total sample | 1756 | 83-90% | fluctuating | 9-15% | sl. increase |
| - Atlantic | 903 | 80-93% | fluctuating | 6-20% | fluctuating |
| - Sub-atlantic | 405 | 93-95% | constant | 5% | constant |
| - Mediterranean | 289 | 76-95% | fluctuating | 2-20% | fluctuating |

For *Pinus sylvestris*, no trends are visible in the percentages of trees in the different discolouration classes (Figure 11). In the Atlantic and Mediterranean regions the percentages of not- and slightly discoloured trees show large fluctuations. In the Sub-atlantic region, overall discolouration has remained unchanged over the period 1987-1990.

Although no significant increase has occurred in the percentage of the damaged trees, the increase of the percentage in the slightly damaged class (warning stage) seems to indicate that the vitality of *Pinus sylvestris* is deteriorating, especially in the Atlantic region.

The similarity of the fluctuations in defoliation and discolouration in the Mediterranean region is remarkable. A sharp decrease in the proportion of healthy trees between 1987 and 1988 has been followed by a steady improvement over the period 1988-1990. The cause of the deterioration between 1987 and 1988 is unknown.

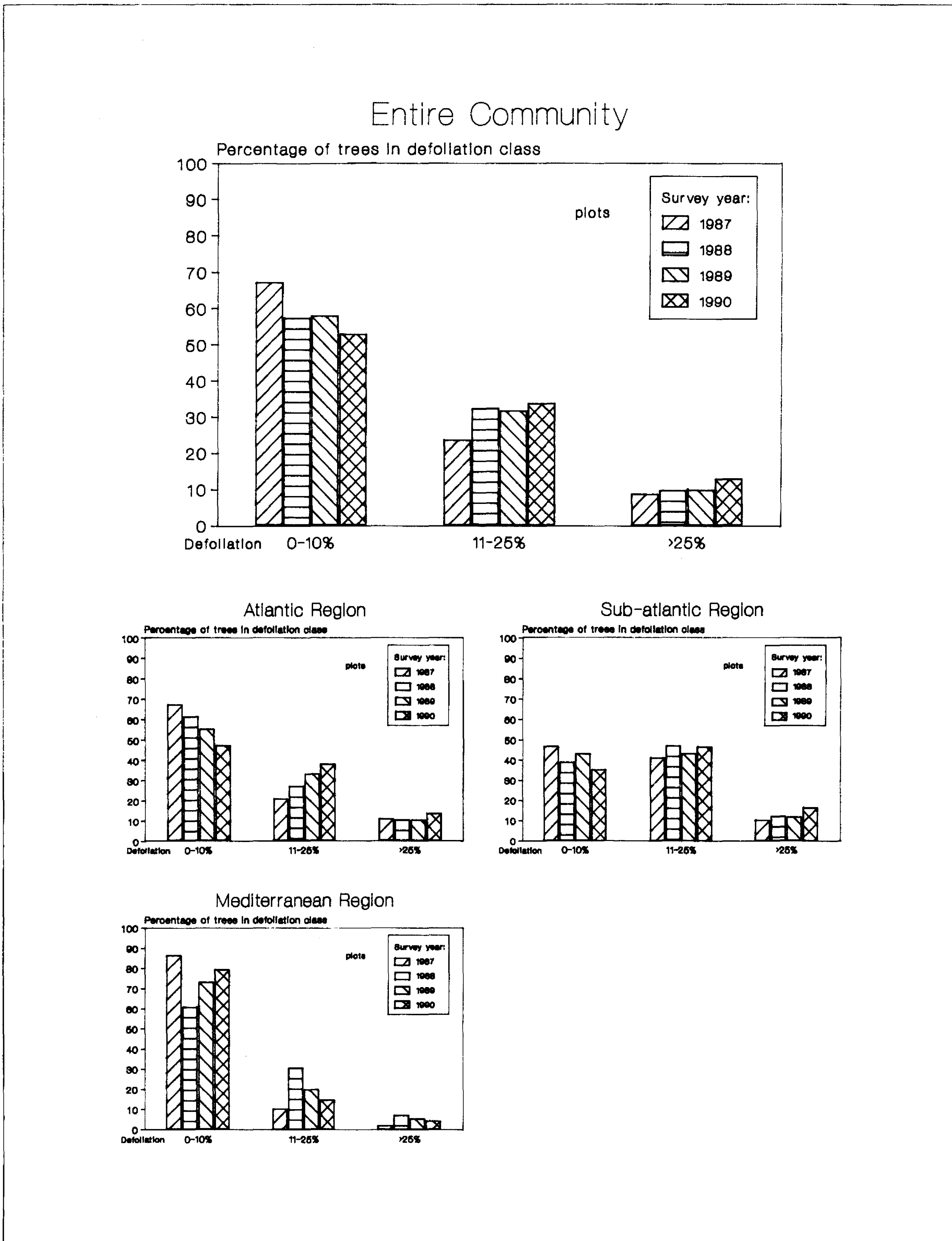



Figure 10 : Changes in defoliation for *Pinus sylvestris* in period 1987-1990. Trees common to the 1987, 1988, 1989 and 1990 surveys.

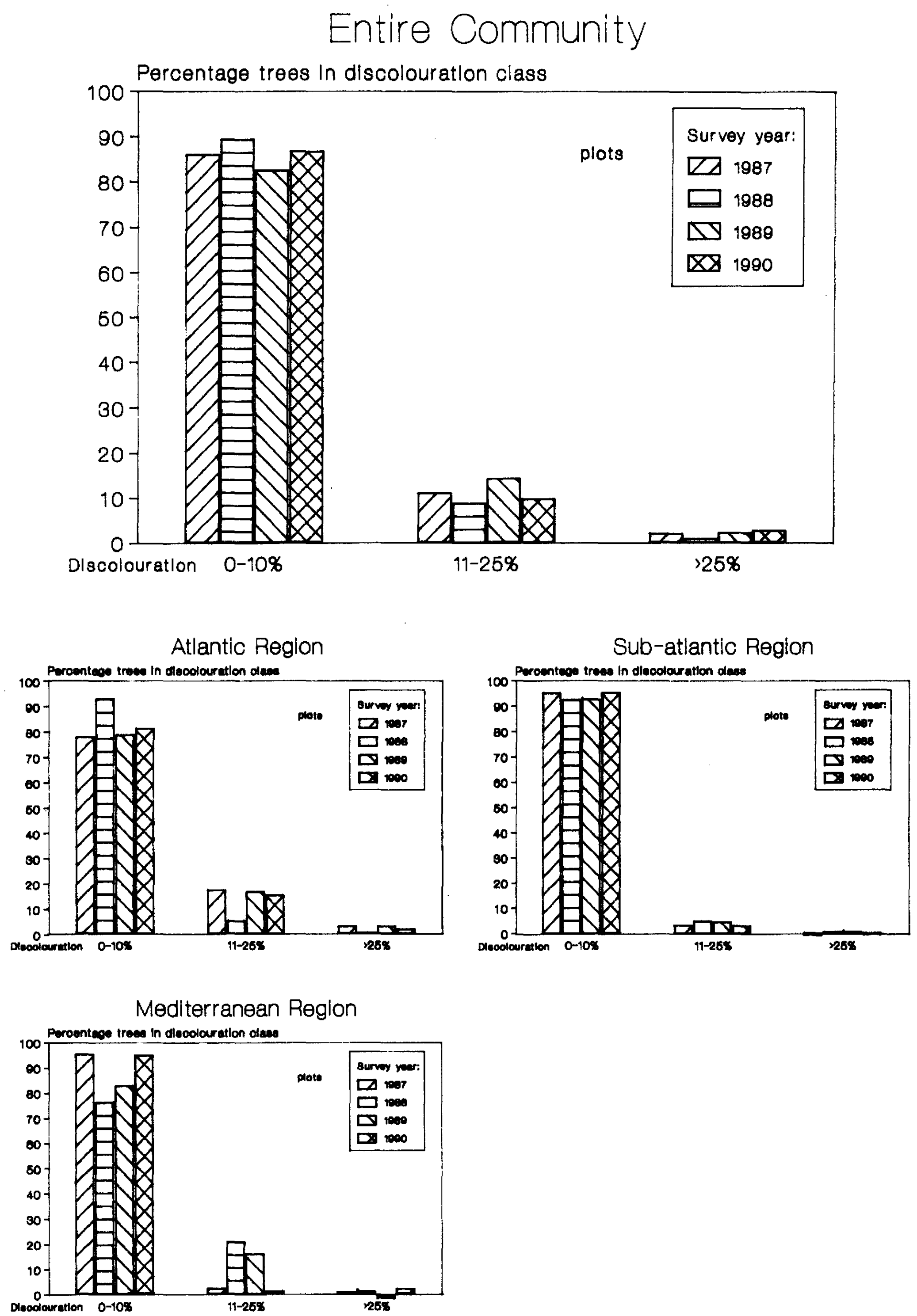



Figure 11 : Changes in discolouration for *Pinus sylvestris* in period 1987-1990. Trees common to the 1987, 1988, 1989 and 1990 surveys.

### 5.3.3 *Fagus sylvatica*

| Defoliation<br>*Fagus sylvatica* | Common trees | Healthy trees (def. 0-10%) range | trend | Damaged trees (def. >25%) range | trend |
|---|---|---|---|---|---|
| Total sample | 1709 | 55-65% | sl. decrease | 10-15% | fluctuating |
| - Atlantic | 159 | 30-55% | decrease | 10-30% | increase |
| - Sub-atlantic | 1022 | 40-50% | fluctuating | 15-20% | sl. decrease |
| - Mediterranean | 331 | 80-95% | fluctuating | 6% | increase |

Over the entire Community, *Fagus sylvatica* has shown a decrease in vitality since 1988 (Figure 12). The percentage of healthy trees decreased with 10% in 1990, while at the same time the percentage of damaged trees increased. Most Common Trees are found in the Sub-atlantic zone. In this region, *Fagus* showed a deterioration in defoliation.
In the Atlantic region *Fagus sylvatica* showed an even stronger deterioration in defoliation (Figure 12). Percentages of healthy trees have decreased considerably since 1988, and the percentages of damaged trees increased over the period 1988-1990.
In the Mediterranean region, the subsample of *Fagus sylvatica* shows remarkably high percentages of not-defoliated trees (Annex III-1, Figure 12). This percentage is fluctuating, but the percentage of damaged trees is slightly increasing in the Mediterranean region, suggesting a slight deterioration.

| Discolouration<br>*Fagus sylvatica* | Common trees | Healthy trees (disc. 0-10%) range | trend | Damaged trees (disc. 11-25%) range | trend |
|---|---|---|---|---|---|
| Total sample | 1709 | 90-92% | constant | 6-7% | constant |
| - Atlantic | 159 | 55-85% | increase | 10-30% | fluctuating |
| - Sub-atlantic | 1022 | 94-97% | constant | 2-5% | constant |
| - Mediterranean | 331 | 87-98% | sl. decrease | 1-10% | constant |

When regarding all Common Trees, no changes in discolouration have occurred for *Fagus sylvatica* (Figure 13). However, differences exist between the different regions.
No change occurred in the discolouration in the Sub-atlantic region. The Atlantic and Mountainous regions however show large fluctuations in discolouration. The percentage of slightly and moderately/severely discoloured trees is remarkably high in the Atlantic region (Figure 13).

Regarding all Common Trees, the overall vitality of *Fagus sylvatica* has not changed. In the Atlantic region, the rapid increase in the percentage of damaged trees in 1988-1990 is accompanied by a decrease in the percentage of trees showing discolouration.

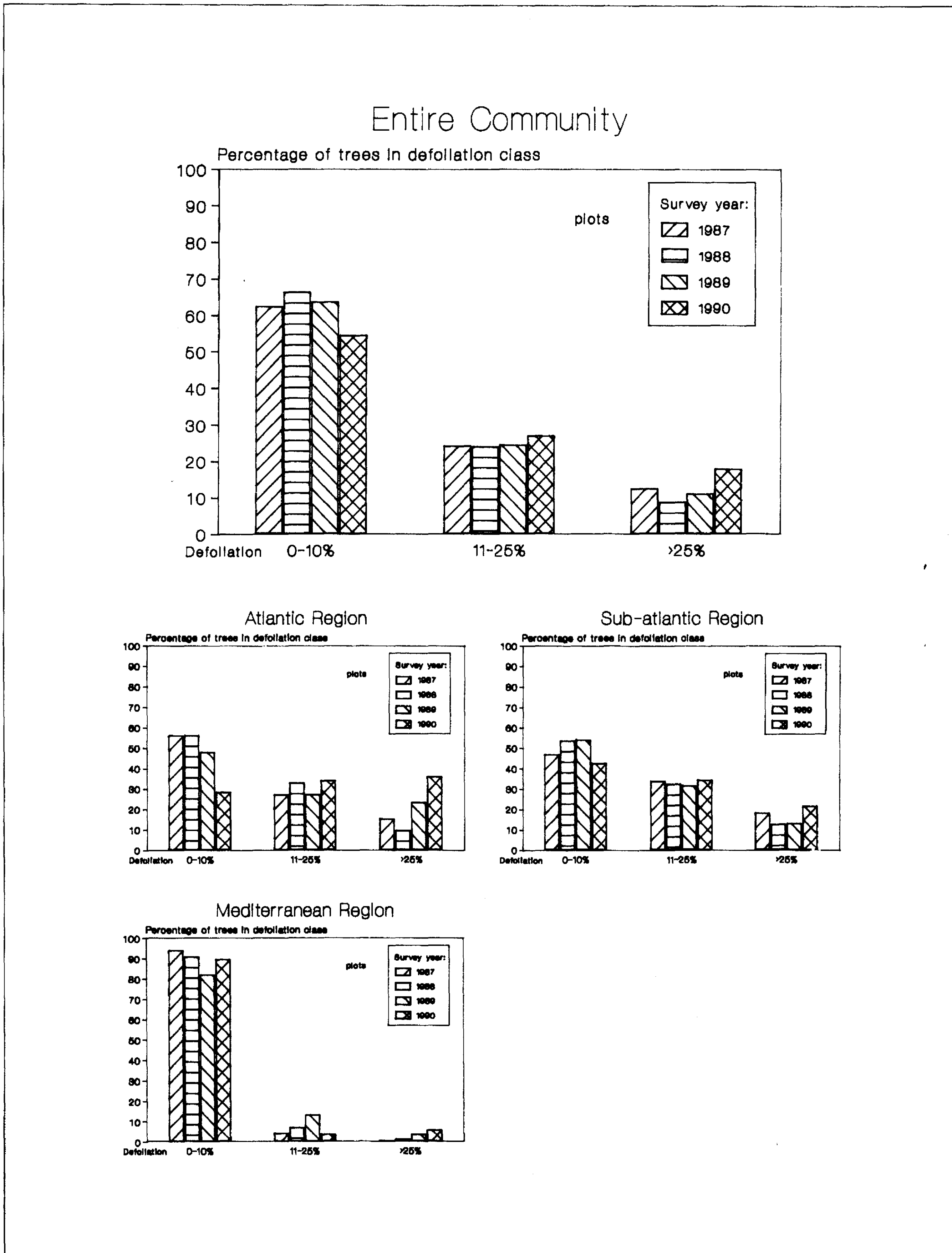



Figure 12 : Changes in defoliation for *Fagus sylvatica* in period 1987-1990. Trees common to the 1987, 1988, 1989 and 1990 surveys.

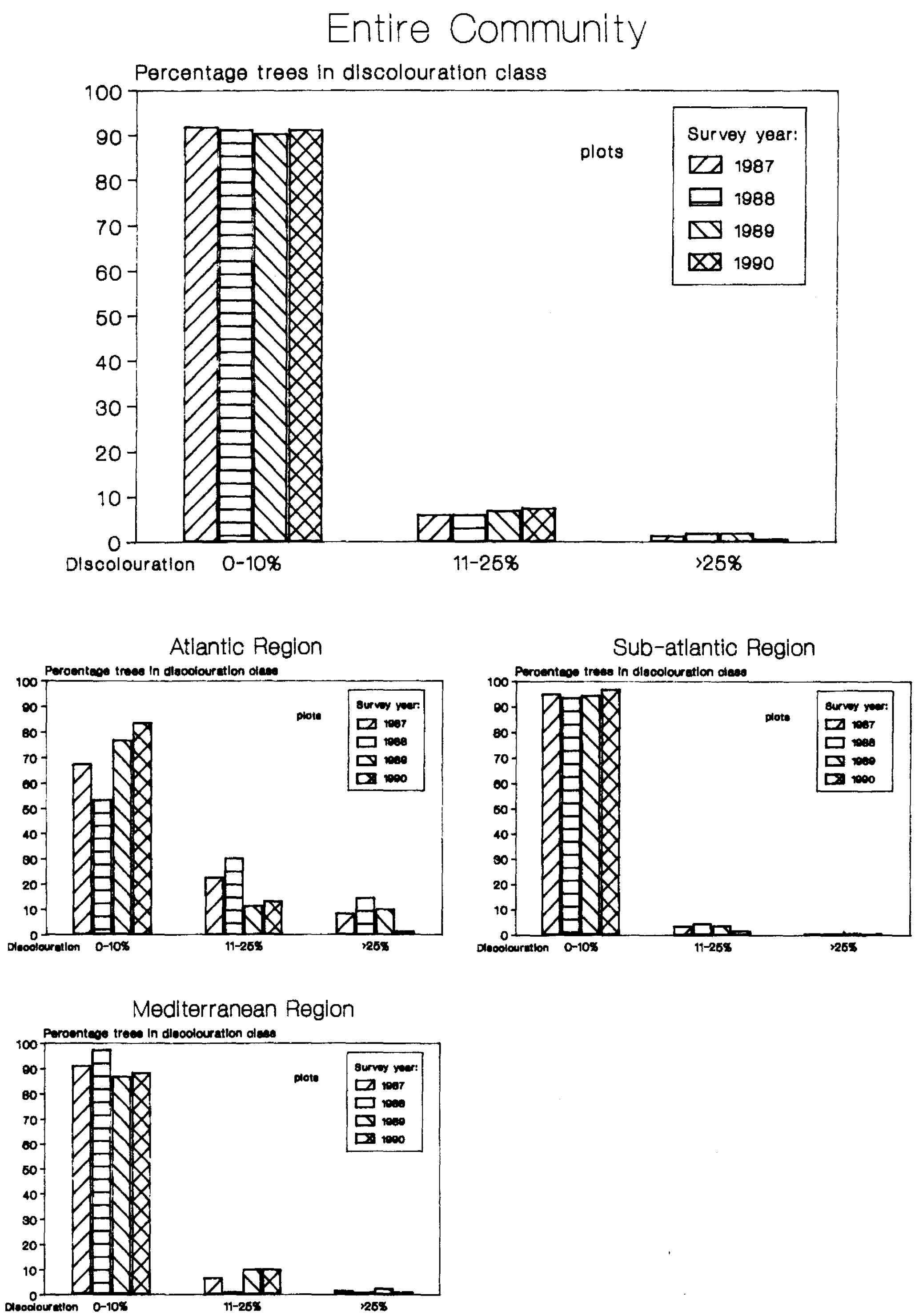



Figure 13 : Changes in discolouration for *Fagus sylvatica* in period 1987-1990. Trees common to the 1987, 1988, 1989 and 1990 surveys.

### 5.3.4 *Quercus ilex*

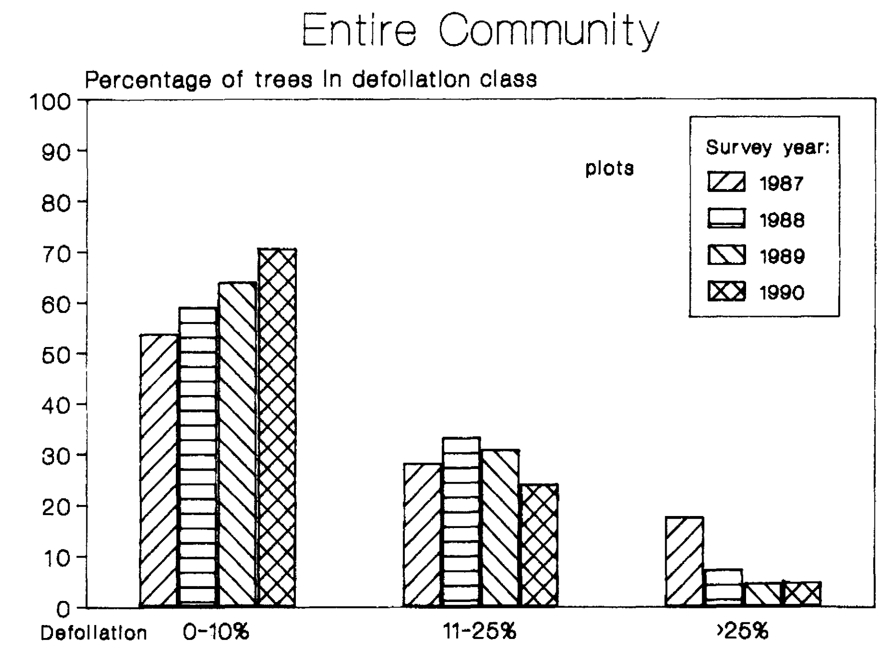
| Defoliation | Common | Healthy trees (def. 0-10%) | | Damaged trees (def. >25%) | |
|---|---|---|---|---|---|
| *Quercus ilex* | trees | range | trend | range | trend |
| Total sample | 1224 | 50-70% | increase | 5-18% | decrease |
| - Mediterranean | 1207 | 50-70% | increase | 5-18% | decrease |

With one exception, all Common Plots containing *Quercus ilex* were found in the Mediterranean region. Within the four year period, *Quercus ilex* has gradually improved in foliation (Figure 14). The percentage of not-defoliated trees increased, while the percentage of damaged trees decreased.

| Discolouration | Common | Healthy trees (disc. 0-10%) | | Damaged trees (disc. 11-25%) | |
|---|---|---|---|---|---|
| *Quercus ilex* | trees | range | trend | range | trend |
| Total sample | 1224 | 64-98% | increase | 1-25% | sl. decrease |
| - Mediterranean | 1207 | 64-98% | increase | 1-25% | sl. decrease |

As to discolouration, *Quercus ilex* has clearly improved over the last four years (Figure 14). Most improvement occurred in the period 1987-1988, and continued in 1989 and 1990.

Overall, the increase in percentages of not-defoliated and not-discoloured trees suggests an improvement in vitality of *Quercus ilex*.



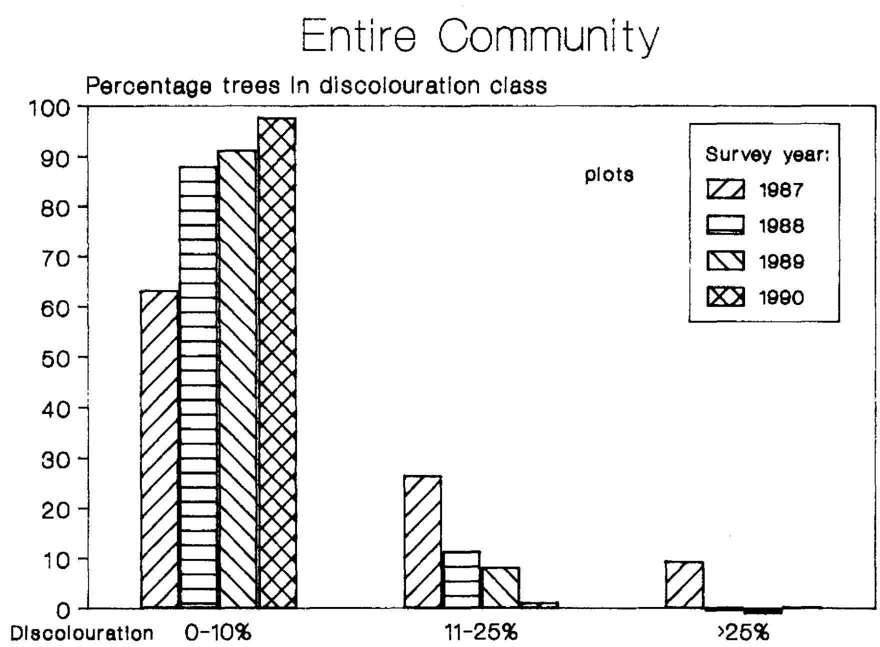




Figure 14 : Changes in defoliation and discolouration for *Quercus ilex* in period 1987-1990. Trees common to the 1987, 1988, 1989 and 1990 surveys.

### 5.3.5 *Pinus halepensis*

| Defoliation *Pinus halepensis* | Common trees | Healthy trees (def. 0-10%) range | trend | Damaged trees (def. >25%) range | trend |
|---|---|---|---|---|---|
| Total sample | 755 | 55% | fluctuating | 5-10% | decrease |
| - Mediterranean | 755 | 55% | fluctuating | 5-10% | decrease |

All Common Trees with *Pinus halepensis* were located in the Mediterranean region. The percentage of damaged trees gradually decreased in the period 1987-1990 (Figure 15). The fraction of healthy trees fluctuates, but seems to stabilize.

| Discolouration *Pinus halepensis* | Common trees | Healthy trees (disc. 0-10%) range | trend | Damaged trees (disc. 11-25%) range | trend |
|---|---|---|---|---|---|
| Total sample | 755 | 74-80% | sl. increase | 20% | constant |
| - Mediterranean | 755 | 74-80% | sl. increase | 20% | constant |

No large changes have occurred with respect to discolouration of *Pinus halepensis*. The percentages of not-discoloured trees show a slight increase. The percentage of slightly discoloured trees fluctuates (Figure 15).

The slight improvements regarding defoliation and discolouration suggest that the overall vitality of *Pinus halepensis*, based on the Common Trees, has slightly improved in the period 1987-1990.

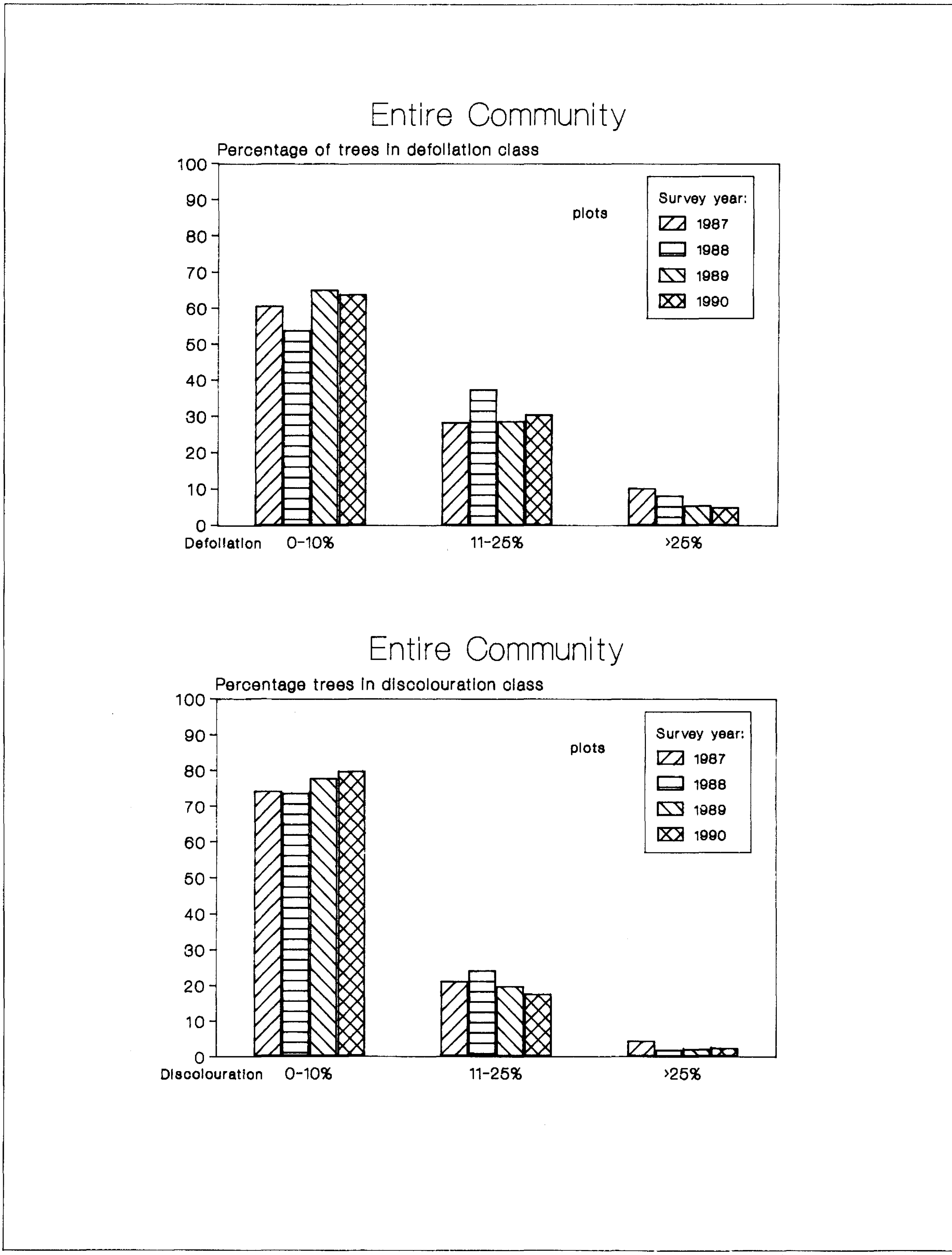



Figure 15 : Changes in defoliation and discolouration for *Pinus halepensis* in period 1987-1990. Trees common to the 1987, 1988, 1989 and 1990 surveys.

### 5.3.6 *Pinus nigra*

| Defoliation<br>*Pinus nigra* | Common trees | Healthy trees (def. 0-10%) range | trend | Damaged trees (def. >25%) range | trend |
|---|---|---|---|---|---|
| Total sample | 584 | 60-80% | fluctuating | 6-10% | fluctuating |
| - Mediterranean | 461 | 60-80% | fluctuating | 6-10% | fluctuating |

Regarding the entire subsample, a sharp decrease has occurred in the last year in the percentages of healthy trees. At the same time the fraction of damaged trees has increased (Figure 16, Annex III-1).
Most Common Trees with *Pinus nigra* are located in the Mediterranean region. Within this region, the percentage of healthy and slightly defoliated trees shows large fluctuations, but the sharp change in defoliation of last year is clearly visible (Figure 16).

| Discolouration<br>*Pinus nigra* | Common trees | Healthy trees (disc. 0-10%) range | trend | Damaged trees (disc. 11-25%) range | trend |
|---|---|---|---|---|---|
| Total sample | 584 | 81-83% | sl. increase | 15% | fluctuating |
| - Mediterranean | 461 | 83-90% | fluctuating | 15% | sl. increase |

The total sample of *Pinus nigra* shows no changes in discolouration (Figure 17). In the Mediterranean region, slight fluctuations have occurred in the percentages of trees in the different disclouration classes.

Overall, no clear trends in vitality can be observed for *Pinus nigra* in the Common Trees.

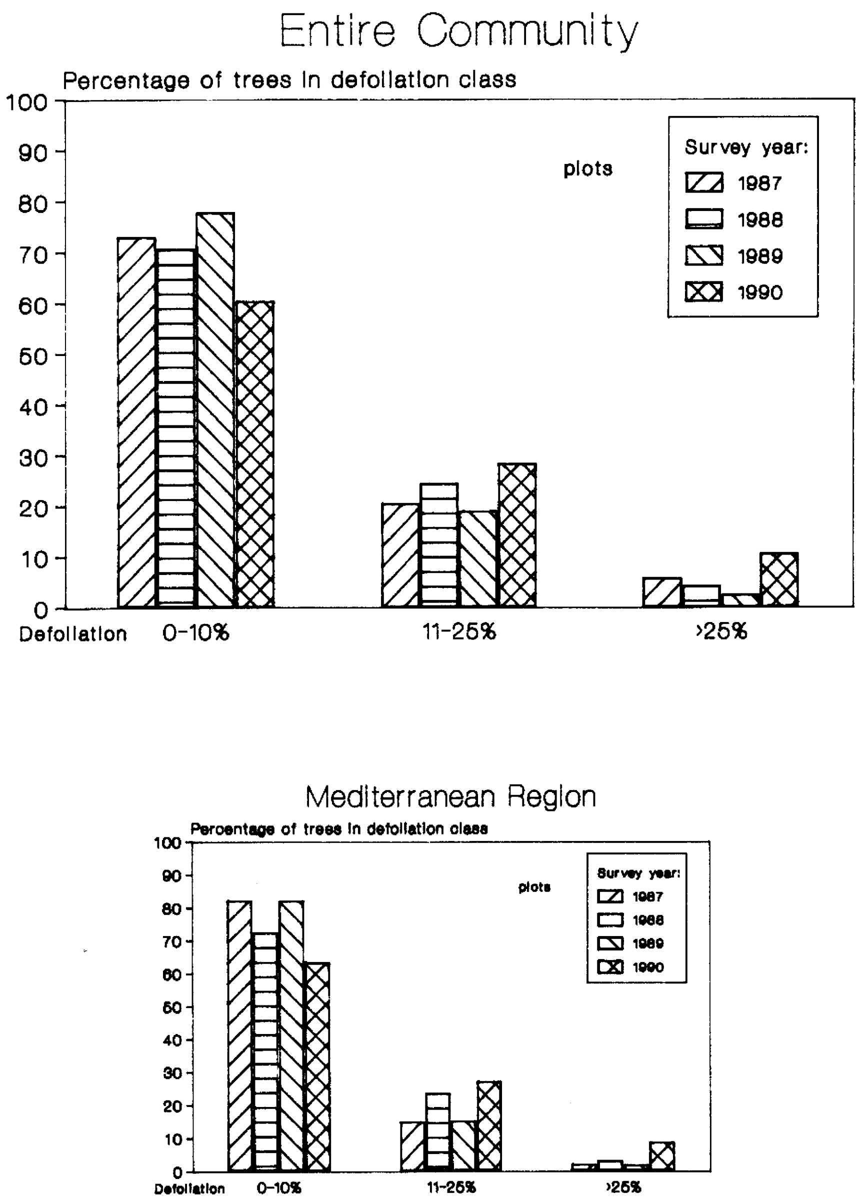



Figure 16: Changes in defoliation for *Pinus nigra* in period 1987-1990. Trees common to the 1987, 1988, 1989 and 1990 surveys.

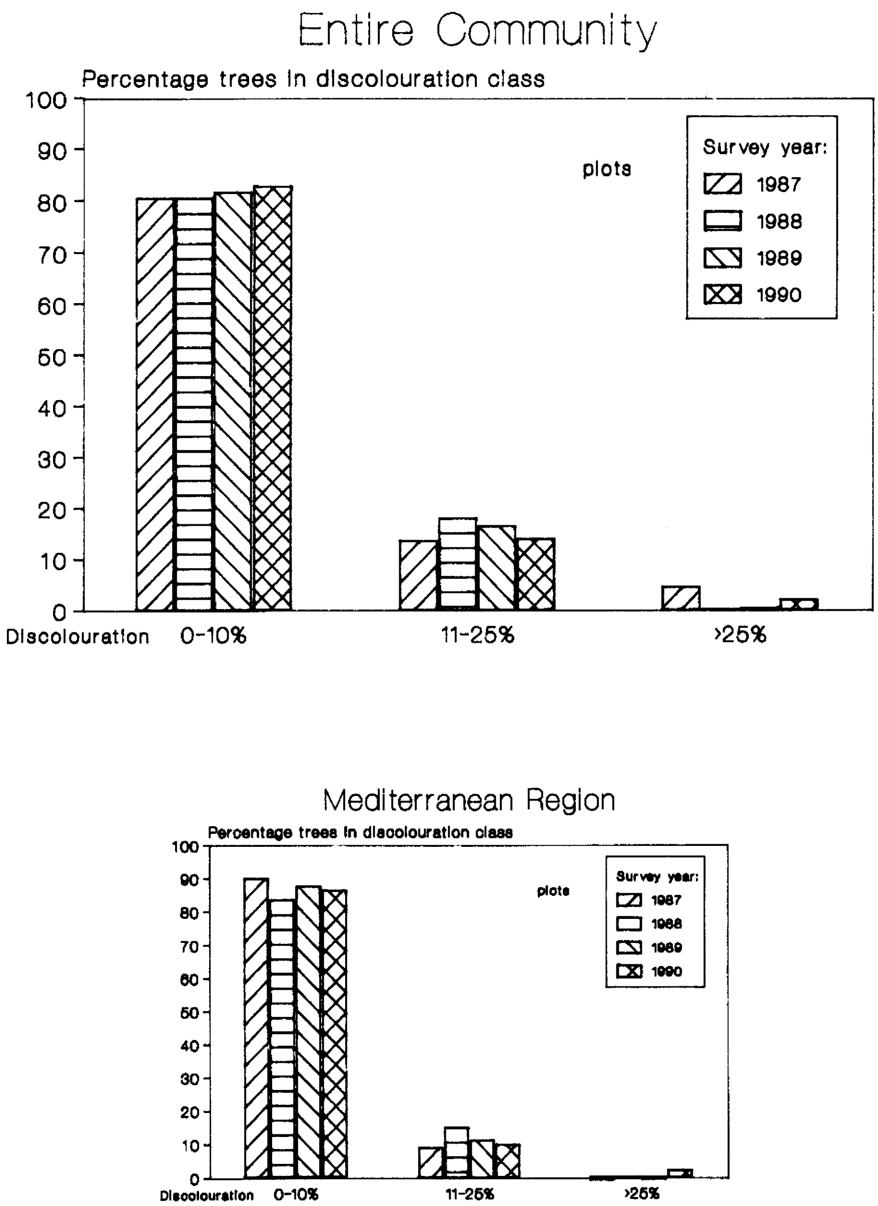



Figure 17: Changes in discolouration for *Pinus nigra* in period 1987-1990. Trees common to the 1987, 1988, 1989 and 1990 surveys.

## 5.3.7 *Pinus pinaster*

| Defoliation | Common | Healthy trees (def. 0-10%) | | Damaged trees (def. >25%) | |
|---|---|---|---|---|---|
| *Pinus pinaster* | trees | range | trend | range | trend |
| Total sample | 600 | 60-70% | constant | 10-15% | decrease |
| - Atlantic | 188 | 60-70% | fluctuating | 1-8% | increase |
| - Mediterranean | 388 | 70% | constant | 10-15% | decrease |

When considering the entire subsample, the percentage of the healthy trees of *Pinus pinaster* shows a slight gradual increase (Figure 18). The two regions in which *Pinus pinaster* is represented show opposite trends.
In the Atlantic region, the proportion of healthy trees decreases, while in the Mediterranean region the percentage of healthy trees increases (Annex III-1, Figure 18).

| Discolouration | Common | Healthy trees (disc. 0-10%) | | Damaged trees (disc. 11-25%) | |
|---|---|---|---|---|---|
| *Pinus pinaster* | trees | range | trend | range | trend |
| Total sample | 600 | 76-83% | sl. increase | 10-20% | fluctuating |
| - Atlantic | 188 | 90-100% | sl. decrease | 0-10% | sl. increase |
| - Mediterranean | 388 | 70-84% | sl. increase | 15-20% | decrease |

Regarding the total subsample of Common Trees, *Pinus pinaster* shows a slight improvement with respect to discolouration. The percentage of not-discoloured trees slightly increased, while the percentage of severely discoloured trees decreased in the period 1987-1990 (Figure 19).
Most improvement occurred in the Mediterranean region.

The slight increase in percentages of not-defoliated and not-discolourated trees in the Common Trees suggest a slight improvement of the vitality of *Pinus pinaster*.

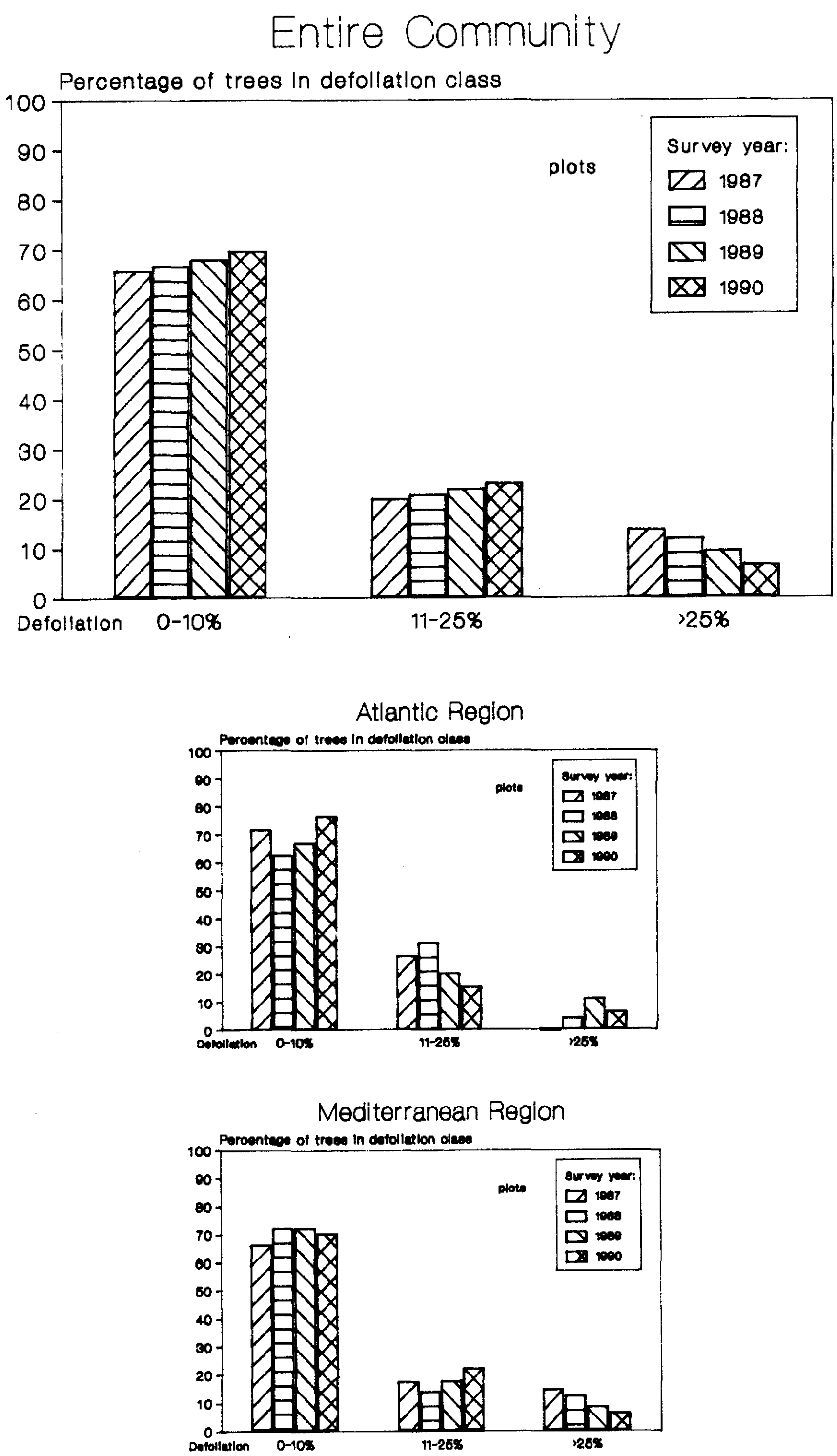



Figure 18: Changes in defoliation for *Pinus pinaster* in period 1987-1990. Trees common to the 1987, 1988, 1989 and 1990 surveys.

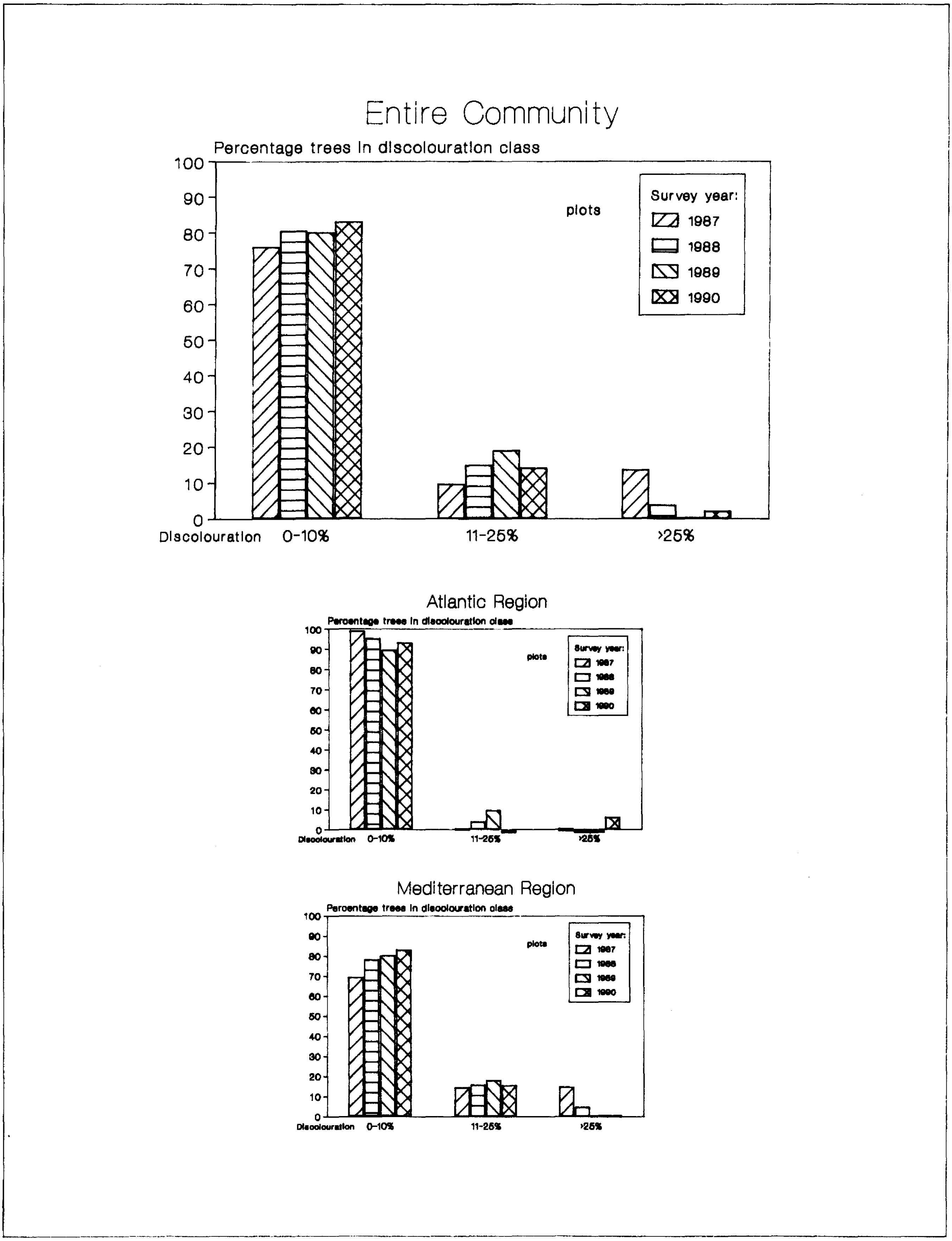



Figure 19: Changes in discolouration for *Pinus pinaster* in period 1987-1990. Trees common to the 1987, 1988, 1989 and 1990 surveys.

### 5.3.8 *Castanea sativa*

| Defoliation | Common | Healthy trees (def. 0-10%) | | Damaged trees (def. >25%) | |
|---|---|---|---|---|---|
| *Castanea sativa* | trees | range | trend | range | trend |
| Total sample | 546 | 65-80% | decrease | 6-20% | increase |
| - Sub-atlantic | 198 | 50-90% | decrease | 5-25% | increase |
| - Mediterranean | 292 | 50-70% | fluctuating | 10-20% | increase |

The percentage of healthy trees of *Castanea* shows large fluctuations in the period 1987-1990, but since 1988 a decrease in the percentage of healthy trees has been observed. At the same time the percentage of damaged trees increased over the years. The total percentages of healthy trees are highest in the Sub-atlantic region (Figure 20). In the Mediterranean region the percentage of damaged trees slightly increased, while in the Sub-atlantic region a sharp increase of the damaged trees was observed in 1990.

| Discolouration | Common | Healthy trees (disc. 0-10%) | | Damaged trees (disc. 11-25%) | |
|---|---|---|---|---|---|
| *Castanea sativa* | trees | range | trend | range | trend |
| Total sample | 546 | 70-80% | fluctuating | 10-20% | constant |
| - Sub-atlantic | 198 | 75-95% | fluctuating | 5-20% | sl. increase |
| - Mediterranean | 292 | 55-80% | fluctuating | 10-35% | fluctuating |

The total sample of Common Plots with *Castanea sativa* shows fluctuating percentages of discolouration (Figure 21). The percentage of not-discoloured trees is remarkably low in the Mediterranean region as compared to the Sub-atlantic region.

The decrease in the percentages of defoliation and discolouration of the healthy trees (especially in the Sub-atlantic region) suggest a deterioration of the *Castanea sativa* in the period 1988-1990.

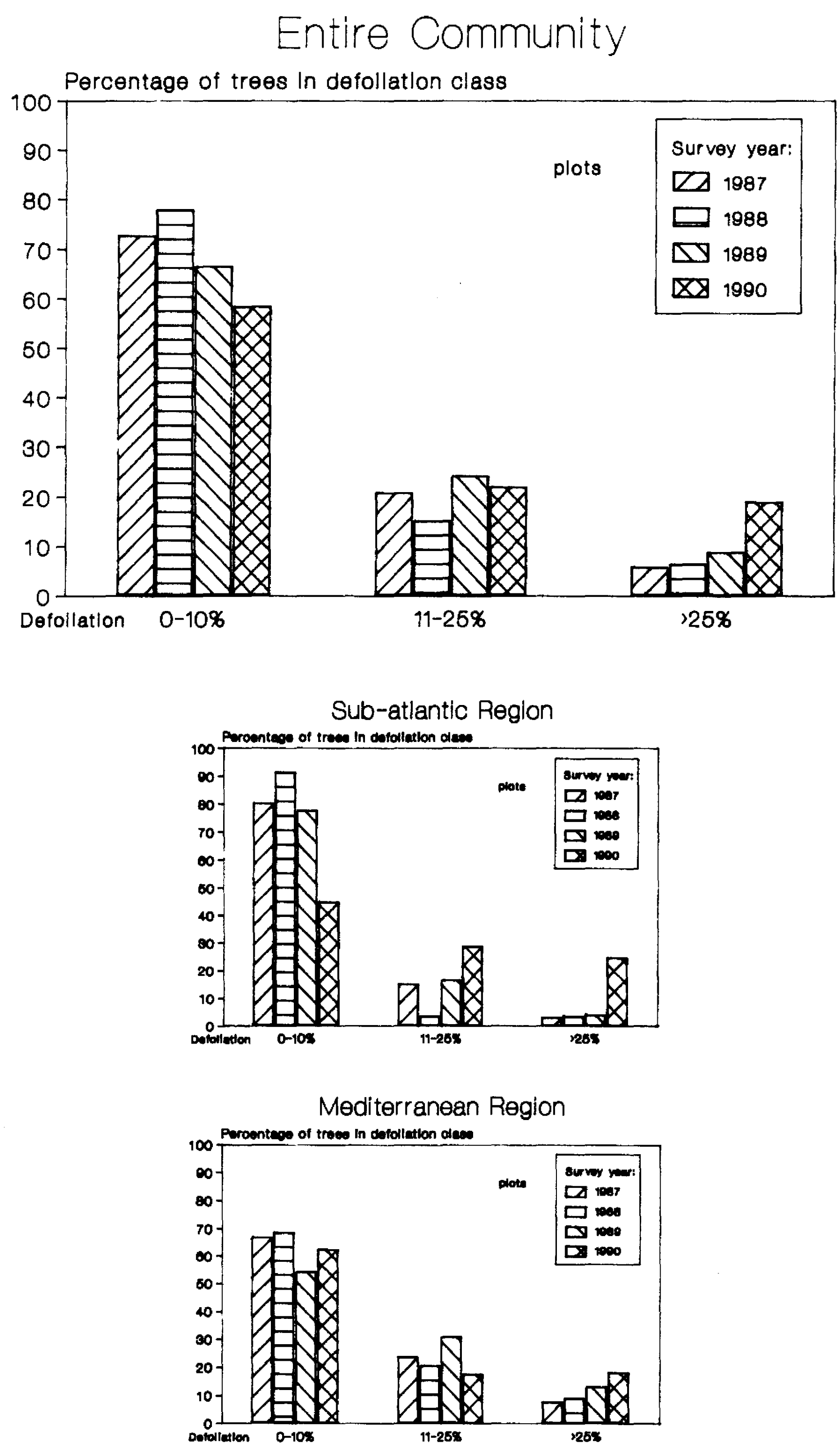



Figure 20: Changes in defoliation for *Castanea sativa* in period 1987-1990. Trees common to the 1987, 1988, 1989 and 1990 surveys.

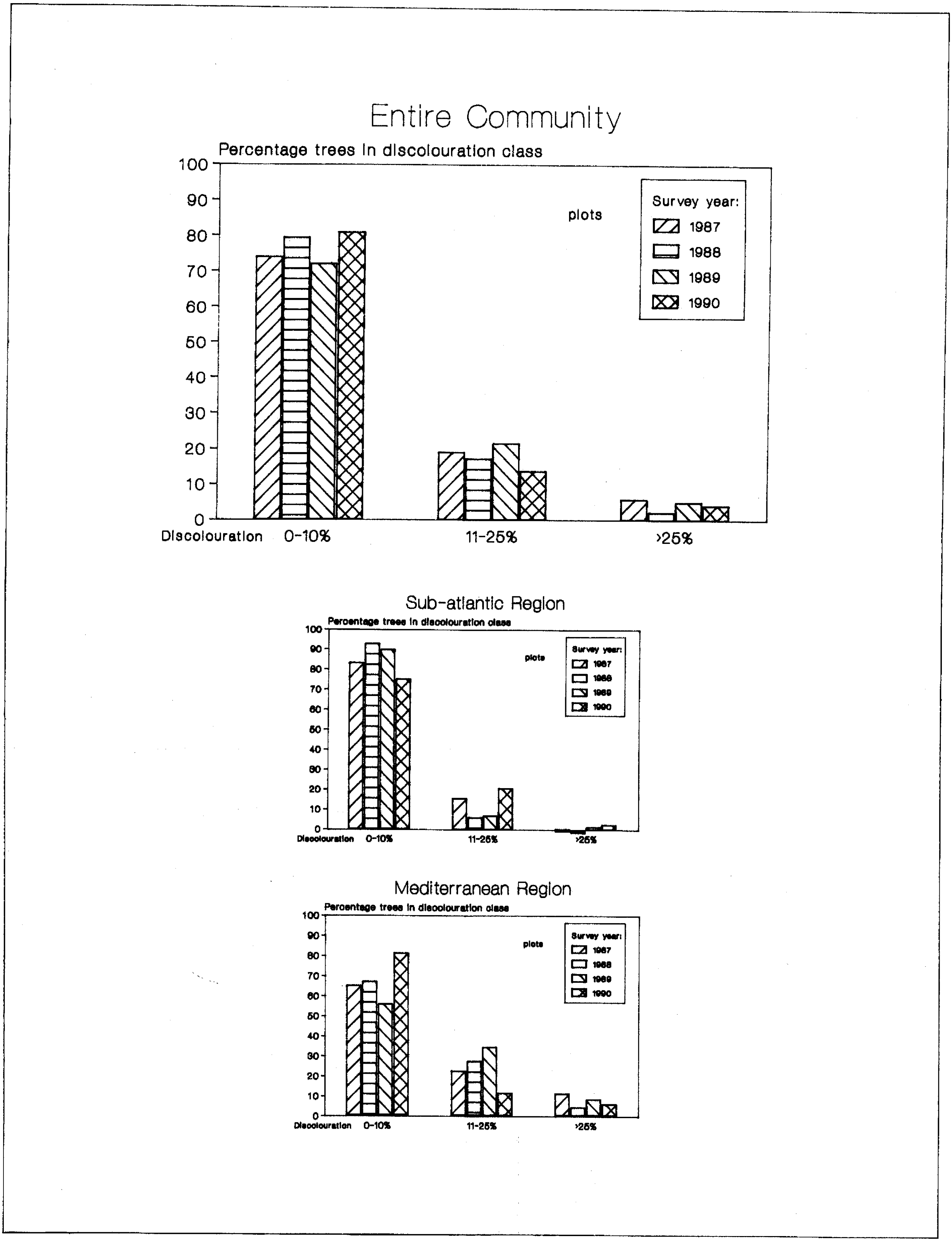



Figure 21: Changes in discolouration for *Castanea sativa* in period 1987-1990. Trees common to the 1987, 1988, 1989 and 1990 surveys.

### 5.3.9 *Picea sitchensis*

| Defoliation<br>*Picea sitchensis* | Common trees | Healthy trees (def. 0-10%) range | trend | Damaged trees (def. >25%) range | trend |
|---|---|---|---|---|---|
| Total sample | 475 | 18-50% | decrease | 20-55% | increase |
| - Atlantic | 472 | 18-50% | decrease | 20-55% | increase |

All Common Plots containing *Picea sitchensis* are located in the Atlantic region. *Picea sitchensis* showed a pronounced deterioration with regard to foliation in the period 1987-1990 (Figure 22). The percentage of healthy trees drops rapidly in this period, while at the same time the percentages of damaged trees increase considerably.
Special attention should be given to *Picea sitchensis* in the future to determine whether this trend will abide.

| Discolouration<br>*Picea sitchensis* | Common trees | Healthy trees (disc. 0-10%) range | trend | Damaged trees (disc. 11-25%) range | trend |
|---|---|---|---|---|---|
| Total sample | 475 | 80-90% | sl. increase | 7-15% | sl. decrease |
| - Atlantic | 472 | 80-90% | sl. increase | 7-15% | sl. decrease |

The trees in the Common Plots for *Picea sitchensis* show an overall decrease in the percentage of severely discoloured trees over the period 1987-1990 (Figure 22). The percentage of not-discoloured trees show a net increase.

Based on the percentages of defoliation, the vitality of *Picea sitchensis* has deteriorated dramatically over the last four years. However, this deterioration is not apparent in the changes regarding discolouration. According to the National Report on forest health of the United Kingdom, this increase in defoliation was primarily due to attacks of the Green spruce aphid (*Elatobium abietinum*).

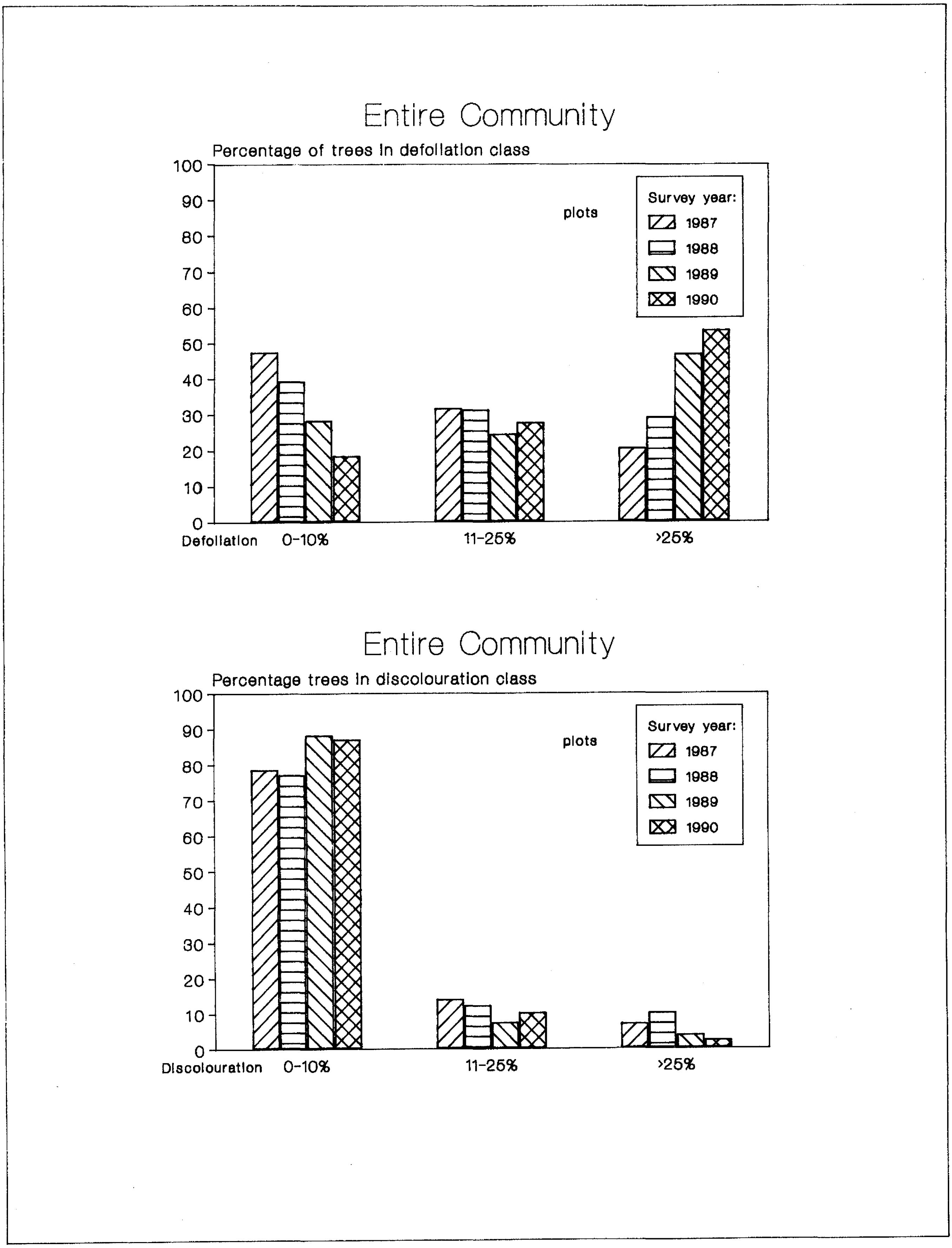



Figure 22: Changes in defoliation and discolouration for *Picea sitchensis* in period 1987-1990. Plots common to the 1987, 1988, 1989 and 1990 surveys.

### 5.3.10 *Quercus robur*

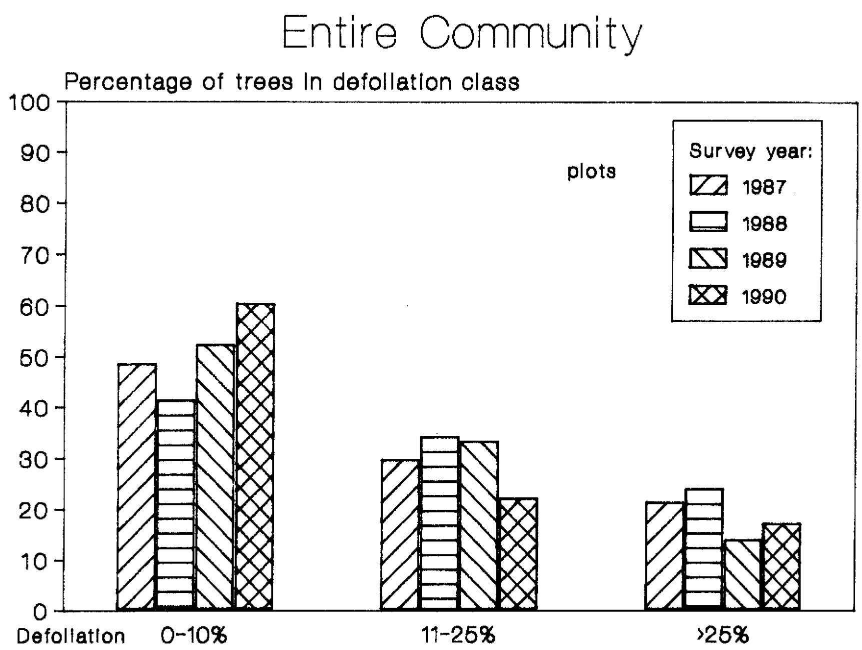
| Defoliation | Common | Healthy trees (def. 0–10%) | | Damaged trees (def. >25%) | |
|---|---|---|---|---|---|
| *Quercus robur* | trees | range | trend | range | trend |
| Total sample | 526 | 40-60% | increase | 15-25% | fluctuating |
| - Atlantic | 347 | 30-55% | increase | 15-35% | fluctuating |

The percentages of trees in the different defoliation classes have fluctuated greatly over the period 1987-1990. However, since 1988, there has been an increase in the percentage of healthy trees (Figure 23).

| Discolouration | Common | Healthy trees (disc. 0–10%) | | Damaged trees (disc. 11–25%) | |
|---|---|---|---|---|---|
| *Quercus robur* | trees | range | trend | range | trend |
| Total sample | 526 | 88-90% | constant | 8% | constant |
| - Atlantic | 347 | 85-90% | constant | 8-11% | constant |

No changes in discolouration occurred in the Common Plots of *Quercus robur* in the period 1987-1990 (Figure 24).

The overall vitality of *Quercus robur* in the Common Plots, based on changes in defoliation, has improved in the period 1988-1990. This improvement was not expressed by changes in discolouration.



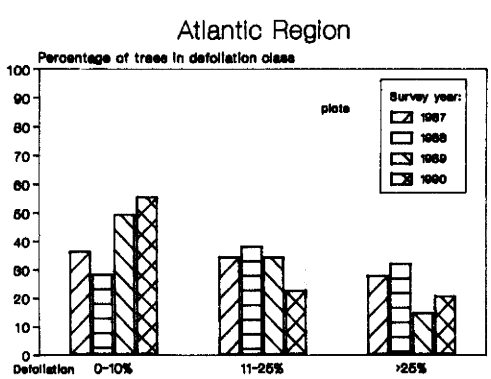
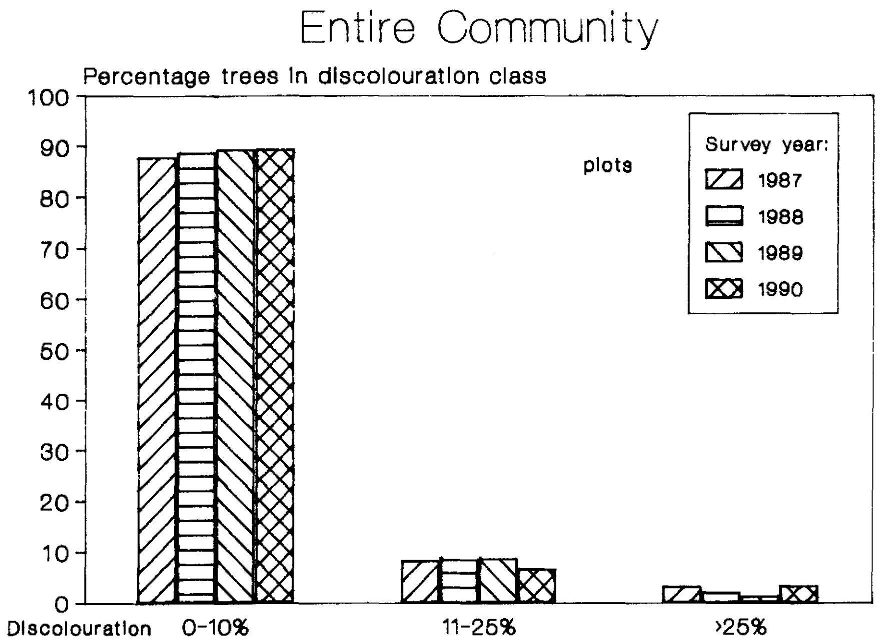




Figure 23: Changes in defoliation for *Quercus robur* in period 1987-1990. Trees common to the 1987, 1988, 1989 and 1990 surveys.



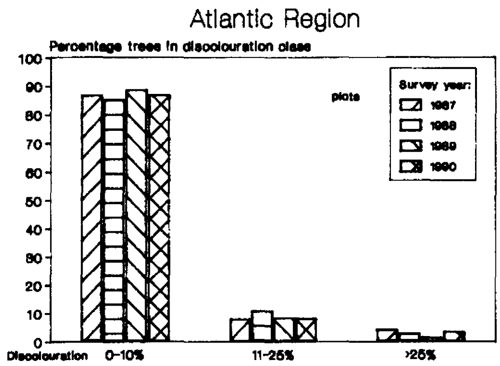




Figure 24: Changes in discolouration for *Quercus robur* in period 1987-1990. Trees common to the 1987, 1988, 1989 and 1990 surveys.

### 5.3.11 *Quercus pubescens*

| Defoliation | Common | Healthy trees (def. 0-10%) | | Damaged trees (def. >25%) | |
|---|---|---|---|---|---|
| *Quercus pubescens* | trees | range | trend | range | trend |
| Total sample | 541 | 60-88% | decrease | 7-15% | constant |
| - Mediterranean | 436 | 60-80% | decrease | 9-15% | fluctuating |

When regarding the entire subsample, the percentage of not-defoliated trees of *Quercus pubescens* decreased, while the percentage of slightly defoliated trees increased. In the last year a sharp increase in damaged trees occurred (Figure 25).

| Discolouration | Common | Healthy trees (disc. 0-10%) | | Damaged trees (disc. 11-25%) | |
|---|---|---|---|---|---|
| *Quercus pubescens* | trees | range | trend | range | trend |
| Total sample | 541 | 77-90% | fluctuating | 2-20% | decrease |
| - Mediterranean | 436 | 77-90% | fluctuating | 2-20% | decrease |

*Quercus pubescens* shows a clear increase in the percentage of slightly discoloured trees. The percentage of not-discoloured trees fluctuates, but seemed to decrease in the period 1987-1990 (Figure 26).

The overall decrease of the defoliation and discolouration suggests a decrease in vitality for *Quercus pubescens* in the period 1987-1990.

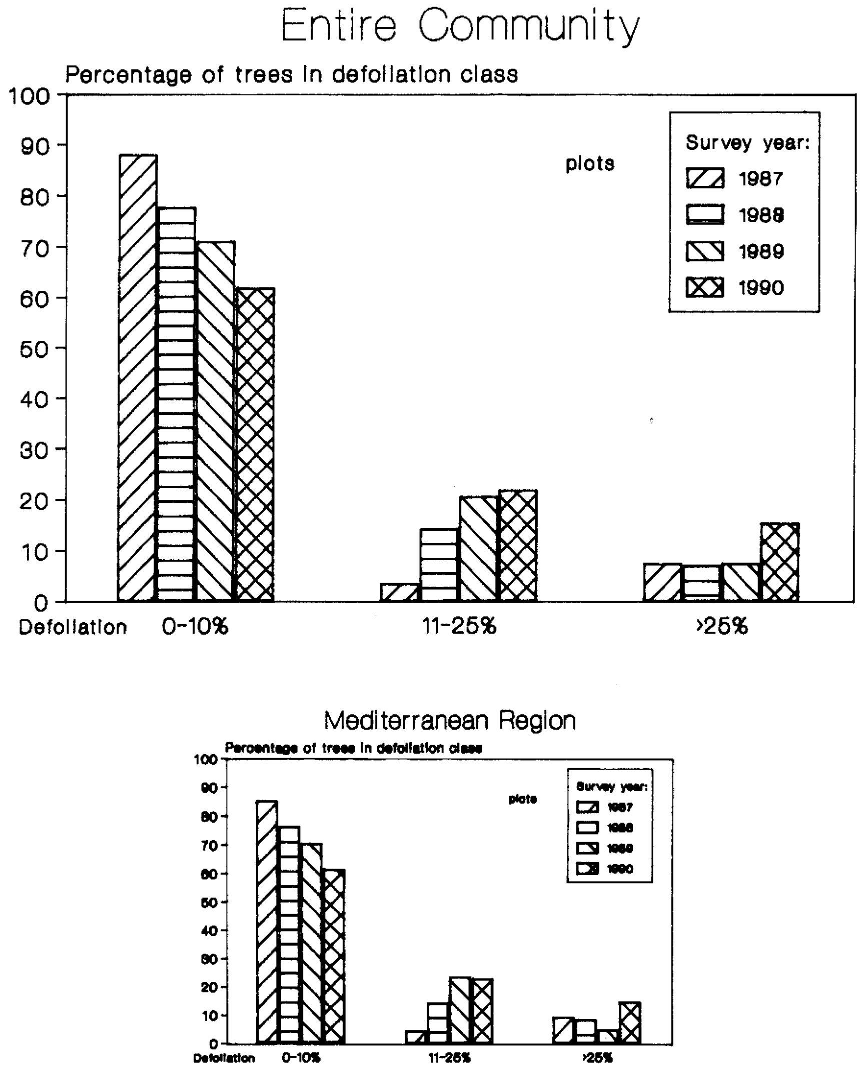
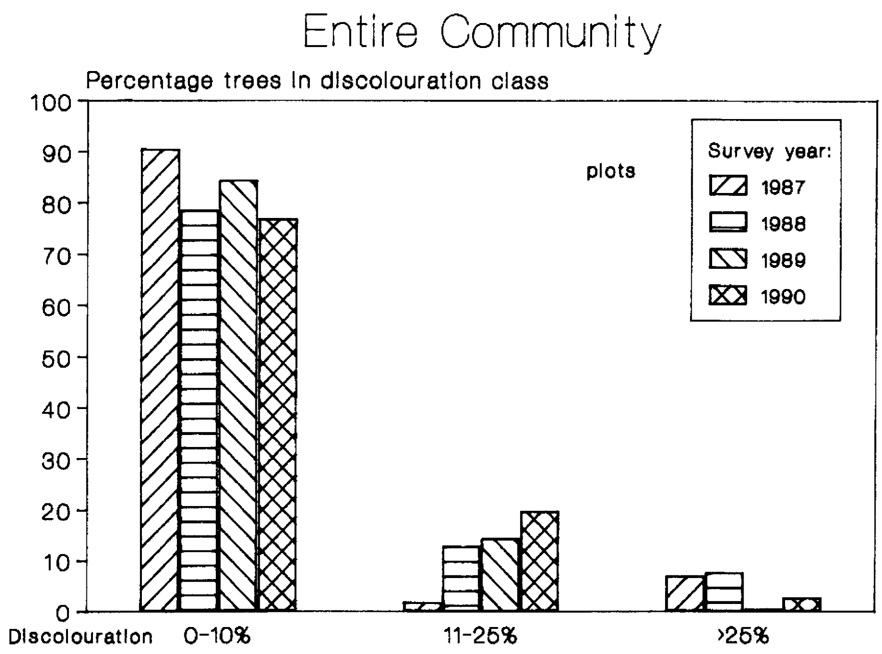



Figure 25: Changes in defoliation for *Quercus pubescens* in period 1987-1990. Trees common to the 1987, 1988, 1989 and 1990 surveys.



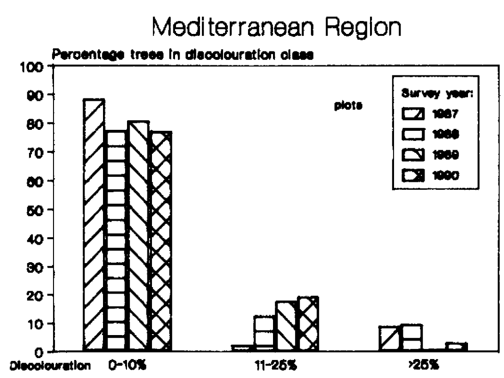




Figure 26: Changes in discolouration for *Quercus pubescens* in period 1987-1990. Trees common to the 1987, 1988, 1989 and 1990 surveys.

### 5.3.12 *Quercus petraea*

| Defoliation | Common | Healthy trees (def. 0-10%) | | Damaged trees (def. >25%) | |
|---|---|---|---|---|---|
| *Quercus petraea* | trees | range | trend | range | trend |
| Total sample | 292 | 60-70% | fluctuating | 5-10% | fluctuating |
| - Sub-atlantic | 261 | 65% | constant | 5-10% | fluctuating |

The percentage of healthy trees of *Quercus petraea* has slowly decreased over the years 1988-1990 (Figure 27). The fraction of slightly damaged trees increased in 1988-1990, while the percentages of the damaged trees showed an increase over the period 1988-1989. Overall, the changes are small, so no trends can be derived from these figures.

| Discolouration | Common | Healthy trees (disc. 0-10%) | | Damaged trees (disc. 11-25%) | |
|---|---|---|---|---|---|
| *Quercus petraea* | trees | range | trend | range | trend |
| Total sample | 292 | 95-100% | sl. decrease | 0-5% | constant |
| - Sub-atlantic | 261 | 95-100% | sl. decrease | 0-5% | constant |

A slight but gradual decrease in discolouration occurred for *Quercus petraea* in the period 1987-1989 (Figure 27).

The vitality of *Quercus petraea* within the subsample seems to have decreased very slightly over the last four years.

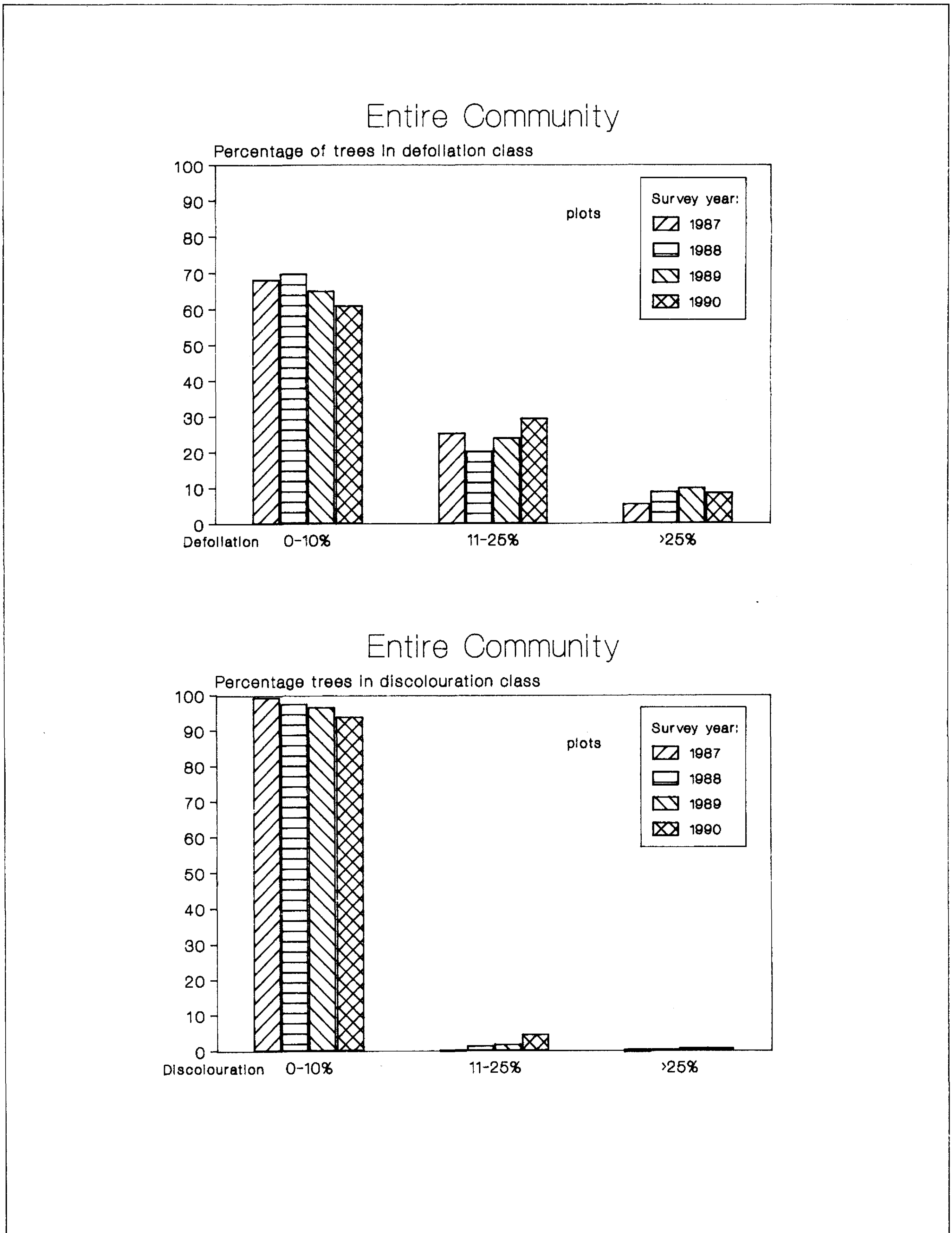



Figure 27: Changes in defoliation and discolouration for *Quercus petraea* in period 1987-1990. Trees common to the 1987, 1988, 1989 and 1990 surveys.

## 5.4 Closing remarks

For the majority of the species included in the investigation, no clear changes in vitality were found over the first four years of the inventory. Because of the incomplete surveys of 1987 and 1988, and the incomplete survey in Germany in 1990, the Common Trees only represent a small part of the total tree sample of the inventory network. Therefore the slight changes in vitality that were observed for some species could in many cases not be regarded as conclusive because of the low number of trees and/or plots.

In many cases the percentages of trees in the different defoliation classes fluctuated considerably. These fluctuations may reflect temporal changes in growing conditions such as extreme weather types (i.e. the hot summers of 1989 and 1990). The fluctuation of discolouration was considerably smaller and annual changes rarely exceeded 10%.

General trends in tree vitality over the period 1987-1990 seem to occur for:

* *Pinus sylvestris*: increase of trees in warning class (Defoliation 11-25%)

* *Quercus ilex*: an improvement of vitality

* *Pinus pinaster*: a slight improvement of vitality.

* *Castanea sativa*: a slight deterioration in the Sub-atlantic region

* *Picea sitchensis*: a strong deterioration of vitality (based on defoliation only; percentage of not-discoloured trees showed an increasing trend). This increase in defoliation was primarily due to attacks by the Green spruce aphid (*Elatobium abietinum*) in the United Kingdom.

* *Quercus robur*: a slight improvement of the vitality

* *Quercus pubescens*: a deterioration of the vitality

Future surveys of the entire network will provide more complete and useful data for the establishment of possible trends in vitality of the different species included in the inventory.

# 6 Extended evaluation

The vitality of forests in general depends on a large number of parameters. These parameters can be site-specific (such as soil, climate, altitude, pollution, etc.), of human origin (species selection, forest management, etc.) or random (pests, fires, etc.). Further, some parameters remain relatively constant over a longer period, while others may vary from year to year, affecting forest vitality in either a positive or a negative way.
In the extended evaluation of the Forest Health Report 1989, the possible relationships between a number of parameters and tree vitality **at plot level** were studied in detail. The conclusions proved to be significant for the parameter **mean stand age**. In view of these results, the data-set of 1990 was searched for analogous correlations. The outcomes may further contribute to the description of the degree of natural variation in crown density. The study of defoliation in relation to mean stand age is an extension of the general analysis presented in section 3.7.

In addition to the evaluation at plot level, a detailed study has been devoted to the **dynamics in defoliation** of **individual trees**. The results are of a descriptive nature and offer a comprehensive overview of the behaviour of individual trees. As the time-period of the forest inventory is restricted to four years, it is impossible to distinguish between patterns due to natural variation and structural trends. In the future longer time-series will play an increasingly important role in the analyses.

A second analysis at tree level concerns those **trees that were excluded from the survey since 1987**. Is it possible to define, from the information available, a reason for their exclusion? Do observations on defoliation, discolouration and damage-types give any plausible cause for the disappearance of trees in the following year? And if such questions can be answered, is it possible to predict the fate of trees in years to come?

Although limited time was available, a special section has been devoted to the study of the relationships between soil type and forest vitality. The study shows interesting results which can be refined and improved when more information on the forest soils becomes available in future surveys.

## 6.1 Defoliation and mean stand age

At plot level, one parameter has been evaluated with respect to its influence on forest vitality, as recorded for each sample plot in the inventory. **Mean stand age** is a stand-dependent parameter and was determined for 92.9% of the total number of trees in the data-set. The remainder of the trees was found on plots of uneven, irregular age. These trees and the trees older than 110 years have been excluded from the analysis as their age cannot be specified.
In order to investigate the effect of age on forest vitality, this parameter was related to the degree of **defoliation** found for trees of different age classes. The discolouration index has proven to show little variation and has not been further analysed. The parameter defoliation has been studied in detail for one of the most common species, *Picea abies*, using the data-set of the **Sub-Atlantic** zone of **1989**.

From experience, it seems unrealistic to expect defoliation to be a linear expression of age. Growth (or decline) of a population does usually not follow a straight line but a curve. In Figure 28 the relation between defoliation and mean stand age is shown for *Picea abies* in the Sub-Atlantic region. The curves for defoliation class 0, 1 and 2 to 4 are typical for the data-set of the whole Inventory.

The mean percentages of trees in the defoliation-classes 0, 1 and 2 to 4 have been calculated for each age class and are plotted against the mean stand age (represented by * in Figure 28). In a second step, lines are drawn that fit best through these points. It seems obvious that these are not straight lines but curves. This is further proven by the fact that the regression coefficient, a measure of the association between the two variables, is higher for the curved lines than if straight lines were fitted (see Annex IV-1).

The shape of the best-fitting curve in Figure 28 is in the first place the result of the model chosen. The curve does not define but only depict any trend present. The significance of the curves at both ends is limited, while extrapolation beyond the age of 110 is not allowed. It is also noted that the dependent variable is expressed in percentages, which implies that, theoretically, summation of the three curves can only yield 100 %.

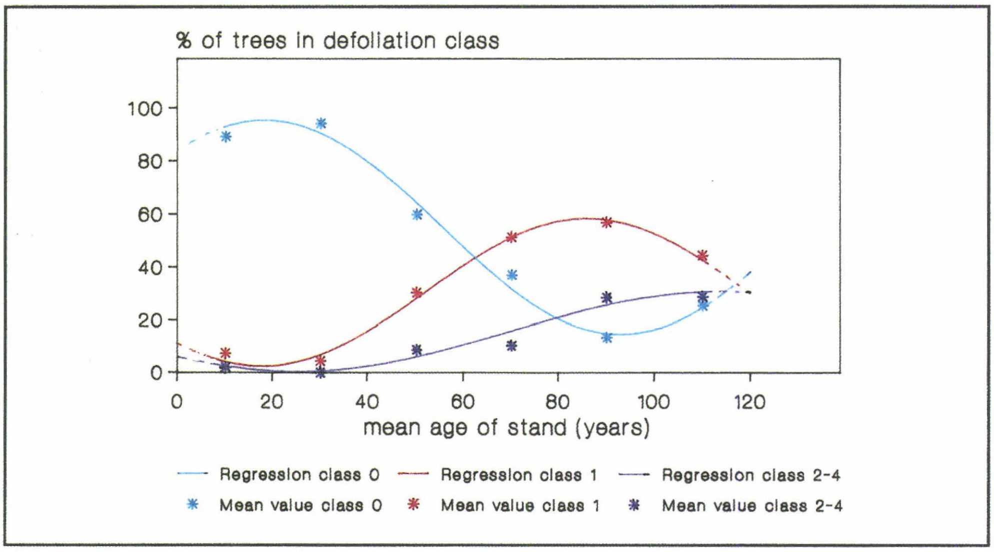



Figure 28: Plot Defoliation by mean stand age. Non-linear regression of percentage of trees in defoliation classes 0, 1 and 2 to 4 by mean stand age for *Picea abies*, Sub-Atlantic region, 1989.

The percentage of not-defoliated trees is initially high in young stands (Figure 28) and gradually diminishes with increasing age. Concurrently, the percentages of trees in defoliation classes 1 and 2 to 4 gradually increase. Interpretion of the curve for defoliation class 0 and disregarding the outer age limits is difficult, and a number of explanations can be formulated.

A first possible explanation of the curve could be that older stands are more sensitive to air pollution than younger stands. Equal levels of air pollution could cause therefore more defoliation in old stands than in younger stands.

Another possible explanation of the curve may be that older trees perform worse due to the fact that they have been prone to air pollution for a much longer time period. It is obvious that if air pollution does affect tree vitality, trees that have been exposed longer to its adverse effects, show a lower crown density than trees that have not, or not as long, been exposed.

A third possible explanation of the curve may be the fact that a single reference tree has been used for trees of all age-classes. Older trees appear less vital because this is a quality inherent to ageing, even when no air pollution is involved.

Summarizing, it is clear that a negative correlation should exist between the percentages of trees in defoliation class 0 and mean stand age. Curves are better able to describe this association than straight lines. However, the question remains how to discriminate between the various factors that influence the observed pattern.

In a similar way the curves for defoliation class 1 and defoliation classes 2 to 4 (Figure 28) show that young stands have almost no defoliation, while needle loss increases with age. The curve for defoliation class 1 shows a clear maximum at the age about 85 years, implying that needle loss continues and more trees shift from class 1 to classes 2-4 than from class 0 to class 1.

## 6.2 Dynamics in defoliation

### 6.2.1 Introduction and Methodology

Natural changes in annual crown density are suspected to contribute strongly to the observed patterns in defoliation. In this section the results for trees common to the 1987-1990 surveys are studied and a description and quantification of the **dynamics in defoliation** of **individual trees** is presented. Obviously, only trees common to each of the annual surveys can be considered.
At present, a data-set of a 4 year time-period is available. The data-set used is extracted from the plots situated in the **Atlantic** zone of the **United Kingdom** and **France**. The description of the dynamics has been restricted to two species; A: *Pinus sylvestris* (214 common trees), and B: *Picea sitchensis* (464 common trees). Comparison of these two species is interesting as they differed considerably in terms of defoliation. The vitality of *Picea sitchensis* is known to be strongly influenced by the occurrence of the green spruce aphid in the United Kingdom.

As it is impossible to depict the dynamics of tree defoliation within a single figure and in order to increase comprehensibility, the changes in crown density are shown in 4 different types of graphs. The graphs are included in section 6.2.2 as they are explained in greater detail there. The background to the graphs is as follows.

In the first pair of graphs (Figure 29), bar graphs have been constructed which show the **distribution** of the trees over the **five defoliation classes** throughout the survey period **1987-1990**. The figures give a general impression of the status quo at a certain point in time and allow for general trends to be detected. However, individual trees cannot be followed over the years as only total annual numbers are expressed.

In the second set of graphs (Figure 30) this problem is partly overcome by addressing trees of a certain defoliation class in 1990 with their corresponding class code of 1987. These graphs show the **distribution** of the trees over the **five defoliation classes** in **1990**, with a further **subdivision** according to their defoliation in **1987**. However, annual dynamics are obscured completely as the intermittent years are not taken into account. Including these latter data into this type of graph would result in an incomprehensible picture with a theoretical total number of $5^4$ = 625 subdivisions.

The third set of graphs (Figure 31) also portrays the handicap of obscuring the dynamics in intermittent years. In these graphs the bars represent the **net change** in defoliation class **since 1987**, as concluded from the 1990-survey. Trees that in 1990 reached a lower defoliation class compared to 1987 showed a negative change in class code and thus improved their crown density.

In the fourth and last set of graphs (Figures 32 and 33) a more suitable expressions of the dynamics in defoliation is presented. By attributing each tree its typical 'pathway' or sequence of defoliation-class codes over the years, e.g. 1-2-2-3 for the years 1987-1988-1989-1990, it becomes possible to evaluate the dynamics in defoliation. Again it is not practical to subdivide the data-set into all 625 possible pathways. To obtain an overview, pathways have been grouped together according to their **consistency of defoliation.** Each bar gives the composition of the total number of trees in that year. Groups of trees with **comparable dynamics**, e.g. constant, are taken together and represented as C-C-C-C (0-0-0-0, 1-1-1-1, 2-2-2-2 etc.). The sequence 'C-C' denotes an unchanged level of defoliation, with C standing for any class code. The sequences 'H-C', 'L-C', 'C-H' and 'C-L' indicate a change in defoliation level, either from or towards a higher ('H') or a lower ('L') class.

The bars are composed in such a way that, starting from the group which remained constant until the end of the inventory-period (pictured in blue), the lower sections of the bar represent groups of trees that remained constant for an increasingly shorter period (C-C-C-L, C-C-C-H, C-C-L-.. and so forth).

Alternatively, trees new to a defoliation class in a specific year are represented on top of the blue section of constant trees. Again, the number of years the trees remained constant in defoliation determines the stacking order (L-C-C-C underneath H-C-C-C and ..-L-C-C andsoforth). Trees with unclear, miscellaneous pathways (e.g. L-C-C-L or C-H-C-H) are grouped separately ('Misc.').

Colour and pattern-intensity are the main clues to the interpretation of Figures 32 and 33. The higher the **pattern-intensity**, the longer the period of unchanged crown density before or after which a change was observed. Thus, starting from the blue-coloured group of trees with an unchanged crown density (C-C-C-C), the pattern intensity decreases both in upward and downward direction of the bar, indicating less **consistency in defoliation.**
The result of this representation is that, in diagonal lines, groups of trees can be followed over the years, with the blue pathway C-C-C-C as the dividing section between trees moving in or out of a certain defoliation class.
The **colours** green and red have been introduced to distinguish groups of trees that showed an **improving** trend in defoliation (**green**) from those **deteriorating** (**red**). Trees with inconclusive pathways are again grouped separately (brown).

### 6.2.2 Results and Interpretation

The overall changes in defoliation for *Pinus sylvestris* and *Picea sitchensis* are depicted in Figure 29. For *Pinus sylvestris* (Figure 29A) the share of not-defoliated trees (class 0) in this sub-sample has reduced considerably over the years, with the exception of 1989. Classes 1 and 2 (slightly and moderately defoliated trees) show the opposite trend, with again an exception for 1989. Overall, there is a decrease in tree vitality, with trees showing increasingly more defoliation.

A similar overview is given in Figure 29B for *Picea sitchensis*. For this species, the largest changes have occurred in classes 0 (a decrease) and 2 and 3 (increases). It is noted that the role of class 1 as a 'warning class' is rather ambiguous here. For both species the changes in classes 2 and 3 are not preceded (or 'forecasted') by similar changes in class 1 of the period before.

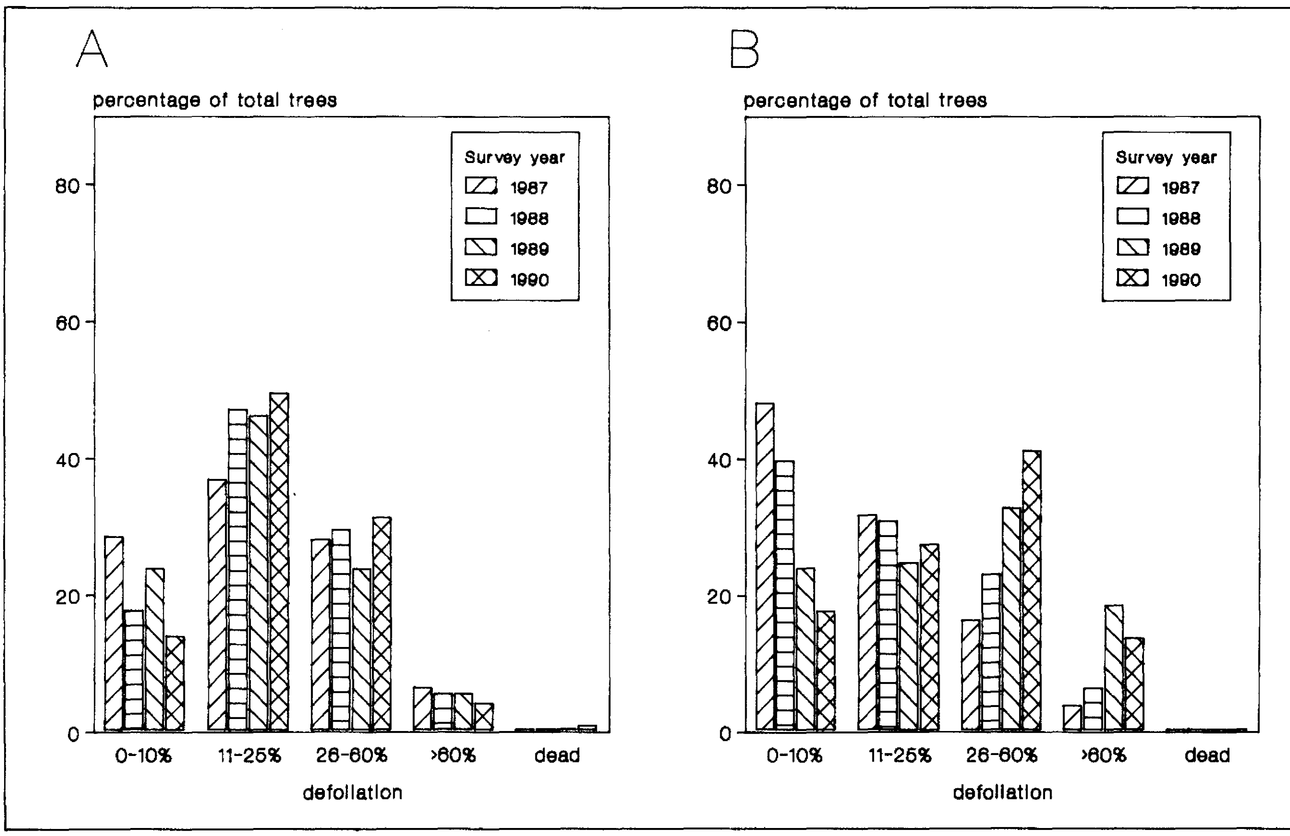



Figure 29: Annual distribution (in %) of trees over the 5 defoliation classes.
A = *Pinus sylvestris*, total number of trees: 214.
B = *Picea sitchensis*, total number of trees: 464.

Data from 1987 to 1990 surveys, United Kingdom and France, Atlantic zone.

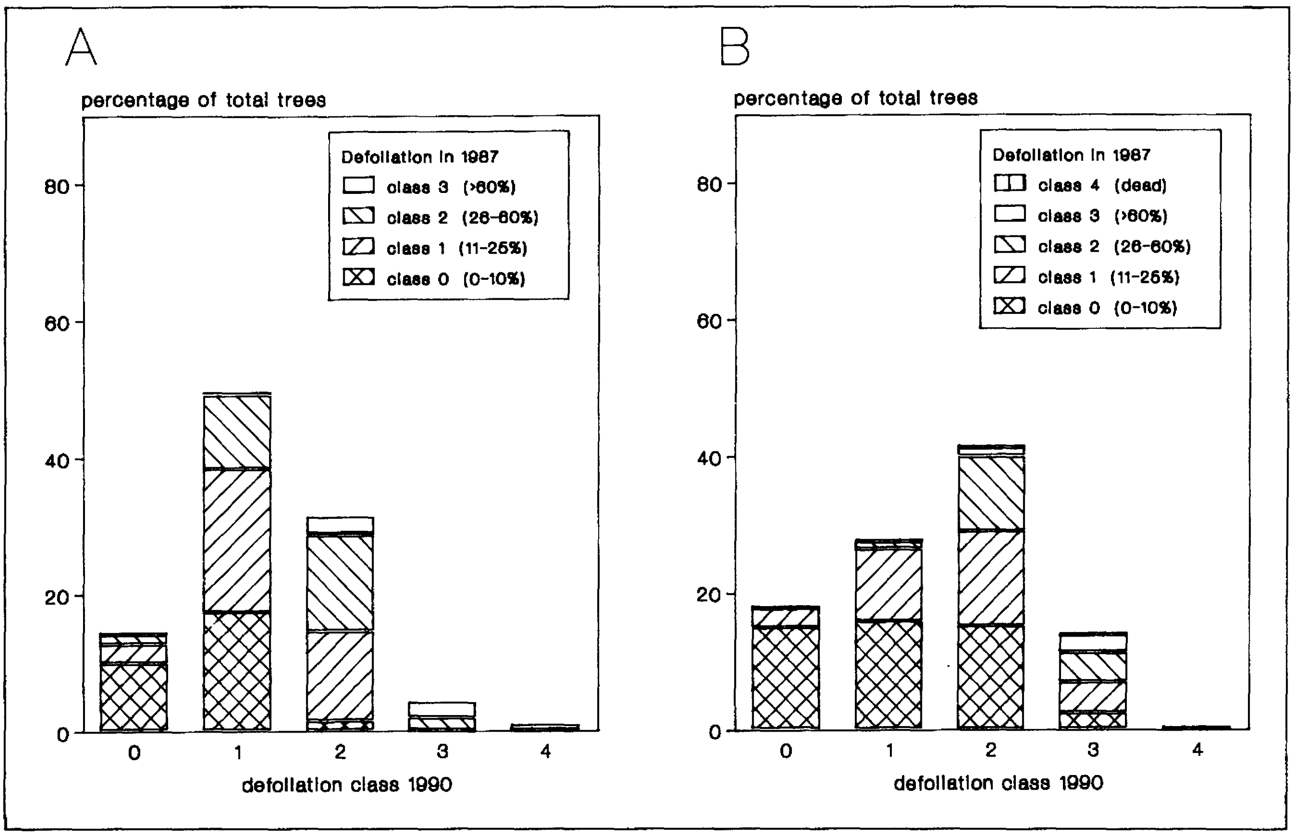



Figure 30: Distribution of trees (in %) over the five defoliation classes in 1990, subdivided according to their defoliation class in 1987.
A = *Pinus sylvestris*, total number of trees: 214.
B = *Picea sitchensis*, total number of trees: 464.

Data from 1987 to 1990 surveys, United Kingdom and France, Atlantic zone.

The 'history' of the trees classified as either 0, 1, 2, 3 or 4 in 1990 is shown in Figures 30 A and B. For *Pinus sylvestris* it can be deduced that two-thirds of the trees in the 1990-defoliation class 0 were also in 1987 classified as not-defoliated. The composition of the 1990-class 1 however shows that substantial changes have taken place, with 35% of this class originating from the 1987-class 0 (and thus deteriorating) and 22% from the 1987-class 2 (which indicates an improvement). A significant share (42%) of the 1990-class 2 consists of trees that belonged to class 1 in 1987, indicating a deterioration. Defoliation class 0 of *Picea sitchensis* (Figure 30B) appears rather constant with 84% of the 1990-class 0 trees having been assigned to the same class in 1987. A much higher degree of dynamics is portrayed by the 1990-class 1. Of these trees 57% originated from defoliation class 0 in 1987 (indicating a deterioration) and only 4% from the 1987-class 2. Also among the moderately defoliated trees (class 2) many shifts have taken place. Of the trees classified as such a third was in 1987 grouped into class 1 and another third into class 0, again indicating a considerable loss in vitality.

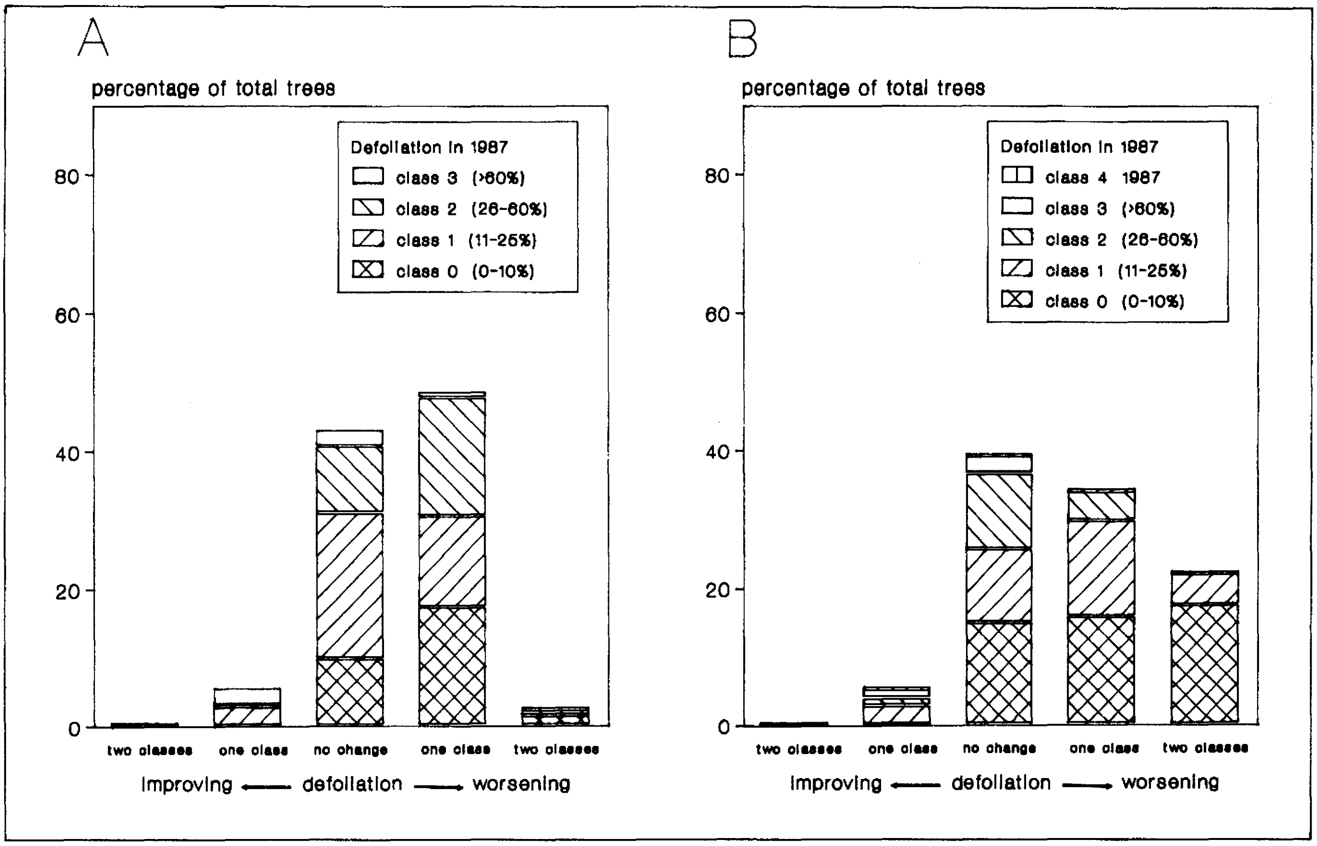



Figure 31: Net change in defoliation class over 1987-1990 survey-period. Computed as 1990-class code minus 1987-class code. Intermittent years not considered.
A = *Pinus sylvestris*, total number of trees: 214.
B = *Picea sitchensis*, total number of trees: 464.

Data from 1987 to 1990 surveys, United Kingdom and France, Atlantic zone.

Figure 31A shows in detail the net shift in defoliation that took place over the 1987-1990 interval for *Pinus sylvestris*. Compared to 1987 less than half of the trees (43%) remained constant in crown density, especially those from 1987-class 1. Changes for the worse (+1 class, 49%) outnumber improvements (-1 class, 6%) as can be seen from the length of the respective bars. This again confirms the trend observed before that, in general, trees were less vital in 1990 than in 1987. Trees deteriorating were those from 1987-class 0 (17%), class 1 (13%) and class 3 (17%); trees improving equally concerned those from the 1987-classes 1 (3%) and 2 (3%). Changes larger than one class were negligible.

*Picea sitchensis* showed a comparable percentage of constant trees (39%, Figure 31B), but considerably more trees deteriorating in terms of defoliation; 34% of all trees worsened one class, 20% worsened two classes and 2% even shifted three classes over the time-interval. Improvements were observed for only 5% of the trees. Compared with *Pinus sylvestris*, shifts of +2 classes (deterioration) are much more frequent and shifts of +1 class (deterioration) much less frequent for *Picea sitchensis*.

Figures 32 and 33 are the final visualization of the dynamics of *Pinus sylvestris* and *Picea sitchensis* respectively. From the figures it can be seen that, from **both species**, about 24% of the trees showed **no change** in crown density over the 1987-1990 period (blue colour). A global look also reveals that more trees deteriorated than improved (colours red versus green), especially among *Picea sitchensis* trees. This confirms the observation from the former graphs.

Over the 1987-1988 period 15% of the *Pinus sylvestris* trees (Figure 32) improved (C-L-.-.) whereas a slightly larger share deteriorated (23% C-H-.-.). The changes appear from the 1988-bar to be very inconsistent as most 'newcomers' (above the blue section) have very unclear dynamics (28% brown) with minor proportions remaining unchanged for the rest of the survey period (7% L-C-C-C and 4% H-C-C-C). Over 1988-1989 the changes were rather balanced with nearly equal shares improving (13% C-C-L-.) and worsening (11% C-C-H-.). The share of trees with 'miscellaneous' pathways has reduced to 21% (brown), indicating more consistency. Equal shares of the trees remained constant for at least 2 years (16% .-L-C-C and 15% .-H-C-C). Over the years 1989-1990 only small proportions of trees deteriorated or improved (9% C-C-C-H and 5% C-C-C-L respectively).

The consistency among *Picea sitchensis* trees is much smaller (Figure 33). Although an equal percentage of trees remained unchanged over the years (24% blue) the overall trend of loss of vitality is obvious. In 1987 a small proportion of trees improved (11% C-L-.-.) whereas a much larger share deteriorated (25% C-H-.-.) in the subsequent year 1988. The changes appear from the 1988-bar to be mainly temporarily; most 'newcomers' (above the blue section) have very unclear dynamics (25% brown) with only a small proportion remaining unchanged for the rest of the survey period (10% L-C-C-C and 1% H-C-C-C). Over 1988-1989 the changes were similar (5% C-C-L-. improving and 26% C-C-H-. worsening). The share of trees with 'miscellaneous' pathways is slightly smaller (21% brown); a large part of the trees remained constant for at least 2 years (30% .-L-C-C and 6% .-H-C-C). Most trees that changed over 1989-1990 did so for the worse (8% C-C-C-H vs 0.2% C-C-C-L), but the rate of deterioration appears to have decreased compared to 1987-1988.

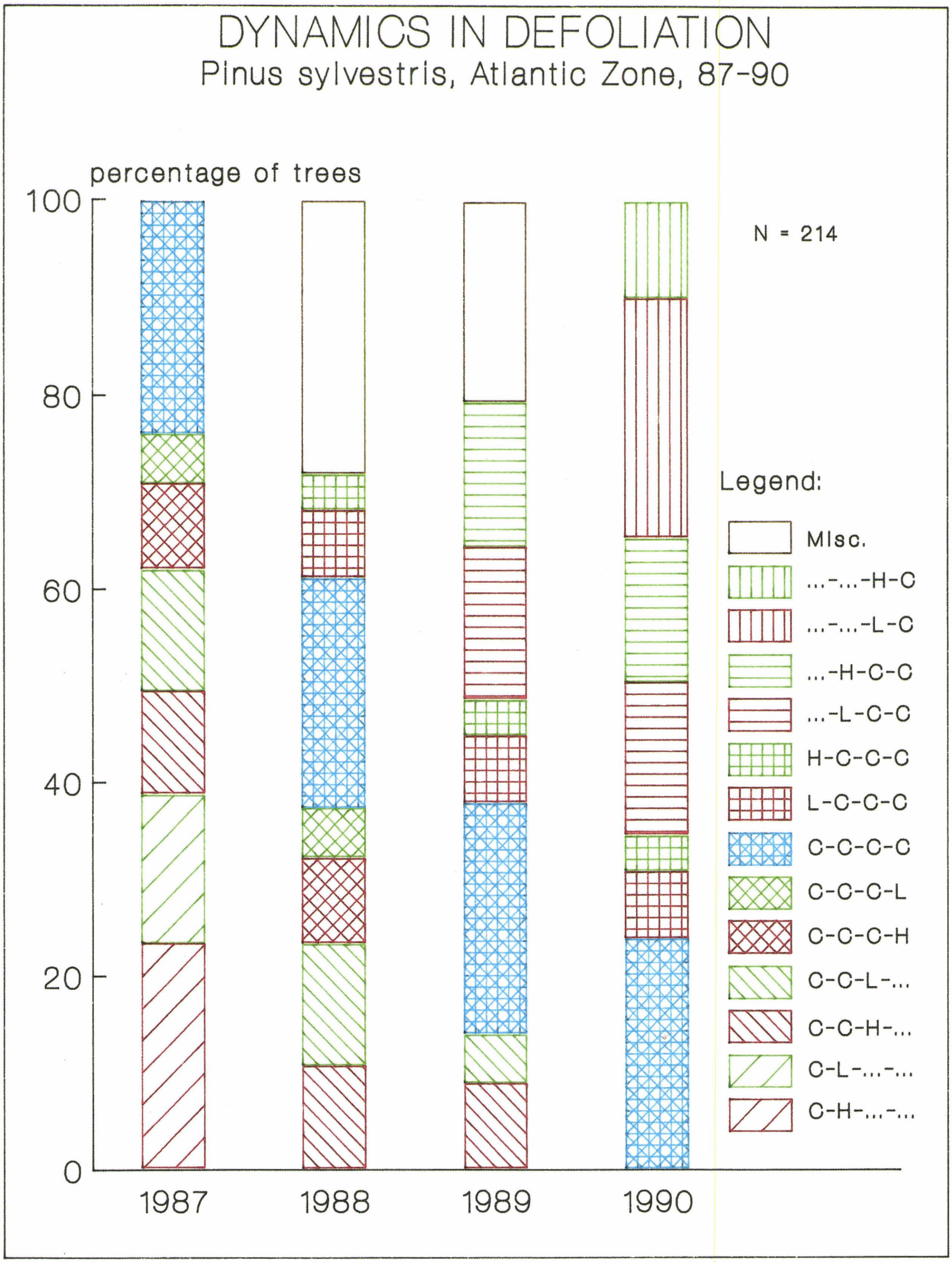



Figure 32: Dynamics in defoliation, all classes. Trees grouped according to consistency of defoliation (length of unchanged period) and year of change.

C = constant H = higher than C Misc. = miscellaneous groups
... = any class L = lower than C

Data from 1987 to 1990 surveys, United Kingdom and France, Atlantic zone, *Pinus sylvestris*.

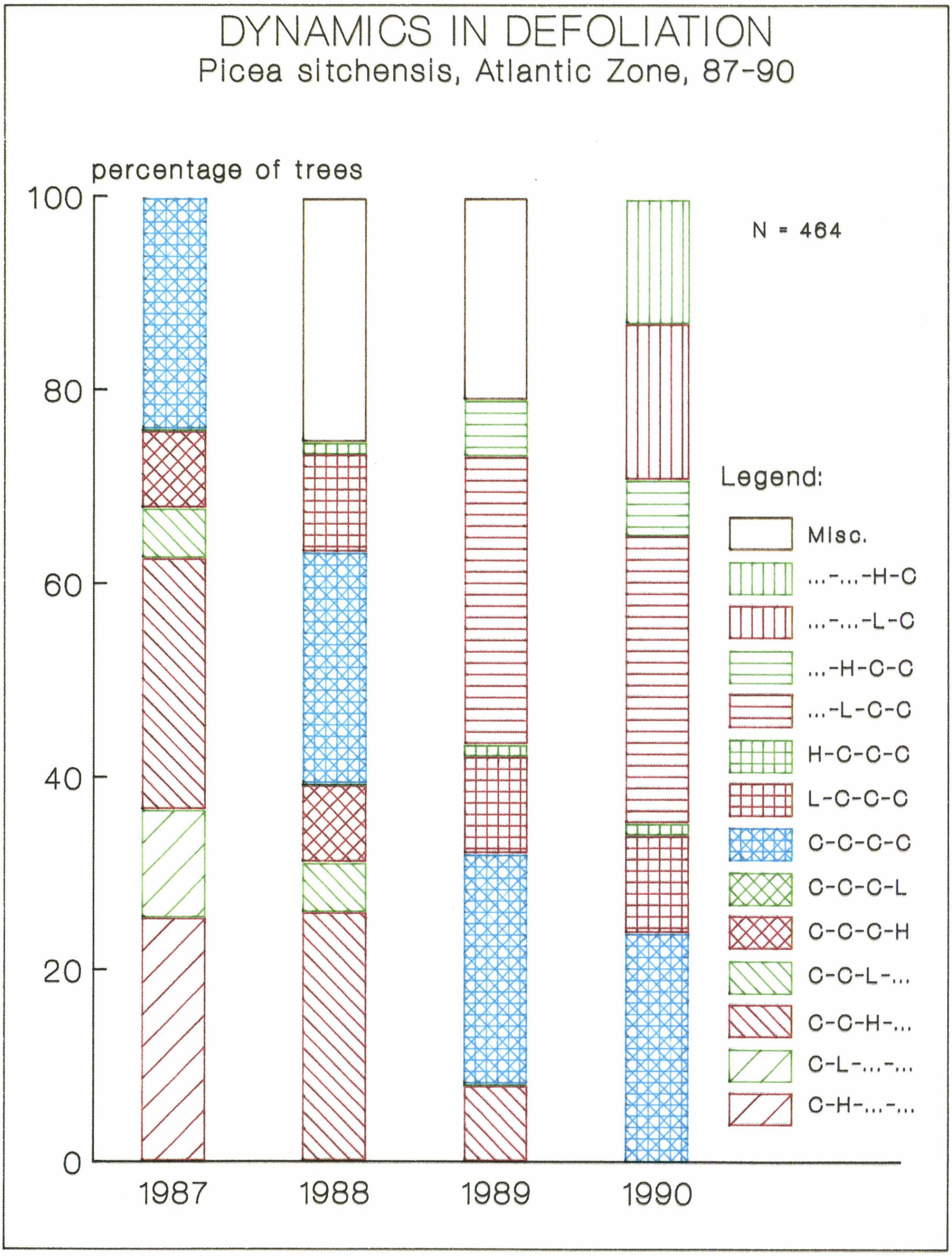



Figure 33: Dynamics in defoliation, all classes. Trees grouped according to consistency of defoliation (length of unchanged period) and year of change.

C = constant H = higher than C Misc. = miscellaneous groups
... = any class L = lower than C

Data from 1987 to 1990 surveys, United Kingdom and France, Atlantic zone, *Picea sitchensis*.

## 6.3 Why are trees excluded from the Inventory ?

Tree exclusion is defined here as the disappearance of a tree from the inventory. It is impossible to find out whether the tree was also physically removed from the plot or merely omitted from the observation list. Both management (e.g. thinning) and actual damage (defoliation, pests, windthrow etc.) may have been the reason for exclusion. The effects of thinning are probably large for trees of the lower storey but can be expected to be relatively small for the pre-dominant, dominant and co-dominant trees of the forest health inventory.

For the study, the information was used from the **1987-1990 surveys** of the **United Kingdom**. During this period, the total number of trees (all species) in the survey fluctuated around 1800. The exact number changed from year to year as a result of certain trees (or even plots) being newly added to the survey while alternatively other trees are being excluded from further monitoring. Finally, a restgroup with irregular and possibly erroneous data can be distinguished.
Which characteristics did the excluded trees have in common according to the inventory of the year before? If the trees have disappeared because of their poor vitality situation, this should have been visible in the year before.

The characteristics of the trees excluded from the inventory in the subsequent year are summarized in Table 18, along with those of the trees remaining. It can be observed that most of the "lost" trees were in their last year classified in a way similar to the trees remaining ("left").

TABLE 18: Characteristics of trees remaining ("Left") and disappearing ("Lost") from the survey.

| | 1987 | | | | 1988 | | | | 1989 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Trees Left | | Trees Lost | | Trees Left | | Trees Lost | | Trees Left | | Trees Lost | |
| | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % |
| def0 | 757 | 44.1 | 28 | 34.1 | 645 | 36.8 | 4 | 10.5 | 574 | 34.1 | 30 | 23.6 |
| def1 | 585 | 34.1 | 34 | 41.5 | 690 | 39.4 | 15 | 39.5 | 558 | 33.1 | 49 | 38.6 |
| def2 | 314 | 18.3 | 19 | 23.2 | 346 | 19.7 | 16 | 42.1 | 425 | 25.2 | 43 | 33.9 |
| def3 | 61 | 3.6 | 1 | 1.2 | 70 | 4.0 | 2 | 5.3 | 123 | 7.3 | 5 | 3.9 |
| def4 | 1 | 0.1 | 0 | 0.0 | 2 | 0.1 | 1 | 2.6 | 4 | 0.2 | 0 | 0.0 |
| dis0 | 1358 | 79.0 | 75 | 91.5 | 1382 | 78.8 | 14 | 36.8 | 1403 | 83.3 | 100 | 78.7 |
| dis1 | 259 | 15.1 | 6 | 7.3 | 279 | 15.9 | 10 | 26.3 | 213 | 12.6 | 20 | 15.7 |
| dis2 | 87 | 5.1 | 0 | 0.0 | 79 | 4.5 | 14 | 36.8 | 59 | 3.5 | 7 | 5.5 |
| dis3 | 14 | 0.8 | 1 | 1.2 | 13 | 0.7 | 0 | 0.0 | 9 | 0.5 | 0 | 0.0 |
| T1 | 58 | 3.4 | 0 | 0.0 | 28 | 1.6 | 0 | 0.0 | 76 | 4.5 | 14 | 11.0 |
| T2 | 458 | 26.7 | 15 | 18.3 | 546 | 31.1 | 26 | 68.4 | 641 | 38.1 | 54 | 42.5 |
| T3 | 63 | 3.7 | 3 | 3.7 | 48 | 2.7 | 0 | 0.0 | 41 | 2.4 | 6 | 4.7 |
| T4 | 156 | 9.1 | 0 | 0.0 | 183 | 10.4 | 18 | 47.4 | 145 | 8.6 | 23 | 18.1 |
| T5 | 10 | 0.6 | 0 | 0.0 | 20 | 1.1 | 1 | 2.6 | 18 | 1.1 | 10 | 7.9 |
| T6 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| T7 | 7 | 0.4 | 0 | 0.0 | 8 | 0.5 | 0 | 0.0 | 7 | 0.4 | 0 | 0.0 |
| T8 | 95 | 5.5 | 6 | 7.3 | 53 | 3.0 | 0 | 0.0 | 25 | 1.5 | 5 | 3.9 |
| Total | 1718 | | 82 | | 1753 | | 38 | | 1684 | | 127 | |

Comparing the results of the 1989 and 1990-surveys as an example, it can be seen that only 39% of the trees "lost" was considered slightly defoliated, compared to 33% of the trees remaining. For the moderately defoliated trees these figures are 34% and 25% respectively. Regarding discolouration, 79% of the trees "lost" was classified as non-discolourated, which is comparable to the 83% of the trees remaining.

In an analogous way the easily identifiable causes of damage were investigated. Again there appear no major differences between the trees "lost" and the remaining trees. The relatively most important damage was caused by insects (T2, 43% of the trees "lost" and 38% of the trees "left"), and to a lesser extent by the action of wind, frost, drought etc. (T4, 18% and 9% respectively).

The distribution over the defoliation-classes in 1989 of the trees that were excluded from the survey in 1990 (red colour) and that of the trees remaining (blue colour) is presented in Figure 34. An expected observation in this Figure would have been that the distribution of the "lost" trees tends to favour the defoliation classes 3 and 4. This would reflect the expected pattern of strong defoliation prior to the exclusion from the survey in the subsequent year. It is therefore interesting to note that such a pattern can not be detected at all and that the trees missing in 1990 are mainly classified as slightly to moderately defoliated in 1989.

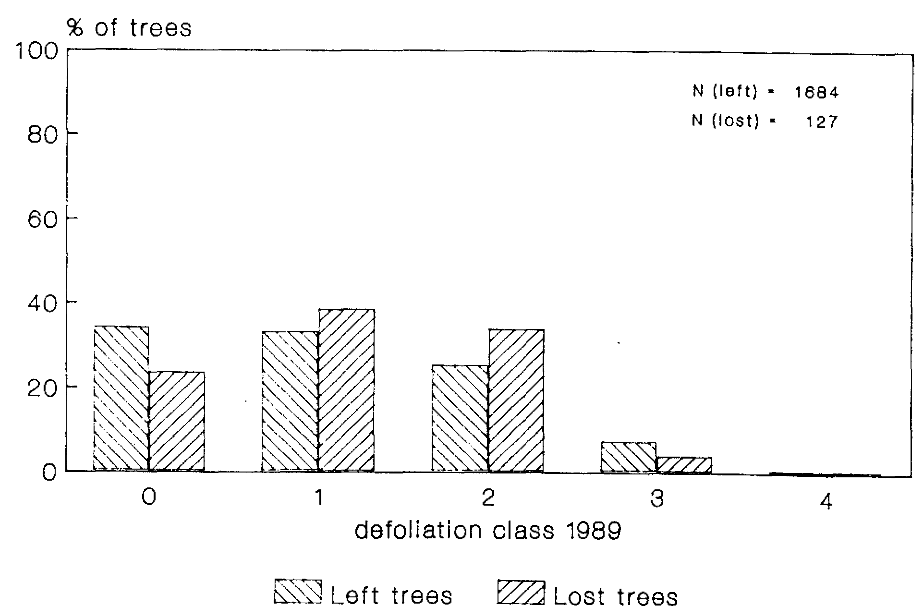



Figure 34: Percentage defoliation for trees remaining (Left) and disappearing (Lost) from the survey.
Data from the United Kingdom, all species, 1989.

Graphs as in Figure 34 may also be set up for the other parameters in 1987, 1988 and 1989. All of these, however, show comparable results and do not offer an explanation for the exclusion in the next year.

Only the smallest group of "lost" trees (1988) shows to be of significantly poorer vitality than the trees remaining in that year. The differences were found in terms of defoliation, discolouration and damage-types T2 and T4. However, as the group consists of only 38 trees the result is considered of limited importance.

From the data available, no reasons can be detected as to why the trees were excluded from the survey in the subsequent year. Only some of the trees disappearing from the inventory did show unfavourable characteristics in their last year of entry, but this correlation is not consistent. In terms of defoliation and discolouration it even appears that the healthier trees are more subject to exclusion than those with stronger canopy damage.

In this data-set no reasons can be found for the disappearance of trees from the survey. Based on the available information in this sub-sample it is not possible to predict the fate of trees in years to come.

## 6.4 Defoliation and soil type

Soil type is a site-dependent parameter with a strong influence on the vitality of the forest. In 1990, soil type was included in the forest health survey for the first time. For 105 plots, situated in the Federal Republic of Germany and Austria, soil type data were received. The soils were classified according to the FAO soil classification system (Soil Map of the European Communities 1985). A global overview of the degree of defoliation and discolouration by soil type has been presented in chapter 3.9. In this section an effort is made to find relationships between the vitality of trees and the characteristics of the soils.

In order to investigate the influence of the type of soil on tree vitality, a **subsample** was selected consisting of trees of species *Picea abies* only. *Picea abies* is the most common species in the data-set for which information on soil type was available (59% of a total of 2924 trees). The age of the trees varied widely, with all age-classes being equally represented. The distribution of the trees over the defoliation classes is given in Table 19.

The most common soil types in the subsample are Podzols, Cambisols, Rendzina's and Luvisols. From a pedological point of view these soils differ largely in their suitability for forest growth. An initial comparison (using parameter-free methods of statistical analysis) of groups of trees from different soil types confirmed that differences in terms of vitality existed. In Table 19 the soil types are arranged by their expected suitability; the percentage of undamaged trees (defoliation class 0+1) ranges from less than 75% on the sandy Arenosols to more than 95% on the more suitable Cambisols and Luvisols. The differences between the various types of Podzols appear large, but are not significant ($P<0.001$). On Leptic Podzols (421 trees) defoliation is more severe ($P<0.001$) than on Dystric Cambisols (238 trees). The difference between Dystric and Eutric Cambisols (210 trees) is small, but significant. This is surprising as the former are of relatively lower fertility. The difference cannot be explained in terms of other plot parameters as stand age, altitude or aspect (only humus type showed a slight difference). Surprisingly, defoliation is worse on Chromic Luvisols than on the imperfectly drained Gleyic Luvisols.

TABLE 19: Percentages of defoliation by soil type.
Picea abies, 66 plots in Germany and Austria, 1990.

| soil type | defoliation | | | | sample trees |
|---|---|---|---|---|---|
| | 0-10% | 11-25% | 0-25% | >25% | |
| Cambic Arenosol | 11.6 | 63.2 | 74.7 | 25.3 | 95 |
| Dystric Histosol | *100* | *0.0* | *100* | *0.0* | 1 |
| Humic Podzol | *22.2* | *11.1* | *33.3* | *66.7* | 9 |
| Luvic Arenosol | 29.4 | 37.6 | 67.1 | 32.9 | 85 |
| Leptic Podzol | 77.9 | 18.1 | 96.0 | 4.0 | 421 |
| Orthic Podzol | 93.3 | 3.3 | 96.7 | 3.3 | 90 |
| Calcic Cambisol | *87.5* | *6.3* | *93.8* | *6.3* | 16 |
| Dystric Cambisol | 81.9 | 17.2 | 99.2 | 0.8 | 238 |
| Eutric Cambisol | 75.7 | 21.0 | 96.7 | 3.3 | 210 |
| Gleyic Cambisol | 100 | 0.0 | 100 | 0.0 | 78 |
| Orthic Rendzina | 66.8 | 27.0 | 93.8 | 6.2 | 211 |
| Chromic Luvisol | 55.2 | 29.3 | 84.5 | 15.5 | 116 |
| Gleyic Luvisol | 92.4 | 7.6 | 100 | 0.0 | 144 |

As soil type has an important influence on the vitality of the trees, a tentative classification was set up (Annex IV-2) to evaluate the suitability of these soils for forest growth. The classification is necessarily very general, as detailed data on the soils are lacking. The evaluation of the soil's suitability is expressed in ratings that indicate the degree of limitations the soil poses with respect to the soil characteristic at hand.
For the evaluation two types of rating have been used: **a multiple rating** consisting of five equally weighted scores for soil qualities as rootable depth, texture and structure, drainage, natural fertility and soil-pH.
The second evaluation is **a single rating** which was assessed as straightforward expression of the soil's suitability for forest growth. The ratings are based on experience and generally accepted knowledge of the suitability of these soil types. It is stressed that they are tentative in that exact analytical data are not yet available.

The analysis of the defoliation data of the trees in the subsample was performed on two levels of aggregation: 1) the **mean per soil type**, and 2) the **mean per soil type per plot**.

At the first level the mean percentage of trees in each of the five defoliation classes is considered for the separate soil types; at the second level the mean values are calculated per plot and a larger part of the variation within the original data is taken into account.

The outcomes of the analyses showed that the values of the regression coefficient $R^2$ are low: if the mean defoliation per soil type is used (level 1) the coefficients are 0.34 and 0.44 for the multiple and single rating respectively. If the mean values per plot are used the coefficients are even lower (see for details Annex IV-2).

However, as it is clear that considerable differences exist between soil types, it is strongly **recommended that soil types are included** in future forest health surveys. An effort has been made to evaluate the suitability of the soils through a number of soil quality ratings, but as the range of the soil properties within each of the soil types is large, this could be the reason why no relationships between soil parameters and vitality have been found. In order to have more accurate values for the soil parameters in respect to the forest vitality in a plot, it is strongly **recommended** that a number of **relevant soil parameters is determined** in the field and made available for further study (as proposed in the NIMFE-programme). Soil characterization can then make a significant contribution towards a better understanding of the patterns in forest vitality.

# 7 National forest damage inventories 1990

## 7.1 General overview

In many of the EC Member States a number of plots are inventoried in addition to the plots in the 16 x 16 km. grid. In Table 20, an overview is given of the national data as they are supplied by Member States, through the submission of National annual reports, including forms, as detailed in Council regulation 1696/87 Annex III[1].

In 1990 the coverage of the forests by the national grids is complete in most countries. Exceptions are Ireland, Italia (Sicily and Sardinia) and The Netherlands.
The grid density varies from 0.3 x 0.3 km in some areas to 16 x 16 km. In Greece an extra wide grid is used for the maquis area (32 x 32 km).

TABLE 20: Summary of National Forest Damage Inventories 1990

| Country | Area (1000 ha) | Coverage (%) | Conifers (%) | Broadl. (%) | Grid density (km x km) | Number of plots | Number of trees | Average trees/plot |
|---|---|---|---|---|---|---|---|---|
| BELGIE ') | 617 | 100.0 | 47.0/50.1 | 53.0/49.9 | 8x8 | 117 | 2808 | 24 |
| DANMARK | 460 | 100.0 | 59.4 | 40.6 | 7x7/16x16 | 68 | 1622 | 24 |
| DEUTSCHLAND | 7388 | 100.0 | 66.1 | 33.9 | .3X.3 - 16x16 | 3252 | 67807 | 21 |
| ELLAS | 2512 | 100.0 | 54.0 | 46.0 | 16x16/32x32* | 84/19* | 2008/455* | 23 |
| ESPANA | 11921 | 100.0 | 48.6 | 51.4 | 16x16 | 447 | 10728 | 24 |
| FRANCE | 13845 | 100.0 | 33.5 | 66.5 | 16x1/16x16 | 510 | 10280 | 24 |
| IRELAND | 320 | 86.1 | 100.0 | -- | 16x16 | 22 | 458 | 21 |
| ITALIA | 8675 | 84.6 | 22.4 | 77.6 | 3x3 | 220 | 1263+4459 | 30 |
| LUXEMBOURG | 84 | 100.0 | 36.4 | 63.6 | 2x2 | 210 | 1868+3155 | 24 |
| NEDERLAND | 330 | 85.0 | 67.4 | 32.6 | 1x1 | 1400 | 33125 | 25 |
| PORTUGAL | 3060 | 100.0 | 40.2 | 59.8 | 16x16 | 155 | 4650 | 30 |
| UNITED KINGDOM | 2112 | 100.0 | 62.5 | 37.5 | 16x16 | 76 | 1812 | 24 |
| ENTIRE COMMUNITY | 51324 | 97.2 | 43.5 | 56.5 | -- | 6580 | 146498 | 22 |

') (Belgium) = Flanders/Wallon region
\+ (Number of trees) = differentiation between Conifers and Broadleaves
/ (Grid) = grid in 7x7 and 16x16 km.
\- (Grid) = grid ranges from .3 x .3 up to 16 x16 km.
* (Greece) = for maquis area

Due to storm damage no inventory was carried out in some parts of Germany (Bavaria and Saarland) and Luxemburg. For the first time a number of plots in the former GDR (neue Länder) were included. Although no official National defoliation figure was received from Germany, an estimate was prepared in order to permit a comparison with the other EC Member states. This estimate for the average defoliation in the forests of Germany was derived from the submitted 1990 information for most Länder, in combination with data from 1989 (for Bavaria and Saarland).

1 OJ no. L 161, 06.22.1987, p. 13-22

## 7.2 Defoliation by Member State

When comparing the percentages of damaged trees (defoliation classes 2 - 4) between the various EC Member States it can be seen that the highest percentages of damaged trees are recorded in the UK (39.0%) and Portugal (30.7%) (Table 21). The lowest percentages of damaged trees are found in Spain (3.8%) and Ireland (5.4%).
Portugal has the highest percentage of dead trees (class 4), while its percentage of severely defoliated trees (class 3) is relatively low.

TABLE 21: Summary of National Forest Damage Inventories 1990
Defoliation in the EC Member States

| Country | Forest Area (1000 ha) | Defoliation (0 - 10%) | (11 - 25%) | (0 - 25%) | (26 - 60%) | (> 60%) | (Dead) |
|---|---|---|---|---|---|---|---|
| BELGIE ') | 617 | 45.1/54.6 | 46.6/26.3 | 91.1/80.9 | 8.1/14.1 | 0.2/4.7 | 0.0/0.3 |
| DANMARK | 460 | 45.3 | 33.5 | 78.8 | 17.4 | 3.3 | 0.5 |
| DEUTSCHLAND °) | 9856 | 37.7 | 39.4 | 77.1 | 21.4 | 0.9 | 0.6 |
| ELLAS | 2512 | 39.5 | 43.0 | 82.5 | 15.4 | 1.6 | 0.5 |
| ESPANA | 11921 | 79.1 | 17.1 | 96.2 | 3.2 | 0.6 | 0.0 |
| FRANCE | 13845 | 76.0 | 16.7 | 92.7 | 6.0 | 1.0 | 0.3 |
| IRELAND | 320 | 67.5 | 27.1 | 94.6 | 5.4 | 0.0 | 0.0 |
| ITALIA | 8675 | 61.4 | 23.8 | 85.2 | 11.7 | 2.6 | 0.5 |
| LUXEMBOURG | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |
| NEDERLAND | 330 | 53.2 | 29.0 | 82.2 | 14.8 | 2.2 | 0.8 |
| PORTUGAL | 3060 | 53.1 | 16.2 | 69.3 | 24.3 | 2.3 | 4.1 |
| UNITED KINGDOM | 2112 | 26.0 | 35.0 | 61.0 | 31.5 | 7.2 | 0.3 |

') Flanders/Wallon region
°) Estimates are partly based on data from 1989 (See Par. 7.1)

## 7.3 Discolouration by Member State

In Table 22 an overview is given of the recorded discolouration in the EC Member States. Unfortunately no complete overview of the discolouration in the EC Member States could be achieved. A number of countries did not send the discolouration data to the CEC.
When the data of discoloured trees (discolouration classes 1 - 4) are compared between the various EC Member States it can be seen that the highest percentage of discoloured trees is recorded in Portugal (43%). The lowest percentage of discoloured trees is found in Denmark (4%).
It is remarkable that the tree sample in Denmark showed a very low discolouration, while the degree of defoliation was relatively high.

TABLE 22 : Summary of National Forest Damage Inventories 1990
Discolouration in the EC Member States.

| Country | Forest Area (1000 ha) | Discolouration (0 - 10%) | (11 - 25%) | (26 - 60%) | (> 60%) | |
|---|---|---|---|---|---|---|
| BELGIE ') | 617 | 54.5/.. | 42.1/.. | 3.4/.. | 0.0/.. | |
| DANMARK | 460 | 95.9 | 3.7 | 0.4 | 0.0 | |
| DEUTSCHLAND °) | 7388 | 97.5 | 1.5 | 0.3 | 0.7 | ") |
| ELLAS | 2512 | 78.7 | 17.4 | 2.8 | 1.1 | |
| ESPANA | 11921 | 93.3 | 6.0 | 0.4 | 0.3 | |
| FRANCE | 13845 | 85.7 | 10.2 | 2.9 | 1.2 | ") |
| IRELAND | 320 | 73.6 | 24.2 | 2.2 | 0.0 | |
| ITALIA | 8675 | 78.0 | 17.9 | 2.9 | 1.2 | ") |
| LUXEMBOURG | 84 | .. | .. | .. | .. | |
| NEDERLAND | 330 | 62.1 | 35.2 | 0.4 | 2.3 | ") |
| PORTUGAL | 3060 | 57.0 | 28.2 | 9.1 | 5.7 | ") |
| UNITED KINGDOM | 2112 | 83.9 | 13.8 | 2.0 | 0.3 | |

') Flanders/Wallon region

.. Not available

°) Estimates are partly based on data from 1989 (See Par. 7.1)

") Including dead trees

## 7.4 Comparison between defoliation of broadleaves and conifers

The most damaged broadleaves (defoliation classes 2-4) have been recorded in Portugal (34.1%) and the United Kingdom (28.8%), while the least damaged broadleaves have been recorded in Spain (4.4%) (Table 23). For conifers the higest percentage of damaged trees has been recorded in the United Kingdom (45%), while the lowest percentage of damaged conifers has been found in Spain. In Portugal the highest percentage of dead trees has found for conifers.

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

In the National reports a chapter is included in which information is presented on the possible causes of observed damage on regional level. The most important possible causes mentioned are: the weather, insects, fungi, forest fires, and air pollution.

### 7.5.1 Weather in 1989/1990

The weather over the period winter 1989 - summer 1990 was in many countries dry, and relatively warm (e.g. Belgium, Federal Republic of Germany, France, The Netherlands, Portugal and the United Kingdom). In a number of places late frost is reported to be the cause for damage in (young) stands (e.g. Belgium, Spain and The Netherlands). The dry and warm summer months is mentioned as the reason for early defoliation and an accelerated discolouration through early-ageing of the leaves in Belgium, Denmark, Federal Republic of Germany, France, Greece, The Netherlands and the United Kingdom (especially *Fagus*).

TABLE 23 : Summary of National Forest Damage Inventories 1990
Defoliation for broadleaves and conifers

| Country | | Defoliation (0 - 10%) | (11 - 25%) | (26 - 60%) | (> 60%) | (Dead) |
|---|---|---|---|---|---|---|
| BELGIE ') | Broadl. | 58.8/62.9 | 36.0/25.8 | 4.7/9.0 | 0.5/2.1 | 0.0/0.2 |
| | Conifers | 34.8/43.0 | 54.5/27.0 | 10.7/21.3 | 0.0/8.4 | 0.0/0.3 |
| | Total | 45.0/54.6 | 46.6/26.3 | 8.2/14.2 | 0.2/4.7 | 0.0/0.2 |
| DANMARK | Broadl. | 27.1 | 47.5 | 24.2 | 1.2 | 0.0 |
| | Conifers | 55.7 | 25.5 | 13.5 | 4.5 | 0.8 |
| | Total | 45.3 | 33.5 | 17.4 | 3.3 | 0.5 |
| DEUTSCHLAND °) | Broadl. | 37.5 | 38.7 | 22.2 | 1.5 | 0.1 |
| | Conifers | 37.7 | 39.7 | 21.1 | 0.7 | 0.8 |
| | Total | 37.6 | 39.4 | 21.4 | 0.9 | 0.6 |
| ELLAS | Broadl. | 26.7 | 46.8 | 23.3 | 2.9 | 0.3 |
| | Conifers | 50.3 | 39.7 | 8.7 | 0.6 | 0.7 |
| | Total | 39.5 | 43.0 | 15.4 | 1.7 | 0.5 |
| ESPANA | Broadl. | 79.4 | 16.2 | 3.5 | 0.9 | 0.0 |
| | Conifers | 79.0 | 17.9 | 2.9 | 0.2 | 0.0 |
| | Total | 79.2 | 17.0 | 3.2 | 0.6 | 0.0 |
| FRANCE | Broadl. | 75.4 | 16.9 | 6.1 | 1.3 | 0.3 |
| | Conifers | 77.2 | 16.2 | 6.0 | 0.4 | 0.2 |
| | Total | 76.0 | 16.7 | 6.1 | 1.0 | 0.3 |
| IRELAND | Broadl. | - | - | - | - | - |
| | Conifers | 67.5 | 27.1 | 5.4 | 0.0 | 0.0 |
| | Total | 67.5 | 27.1 | 5.4 | 0.0 | 0.0 |
| ITALIA | Broadl. | 60.0 | 24.6 | 12.5 | 2.7 | 0.2 |
| | Conifers | 66.3 | 20.9 | 8.9 | 2.3 | 1.6 |
| | Total | 61.4 | 23.8 | 11.7 | 2.6 | 0.5 |
| LUXEMBOURG | Broadl. | . . | . . | . . | . . | . . |
| | Conifers | . . | . . | . . | . . | . . |
| | Total | . . | . . | . . | . . | . . |
| NEDERLAND | Broadl. | 57.9 | 30.6 | 8.8 | 1.6 | 1.1 |
| | Conifers | 50.4 | 28.2 | 18.3 | 2.5 | 0.6 |
| | Total | 53.1 | 29.1 | 14.8 | 2.2 | 0.8 |
| PORTUGAL | Broadl. | 49.4 | 16.5 | 29.6 | 3.3 | 1.2 |
| | Conifers | 58.6 | 15.7 | 16.7 | 0.8 | 8.2 |
| | Total | 53.1 | 16.2 | 24.4 | 2.3 | 4.0 |
| UNITED KINGDOM | Broadl. | 34.2 | 37.0 | 25.8 | 2.7 | 0.3 |
| | Conifers | 21.2 | 33.8 | 34.8 | 9.9 | 0.3 |
| | Total | 26.0 | 35.0 | 31.5 | 7.3 | 0.3 |

') Flanders/Wallon region
°) Estimates are partly data from 1989 (See Par. 7.1)
. . No data available

Greece reported severe damage (discolouration, defoliation and in some cases even dying of trees (i.e. *Abies cephalonica*) due to the long dry periods over the last years.
The storms of the winter 89/90 have in various places caused defoliation of Spruce (Belgium, Federal Republic of Germany, The Netherlands), while also root damage was reported. In southern Germany (Bavaria) large areas of forest were damaged and the United Kingdom reported that the storm resulted in the loss of trees and plots.

7.5.2 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.*)

7.5.3 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).

7.5.4 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.).

7.5.5 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.

7.5.6 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*) the Federal Republic of Germany (*Fagus*), The Netherlands (*Fagus* and *Pseudotsuga menziesii*) and the United Kingdom (*Fagus*).

7.5.7 Other possible causes of observed damage

Greece reported damage caused by overgrazing (especially in the maquis area) and areas near 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.

# 8 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 **20.8%** of the trees to be **damaged** (defoliation more than 25%). For the subsamples of the EC and the Non-EC countries, these figures were 15.1% and 35.3% respectively. Corresponding figures for the defoliation in the EC in 1987, 1988 and 1989 were 14.3%, 10.2% and 9.9% respectively.
In 1990 a **discolouration of more than 10%** was observed for **13.8%** of the trees (EC: 14.4%, Non-EC: 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.

**Conifers** were slightly more damaged than **broadleaves**. In 1990, defoliation of more than 25% was found for 24.2% of the conifers and 16.6% of the broad-leaves (EC: 15.4% and 14.9%, Non-EC: 38.4% and 25.5% respectively). Of the most common species in the survey, ***Quercus suber*** showed the **highest defoliation** in the EC and other ***Quercus*** species in the Non-EC, with respectively 41.6% and 24.8% of the trees damaged. The broadleaves ***Eucalyptus*** sp. (3% damaged) and ***Castanea sativa*** (15.4% damaged) showed the **lowest** degree of defoliation in the EC and the Non-EC countries respectively.
**Discolouration** was more pronounced in broadleaves (17.6% damaged) than conifers (10.8% damaged). For the subsample of the EC-Member States these figures were 16.2% and 12.5% respectively; in the Non-EC countries damage in terms of discolouration averaged 24.9% among broadleaves and 8.1% among conifers. The percentage of broadleaves with more than 10% discolouration was **highest** for ***Quercus suber*** (48.4%) in the EC and for other *Quercus* species in the Non-EC.
Among conifers the differences in discolouration between species were small, especially in the EC. In the Non-EC countries, *Abies* (32.5%) showed the highest discolouration, whereas *Picea* sp. (2.3%) showed the lowest discolouration.

Within the subsample of Common Sample Trees 1989-1990, **the percentage of damaged trees increased slightly** from 8.2% in 1989 to 13.4% in 1990. The largest change in damage occurred in the Mediterranean region where the percentage of damaged trees increased from 6.3% in 1989 to 13.2% in 1990. The damage increase was observed for all species, but was largest for *Quercus suber* (from 9.3% in 1989 to 41.4% in 1990). The percentage of trees remained constant only for *Quercus ilex*. Changes among coniferous species were less pronounced than among broadleaves.
Discolouration among Common Sample Trees showed no large changes over the 1989-1990 period.
The cause of the clear deterioration in health of *Quercus suber* between 1989 and 1990 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. Fluctuations in the damage classes are often inconsistent and may also reflect natural changes in crown density, for instance due to adverse weather conditions. A weak trend of **improvement** in vitality appears to occur for *Pinus* *pinaster* and *Quercus robur*. For *Quercus ilex* the improvement in crown density is clearest. *Pinus sylvestris* shows a shift towards the warning class of 11-25% defoliation; *Castanea sativa* deteriorated slightly in the Sub-atlantic zone. A clearer **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. For *Quercus pubescens* no reasons for deterioration are known.

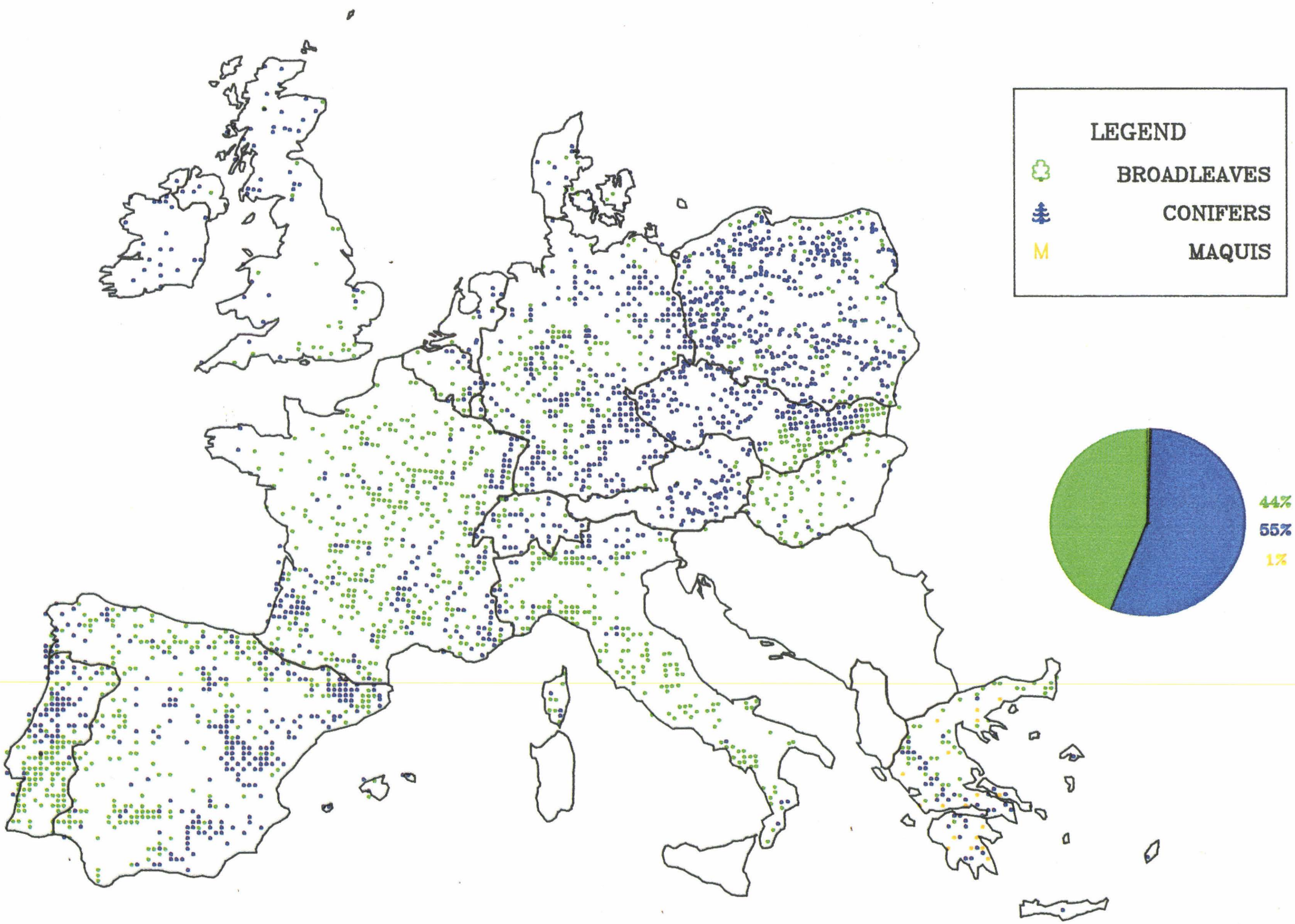
There is a major problem in **separating** changes in crown density or colouration **attributable to pollution from those caused by other factors**. However, research has indicated that air pollution in many cases plays a significant role in forest decline.

In the extended evaluation it was shown that trees in a higher **age** class appear to be more **defoliated**. The relationship between defoliation and mean stand age is different for trees of each defoliation class. Curves have been used to describe the various relationships. It is not possible to discriminate the factors underlying the observed trends.
An in-depth analysis showed that the **dynamics in defoliation** are strong, even among species that remained, on average, unchanged in defoliation. Individual trees of species *Pinus sylvestris* were compared with *Picea sitchensis*, which are known to have deteriorated in vitality over the last four years. For both species it is shown that less than 25% of the trees remained unchanged in terms of defoliation. **Most trees show yearly shifts in defoliation classes**. Even among the relatively healthy stands of *Pinus sylvestris* there appears to be a **large annual variation** in defoliation. Futher studies into these dynamics in crown density are recommended as data from more annual surveys become available.
In a separate analysis the characteristics of trees excluded from the inventory during a subsequent annual survey were studied in detail. In the data-set used, the available information did not give any plausible clue as to why the trees were excluded. The trees excluded showed characteristics similar to trees remaining.
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** and **soil properties** in future forest health surveys.

**The parameters presently recorded in the survey do not provide a complete and extensive description of site conditions**. The collection of **more detailed information** on site and stand parameters deserves high priority in order to be able to investigate the possible relationships between forest vitality and immissions of air pollutants in the forest.

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.

# BROADLEAVES AND CONIFERS




Source: 1990 EEC/ICP Inventory of Forest Damage

**Annex I-2 List of Species - 1990**

| EUROPEAN TOTAL | OBSERVED TREES | | OBSERVED PLOTS | |
|---|---|---|---|---|
| | COUNT | % | COUNT | % |
| SPECIES | | | | |
| Pinus sylvestris | 13709 | 20.36 | 814 | 14.50 |
| Picea abies | 10668 | 15.84 | 575 | 10.24 |
| Fagus sylvatica | 5650 | 8.39 | 485 | 8.64 |
| Pinus pinaster | 3761 | 5.59 | 193 | 3.44 |
| Quercus robur | 3350 | 4.98 | 337 | 6.00 |
| Quercus ilex | 3099 | 4.60 | 202 | 3.60 |
| Quercus petraea | 2091 | 3.11 | 235 | 4.19 |
| Pinus halepensis | 1871 | 2.78 | 107 | 1.91 |
| Quercus pubescens | 1578 | 2.34 | 147 | 2.62 |
| Pinus nigra | 1536 | 2.28 | 113 | 2.01 |
| Quercus suber | 1470 | 2.18 | 90 | 1.60 |
| Castanea sativa | 1338 | 1.99 | 135 | 2.41 |
| Abies alba | 1218 | 1.81 | 134 | 2.39 |
| Eucalyptus sp. | 1039 | 1.54 | 60 | 1.07 |
| Quercus pyrenaica | 903 | 1.34 | 53 | 0.94 |
| Larix decidua | 803 | 1.19 | 124 | 2.21 |
| Picea sitchensis | 839 | 1.25 | 51 | 0.91 |
| Carpinus betulus | 747 | 1.11 | 131 | 2.33 |
| Quercus cerris | 789 | 1.17 | 81 | 1.44 |
| Fraxinus excelsior | 668 | 0.99 | 133 | 2.37 |
| Quercus rotundifolia | 681 | 1.01 | 33 | 0.59 |
| Betula pendula | 594 | 0.88 | 114 | 2.03 |
| Betula pubescens | 646 | 0.96 | 51 | 0.91 |
| Robinia pseudacacia | 604 | 0.90 | 57 | 1.02 |
| Pseudotsuga menziesii | 517 | 0.77 | 47 | 0.84 |

(CONTINUED)

| EUROPEAN TOTAL | OBSERVED TREES | | OBSERVED PLOTS | |
|---|---|---|---|---|
| | COUNT | % | COUNT | % |
| SPECIES | | | | |
| Populus hybrides | 488 | 0.72 | 29 | 0.52 |
| Alnus glutinosa | 421 | 0.63 | 53 | 0.94 |
| Acer pseudoplatanus | 336 | 0.50 | 88 | 1.57 |
| Quercus faginea | 363 | 0.54 | 46 | 0.82 |
| Pinus pinea | 339 | 0.50 | 30 | 0.53 |
| Quercus frainetto | 290 | 0.43 | 18 | 0.32 |
| Pinus contorta | 286 | 0.42 | 21 | 0.37 |
| Abies cephalonica | 292 | 0.43 | 14 | 0.25 |
| Ostrya carpinifolia | 255 | 0.38 | 38 | 0.68 |
| Prunus avium | 210 | 0.31 | 77 | 1.37 |
| Quercus coccifera | 265 | 0.39 | 19 | 0.34 |
| Other broadleaves | 220 | 0.33 | 60 | 1.07 |
| Juniperus thurifera | 243 | 0.36 | 20 | 0.36 |
| Populus tremula | 175 | 0.26 | 60 | 1.07 |
| Abies borisii-regis | 185 | 0.27 | 11 | 0.20 |
| Tilia cordata | 152 | 0.23 | 32 | 0.57 |
| Pinus uncinata | 158 | 0.23 | 11 | 0.20 |
| Larix kaempferi | 149 | 0.22 | 17 | 0.30 |
| Pinus radiata | 142 | 0.21 | 9 | 0.16 |
| Acer campestre | 106 | 0.16 | 42 | 0.75 |
| Quercus rubra | 127 | 0.19 | 18 | 0.32 |
| Olea europaea | 123 | 0.18 | 18 | 0.32 |
| Fagus moesiaca | 121 | 0.18 | 6 | 0.11 |
| Populus nigra | 110 | 0.16 | 16 | 0.29 |
| Fraxinus ornus | 89 | 0.13 | 25 | 0.45 |

(CONTINUED)

| EUROPEAN TOTAL | OBSERVED TREES | | OBSERVED PLOTS | |
|---|---|---|---|---|
| | COUNT | % | COUNT | % |
| SPECIES | | | | |
| Alnus cordata | 101 | 0.15 | 8 | 0.14 |
| Pinus brutia | 101 | 0.15 | 7 | 0.12 |
| Juniperus oxycedrus | 68 | 0.10 | 18 | 0.32 |
| Platanus orientalis | 77 | 0.11 | 6 | 0.11 |
| Populus alba | 66 | 0.10 | 4 | 0.07 |
| Sorbus aria | 41 | 0.06 | 24 | 0.43 |
| Pinus cembra | 56 | 0.08 | 7 | 0.12 |
| Arbutus unedo | 53 | 0.08 | 9 | 0.16 |
| Ulmus minor | 50 | 0.07 | 10 | 0.18 |
| Pinus strobus | 54 | 0.08 | 5 | 0.09 |
| Acer monspessulanum | 41 | 0.06 | 15 | 0.27 |
| Juniperus phoenicea | 44 | 0.07 | 9 | 0.16 |
| Salix caprea | 36 | 0.05 | 15 | 0.27 |
| Populus canescens | 45 | 0.07 | 4 | 0.07 |
| Quercus trojana | 44 | 0.07 | 5 | 0.09 |
| Sorbus aucuparia | 31 | 0.05 | 13 | 0.23 |
| Juniperus communis | 34 | 0.05 | 9 | 0.16 |
| Salix sp. | 30 | 0.04 | 11 | 0.20 |
| Phillyrea latifolia | 32 | 0.05 | 7 | 0.12 |
| Cupressus sempervirens | 32 | 0.05 | 6 | 0.11 |
| Abies nordmanniana | 35 | 0.05 | 3 | 0.05 |
| Sorbus torminalis | 19 | 0.03 | 17 | 0.30 |
| Tilia platyphyllos | 29 | 0.04 | 7 | 0.12 |
| Other conifers | 26 | 0.04 | 6 | 0.11 |
| Corylus avellana | 21 | 0.03 | 9 | 0.16 |

(CONTINUED)

| EUROPEAN TOTAL | OBSERVED TREES | | OBSERVED PLOTS | |
|---|---|---|---|---|
| | COUNT | % | COUNT | % |
| SPECIES | | | | |
| Ulmus glabra | 17 | 0.03 | 13 | 0.23 |
| Buxus sempervirens | 24 | 0.04 | 5 | 0.09 |
| Acer platanoides | 17 | 0.03 | 11 | 0.20 |
| Pinus mugo | 24 | 0.04 | 1 | 0.02 |
| Arbutus andrachne | 22 | 0.03 | 2 | 0.04 |
| Quercus macrolepsis | 21 | 0.03 | 1 | 0.02 |
| Sorbus domestica | 13 | 0.02 | 8 | 0.14 |
| Acer opalus | 13 | 0.02 | 8 | 0.14 |
| Pyrus communis | 14 | 0.02 | 7 | 0.12 |
| Ilex aquifolium | 14 | 0.02 | 6 | 0.11 |
| Quercus fruticosa | 18 | 0.03 | 1 | 0.02 |
| Carpinus orientalis | 14 | 0.02 | 4 | 0.07 |
| Phillyrea augustifolia | 17 | 0.03 | 1 | 0.02 |
| Rhamnus alaternus | 14 | 0.02 | 1 | 0.02 |
| Alnus viridis | 11 | 0.02 | 2 | 0.04 |
| Cercis siliquastrum | 11 | 0.02 | 2 | 0.04 |
| Tsuga sp. | 11 | 0.02 | 1 | 0.02 |
| Fagus orientalis | 11 | 0.02 | 1 | 0.02 |
| Pinus leucodermis | 11 | 0.02 | 1 | 0.02 |
| Salix alba | 6 | 0.01 | 5 | 0.09 |
| Pistacia terebinthus | 10 | 0.01 | 1 | 0.02 |
| Abies grandis | 6 | 0.01 | 2 | 0.04 |
| Alnus incana | 6 | 0.01 | 2 | 0.04 |
| Salix eleagnos | 6 | 0.01 | 2 | 0.04 |
| Prunus dulcis | 7 | 0.01 | 1 | 0.02 |

(CONTINUED)

| EUROPEAN TOTAL | OBSERVED TREES | | OBSERVED PLOTS | |
|---|---|---|---|---|
| | COUNT | % | COUNT | % |
| SPECIES | | | | |
| Thuya sp. | 4 | 0.01 | 1 | 0.02 |
| Juniperus sabina | 4 | 0.01 | 1 | 0.02 |
| Taxus baccata | 2 | 0.00 | 2 | 0.04 |
| Pistacia lentiscus | 2 | 0.00 | 1 | 0.02 |
| Cedrus atlantica | 1 | 0.00 | 1 | 0.02 |
| Fraxinus angustifolia | 1 | 0.00 | 1 | 0.02 |
| Juglans regia | 1 | 0.00 | 1 | 0.02 |
| Ceratonia siliqua | 1 | 0.00 | 1 | 0.02 |
| Prunus serotina | 1 | 0.00 | 1 | 0.02 |
| TOTAL SPECIES | 67335 | 100.00 | 5613 | 100.00 |

**Annex I-3** **Defoliation by species group and climatic region - 1990**

| TOTAL CLIMATIC REGIONS EC | DEFOLIATION | | | | | |
|---|---|---|---|---|---|---|
| | NONE | SLIGHT | MODERATE | SEVERE | DEAD | TOTAL |
| | % | % | % | % | % | % |
| SPECIES | | | | | | |
| Castanea sativa | 69.05 | 17.76 | 9.83 | 2.52 | 0.84 | 100.00 |
| Eucalyptus sp. | 91.43 | 5.58 | 1.73 | 0.29 | 0.96 | 100.00 |
| Fagus sp. | 57.45 | 28.47 | 13.01 | 1.00 | 0.07 | 100.00 |
| Quercus (deciduous) sp | 62.13 | 24.59 | 11.01 | 1.46 | 0.81 | 100.00 |
| Quercus ilex | 75.70 | 21.04 | 2.84 | 0.10 | 0.32 | 100.00 |
| Quercus suber | 39.59 | 18.78 | 36.60 | 4.76 | 0.27 | 100.00 |
| Other broadleaves | 56.80 | 24.07 | 15.56 | 2.83 | 0.74 | 100.00 |
| TOTAL BROADLEAVES | 61.88 | 23.20 | 12.57 | 1.77 | 0.59 | 100.00 |
| Abies sp. | 53.61 | 27.57 | 16.51 | 1.46 | 0.84 | 100.00 |
| Larix sp. | 64.31 | 23.62 | 11.17 | 0.51 | 0.39 | 100.00 |
| Picea sp. | 44.74 | 34.01 | 19.23 | 1.89 | 0.12 | 100.00 |
| Pinus sp. | 61.81 | 25.20 | 11.02 | 1.09 | 0.88 | 100.00 |
| Other conifers | 68.89 | 17.15 | 12.73 | 1.23 | . | 100.00 |
| TOTAL CONIFERS | 57.44 | 27.16 | 13.47 | 1.30 | 0.63 | 100.00 |
| TOTAL | 59.77 | 25.08 | 13.00 | 1.55 | 0.61 | 100.00 |

| TOTAL CLIMATIC REGIONS NON-EEC | DEFOLIATION | | | | | |
|---|---|---|---|---|---|---|
| | NONE | SLIGHT | MODERATE | SEVERE | DEAD | TOTAL |
| | % | % | % | % | % | % |
| SPECIES | | | | | | |
| Castanea sativa | 65.38 | 19.23 | . | . | 15.38 | 100.00 |
| Fagus sp. | 39.82 | 42.71 | 16.58 | 0.69 | 0.19 | 100.00 |
| Quercus (deciduous) sp | 33.45 | 41.76 | 22.58 | 1.18 | 1.04 | 100.00 |
| Other broadleaves | 37.62 | 28.43 | 25.67 | 6.99 | 1.29 | 100.00 |
| TOTAL BROADLEAVES | 37.24 | 37.32 | 21.50 | 3.03 | 0.92 | 100.00 |
| Abies sp. | 12.21 | 30.88 | 47.24 | 8.99 | 0.69 | 100.00 |
| Larix sp. | 54.34 | 26.59 | 17.92 | 1.16 | . | 100.00 |
| Picea sp. | 40.47 | 25.28 | 29.40 | 3.90 | 0.95 | 100.00 |
| Pinus sp. | 13.79 | 45.25 | 37.97 | 2.87 | 0.11 | 100.00 |
| Other conifers | 91.67 | 8.33 | . | . | . | 100.00 |
| TOTAL CONIFERS | 25.00 | 36.55 | 34.54 | 3.45 | 0.46 | 100.00 |
| TOTAL | 28.04 | 36.74 | 31.31 | 3.34 | 0.58 | 100.00 |

| ATLANTIC EC | DEFOLIATION | | | | | TOTAL |
|---|---|---|---|---|---|---|
| | NONE | SLIGHT | MODERATE | SEVERE | DEAD | |
| | % | % | % | % | % | % |
| SPECIES | | | | | | |
| Castanea sativa | 82.92 | 11.46 | 3.75 | 0.83 | 1.04 | 100.00 |
| Eucalyptus sp. | 88.52 | 7.38 | 1.64 | . | 2.46 | 100.00 |
| Fagus sp. | 49.59 | 32.72 | 16.67 | 1.03 | . | 100.00 |
| Quercus (deciduous) sp | 72.94 | 17.07 | 7.41 | 1.43 | 1.15 | 100.00 |
| Quercus ilex | 100.00 | . | . | . | . | 100.00 |
| Other broadleaves | 60.77 | 23.50 | 11.57 | 3.20 | 0.95 | 100.00 |
| TOTAL BROADLEAVES | 68.22 | 19.80 | 9.12 | 1.87 | 0.99 | 100.00 |
| Abies sp. | 69.61 | 22.55 | 5.88 | 0.98 | 0.98 | 100.00 |
| Larix sp. | 47.24 | 37.80 | 13.39 | 0.79 | 0.79 | 100.00 |
| Picea sp. | 42.26 | 26.93 | 23.67 | 6.91 | 0.24 | 100.00 |
| Pinus sp. | 61.93 | 22.94 | 11.32 | 1.87 | 1.94 | 100.00 |
| Other conifers | 42.90 | 21.77 | 32.18 | 3.15 | . | 100.00 |
| TOTAL CONIFERS | 55.21 | 24.31 | 15.93 | 3.24 | 1.31 | 100.00 |
| TOTAL | 62.03 | 21.94 | 12.35 | 2.53 | 1.14 | 100.00 |

| SUB-ATLANTIC EC | DEFOLIATION | | | | | TOTAL |
|---|---|---|---|---|---|---|
| | NONE | SLIGHT | MODERATE | SEVERE | DEAD | |
| | % | % | % | % | % | % |
| SPECIES | | | | | | |
| Castanea sativa | 53.04 | 27.01 | 16.06 | 3.16 | 0.73 | 100.00 |
| Fagus sp. | 48.66 | 33.05 | 17.26 | 1.03 | . | 100.00 |
| Quercus (deciduous) sp | 63.94 | 23.52 | 11.20 | 1.20 | 0.13 | 100.00 |
| Other broadleaves | 59.17 | 23.24 | 14.44 | 3.06 | 0.09 | 100.00 |
| TOTAL BROADLEAVES | 56.77 | 26.83 | 14.48 | 1.81 | 0.11 | 100.00 |
| Abies sp. | 50.35 | 22.36 | 25.18 | 1.94 | 0.18 | 100.00 |
| Larix sp. | 58.16 | 24.04 | 16.62 | 0.89 | 0.30 | 100.00 |
| Picea sp. | 44.15 | 36.20 | 19.07 | 0.51 | 0.08 | 100.00 |
| Pinus sp. | 41.32 | 38.60 | 18.31 | 1.71 | 0.06 | 100.00 |
| Other conifers | 79.91 | 17.47 | 2.62 | . | . | 100.00 |
| TOTAL CONIFERS | 44.93 | 35.26 | 18.63 | 1.09 | 0.08 | 100.00 |
| TOTAL | 50.38 | 31.38 | 16.72 | 1.42 | 0.10 | 100.00 |

| SUB-ATLANTIC NON-EEC | DEFOLIATION | | | | | TOTAL |
|---|---|---|---|---|---|---|
| | NONE | SLIGHT | MODERATE | SEVERE | DEAD | |
| | %. | % | % | % | % | % |
| SPECIES | | | | | | |
| Castanea sativa | 65.38 | 19.23 | . | . | 15.38 | 100.00 |
| Fagus sp. | 39.92 | 42.31 | 16.99 | 0.65 | 0.13 | 100.00 |
| Quercus (deciduous) sp | 33.45 | 41.76 | 22.58 | 1.18 | 1.04 | 100.00 |
| Other broadleaves | 37.69 | 28.36 | 25.66 | 7.00 | 1.29 | 100.00 |
| TOTAL BROADLEAVES | 37.27 | 37.12 | 21.67 | 3.03 | 0.90 | 100.00 |
| Abies sp. | 12.06 | 29.79 | 48.23 | 9.22 | 0.71 | 100.00 |
| Larix sp. | 50.56 | 23.60 | 23.60 | 2.25 | . | 100.00 |
| Picea sp. | 35.67 | 25.32 | 33.73 | 4.64 | 0.64 | 100.00 |
| Pinus sp. | 13.64 | 45.31 | 38.07 | 2.88 | 0.10 | 100.00 |
| Other conifers | 91.67 | 8.33 | . | . | . | 100.00 |
| TOTAL CONIFERS | 21.60 | 37.64 | 36.75 | 3.70 | 0.31 | 100.00 |
| TOTAL | 25.75 | 37.50 | 32.76 | 3.52 | 0.47 | 100.00 |

| MOUNTAINOUS EC | DEFOLIATION | | | | | TOTAL |
|---|---|---|---|---|---|---|
| | NONE | SLIGHT | MODERATE | SEVERE | DEAD | |
| | % | % | % | % | % | % |
| SPECIES | | | | | | |
| Fagus sp. | 75.15 | 21.86 | 2.99 | . | . | 100.00 |
| Quercus (deciduous) sp | 71.87 | 28.12 | . | . | . | 100.00 |
| Other broadleaves | 72.93 | 15.47 | 10.50 | 0.55 | 0.55 | 100.00 |
| TOTAL BROADLEAVES | 74.22 | 20.11 | 5.30 | 0.18 | 0.18 | 100.00 |
| Abies sp. | 80.91 | 10.91 | 4.55 | 1.82 | 1.82 | 100.00 |
| Larix sp. | 77.15 | 17.88 | 4.64 | . | 0.33 | 100.00 |
| Picea sp. | 51.35 | 36.58 | 11.53 | 0.36 | 0.18 | 100.00 |
| Pinus sp. | 75.34 | 17.48 | 4.20 | 0.41 | 2.57 | 100.00 |
| Other conifers | 64.71 | 29.41 | . | 5.88 | . | 100.00 |
| TOTAL CONIFERS | 68.18 | 23.40 | 6.62 | 0.46 | 1.34 | 100.00 |
| TOTAL | 69.63 | 22.61 | 6.30 | 0.40 | 1.06 | 100.00 |

| MOUNTAINOUS NON-EEC | DEFOLIATION | | | | | TOTAL |
|---|---|---|---|---|---|---|
| | NONE | SLIGHT | MODERATE | SEVERE | DEAD | |
| | % | % | % | % | % | % |
| SPECIES | | | | | | |
| Fagus sp. | 36.36 | 56.82 | 2.27 | 2.27 | 2.27 | 100.00 |
| Other broadleaves | . | 66.67 | 33.33 | . | . | 100.00 |
| TOTAL BROADLEAVES | 34.04 | 57.45 | 4.26 | 2.13 | 2.13 | 100.00 |
| Abies sp. | 18.18 | 72.73 | 9.09 | . | . | 100.00 |
| Larix sp. | 58.33 | 29.76 | 11.90 | . | . | 100.00 |
| Picea sp. | 58.36 | 25.17 | 13.25 | 1.16 | 2.07 | 100.00 |
| Pinus sp. | 57.14 | 28.57 | 10.71 | . | 3.57 | 100.00 |
| TOTAL CONIFERS | 58.00 | 25.92 | 13.07 | 1.05 | 1.95 | 100.00 |
| TOTAL | 57.18 | 27.00 | 12.77 | 1.09 | 1.96 | 100.00 |

| MEDITERRANEAN | DEFOLIATION | | | | | |
|---|---|---|---|---|---|---|
| | NONE | SLIGHT | MODERATE | SEVERE | DEAD | TOTAL |
| | % | % | % | % | % | % |
| SPECIES | | | | | | |
| Castanea sativa | 68.88 | 15.91 | 10.69 | 3.80 | 0.71 | 100.00 |
| Eucalyptus sp. | 91.82 | 5.34 | 1.74 | 0.33 | 0.76 | 100.00 |
| Fagus sp. | 78.01 | 16.76 | 3.63 | 1.28 | 0.32 | 100.00 |
| Quercus (deciduous) sp | 51.74 | 31.57 | 13.96 | 1.69 | 1.05 | 100.00 |
| Quercus ilex | 75.57 | 21.16 | 2.86 | 0.10 | 0.32 | 100.00 |
| Quercus suber | 39.59 | 18.78 | 36.60 | 4.76 | 0.27 | 100.00 |
| Other broadleaves | 51.12 | 25.73 | 19.44 | 2.55 | 1.16 | 100.00 |
| TOTAL BROADLEAVES | 61.64 | 22.64 | 13.23 | 1.78 | 0.71 | 100.00 |
| Abies sp. | 48.28 | 37.74 | 11.69 | 0.96 | 1.34 | 100.00 |
| Larix sp. | 92.31 | 7.69 | . | . | . | 100.00 |
| Picea sp. | 97.06 | 2.94 | . | . | . | 100.00 |
| Pinus sp. | 70.45 | 20.35 | 8.01 | 0.53 | 0.66 | 100.00 |
| Other conifers | 82.97 | 12.90 | 3.89 | 0.24 | . | 100.00 |
| TOTAL CONIFERS | 69.79 | 21.01 | 7.99 | 0.54 | 0.66 | 100.00 |
| TOTAL | 64.83 | 22.00 | 11.18 | 1.29 | 0.69 | 100.00 |

## Annex I-4 Discolouration by species group and climatic region - 1990

| TOTAL CLIMATIC REGIONS EC | DISCOLOURATION | | | | | TOTAL |
|---|---|---|---|---|---|---|
| | NONE | SLIGHT | MODERATE | SEVERE | DEAD | |
| | % | % | % | % | % | % |
| SPECIES | | | | | | |
| Castanea sativa | 81.71 | 13.19 | 3.28 | 0.99 | 0.84 | 100.00 |
| Eucalyptus sp. | 95.00 | 3.66 | 0.38 | . | 0.96 | 100.00 |
| Fagus sp. | 88.76 | 9.02 | 1.69 | 0.45 | 0.07 | 100.00 |
| Quercus (deciduous) sp | 86.45 | 10.31 | 1.89 | 0.55 | 0.81 | 100.00 |
| Quercus ilex | 97.61 | 1.81 | 0.13 | 0.13 | 0.32 | 100.00 |
| Quercus suber | 51.56 | 32.31 | 12.99 | 2.86 | 0.27 | 100.00 |
| Other broadleaves | 77.11 | 16.44 | 4.34 | 1.38 | 0.74 | 100.00 |
| TOTAL BROADLEAVES | 83.84 | 11.81 | 2.93 | 0.83 | 0.59 | 100.00 |
| Abies sp. | 80.26 | 15.36 | 3.30 | 0.23 | 0.84 | 100.00 |
| Larix sp. | 92.43 | 6.03 | 0.90 | 0.26 | 0.39 | 100.00 |
| Picea sp. | 93.35 | 5.06 | 0.99 | 0.49 | 0.12 | 100.00 |
| Pinus sp. | 85.01 | 11.84 | 1.94 | 0.33 | 0.88 | 100.00 |
| Other conifers | 95.17 | 4.21 | 0.62 | . | . | 100.00 |
| TOTAL CONIFERS | 87.52 | 9.81 | 1.69 | 0.35 | 0.63 | 100.00 |
| TOTAL | 85.59 | 10.86 | 2.34 | 0.60 | 0.61 | 100.00 |

| TOTAL CLIMATIC REGIONS NON-EEC | DISCOLOURATION | | | | | TOTAL |
|---|---|---|---|---|---|---|
| | NONE | SLIGHT | MODERATE | SEVERE | DEAD | |
| | % | % | % | % | % | % |
| SPECIES | | | | | | |
| Castanea sativa | 84.62 | . | . | . | 15.38 | 100.00 |
| Fagus sp. | 84.67 | 11.93 | 3.08 | 0.13 | 0.19 | 100.00 |
| Quercus (deciduous) sp | 76.25 | 18.70 | 3.67 | 0.35 | 1.04 | 100.00 |
| Other broadleaves | 64.71 | 21.81 | 10.97 | 1.23 | 1.29 | 100.00 |
| TOTAL BROADLEAVES | 75.14 | 17.38 | 5.99 | 0.58 | 0.92 | 100.00 |
| Abies sp. | 67.51 | 17.97 | 11.98 | 1.84 | 0.69 | 100.00 |
| Larix sp. | 95.95 | 3.47 | 0.58 | . | . | 100.00 |
| Picea sp. | 97.67 | 0.54 | 0.25 | 0.60 | 0.95 | 100.00 |
| Pinus sp. | 89.03 | 7.83 | 2.79 | 0.24 | 0.11 | 100.00 |
| Other conifers | 100.00 | . | . | . | . | 100.00 |
| TOTAL CONIFERS | 91.93 | 5.15 | 2.02 | 0.43 | 0.46 | 100.00 |
| TOTAL | 87.77 | 8.19 | 3.01 | 0.46 | 0.58 | 100.00 |

| ATLANTIC | DISCOLOURATION | | | | | |
|---|---|---|---|---|---|---|
| | NONE | SLIGHT | MODERATE | SEVERE | DEAD | TOTAL |
| | % | % | % | % | % | % |
| SPECIES | | | | | | |
| Castanea sativa | 82.29 | 11.46 | 4.17 | 1.04 | 1.04 | 100.00 |
| Eucalyptus sp. | 97.54 | . | . | . | 2.46 | 100.00 |
| Fagus sp. | 79.01 | 15.23 | 4.73 | 1.03 | . | 100.00 |
| Quercus (deciduous) sp | 88.91 | 7.20 | 1.96 | 0.78 | 1.15 | 100.00 |
| Quercus ilex | 94.12 | . | 5.88 | . | . | 100.00 |
| Other broadleaves | 83.86 | 10.86 | 3.26 | 1.07 | 0.95 | 100.00 |
| TOTAL BROADLEAVES | 85.97 | 9.33 | 2.81 | 0.90 | 0.99 | 100.00 |
| Abies sp. | 86.27 | 8.82 | 3.92 | . | 0.98 | 100.00 |
| Larix sp. | 92.13 | 5.51 | 1.57 | . | 0.79 | 100.00 |
| Picea sp. | 88.09 | 9.61 | 1.75 | 0.32 | 0.24 | 100.00 |
| Pinus sp. | 83.85 | 12.81 | 1.22 | 0.17 | 1.94 | 100.00 |
| Other conifers | 94.64 | 4.42 | 0.95 | . | . | 100.00 |
| TOTAL CONIFERS | 85.97 | 11.12 | 1.41 | 0.19 | 1.31 | 100.00 |
| TOTAL | 85.97 | 10.18 | 2.14 | 0.56 | 1.14 | 100.00 |

| SUB-ATLANTIC EC | DISCOLOURATION NONE | SLIGHT | MODERATE | SEVERE | DEAD | TOTAL |
|---|---|---|---|---|---|---|
| | % | % | % | % | % | % |
| SPECIES | | | | | | |
| Castanea sativa | 81.02 | 16.06 | 1.22 | 0.97 | 0.73 | 100.00 |
| Fagus sp. | 92.40 | 5.71 | 1.40 | 0.49 | . | 100.00 |
| Quercus (deciduous) sp | 91.12 | 7.18 | 1.29 | 0.27 | 0.13 | 100.00 |
| Other broadleaves | 81.81 | 12.87 | 4.07 | 1.16 | 0.09 | 100.00 |
| TOTAL BROADLEAVES | 88.20 | 8.89 | 2.15 | 0.65 | 0.11 | 100.00 |
| Abies sp. | 91.37 | 6.16 | 2.11 | 0.18 | 0.18 | 100.00 |
| Larix sp. | 94.96 | 3.86 | 0.89 | . | 0.30 | 100.00 |
| Picea sp. | 95.82 | 2.88 | 0.69 | 0.54 | 0.08 | 100.00 |
| Pinus sp. | 91.77 | 6.32 | 1.71 | 0.14 | 0.06 | 100.00 |
| Other conifers | 96.51 | 2.18 | 1.31 | . | . | 100.00 |
| TOTAL CONIFERS | 93.86 | 4.51 | 1.22 | 0.32 | 0.08 | 100.00 |
| TOTAL | 91.26 | 6.53 | 1.65 | 0.47 | 0.10 | 100.00 |

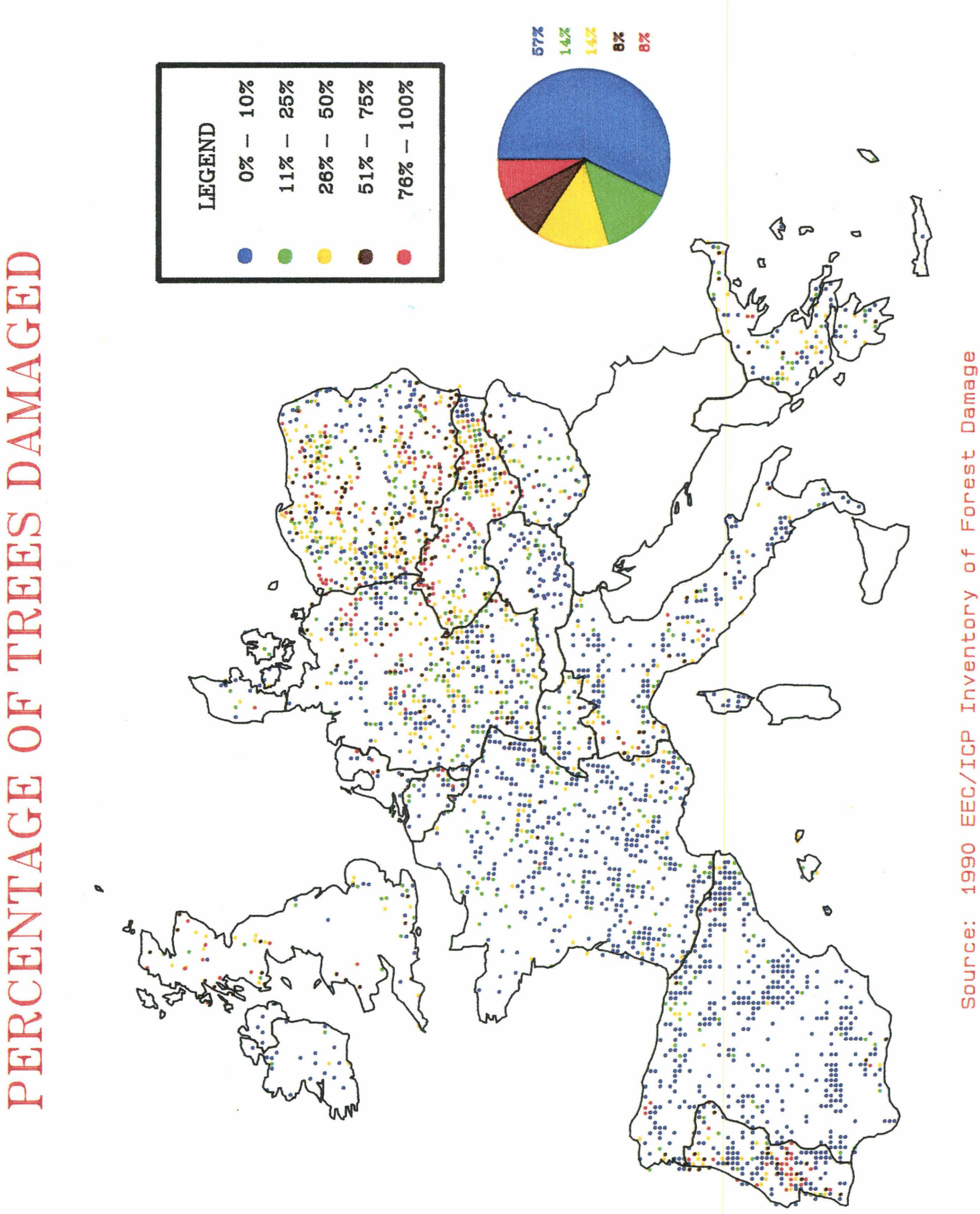
| SUB-ATLANTIC NON-EEC | DISCOLOURATION NONE | SLIGHT | MODERATE | SEVERE | DEAD | TOTAL |
|---|---|---|---|---|---|---|
| | % | % | % | % | % | % |
| SPECIES | | | | | | |
| Castanea sativa | 84.62 | . | . | . | 15.38 | 100.00 |
| Fagus sp. | 84.30 | 12.27 | 3.17 | 0.13 | 0.13 | 100.00 |
| Quercus (deciduous) sp | 76.25 | 18.70 | 3.67 | 0.35 | 1.04 | 100.00 |
| Other broadleaves | 64.64 | 21.85 | 10.99 | 1.23 | 1.29 | 100.00 |
| TOTAL BROADLEAVES | 74.91 | 17.56 | 6.05 | 0.58 | 0.90 | 100.00 |
| Abies sp. | 67.85 | 17.26 | 12.29 | 1.89 | 0.71 | 100.00 |
| Larix sp. | 92.13 | 6.74 | 1.12 | . | . | 100.00 |
| Picea sp. | 98.29 | 0.60 | 0.31 | 0.16 | 0.64 | 100.00 |
| Pinus sp. | 89.07 | 7.78 | 2.80 | 0.24 | 0.10 | 100.00 |
| Other conifers | 100.00 | . | . | . | . | 100.00 |
| TOTAL CONIFERS | 91.63 | 5.57 | 2.23 | 0.26 | 0.31 | 100.00 |
| TOTAL | 87.20 | 8.74 | 3.24 | 0.35 | 0.47 | 100.00 |

| MOUNTAINOUS EC | DISCOLOURATION | | | | | TOTAL |
|---|---|---|---|---|---|---|
| | NONE | SLIGHT | MODERATE | SEVERE | DEAD | |
| | % | % | % | % | % | % |
| SPECIES | | | | | | |
| Fagus sp. | 79.94 | 18.56 | 1.50 | . | . | 100.00 |
| Quercus (deciduous) sp | 81.25 | 15.63 | 3.12 | . | . | 100.00 |
| Other broadleaves | 81.77 | 7.73 | 9.94 | . | 0.55 | 100.00 |
| TOTAL BROADLEAVES | 80.62 | 14.81 | 4.39 | . | 0.18 | 100.00 |
| Abies sp. | 90.00 | 7.27 | 0.91 | . | 1.82 | 100.00 |
| Larix sp. | 89.40 | 8.94 | 0.66 | 0.66 | 0.33 | 100.00 |
| Picea sp. | 87.57 | 10.27 | 1.44 | 0.54 | 0.18 | 100.00 |
| Pinus sp. | 80.62 | 16.12 | 0.54 | 0.14 | 2.57 | 100.00 |
| Other conifers | 100.00 | . | . | . | . | 100.00 |
| TOTAL CONIFERS | 85.19 | 12.25 | 0.87 | 0.35 | 1.34 | 100.00 |
| TOTAL | 84.09 | 12.87 | 1.72 | 0.26 | 1.06 | 100.00 |

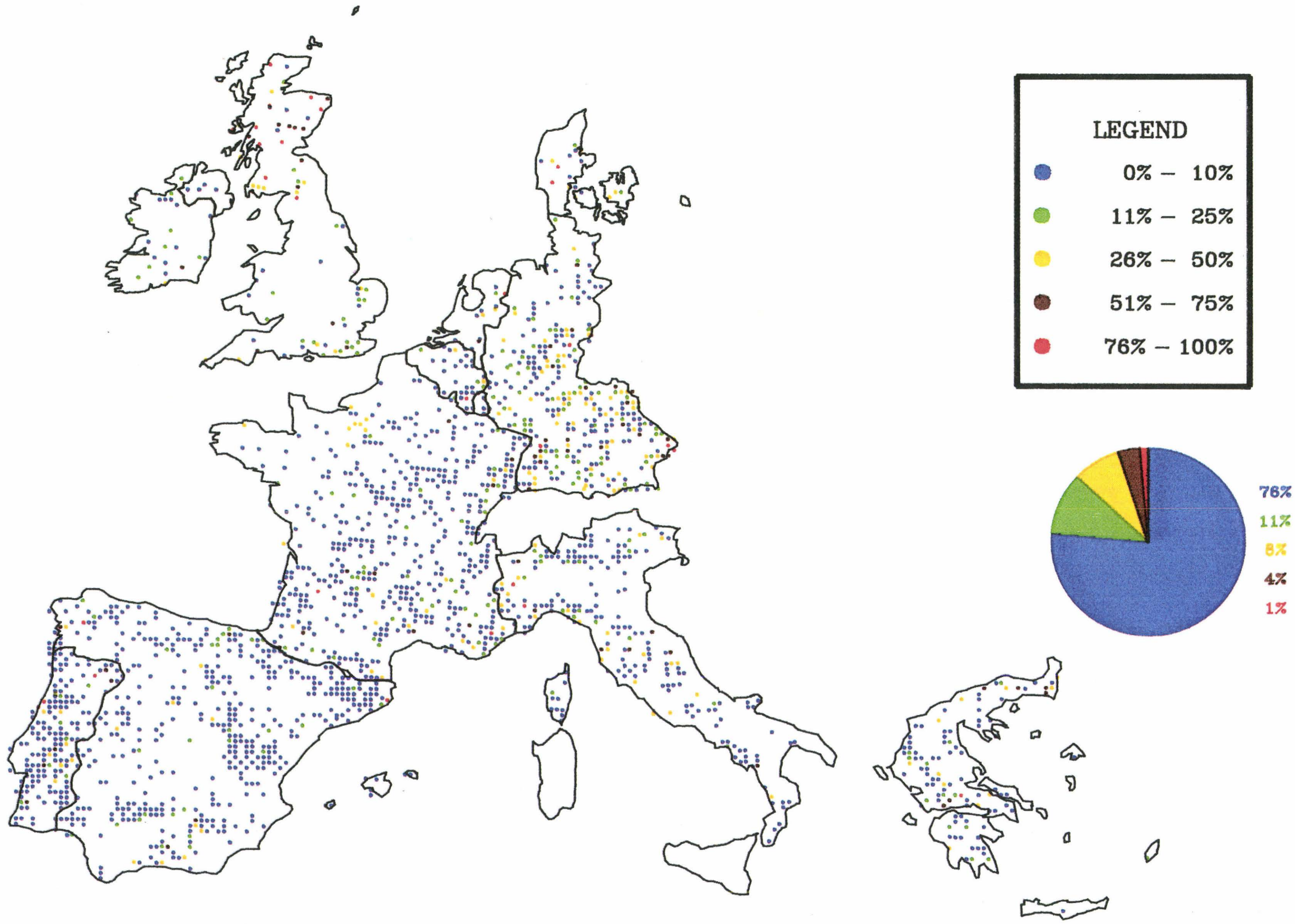
| MOUNTAINOUS NON-EEC | DISCOLOURATION | | | | TOTAL |
|---|---|---|---|---|---|
| | NONE | SLIGHT | SEVERE | DEAD | |
| | % | % | % | % | % |
| SPECIES | | | | | |
| Fagus sp. | 97.73 | . | . | 2.27 | 100.00 |
| Other broadleaves | 100.00 | . | . | . | 100.00 |
| TOTAL BROADLEAVES | 97.87 | . | . | 2.13 | 100.00 |
| Abies sp. | 54.55 | 45.45 | . | . | 100.00 |
| Larix sp. | 100.00 | . | . | . | 100.00 |
| Picea sp. | 95.36 | 0.33 | 2.24 | 2.07 | 100.00 |
| Pinus sp. | 75.00 | 21.43 | . | 3.57 | 100.00 |
| TOTAL CONIFERS | 94.89 | 1.13 | 2.03 | 1.95 | 100.00 |
| TOTAL | 94.99 | 1.09 | 1.96 | 1.96 | 100.00 |

| MEDITERRANEAN | DISCOLOURATION | | | | | TOTAL |
|---|---|---|---|---|---|---|
| | NONE | SLIGHT | MODERATE | SEVERE | DEAD | |
| | % | % | % | % | % | % |
| SPECIES | | | | | | |
| Castanea sativa | 81.71 | 12.35 | 4.28 | 0.95 | 0.71 | 100.00 |
| Eucalyptus sp. | 94.66 | 4.14 | 0.44 | . | 0.76 | 100.00 |
| Fagus sp. | 87.51 | 10.99 | 0.96 | 0.21 | 0.32 | 100.00 |
| Quercus (deciduous) sp | 80.94 | 15.18 | 2.26 | 0.57 | 1.05 | 100.00 |
| Quercus ilex | 97.63 | 1.82 | 0.10 | 0.13 | 0.32 | 100.00 |
| Quercus suber | 51.56 | 32.31 | 12.99 | 2.86 | 0.27 | 100.00 |
| Other broadleaves | 68.48 | 23.65 | 4.86 | 1.85 | 1.16 | 100.00 |
| TOTAL BROADLEAVES | 80.54 | 14.43 | 3.38 | 0.94 | 0.71 | 100.00 |
| Abies sp. | 64.94 | 28.35 | 4.98 | 0.38 | 1.34 | 100.00 |
| Larix sp. | 100.00 | . | . | . | . | 100.00 |
| Picea sp. | 97.06 | 2.94 | . | . | . | 100.00 |
| Pinus sp. | 82.62 | 13.70 | 2.50 | 0.51 | 0.66 | 100.00 |
| Other conifers | 94.65 | 5.35 | . | . | . | 100.00 |
| TOTAL CONIFERS | 82.17 | 14.16 | 2.52 | 0.48 | 0.66 | 100.00 |
| TOTAL | 81.18 | 14.33 | 3.04 | 0.76 | 0.69 | 100.00 |

**Annex I-5** **Percentage of trees damaged - 1987, 1988, 1989 and 1990**

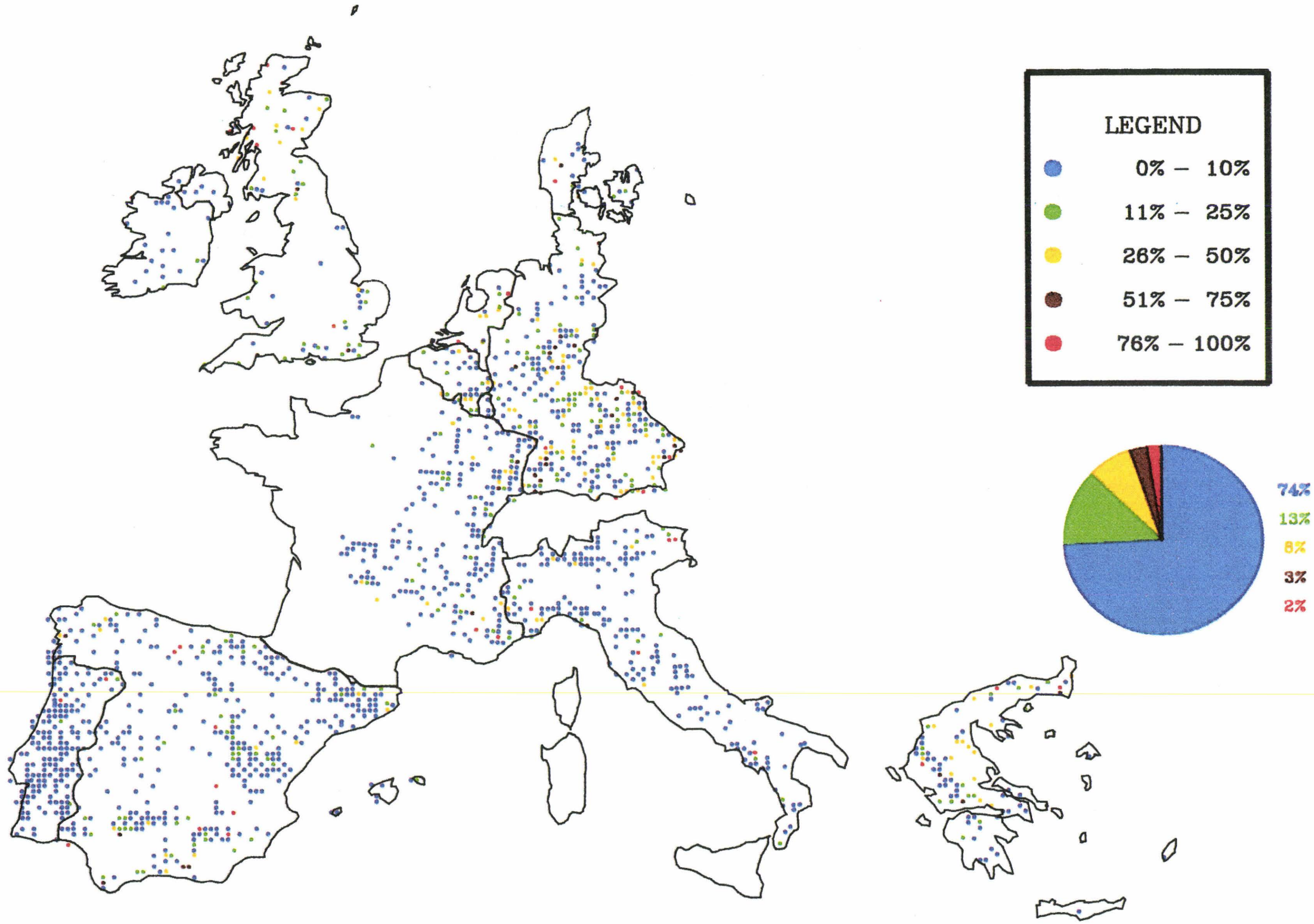


# PERCENTAGE OF TREES DAMAGED



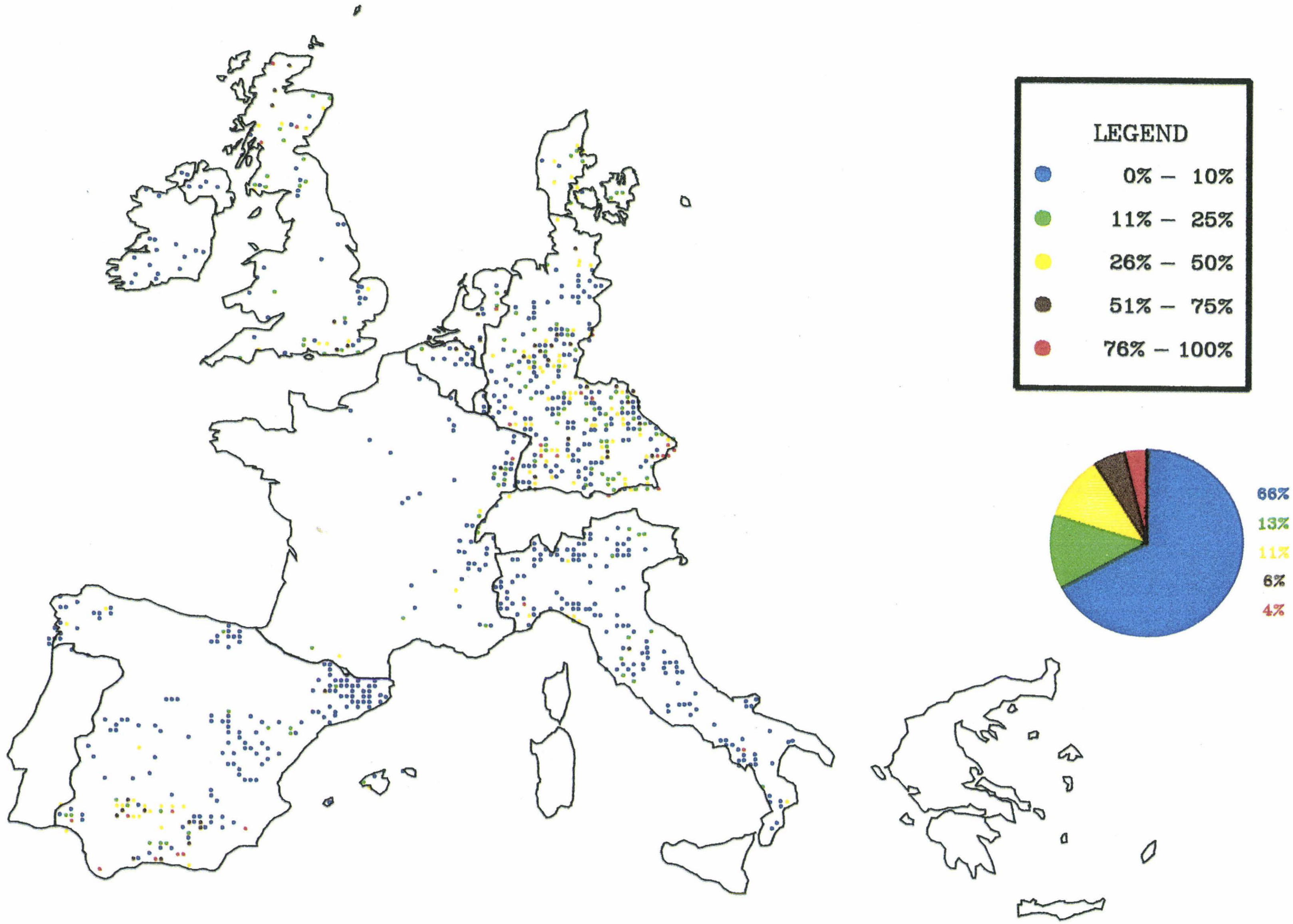

Source: 1989 Community Inventory of Forest Damage

# PERCENTAGE OF TREES DAMAGED



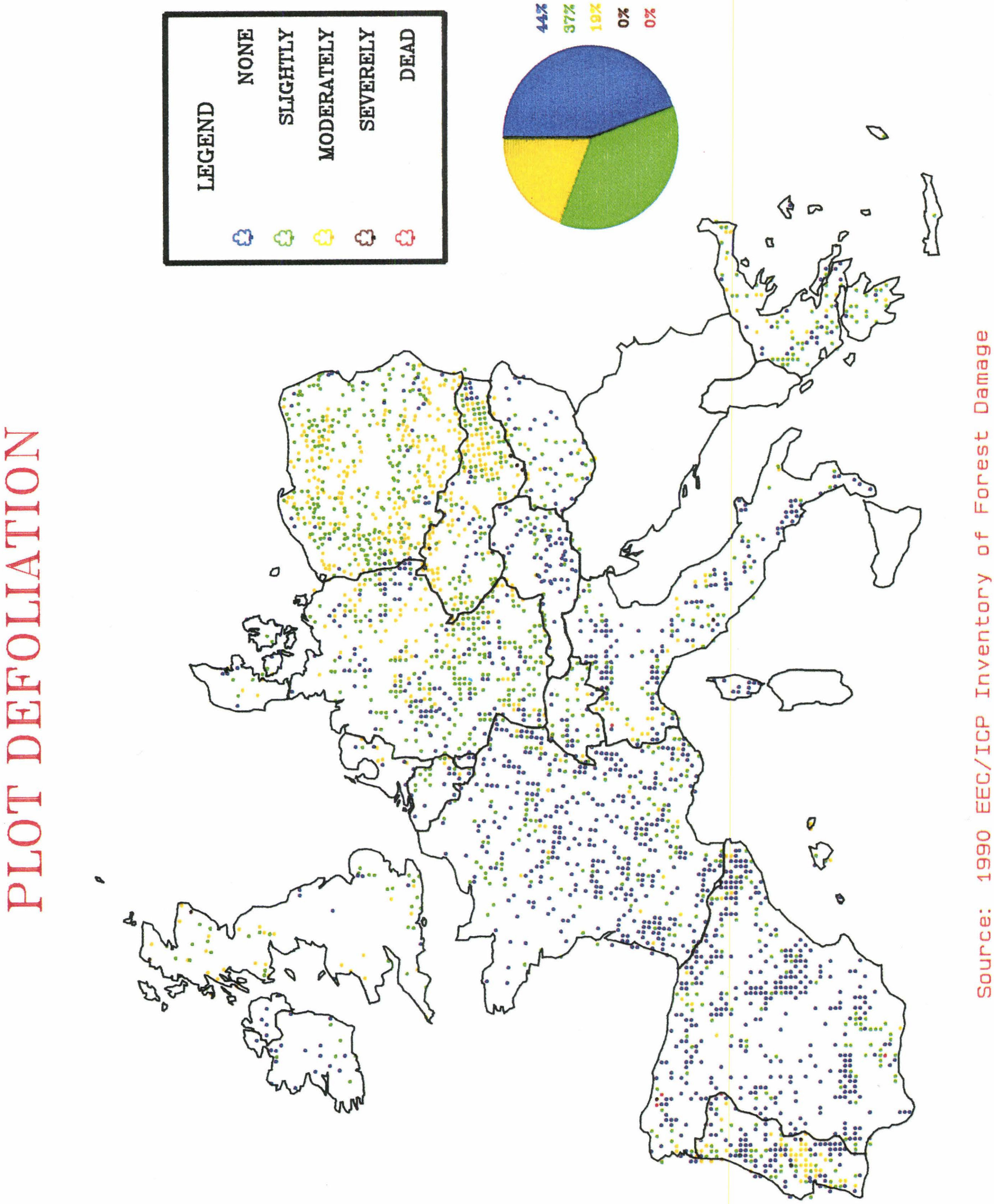

Source: 1988 Community Inventory of Forest Damage

# PERCENTAGE OF TREES DAMAGED

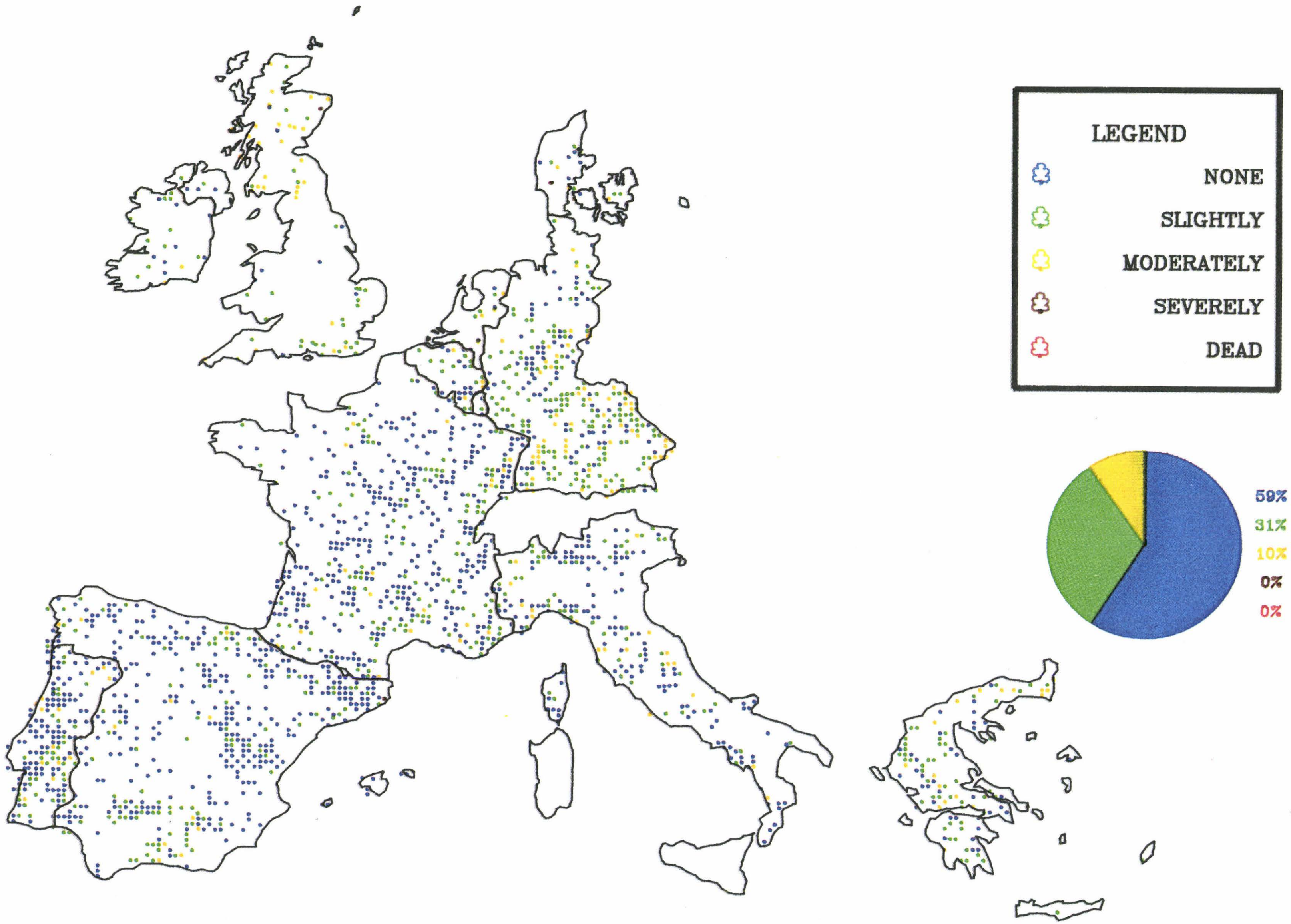



Source: 1987 Communiy Inventory of Forest Damage

**Annex I-6 Plot defoliation - 1987, 1988, 1989 and 1990**

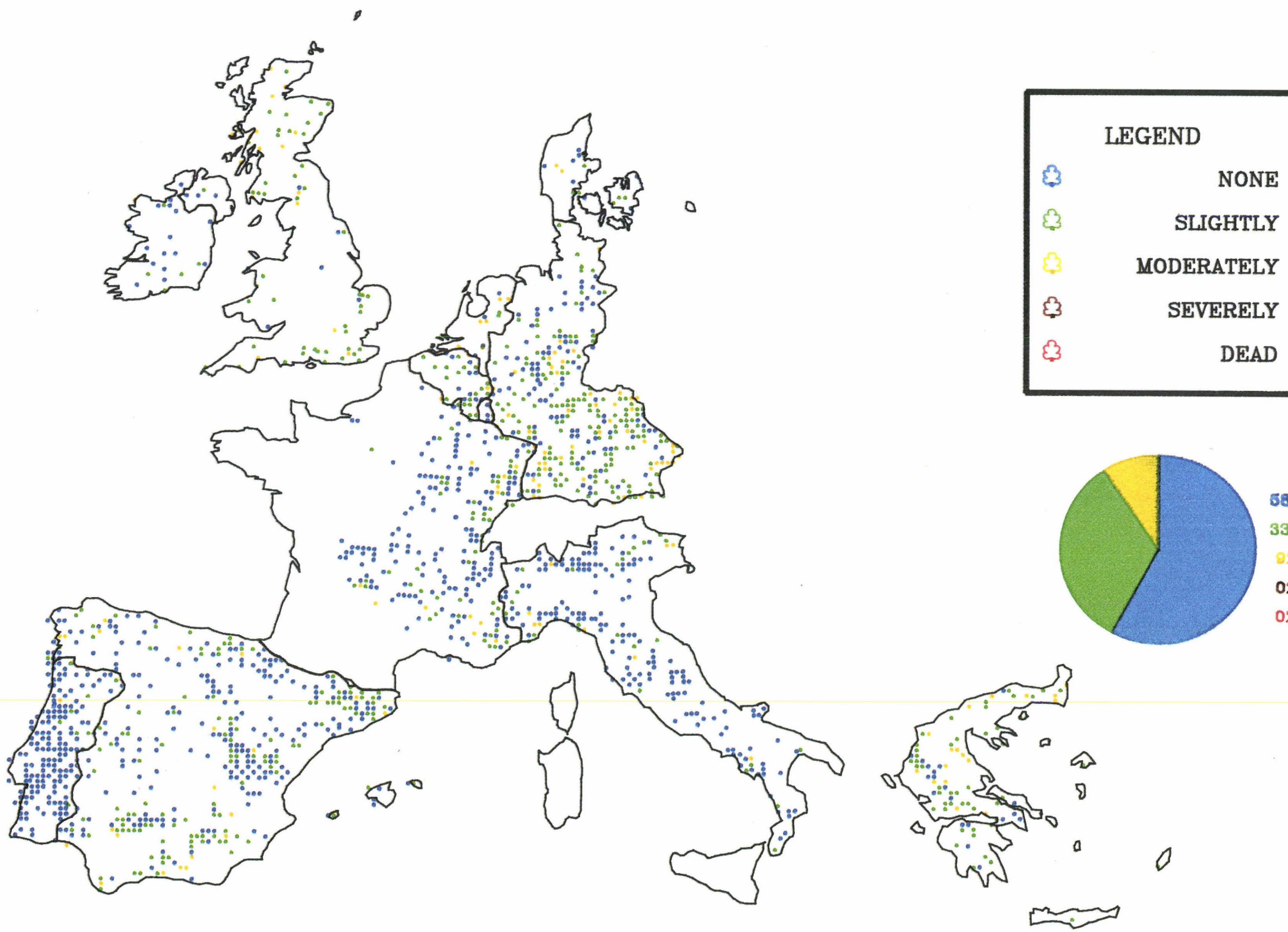


# PLOT DEFOLIATION



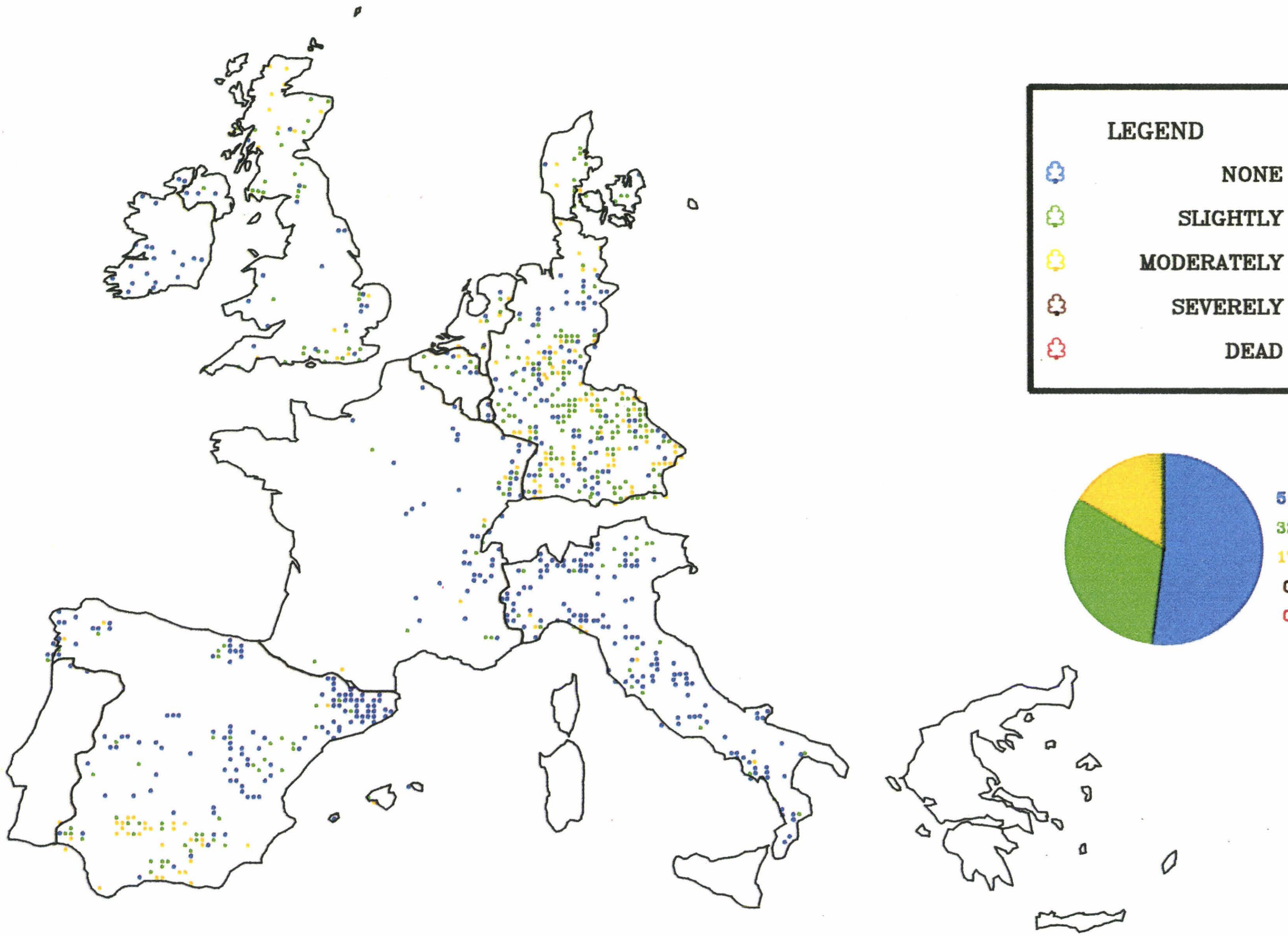

Source: 1989 Community Inventory of Forest Damage

# PLOT DEFOLIATION



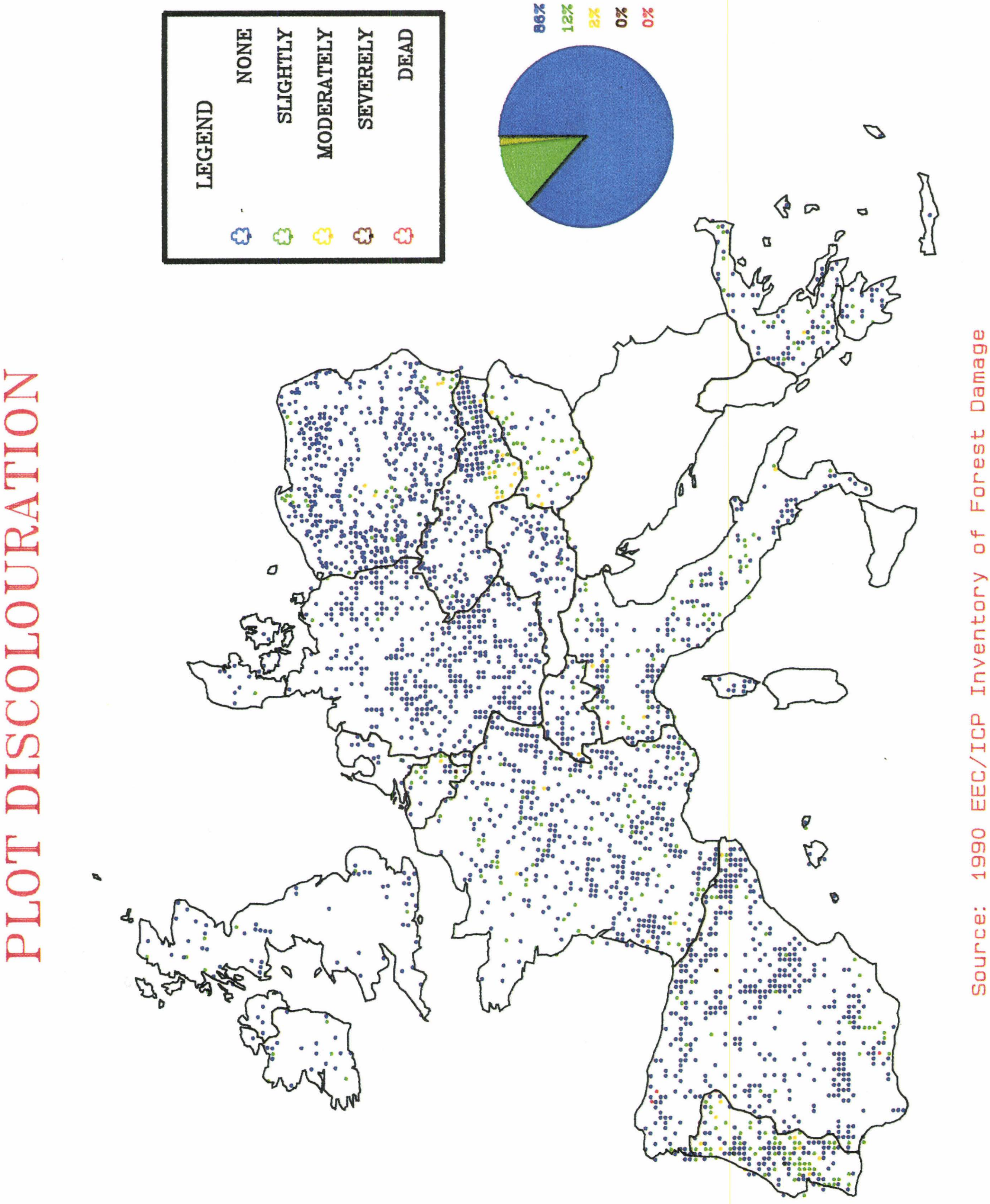

Source: 1988 Community Inventory of Forest Damage

# PLOT DEFOLIATION

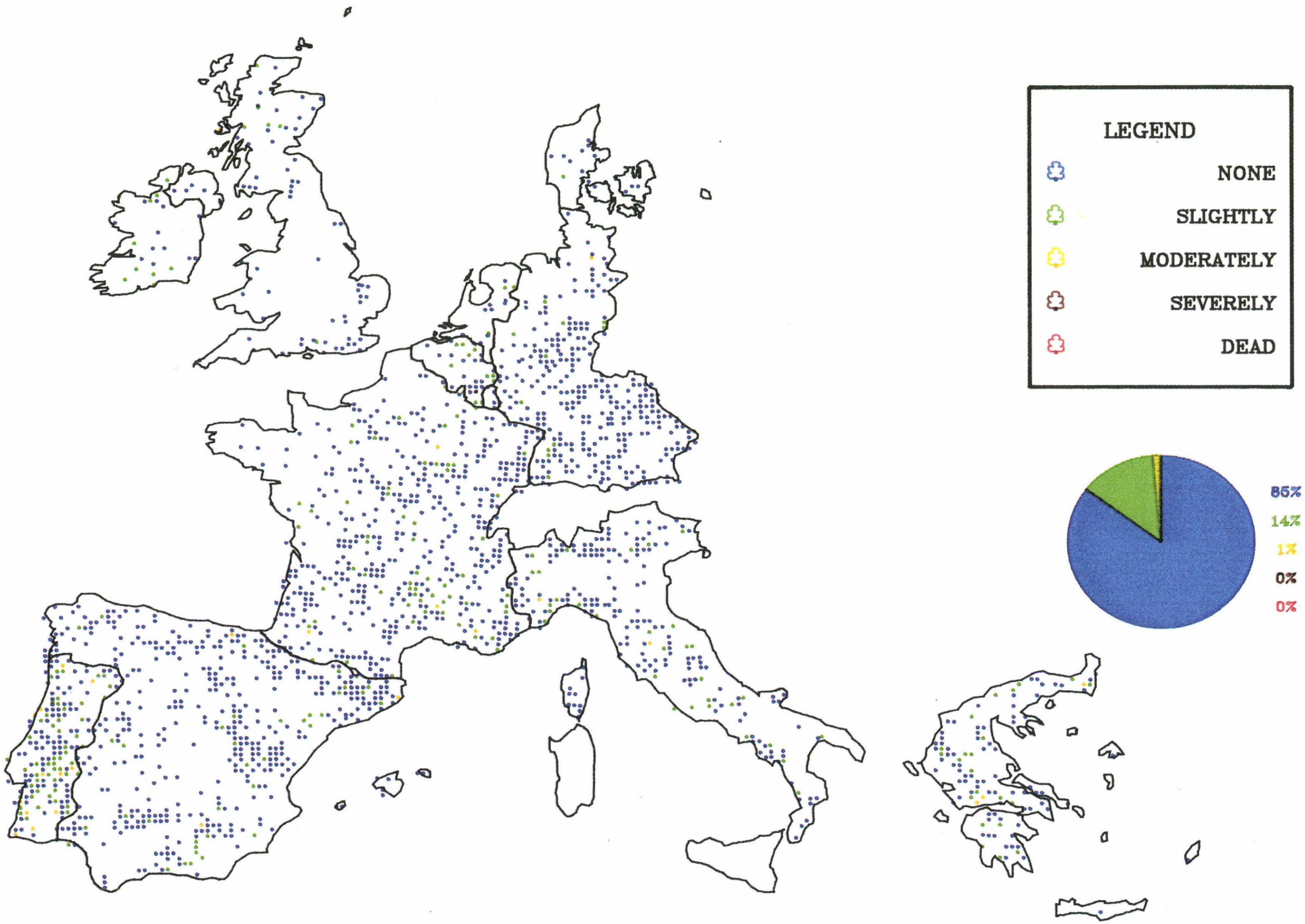



Source: 1987 Community Inventory of Forest Damage

**Annex I-7 Plot discolouration - 1987, 1988, 1989 and 1990**

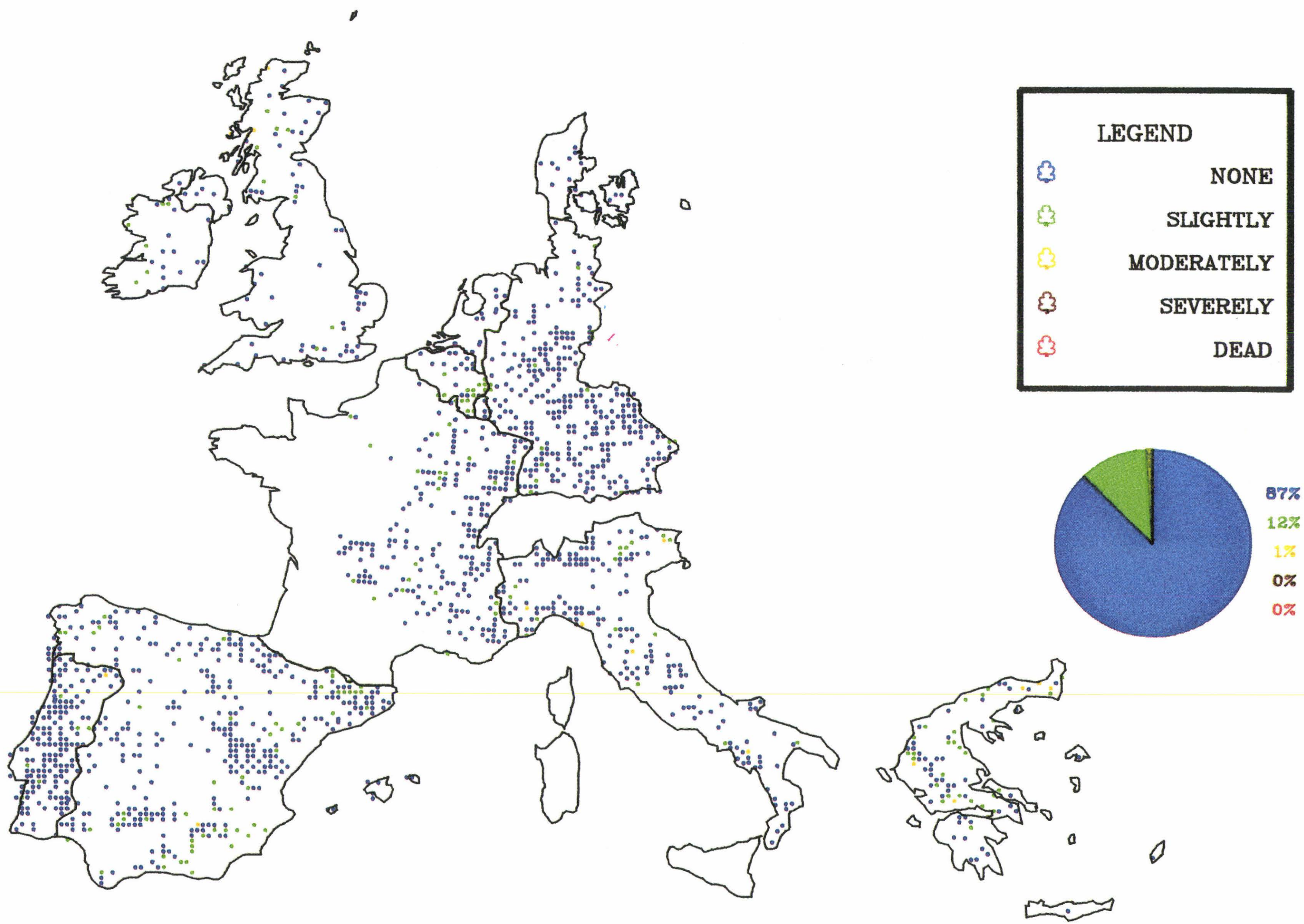


# PLOT DISCOLOURATION FOR THE COMMUNITY



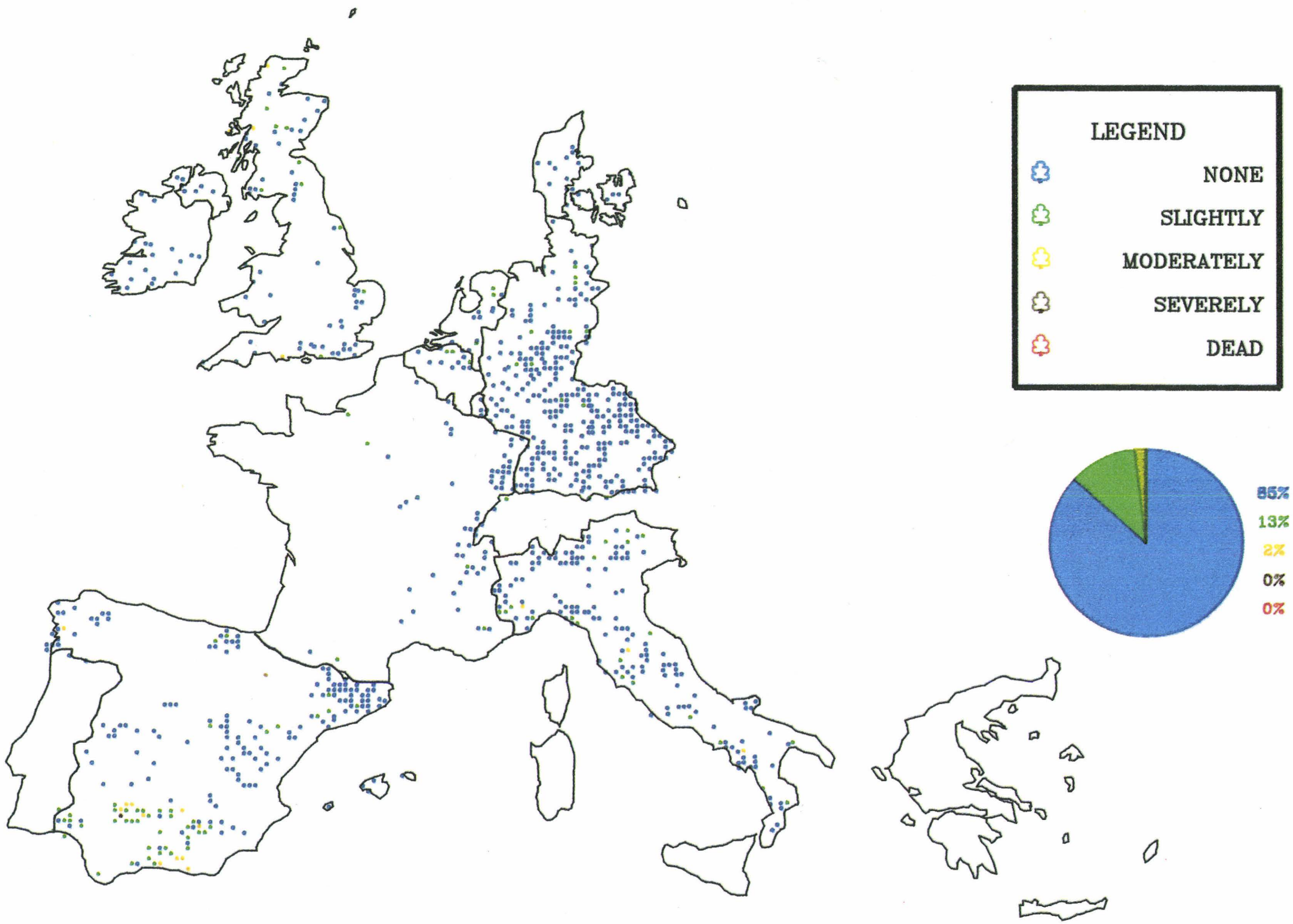

Source: 1989 Community Inventory of Forest Damage

# PLOT DISCOLOURATION




Source: 1988 Community Inventory of Forest Damage

# PLOT DISCOLOURATION




Source: 1987 Community Inventory of Forest Damage

## Annex I-8 Defoliation and discolouration by altitude - 1990

| EUROPEAN COMMUNITY | DEFOLIATION | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | NOT OR SLIGHTLY | | MODERATELY | | SEVERELY | | DEAD | | TOTAL |
| | NO. | % | NO. | % | NO. | % | NO. | % | NO. |
| ALTITUDE | | | | | | | | | |
| 0- 250 m | 12447 | 80.2 | 2708 | 17.4 | 300 | 1.9 | 65 | 0.4 | 15520 |
| 251- 500 m | 10019 | 83.4 | 1698 | 14.1 | 260 | 2.2 | 35 | 0.3 | 12012 |
| 501- 750 m | 6640 | 85.1 | 978 | 12.5 | 82 | 1.1 | 101 | 1.3 | 7801 |
| 751-1000 m | 4927 | 90.9 | 397 | 7.3 | 44 | 0.8 | 54 | 1.0 | 5422 |
| 1001-1250 m | 3581 | 91.3 | 283 | 7.2 | 45 | 1.1 | 12 | 0.3 | 3921 |
| 1251-1500 m | 1904 | 91.8 | 156 | 7.5 | 9 | 0.4 | 6 | 0.3 | 2075 |
| >1500 m | 1380 | 94.5 | 55 | 3.8 | 5 | 0.3 | 21 | 1.4 | 1461 |
| TOTAL | 40898 | 84.8 | 6275 | 13.0 | 745 | 1.5 | 294 | 0.6 | 48212 |

| NON-EEC TOTAL | DEFOLIATION | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | NOT OR SLIGHTLY | | MODERATELY | | SEVERELY | | DEAD | | TOTAL | |
| | NO. | % | NO. | % | NO. | % | NO. | % | NO. | % |
| ALTITUDE | | | | | | | | | | |
| 0- 250 m | 973 | 69.6 | 291 | 20.8 | 105 | 7.5 | 29 | 2.1 | 1398 | 100.0 |
| 251- 500 m | 1446 | 63.8 | 700 | 30.9 | 103 | 4.5 | 16 | 0.7 | 2265 | 100.0 |
| 501- 750 m | 1364 | 67.6 | 555 | 27.5 | 85 | 4.2 | 13 | 0.6 | 2017 | 100.0 |
| 751-1000 m | 973 | 71.9 | 309 | 22.8 | 54 | 4.0 | 18 | 1.3 | 1354 | 100.0 |
| 1001-1250 m | 374 | 75.6 | 104 | 21.0 | 10 | 2.0 | 7 | 1.4 | 495 | 100.0 |
| 1251-1500 m | 423 | 87.6 | 52 | 10.8 | 3 | 0.6 | 5 | 1.0 | 483 | 100.0 |
| >1500 m | 363 | 90.7 | 20 | 5.0 | 2 | 0.5 | 15 | 3.7 | 400 | 100.0 |
| TOTAL | 5916 | 70.3 | 2031 | 24.1 | 362 | 4.3 | 103 | 1.2 | 8412 | 100.0 |

| EUROPEAN COMMUNITY | DISCOLOURATION | | | | | TOTAL |
|---|---|---|---|---|---|---|
| | NONE | SLIGHT | MODERATE | SEVERE | DEAD | |
| | % | % | % | % | % | NO |
| ALTITUDE | | | | | | |
| 0- 250 m | 82.9 | 12.7 | 3.1 | 0.8 | 0.4 | 15500 |
| 251- 500 m | 87.3 | 9.3 | 2.5 | 0.5 | 0.3 | 12012 |
| 501- 750 m | 87.1 | 8.9 | 1.9 | 0.8 | 1.3 | 7801 |
| 751-1000 m | 86.7 | 10.5 | 1.5 | 0.4 | 1.0 | 5422 |
| 1001-1250 m | 87.4 | 10.9 | 1.2 | 0.2 | 0.3 | 3921 |
| 1251-1500 m | 84.7 | 12.3 | 2.3 | 0.3 | 0.3 | 2075 |
| >1500 m | 82.3 | 14.5 | 1.6 | 0.1 | 1.4 | 1461 |
| TOTAL | 85.5 | 10.9 | 2.3 | 0.6 | 0.6 | 48192 |

| NON-EC TOTAL | DISCOLOURATION | | | | | TOTAL |
|---|---|---|---|---|---|---|
| | NONE | SLIGHT | MODERATE | SEVERE | DEAD | |
| | % | % | % | % | % | NO |
| ALTITUDE | | | | | | |
| 0- 250 m | 51.1 | 30.0 | 14.8 | 2.0 | 2.1 | 1398 |
| 251- 500 m | 77.5 | 14.9 | 6.7 | 0.2 | 0.7 | 2265 |
| 501- 750 m | 95.0 | 2.8 | 1.4 | 0.1 | 0.6 | 2017 |
| 751-1000 m | 94.9 | 1.8 | 0.9 | 1.1 | 1.3 | 1354 |
| 1001-1250 m | 97.6 | 0.2 | | 0.8 | 1.4 | 495 |
| 1251-1500 m | 94.2 | 1.0 | | 3.7 | 1.0 | 483 |
| >1500 m | 92.7 | 2.2 | | 1.3 | 3.7 | 400 |
| Total | 83.0 | 10.1 | 4.7 | 0.9 | 1.2 | 8412 |

## Annex I-9 Defoliation and discolouration by aspect - 1990

| EUROPEAN COMMUNITY | DEFOLIATION | | | | | | | | | | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | NONE | | SLIGHT | | MODERATE | | SEVERE | | DEAD | | |
| | NO. | % | NO. | % | NO. | % | NO. | % | NO. | % | NO. |
| ASPECT | | | | | | | | | | | |
| N | 3692 | 62.7 | 1370 | 23.3 | 769 | 13.1 | 51 | 0.9 | 10 | 0.2 | 5892 |
| NE | 2827 | 58.9 | 1198 | 24.9 | 658 | 13.7 | 48 | 1.0 | 71 | 1.5 | 4802 |
| E | 2274 | 61.0 | 943 | 25.3 | 403 | 10.8 | 99 | 2.7 | 7 | 0.2 | 3726 |
| SE | 2287 | 58.7 | 1035 | 26.6 | 481 | 12.3 | 65 | 1.7 | 27 | 0.7 | 3895 |
| S | 2925 | 63.0 | 1048 | 22.6 | 483 | 10.4 | 103 | 2.2 | 85 | 1.8 | 4644 |
| SW | 2468 | 63.5 | 917 | 23.6 | 390 | 10.0 | 89 | 2.3 | 21 | 0.5 | 3885 |
| W | 2418 | 61.0 | 904 | 22.8 | 555 | 14.0 | 68 | 1.7 | 16 | 0.4 | 3961 |
| NW | 2924 | 60.6 | 1296 | 26.8 | 537 | 11.1 | 54 | 1.1 | 18 | 0.4 | 4829 |
| FLAT | 6970 | 55.5 | 3376 | 26.9 | 1996 | 15.9 | 167 | 1.3 | 39 | 0.3 | 12548 |
| TOTAL | 28785 | 59.7 | 12087 | 25.1 | 6272 | 13.0 | 744 | 1.5 | 294 | 0.6 | 48182 |

| NON-EEC TOTAL | DEFOLIATION | | | | | | | | | | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | NONE | | SLIGHT | | MODERATE | | SEVERE | | DEAD | | |
| | NO. | % | NO. | % | NO. | % | NO. | % | NO. | % | NO. |
| ASPECT | | | | | | | | | | | |
| N | 477 | 38.7 | 418 | 33.9 | 284 | 23.0 | 43 | 3.5 | 11 | 0.9 | 1233 |
| NE | 236 | 78.7 | 53 | 17.7 | 10 | 3.3 | 1 | 0.3 | . | . | 300 |
| E | 221 | 40.2 | 188 | 34.2 | 94 | 17.1 | 43 | 7.8 | 4 | 0.7 | 550 |
| SE | 87 | 63.5 | 30 | 21.9 | 19 | 13.9 | 1 | 0.7 | . | . | 137 |
| S | 340 | 41.5 | 259 | 31.6 | 166 | 20.2 | 40 | 4.9 | 15 | 1.8 | 820 |
| SW | 196 | 59.4 | 111 | 33.6 | 22 | 6.7 | . | . | 1 | 0.3 | 330 |
| W | 367 | 37.3 | 324 | 32.9 | 245 | 24.9 | 34 | 3.5 | 14 | 1.4 | 984 |
| NW | 112 | 77.8 | 26 | 18.1 | 6 | 4.2 | . | . | . | . | 144 |
| FLAT | 15 | 4.6 | 61 | 18.8 | 175 | 53.8 | 67 | 20.6 | 7 | 2.2 | 325 |
| TOTAL | 2051 | 42.5 | 1470 | 30.5 | 1021 | 21.2 | 229 | 4.7 | 52 | 1.1 | 4823 |

| EUROPEAN COMMUNITY | DISCOLOURATION | | | | | | | | | | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | NONE | | SLIGHT | | MODERATE | | SEVERE | | DEAD | | |
| | NO. | % | NO. | % | NO. | % | NO. | % | NO. | % | NO. |
| ASPECT | | | | | | | | | | | |
| N | 5068 | 86.0 | 698 | 11.8 | 103 | 1.7 | 13 | 0.2 | 10 | 0.2 | 5892 |
| NE | 4077 | 84.9 | 526 | 11.0 | 94 | 2.0 | 34 | 0.7 | 71 | 1.5 | 4802 |
| E | 3122 | 83.8 | 489 | 13.1 | 82 | 2.2 | 26 | 0.7 | 7 | 0.2 | 3726 |
| SE | 3239 | 83.2 | 498 | 12.8 | 108 | 2.8 | 23 | 0.6 | 27 | 0.7 | 3895 |
| S | 3872 | 83.4 | 492 | 10.6 | 170 | 3.7 | 25 | 0.5 | 85 | 1.8 | 4644 |
| SW | 3292 | 84.7 | 440 | 11.3 | 106 | 2.7 | 26 | 0.7 | 21 | 0.5 | 3885 |
| W | 3352 | 84.6 | 457 | 11.5 | 111 | 2.8 | 25 | 0.6 | 16 | 0.4 | 3961 |
| NW | 4187 | 86.7 | 479 | 9.9 | 118 | 2.4 | 27 | 0.6 | 18 | 0.4 | 4829 |
| FLAT | 11001 | 87.7 | 1176 | 9.4 | 240 | 1.9 | 92 | 0.7 | 39 | 0.3 | 12548 |
| TOTAL | 41210 | 85.5 | 5255 | 10.9 | 1132 | 2.3 | 291 | 0.6 | 294 | 0.6 | 48182 |

| NON-EEC TOTAL | DISCOLOURATION | | | | | | | | | | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | NONE | | SLIGHT | | MODERATE | | SEVERE | | DEAD | | |
| | NO. | % | NO. | % | NO. | % | NO. | % | NO. | % | NO. |
| ASPECT | | | | | | | | | | | |
| N | 1037 | 84.1 | 103 | 8.4 | 77 | 6.2 | 5 | 0.4 | 11 | 0.9 | 1233 |
| NE | 298 | 99.3 | 1 | 0.3 | . | . | 1 | 0.3 | . | . | 300 |
| E | 456 | 82.9 | 61 | 11.1 | 22 | 4.0 | 7 | 1.3 | 4 | 0.7 | 550 |
| SE | 134 | 97.8 | . | . | . | . | 3 | 2.2 | . | . | 137 |
| S | 719 | 87.7 | 67 | 8.2 | 14 | 1.7 | 5 | 0.6 | 15 | 1.8 | 820 |
| SW | 310 | 93.9 | 1 | 0.3 | . | . | 18 | 5.5 | 1 | 0.3 | 330 |
| W | 845 | 85.9 | 72 | 7.3 | 42 | 4.3 | 11 | 1.1 | 14 | 1.4 | 984 |
| NW | 144 | 100.0 | . | . | . | . | . | . | . | . | 144 |
| FLAT | 56 | 17.2 | 116 | 35.7 | 132 | 40.6 | 14 | 4.3 | 7 | 2.2 | 325 |
| TOTAL | 3999 | 82.9 | 421 | 8.7 | 287 | 6.0 | 64 | 1.3 | 52 | 1.1 | 4823 |

## Annex I-10 Defoliation and discolouration by water availability - 1990

| TOTAL CLIMATIC REGIONS | DEFOLIATION | | | | | | | | | | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | NONE | | SLIGHT | | MODERATE | | SEVERE | | DEAD | | |
| | NO. | % | NO. | % | NO. | % | NO. | % | NO. | % | NO. |
| WATER AVAILABILITY | | | | | | | | | | | |
| INSUFFICIENT | 3216 | 50.0 | 2236 | 34.7 | 856 | 13.3 | 98 | 1.5 | 29 | 0.5 | 6435 |
| SUFFICIENT | 26645 | 61.9 | 10147 | 23.6 | 5359 | 12.4 | 629 | 1.5 | 266 | 0.6 | 43046 |
| EXCESSIVE | 515 | 59.7 | 172 | 19.9 | 147 | 17.0 | 26 | 3.0 | 3 | 0.3 | 863 |
| TOTAL | 30376 | 60.3 | 12555 | 24.9 | 6362 | 12.6 | 753 | 1.5 | 298 | 0.6 | 50344 |

| TOTAL CLIMATIC ZONES | DISCOLOURATION | | | | | | | | | | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | NONE | | SLIGHT | | MODERATE | | SEVERE | | DEAD | | |
| | NO. | % | NO. | % | NO. | % | NO. | % | NO. | % | NO. |
| WATER AVAILABILITY | | | | | | | | | | | |
| INSUFFICIENT | 5370 | 83.4 | 821 | 12.8 | 157 | 2.4 | 58 | 0.9 | 29 | 0.5 | 6435 |
| SUFFICIENT | 37227 | 86.5 | 4325 | 10.0 | 957 | 2.2 | 271 | 0.6 | 266 | 0.6 | 43046 |
| EXCESSIVE | 728 | 84.4 | 111 | 12.9 | 18 | 2.1 | 3 | 0.3 | 3 | 0.3 | 863 |
| TOTAL | 43325 | 86.1 | 5257 | 10.4 | 1132 | 2.2 | 332 | 0.7 | 298 | 0.6 | 50344 |

## Annex I-11 Defoliation and discolouration by humus type - 1990

| EUROPEAN COMMUNITY | DEFOLIATION | | | | | TOTAL |
|---|---|---|---|---|---|---|
| | NONE % | SLIGHT % | MODERATE % | SEVERE % | DEAD % | NO |
| HUMUS TYPE | | | | | | |
| MULL | 61.8 | 22.7 | 13.4 | 1.7 | 0.3 | 18310 |
| MODER | 60.1 | 27.3 | 10.7 | 1.2 | 0.8 | 18229 |
| MOR | 60.8 | 21.4 | 14.6 | 2.1 | 1.0 | 7623 |
| ANMOR | 51.6 | 27.6 | 19.6 | 1.3 | 0.0 | 225 |
| PEAT | 51.9 | 22.0 | 20.0 | 6.1 | 0.0 | 591 |
| OTHER | 46.4 | 34.6 | 18.1 | 0.6 | 0.3 | 3206 |
| TOTAL | 59.8 | 25.1 | 13.0 | 1.5 | 0.6 | 48192 |

| NON-EC TOTAL | DEFOLIATION | | | | | TOTAL |
|---|---|---|---|---|---|---|
| | NONE % | SLIGHT % | MODERATE % | SEVERE % | DEAD % | NO |
| HUMUS TYPE | | | | | | |
| MULL | 73.7 | 22.2 | 2.6 | 1.1 | 0.4 | 270 |
| MODER | 73.0 | 22.2 | 4.4 | 0.2 | 0.2 | 1712 |
| MOR | 79.3 | 18.0 | 2.0 | 0.7 | 0.0 | 150 |
| TOTAL | 73.5 | 21.9 | 4.0 | 0.4 | 0.2 | 2132 |

| EUROPEAN COMMUNITY | HUMUS TYPE | | | | | | TOTAL |
|---|---|---|---|---|---|---|---|
| | MULL | MODER | MOR | ANMOR | PEAT | OTHER | |
| | % | % | % | % | % | % | % |
| DISCOLOURATION | | | | | | | |
| NONE | 36.1 | 38.6 | 16.3 | 0.5 | 1.0 | 7.5 | 100.0 |
| SLIGHT | 49.0 | 34.5 | 11.8 | 0.6 | 2.3 | 1.8 | 100.0 |
| MODERATE | 57.5 | 24.7 | 13.3 | 0.5 | 1.9 | 2.0 | 100.0 |
| SEVERE | 51.9 | 25.4 | 13.7 | 0.3 | 6.9 | 1.7 | 100.0 |
| DEAD | 21.1 | 48.3 | 26.9 | . | . | 3.7 | 100.0 |
| TOTAL | 38.0 | 37.8 | 15.8 | 0.5 | 1.2 | 6.7 | 100.0 |

| NON-EEC TOTAL | HUMUS TYPE | | | | | | TOTAL | |
|---|---|---|---|---|---|---|---|---|
| | MULL | | MODER | | MOR | | | |
| | NO. | % | NO. | % | NO. | % | NO. | % |
| DISCOLOURATION | | | | | | | | |
| NONE | 263 | 12.6 | 1675 | 80.5 | 143 | 6.9 | 2081 | 100.0 |
| SLIGHT | 2 | 33.3 | 2 | 33.3 | 2 | 33.3 | 6 | 100.0 |
| SEVERE | 4 | 9.8 | 32 | 78.0 | 5 | 12.2 | 41 | 100.0 |
| DEAD | 1 | 25.0 | 3 | 75.0 | . | . | 4 | 100.0 |
| TOTAL | 270 | 12.7 | 1712 | 80.3 | 150 | 7.0 | 2132 | 100.0 |

## Annex I-12 Defoliation and discolouration by mean age - 1990

| EUROPEAN COMMUNITY | DEFOLIATION | | | | | TOTAL |
|---|---|---|---|---|---|---|
| | NONE | SLIGHT | MODERATE | SEVERE | DEAD | |
| | % | % | % | % | % | % |
| MEAN AGE | | | | | | |
| 0- 20 years | 75.8 | 15.3 | 6.3 | 1.5 | 1.1 | 100.0 |
| 21- 40 years | 63.5 | 22.9 | 11.2 | 1.9 | 0.6 | 100.0 |
| 41- 60 years | 57.1 | 27.6 | 12.9 | 1.6 | 0.8 | 100.0 |
| 61- 80 years | 54.7 | 30.4 | 13.6 | 1.0 | 0.4 | 100.0 |
| 80-100 years | 42.7 | 34.2 | 21.8 | 1.1 | 0.2 | 100.0 |
| 101-120 years | 36.9 | 37.4 | 23.0 | 2.5 | 0.2 | 100.0 |
| >120 years | 31.6 | 33.6 | 32.5 | 2.1 | 0.2 | 100.0 |
| Irregular Stands | 72.6 | 18.8 | 6.8 | 1.1 | 0.7 | 100.0 |
| TOTAL | 59.7 | 25.1 | 13.0 | 1.6 | 0.6 | 100.0 |

| NON-EEC TOTAL | DEFOLIATION | | | | | TOTAL |
|---|---|---|---|---|---|---|
| | NONE | SLIGHT | MODERATE | SEVERE | DEAD | |
| | % | % | % | % | % | % |
| MEAN AGE | | | | | | |
| 0- 20 years | 58.4 | 18.9 | 18.7 | 1.9 | 2.1 | 100.0 |
| 21- 40 years | 53.1 | 22.7 | 20.2 | 1.8 | 2.1 | 100.0 |
| 41- 60 years | 23.6 | 40.3 | 31.5 | 4.0 | 0.5 | 100.0 |
| 61- 80 years | 26.0 | 38.4 | 32.2 | 2.9 | 0.5 | 100.0 |
| 80-100 years | 24.6 | 37.9 | 33.7 | 3.6 | 0.2 | 100.0 |
| 101-120 years | 31.7 | 41.1 | 25.8 | 1.0 | 0.3 | 100.0 |
| >120 years | 42.5 | 34.3 | 19.2 | 2.2 | 1.8 | 100.0 |
| TOTAL | 28.1 | 37.7 | 30.4 | 3.1 | 0.6 | 100.0 |

| EUROPEAN COMMUNITY | DISCOLOURATION | | | | | TOTAL |
|---|---|---|---|---|---|---|
| | NONE | SLIGHT | MODERATE | SEVERE | DEAD | |
| | % | % | % | % | % | % |
| MEAN AGE | | | | | | |
| 0- 20 years | 87.9 | 8.9 | 1.7 | 0.4 | 1.1 | 100.0 |
| 21- 40 years | 84.7 | 11.9 | 2.2 | 0.6 | 0.6 | 100.0 |
| 41- 60 years | 86.2 | 10.5 | 2.2 | 0.4 | 0.8 | 100.0 |
| 61- 80 years | 85.8 | 10.5 | 2.3 | 1.0 | 0.4 | 100.0 |
| 80-100 years | 82.6 | 12.4 | 3.8 | 1.0 | 0.2 | 100.0 |
| 101-120 years | 84.7 | 10.8 | 3.9 | 0.4 | 0.2 | 100.0 |
| >120 years | 82.4 | 13.3 | 3.4 | 0.7 | 0.2 | 100.0 |
| Irregular Stands | 87.2 | 10.2 | 1.6 | 0.3 | 0.7 | 100.0 |
| TOTAL | 85.5 | 10.9 | 2.4 | 0.6 | 0.6 | 100.0 |

| NON-EEC TOTAL | DISCOLOURATION | | | | | TOTAL |
|---|---|---|---|---|---|---|
| | NONE | SLIGHT | MODERATE | SEVERE | DEAD | |
| | % | % | % | % | % | % |
| MEAN AGE | | | | | | |
| 0- 20 years | 74.7 | 18.0 | 4.9 | 0.2 | 2.1 | 100.0 |
| 21- 40 years | 60.5 | 26.3 | 9.5 | 1.7 | 2.1 | 100.0 |
| 41- 60 years | 87.6 | 8.0 | 3.3 | 0.6 | 0.5 | 100.0 |
| 61- 80 years | 85.4 | 9.9 | 3.9 | 0.3 | 0.5 | 100.0 |
| 80-100 years | 89.6 | 7.4 | 2.4 | 0.5 | 0.2 | 100.0 |
| 101-120 years | 94.9 | 3.7 | 0.5 | 0.6 | 0.3 | 100.0 |
| >120 years | 95.0 | 2.5 | 0.4 | 0.4 | 1.8 | 100.0 |
| TOTAL | 86.8 | 8.8 | 3.2 | 0.5 | 0.6 | 100.0 |

## Annex I-13 Defoliation and discolouration by identifiable damage type - 1990

| EUROPEAN TOTAL | DEFOLIATION OF SAMPLE TREES | | | | | TOTAL |
|---|---|---|---|---|---|---|
| | NONE | SLIGHT | MODERATE | SEVERE | DEAD | |
| | NO. | NO. | NO. | NO. | NO. | NO. |
| GAME AND GRAZING | 383 | 212 | 152 | 24 | 2 | 773 |
| INSECTS | 4806 | 2259 | 1312 | 186 | 13 | 8576 |
| FUNGI | 2206 | 1086 | 688 | 113 | 15 | 4108 |
| ABIOTIC AGENTS | 1643 | 1086 | 599 | 150 | 21 | 3499 |
| ACTION OF MAN | 1988 | 787 | 736 | 91 | 25 | 3627 |
| FIRE | 488 | 223 | 187 | 28 | 7 | 933 |
| KNOWN POLLUTION | 32 | 15 | 11 | 3 | 0 | 61 |
| OTHER | 418 | 261 | 201 | 22 | 4 | 906 |
| ANY IDENT. DAMAGE | 9334 | 4672 | 3032 | 478 | 76 | 17592 |
| NO IDENT. DAMAGE | 24900 | 14427 | 9184 | 904 | 328 | 49743 |
| MULTIPLE DAMAGE | 2315 | 1112 | 752 | 116 | 10 | 4305 |

| EUROPEAN TOTAL | DISCOLOURATION OF SAMPLE TREES | | | | | TOTAL |
|---|---|---|---|---|---|---|
| | NONE | SLIGHT | MODERATE | SEVERE | DEAD | |
| | NO. | NO. | NO. | NO. | NO. | NO. |
| GAME AND GRAZING | 625 | 115 | 14 | 17 | 2 | 773 |
| INSECTS | 6984 | 1247 | 288 | 44 | 13 | 8576 |
| FUNGI | 3312 | 595 | 133 | 53 | 15 | 4108 |
| ABIOTIC AGENTS | 2299 | 847 | 243 | 89 | 21 | 3499 |
| ACTION OF MAN | 2450 | 882 | 221 | 49 | 25 | 3627 |
| FIRE | 792 | 81 | 33 | 20 | 7 | 933 |
| KNOWN POLLUTION | 27 | 27 | 5 | 2 | 0 | 61 |
| OTHER | 699 | 158 | 33 | 12 | 4 | 906 |
| ANY IDENT. DAMAGE | 13404 | 3085 | 788 | 239 | 76 | 17592 |
| NO IDENT. DAMAGE | 44633 | 3728 | 914 | 140 | 328 | 49743 |
| MULTIPLE DAMAGE | 3286 | 797 | 169 | 43 | 10 | 4305 |

## Annex I-14 Defoliation and discolouration by soil type - 1990

| EUROPEAN TOTAL *) | DEFOLIATION | | | | | | | | | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NONE | | SLIGHT | | MODERATE | | SEVERE | | DEAD | | | |
| | NO. | % | NO. | % | NO. | % | NO. | % | NO. | % | NO. | % |
| SOIL TYPE | | | | | | | | | | | | |
| 15 | 16 | 9.5 | 87 | 51.8 | 65 | 38.7 | . | . | . | . | 168 | 100.0 |
| 16 | 49 | 40.8 | 40 | 33.3 | 31 | 25.8 | . | . | . | . | 120 | 100.0 |
| 17 | 192 | 59.3 | 99 | 30.6 | 30 | 9.3 | 1 | 0.3 | 2 | 0.6 | 324 | 100.0 |
| 29 | 239 | 74.2 | 72 | 22.4 | 9 | 2.8 | 2 | 0.6 | . | . | 322 | 100.0 |
| 30 | 271 | 71.5 | 98 | 25.9 | 9 | 2.4 | . | . | 1 | 0.3 | 379 | 100.0 |
| 32 | 129 | 86.0 | 18 | 12.0 | 1 | 0.7 | 2 | 1.3 | . | . | 150 | 100.0 |
| 33 | 28 | 93.3 | 1 | 3.3 | . | . | . | . | 1 | 3.3 | 30 | 100.0 |
| 37 | 113 | 53.8 | 77 | 36.7 | 18 | 8.6 | 2 | 1.0 | . | . | 210 | 100.0 |
| 41 | 136 | 91.3 | 13 | 8.7 | . | . | . | . | . | . | 149 | 100.0 |
| 43 | 84 | 93.3 | 3 | 3.3 | 2 | 2.2 | 1 | 1.1 | . | . | 90 | 100.0 |
| 44 | 431 | 78.4 | 101 | 18.4 | 18 | 3.3 | . | . | . | . | 550 | 100.0 |
| 45 | 192 | 53.3 | 147 | 40.8 | 20 | 5.6 | 1 | 0.3 | . | . | 360 | 100.0 |
| 48 | 9 | 37.5 | 12 | 50.0 | 3 | 12.5 | . | . | . | . | 24 | 100.0 |
| 51 | 23 | 47.9 | 19 | 39.6 | 5 | 10.4 | . | . | 1 | 2.1 | 48 | 100.0 |
| TOTAL | 1912 | 65.4 | 787 | 26.9 | 211 | 7.2 | 9 | 0.3 | 5 | 0.2 | 2924 | 100.0 |

| EUROPEAN TOTAL *) | DISCOLOURATION | | | | | | | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|
| | NONE | | SLIGHT | | SEVERE | | DEAD | | | |
| | NO. | % | NO. | % | NO. | % | NO. | % | NO. | % |
| SOIL TYPE | | | | | | | | | | |
| 15 | 168 | 100.0 | . | . | . | . | . | . | 168 | 100.0 |
| 16 | 120 | 100.0 | . | . | . | . | . | . | 120 | 100.0 |
| 17 | 316 | 97.5 | 1 | 0.3 | 5 | 1.5 | 2 | 0.6 | 324 | 100.0 |
| 29 | 310 | 96.3 | . | . | 12 | 3.7 | . | . | 322 | 100.0 |
| 30 | 366 | 96.6 | 1 | 0.3 | 11 | 2.9 | 1 | 0.3 | 379 | 100.0 |
| 32 | 150 | 100.0 | . | . | . | . | . | . | 150 | 100.0 |
| 33 | 28 | 93.3 | 1 | 3.3 | . | . | 1 | 3.3 | 30 | 100.0 |
| 37 | 207 | 98.6 | . | . | 3 | 1.4 | . | . | 210 | 100.0 |
| 41 | 149 | 100.0 | . | . | . | . | . | . | 149 | 100.0 |
| 43 | 85 | 94.4 | 3 | 3.3 | 2 | 2.2 | . | . | 90 | 100.0 |
| 44 | 542 | 98.5 | . | . | 8 | 1.5 | . | . | 550 | 100.0 |
| 45 | 360 | 100.0 | . | . | . | . | . | . | 360 | 100.0 |
| 48 | 24 | 100.0 | . | . | . | . | . | . | 24 | 100.0 |
| 51 | 47 | 97.9 | . | . | . | . | 1 | 2.1 | 48 | 100.0 |
| TOTAL | 2872 | 98.2 | 6 | 0.2 | 41 | 1.4 | 5 | 0.2 | 2924 | 100.0 |

* 72 Austrian plots and 33 German plots

ANNEX II-1: Changes in defoliation and discolouration for 1989 and 1990 Common Sample Trees.
First number: percentage of trees in class in 1989.
Second number: percentage of trees in class in 1990.

| Climatic region: | Defoliation | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0-10% | 11-25% | **0-25%** | 26-60% | >60% | dead | No. of trees |
| Atlantic | 68.0 / 63.1 | 20.2 / 22.0 | **88.2 / 85.1** | 9.8 / 11.1 | 1.9 / 2.6 | 0.1 / 1.2 | 9169 |
| Sub-atlantic | 66.3 / 60.5 | 24.0 / 25.5 | **90.4 / 86.1** | 8.7 / 12.1 | 0.9 / 1.7 | 0.0 / 0.1 | 9508 |
| Mountainous | 79.6 / 73.6 | 15.5 / 19.7 | **95.1 / 93.2** | 4.7 / 5.4 | 0.2 / 0.3 | 0.0 / 1.1 | 1983 |
| Mediterranean | 71.8 / 64.7 | 22.0 / 22.1 | **93.7 / 86.8** | 5.7 / 11.2 | 0.4 / 1.3 | 0.1 / 0.7 | 19648 |
| Total | 70.0 / 63.8 | 21.7 / 22.8 | **91.8 / 86.6** | 7.3 / 11.1 | 0.8 / 1.6 | 0.1 / 0.7 | 40308 |

| | Discolouration | | | | | |
|---|---|---|---|---|---|---|
| | **0-10%** | 11-25% | 26-60% | >60% | dead | |
| Atlantic | **85.3 / 85.3** | 12.0 / 10.7 | 2.2 / 2.3 | 0.3 / 0.5 | 0.1 / 1.2 | 9169 |
| Sub-atlantic | **87.0 / 87.7** | 9.7 / 9.2 | 2.6 / 2.3 | 0.6 / 0.7 | 0.0 / 0.1 | 9508 |
| Mountainous | **85.7 / 83.4** | 13.0 / 13.5 | 1.2 / 1.8 | 0.1 / 0.3 | 0.0 / 1.1 | 1983 |
| Mediterranean | **79.9 / 81.1** | 16.5 / 14.4 | 3.1 / 3.1 | 0.4 / 0.8 | 0.1 / 0.7 | 19648 |
| Total | **83.1 / 83.7** | 13.7 / 12.2 | 2.7 / 2.7 | 0.4 / 0.7 | 0.1 / 0.7 | 40308 |

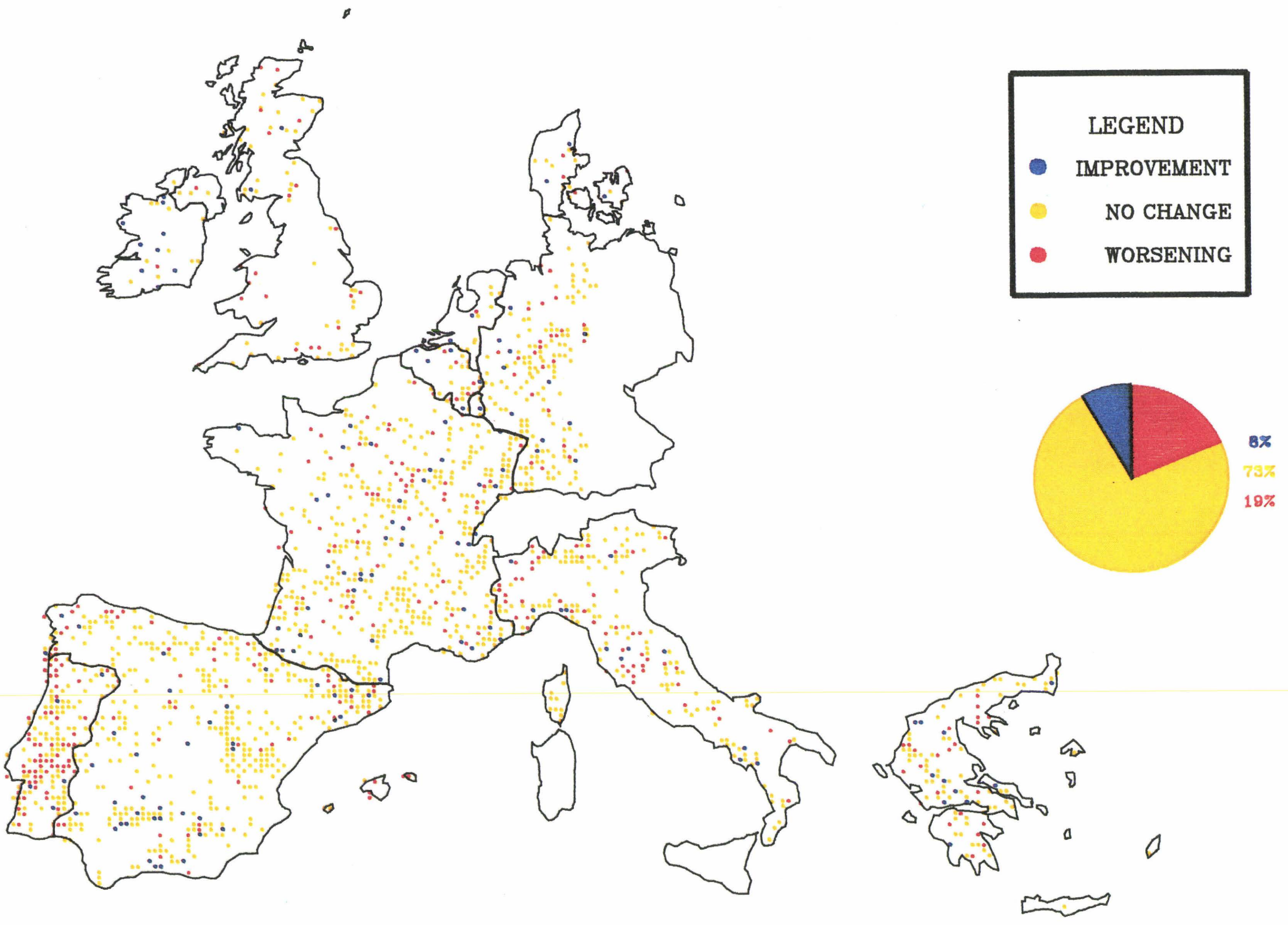
ANNEX II-2: Changes in defoliation for 1989 and 1990 Common Sample Trees, by species group.
First number: percentage of trees in class in 1989.
Second number: percentage of trees in class in 1990.

| Species group | Defoliation | | | | | No. of trees |
|---|---|---|---|---|---|---|
| | 0-10% | 11-25% | 26-60% | >60% | dead | |
| *Castanea sativa* | 71.8/69.3 | 20.4/17.6 | 6.4/ 9.7 | 1.2/ 2.5 | 0.2/ 0.9 | 1285 |
| *Eucalyptus sp.* | 96.3/90.9 | 3.1/ 5.9 | 0.6/ 1.8 | 0.0/ 0.3 | 0.0/ 1.0 | 977 |
| *Fagus sp.* | 67.5/61.8 | 24.3/25.9 | 7.8/11.3 | 0.3/ 0.9 | 0.1/ 0.1 | 3487 |
| *Quercus sp.* (deciduous) | 71.7/64.0 | 19.8/24.0 | 7.7/ 9.8 | 0.7/ 1.4 | 0.1/ 0.9 | 7178 |
| *Quercus ilex* | 69.7/75.7 | 27.0/21.0 | 3.2/ 2.9 | 0.1/ 0.1 | 0.0/ 0.3 | 3052 |
| *Quercus suber* | 64.3/39.9 | 26.4/18.7 | 9.1/36.4 | 0.2/ 4.7 | 0.0/ 0.3 | 1449 |
| Other broadleaves | 69.9/57.6 | 21.4/23.8 | 7.8/14.9 | 0.9/ 2.8 | 0.1/ 0.8 | 5883 |
| Total broadleaves | 70.9/63.5 | 21.6/22.4 | 6.9/11.7 | 0.6/ 1.7 | 0.1/ 0.6 | 23311 |
| *Abies sp.* | 58.8/55.5 | 26.4/27.6 | 13.6/15.1 | 0.9/ 1.1 | 0.3/ 0.7 | 1175 |
| *Larix sp.* | 69.8/68.6 | 23.2/22.3 | 6.8/ 8.2 | 0.0/ 0.5 | 0.2/ 0.5 | 646 |
| *Picea sp.* | 57.3/54.3 | 25.1/27.0 | 13.9/15.6 | 3.7/ 3.0 | 0.0/ 0.1 | 3317 |
| *Pinus sp.* | 72.7/67.2 | 21.0/22.3 | 5.6/ 8.2 | 0.6/ 1.1 | 0.1/ 1.1 | 10969 |
| Other conifers | 76.1/71.1 | 15.5/15.8 | 8.2/11.8 | 0.2/ 1.2 | 0.0/ 0.0 | 890 |
| Total conifers | 68.8/64.1 | 22.0/23.3 | 7.9/10.3 | 1.2/ 1.5 | 0.1/ 0.8 | 16997 |
| Total species | 70.0/63.8 | 21.7/22.8 | 7.3/11.1 | 0.8/ 1.6 | 0.1/ 0.7 | 40308 |

ANNEX II-3: Changes in discolouration for 1989 and 1990 Common Sample Trees, by species group.
First number: percentage of trees in class in 1989.
Second number: percentage of trees in class in 1990.

| Species group | Discolouration | | | | | No. of trees |
|---|---|---|---|---|---|---|
| | 0-10% | 11-25% | 26-60% | >60% | dead | |
| *Castanea sativa* | 77.4/81.7 | 17.5/13.1 | 4.0/ 3.3 | 0.8/ 0.9 | 0.2/ 0.9 | 1285 |
| *Eucalyptus sp.* | 86.5/94.7 | 13.2/ 3.9 | 0.2/ 0.4 | 0.1/ 0.0 | 0.0/ 1.0 | 977 |
| *Fagus sp.* | 88.4/87.8 | 10.0/ 9.8 | 1.4/ 1.9 | 0.2/ 0.4 | 0.1/ 0.1 | 3487 |
| *Quercus sp.* (deciduous) | 87.9/86.2 | 10.3/10.4 | 1.2/ 1.9 | 0.4/ 0.6 | 0.1/ 0.9 | 7178 |
| *Quercus ilex* | 93.2/97.6 | 6.5/ 1.8 | 12.7/12.6 | 0.1/ 0.1 | 0.0/ 0.3 | 3052 |
| *Quercus suber* | 54.0/51.8 | 32.2/32.4 | 4.9/ 4.6 | 1.2/ 2.8 | 0.0/ 0.3 | 1449 |
| Other broadleaves | 79.0/75.8 | 15.4/17.4 | 2.9/ 3.0 | 0.6/ 1.4 | 0.1/ 0.8 | 5883 |
| Total broadleaves | 83.7/83.3 | 12.9/12.2 | 2.9/ 3.0 | 0.4/ 0.8 | 0.1/ 0.7 | 23311 |
| *Abies sp.* | 75.1/78.6 | 20.3/16.8 | 4.1/ 3.7 | 0.3/ 0.3 | 0.3/ 0.7 | 1175 |
| *Larix sp.* | 88.1/91.8 | 9.8/ 6.8 | 2.0/ 0.6 | 0.0/ 0.3 | 0.2/ 0.5 | 646 |
| *Picea sp.* | 86.4/91.1 | 10.4/ 6.5 | 2.3/ 1.4 | 0.8/ 0.8 | 0.0/ 0.1 | 3317 |
| *Pinus sp.* | 81.0/81.6 | 16.2/14.5 | 2.4/ 2.4 | 0.2/ 0.4 | 0.1/ 1.1 | 10969 |
| Other conifers | 89.6/94.7 | 9.3/ 4.6 | 1.0/ 0.7 | 0.1/ 0.0 | 0.0/ 0.0 | 890 |
| Total conifers | 82.4/84.3 | 14.8/12.3 | 2.4/ 2.1 | 0.3/ 0.5 | 0.1/ 0.8 | 16997 |
| Total species | 83.1/83.7 | 13.7/12.2 | 2.7/ 2.7 | 0.4/ 0.7 | 0.1/ 0.7 | 40308 |

# CHANGES IN PLOT DEFOLIATION OVER THE COMMUNITY



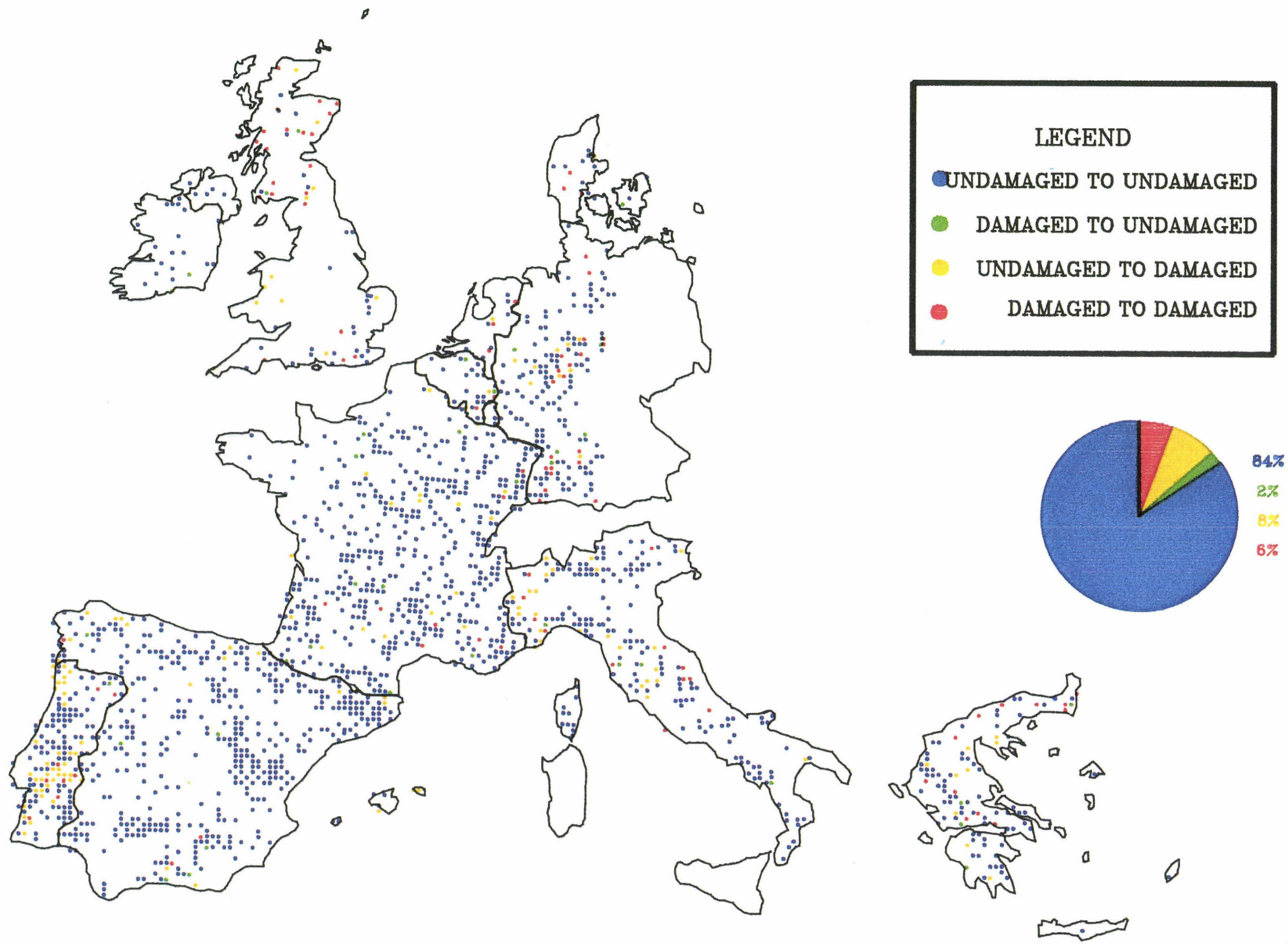

Source: Trees Common to the 1989 & 1990 Inventories of Forest Damage



Changes in Plot Defoliation over the Community 1989-1990

Changes in Plot Damage Classes over the Community 1989-1990

# CHANGES IN PLOT DAMAGE CLASSES OVER THE COMMUNITY




Source: Trees Common to the 1989 & 1990 Inventories of Forest Damage

ANNEX II-6 Changes in defoliation and discolouration in Common trees in 1988, 1989 and 1990 surveys.

DEFOLIATION

| Defoliation classes | Common Trees in 1988, 1989 and 1990 | | |
|---|---|---|---|
| | 1988 | 1989 | 1990 |
| 0 - 10% | 69.8 | 68.2 | 61.8 |
| 11 - 25% | 21.6 | 22.9 | 23.5 |
| 26 - 60% | 7.6 | 7.8 | 12.3 |
| >60% | 0.9 | 1.0 | 1.8 |
| dead | 0.0 | 0.1 | 0.7 |
| No. of trees | 30765 | 30765 | 30765 |

DISCOLOURATION

| Discolouration classes | Common Trees in 1988, 1989 and 1990 | | |
|---|---|---|---|
| | 1988 | 1989 | 1990 |
| 0 - 10% | 86.1 | 81.7 | 83.4 |
| 11 - 25% | 11.7 | 14.7 | 12.7 |
| 26 - 60% | 2.0 | 3.1 | 2.7 |
| >60% | 0.2 | 0.4 | 0.6 |
| dead | 0.0 | 0.1 | 0.7 |
| No. of trees | 30765 | 30765 | 30765 |

ANNEX III-1: Percentages of trees in defoliation classes 0 (0-10%), 1 (11-25%) and 2+3+4 (>25% or dead) for 12 most represented species of 1987-1990 Common Sample Trees, for all individuals and by climatic region.

| Species/ Class | Survey years / Climatic region | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | '87 | '88 | '89 | '90 | '87 | '88 | '89 | '90 | '87 | '88 | '89 | '90 | '87 | '88 | '89 | '90 |
| *Picea abies* | | | | | | | | | | | | | | | | |
| | All trees | | | | Atlantic | | | | Sub-atlantic | | | | Mountainous | | | |
| 0-10% | 64.0 | 61.5 | 59.9 | 56.0 | 41.0 | 42.0 | 43.0 | 34.0 | 65.7 | 60.5 | 59.1 | 56.4 | 65.4 | 71.3 | 68.2 | 61.4 |
| 11-25% | 23.5 | 26.3 | 26.9 | 30.0 | 33.0 | 30.0 | 43.0 | 46.0 | 22.1 | 27.2 | 27.1 | 29.2 | 25.6 | 21.9 | 21.3 | 27.8 |
| >25% | 12.4 | 12.2 | 13.2 | 14.0 | 26.0 | 28.0 | 14.0 | 20.0 | 12.2 | 12.3 | 13.9 | 14.4 | 9.0 | 6.8 | 10.5 | 10.8 |
| *Pinus sylvestris* | | | | | | | | | | | | | | | | |
| | All trees | | | | Atlantic | | | | Sub-atlantic | | | | Mediterranean | | | |
| 0-10% | 67.3 | 57.5 | 58.1 | 53.0 | 67.6 | 61.8 | 55.7 | 47.5 | 47.4 | 39.5 | 43.7 | 35.8 | 86.9 | 61.2 | 73.7 | 79.9 |
| 11-25% | 23.8 | 32.6 | 31.8 | 33.9 | 21.2 | 27.5 | 33.6 | 38.4 | 41.7 | 47.7 | 44.0 | 47.2 | 10.7 | 31.1 | 20.4 | 15.2 |
| >25% | 8.9 | 9.9 | 10.1 | 13.1 | 11.3 | 10.7 | 10.7 | 14.1 | 10.9 | 12.8 | 12.3 | 17.0 | 2.4 | 7.6 | 5.9 | 4.8 |
| *Fagus sylvatica* | | | | | | | | | | | | | | | | |
| | All trees | | | | Atlantic | | | | Sub-atlantic | | | | Mediterranean | | | |
| 0-10% | 62.7 | 66.6 | 64.0 | 54.7 | 56.6 | 56.6 | 48.4 | 28.9 | 47.3 | 54.1 | 54.5 | 43.2 | 94.6 | 91.2 | 82.5 | 90.0 |
| 11-25% | 24.6 | 24.3 | 24.8 | 27.3 | 27.7 | 33.3 | 27.7 | 34.6 | 34.1 | 32.9 | 32.0 | 34.8 | 4.5 | 7.3 | 13.6 | 3.9 |
| >25% | 12.8 | 9.0 | 11.3 | 18.0 | 15.7 | 10.1 | 23.9 | 36.5 | 18.6 | 13.0 | 13.5 | 22.0 | 0.9 | 1.5 | 3.9 | 6.0 |
| *Quercus ilex* | | | | | | | | | | | | | | | | |
| | All trees | | | | Mediterranean | | | | | | | | | | | |
| 0-10% | 53.9 | 59.2 | 64.1 | 70.8 | 53.7 | 59.2 | 64.3 | 70.3 | | | | | | | | |
| 11-25% | 28.3 | 33.4 | 31.0 | 24.3 | 28.3 | 33.3 | 31.0 | 24.6 | | | | | | | | |
| >25% | 17.7 | 7.4 | 4.8 | 5.0 | 18.0 | 7.5 | 4.7 | 5.1 | | | | | | | | |
| *Pinus halepensis* | | | | | | | | | | | | | | | | |
| | All trees | | | | Mediterranean | | | | | | | | | | | |
| 0-10% | 60.9 | 54.0 | 65.4 | 64.1 | 60.9 | 54.0 | 65.4 | 64.1 | | | | | | | | |
| 11-25% | 28.6 | 37.6 | 28.9 | 30.7 | 28.6 | 37.6 | 28.9 | 30.7 | | | | | | | | |
| >25% | 10.5 | 8.3 | 5.7 | 5.2 | 10.5 | 8.3 | 5.7 | 5.2 | | | | | | | | |
| *Pinus nigra* | | | | | | | | | | | | | | | | |
| | All trees | | | | Mediterranean | | | | | | | | | | | |
| 0-10% | 73.3 | 70.9 | 78.1 | 60.6 | 82.4 | 72.7 | 82.4 | 63.6 | | | | | | | | |
| 11-25% | 20.7 | 24.7 | 19.2 | 28.6 | 15.2 | 23.9 | 15.4 | 27.3 | | | | | | | | |
| >25% | 6.0 | 4.5 | 2.7 | 10.8 | 2.4 | 3.5 | 2.2 | 9.1 | | | | | | | | |

(continued)

ANNEX III-1 (continued).

| | Survey years / Climatic region | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species/ Class** | '87 | '88 | '89 | '90 | '87 | '88 | '89 | '90 | '87 | '88 | '89 | '90 | '87 | '88 | '89 | '90 |
| *Pinus pinaster* | | | | | | | | | | | | | | | | |
| | **All trees** | | | | **Atlantic** | | | | **Mediterranean** | | | | | | | |
| 0-10% | 65.8 | 66.8 | 68.2 | 69.8 | 72.3 | 63.3 | 67.6 | 77.1 | 66.8 | 72.7 | 72.7 | 70.6 | | | | |
| 11-25% | 20.2 | 21.0 | 22.2 | 23.3 | 27.1 | 31.9 | 20.7 | 16.0 | 18.0 | 14.4 | 18.3 | 22.7 | | | | |
| >25% | 14.0 | 12.2 | 9.7 | 6.8 | 0.5 | 4.8 | 11.7 | 6.9 | 15.2 | 12.9 | 9.0 | 6.7 | | | | |
| *Castanea sativa* | | | | | | | | | | | | | | | | |
| | **All trees** | | | | **Sub-atlantic** | | | | **Mediterranean** | | | | | | | |
| 0-10% | 72.9 | 78.0 | 66.7 | 58.6 | 80.8 | 91.9 | 78.3 | 45.5 | 67.5 | 69.2 | 54.8 | 63.0 | | | | |
| 11-25% | 21.1 | 15.4 | 24.4 | 22.2 | 15.7 | 4.0 | 17.2 | 29.3 | 24.3 | 21.2 | 31.5 | 18.2 | | | | |
| >25% | 6.0 | 6.6 | 9.0 | 19.2 | 3.5 | 4.0 | 4.5 | 25.3 | 8.2 | 9.6 | 13.7 | 18.8 | | | | |
| *Picea sitchensis* | | | | | | | | | | | | | | | | |
| | **All trees** | | | | **Atlantic** | | | | | | | | | | | |
| 0-10% | 47.6 | 39.4 | 28.4 | 18.5 | 47.5 | 39.2 | 28.2 | 18.0 | | | | | | | | |
| 11-25% | 31.8 | 31.4 | 24.6 | 27.8 | 31.8 | 31.4 | 24.6 | 28.0 | | | | | | | | |
| >25% | 20.6 | 29.3 | 46.9 | 53.7 | 20.8 | 29.4 | 47.2 | 54.0 | | | | | | | | |
| *Quercus robur* | | | | | | | | | | | | | | | | |
| | **All trees** | | | | **Atlantic** | | | | | | | | | | | |
| 0-10% | 48.7 | 41.4 | 52.5 | 60.5 | 36.9 | 28.8 | 49.9 | 55.9 | | | | | | | | |
| 11-25% | 29.8 | 34.4 | 33.5 | 22.2 | 34.9 | 38.6 | 34.9 | 23.1 | | | | | | | | |
| >25% | 21.5 | 24.1 | 14.1 | 17.3 | 28.2 | 32.6 | 15.3 | 21.0 | | | | | | | | |
| *Quercus pubescens* | | | | | | | | | | | | | | | | |
| | **All trees** | | | | **Mediterranean** | | | | | | | | | | | |
| 0-10% | 88.4 | 78.0 | 71.3 | 62.1 | 85.6 | 76.6 | 70.9 | 61.7 | | | | | | | | |
| 11-25% | 3.9 | 14.6 | 20.9 | 22.2 | 4.8 | 14.7 | 23.9 | 23.2 | | | | | | | | |
| >25% | 7.8 | 7.4 | 7.8 | 15.7 | 9.6 | 8.7 | 5.3 | 15.1 | | | | | | | | |
| *Quercus petraea* | | | | | | | | | | | | | | | | |
| | **All trees** | | | | **Sub-atlantic** | | | | | | | | | | | |
| 0-10% | 68.5 | 70.2 | 65.4 | 61.3 | 67.4 | 68.2 | 62.8 | 63.2 | | | | | | | | |
| 11-25% | 25.7 | 20.5 | 24.3 | 29.8 | 26.8 | 21.8 | 26.1 | 28.0 | | | | | | | | |
| >25% | 5.8 | 9.2 | 10.3 | 8.9 | 5.7 | 10.0 | 11.1 | 8.8 | | | | | | | | |

ANNEX III-2: Percentages of trees in discolouration classes 0 (0-10%), 1 (11-25%) and 2+3+4 (>25% or dead) for 12 most represented species of 1987-1990 Common Sample Trees, for all individuals and by climatic region.

| Species/ Class | Survey years / Climatic region | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | '87 | '88 | '89 | '90 | '87 | '88 | '89 | '90 | '87 | '88 | '89 | '90 | '87 | '88 | '89 | '90 |
| *Picea abies* | | | | | | | | | | | | | | | | |
| | All trees | | | | Atlantic | | | | Sub-atlantic | | | | Mountainous | | | |
| 0-10% | 89.9 | 90.5 | 89.7 | 96.6 | 98.0 | 95.0 | 99.0 | 99.0 | 92.1 | 91.2 | 89.8 | 99.0 | 79.6 | 86.7 | 88.9 | 87.3 |
| 11-25% | 8.8 | 7.5 | 8.5 | 2.6 | 2.0 | 5.0 | 1.0 | 1.0 | 6.7 | 7.0 | 8.2 | 0.7 | 18.2 | 10.2 | 9.6 | 9.9 |
| >25% | 1.3 | 2.0 | 1.8 | 0.8 | 0.0 | 0.0 | 0.0 | 0.0 | 1.2 | 1.8 | 2.1 | 0.3 | 2.2 | 3.1 | 1.5 | 2.8 |
| *Pinus sylvestris* | | | | | | | | | | | | | | | | |
| | All trees | | | | Atlantic | | | | Sub-atlantic | | | | Mediterranean | | | |
| 0-10% | 86.3 | 89.7 | 82.8 | 87.0 | 78.4 | 93.2 | 79.2 | 81.7 | 95.8 | 93.1 | 93.3 | 95.8 | 95.8 | 76.8 | 83.4 | 95.5 |
| 11-25% | 11.3 | 9.1 | 14.6 | 10.0 | 17.9 | 5.8 | 17.3 | 15.8 | 4.0 | 5.7 | 5.2 | 3.7 | 2.8 | 21.5 | 16.6 | 1.7 |
| >25% | 2.4 | 1.2 | 2.6 | 3.0 | 3.7 | 1.0 | 3.5 | 2.4 | 0.2 | 1.2 | 1.5 | 0.5 | 1.4 | 1.7 | 0.0 | 2.8 |
| *Fagus sylvatica* | | | | | | | | | | | | | | | | |
| | All trees | | | | Atlantic | | | | Sub-atlantic | | | | Mediterranean | | | |
| 0-10% | 92.2 | 91.5 | 90.6 | 91.5 | 67.9 | 54.1 | 77.4 | 84.3 | 95.4 | 94.0 | 94.8 | 97.3 | 91.2 | 97.6 | 87.0 | 88.5 |
| 11-25% | 6.3 | 6.3 | 7.2 | 7.7 | 23.3 | 30.8 | 11.9 | 13.8 | 4.0 | 5.0 | 4.1 | 2.2 | 6.9 | 1.2 | 10.3 | 10.3 |
| >25% | 1.6 | 2.2 | 2.2 | 0.9 | 8.8 | 15.1 | 10.7 | 1.9 | 0.6 | 1.0 | 1.1 | 0.6 | 1.8 | 1.2 | 2.7 | 1.2 |
| *Quercus ilex* | | | | | | | | | | | | | | | | |
| | All trees | | | | Mediterranean | | | | | | | | | | | |
| 0-10% | 63.6 | 88.3 | 91.5 | 97.9 | 63.9 | 88.2 | 91.5 | 97.9 | | | | | | | | |
| 11-25% | 26.8 | 11.6 | 8.5 | 1.5 | 26.3 | 11.7 | 8.5 | 1.5 | | | | | | | | |
| >25% | 9.6 | 0.1 | 0.0 | 0.7 | 9.8 | 0.1 | 0.0 | 0.6 | | | | | | | | |
| *Pinus halepensis* | | | | | | | | | | | | | | | | |
| | All trees | | | | Mediterranean | | | | | | | | | | | |
| 0-10% | 74.3 | 73.8 | 77.9 | 79.9 | 74.3 | 73.8 | 77.9 | 79.9 | | | | | | | | |
| 11-25% | 21.2 | 24.2 | 19.9 | 17.6 | 21.2 | 24.2 | 19.9 | 17.6 | | | | | | | | |
| >25% | 4.5 | 2.0 | 2.3 | 2.5 | 4.5 | 2.0 | 2.3 | 2.5 | | | | | | | | |
| *Pinus nigra* | | | | | | | | | | | | | | | | |
| | All trees | | | | Mediterranean | | | | | | | | | | | |
| 0-10% | 81.0 | 81.0 | 82.2 | 83.2 | 90.5 | 83.9 | 88.1 | 86.8 | | | | | | | | |
| 11-25% | 14.0 | 18.5 | 17.0 | 14.4 | 9.5 | 15.6 | 11.7 | 10.4 | | | | | | | | |
| >25% | 5.0 | 0.5 | 0.9 | 2.4 | 0.0 | 0.4 | 0.2 | 2.8 | | | | | | | | |

(continued)

ANNEX III-2 (continued).

| Species/ Class | Survey years / Climatic region | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | '87 | '88 | '89 | '90 | '87 | '88 | '89 | '90 | '87 | '88 | '89 | '90 | '87 | '88 | '89 | '90 |
| *Pinus pinaster* | | | | | | | | | | | | | | | | |
| | All trees | | | | Atlantic | | | | Mediterranean | | | | | | | |
| 0-10% | 76.3 | 80.8 | 80.3 | 83.3 | 99.5 | 95.7 | 89.9 | 93.6 | 69.8 | 78.6 | 80.7 | 83.5 | | | | |
| 11-25% | 9.8 | 15.2 | 19.2 | 14.3 | 0.5 | 4.3 | 10.1 | 0.0 | 14.9 | 16.2 | 18.6 | 16.0 | | | | |
| >25% | 13.8 | 4.0 | 0.5 | 2.3 | 0.0 | 0.0 | 0.0 | 6.4 | 15.2 | 5.2 | 0.8 | 0.5 | | | | |
| *Castanea sativa* | | | | | | | | | | | | | | | | |
| | All trees | | | | Sub-atlantic | | | | Mediterranean | | | | | | | |
| 0-10% | 74.4 | 79.9 | 72.5 | 81.3 | 83.8 | 93.4 | 90.4 | 75.8 | 65.4 | 67.5 | 56.2 | 81.5 | | | | |
| 11-25% | 19.4 | 17.6 | 22.0 | 14.1 | 16.2 | 6.6 | 7.6 | 21.2 | 22.9 | 27.7 | 34.9 | 12.0 | | | | |
| >25% | 6.2 | 2.6 | 5.5 | 4.6 | 0.0 | 0.0 | 2.0 | 3.0 | 11.6 | 4.8 | 8.9 | 6.5 | | | | |
| *Picea sitchensis* | | | | | | | | | | | | | | | | |
| | All trees | | | | Atlantic | | | | | | | | | | | |
| 0-10% | 78.7 | 77.3 | 88.4 | 87.2 | 78.8 | 77.1 | 88.3 | 87.1 | | | | | | | | |
| 11-25% | 14.1 | 12.4 | 7.6 | 10.3 | 14.0 | 12.5 | 7.6 | 10.4 | | | | | | | | |
| >25% | 7.2 | 10.3 | 4.0 | 2.5 | 7.2 | 10.4 | 4.0 | 2.5 | | | | | | | | |
| *Quercus robur* | | | | | | | | | | | | | | | | |
| | All trees | | | | Atlantic | | | | | | | | | | | |
| 0-10% | 88.0 | 89.0 | 89.5 | 89.5 | 87.0 | 85.6 | 89.0 | 87.3 | | | | | | | | |
| 11-25% | 8.6 | 8.7 | 8.9 | 6.8 | 8.4 | 11.2 | 8.9 | 8.6 | | | | | | | | |
| >25% | 3.4 | 2.3 | 1.5 | 3.6 | 4.6 | 3.2 | 2.0 | 4.0 | | | | | | | | |
| *Quercus pubescens* | | | | | | | | | | | | | | | | |
| | All trees | | | | Mediterranean | | | | | | | | | | | |
| 0-10% | 90.8 | 78.9 | 84.7 | 77.1 | 88.5 | 77.5 | 81.0 | 77.3 | | | | | | | | |
| 11-25% | 2.0 | 13.1 | 14.6 | 20.0 | 2.5 | 12.8 | 18.1 | 19.5 | | | | | | | | |
| >25% | 7.2 | 7.9 | 0.7 | 3.0 | 8.9 | 9.6 | 0.9 | 3.2 | | | | | | | | |
| *Quercus petraea* | | | | | | | | | | | | | | | | |
| | All trees | | | | Sub-atlantic | | | | | | | | | | | |
| 0-10% | 99.7 | 97.9 | 96.9 | 94.2 | 100 | 98.5 | 96.6 | 94.6 | | | | | | | | |
| 11-25% | 0.3 | 1.7 | 2.1 | 4.8 | 0.0 | 1.1 | 2.3 | 4.2 | | | | | | | | |
| >25% | 0.0 | 0.3 | 1.0 | 1.0 | 0.0 | 0.4 | 1.1 | 1.1 | | | | | | | | |

## ANNEX IV-1 Regression analysis of plot defoliation with mean stand age.

Regression analysis was performed with the **percentage of trees per plot** in a certain defoliation class as the dependent variable and the **mean stand age** as the sole independent variable. Only plots with at least 10 specimens of a species, c.q. *Picea abies*, were included. Furthermore only plots from the **Sub-atlantic region** with a mean stand age of **not more than 110 years** were used. In a separate run, only plots on **moder humus** were considered.

A **sinus/cosinus-model** was considered to yield the most acceptable results as it is able to describe a wave-like curve with more than one (relative) maximum.
Using specific, iterative computer-programmes the results all had the shape of:

$$Def = a * (c * (\cos (\pi*(Age-d)/b) + 1)$$

in which:

| | | |
|---|---|---|
| Def | = | the percentage of trees to be predicted, |
| Age | = | the mean stand age of the plot, |
| a,c | = | scale factors determining the minimum and maximum values, |
| b | = | the scale factor determining the 'wavelenght' of the function, |
| d | = | the 'phase factor' shifting the curve along the X-axis, |
| $\pi$ | = | pi (3.14159...). |

The calculations yielded values for a, b, c, d, Def and the residual, which is calculated as the predicted value of Def minus the observed value of Def (the formulae and the specific values of a, b, c and d are given in Table IV-2 at the end of this section). The resulting curves for the data-set of all plots are depicted in Figure IV-1, along with the range in the plot defoliation data.

TABLE IV-1: Regression coefficients ($R^2$) of plot defoliation by mean stand age. Data for Picea abies, Sub-atlantic region, 1989.

| defoliation | all plots | | | moder humus plots | | |
|---|---|---|---|---|---|---|
| | I | II | III | I | II | III |
| 0-10% (Class 0) | 0.50 | 0.56 | 0.55 | 0.72 | 0.77 | 0.77 |
| 11-25% (Class 1) | 0.35 | 0.46 | - | 0.52 | 0.57 | - |
| >26% (Class 2-4) | 0.27 | 0.29 | - | 0.33 | 0.39 | - |

I = Linear (straight line) model Def = a*Age + b

II = Non-linear (cosinus) model Def = a*(c*(cos(Age-d)/b)+1)

III = Non-linear (logistic) model Def = a/(1+b*exp(c*Age))

Evaluating the 'goodness of fit' of the models described can be performed by scrutinizing the residuals for possible trends remaining uncaptured, and by interpreting the value of the regression coefficient $R^2$ (see Table IV-1). The analysis proved that the non-linear model fits better to the data-set than the linear model. The curve explains a larger part of the variation and its residuals (not shown) are scattered uniformly around a mean of zero. This indicates that no systematic variation is left undiscribed. Table IV-1 shows how the values of $R^2$ have improved in the non-linear model compared to the linear analysis. The results are very acceptable for variables with such a large variation.

Associations of natural growth (or decline) are usually described by logistic or S-curve models. Within the data set, the plot defoliation of trees in defoliation class 0 appears to be distributed closely along such an S-curve. For the other classes of defoliation, this is less clear and use of the logistic model would require the data-set to be cut in two; one part fitting a real growth model; the other part fitting its 'reverse', a model of decline.

The logistic model is defined by the equation:

$$Def = \frac{a}{1+b*e^{-c*Age}}$$

in which $a > 0$ and $b > 0$. The parameter c determines the shape of the curve; for $c > 0$, the model describes growth, for $c < 0$ decline of the predictand with increasing values of the regressor. Of course, instead of the condition $c < 0$, the minus-sign in the equation may also be omitted (Table IV-2). The model has a maximum (for Age = 0) of a/1+b and an asymptotic minimum of Lim Def(Age->oo) = 0. The results of the statistical computations for this model are also shown in Table IV-2.

Other models that have been assessed involved terms as Def= Age*Log(Age), or were modifications of models already discussed above. Also some other linear applications as quadratic and cubic expressions of defoliation in terms of mean stand age were evaluated but these showed no acceptable results ($R^2 < 0.25$).

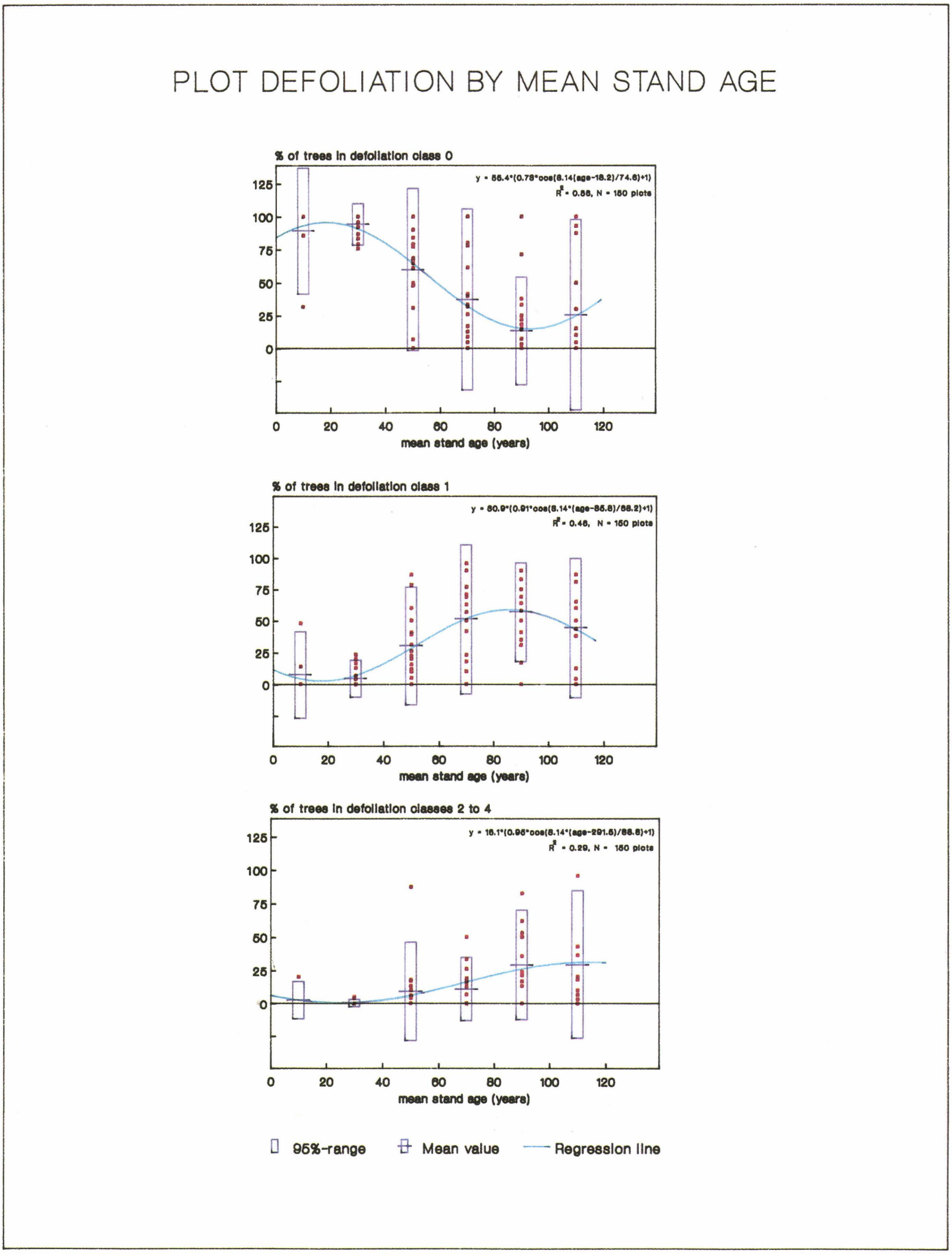



Figure IV-1. The percentage of trees in defoliation classes 0, 1 and 2 to 4 as dependent of mean stand age. Non-linear regression of plot defoliation data from the Sub-atlantic region, *Picea abies*. Plots with at least 10 trees of species.

TABLE IV-2: Model coefficients for Non-Linear Regression Analysis of plot defoliation and mean stand age.
Data for Picea abies, Sub-atlantic region, 1989.

| **defoliation** | **Model II** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **all plots** | | | | **moder humus plots** | | | |
| | a | b | c | d | a | b | c | d |
| 0-10% (Class 0) | 55.4 | 74.6 | 0.73 | 18.2 | 52.7 | 81.3 | 0.85 | 14.0 |
| 11-25% (Class 1) | 30.9 | 68.2 | 0.91 | 85.8 | 30.2 | 92.5 | 1.05 | 92.1 |
| >26% (Class 2-4) | 16.1 | 88.8 | 0.95 | 291.5 | 13.8 | 67.8 | 1.25 | 233.0 |

| **defoliation** | **Model III** | | | | | |
|---|---|---|---|---|---|---|
| | **all plots** | | | **moder humus plots** | | |
| | a | b | c | a | b | c |
| 0-10% (Class 0) | 107.9 | 0.090 | 0.048 | 102.3 | 0.018 | 0.072 |

II = Non-linear (cosinus) model Def = a*(c*(cos(Age-d)/b)+1)

III = Non-linear (logistic) model Def = a/(1+b*exp(c*Age))

## ANNEX IV-2 Evaluation of soil suitability and forest vitality.

TABLE IV-3: Tentative soil suitability ratings.
1 = severe limitations, 4 = no limitations

| soil type | multiple rating | | | | | single rating |
|---|---|---|---|---|---|---|
| | depth | matrix | drainage | nutrient | pH+buffer | |
| Cambic Arenosol | 4 | 1 | 4 | 1 | 2 | 1 |
| Luvic Arenosol | 4 | 2 | 4 | 2 | 2 | 2 |
| Orthic Rendzina | 1 | 3 | 4 | 2 | 4 | 3 |
| Eutric Cambisol | 3 | 3 | 4 | 3 | 3 | 3 |
| Dystric Cambisol | 3 | 3 | 4 | 2 | 3 | 3 |
| Gleyic Cambisol | 2 | 3 | 2 | 2 | 2 | 3 |
| Calcic Cambisol | 3 | 3 | 4 | 3 | 4 | 3 |
| Chromic Luvisol | 4 | 4 | 4 | 4 | 3 | 4 |
| Gleyic Luvisol | 2 | 4 | 2 | 3 | 3 | 4 |
| Orthic Podzol | 2 | 2 | 3 | 1 | 2 | 2 |
| Leptic Podzol | 2 | 2 | 3 | 1 | 2 | 2 |
| Humic Podzol | 2 | 2 | 3 | 1 | 2 | 2 |
| Eutric Planosol | 2 | 2 | 2 | 2 | 2 | 1 |
| Dystric Histosol | 1 | 2 | 1 | 2 | 1 | 1 |

Explanation to the Table IV-3:

The multiple rating is composed of the suitability scores for the most important soil qualities, as far as these can be deduced from the available information. The five qualities determining the rating are:

**Depth**, which is an evaluation of the land quality related to the rootable depth (or physiological depth) of the soil.
**Matrix**, which refers to texture, structure and consistence of the soil. It therefore also expresses the soil's suitability in terms of water holding capacity and aeration.
**Drainage**, which refers to the occurence of (perched) high groundwaterlevels, as deduced from gleyic properties.
**Nutrients**, which is an assessment of the amount of primary nutrients, the Cation Exchange Capacity of the fine earth fraction, and organic matter.
**pHbuffer**, which is an arbitrarily evaluation of the soil reaction and the calcium carbonate content, and indirectly reflects the buffering capacity of the soil.

Independently from the above, a direct and straightforward evaluation of the suitability of the soil, without distinguishing any composing land qualities, is expressed in the **single rating** given in the last column of the Table IV-3.

TABLE IV-4: Coefficients ($R^2$) of linear regression of defoliation by soil type.
Data from Germany and Austria, plots with soil data, Picea abies, 1990.

| **defoliation expressed as:** | **soil type expressed as:** | |
|---|---|---|
| | multiple rating | single rating |
| mean percentage per soil type | 0.34 | 0.44 |
| mean percentage per plot | 0.12 | 0.05 |
| defoliation individual trees | 0.15 | 0.05 |

## Annex V Forms used for the recording of inventory data

COMMON METHODS FOR THE ESTABLISHMENT OF A PERIODIC INVENTORY OF DAMAGE CAUSED TO FORESTS

### FORM 1

**Common forest damage inventory data to be forwarded to the Commission**

| | | | |
|---|---|---|---|
| Country (1) | | Date of observation (6) | |
| Observation point number (2) | | Actual latitude coordinate (7) | |
| Availability of water to principal species (3) | | Actual longitude coordinate (7) | |
| Humus types (4) | | Aspect (8) | |
| Altitude (5) | | Mean age of predominant story (9) | |

| Sample tree number (10) | Species (11) | Defoliation (12) | Discolouration (13) | Easily identifiable causes of damage Type: T (14) | | | | | | | | Identification of damage type if possible (15) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | T 1 | T 2 | T 3 | T 4 | T 5 | T 6 | T 7 | T 8 | |
| 1 | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | |
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Other observations (16):

For the replacing of trees of the sample see the form in Annex.

**FORM 1 — Annex**

**Replaced trees** [17]

| Sample tree number [10] | Species [11] | | | Defoliation [12] | Discolouration [13] | Easily identifiable causes of damage Type: T [14] | | | | | | | | Identification of damage type if possible [15] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | T 1 | T 2 | T 3 | T 4 | T 5 | T 6 | T 7 | T 8 | |
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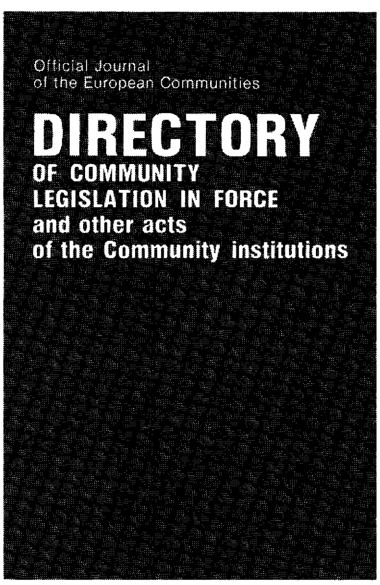


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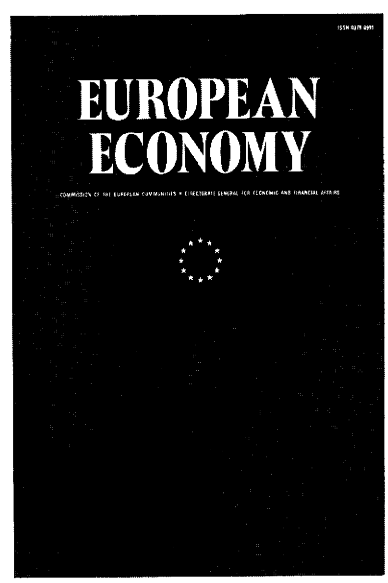


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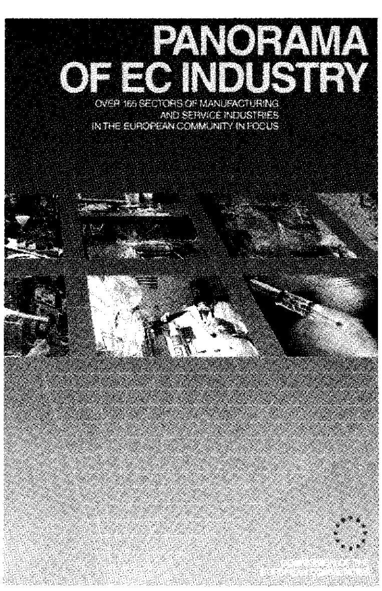


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07/10/91

European Communities - Commission

**Forest health report 1991 - Technical report on the 1990 survey**

*Document*

Luxembourg: Office for Official Publications of the European Communities

1991 - X, 146 pp., 49 illus. - 21.0 x 29.7 cm

ISBN 92-826-0549-3

Catalogue number: CH-72-91-237-EN-C

Price (excluding VAT) in Luxembourg: ECU 16