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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Internal Review of ICP Forests

Prepared by: **Federal Research Centre for Forestry and Forest Products (BFH)**

Internal Review of ICP Forests

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Internal Review of ICP Forests

Contents

Summary

ICP Forests has successfully finalised its internal review started two years ago. Although important recommendations for a revision of ICP Forests have been gained, the review will remain a permanent tasks.

The main results achieved within this review are:

- The programme has developed into a a **unique biomonitoring system worldwide** and the external demands for the data are increasing.
- **The objectives of ICP Forests should be widened.** Forests are affected by a complex of anthropogenic and natural stressors. Air pollution continues to be regarded as an important stress factor. However, a large number of other stress factors are also influencing forest condition and must therefore be taken into consideration. ICP Forests could contribute with its data also to **other aspects of relevance for forest policy,** such as effects of climatic changes on forests or biodiversity in forests.

- **Methods and design of the ICP Forests monitoring** have been developed based on the state of knowledge on forest functioning and the objectives agreed upon. On Level I the crown condition results for the main tree species results show sufficient precision for large regions in Europe. At Level II, as well, the precicion of the measurements lies within the accepted limits.
- Therefore, Level I and Level II should remain basically unchanged. However, more efforts should be paid in future to link results of both levels in order to come to integrated evaluations.
- The **structure of ICP Forests** has proven to be efficient. In particular the Expert Panels are contributing to the success of ICP Forests. It will be of importance in future that the links between the groups will be improved and integrated evaluation approaches are increased.

- The **major aim of Level I**, to monitor **crown condition** changes at a large scale has been reached. **Defoliation** remains an important key parameter of crown condition assessment, as it is a a useful general stress factor that can be easily identified over large areas. The value of the parameter has been supported by the evaluation of other response variables. With the installation of new surveys at the Intensive Monitoring Level it has, however, become one important response variable among others. **Quality assurance concepts** need to be further developed, including e.g. digital image processing techniques and new concepts of inter-calibration courses.
- The **soil condition at Level I** has been assessed once. In order to monitor and to document changes in soil chemistry, in particular at forest sites that are subjected to high loads of atmospheric pollution and to assess relevant soil parameters and soil layers not considered in the first survey a new soil survey would be desirable. However, the further standardisation of methods, a revision of key parameters and improvements in the laboratory (and sampling) procedures have to be guaranteed. **Foliar analyses** on the same Level I plots would be a useful additional information for investigating forests condition. It is therefore recommended to include this survey.

- The **Level II programme** aims at the recognition of key factors in the functioning of forest ecosystems. Although the programme part is rather young compared to Level I it has been proven that the surveys carried out at the intensive monitoring plots are relevant. The **quality assurance** will remain a field of further improvement. Although important milestones have been reached with the agreement on harmonised methods and a common data transfer system, the need for more efforts are obvious.
- It is recommended to concentrate the **continuous measurements** on soil solution, meteorological parameters and deposition/air concentration measurements at the same plot if not all plots in a country can be equipped.
- In future **air concentration measurements** should attract more importance within the Level II programme.
- Proposals to improve the recording of damage causes to leaves and needles as well as litterfall assessments are under work.
- Suggestions to **streamline the programme and to decrease the funds** involved have been made by the Expert Panels. Examples are the reduction of assessment frequencies or the concentration of more assessments on a lower number of Level II plots

- ICP Forests has contributed substantially to the progress achieved within the **Working Group on Effects**. This will remain of major importance also in future.
- The **co-operation with the European Union** scheme on the protection of forests against atmospheric pollution is of vital interest for ICP Forests and should be continued. ICP Forests should also continue its **co-operation with other programmes under the CLRTAP**.

- The **Executive Report** will remain the basic document in order to spread the monitoring results obtained. A proposal for cost reduction reduce costs is to yearly alternate the two **Technical Reports**.
- In comparison to printed media, the Internet will gain increasing importance for the dissemination of results to all target groups.

Preface

In response to widespread concern that air pollution could effect forest condition, the International Co-operative Programme on the Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) was established in 1985 under the UN/ECE Convention on Long-range Transboundary Air Pollution (CLRTAP). In 1986 the European Union adopted the scheme on the protection of forests against atmospheric pollution and with Regulation (EEC) No. 3528/86 the legal basis for the relevant assessments was provided. The monitoring activities pursue the objectives of Resolution S1 of the Strasbourg, the Resolution H1 of the Helsinki and Resolution L2 of the Lisbon Ministerial Conference on the protection of Forests in Europe.
Since 1986 the monitoring of forest condition and development has been carried out under both programmes in close co-operation. At present, 37 European countries as well as the United States of America and Canada are participating in the programmes, which include assessments according to harmonised methods (see also ICP Forests Manual) and which have developed as an important platform for the exchange of expert knowledge. Results of the ICP Forests programme provide the scientific basis for political decisions on air pollution control and other environment related policies.

In 1997, ICP Forests at its 13th Task Force meeting decided to carry out an internal review on its programme. It was agreed that the results of this review should be presented to the 16th Task Force meeting for discussion and approval. As a consequence, an updated programme scheme should be agreed upon.

This report is the third document in a series aimed to lay down the results of the internal review (see also Strategy Paper 1998 and Progress report 1999). The report will provide the Task Force with all relevant background information on the outcome of the review process. Furthermore the report documents the progress archived in improving harmonised methods and quality assurance. It will serve as a basis for decicions on the future of ICP Forests, but does not contain the future strategy of the programme.

Substantial contributions were received by all Expert Panels of ICP Forests and the Programme Co-ordinating Group. The contributions and assistance received is gratefully acknowledged.

1. Background

After more than a decade of monitoring forest condition in Europe, the Task Force of ICP Forests decided at its 13th meeting in 1997 to subject the programme to an internal review.
This internal review was seen in the context with the continuous revision of the monitoring activities over the past years which had led to several updates of the ICP Forests' Manual. Going beyond this, the main reasons for this internal review were

- that the objectives and activities of of all programmes under the Working Group on Effects (WGE) were to be adjusted to the long-term priorities of the Executive Body (EB) within an external report of the WGE;
- budget needs in the participating countries requiring a streamlining of the monitoring activities;
- changes in the deposition environment requiring new priorities in the monitoring activities;
- considerations regarding possible contributions to further high priority issues of environmental policies, such as climate change, biodiversity and the sustainable development of forests;
- criticism on certain parts of the programme.

In particular, the Task Force agreed that

- the review should be carried out in the period 1998-2000 in close co-operation with the European Commission;
- external experts should be involved;
- the Programme Coordinating Group should promote and supervise the review and propose options for action in view of the future shape of the programme;
- the Expert Panels should be invited to review the monitoring methods and to prepare a list of those parameters indispensable for future evaluations;
- a final report on the results should be presented to the 16th Task Force meeting;
- as a result of the review, the ICP Forests programme should be updated afterwards.
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2. Mandate and Objectives

Launched by the Executive Body of the CLRTAP as a reaction to widespread forest damage which was supposed to be a possible effect of long range transboundary air pollution, ICP Forests was mandated to monitor air pollution effects on forests and to contribute to a better understanding of cause-effect relationships (ECE/EB.AIR/7).

After a decade of monitoring it became obvious, that forests are affected by a complex of anthropogenic and natural stresses.
Air pollution continues to be regarded as an important stress factor. However the importance of atmospheric pollution varies, its impact depends on the region and its effects on site and stand conditions. Air pollution and its effects on forest ecosystems are complex and difficult to isolate and quantify. A large number of other stress factors also have an influence on forest condition and must therefore be taken into consideration.

Therefore, the ICP Forests mandate has been slightly revised:

- to monitor effects of anthropogenic (in particular air pollution) and natural stress factors on the condition and development of forest ecosystems in Europe and
- to contribute to a better understanding of cause-effect relationships in forest ecosystem functioning in various parts of Europe.

Based on its mandate, ICP Forests pursues the following objectives:

(a) to provide a periodic overview on the spatial and temporal variation in forest condition in relation to anthropogenic (in particular air pollution) as well as natural stress factors on an European and national large-scale systematic network (Level I),
(b) to contribute to a better understanding of the relationships between the condition of forest ecosystems and anthropogenic (in particular air pollution) as well as natural stress factors through intensive monitoring on a number of selected permanent observation plots spread over Europe (Level II) and to study the development of important forest ecosystems in Europe,
(c) to provide a deeper insight into the interactions between the various components of forest ecosystems by compiling available information from related studies,
(d) to contribute in close co-operation with the ICP on Modelling and Mapping to the calculation of critical levels/loads and their exceedances in forests and to improve collaboration with other environmental monitoring programmes inside and outside the CLRTAP,
(e) to contribute by means of the monitoring activities to other aspects of relevance for forest policy at national, pan-European and global level, such as effects of climate changes on forests, sustainable forest management and biodiversity in forests,
(f) to provide policy-makers and the general public with relevant information.

3. Concepts of the Monitoring Intensity Levels

ICP Forests has implemented a hierarchy of three monitoring intensity levels in order to reach the objectives specified in Chapter 2. Level I consists of a systematic large-scale monitoring featuring a high number of plots and low monitoring intensity per plot. The forest condition data assessed at this level have the advantage of being representative on the European-wide scale. They can be correlated with large-scale data resulting from other programmes, but do not permit conclusions regarding cause-effect relationships. Cause-effect relationships are derived at Level II which constitutes an intensive monitoring on a smaller number of permanent observation plots. The results derived at Level II in turn are lacking large-scale representativity. However, the concept of the monitoring intensity levels has from the beginning on foreseen their linkage by using the extensive data at Level I for extrapolating Level II data and relationships to the large-scale. Such extrapolations of relationships identified at Level II aim at:

- assessments of the importance of the relationships at the European scale;
- delimitations of the geographical area (within Europe) for which the relationship holds true.

The harmonisation of the monitoring levels which is carried out in the course of the review is a pre-requisite for the extrapolation of relationships.

Level III is the highest within the hierarchy of monitoring intensity levels. It foresees in-depth understanding of interactions within forest ecosystems, based on scientific literature and the results of monitoring reaching beyond the activities at Level II, rather than on an additional monitoring system.

The concepts of all three levels are described in the following three subchapters.

3.1 Level I

3.1.1 Objectives

The original major aim of the Level I assessments has been formulated as “to gain knowledge of the spatial and temporal variation in forest condition and of its relationship to stress factors including air pollution on regional, national and international scales”.Up to the present time annual crown condition assessments on national and transnational gridnets as well as one soil survey and one chemical foiliar analysis have been performed.

Results indicate that forest condition is influenced by a complex of multiple stress factors which must be analzed as a whole in order to identify effects specifically of air pollution. Thus the revised and more specific objectives of the Level I forest condition monitoring are defined as to:

- systematically assess spatial and temporal trends in forest condition at the large-scale, based in particular on crown condition, soil and foliage surveys;

- study large-scale interactions between components of the forest ecosystems and natural and anthopogenic stress factors (in particular air pollution), integrating Level I and other large-scale data ("integrative evaluations");
- serve as a basis for extrapolating processes identified at Level II to the large scale;
- contribute to other programmes, e.g. under the international political processes on sustainability, biodiversity and climate change.

These revised objectives contribute to the overall aims of ICP Forests as they are summarized under items (a), (c) and (e) in Chapter 2.

3.1.2 Survey design

Aimed to gain knowledge of the spatial and temporal variation in forest condition at the large scale, the Level I surveys are performed on a 16 x 16 km transnational monitoring grid. The latitude and longitude of the sampling points were calculated by the European Commission (CORINE project). If a country had already established plots with coordinates deviating from the calculated ones, the existing plots were accepted, provided that the mean point density resembled that of a 16 x 16 km grid, and that the assessment methods corresponded to those of the ICP Forests Manual and the relevant EU-Regulations. Only in boreal areas and in maquis area, wider grids are applied (16 x 32 or 32 x 32 km). Grid points falling into forest land qualify for the installation of sample plots. In 1999, the number of sample plots amounted to more than 5 700.

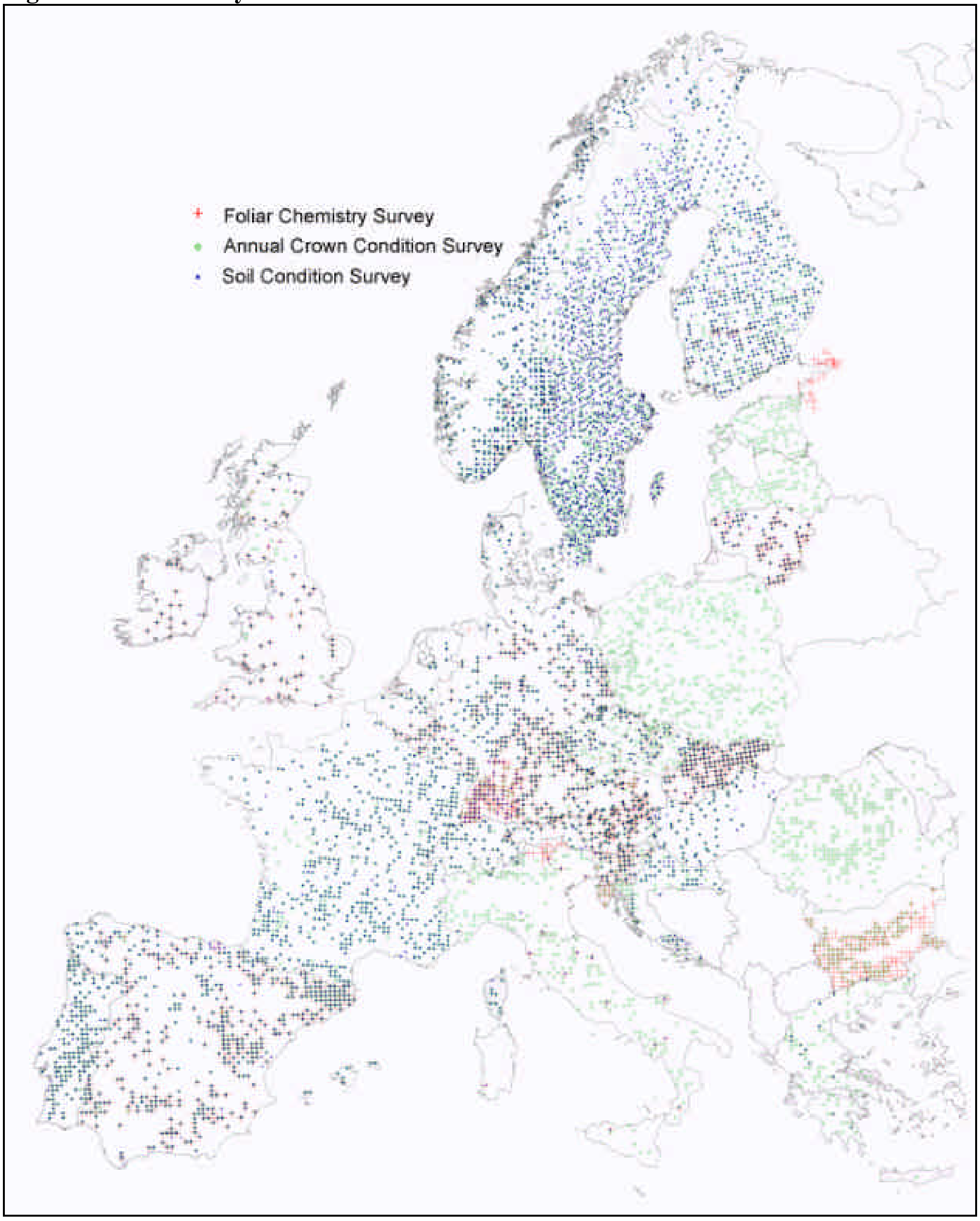
Each Level I plots is characterized by a number of plot variables, and crown condition is reported for the trees of each plot every year. In addition, soil and foliage surveys were carried out once on part of the plots (Table 3.3.2-1). These surveys are intended to be repeated in order to assess changes.

The frequency distribution of defoliation as derived from the crown condition assessments on the transnational grid is thought to be representative for the forests at the large scale. But the interpretability of spatial patterns of defoliation with respect to stress factors remains limited as long as the spatial distribution of tree species and the effects of ageing remain unaccounted for. Also, stratification of the sample according to species, age and site conditions necessary at the analytical stage quickly leads to sample sizes too small for detecting significant trends. Other sources of error result from the design of the plots and the selection of trees, which moreover differ between individual countries.

Table 3.1.2-1: Surveys carried out at Level I

Surveys conducted	Periodicity	Intensity	Number of plots
Crown condition	annually	all plots	>5 700
Soil chemistry	once 1994-95	selected transnational and national Level I plots	5 289
	repetition foreseen in 2004-06	to be determined	to be determined
Foliar chemistry	once 1994-95	selected plots	1 444
	repetition foreseen in 2005	to be determined	to be determined

Figure 3.1.2-1: Surveys carried out at Level I



3.1.3 Crown condition monitoring (see also Chapter 4.2)

The key parameters of the crown condition assessments, defoliation and discolouration, are annually assessed on approximately 130 000 trees on the sample plots of the transnational grid. Analyses of scenarios with a less dense grid and bi-annual assessments show that the present survey design yields a reasonable relation of costs and reliability of results. The fact that the grid is less dense in parts of the boreal forests can be shown to be of negligibly small influence on results on the European-wide scale due to the homogeneity of these forests and their current forest condition.

Crown condition responds quickly to a wide range of environmental factors and can be assessed at relatively low costs. Its monitoring is therefore an economic way to continuously search on the large-scale for tree reactions on any detrimental influences. However, because of the lacking specificity of crown condition for individual types of damage, it must be subjected to integrated evaluations, involving results of the other Level I surveys as well as large-scale data of programmes other than ICP Forests. For about half of the sample trees, the presence of identified damage types (i.e. biotic and abiotic damage by e.g. insects, fungi, weather, fire action of man etc.) is reported. Identified damage type will become of utmost value for the interpretation of crown condition data as soon as their occurrence is quantified in harmonized and parametrized way on all sample trees.

Data quality assurance and control (QA/QC) are based on the use of common photo guides, national and international intercalibration courses and reassessments of control samples by independent assessors. In view of forthcoming evaluations, QA and QC are receiving particular attention. New intercalibration concepts also including photography are under development.

3.1.4 Soil survey (see also Chapter 4.3)

The soil surveys aim to assess basic information on the chemical soil status and on properties of the soil which determine its sensitivity to depositions. This information, together with the results of the Level I crown condition assessments, helps to determine whether forest damage observed throughout Europe is related to soil condition, particularly accelerated by chemically induced soil degradation. A first soil survey was already performed in 1994/95 on 5 289 Level I plots in 31 countries. The repetition of the soil survey in the years 2004 – 2006 would thus enable to evaluate changes in the chemical soil condition for most of the Level I plots. The resulting data will in addition open new possibilities for integrated evaluations of Level I data. QA and QC is so far based on two interlaboratory comparisons (ring tests) in which all national soil laboratories involved in the analyses participated.

3.1.5 Foliar survey (see also Chapter 4.5)

Chemical foliar analyses provide information on the chemical contents of needles and leaves, which may reveal nutrient deficiencies or imbalances, as the may occur as a result of several impacts on trees, including changes in the chemical status of forest soils. First analyses have been carried out on 1 444 plots in 16 countries in 1994/95. A favourable period for a complete forest foliar survey on all Level I plots will therefore be in 2005. Reflecting representative information on the nutritional status of trees and possibly its changes (if compared with the first analyses conducted), the data will be of great value for forthcoming integrated evaluations at Level I.

3.2 Level II

3.2.1 Objectives

Current objectives in view of air pollution effects

The original major aim of the 'Pan-European Programme for the Intensive Monitoring of Forest Ecosystems' has been formulated as: 'to gain a better insight in the impacts of air pollution (specifically the elevated deposition levels of SO_x, NO_x and NH_x) and other stress factors on forest ecosystems'. Scientific evaluations should thus be focused on the investigation of relationships between the response parameters (such as defoliation, growth and nutrition) and the predictors (such as site and stand characteristics, meteorology and deposition). Concerning the need of (i) contributing to the further development of air pollution protocols and (ii) deriving insight in the effects of present emission control measures, more specific objectives of the Intensive Monitoring Programme are:

- the assessment of responses of forest ecosystems to changes in air pollution by deriving trends in stress factors and ecosystem condition.
- the calculation of critical loads of atmospheric deposition, related to the chemical ecosystem condition, in relation to present loads by evaluating the fate of atmospheric pollutants in the ecosystem in terms of accumulation, release and leaching.
- the assessment of trace gas fluxes, in particular with respect to acidification and eutrophication processes as well as to photochemical oxidants.
- the evaluation of impacts of future scenarios of atmospheric deposition on the (chemical) ecosystem condition.
- to derive information of the relevance of the results on a European scale, to contribute to an European wide overview of impacts of air pollution and its control strategies.

Comparing the themes of the third objective with the assessed parameters under Level II it becomes clear that to the first two themes the Intensive Monitoring programme has already contributed with its present parameter set. The inclusion of ambient air quality (e.g. ozone measurements) would enable the programme to also contribute to the assessment of photochemical oxidants. The inclusion of heavy metal measurements would enable the programme to assess the impact of toxic substances. The two latter objectives require the combination of results of the Intensive Monitoring Programme with other data available from extensive research or monitoring programmes. The last objective in particular requires the combination of results with data from the Level I monitoring net.

Possible objectives in view of the development of criteria and indicators for sustainable forest management

Various resolutions in the first and second Ministerial Conferences on the Protection of Forests in Europe cover fields to which the results of the Intensive Monitoring Programme can contribute (De Vries, 1999). Examples are the function of (i) forests as a net carbon sink to reduce the build up of atmospheric greenhouse gasses, (ii) forest ecosystem health and vitality, (iii) forest production, (iv) biological diversity of ground vegetation and (v) protective functions of soil and water resources.

Possible objectives of the Intensive Monitoring Programme related to this topic could be the

- Assessment of effects of climatic changes, in particular of changes in carbon storage in forests (net carbon sequestration)
- Further development and monitoring of indicators related to the various functions of forest ecosystems to assess its long-term sustainability.

The first objective is primarily related to the impact of climate change. This topic has gained increasing importance since 181 nations have ratified the United Nations Framework Convention on Climate Change (UNFCCC) until December 1999. In the context of this so-called Kyoto Protocol, information on changes in carbon pools, both above-ground in standing biomass and below-ground in soils, over a large number of forest stands are necessary in order to calculate full carbon budgets.

The second objective includes the derivation of critical loads, since the critical load concept for forests is based on the concept of long-term sustainability of forest soils (in terms of nutrient availability and the occurrence of toxic elements).

Evaluation

The comparison of the various aims in the different sections shows a substantial overlap. The original aim, focused on air pollution effects also includes the assessment of other stress factors and the forest is seen in a broader perspective than trees alone, including soil and (soil) water resources and the ground vegetation. This implies that it partly overlaps with the aims related to criteria and indicators for sustainable forest management. This includes the assessment of criteria and indicators for forest ecosystem health and vitality, forest production, biodiversity and protective functions of soil and water resources. The biological diversity of forests is, however, limited to the species diversity of the ground vegetation (forest understorey) and does not include the biodiversity of e.g. soil organisms (microbiota, soil fauna) while the water resources are focused on soil water (leaching to groundwater). The original aim partly includes concerns with respect to trace gas fluxes and ecosystem functioning, specifically those related to acidification, eutrophication and to a lesser extent photochemical oxidants. New aspects in those concerns are related to toxic substances. With respect to climate the relevance of forests to act as a net carbon sink to reduce the build up of atmospheric greenhouse gasses, in relation to N availability is an important topic.

In view of those statements but considering the fact that the Convention on Long Range Transboundary Air Pollution is one of the main legal pillars of the Intensive Monitoring Programme it seems relevant that the overall objectives of the current Intensive Monitoring programme are revised and widened. The revised aims are summarized under the points (b), (d) and (e) in Chapter 2.

3.2.2 Plot selection and surveys

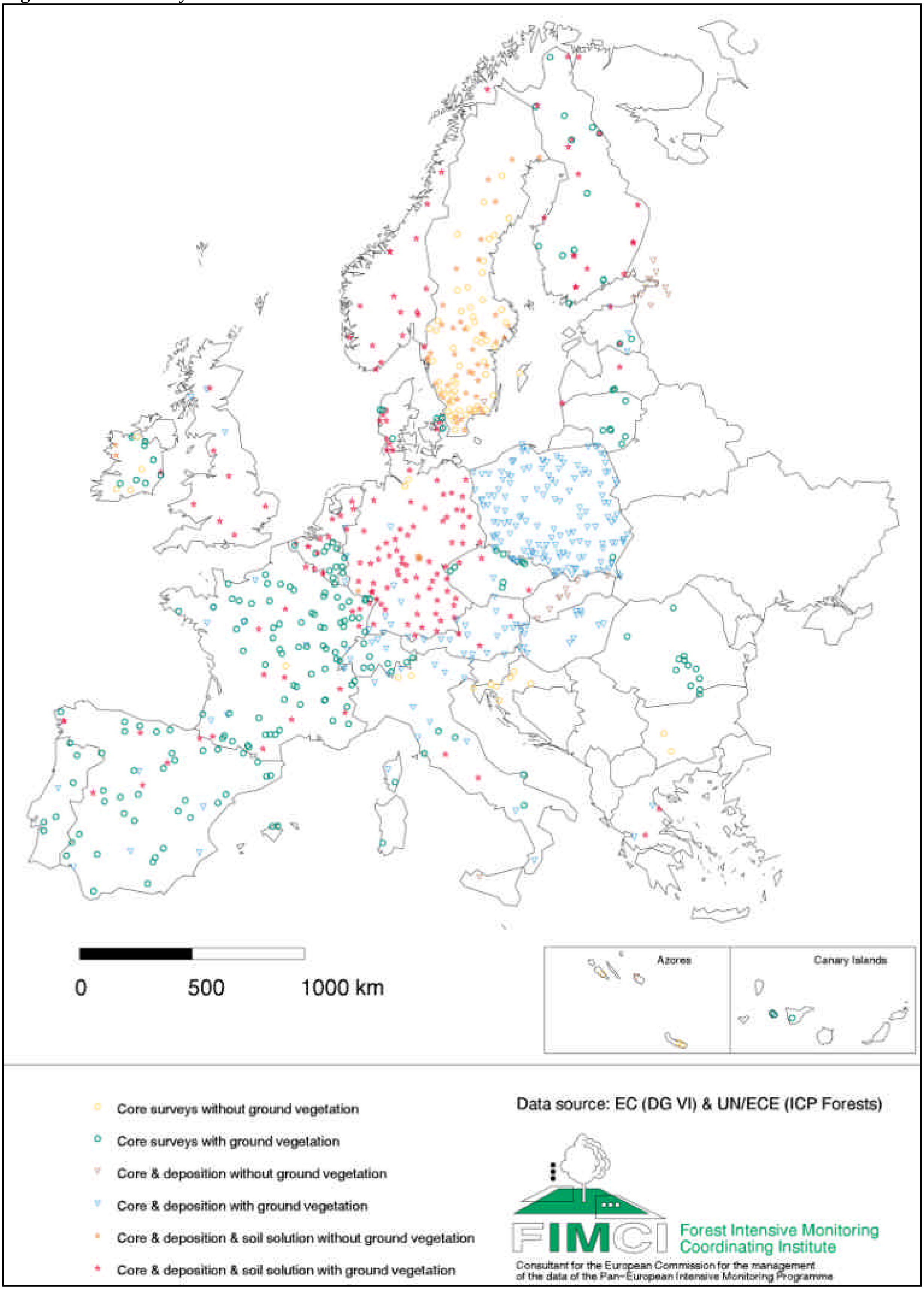
The intensive monitoring at Level II has been implemented since 1995 in close co-operation with EU. Up to now 865 Level II plots have been selected in 30 European countries. The selection of Level II plots, the plot design and the sampling methodology are considerably different from the Level I approach: on a lower number of plots more parameters are assessed more frequently and with a higher intensity. The plots of the intensive monitoring are selected in such a way that the more important forest-ecosystems and more widespread growing conditions in the respective country are represented. The plots have a minimum size of 0.25 ha.

Currently 11 different surveys are carried out in a harmonized way on the Level II plots (see Tab. 3.3.2-1). They are conducted in different intensities according to individual time schedules. As data submission, validation, correction and evaluation takes over two years, the latest available data on a transnational scale are from 1997. At that time monitoring activities have still not been conducted to a full extent. Therefore the number of plots from which data are available is in most cases still smaller than the number of selected and installed plots.

Table 3.3.2-1: Surveys carried out on Level II

Surveys conducted	Periodicity	Planned intensity	Selec-ted plots	Plots with data submitted until 1997	Density of selected plots in different parts of Europe
Crown condition	annually	all plots	865	754	high
Foliar condition	every 2 years	all plots	858	727	high
Soil chemistry	every 10years	all plots	865	604	high
Tree growth	every 5 years	all plots	861	526	high
Atmospheric deposition	continuously	> 10% of the plots	496	488	central, east: high north, south, west: medium
Soil solution chemistry	continuously	> 10% of the plots	242	201	central: high north: medium others: low
Ground vegetation	every 5 years	> 10% of the plots	621	62	high/medium
Meteorological condition	continuously	> 10% of the plots	189	138	central: high west: low others: low/none
Ambient air quality	every 1 – 4 weeks	at meteo and soil solution plots	-	-	-
Phenology			O p t i o n a l		
Remote sensing			O p t i o n a l		

Figure 3.3.2-1: Surveys carried out on Level II



Crown condition survey (see also Chapter 4.2)

As defoliation and discoloration are annual mandatory assessments on all Level II plots, and as crown condition surveys have traditionally been a core activity under ICP Forests the data coverage is high throughout Europe. In 1997 there were crown condition data available for 754 plots.

Foliar chemistry (see also Chapter 4.5)

Chemical foliar analyses are mandatory on all Level II plots every second year. In 1997 there were foliar data available for 724 plots.

Soil chemistry (see also Chapter 4.3)

Chemical soil analyses are mandatory on all Level II plots. For this survey the data coverage is still considerably smaller than for crown condition data. In 1997 there were soil data available for 604 plots.

Forest growth (see also Chapter 4.6)

DBH measurements are mandatory on all Level II plots and have been submitted for 526 plots until 1997. As soon as the still missing data will be validated there will be a rather good spatial coverage. Tree height measurements are currently optional on Level II plots.

Atmospheric deposition (see also Chapter 4.6)

Deposition measurements are mandatory on at least 10 % of the Level II plots. Until 1997 496 of 865 Level II plots in Europe have been selected for these measurements. This is a relatively high coverage. During the past few years the installation of the deposition measurement equipment has been completed. Data availabilty has therefore considerably increased. Deposition measurements are concentrated in central and eastern parts of Europe. However it has to be taken into account that for some plots in eastern regions only bulk deposition is measured and no throughfall data are available. In other parts of Europe the density of plots with deposition measurements is lower.

Meteorology (see also Chapter 4.7)

Meteorological measurements are mandatory on at least 10 % of the Level II plots. In 1997 189 of 865 Level II plots in Europe have been selected. This results in a rather low coverage in Europe and is a major constraint in view of the significance of meteorological variables on forest health. The density of plots with meteorological measurements is highest in central Europe. In other parts only scattered plots can be found.
Data of meteorological monitoring has in 1997 been submitted for a total number 138 plots, of which France and Germany supplied the greatest proportions.

Soil solution chemistry (see also Chapter 4.4)

Measurement of soil solution chemistry is mandatory on at least 10 % of the Level II plots. Until 1997 242 of 865 Level II plots in Europe have been selected for soil solution monitoring. This is a relatively low coverage. Plots with soil solution monitoring are concentrated in central Europe. Northern Europe is as well homogeneousely covered by plots with soil solution measurements, yet the density of these plots is much lower in this region. In southern and eastern parts of Europe only scattered plots can be found.

Soil solution data of the year 1997 has been submitted for a total number 201 plots. Data for the years before 1996 is not available, at least not within the UN/ECE-network. However, as several plots installed during the 1980s within forest decline research programmes have been continued as Level II plots, there are some "historical" time series stored at NFCs.

Ground vegetation (see also Chapter 4.11)

First ground vegetation data from 62 plots are available for 1997. As this part of the programme is a rather young one, data availability will considerably increase during the coming years. The selected 621 plots show a rather good coverage throughout Europe.

Ambient air quality (see Chapter 4.8)

Air quality surveys have only been adopted by the Task Force in the year 2000. Ambient air pollutants of interst include nitrogen dioxide, sulphur dioxide and ozone. It is foreseen to assess their concentrations by passive sampling in weekly to four weekly periods. The installation of passive samplers is recommended at sites were soil solution and deposition measurements are carried out.

Evaluation

The results of the Intensive Monitoring Programme provide an overview on the conditions of the most common and widespread forest and site types in Europe. In addition the linking with the representative Level I gridnet offers the possibility to derive information on the spatial relevance of monitoring results.

Under the hypothesis, that in-depth studies (i) of element specific input-output budgets of forest soils and ecosystems and (ii) of the effects of meteorological variables on processes and properties of forest ecosystems are fundamental for an explanation of the spatial pattern and temporal development of forest health, only those Level II plots, for which the mandatory parameter set of the surveys on atmospheric deposition, soil solution chemistry and meteorology is reported, provide an adequate database. In order to attain reliable estimates of the input output budget, the plots should have been monitored for at least 3 years.

In addition, there is some chance that the parameter set of plots, on which deposition and soil solution monitoring is conducted, can be upgraded by a (careful) estimation of meteorological variables (e.g. using nearby weather stations and deposition measurements for the modelling of daily precipitaion rates). A successful estimation of meteorology on these plots would increase significantly (i) the geographical area covered by a high density of "complete" parameter sets and (ii) the density itself. As shown, the spatial distribution of Level II plots on which the “complete“ parameter set is assessed is rather uneven throughout Europe.

Assessments of the (relative) relevance of forest decline hypotheses as well as discoveries of empirically well supported relationships explaining the spatial and/or temporal variability of forest health will, in the near future, focus on those Level II plots from which monitoring results of the above mentioned assessments are available. Only there it can be expected, that a sufficient variability of explained and explaining variables coincides with a sufficiently large number replicates, which is fundamental for multivariate statistics. Therefore, in order to achieve results on a transboundary scale, efforts on data evaluation and data analysis might at first be focused on that region of the Level II network, which comprises the highest coverage and the best availability of data. At the same time there should be efforts to intensify the measurements in regions with a lower density in order to include all major regions. In case that financial resources are not available to intensify the measurements on all Level II plots throughout Europe, the monitoring activities might be concentrated and intensified on a smaller number of plots. In regions with already existing Level II plots the completion of existing plots should in general have priority above the installation of new ones. The intensification should above all aim to install soil solution and meteorological measurements at plots were they are still missing.

3.2.3 References

De Vries (1999): Intensive Monitoring of Forest Ecosystems in Europe, a strategy document forthe scientific evaluation of the data. EC, UN/ECE, 1999, Brussels, Geneva, 32 pp

3.3 Level III

The objectives of Level III were formulated already at the beginning of ICP Forests as

- to gain deeper insight into cause-effect relationships by means of forest ecosystems analysis with special regard to the effects of air pollution.

As this objective requires an integrated monitoring approach, Level III is foreseen to be implemented in close co-operation with ICP on Integrated Monitoring (ICP IM). For this reason, both ICPs have harmonized their manuals as far as possible. The implementation of Level III does not necessarily mean the installations of new plots. Instead, all knowledge gained from forest plots of ICP IM and those plots of ICP Forests, on which monitoring beyond Level II is performed, will be collated. The first steps towards a realization of this concept are

- identification of those permanent observation plots in the participating countries on which a greater variety of parameters with respect to the above mentioned aim is measured. This will be done by a questionnaire, circulated among the National Focal Centres;
- compilation of the results and publications from these plots;
- synthesis and interpretation of these results in connection with the newest literature in the framework of another report on cause-effect relationships.

4. Review Results of Individual Surveys

4.1 Plot data, stand and site characteristics

On Level I plots the following general plot data have to be recorded in order to permit plot identification and localization:
- country code
- plot number
- latitude
- longitude

These parameters are very basic and it is crucial that they are accurately assessed There is no need for changes here. Those data do also allow the assessment of a climatic region: even though often criticised the climatic regions help to stratify Level I and Level II plots throughout Europe. A more precise classification would, however, be helpful. As long as the benefits of a new classification are unclear, the existing climatic regions should remain unchanged.

4.1.1 Parameters

Relevant stand and site characteristics
Information on stand and site characteristics is crucial in most data evalutions. This refers specifically to the assessment of relationships between the crown condition or the soil and foliar chemistry and environmental factors; specifically meteorological stress and atmospheric deposition. Those relationships depend on various stand and site characteristics and in the statistcial analyses of the data, those differences have to be accounted for. Furthermore, information on those characteristics can be important to estimate environmental stress factors at plots where measurements are missing. This is specifically relevant when upscaling results from level II to level I plots.

An overview of the stand and site characteristics that are important for the estimation of stress factors and the assessment of relationships is given in Table 4.1.1.

The relationship between atmospheric deposition and several factors influencing or related to the emission or deposition of N (and S) compounds has already been shown for the level II plots (De Vries et al., 1999, 2000). This refers to the influence of altitude, tree species, stand height and stand structure. Specifically, the emission and deposition of NH_3 is clearly influenced by the land use in the neighbourhood and distance of forests to the nearest land use (e.g. De Vries et al., 1995). Furthermore, exposition might influence the deposition. Altitude does influence the precipitation and potential evapotranspiration and is thus relevant when interpolation those data from nearby meteorological stations. Furthermore, exposition gives information on different microclimates and is in particular useful for the stratification of plots in mountainous regions.

Table 4.1.1. Relevant stand and site characteristics for the estimation of stress factors and the assessment of relationships with forest condition

Characteristics	Estimate/upscaling		Relationships		
	Deposition	Meteo	Hydrology	Soil	Crown/ foliar
Site					
Altitude	X	X			X
Soil type[1)]			X	X	X
Horizon			X	X	
Text. Class			X	X	
Humus type			(X)	(X)	
Humus thickness				X	
Distance to forest edge	X				
Soil use in neighbourhood.	X				
Stand					X
Tree species	X		X		X
Stand age					X
Stand height	X		X		
Forest management				X	X
Exposition	X?	X			
Topography			X		

[1)] Including estimates on the texture of the soil

Information on the soil type and the texture of the soil is crucial to assess water fluxes through the ecosystem. Calculation of those fluxes requires information on the moisture retention curve and the hydraulic conductivity of the soil; soil physical parameters that are neither mandatory nor optional at both level I and Level II plots. An indication can however be derived when data on the soil horizon, texture (class) and the organic matter content (mandatory at both level I and Level II plots) are known (e.g. Wosten et al., 1999). Those data are also relevant when deriving relationships between e.g. soil chemistry (e.g. element pools or dissolved concentrations) and environmental factors (de Vries et al., 1999, 2000). Information on the texture is relkevant in deriving bulk densities of the soil thus allowing the calculation of soil pools.

Various stand characteristics mentioned in Table 4.1.1 are also relevant in calculating water fluxes, as it influences the actual evapotranspiration. Those characteristics are furthermore important when assessing relationships with e.g. crown and foliar condition (and in the future species diversity of the ground vegetation). A connection of most of the mentioned parameters with mean defoliation has e.g. been shown in former Level I reports (UN/ECE and EC 1998, UN/ECE and EC 1997) and Level II reports (De Vries et al., 2000). Mean age of the dominant story has, for example, in many evaluations turned out to be a significant influence on defoliation (for an overview see Seidling 1999).

Recording of the parameters
Most of the suggested parameters are already assessed in various classes as summarised below
- Altitude: has to be recorded in 50m classes. There is no need for changes.
- Humus type: seven classes of the most common humus types have been set up and can remain unchanged.
- Soil type: has to be recorded according to the FAO soil units (FAO 1988). There are no changes necessary.
- Mean age of the dominant story: considering the significant influence on defoliation it is recommended to have exact information on the planting year to derive an age. Otherwise the age intervals should be less than 20 years. It is suggested to have at the maximum 10-year intervals.
- Exposition: is reported in eight classes. There are no changes necessary.

New parameters include:
- Texture class; actually, this parameter is not really new, since an assessment of the soil type according to the FAO guidelines includes an estimate of the texture (class). The classes are 0-8%, 8-18%, 18-35% and 35%. A more precise estimate is preferred.
- Humus thickness: this is relevant to get information on the bulk density of the forest floor, by combining it with (mandatory) information on the amount of organic layer. Best information is the exact thickness at several (e.g. 20 points) to have (indirect) information on the spatial variability of this amount.
- Distance to forest edge should be given in 100m. intervals up to 1 km and in km intervals if the distance is larger.
- Soil use in neighbourhood should be divided in grassland, maize, agriculture or industry.
- Stand height should be recorded in 5m. intervals for the dominant trees based on a visual inspection.
- Topography is easy to assess and a useful criterion for stratification, as it influences water and nutrient supply in most forests. It is assessed once per plot and should be classified (after Dierssen, K. 1990) into:

* upper slope
* intermediate slope
* lower slope
* plain
* hollow
* top
* undulating

Inversely, the estimated soil water availability's have proven to be useless as the estimation of the required three classes is too subjective. The parameter should therefore be omitted. Instead, the possibility to derive hydrological fluxes from data on moisture retention curve and the hydraulic conductivity of the soil derived from clay and organic matter content are much more useful (see before).

4.1.2 References

Dierssen, K. (1990): Einführung in die Pflanzensoziologie. Wissenschaftliche Buschgesellschaft, Darmstadt.

FAO, (1988): FAO-Unesco Soil Map of the World. Revised Legend.FAO, Rome, 79 p.

UN/ECE and EC (1997): Forest Condition in Europe. Report on the 1996 survey. Geneva and Brussels: UN/ECE and EC 1997, 160 p., ISSN 1020-3729

UN/ECE and EC (1998): Forest Condition in Europe. Report on the 1997 survey. Geneva and Brussels: UN/ECE and EC 1998, 180 p., ISSN 1020-3729

Seidling W. (1999). Overview Report on Integrated Studies in Europe. Internal Report, PCC, Hamburg, Germany. 40 pp. + annexes.

De Vries, W., J.J.M. Van Grinsven, N. Van Breemen, E.E.J.M. Leeters and P.C. Jansen (1995). Impacts of acid atmospheric deposition on concentrations and fluxes of solutes in Dutch forest soils. Geoderma 67: 17-43.

De Vries, W., G.J. Reinds, H.D. Deelstra, J. M Klap and E.M. Vel (1999). Intensive Monitoring of Forest Ecosystems in Europe. Technical Report 1999. UN/ECE, EC, Forest Intensive Monitoring Coordinating Institute, 173 pp.

De Vries, W., G.J. Reinds, M. Kerkvoorde, C.M.A. Hendriks, E.E.J.M. Leeters, C.P. Gross, J.C.H. Voogd and E.M. Vel (2000). Intensive Monitoring of Forest Ecosystems in Europe. Technical Report 2000. UN/ECE, EC, Forest Intensive Monitoring Coordinating Institute,188 pp.

Wosten, J.H.M, A.Lily, A Nemes and C. le Bas (1999). Development and use of a database of hydraulic properties of fEuropean soils. Geoderma 90: 169-185.

4.2 Crown Condition

4.2.1 Summary

Crown condition assessment is mandatory on all Level I and Level II plots. Traditionally it is a core activity under ICP Forests. With the installation of new surveys at Level II defoliation has become one important response variable among others. The review showed that:

- The continuation of the crown condition monitoring at Level I is an important part of the monitoring activities.
- Crown condition at Level I is based on a representative sample of the European forests. With respect to sampling errors, the main tree species results show sufficient precision for large regions in Europe on the 16 km x 16 km net. The 16 km x 16 km grid net is the minimum density for an European scale.
- The interpretation may be limited by low observation (or: plot) numbers for some countries, smaller regions or for less common tree species. The suitability of the present design to study spatial pattern of defoliation is limited by the intrinsic variability of the sampled population.
- Time series give a reliable information on changes in tree condition. The importance of the better use of existing data has to be underlined as well as the selection of appropriate methods for data processing and evaluation.
- For reasons of data quality and continuation of time series the annual assessment on all plots is essential. In addition, a large sample size is important for evaluation purposes like stratification or documentation of rare events, such as mortality rate.
- There is a strong need to combine the two systems: The synergy of the detection system on the one hand (Level I) and the understanding system (Level II) on the other allows to develop information suitable for multiple political, scientifically and public interests. Level II cannot replace Level I, therefore.

The following recommendations on parameters can be given:

- Defoliation remains an important key parameter of crown condition assessment.
- The assessing of needle and leaf yellowing is often limited from the ground and was criticised externally and internally as well. Though it is not considered to be a symptom equally informative for all tree species and applicable in all kinds of natural conditions, the experts agreed to recommend discoloration to be a sensitive indicator of certain stresses (i. e. drought, nutrient deficiency). Therefore the continuation of the discoloration assessment is recommended.
- Litterfall is regarded as a very important parameter for the whole Level II - ICP Forests programme. It is suggested to check if the recording of litterfall should become a mandatory feature for Level II- plots. An ad hoc working group should elaborate recommendations to amend the litterfall manual prepared by the Expert Panel on Meteorology and Phenology.
- The assessment of damage causes to leaves or needles should be intensified on Level I and on Level II. Since this assessment should include more aspects of traditional entomology and phytopathology a temporary working group was established to improve the assessment

methods.

- The information on crown form / morphology is mainly important on Level II plots (e.g. Fagus and Quercus spp.) and the assessment should be encouraged for the species with appropriate methodology.
- Flowering and fruiting on Level II plots are both important; if only one assessment is done priority should be given to the assessment of fruiting.
- The documentation of methodological comparability should be improved by formally developed quality assurance concepts including eg. digital image processing techniques and new concepts of inter-calibration courses. A temporary working group will elaborate a proposal for the use of image processing.
- Crown condition parameters are essential tools to characterise effects of environmental changes on trees and forest ecosystems. The task to contribute to the understanding of the tree condition changes in Europe requires a procedure which integratingly connects development patterns of crown condition with reaction types of other tree compartments like branching architecture, tree growth, fruiting and biotic diseases. A standardization of the influence of age and tree sociological development helps to make cause effect relations clearer. This concept puts forward the integration of biological components within the monitoring activities.
- The recommended ad hoc groups – established under the revision process - support the quality, the use and integration of existing data and methods. This means a better efficiency without increasing the costs substantially.

Table 4.2.1-1: Parameters of Crown Condition Assessments

Parameter	**Level I**		**Level II**	
	Current state	**proposal**	**current state**	**proposal**
Crown size			O	O
Crown shading			O	O (strongly recommended)
Visibility			O	O (strongly recommended)
Defoliation	M	M	M	M
Defoliation type			O	**not recommended**
Foliage transparency			O	O
Foliage Discoloration	M	M	M	M
Nature of discoloration			O	**Not recommended**/ assess in the course of Foliage sampling
Foliage size			O	
Damage causes to leaves or needles	M	M	O	**M**
Dieback / Shoot death			O	O
Crown form / morphology			O	**M** (*Fag. + Querc. ssp.*[1])
Secondary shoots			O	O
Epiphytes and other plants in the crown			O	**Not recommended** [2]
Damages to the branches			O	(O)
Flowering/Fruiting			O	O
Damage to the woody parts of the stem			O	O
Litterfall[3]				**O** (strongly recommended)

Abbreviations, codes : M = mandatory parameter, O = optional parameter, **blue** = excluded from survey, **red** = new optional or new mandatory parameter, **green** = change from optional to mandatory or from mandatory to optional

1 In some stands the assessment of crown architecture may cause an assessment within the non vegetation period.
2 An assessment of the genus of Viscum may be usefull for pine or fir.
3 The task shall be organized in an ad hoc group by contributions of different Expert Panels

4.2.2 Objectives

Tree crown assessment is aimed to record data on tree status in order to derive information about pattern and trends on forest condition in Europe.

Crown condition at Level I is a method which can detect temporal trends and regional patterns of tree vitality. Time series give a reliable information on tree condition.
Level II is focused on the understanding of tree vitality aspects. Both levels are therefore needed to fulfil the monitoring objectives.

4.2.3. Sampling design and sampling frequency

4.2.3.1 Level I

Survey form, location methods, grid density and plot design have been examined (see Annex 1).

The adopted CFI (Continuous Forest Inventory) survey form has practical advantage and it is likely to provide an efficient estimation of changes in defoliation, provided that autocorrelation and age-effect are taken into account.

The systematic sampling design uses a 16 km x 16 km net. This method seems able to provide a representative sample of the European forests. The nature of the present design allows a classification of the population under consideration into defoliation classes using methods of descriptive statistics.

The main tree species results show sufficient precision for large regions in Europe on the 16 km x 16 km net.
However, the interpretation may be limited by low observation (or: plot) numbers for countries, smaller regions, for less common tree species or other subgroups. The grid net approach shows a variety of site and stand structures.
The suitability of the present design to study spatial pattern of defoliation is limited by the intrinsic variability of the sampled population. With regards to the data evaluation maps can be prepared: however the development of maps should account for species, age and competition and should consider spatial autocorrelation.

Time series give a reliable information on changes in tree condition, provided that the influence of factors like age and the time constancy of methods is documented (e.g. by NFC´s). The importance of the better use of existing data has to be underlined as well as the selection of appropriate methods for data processing and evaluation.
For reasons of data quality and continuation of time series the annual assessment on all plots is essential.

Regarding Level I, the variety of stand and site characteristics as well as the combination of environmental influences causes serious problems to study defoliation as an effect of air pollution (or other stressors) on forests. This is something well acknowledged at the analytical stage, when post-hoc stratification is often attempted.
The synergy of Level I (the detection system) and Level II (the understanding system) may help to gain reliable information.

Conclusion

Crown condition at Level I is based on a representative sample of the European forests. The main tree species results show sufficient precision for large regions in Europe on the 16 km x 16 km net. The 16 km x 16 km grid net is the minimum density for an European scale.

Time series can give a reliable information on changes in tree condition, provided that age and time constancy of methods are taken into account. However, the suitability of the present design to study spatial pattern of defoliation is limited.

The interpretation may be limited by low observation (or: plot) numbers for some countries, smaller regions or for less common tree species. Also the variety of site and stand structures may reduce the number of sample trees within a group when stratification methods are applied.

4.2.3.2 Discussion of a Level I – grid net modification (see Annex)

Different scenarios for future crown condition surveys have been analysed and discussed in ICP Forests in order to find the optimum solution (see Annex).

Advantages of the present setup

Advantages of annual assessments:

- The time series of crown condition are regarded as one of the most valuable outcomes of the Level I monitoring. They can only be continued by annual assessments.
- Defoliation reacts quickly upon changes in numerous environmental conditions, such as weather fluctuations and pests. Integrated studies and other in depth evaluations depend on annual data to determine the influence of these factors.
- Through annual assessments the necessary infrastructure in the countries can be maintained.
- Through annual assessments it is much easier to keep a continuous quality of the estimates.

Advantages of the systematic 16 km * 16 km grid

- Stratification of assessment data requires big sample sizes. A reduction of tree or plot numbers would therefore hamper stratified data evaluations.
- The strength of the Level I grid is its representativity on a European-wide scale. Besides crown condition, soil and foliar surveys the grid also might offer possibilities to assess additional parameters that are of importance in the future.
- The large-scale coverage has to be maintained to enable all European countries to participate. A reduction of plots would exclude certain smaller countries that may loose interest to participate in the European programme.
- The systematic design of the Level I grid provides to a certain extent information on rare species. By a reduction of plots this information would be lost.

Conclusion

It is recommended to maintain the complete Level I survey system for crown condition assessments.

A special selection of plots could hamper the representativity of the Level I grid-net. The idea of a pan-European monitoring programme would be lost. For reasons of data quality and continuation of time series the annual assessment on all plots is essential. In addition, the large sample size is important for evaluation purposes (e.g. stratification, documentation of rare events, such as mortality rate).

4.2.3.3 Level II

The Level II network was created by an expert selection of case studies, within which regional characteristic ecosystems or important forest plant communities are represented. The plots are allocated in a variety of forest ecosystems subjected to a variety of site conditions and different pollution climates. Until today, it could not be prooved, that the selected case studies are statistically representative for the European forests. They can only be used for statistical inference, if the model that relates such case studies to the target population is clarified and the underlying assumptions are explicited.

Level II can provide valuable data for generating hypothesis, and in this context the collection of crown condition data will be of help. Observational units, location, selection of sample trees are subjected to the same criticisms as Level I, although larger sample size at plot level may help in reducing sampling errors.

In the Level II program the limited number of obligatory crown condition parameters (see: Level I) is fundamentally extended by optional features. The selection of suitable tree condition indices for the intensive monitoring (Level II) plots in Europe has been an important Expert Panel activity during the past two years. The optional parameters are defined in the Manual on Crown Condition (Eichhorn et al., 1997), were subjected to an expert review (Eichhorn et al., 1999) and have been tested under field conditions. Using the operational optional and mandatory parameters it is possible to describe the biological condition and stability of the forests ecosystems sufficiently. This may help to understand effects of environment changes on forests. However, a statistical evaluation of cause effect relations requires new, integrating strategies in the recording of biological compartments.

Conclusion

Level II can provide valuable data for generating hypothesis and helps to understand cause effect relationships. In the Level II program the limited number of obligatory crown condition parameters (see: Level I) is fundamentally extended by optional features.The use of a selection of optional parameters could be recommended by the EPC.

4.2.4. Parameters

In the following chapters all parameters recommended in the Level I or Level II crown condition assessment are reviewed also in view of their reliability and relevance. The definition of each parameters can be found in the Manual.
In some cases the value of a certain parameter on European level is debated by the panel, however the parameter and the assessment method may remain an optional part of the Manual, as this parameters could have a local importance.

4.2.4.1 Crown size

Conclusion

Crown size measurements like crown height, crown length and crown width, all of which are standard biometrics measurements are useful information to characterise tree condition and vitality.
However, the interpretation of growth data is rather complex.

Recommendation
A close co-operation between the two responsible Expert Panels is needed. Crown size measurements should be carried out in the frame of growth measurements at Level II - plots.

4.2.4.2 Crown shading

Concerning the assessment of crown shading it should be specified that a healthy tree is regarded as significantly affected if the distance between its crown and the crown of a tree in the vicinity is less than 1/3 of the average crown diameter. Crown shading will be assessed on a six-point scale according to the manual.

During a test phase in 1998 several countries worked on this parameter. The majority had no problems with the definition or the assessment using these indices.

Conclusion

Crown shading is a valuable relative parameter that gives information on crown ecology. The stand record can supply useful information for the interpretation of changes in individual tree conditions.

Recommendation
It is suggested that the definition of crown shading should be illustrated with a simple diagram.

4.2.4.3 Visibility

Results of free-lance control assessments show that differences between teams occur more often if the visibility of crowns is poor. Following the manual, however, crowns with poor visibility are not to be excluded from the sample.
The countries which took part in the test phase 1998 principally agree on the definition and method of the manual.

Recommendation:
For the codes 3 and 4 of the manual it is proposed to add, that an assessment of the crown condition from directly underneath the crown cannot be accepted. All other possible parameters will be assessed, even if the assessable part of the crown is only small. Crown condition assessment in back-lighting (code 3) has to be regarded as being problematic as defoliation (the defoliation extent is often overestimated) and discolouration is difficult to score.

Conclusion

Information on crown visibility is very important in connection with the requirement of adequate quality assurance.

4.2.4.4 Defoliation

With few exceptions, stress or damage will result in a lowering of the foliage mass or an alteration in the foliar quality, in particular reduced pigment concentrations in a given tree. It appears that the amount and quality of foliage, corresponding to foliar mass and colour, is an important (determining) factor for the ability to resist against stressors and to compete within stand conditions.

In general, defoliation and yellowing have been correlated to growth. Concerning foliar mass, pruning experiments have shown that severe reductions of foliage were sometimes resulted the reduction of growth (MARGOLIS et al., 1988). This could be at least partly be explained by the observation that foliage in lower and inner parts of tree crowns do not contribute to the net carbon gain in the tree (GRUBER, 1990).

Does crown condition reflect the ability of further survival, the trees ability to defend themselves against, to tolerate, and recover from stress? According to CHRISTIANSEN et al. (1987), dealing with bark beetles and their associated blue stain fungi“ ... any environmental factor that restricts the size of the canopy or its photosynthesis efficiency can weaken the trees resistance. ...It appears that the determining factor for this aspect of health is the amount of foliage and the quality of foliage, corresponding to foliar mass and colour.

A further clarification is needed:
whether to consider

- mechanical damage from snow or wind,
- unusually sized or formed needles/leaves and shoots (e.g. leaf rolling),
- influence of flowering and fruiting, (e.g. male flowering in Scots pine Pinus sylvestris L.)
- sparse branching,
- epicormics on the trunk below the primary crown, and
- whether to regard known or only unknown causes.

Crown condition assessments were found to be reproducible and to reflect real features of the trees. However, the crudeness of crown condition data can be demonstrated.

The precise accuracy of the assessments can not be determined, as the true values are unknown and can hardly be measured in the field. However, considerable systematic differences between observers (observer bias) are evident from control surveys (STRAND, 1995)

Conclusion

Defoliation remains an important key parameter of crown condition assessments. The suitability of crown condition assessments for forest health monitoring was elucidated by evaluating reproducibility of the assessments, and correlating crown condition to other features which are related to forest health.

4.2.4.5 Defoliation type

The experiences of the 1998 test-phase show that several countries consider the parameter defoliation type to be quite problematic. The diagrams of defoliation types in broadleaf's printed in the manual do not match the typical crown development of beech nor of oak. It is not easy to determine defoliation type classes especially for low defoliation extents (5-15%) (Belgium).

Conclusion

The scoring of defoliation type is not practicable in the traditional way, continuation is not recommended. The assessment of defoliation type could partially be integrated into the crown form/ morphology.

4.2.4.6 Foliage transparency

Foliage transparency is considered as an indirect estimation of defoliation and it has been proposed because it allows the use of absolute references, like photoguides or transparency cards. The countries taking part in a test phase in 1998, gave quite different valuations of the assessment of foliage transparency. While it has been a standard assessment in the United States (Forest Health Monitoring) and in Italy for some years, other countries argue that the assessment of foliage transparency in accordance with the definition and method of the manual is only possible if the assessable crown is openly visible. This contradicts the reality of numerous Level II plots.

Just like defoliation foliage transparency is a function of the site, the tree species (light-demanding or shade-bearing tree species), the age of the tree and the weather conditions. On extreme sites for example crowns may appear transparent although there is no defoliation. In other cases, dense crowns can be defoliated (e.g. evergreen oaks in Italy) as defoliation is definecd sharply. Similarly to defoliation, this limits statements concerning the health condition of trees and their reaction to changing environmental conditions e.g. air pollution, which becomes possible only after the interpretation of time series.

On the other hand the methodical concept of estimating foliage transparency of open visible crowns makes it possible to use standardised techniques. The utilisation of photographs both conventional and digital becomes possible. That is why it is suggested that in addition trees with good visible crowns (class 1 and 2) should be assessed for foliage transparency once a year.

Conclusion

The transparency assessment should remain as an optional parameter.
Based on an objective references (transparency sheets) the assessment can be accurate and reproducible within established data quality limits. Additional methods - like photo interpretation - can be applied successfully.

Difficulties derive from the definition of crown outline, crown overlapping may also cause difficulties.
Due to the high natural variation of crown forms, interpretation of transparency scores is difficult in general, however temporal changes are well reflected and a reliable interpretation can be made.

4.2.4.7 Foliage Discoloration

The manual requires as a mandatory assessment on Level I and II the scoring of discolouration in 4 classes. On Level II it is proposed to further differentiate the extent of discolouration in 5% steps - optional parameter. The relative value is the actual needle/leaf area. The results of the test phase in 1998 show that such a differentiation is not practicable. A 5% -accuracy as proposed in the manual doesn't seem to be realistic. At best 10% - nuances look to be operational. As discolouration is a key parameter for crown assessments, its scoring should be a topic of intercalibration /exercise courses.

Conclusion

The assessment of needle and leaf yellowing is often limited from the ground. The symptoms are often developed on the needles upper side. Different light conditions may cause a high variability of data.

Due to these reasons the assessment of discoloration was criticised externally and internally as well. Though it is not considered to be a symptom equally informative for all tree species and applicable in all kinds of natural conditions, the experts agreed to recommend discoloration to be a sensitive indicator of certain stresses (. i e. drought, nutrient deficiency). Therefore the continuation of the discoloration assessment received a clear support.
Interpretation should focus on the regions/tree species where the symptom occurs.
Discolouration scoring should incorporate the proportion of the leaves affected, and the intensity of discolouration.

It is difficult to assess the extent of discolouration in 5 % classes on the Level II – plots. Consequently 10 % - classes are recommended in the future.

4.2.4.8 Nature of discoloration

Conclusion and recommendation

Scoring: important, but not assessable on tall trees.

In older stands specification of the type of discoloration is regarded as being critical. A scoring of this parameter is - if at all- only possible in very good weather conditions. In tall stands the resolving power of binoculars will not be sufficient to determine the nature of discoloration. Therefore it is proposed to assess and document nature of discoloration in the course of "Sampling and Analysis of Needles and Leaves".

4.2.4.9 Foliage size

Conclusion and recommendation

The assessment of foliage size is not practicable in tall stands. Therefore it is proposed to assess and document this parameter in the course of "Sampling and Analysis of Needles and Leaves".

4.2.4.10 Damage causes to leaves or needles

The assessed “easily identifiable damage types” give important hints on the importance of different damaging factors. The experiences of forest pathology clearly show that “insects” and “fungi” have an important influence on the crown condition of trees.

In the summer 1998 this parameter was assessed on Level II plots in a great number of countries. Most of the countries judge the 5% -scoring as being critical. The so given accuracy does not correspond with the real practicability of assessment ; the scoring system is not practical. Belgium proposes to simplify the assessment into 3 classes (1 = absent or scarce; 2 = common; 3 = abundant) instead of the 5 % steps.

In this context critical annotations are made concerning the different codification on Level I and Level II - plots. In Germany for example damage causes to leaves or needles are recorded in 4 classes on Level I plots and several damages types (insects, biotic diseases, abiotic damages) can be recorded separately with their extent.
In order to increase accuracy it would be desirable to assess damage causes to leaves or needles also in the course of “Sampling and Analysis of Needles and Leaves“.

The assessment of damage causes to leaves or needles is relevant for various tasks within the monitoring programme (e.g. forest growth, nutrient deficiencies).

Conclusion

The assessment of damage causes to leaves or needles is important.

In many cases the regular crown condition assessments allow only a fragmentary picture of biotic diseases, as one annual assessment is not sufficient to identify all kinds of damages.

More specific information efforts the traditional way of work in the fields of forest pathology and entomology. A further developed co-operation could be very useful. A more detailed information can be derived from branches taken in order to get tree samples of needle/leaf nutrition. However, up to now this information is not annually available.

Recommendation
During the in-depth discussions the experts expressed the need to set up of an ad hoc group chaired by Belgium Flanders to improve the methodology in the Manual.
Additional assessments e.g. in spring may be useful for some species (e.g. oak).
The experience with the data evaluation shows in addition that it is of big importance to use the existing codes to indicate whether damage types have not been assessed or whether they were assessed but not present.

4.2.4.11 Dieback / Shoot death

Conclusion

Dieback / Shoot death is a very worthwhile parameter, but not easy to assess.
The definition given in the manual is too vague and allows a huge variation in the interpretation of this parameter. Furthermore it does not differentiate clearly between dieback and damages to branches.

Recommendation
The scoring of the extent according to the definition of the manual seems to be unoperational, the 5 % accuracy is unrealistic, at best a 10 % accuracy is possible.

4.2.4.12 Crown form / morphology

In all the classification for *Fagus sylvatica* is accepted with minor modifications. The diagrams of ROLOFF printed in the manual do however not clearly represent the different stages.

Recommendation:
- additional diagrams should be printed

Conclusion and recommendation

The information on crown form / morphology is important on Level II plots. Crown form classification should be completed for Fagus and Quercus spp.

A 5-year- interval for the assessment of crown form is regarded as being sufficient in general.
Crown form of Quercus petrea should be assessed every second year in winter because of the high regeneration capacity of oak.

4.2.4.13 Secondary shoots

For many tree species the development of shoots from dormant buds is the normal part of crown formation, showing the capacity of the tree to respond to various environmental influences.

Concerning the assessment of this parameter, some countries mention, that the scoring of secondary shoots is not clear enough and that they had no good examples.

Recommendation:
- The definition in the manual should be completed by diagrams and photos.

Conclusion

The information on secondary shoots is important. The Manual should be completed by diagrams.

4.2.4.14 Epiphytes and other plants in the crown

Conclusion

The present score gives only results with little message. An assessment of the genus of Viscum may be useful for some species like pine or fir.

Recommendation
The definition and the scoring of the parameter should remain in the manual as optional parameter. However the use of the parameter seems to be not very relevant on an European scale.

4.2.4.15 Damages to the branches

Conclusion

It is doubtful if this parameter is operational.
The scoring system is regarded as being poorly practicable.

Recommendation
In case of assessment, only 3 classes are recommended.

4.2.4.16 Flowering/Fruiting

Definition and arguments of the manual are confirmed. Contrary to the specification in the manual a majority of the countries, which took part in the test phase 1998 state that they make only one assessment of flowering and fruiting in the whole crown. The differences of the steps 1, 2 and 3 should be demonstrated in detail with the help of photos.

For some species the assessment of flowering is not possible during the crown condition assessment in summer. That is why emphasis is put on the assessment of fruiting. Only fruits produced in the year of assessment are included.

Comparative studies in Finland prove that for example for Norway spruce and Scots pine assessments of fruiting in the assessable crown and in the whole crown lead to similar results. One assessment is regarded as being sufficient.

Conclusion

Flowering and fruiting are both important.

Recommendation
If only one assessment is done priority should be given to the assessment of fruiting. Object of the assessment: the whole crown.

4.2.4.17 Damage to the woody parts of the stem

Actual situation:

- After a test phase the responding countries scored the parameter as important and is easy to assess.
- The types defined in the manual (5.5.2) do not cover sufficiently all types of damage which occur in reality, comments have to be used rather often. There were some recommendations to extend the categories of damage type, like stem distortion (Rhiacionia buoliana).
- The categories to define the location of damages in the manual is sufficient (quite detailed).
- Although the parameter is well accepted, the „adverse effect” in the definition can be interpreted in a different way by the participating countries, therefore the data analysis on the European scale may face the common problem of incomparability.
- There was no information received about the results of data evaluation on stem damage, therefore the real value and importance of this parameter is difficult to estimate. (Previous evaluations indicated relation between crown condition and stem damages.)

Conclusion

In general this parameter is easy to assess and acceptable.

The experiences of various countries show, that there are special situations which demand the use of unclassified comments. The given code numbers can often not characterise sufficiently all types of damage which occur in reality.

Recommendation:
Stem damage should remain an optional parameters in the Manual (minor adjustments in the text), but may have to be revised as soon as sufficient results of data analysis are available.

4.2.4.18 Litterfall

Litterfall is regarded as a very important parameter for the whole ICP Forests programme. It is suggested to check if the recording of litterfall should become a mandatory parameter on Level II-plots.The quantitative recording of the litterfall represents a central addition to the assessment of crown condition. The data are particularly suitable for a long time observation of forests.

Due to the various use of the data there is a demand in different fields of the ICP Forests program:

- in phenology litterfall data gives quantitative information on annual biological cycles like flowering, fruiting or leafloss.
- in nutrient analysis and deposition items litterfall gives information on chemical cycles and material balances.
- in crown condition litterfall provides biomass data per hectar, e.g. dropping of leaves, fruits or branches.
- with respect to integrated evaluations, litterfall has a transfer function between crown assessments and biomass and nutritional measurements

There is various information about litterfall available already today (e.g. references from Belgium, Denmark, France and Germany). Time series of litterfall measurements on Level II-stands are important as a reference for future evaluations.

Due to the various interests it is necessary define the procedure very precisely. The given definition of the method is still too imprecise, the methods must become clearer. The instruction must take the various uses of the data into account.

The experts assign a high priority to this kind of measurements in the future of Level II.
It is suggested to check if the recording of litterfall should become a mandatory feature. A considerable support of the complete project is expected by a recording of litterfall.

Further activities are required. A decision on priorities and cost regulation by the next Task Force has to be prepared.

It is suggested to establish a temporary subgroup to amend the manual for litterfall measurements prepared by the Expert Panel on Meteorology and Phenology.

Conclusion

Litterfall is regarded as a valuable measurement for the whole ICP Forests programme.

Recommendation
It is suggested to discuss the methodology with the phenology experts and check if the recording of litterfall should become a mandatory parameter on Level II-plots.

4.2.5. Quality control

Some of the four major branches of the QA procedures were adopted by the crown condition monitoring program, namely Quality Assurance and Quality Control. Manuals were produced as part of the Quality Assurance: however their first edition were so generic that a variety of Country specific manuals and reference standard were prepared and this create the basis for shifts in the methods and for poor comparability of the data. Quality control based on common intercalibration courses were largely supported in the past, and it provide a valuable basis for monitoring the comparability of data between reference teams from different countries. Field checks were also carried out at national level, without being organised into an international frame. Quality evaluations were carried out, but no data quality section has found a place in the Forest Condition Reports. However, data quality highlights problems with spatial and temporal comparability with the crown condition data.
Major problems were identified with Quality Management, especially with the early stages of the program. It may have caused some problems with the whole design (see sampling strategy) of the crown condition survey.
A full assessment of the precision of crown condition data accounting for sampling and non sampling error has yet to be done.

Conclusion

It is suggested to develop the quality assurance program formally in order to improve the crown data quality.

However, at present, the recording of crown data is already subject to various quality assurance activities. There are quality assurance plans in different countries at a national level. They include information on: Definitions and standards, methods of optional and mandatory parameters, requirements on the observer qualification, training and intercalibration courses, ways of plausibility check and data processing and data reporting. It is recommended that information from different countries is collected. This is essential for documentation of presently existing quality procedures. First steps for such a compilation have been undertaken.

Another concept to refresh the sensitive system of crown condition assessment can be seen in the supplementary or improved use of alternative parameters, like litterfall, biotic diseases, crown morphology (beech, oak) or fruiting (beech).

4.2.5.1 Future International Intercalibration Courses (IICs)
Proposals concerning the future IICs should consider:

- assessment condition
- reference standard
- what forest species, how many plots per species, how many trees per plot
- frequency and location of the intercalibration courses

There are a variety of possible designs for future IICs (see Fabiamek, 1998, Ferretti, 1998a, b; PCC, 1997). However, if we accept the perspective of linking functionally the different elements and compartments of the CCS, the main task of the IICs should be to: provide data at a given level of confidence, and give a real estimation of the comparability of the international survey results through space and time in order to allow the derivation of species- and operator-specific correction factors. Therefore, the IICs should be designed accordingly . In particular:

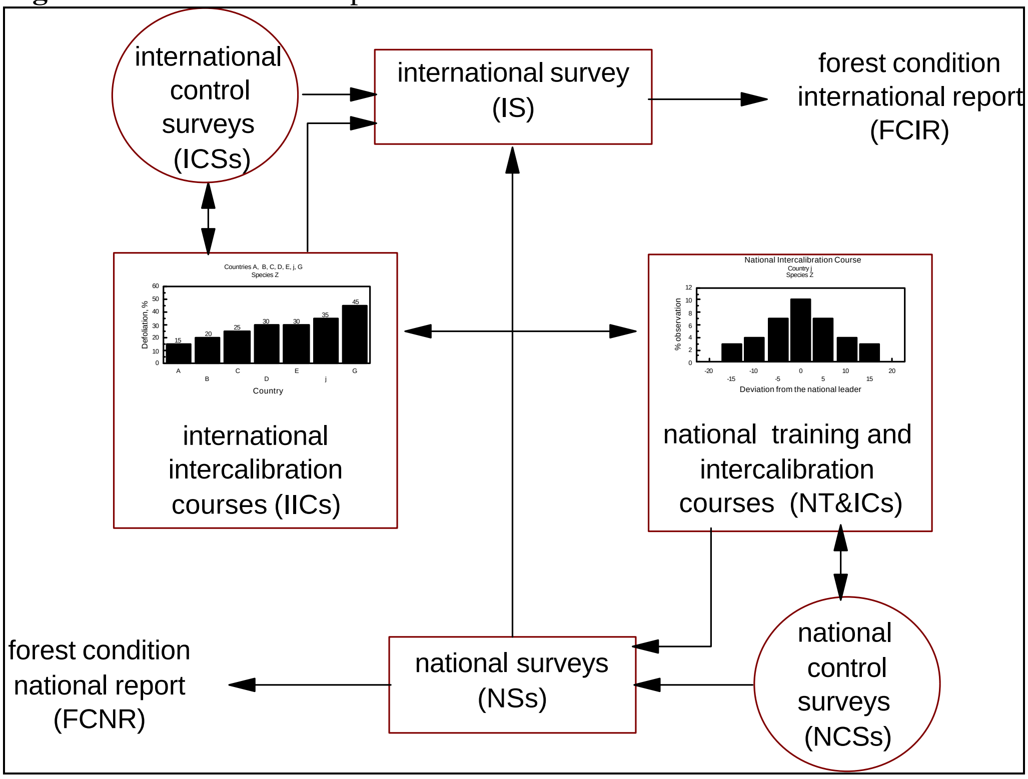
1. they should concentrate on the major species of the international survey, i.e. the species with greater weight on the statistical population examined. In general, these species are similar for both Level I and II (on the whole and for regional populations). Species of merely local interest should be examined at the level of the NT&ICs.

2. the design of the exercises should be consistent with the design of the field surveys. Therefore:
   - the target trees should be located in forest plots, under the similar condition of the "true" sample plots (e.g. isolated trees with crowns in good condition of visibility should be avoided);
   - the number of trees per plot should be 20-30;
   - to ensure adequate numbers for statistical analysis, adequate replication is necessary. This will be easier since IIC will concentrate on 2, max. 3, species. Also for this reason, it is better that IICs will keep their regional organisation (e.g. North, Central and South Europe): in this way, a number of species can be examined each year. This will also allow comparisons in different situations. This way IICs will also maintain their characteristic of "forum" for expert discussion by the presentation of local problems (e.g. ozone symptoms in southern Europe etc.)
   - participants should use their national reference method.

Closing the loop: an International Control Survey

The link between IICs and NT&ICs should provide the basis for calculate meaningful correction factors and – in principle – it might be possible to know the position of any national team with respect to any NRT. However, it is still in part theoretical. . In addition, there is not concrete link with the IS yet. To complete the linkage a further element is needed: an International Control Survey (ICS) that will provide real data on the actual comparability of field estimate by local teams and an International Reference Team (IRT), e.g. a NRT that operate at international level (Fig.). IRT should work according to a standardised protocol (which species, which countries, how many plots,..) and to an annual workplan (which plots, at which time, ..). IRT may use more also more objective method (e.g. digital camera), provided they can be used in true field condition.

Figure 4.2.5.1 – 1: Development of the functional connections within the CCS.



Conclusion

Various ideas to improve the use of intercalibration courses are documented. A future discussion on this topic is needed.

Recommendation

Countries should remain at their definition and level of crown assessment. This helps to ensure the national level of assessment within time series. However, an improvement in the present strategy may be achieved by a quantitative connection between national and international Intercalibration Courses. Correction factors should be derived. International control teams may become necessary.

This concept

- uses real assessment plots, creating actual field conditions
- combines these plots with particularly select areas (visibility, variability of the crown condition)
- restricts the address to main tree species
- enlarges the number of parameters (besides defoliation other optional and mandatory features Level I and II)
- evaluates the data (e.g. in a form to be standardised)
- attaches a workshop to the discussion of results (like Scandinavia)

Mr. Ferretti and the temporal ad hoc working group "Intercalibration Courses" agreed to give a proposal of the future Intercalibration Course structure to the PCC (Mr. Lorenz) this spring. The proposal will be discussed and partially realised in the IC courses of the year 2000.

4.2.5.2 Examples of quality assurance tools

Observation:

a) There are differences of the average crown condition at country frontiers (country effect). Quality assurance measures must become evident, whether it is to put this down to various ecological conditions or whether methodological differences exist.
b) The average crown condition shows trends for in Europe for beech and oak (trend effect). Some countries like England reported methodological changes however. Quality assurance measures must prove, whether methodological changes also had an influence on the result of the crown condition .

Possible solutions

A) country effect (spatial stability the readings)
- Use of available methods of quality assurance on national and international Level
- installing an international control team, which assesses gradients from the heart of one country to the next (gradient concept)
- Use of comparative parameters (e.g. mortality rate, growth indicators, crown structure, litterfall) in relation to a terrestrial assessment
- using temporal trends instead of one years results. No border effects are provable in the temporal trends.
- Use of digital image processing and digital evaluation

B) trend effect (temporal stability of the readings)
- Use of available methods of quality assurance on national and international Level (e.g. Photoguides)
- Use of comparative parameters (e.g. mortality rate, growth indicators, crown structure, litterfall) in relation to a terrestrial assessment
- using temporal trends instead of one years results. No border effects are provable in the temporal trends.
- Use of digital image processing and digital evaluation

4.2.5.3 Strategy of a digital image processing (photography)

Pictures can be scanned from a photoguide. The use of older photoguides offers additional retrospective possibilities. With good crown visibility the photoguide images can be complemented by real photos of plots. The images represent different levels of the possible crown condition for the main tree species. After this a digital assessment of defoliation (e.g. method MITZOUE, 1998) is carried out with standardised software.

Every single observer assesses the pictures visually. His personal deviation of the digital result can be quantified. This deviation may be linear or non linear. If one knows how single observers differ, one can quantify these differences
a) with respect to persons
B) with respect to countries.
Standards can be covered with this strategy over the time or over country limits.

With this method we will be able to document a temporal stability of crown assessment very well. However, the outline of the tree crowns must be defined in the photographs precisely.

- Comparisons of pictures always represent only a virtual reality. Differences between the countries often consist of things which cannot be recognised on a photo. Example Norway: A photographically similar crown condition has to be assessed in southern Norway completely different than in northern Norway. Hungary feels only are limited usage of images, because the assessment of a tree in a photo or in nature can show differences of more than 20% defoliation.

Conclusion

A developed method using digital image processing (photography) may help to document the temporal and spatial stability of crown assessment.

Recommendation
An ad hoc group chaired by the UK (Mr. Durrant) analyses the possibilities of the use photographs in order to improve the documentation of assessment levels in Europe.

4.2.6 Resources required

The costs of crown condition assessments may differ considerably in the participating countries due to the differences in the number of sample plots, number of sample trees, distance between the plots, road conditions, number of field teams, wages, travelling costs, accommodation etc.. Therefore some generalisations had to be made and the calculations are based on the time necessary to assess an imagined „average" plot in Europe.
Despite the guidelines of the revision report it is not feasible to share the costs of assessment by parameters, as considerable time is spent to reach the plot and find the best position for observation, while the time spent to assess a defined parameter can be only some seconds.

In the majority of the participating countries several groups do the assessment. To follow the quality assurance guidelines, training courses and control assessments are essential parts of the annual assessment procedures. Costs of training courses and field checks are estimated to increase the basic expenditures (costs of field assessment) by 20%.

Additional costs, like data processing and evaluation, consumables, administration etc. are estimated as 30 % of the basic expenditures (assessment costs), and added separately.

(Additional costs do not increase proportionally with the number of plots. Larger countries with more plots have lower additional cost/plot than the small ones.)

Level I

Assumptions:
20 sample trees/plot (average in Europe)
3 plots assessed daily (unfavourable weather conditions may decrease the number of plots assessed daily)
2 experts do the assessment
daily travelling distance is about 150 km

One plot can be assessed by 2/3 man-day, adding the travelling costs, accommodation and the costs of training and field checks, it is about 240-270 ECU

The costs of data processing, analysis, consumables, administration is about 70 - 80 ECU

Total costs/plot: 320 - 350 ECU

Level II

Assumptions:
45 sample trees/plot (average in Europe)
2 plots assessed daily (unfavourable weather conditions may decrease the number of plots assessed daily)
all mandatory and optional parameters are assessed
2 experts (one M.Sc.) do the assessment
daily travelling distance is about 200 km

One plot can be assessed by 1 man-day, adding the travelling costs, accommodation and the costs of training and field checks, it is about 550-600 ECU

The costs of data processing, analysis, consumables, administration is about 165-180 ECU

Total costs/plot: 715 - 780 ECU

In case the optional parameters are not assessed - although their number is much higher than the number of mandatory parameters - the total costs would decrease only about15 -20 %. The reasons are the longer distances between the level II plots that does not necessarily enable the assessors to visit 3 plots/day, and the fact, that during the assessment of defoliation - mandatory parameter - a detailed observation of the crown is made anyhow, that helps the observers to score the majority of the optional parameters within a very short time.

Actually one observation is recommended in the Manual annually. In case a second observation is recommended - it can be restricted to some selected tree species and only some specific parameters - the annual assessment costs of these plots may increase by 60-100 %.

4.2.7 References

AMLID, D., SOLHEIM, H.& VENN, K. (1991): Skogskader. Veiledning i overvaking av skogskader. Norsk institutt for skogforskning, As, 53pp. s et al.

BURSCHEL, P.; HUSS, J. (1987): Grundriss des Waldbaus. Paul Paray, Hamburg and Berlin.

CHRISTIANSEN, E., WARING, R.H. & BERRYMAN, A.A. (1987). Resistance of conifers to bark beetle attack: Searching for general relationships. Fgorest ecology and management 22: 89-106.

DIERSSEN, K. (1990): Einführung in die Pflanzensoziologie. Wissenschaftliche Buschgesellschaft, Darmstadt.

DOBBERTIN, M.; G. LANDMANN, J.-C. PIERRAT, CH. MÜLLER-EDZARDS, (1997): Quality of crown conditon data. In: Müller-Edzards, Ch.; W. de Vries; J.W. Erisman. 1997. Ten Years of Monitoring Forest Condition in Europe: Studies on Temporal Development, Spatial Distribution and Impacts of Natural and Anthropogenic Stress Factors. Technical Background Report. xii, 386 p. Brussels and Geneva. p. 101-104

EICHHORN, J. and E. ACKERBAUER, (1987): Nadelkoeffizient und Kronenschadstufe als Vitalitätsweiser zur Beurteilung des Gesundheitszustandes von Fichten (Picea abies KARST.). In: Forschungsberichte der Hess. Forstl. Versuchsanstalt, No. 4.

EICHHORN, J., FERRETTI, M., INNES, J.L., ROSKAMS, P., VEL, E. (eds.), (1997): Visual assessment of tree condition UN/ECE ICP Forests, Manual on method and criteria for harmonized sampling, assessment, monitoring and analysis of air pollution on forests 4th edition. PCC of ICP Forests BFH, Hamburg

EICHHORN, J., FERRETTI, M., KOERVER, F. AND SZEPESI, A. (1998) Selection of tree condition indices for the intensive monitoring (Level II) plots in Europe. In.: Report 1st meeting Expert Panel on Crown Condition Assessment, HLFWW Hann. Münden 11-19

EICHHORN, J.; SCHULZE, E. D.; ANDERS, S.; BLOCK, J.; GRAVENHORST, G.; HARTMANN, G.; HILDEBRAND, E.-E.; HOFMANN, G.; HRADETZKY, J.; KALLWEIT, R.; KREUTZER, K.; MATYSSEK, R.; NEBE, W.; PRETZSCH, H., (1998): Critical review of forest condition assessment in Germany. Report on behalf of the Federal Ministery of Nutrition, Agriculture and Forestry. In.: Waldzustandsbericht der Bundesregierung 1997, BML, Bonn. 169 - 209.

FERRETTI, M. (1998) Potential and limitations of visual indices of tree condition. Chemosphere, 36, IV-V: 1031-1036

FERRETTI, M. (1999): Future International Intercalibration Courses (IICs) – Developing a concept. Internal discussion paper.

GOSH ET AL. (1997) in Müller-Edzards, Ch.; W. de Vries; J.W. Erisman. (1997): Ten Years of Monitoring Forest Condition in Europe: Studies on Temporal Development, Spatial Distribution and Impacts of Natural and Anthropogenic Stress Factors. Technical Background Report, 386 p. Brussels and Geneva. p. 101-104

GOSH, S., LANDMANN, G., PIERRAT, J.C. & MÜLLER-EDZARDS, C. (1997). Spatio-temporal variations in defoliation. P. 35-50. In: Müller-Edzards, C., De Vries, W. & Erisman, J.W. (Eds): Ten years of monitoring forest condition in Europe. Studies on temporal deveelopment, spatial distribution and impacts of natural and anthropogenic stress factors. UN-ECE. Brussels, Geneva. 386 pp.

GRUBER, F. (1990): Verzweigungssystem, Benadelung und Nadelfall der Fichte (Picea abies). Birkhäuser, Basel. 136 pp.

INNES, J.L., (1990): Assessment of tree condition. Forestry Commission Field book 12, London.

INNES, J.L., LANDMANN, G.& METTENDORF, B. (1993): Consistency of observations of defoliation amongst three different European countries. Environmental Monitoring and Assessment 25: 29-40

INNES, J.L. (1993) Forest health: Its assessment and status. Commonwealth Agricultural Bureau. Wallingford, 677 pp.

INNES J.L., 1994. The occurrence of flowering and fruiting on individual trees over 3 years and their effects on subsequent crown condition. Trees 8: 139-150.

MIZOUE, N., 1999: Development of image analysis system for crown condition assessment in forest health monitoring, CROCO. Dissertation, Kyushu, University. 89 S.

JACOBSEN, C., SZEPESI, A.(1998): Status of crown condition assessment for the intensive monitoring (Level II). Evaluation founding on DAR questionnaire of FIMCI. In.: Report 1st meeting Expert Panel on Crown Condition Assessment, HLFWW Hann. Münden. 22-28

KÖHL, M. (1991): Waldschadensinventuren: mögliche Ursachen der Variation der Nadel-/Blattverlustschätzung zwischen Beobachtern und Folgerungen für Kontrollaufnahmen. Allg. Forst- u. J.-Ztg., 162, 11/12: 210-221.

KÖHL, M. (1992): Quantifizierung der Beobachterfehler bei Nadel-/Blattverlustschätzungen. Allg. Forst- u. J.-Ztg., 164, 5: 83-92.

SABOROWSKI, J., Dahm, S., Ackermann, J. (1998): Stichprobentheoretische Analyse der Waldschadenserhebung in Niedersachsen. AFJZ 3/1998.

SCHADAUER, K. (1991): Die Ermittlung von Genauigkeitsmaßen terrestrischer Kronenzustandsinventuren im Rahmen der Österreichischen „Waldzustandsinventur“. Centralblatt für das gesamte Forstwesen 108, 3: 253-282.

SEIDLING, W. (1999): Integrated study on crown condition, soil data and leaf contents. in: Second Interim Report of the FSCC, 1999.

SOLBERG, S. (1999): Forest health monitoring: Evaluation of methods, trends and causes based on a Norwegian nationwide set of monitoring plots. Norges landbrukshogskole. Norsk institutt for skogforskning. ISBN 82-7169-897-4. As. Pp. 120

ANNEXES

Annex 1:
SAMPLING DESIGN
M. Ferretti
(available upon request from the Expert Panel on Crown Condition Assessments)

Annex 2:
QUALITY ASSURANCE
D. Durrant, M. Ferretti, S. Solberg
(available upon request from the Expert Panel on Crown Condition Assessments)

Annex 3:
FUTURE INTERNATIONAL INTERCALIBRATION COURSES (IICS) - DEVELOPING A CONCEPT
M Ferretti
(available upon request from the Expert Panel on Crown Condition Assessments)

Annex 4:
SCENARIOS FOR FUTURE CROWN CONDITION SURVEY
M. Lorenz and R. Fischer, PCC of ICP Forests, BFH Hamburg
(available upon request from the Expert Panel on Crown Condition Assessments)

Annex 5:
THE FUTURE ORGANISATION OF INTERCALIBRATION COURSES
by R. MAVSAR
(available upon request from the Expert Panel on Crown Condition Assessments)

4.3 Soil chemistry

4.3.1 Summary

Soil chemistry has been assessed once on both levels up to now. What appeared to be a major drawback of this first survey, was the heterogeneity of the sampling procedure followed by the different countries. A second important constraint was the quality of the analysis: recommended reference methods have clearly not urged all the participating countries to actually use these methods, and even if they do so, differences between laboratories remained.
However, it is important to state that the investigation of changes in soil chemistry which is an important objective for both monitoring levels can only be carried out after at least one re-assessment.
Thus it is recommended to repeat the soil survey on Level I. In order (i) to make use of the representativity of the Level I gridnet and (ii) to complete and improve the existing database, it is recommended to conduct the survey on all Level I plots.
The repetition on Level II is already foreseen in the programme.
On plots that have already been assessed with the recommended methods during the first survey the expenses for the second survey can be reduced, as the general characterisation of the soil will not be required. In addition there will be several parameters in the mineral subsoils of Level II plots that will not have to be reassessed in the second soil survey.

However these repetitions should only be conducted under the following pre-conditions:

- Further standardisation in the procedures for soil sample site allocation and collection has to be applied, according to a new submanual as it will be presented to the Task Force.
- The list of key parameters has to be revised accordingly and included into the new submanual.
- Improvements in the laboratory (and sampling) procedures are necessary. Strict quality control measures have therefore been elaborated by the responsible Expert Panel in order to ascertain a better quality of the database,

Table 4.3.1-1: Parameters of the soil survey

PROPOSAL OF SELECTED KEY PARAMETERS FOR SOIL CONDITION SURVEYS AT LEVEL I & II [(1)]
with indication of changes compared to current state

	Parameter		Unit	Level I				Level II					
				Organic layers		Mineral layers		Organic layers		Mineral layers [(2)]			
				L	*F+H* [(3)]	0-10 cm	10-20 cm	*L*	*F+H* [(3)]	0-10 cm	10-20 cm	20-40 cm	40-80 cm
1	pH($CaCl_2$)		-	-	M	M	M	-	M	M	M	M	M
2	Organic Carbon		g/kg	-	M	M	M	-	M	M	M	*O*	*O*
3	Total N		g/kg	-	M	M	M	-	M	M	M	*O*	*O*
4	$CaCO_3$		g/kg	-	*M if pH>5.5*	M if pH> 6	M if pH> 6	-	*M if pH>5.5*	M if pH>6	M if pH>6	*O*	*O*
5	Aqua Regia extracted nutrients	Ca, K, Mg	mg/kg	*O*	M	*O*	*O*	*O*	M	*O*	*O*	-	-
		P								O	O	~~O~~	~~O~~
		Mn			*M*				*M*	*O*	*O*	-	-
	Aqua Regia extracted heavy metals	Cu, Pb, Cd, Zn	mg/kg	*O*	*M*	*M*	-	*O*	*M*	*M*	~~O~~	~~O~~	~~O~~
	Aqua Regia extracted	Al, Fe, Cr, Ni, Na	mg/kg	*O*	O	*O*	-	*O*	O	*O*	-	-	-
		Hg			*O*								
		S								O	~~O~~	~~O~~	~~O~~
6	Exchangeable Acidity		cmol+/kg	-	*O*	*M*	*M*	-	*M* [(4)]	M	M	M	M
	Exchangeable Cations: Ca, Mg,K, Na, Al, Fe^{3+}, Mn, H *(5)*		cmol+/kg	-	*O*	*M*	*M*	-	*M* [(4)]	M	M	M	M
	CEC, BS: *(5)*		cmol+/kg	-	~~O~~	~~M~~	~~M~~	-	~~M~~	~~M~~	~~M~~	~~M~~	~~M~~
7	pH(H_2O)		-	-	*O*	*O*	*O*	-	O	O	O	O	O
8	Total Elements: Ca, Mg, Na, K, Al, Fe, Mn		mg/kg	-	-	-	-	-	-	O	O	O	O
9	Electrical conductivity		mmho/cm	-	-	-	-	-	~~O~~	~~O~~	~~O~~	~~O~~	~~O~~

[1] Abbreviations, codes : M = mandatory parameter, O = optional parameter, ~~*blue*~~ = excluded from survey, *red* = new optional or new mandatory parameter, green = change from optional to mandatory or from mandatory to optional

[2] In case of a re-assessment (if the parameter was already measured according to the reerence method for the first survey) , the measurement of all the parameters in the subsoil (mineral layers 20 - 40 cm and 40- 80 cm) is optional.

[3] If the H - layer > 1 cm, the F - and the H - layer should be analysed separately and each value has to be reported

[4] In calcareous soil, the measurement of this parameter is optional

[(5)] The exchangeable cations have to be measured and reported each (instead of reporting ACE and BCE). The parameters CEC and BS will then be calculated from the exchangeable cations. As such, values for CEC and BS no longer have to be submitted.

SELECTED PHYSICAL SOIL PARAMETERS: current set vs. proposal (1)

	Parameter		Level I				Level II					
			Organic layers		**Mineral layers (3)(4)**		**Organic layers**		**Mineral layers (3)**			
			L	**F+H (2)**	**0-10 cm**	**10-20 cm**	**L**	**F+H (2)**	**0-10 cm**	**10-20 cm**	**20-40 cm**	**40-80 cm**
1	Texture		-	-	***M***	***M***	-	-	M	M	M	M
		Clay	-	-	***M***	***M***	-	-	M	M	M	M
		Silt	-	-	O	O	-	-	M	M	M	M
		Sand	-	-	O	O	-	-	M	M	M	M
2	Bulk density		-	-	***M*** (5)	***O***	-	-	**M** (5)	**O**	**O**	**O**
		Coarse fragments	-	-	***M***	***O***	-	-	**M**	**O**	**O**	**O**
3	Weight		**O**	M	-	-	**O**	M	-	-	-	-

[1] Abbreviations: M = mandatory parameter, O = optional parameter, A = advised, **Red-underlined** = change from optional/advised to mandatory (/optional)
[2] If the H - layer > 1 cm, the F - and the H - layer should be measured separately and each value has to be reported
[3] In case of a re-assessment (if the parameter was already measured according to the reference method for the first survey) , the measurement is optional.
[4] *Field estimates* are allowed, measurement not mandatory
[5] Mandatory in non-stony soils

4.3.2 Objectives

The main objective of the assessment of the soil condition is the investigation of spatial and temporal patterns in the forest soil chemistry as affected by (changes in) air pollution (atmospheric deposition) and other environmental issues, such as heavy metal pollution and carbon sequestration.

The data from both levels should in addition provide a basis for integrated studies, in which effects of atmospheric deposition (or other environmental issues) on forest ecosystems can be investigated.

4.3.3 Benefits and pre-requisites of a re-assessment

The primary objectives of a second assessment of the soil condition (at either one or both levels) is the investigation of significant changes in the forest soil chemistry due to (changes in) air pollution after ten years.

Secondary, a re-assessment will contribute to an improvement of the existing data base, by means of:

- the completion of relevant parameters (or layers) that were not or only partly included in the previous survey,
- an improved trans-national comparability, and
- improvement of the quality of the data.

Completion of relevant parameters
The selection of parameters in the first survey was based on the knowledge level at that moment. Since then, new knowledge has been gained into effects of atmospheric deposition (and other environmental issues), leading to an update of the selection of relevant parameters. Furthermore, several plots had already been sampled before the issue of the former guidelines, which, in some cases, has led to a deviating set of variables (and layers). A re-assessment offers an opportunity to complete the database with relevant soil parameters and soil layers that were not considered (or only optional) in the first survey. This refers also to recent findings on the possible impacts of heavy metals on forest ecosystems (e.g. the request from the recent UN/ECE workshop on heavy metals in Schwerin, in order to calculate critical loads for heavy metals).

The strength of the Level I data base is its representativity, since it is based on a systematic 16 x 16 km gridnet. From the position of cost effectiveness, a re-assessment could be limited to a subset of plots that are most likely to show a change (e.g. plots sensitive to acidification and/or having a large atmospheric deposition). However, this would certainly introduce bias and would lead to a loss of representativity. A full repetition moreover allows the improvement and completion of the database.

Trans-national comparability
Trans-national comparability of data obtained through monitoring activities is an objective that hasn't been entirely met at different Levels in the sub-programmes of ICP Forests. At the base of this problem were differences in methodology applied at national level, sometimes also at smaller regional level, resulting in data variability that complicated the interpretation of the monitoring results on a European scale. Difficulties with data comparability, caused by differences in methodology, have also been recognised within the soil-monitoring programme. There have been methodological differences in the applied (i) sampling procedures and (ii) soil analysis methods. Further standardisation in the procedures for soil sample site allocation and collection could also contribute to a better trans-national comparability.

Improvement of the quality
The improvement of the quality does not only include a further standardisation of the applied methods, but also improvements in the laboratory (and sampling) procedures, even if these procedures are already following the guidelines. The results of the ring tests showed that there was considerable variation in the results for several elements, even when the reference methods were applied. Strict quality control measures are thus required to ascertain a better quality of the database.

4.3.4 Sampling design and methods

The procedures for soil sample site allocation and collection are not adequately defined in the Manual. From the critical review of soil sampling methods in the ICP Forests programme (Baert et al., 1998), it is obvious that the large variability generally observed in both forest mineral soil and forest floor leads to large variances for chemical and physical parameters, depending on the applied sampling method, and more in particular on the sampling design and the number of samples taken. However, precisely the guidelines for a sampling design and number of samples to be taken are missing. The resulting differences in national sampling procedures have been recognised in the technical reports of the soil monitoring programmes at both Level I and Level II as an undesirable source of data variability. As such there is an urgent need for a common sampling strategy in function of a further harmonisation of the methods applied in the ICP Forests Programme.

Sampling Design and Number of Samples

The model-based sampling approach, requiring a previous geostatistical study, appears to be the most appropriate sampling method for excluding differences due to spatial variability (Baert et al., 1998). However, this method is very time consuming and expensive, since it requires a large number of analyses of individual samples, and is not considered as feasible for the surveys concerned. For determining a practical sampling design, a distinction should be made between Level I and II, to take into account the different scale (number of plots) and approach of both levels.

As the level I survey covers many plots, it is acceptable that the demands for estimating the variability of the site - so as to be able to make a distinction with temporal changes - are less severe than for the Level II plots. Anyway, for the Level I survey no conclusions should be drawn from a single plot, it is meant for a mass statistical approach. As such for Level I a more practical sampling design (judgmental) is recommended. As before only the organic and upper mineral layers should be sampled. A recommended minimum of samples per plot has to be taken and analysed, determination of the variability of the site is recommended to be optional.

The sampling design for Level II has to fulfill two objectives: (i) to provide one (or more) sample(s) that are representative for conditions at the entire plot, and (ii) to provide information about the variability within the plot, in order to make sound statements about the significance of changes between consecutive measurements. A systematic design with a random component is recommended, as well as a defined minimum of samples to be taken and analysed Where certain data were not provided or were not measured with the reference methods during the first Level II soil survey, sampling of subsoil layers is required in addition to sampling of the organic and upper mineral layers (unlike for the first survey where all layers had to be sampled and analysed).

Additional Specifications Required

In contrast to the present guidelines, only sampling by fixed layers should be allowed. Sampling by genetic horizons (presently allowed as an alternative) requires recalculation of the data (resulting in possible errors) and has to be avoided.
Apart from guidelines concerning the sampling design, layers and number of samples, for both levels information on the sampling time is important, as the season has an influence on bio-chemical and chemical reactions going on in the soil. Thus recommendations on the sampling time have to be included in the manual.
Some details with regard to the sampling sites to be avoided (core of the plot for Level II, disturbances like animal holes, uprooted trees, areas within 1 meter distance to the tree) and the method (sampling equipment) have to be added to improve the quality of the sampling.

It can be concluded that, the procedure for sampling as presently described in the Soil Manual was not detailed enough to meet the standards to guarantee harmonised sampling throughout Europe, nor did it include measures to allow the assessment of the spatial variability, which is particularly essential for the Level II survey. Both for Level I and Level II an updated manual with detailed procedures for sampling will be proposed which will have to be followed (mandatory) by all the participating countries. This is an important prerequisite for a higher comparability of the data to be generated.

Pedological Characterisation

The pedological characterisation of the soil is of prime importance to classify the soil correctly, and to provide static background information on the concerned soil in order to improve the interpretation of other data that have to be collected. Therefore it has to be mandatory not only for Level II (as is presently recommended in the manual), but also for Level I.

4.3.5 Parameters

4.3.5.1 Type of Parameters Selected

Physical soil parameters **required for the general characterisation of the soil as well as for calculations/conversions of chemical parameters are:**
soil texture: required for proper classification of the soil (re pedological characterisation), and for correct interpretation of other (chemical) parameters; it should be mandatory not only for Level II (as now in the manual), but also for Level I although for this level field estimates are acceptable
bulk density: important for determining nutrient supply, influences concentrations of air pollutants in the soil; assessment of this parameter is only 'advised' now, but should be mandatory for both Level I (at least by estimate or pedo-transfer functions) and for Level II (by measurement)
weight (amount) of the organic layer: required for the correct interpretation/recalculation of other soil data; should remain mandatory for both levels.

Selected chemical soil parameters include:
carbon and nitrogen: should remain mandatory, but only for organic and upper mineral layers
heavy metals (Pb, Cu, Zn, Cd): with regard to the main objectives it is proposed to make these parameters mandatory for both Level I and Level II, only for the organic layer and the mineral topsoil, on the condition that the quality problems are solved.
nutrients (P, Ca, Mg, K, Mn): can be determined from the same extract required for heavy metals and are therefore included in the list of key parameters, as before mandatory for the organic layer, now additionally (but optional) for mineral topsoil.
Parameters describing the acidity status and exchange characteristics of the soil: important with regard to the main objectives, in particular for the upper soil layers

- pH: should remain mandatory; pH($CaCl_2$) should be mandatory, and pH(H_2O) optional for comparison reasons with literature
- $CaCO_3$: should become mandatory also for the organic layer; needed for correction of the organic carbon content
- exchangeable cations (Ca, Mg, K, Na, Al, Fe^{3+}, Mn and H): should be reported separately, this gives more information for the same amount of work
- exchangeable acidity
- CEC and base saturation: these two parameters can be calculated from submitted data and do not have to be reported by the countries

other elements (Al, Fe, Cr, Ni, S, Hg, Na): less important with regard to the main objectives, some of them can however be easily determined in the extract required for heavy metals and should therefore remain optional
electrical conductivity: no real need for keeping this parameter (now optional for Level II); it should therefore be excluded from the list.
total elements (Ca, Mg, Na, K, Al, Fe, Mn): important for weathering rates (key parameter for critical load of acidity); their determination requires special skill and should therefore be optional for Level II only.

4.3.5.2 Relevance

The soil parameters have been selected with regard to their relevance for monitoring changes due to atmospheric deposition, the buffering capacity for acid inputs, and related damages or potential damages to forest ecosystems. Atmospheric deposition of sulphur and nitrogen compounds can lead to acidification of the soil and hence cause a loss of vitality of the forests. On the short term, chemical immobilisation mechanisms protect the plants from direct toxic effects of heavy metal accumulations. However, acidifying compounds have a triggering effect on heavy metal availability and may cause damage in the long term. The results from the first soil survey showed a correlation between soil chemistry and atmospheric deposition of nitrogen, acidity and heavy metals. The vulnerability of the ecosystem and hence indication of possible damages can be assessed by critical load calculations that make use of the soil data generated by the surveys.

Table 4.3.5.2-1: Relevance of the key parameters

Type of parameter	Key parameters	Layer	Relevance
Carbon and nitrogen	C_{tot}, $N_{tot,}$ ($CaCO_3$)	Organic	Forest nutrition, atmospheric N deposition, climate change
		Mineral	Forest nutrition (0-20 cm)
Nutrients	Total P, Ca, Mg, K, Mn	Organic	Atmospheric deposition of basic cations, stock of main nutrients
		Mineral	Weathering rates, critical loads of acidity, stock of main nutrients
Acidity, Exchange characteristics	pH, $CaCO_3$, CEC, BS, Exchangeable cations, Exchangeable Acidity	Organic	Buffering acid input
	pH, CaCO3, CEC, BS, Exchangeable cations, Exchangeable Acidity, Al_{ox}, Fe_{ox}	Mineral	
Heavy metals	Pb, Cu, Zn, Cd	Organic	Atmospheric metal deposition
		Mineral	Atmospheric metal deposition, calculation critical loads (0-20 cm)

The atmospheric deposition of acid compounds and heavy metals is a continuous process. With time this can cause changes in the acidity status of the soil and hence alter the potential risk for toxicity to the plant community. This is particularly so at places with a high deposition of these hazardous compounds and which in addition include soils vulnerable for acidification and already containing high levels of potentially toxic elements (heavy metals). These changes are expected mainly in the upper soil layers, and for temporal studies, only for these layers the relevant parameters have to be re-measured. Measurement of these parameters in the subsoil is not required if they were already measured with the reference methods for the first survey.

4.3.5.3 Practicability

Parameters that are only needed for the general characterisation of the soil, and that were determined according to the reference methods during the first soil surveys, do not have to be re-assessed.

Further, with regard to the physical parameters, a distinction has been made between Level I and Level II: where measurements are mandatory for Level II, field estimates or estimates by modelling (e. g. pedo - transfer functions for bulk density) are allowed for Level I. Also these parameters are not apt to change over time and do not need a re-assessment if they were already determined according to the reference method.

Chemical parameters that require special equipment or particular skill to determine correctly have been made optional or were skipped altogether. Only parameters important for the study of temporal changes have to be re-assessed, and only for the organic and upper mineral layers. Re-assessments of some other parameters and for the mineral subsoil are only needed if they were not measured during the first survey with the reference methods

4.3.6 Analyses

With regard to the measurement of the parameters, the analytical methods proposed as the reference methods for the 1st survey, as described in the Manual on methodologies and criteria for harmonised sampling, assessment, monitoring and analysis of the effect of air pollution on forests (UN/ECE, 1998), are proposed again for the second survey. Only some minor additions/corrections to the descriptions of the methods are needed.

The reason for choosing the existing reference methods is the fact that the majority of countries, representing an even larger share of plots, used the reference methods in the 1st survey. As such the possibility of comparing the results of the first survey with future ones will be greater when sticking to these methods.

It has to be stressed however that all countries should follow the recommendations. The variation of soil analysis methods used for the first survey and its influence on the obtained results have been revealed by two intercalibration exercises. Such variation has to be avoided in future surveys.

For the assessment of some of the physical parameters (texture, bulk density), field estimates or modelling are acceptable for Level I.

4.3.7 Resources Required for the Assessments on Level I

Costs per plot vary widely between the different countries or even within the countries, due to different costs for labour and material, as well as differences in plot location (distances and ease of access) and plot characteristics (labour required per sample).

The average total cost per Level I plot is estimated to amount to 960 Euro. This includes the costs of the fieldwork required, the preparation of the samples and the costs of the analyses. The extra costs for optional measurements will be small or negligible compared to the total cost and most likely fall within the margin of error of the average total estimate given.

The Level I grid covers over 5000 plots in Europe, of which more than 3000 in the European Union. A 50% co-financing of the EU would require a budget of about 3.2 Million Euro.

4.3.8 Quality Control

What appeared to be a major drawback of the first survey, was the heterogeneity of the sampling procedure followed by the different countries. The more detailed guidelines which are now recommended, in particular on the sampling design and the number of samples, and the mandatory determination of the sampling variability on Level II, should lead to better data and trans-national comparability.
A second important issue is the quality of the analysis: recommending reference methods have clearly not urged all the participating countries to actually use these methods, and even if they do so, differences between laboratories remain.

The following measures are therefore proposed:

1. A ring test has to be done prior to a new survey
2. The reference method has to be mandatory
3. Following the guidelines should be a prerequisite for funding by the EC
4. Participation of all the labs in international quality control programmes has to be mandatory
5. The results of the control programme have to be reported to the centres responsible for the data (and the data evaluation), as a quality document accompanying the data but not for publication
6. The DAR-Q will make provision for info on the method used, taking into account that not all countries can follow the guidelines. A code will be given to the different methods.

A consequence of the measures proposed is that for the countries that did not use the reference methods for the first survey, the data from both surveys will not be directly comparable. These countries are advised to use both their national method and the recommended method, but with regard to the costs involved, such a 'double' measurement is not mandatory. Clearly here a choice has been made for better quality with regard to trans-national comparability.

4.3.9 References

Baert G., L. Vanmechelen and E. Van Ranst. 1998. Critical review of soil sampling methods in the ICP Forests programme: Background document. Forest Soil Co-ordinating Centre (FSCC), 19 pp.

EC and UN/ECE. 1997a. De Vries, W., G.J. Reinds, E.M. Vel and H.D. Deelstra. Intensive Monitoring of Forest Ecosystems in Europe. Technical Report, Brussels, Geneva, 104 pp

EC and UN/ECE. 1997b. Vanmechelen L., R. Groenemans, E. Van Ranst. Forest Soil Condition in Europe. Technical Report, Brussels, Geneva, 261 pp.

Ministerie van de Vlaamse Gemeenschap (ed.). 1990. Report Soil Expert Panel Meeting held in Leuven, Belgium, November 11-14, 1990. 8 pp. + annexes.

Seidling W. 1999. Overview Report on Integrated Studies in Europe. Internal Report, PCC, Hamburg, Germany. 40 pp. + annexes.

Starr, M. R. (ed.). 1990. Report Soil Expert Panel Meeting held in Helsinki, Finland, January 9-10, 1990. 66 pp.

UN/ECE. 1998. Manual on methodologies and criteria for harmonised sampling, assessment, monitoring and analysis of the effect of air pollution on forests, Hamburg, PCC-BFH (ed.).

4.4 Soil solution

4.4.1 Summary

Soil solution monitoring is presently carried out on at least 10 % of the Level II plots of each participating country. In combination with deposition and meteorological measurements it provides valuable information on available nutrients and toxic substances as well as on water fluxes in the forest ecosystem.
Presently a lysimeter intercomparison is carried out. It shows that there are only minor changes necessary at the moment. These will be included in a proposal for an update of the respective Submanual of ICP Forests. In principal the assessments should remain unchanged.

Table 4.4.1-1: Key parameters of the soil solution survey[1)]

PARAMETER	UNIT	CURRENT STATE	PROPOSAL
conductivity	µS/cm	O	**M**
pH		M	M
alkalinity	µmolc/l	O (if pH > 5)	O (if pH > 5)
DOC	mg/l	M	M
Na	mg/l	O[1)]	**M**
K, Mg, Ca,	mg/l	M	M
Al (total)	mg/l	M (if pH < 5)	M
Al (labile)	mg/l	O	O
Fe, Mn,	mg/l	O	**M**
Total P (total)	mg/l	O	O
NO_3-N, SO_4-S	mg/l	M	**M**
NH_4-N	mg/l	O[3)]	**M**
Cl	mg/l	O[2)]	**M**
Zn, Cu, Pb, Cd	µg/l	O	O
Cr, Ni,	µg/l	O	**excluded**
Si	mg/l	O	O

1) Abbreviations, codes : M = mandatory parameter, O = optional parameter, **blue** = excluded from survey, **red** = new optional or new mandatory parameter, **green** = change from optional to mandatory or from mandatory to optional
2) For the calculation of acid base budgets all cations and anions which contribute significantly to the budget are needed. This is also necessary to check whether the sum of the cations equals the sum of the anions. Consequently, it is advised to measure the concentration of Na and Cl.
3) Advised to measure NH_4 in areas with high NH_x deposition (e.g. above 20 kg NH_x ha^{-1} yr^{-1}).

4.4.2 Objectives

The general objective of the chemical analysis of soil solution at the Level II plots is to study the long-term trends and seasonal variations of soil solution chemistry in response to atmospheric deposition (and climate change).

- In this context, the chemical characterization of the soil solution provides information about the nutrient availability and possible inhibition of nutrient uptake due to potential toxic effects of aluminium and/or heavy metals to plant roots and mycorrhizas.
- Furthermore, in conjunction with water fluxes, the leaching of elements from the rooting layer can be assessed in case of intensive monitoring .

In order to determine the element fluxes with the soil solution leaving the rooting zone, rates of water fluxes have to be assessed. The assessment of leaching fluxes is only useful in combination with deposition data (bulk deposition and stand throughfall), thus providing an overall picture of the changes in soil solution quality taking place as it passes through forest ecosystems, and facilitating in-depth studies of the processes involved, through input-output budgets of elements.

4.4.3 Parameters

The list of key parameters to be measured in the soil solution is as follows:

conductivity: should be changed from optional to mandatory, because of its importance as quality test for measured and calculated conductivity

pH: relevant with regard to buffering of the soil, should remain mandatory

Alkalinity: can be used for data quality control, to check charge balance, important for ion balance, should remain optional for pH > 5

DOC: to check charge balance; extremely important in complexing Al and heavy metals thus increasing the total concentration, but lowering the toxic free metal ion form; should remain mandatory

DON, N(total): new optional parameter; with N in total solution, and if NO_3-N, SO_4-S and NH_4-N are analysed, Norg can be determined; also suggested by deposition group; important too for N-budget

Na and Cl: both should change from optional to mandatory because of high importance for quality check (check of charge balance); Cl is in addition an important trace element allowing the validation of water flux models

K, Mg, Ca: mandatory as before; gives information about buffering of soil

Al(total): has to be mandatory, not only if the pH > 5 as is the case at present, for information on buffering of the soil

Mn and Fe: mandatory for information on nutrition and possible impacts

Total P: easy to determine, but more relevant for agricultural soils, therefore kept optional

Si: less important with regard to the main objectives; meaningful for calculation of weathering rates, if combined with hydrological fluxes also interesting for interpretation

Heavy metals (Zn, Cu, Pb, Cd): very important with regard to the calculation of critical loads of heavy metals, effects and model validation; requires specialised equipment and is kept optional (note: *Cr and Ni* are excluded from the survey)

NO_3-N, SO_4-S and NH_4-N: NH_4-N has to change from optional to mandatory, as is the case for NO_3-N, SO_4-S; these parameters are important for the study of impacts on N and S deposition; in addition NH_4-N is crucial as it determines the charge balance, and also to assess input-output budgets of N since NH_4 is measured in deposition

Al (labile): this is the toxic form of Al; the analysis is not commonly done; optional as before

Practicability

Similarly as for the selection of optional and mandatory parameters for soil, parameters that require specialised (expensive) equipment or particular skill have been made optional or were excluded.
In addition, a priority list of parameters to be analysed is provided to be used in case the amount of soil solution does not suffice for all the analyses. If only little sample remains after the measurement of pH and conductivity, the sample can be diluted in order to obtain sufficient sample for the measurement of the major ions.

Table 4.4.3.-1: Priority list in case of insufficient sample for the measurement of key parameters for soil solution

1. pH, conductivity	6. Fe, Mn
2. NO_3-N, SO_4-S, Cl	7. Zn, Cu, Cd, Pb
3. NH_4-N	8. Alkalinity
4. K, Mg, Ca, Al(total), Na	9. N(total)
5. DOC	

4.4.4 Analyses

The sampling methods are under revision. As for the analytical methods to be used for the measurement of the key parameters, the reference methods presently recommended in the Manual on methodologies and criteria for harmonised sampling, assessment, monitoring and analysis of the effect of air pollution on forests remain valid. For the optional determination of labile Al, a detailed description has to be added.

4.4.5 Quality Control

With regard to the completion and upgrade of the soil solution manual experts from Finland and Denmark jointly conducted a study to evaluate the lysimeter techniques employed in monitoring soil solution quality in the European Level II Intensive Plot Network, and to assess the future intercomparability of the soil solution data. Experiences so far have shown that different sampling methodologies (different equipment) can lead to different results. The full report of the study, and measures to be taken consequently, will be discussed by an ad hoc working group on soil solution. The outcome of the study and the discussions will lead to an upgrade of the actual soil solution sampling procedure as well as to an updated list of key parameters. report of the study, and measures to be taken consequently, will be discussed by an ad hoc working group on soil solution. The outcome of the study and the discussions will lead to an upgrade of the actual soil solution sampling procedure as well as to an updated list of key parameters.

4.5 Foliage Chemistry

4.5.1 Summary

Forest condition and tree nutrition are closely related and changes in forest condition may manyfest themselves in foliar nutrient concentrations.

The first foliar survey (1994/95) organised by ICP Forests at Level I covered only part of Europe, because only a few European countries (16) were able to participate in the survey. An additional problem was that the samples were collected in different countries in different years. The data base on tree nutrition at European level is therefore incomplete and needs to be amended. The foliar survey covering all the European regions should be implemented at the same time as the soil chemical survey using the same Level I plots. It is therefore to be recommended that countries willing to carry out the Level I foliar survey should sample and analyse foliar composite samples according to the foliar submanual every ten years.

The foliar survey at Level II is mandatory. Sampling and analysis must be carried out every two years at the least. The Level II foliar survey covers 847 selected plots throuhout Europe, the first survey being implemented in 1995. Regularly repeated Level II surveys provide a good basis for multivariate statistics and trend analysis of forest condition.

Because composite samples are used for conventional foliar analysis, the variation between individual trees is not necessarily taken into account. However, the variation between individuals represents a useful additional indicator, and it may therefore be more imformative to analyse the samples on an individual tree basis on the Level II plots. Some countries have already used this procedure. The sampling and analyses of leaves and needles could be implemented every five years on Level II plots for financial reasons. If the survey interval at Level II were to be changed, the foliar surveys carried out on the Level I and II plots should be synchronized such that both surveys are carried out simultaneously every ten years.
The review clearly demonstrates that the sampling and analyses procedures, as well as the selection of key parameters, have proven their worth. However, a number of small additions and modifications to the sampling procedure could provide more information than the sampling procedures currently recommended in the submanual.

A large number of factors affect the concentration of elements in needles and leaves. These factors need to be taken into account in sampling, analyses and interpretation. One constraint is the varying quality of the foliar surveys carried out in the individual countries. Quality control should therefore also be taken into account also in the sampling, and not only in the chemical analysis. The inter-laboratory ring tests, for instance, represent an important regulating instrument. Their results have led to modifications in the submanual in the past, and will continue to do so in the future.

Table 4.5.1-1: Key parameters[1)] of the foliaar survey (Level I and Level II)

Parameter	Current state	Proposal
N, S, P, Ca, Mg, K	M	M
Date of analysis	M	M
Number of sample trees	M	M
Mass of 100 leaves	M	M
Mass of 1000 needles	M	M
Na, Zn, Mn, Fe, Al, B, Pb, Cu, Cd, and C	O	O

[1)] Abbreviations, codes : M = mandatory parameter, O = optional parameter

4.5.2 Introduction

The nutritional status of trees provides an important diagnostic tool for estimating their condition. Chemical foliar analysis is a widely used diagnostic and monitoring method in forestry and environmental studies. It has been used to estimate nutrient deficiencies and toxicity states, and to monitor the nutritional status of trees, particularly with respect to maximising growth or evaluating mitigation measures (liming). Chemical foliar analysis can also be employed when studying the impact of air pollutants and their severity .

The foliar and soil surveys were designed and carried out by ICP Forests in order to improve our understanding of the role of atmospheric pollution in relation to crown condition and the nutritional status of trees. Harmonized sampling and analysis methods for foliage were agreed on in 1994. Only a few European countries were able to participate in the first foliar survey. This was mainly due to the heavy work load that coincided with the survey – implementation of the soil condition survey and installation of the Level II plots. The first foliar survey was therefore only a pilot survey of the nutritional status of forests at the European level.

4.5.3 Objectives

The main objectives of the foliar survey are:

- to produce spatial information at regular intervals about the nutritional status of forests at the European level,
- to detect deficiencies, disturbances or imbalances in tree nutrition,
- to provide a basis for future correlative and upscaling studies between the foliar data and other datasets, e.g. crown condition, litterfall and soil, and
- to maintain a European-wide database and ensure comparability of the submitted data.

4.5.4 Sampling design and methods

Crown position for taking samples from conifers

A large number of factors affect the concentration of elements in needles and leaves, and these factors need to be taken into account in sampling, and in interpreting the results (Raitio 1995a). The comprehensive investigations on foliar analysis made by e.g. Tamm (1956), Strebel (1960), Höhne (1963), and Reemtsma (1966) were carried out with material from the top whorl of conifers. However, this crown position is rather inadequate for determining the mobile nutrient supply to conifers on the basis of more than one needle age class, because the top of the tree has an optimum nutrient supply. This is also true for the youngest compared to the oldest parts of the side branches (Hunger 1972). For this reason, the investigations of Reemtsma (1966) on the nutritional status of Norway spruce stands concentrated on the nutrient concentrations in older needle age classes.

The sampling of current (C) and previous-year (C+1) needles is optional on Level I plots, and is recommended on Level II plots. While the current-year needles or leaves of evergreen species are most suitable for assessing the actual nutritional state for a number of elements, the comparison of element concentrations in older needles with that in current-year needles is also of interest. Furthermore, by ensuring that all the orientations are represented in the set of sample trees, the effects of crown position on the chemical composition of both needles and leaves have been partly eliminated.

Crown position for taking samples from broadleaved species

There is no corresponding standard for sampling on deciduous trees. Fully developed leaves from the upper, light-exposed crown position are usually collected. A more exact definition is given by Rzeznik and Nebe (1987), who collected the third and fourth leaf from the top of each of three shoots at the top of beech trees. Leaves from the inside of the crown have been collected and analysed by some authors, but the increase in information about the nutritional state given by this method is unclear. Only a few investigations have been carried out on the seasonal variation of leaves of broad-leaved trees (Ferm and Markkola 1985). In the foliar submanual it has been pointed out that it is important that the sampled leaves have developed in full light, and that the sampling of deciduous species must be performed during the second half of the growing season and well before the beginning of autumnal yellowing and senescence.

Number of sampled trees

In addition to variation in the amount of needles collected from individual trees, research carried out in this field also varies with regard to the number of trees from which the needles or leaves are collected for the composite samples. Several authors propose that needles should be collected from 20 trees (Morrison 1985, Wells 1969, Will 1985). When this is done, the nitrogen and sulphur concentrations are believed to be representative of the average situation in the stand. Because the number of trees sampled strongly affects the costs of sampling, it is recommended to sample at least 3 trees on Level I and 5 trees on Level II plots. For statistical reasons, however, it is recommended to sample more trees, e.g. at least 5 trees on Level I and 10 trees on Level II plots. The number of trees sampled is the most critical factor in the foliar survey of ICP Forests.

Seasonal variation in the chemical foliar composition

Seasonal variation in the chemical composition of Scots pine and Norway spruce needles has recently been investigated by Raitio and Merilä (1998). They observed that the pattern of seasonal variation in element concentrations was rather similar in both tree species. However, the concentrations in spruce and pine needles were at different levels. Seasonal variation in the element concentrations was highly dependent on changes in the dry weight of the needles, especially in pine. They also found that biotic diseases may have drastic effects on the chemical composition of needles before the appearance of visual symptoms. Therefore the foliar expert panel has pointed out that it would be useful to record additional information about discoloration and symptoms of different diseases, as well as about insect attacks, on the needle/leaf samples.

To ensure the comparability of the results of needle nutrient analysis it is essential to sample needles during the period when there are no fluctuations in needle dry weight or nutrient retranslocation (Raitio and Merilä 1998). This has been taken into account in the foliar submanual.

4.5.5 Parameters

The mandatory parameters of the foliar survey are N, P, K, Ca, Mg, S, date of analysis, mass of 100 leaves and mass of 1000 neeles . The optional parameters are Na, Zn, Mn, Fe, Al, B, Pb, Cu, Cd and C. Most of the laboratories analyse the nitrogen and carbon concentrations on a CHN analyser, and the other elements, following wet digestion, by inductively coupled plasma atomic emission spectroscopy (ICP/AES). This procedure means that the analysis of the mandatory parameters simultaneously produces the results of the optional parameters. It is therefore cost effective and, for instance the C/N ratio will be available. The C/N ratio is important e.g. in litter decomposition studies.

Benefits of the parameters

The overall significance of mineral nutrients for plants, and the consequences of mineral deficiencies and excesses, have been treated by Mengel (1984), Shkolnik (1984), Bergmann (1988), and Marschner (1995). A state of deficiency can be caused by a number of factors, the deficiency being either primary or secondary. A primary deficiency occurs when the substrate contains insufficient nutrients. A secondary deficiency takes place when there are sufficient nutrients in the substrate, but either nutrient uptake or transport is disturbed, e.g. as a result of structural damage caused by insects or frost (Raitio 1993).

4.5.5.1 Mandatory parameters

Nitrogen, phosphorus and potassium

Nitrogen is an important nutrient and in most cases the factor limiting forest growth. However, the impact of airborne nitrogen is harmful due to its toxic and fertilising effects, eutrophication and acidification. Nitrogen deposition can cause imbalances of other nutrients, e.g. P, K, Ca, Mg and B. The possible effects of excess nitrogen are an important topic in the current discussion on the dangers of "nitrogen saturation" of ecosystems (Ulrich 1989, Isermann 1990). Nitrogen deposition represents a significant portion of the nitrogen available to the trees, in addition to the nitrogen released from the organic litter by microbial decomposition.

An increased nitrogen supply implies far-reaching changes in the ecology of the forests (Tamm 1991) because nitrogen is a leading element in plant nutrition that considerably affects the quantitative demand for other nutrients (Ingestad 1987). The turnover of nitrogen is causing changes in the acidity status of the soil. Such changes are a driving force for important ecosystem processes associated with mobilisation, leaching, the availability of other nutrients, as well as the levels of toxic substances (Ulrich and Sumner 1991).

An excessive nitrogen supply implies a risk to the health of the trees because it may lead to nutritional imbalances. Forest damage in Central and Northern Europe clearly caused by an excessive nitrogen supply has occurred in the vicinity of intensive cattle, pig and fur farming and fertiliser plants (Hofmann et al. 1990, Ferm et al. 1990). The forest damage e.g. in the Harz, the Bavarian Forest, the Black Forest and the Vosges caused by magnesium deficiency (Zech and Popp 1983, Zöttl 1985, Landmann et al. 1997), seems to be partly induced, in some regions, by the high nitrogen supply in combination with other factors (Kreutzer and Heil 1989). The appearance of potassium deficiency symptoms is assumed to be causally related to the abundant nitrogen supply in some areas. A decrease in phosphorus concentrations with increasing defoliation and increase in potassium concentrations have been reported by Heinsdorf et al. (1988). The K/Zn ratio has also been recommended by Liu and Hüttl (1991) as a useful indication of the new type of forest damage.

Forest growth and site productivity have changed considerably in many European countries in recent decades. The reasons for these changes are still unclear. One of the possible causes is nitrogen deposition. The significance of individual factors may vary in space and time (Spiecker et al. 1996). A shortage of available nitrogen, and in some cases also potassium and phosphorus deficiency, is the primary factor limiting growth e.g. in Scandinavia (Kaunisto 1997, Raitio 1999, Tamm 1991).

The response of forest ecosystems to an increase in the nitrogen supply varies of course over a wide range, depending on the site and stand properties. The original nitrogen status naturally plays a dominant role compared to other factors. The foliar nitrogen, phosphorus and potassium concentrations have been found to be good indicators of the status of these elements, and they are widely used in practical forestry.

Magnesium and calcium

Magnesium deficiency is the most common nutritional disorder associated with the so-called new types of forest damage occurring in planted as well as more natural forests in Europe (Landmann et al. 1997). Acid deposition is widely accepted as an important causal factor of magnesium deficiency, expect in areas near the coast, where the deposition of magnesium is high.. Recent studies on nutrient cycling in stands affected by magnesium deficiency have demonstrated that current losses of magnesium by leaching are generally greater than the losses attributable to tree uptake and harvesting (Johnson et al. 1991, Dambrine et al. 1995). It may therefore be concluded that acidic deposition, by promoting magnesium leaching, is one of the main driving forces of this problem. However, the influence of past land use and forest history and management should not be overlooked. The spatial distribution of magnesium deficiency symptoms is reasonably well known, and the continuous monitoring of forest health since 1985 has allowed its temporal development to be followed.

Magnesium deficiency has appeared in forest stands on a larger scale only within the last two decades in the form of the so-called "high elevation yellowing" of mainly Norway spruce stands, as well as on a range of sites and tree species (Ende and Evers 1997). Close correlations have been found between the magnesium concentrations in the soil and the foliage. Due to the dependence on climatic factors and genetic variation, the magnesium status of trees cannot be estimated from the symptomatology alone. Reliable information can only be obtained through foliar analysis. Because of the temporal fluctuations in foliar magnesium concentrations, already pointed out by Evers (1972), repeated analyses may be needed to unambiguously characterise magnesium nutrition and to identify long-term trends. A high atmospheric nitrogen input into forest ecosystems may result in elevated N/Mg ratios and an imbalanced magnesium nutrition (Ende and Evers 1997).

The concentrations of immobile nutrients such as calcium are usually higher in older than in current-year needles, and no retranslocation of these nutrients occurs. Since the calcium content of most soils is sufficient to meet the physiological demands of plants, deficiency symptoms usually do not result from an insufficient supply, but from secondary factors (Raitio 1993).

Sulphur

Forest decline in Europe and elsewhere in the world has been widely associated with sulphur emissions and deposition. The increased foliar leaching due to acidifying deposition causes changes in foliar nutrient concentrations. The foliar sulphur concentration has been reported to rise as a consequence of elevated concentrations of sulphur dioxide in the atmosphere and of sulphate in the soil (e.g. Landolt et al. 1989, Raito et al. 1995). The atmospheric sulphur dioxide concentration, as an indicator of sulphur pollution, has been found to correlate with the foliar sulphur concentrations better than other indices, including wet and dry sulphate deposition and the concentration of particulate sulphate (Innes and Boswell 1989).

Foliar analysis has been widely used for many years to monitor sulphur pollution. Studies performed already in the mid-1970's in Poland showed the potential of using sulphur analysis of Scots pine needles to monitor the effects of air pollutants (Bytnerowicz et al. 1981/82, Dmuchowski et al. 1981/82). The foliar sulphur concentrations provide a good index of the level of sulphur dioxide pollution (Materna 1982, Mankovská 1988, Innes and Boswell 1989, Raitio et al. 1995). However, Malcolm and Garforth (1977) concluded that the S/N ratio is a more sensitive indicator of the accumulation of sulphur in conifer foliage exposed to atmospheric pollution than analysis of elemental sulphur alone. The inorganic and organic proportions of foliar sulphur have also been observed to be rather good indicators of sulphur pollution (e.g. Manninen 1995, Raitio et al. 1995).

4.5.5.2 Optional parameters

Carbon

The effects of increasing concentrations of atmospheric carbon dioxide are of concern with regard to global warming. In general, plants react to rising CO_2 concentrations by an increase in biomass production. An increase in biomass production can cause short-term changes in the nutrient status of the trees due to the dilution effect.

Seasonal variation in the element concentrations is highly dependent on changes in the dry weight of the needles, and it is therefore essential to sample needles during the period when there is no needle dry weight fluctuation or nutrient retranslocation (Raitio and Merilä 1998). Linder (1995) also recommended that the carbohydrate concentration must be determined in order to permit normalisation of the values if nutrient concentrations are assessed on samples taken during the period late spring to early autumn. Nutrient imbalances can, however, be detected without correcting for carbohydrate reserves, by calculating the ratio between elements.

Aluminium and iron

Aluminium is a non-essential element for living organisms, but is a critical geochemical component of most natural ecosystems, including forests. It has been hypothesised that one of the major ecological consequences of atmospheric sulphur and nitrogen deposition is the increased mobilisation and transport of aluminium in forest soils (Ulrich et al. 1980). Because of the potential toxicity of aluminium, it was proposed that aluminium could be a critical link between atmospheric pollution and the condition of forests exposed to acidic deposition. However, only a few studies have been carried out on foliar aluminium concentrations. The concentrations of aluminium, manganese and calcium in tree foliage appear to be closely linked, and have been treated together. Kazda and Zvacek (1989) examined the foliar aluminium, manganese and calcium concentrations in Norway spruce and found no relationships between either the calcium or aluminium concentrations of the needles and molar Ca/Al ratios in the soil. With regard to the indirect effects of aluminium, a decreased uptake of calcium, magnesium and potassium by plant roots has been observed as a result of ionic competition between these cations at the root surface. Thus, aluminium may induce nutrient imbalances in leaves and needles (Janhunen et al. 1995). However, it should be remembered that the most of the aluminium concentrations mentioned in the investigations are too low because the analysis has been done without HF digestion. In contrast to geochemical studies, where HF digestion has been widely used for many decades, plant analysts still avoid the use of HF (Bartels' personal communication).

Iron makes up about 5% by weight of the earth's crust and is invariably present in all soils. Iron deficiency may be a problem in calcareous soils, and it may also occur in degraded sandy soils, but this is not common. Lime-induced chlorosis is not caused by absolute iron deficiency. Foliar iron analysis is, however, problematic because needles and leaves are, in many cases, often affected by external contamination from dust. It is not generally certain to what extent are the measured iron concentrations attributable to the endogenous part of the sample. Wyttenbach et al. (1993) pointed out that these difficulties have been known for the past 50 years, but the scientific community seems to be very slow in recognising them. Iron interacts with many other elements, e.g. phosphorus, copper, zinc and heavy metals. These interactions should be taken into account in interpreting the results of chemical needle analyses. However, rather few investigations have involved the monitoring of the iron status of trees.

Sodium

Sodium deposition is closely related to that of chloride. Sodium toxicity does not seem to be as widespread as chloride toxicity, although sodium may displace other cations (Lazof and Bernstein 1999). Salt (NaCl) damage mainly occur in tidewater zones, in saline agricultural soils, either naturally or after incorrect irrigation, or as a consequence of the use of de-icing salt along roadsides. Salt damage, caused by the application of de-icing salt in winter, is especially prominent in trees growing in urban areas or along roads. Excessive needle loss and high foliar sodium concentrations have been reported from some Atlantic areas, which have experienced an extraordinary high sea salt deposition in combination with storms in the late 80's and first half of the 90's.

The inter-laboratory tests organised by ICP Forests have shown that foliar sodium analysis is rather problematic, and the results of the chemical analyses are therefore not comparable. The very poor results for sodium may be due to contamination in the laboratory and equipment, i.e. through dishwashers or the use of sodium-containing glass (Bartels 1998).

Boron and manganese

Boron deficiency of forest trees occurs in many countries, notably in exotic tree plantations, but also in natural stands of native species on soils where the nutrient status has been altered by macro-nutrient fertilisation, fire or erosion. In Scandinavia and Finland, boron deficiencies are rather well known especially in peatland forests as a result of draining and macro-nutrient fertilisation (Braekke 1993, Kolari 1979, Raitio 1979). However, low boron availability on mineral soils is not as widely recognized as it is on peatlands, although needle concentrations have been found to fall below the deficiency limit as a result of nitrogen fertilisation (Mälkönen et al. 1990) and liming (Lehto and Mälkönen 1994) on mineral soils. On sites with a naturally low boron availability, only a small change in the nutrient balance is needed to cause deficiency symptoms, and nitrogen deposition is currently causing such changes. All factors bringing about an increase in growth could cause boron deficiency due to the dilution effect. Boron deficiency is thought to make trees more susceptible to frost damage (e.g. Wikner 1985). Recently Merilä et al. (1998) observed a strong positive correlation between the foliar boron concentrations of Norway spruce and defoliation. They assumed that the increased boron concentration in trees with a reduced needle mass is due to the accumulation of boron in the remaining needles of a defoliated crown as a consequence of xylem water flow. Boron toxicity in forest trees is uncommon but can arise from a variety of causes.

Gärtner (1985) and Zvacek (1988) reported strong correlation between soil and foliar manganese. Gärtner (1985) observed that manganese concentrations were consistently negatively correlated with the degree of defoliation. Raitio (1983) observed that a high foliar manganese concentration is a good indicator of the soil water balance under certain conditions. A fall in the manganese concentration in needles due to the impact of air pollutants is also quite common (Hutchinson and Whitby 1974, Kreutzer et al. 1983, Raitio 1992).

Foliar/leaf analysis is an optimal, very sensitive method for assessing the boron and manganese status of trees because the majority of these nutrients are located in the needles or leaves (Raitio 1993).

Copper and zinc

Copper deficiency is of particular concern for forest growers because of the loss of merchantable wood caused by a deformed stem. Copper deficiency in conifers is associated with decreased lignification (Turvey and Grant 1990). Many researchers have also reported an interaction between copper and nitrogen. The inducement of copper deficiency by nitrogen excess in the soil is well established (Hill and Lambert 1981, Robson and Pitman 1983). Recently Merilä et al. (1998) reported that the needle copper concentrations were negatively correlated with crown defoliation and discoloration of Norway spruces in Western Finland. In this case the needle Cu concentrations were also clearly positively correlated to the needle nitrogen concentrations. The low Cu concentrations in needles might thus be partly due to the poor nitrogen supply of the stands.

Problems with excess copper can arise from a variety of causes. The copper smelting and refining industries, the manufacture of copper products and sewage disposal processes all contribute to the man-made input of copper into the biosphere. Excess copper availability in soils reduces the uptake of calcium and iron, possibly inducing deficiencies in these elements (Lepp 1981).

Zinc sufficiency is particularly important for forestry owing to its vital role in ensuring the regeneration of trees and other plants. The availability of zinc in the forest environment has, with few exceptions, not been considered to be of much importance in forest nutrition and management. Anthropogenic sources have been found to exceed, or have the potential to exceed in the short term, natural sources of zinc and to reach toxic levels in forest ecosystems (Boardman and McGuire 1990). Low zinc concentrations, coupled with magnesium deficiencies, have been observed in parts of Central Europe, e.g. in those areas where the so-called “new type“ of forest damage has been observed (e.g. Hüttl 1986).

Lead, cadmium and other heavy metals

The absorption of cadmium by plants has not been extensively studied until recently. All the data regarding cadmium concentrations in plant tissue have accumulated during the past decade. The current widespread interest in the cadmium concentrations of plants arises from investigations revealing the harmful effects of cadmium on human health. Diagnostic procedures based on foliar and soil analyses are useful techniques in assessing the detrimental effects of cadmium on plant growth (e.g. Page et al. 1981).

Plants growing near highways are usually exposed to more lead than other locations (Zimdahl and Hassett 1977). The source of lead is primarily the aerosol particles in the exhaust gases of automobiles in the form of lead halogens (Rolfe and Reinbold 1977). Lead accumulation in areas near to pollution sources probably have little direct effect on plants growing in these areas. This lack of an effect is usually due to the almost irreversible binding of lead to soil particles and extracellular root surfaces. Lead aerosol particles do not enter plants and have no demonstrable physical effect on the foliar surface of plants. Lead can pose little, if any, problems to plants themselves, with the possible exception of areas where soil fertility, and the organic matter and colloid content are very low. The major problem with the lead in plants in ecosystems lies in the food chain (Koeppe 1981).

Many heavy metals are required in small quantities for the normal physiological processes of plants. Heavy metal contamination is one of the most serious environmental problems at many industrial sites (Reddy and Prasad 1990). Most of the effects of heavy metals appear to occur through interactions in the rhizosphere. Relatively few studies have looked at foliar heavy metals in trees, probably because trees can normally exclude or isolate excess quantities. Most of the investigations dealing with foliar analysis have been made in the surroundings of metal smelters (e.g. Hutchinson and Whitby 1974, Kukkola 1999).

4.5.6 Analysis

Composite samples

Composite samples are used for conventional foliar analysis, the variation between individual trees not necessarily being taken into account. However, the variation between indiduals represents a useful additional indicator. For exsample, when a forest stand is damaged, the disturbances become visible step by step, indicating that the variation between trees is increasing. In some cases only the variation between individuals may change, without having any effects on the mean value.

Several different methods of combining individual sub-samples to produce a composite sample have been utilised in forestry. The methods differ in the weights of individual sub-samples that are combined. For instance, if a handful of needles is collected from each of a number of trees and combined afterwards the weight of the individual sub-sample is unknown. Alternatively, equal weights or equal numbers of needles or leaves from each tree may be combined. Sub-samples may also be combined in proportion to some measure of tree size, such as basal area or height or diameter at breast height. Composite samples based on equal dry mass of needles are generally the most appropriate method (Snowdon and Waring 1984), as is recommended in the foliar submanual (if the samples are analysed individually, the mean value is calculated for each element).

It could be reccommended that the composite samples are analysed on Level I plots and on tree-wise samples on Level II plots. Many countries follow already this procedure.

Frequency and date

Foliar analysis is optional on Level I plots. If a country decides to perform such analyses, it is recommended that sampling and analysis are made every five years at least.

The first Level I foliar survey (1994/95) organised by ICP Forests I covered only part of Europe, because only a few European countries were able to participate in the survey. An additional problem was that the samples were collected in different countries in different years. The data base on tree nutrition at European level is therefore incomplete and needs to be amended. The foliar survey covering all the European regions should be implemented at the same time as the soil chemical survey using the same Level I plots. It is therefore to be recommended that countries willing to carry out the foliar survey should sample and analyse foliar composite samples according to the foliar submanual every ten years together with the soil survey.

Foliar analysis is mandatory at Level II. Sampling and analysis must be carried out every two years at the least. The sampling and analyses of leaves and needles could be implemented every five years on Level II plots for financial reasons. If the survey interval at Level II were to be changed, the foliar survey carried out on Level I and II plots should be synchronized such that both surveys are carried out simultaneously every ten years.

Preparation of sampling material

Traditionally, chemical foliar analyses have been made on dried and ground needle or leaf material using either dry or wet digestion . Nowadays, methods based on the direct analysis of ground plant material are more common. The usual practice is to analyse unwashed material. According to the literature review by Raitio (1995b), it is recommended that the foliage samples be washed for a short time in distilled water or chloroform in order to distinguish between superficially adsorbed and biomass-incorporated, i.e. physiologically active, elements. Washing is necessary for the chemical analysis of Al, Fe, Pb and other heavy metals, but for most of the major elements, e.g. N, P, K, Ca, Mg and S, and the micronutrients B, Mn and Zn, no significant change in the concentrations has been observed after washing (Raitio 1995b).

Washing the needles or leaves with distilled water removes only part of the surface deposition. In contrast, washing the samples with chloroform almost complete removes surface deposition.

Chemical composition

The data on foliar chemical composition are traditionally reported in concentration units. However, new analysis methods have been developed for the field of air pollution research. For example, the inorganic and organic sulphur fractions are determined as well as the total sulphur concentration (Gasch et al. 1988).
Chemical composition may be expressed as concentration or absolute content. The difference is obvious. However, these two terms have often been used synonymously and at times erroneously. Concentration is the amount of a particular element present in a specific unit amount of plant material (e.g. mg/kg), whereas content is the amount of nutrient in a specific amount of plant material (e.g. mg/needle). Hence concentration is an intensive property independent of size, while content is an extensive property that is size dependent. Thus, whole needles of different dry mass may be found to have the same element concentration, although they contain different amounts of the element. A close relationship may exist between the two terms, but they should not be used interchangeably.

Concentration in plant material is commonly expressed in proportional units of tissue dry mass (in per cent or grams per kilogram); the nutrient content of a component is the product of its concentration and total dry weight, and is expressed in any unit of mass relevant to the component (mg per needle). The amount or content of a specific nutrient found in a plant is a useful measure with regard to its uptake or accumulation in the plant.

Since needle or leave analysis is extremely work-intensive to perform, the usual practice has been to confine such analyses to the nutrient contents of 1000 or 100 needles or leaves. The current practice with regard to the interpretation of analysis results is, however, based solely on nutrient concentrations which are compared to critical limit values or to the nutrient ratios. This practice has also been used in the first ICP Forests foliar survey.

Sensitivity

The sensitivity of foliar analysis with respect to the nutrient status of the trees varies according to the particular element studied. Foliar analysis is an optimal method for estimating the boron and manganese status of trees because the majority of the boron and manganese is located in the needles and leaves. Foliar analysis is not adequate method for assessing the iron, copper and aluminium status of trees because these elements are primarily located in the roots.

Interpretation

The interpretation of the results of chemical foliar analysis generally relies on threshold values of the element concentrations. Deficiency and toxic levels have to be determined for each species and all elements. These values are frequently based on pot or field fertilisation trials in which regression techniques are used to identify threshold values by relating growth response to the range of nutrient concentrations in the plant tissue encountered in the trial (e.g. Miller et al. 1981). The diagnostic reliability of the critical nutrient levels has also been questioned by some researchers. A critical limit value holds true only for the conditions of its determination, extrapolation to different conditions therefore requiring validation and probably recalibration and adjustment. The foliar element concentrations of the first foliar survey of ICP Forests have therefore been classified into three classes only. These classes only approximately describe the deficiency, optimal or excess values of element concentrations.

The concept of nutrient balance is based on the knowledge that plant growth depends on proper amounts and proportions of nutrients (Shear et al. 1948). Nutrient balance can be assessed in terms of the ratios of nutrient concentrations. Ratios are less affected by growth dilution and other factors than the nutrient concentrations (Timmer 1991).

Timmer (1991) has reviewed the comparison of different diagnostic methods: concentrations, nutrient ratios, the DRIS (Diagnosis and Recommendation Integrated System) technique and vector analysis.

4.5.7 Resources required

The total costs of the foliar survey consists of the costs of sampling, transport, storage, pre-treatment, analyses and the evaluation of the results. The total costs of the foliar analysis vary in different countries (10 – 970 Euro/sample; average value 300 Euro/sample; n = 14 countries). The sampling and pre-treatment costs account for the main part of the total costs (50 - 70 % of the total costs).

4.5.8 Quality controlHigh-quality chemical analysis in all the participating countries is indispensable for the European-wide survey of the nutrition state of the forests. Needle/leaf inter-laboratory tests have been organised in order to control the quality of the results and to develop the chemical analyses. The first European needle/leaf inter-laboratory test on two certified standards (BCR 100/beech leaves and BCR 101/spruce needles) with 24 laboratories from 21 countries was organized by France in 1993 (Bartels 1996). The second and third inter-laboratory tests were organised by Germany in 1995/96 with 39 laboratories from 25 countries, and in 1997/98 with 51 laboratories from 29 countries (Bartels 1996, 1998). In the third needle/leaf inter-laboratory test (1997/98), the results for some elements (S, Na, Cu, Pb, B and Cd) were better, while other elements such as (P, Ca, Mg, P and Mn) worse, than the results of the second inter-laboratory test (Bartels 1998).

The fourth inter-laboratory test is currently been conducted in tandem with the Level II foliar survey (1999/2000). Many of the changes in the analytical section of the foliar submanual, as well as improvements in the quality control procedures employed in the chemical analyses, are based on the results of these three inter-laboratory tests.

A large number of factors affect the concentration of elements in needles and leaves. These factors need to be taken into account in sampling especially. Samples should be collected from every tree and from every plot according to the same procedure. The largest errors in the foliar survey often occur during sampling. Quality control should therefore also be taken into account in sampling, and not only in the chemical analyses.

4.5.8 References

Bartels, U. 1996. ICP-Forests. 2nd Needle/leaf Interlaboratory Test 1995/96. 2nd report. Evaluation based on robust statistics. LUA Landesumweltamt Nordrhein Westfalen, Dezernat 333. 2 p + Annex.

Bartels, U. 1998. ICP-Forests. 3rd Needle/leaf Interlaboratory Test 1997/98.Convention on long-range transboundary air pollution international co-operative programme on assessment and monitoring of air pollution effects on forests and European Union Scheme on the protection of forests against atmospheric pollution. 81 p + appendex.

Bergmann, W. 1988. Ernährungsstörungen bei Kulturpflanzen. 2nd ed. Gustav Fischer Verlag, Stuttgart, Jena, New York. 762 p.

Boardman, R. & McGuire, D.O. 1990. The role of zinc in forestry. I. Zinc in forest environments, ecosystems and tree nutrition. Forest Ecology and Management 37:167-205.

Braekke, F. 1983. Occurrence of growth disturbance problems in Norwegian and Swedish forestry. Commun. Inst. For. Fenn. 166:20-24.

Bytnerowicz, A., Dmuchowski, W. & Molski, B. 1981/1982. Effects of needle harvest time, age of needles and age of Scots pine (Pinus silvestris L.) trees o the accumulation of total sulphur. Rocznik Dendrologiczny 34:51-68.

Dambrine, E., Bonneau, M., Ranger, J., Mohammed, A.D., Nys, C. & Gras, F. 1995. Cycling and budgets of acidity and nutrients in Norway spruce stands in Northeastern France and the Erzgebirge (Chech Republic). In: Landmann, G. & Bonneau, M. (Eds.). Forest decline and atmospheric deposition effects in the French Mountains. Spriger-Verlag, Berlin. Pp. 233-258.

Dmuchowski, W., Bytnerowicz, A. & Molski, B. 1981/1982. The influence of boreal sites on the accumulation of total sulphur in Scots pine (Pinus silvestris L.) needles. Rocznik Dendrologiczny 34:69-77.

Ende, H.-P. & Evers, F.H. 1997. Magnesium deficiency. Symptoms and development. In: Hüttl, R.F. & Schaaf, W. (Eds.). Magnesium deficiency in forest ecosystems. Kluwer Academic Publishers, Dordrecht, Boston, London. pp.3-22.

Evers, F.H. 1972. Die jahrweisen Fluktuationen der Nährelementkonzentrationen in Fichtennadeln und ihre Bedeutung für die Interpretation nadelanalytischer Befunde. Allg. Forst-Jagdzg. 143:68-74.

Ferm, A. & Markkola, A.-M. 1985. Hieskoivun lehtien, oksien ja silmujen ravinnepitoisuuksien kasvukautinen vaihtelu. Summary: Nutritional variation of leaves, twigs and buds in Betula pubescens stands during the growing sason. Folia Forestalia 613:1-28.

Ferm, A., Hytönen, J., Lähdesmäki, P., Pietiläinen, P. & Pätilä, A. 1990. Effects of high nitrogen deposition on forests:case studies close to fur animal farms. In: Kauppi, P., Anttila, P. & Kenttämies, K. (Eds.). Acidification in Finland. Springer-Verlag, Berlin. pp. 635-668.

Gasch, G., Grünhage, L., Jäger, H.-J. & Wentzel, K.-F. 1988. Das Verhältnis der Schwefelfraktionen in Fichtennadeln as Indikator für Immissionsbelastungen durch Schwefeldioxid. Angew. Botanik 62:73-84.

Gärtner, E. 1985. Mangangehalte in Altfichten, Boden und Kronendurchclass an jeweils gleichen Standorten. In: Stratmann, H. (Ed.). Waldschäden. Einflussfaktoren und ihre Bewertung. Kolloquium Goslar, 18. Bis 20 Juni 1985. VDI-Bericht 560:559-573.

Heinsdorf, D., Krauss, H.H. & Hippeli, P. 1988. Ernährungs- und bodenkundliche Untersuchungen in Fichtenbeständen des mittleren Thüringer Waldes unter Berücksichtigung der in den letzten Jahren aufgetretenen Umweltbelastungen. Beiträge für die Forstwirtschaft 22:160-167.

Hill, J. & Lambert, M.J. 1981. Physiology and managemen of micronutrients in forest trees in Australia. In: Turvey, N.D. (Ed.).Proceeings of Australian Forest Nutrition Workshop, Productivity in Perpetuity, Canberra, 10-14 August 1981. CSIRO, Melbourne, pp. 93-104.

Hoffmann, G., Hemsdorf, D. and Krauss, H.H. 1990. Wirkung atmogener Stickstoffeinträge auf Produktivität und Stabilität von Kiefern-Forstökosystemen. Beiträge für die Forstwirtschaft 24:59-73.

Hunger, W. 1972. Zum Ernährungszustand älterer Fichtenbestände im Klimagefälle des Sächsichen Hüdellandes. Flora 161:472-494.

Hutchinson, T.C. & Whitby, L.M. 1974. Heavy-metal pollution in the Sudbury mining and smelting region of Canada. I. Soil and vegetation contamination by nickel, copper and other metals. Environ. Cons. 1:123-132.

Hüttl, R.F. 1986. Neuartige Waldschäden und Ernährungszustand von Fichtenbeständen (Picea abies Karst.) in Südwestdeutschland. Freiburger Bodenkundliche Abhandlungen 16:1-195.

Höhne, H. 1963. Blattanalytische Untersuchungen an jüngeren Fichtenbeständen. Arch. f. Forstwesen 12:341-360.

Ingestad, T. 1987. New concets on soil fertility and plant nutrition as illustrated by research on forest trees and stands. Geoderma 40:237-252.

Innes, J.L. & Boswell, R.C. 1989. Sulphur contents of conifer nedles in Great Britain. GeoJournal 19:63-66.

Isermann, K. 1990. Ammoniakemissionen der Landwirtschaft als Bestandteil ihrer Stickstoffbilanz und hinreichende Lösungsansätze zur Minderung. Gemeinsames KTBL/VDI-Symposium:Ammoniak in der Umwelt – Kreisläufe, Wirkung, Minderung – 10.-12.10.90 in Braunschweig.Kuratorium für Technik und Bauwesen in der Landwirtschaft e.v. Darmstadt. Verein Deutscher Ingenieure (VDI), Düsseldorf, Landwirtschats-verlag, Münster-Hiltrup.

Janhunen, S., Palomäki, V. & Holopainen, T. 1995. Aluminium causes nutrient imbalance and structural changes in the needles of Scots pine without inducing clear root injuries. Trees 9:134-142.

Johnson, D.W., Cresser, M.S., Nilsson, S.I., Turner, J., Ulrich, B., Binkley, D. & Cole, D.W. 1991. Soil changes in forest ecosystems: evidence for and probable causes. Proc. R. Sco. Edinburgh. 97B:81-116.

Kaunisto, S.1997. Peatland forestry in Finland: problems and possibilities from the nutritional point of view. In: Trettin, C.C., Jurgensen, M.F., Grigal, D.F., Gala, M.R. & Jeglum, J.K. (Eds.). Northern Forested Wetlands. Ecology and management CRC Press, Boca Raton, Florida. pp. 387-401.

Kaupenjohann, M., Zech, W., Hantschel, R., Horn, R. & Schneider, B.U. 1989. Mineral nutrition of forest trees: A regional survey. In: Schulze, E.-D., Lange, O.L. & Oren, R. (Eds.). Forest decline and air pollution. A study of spruce (Picea abies) on acid soils. Ecol. Stud. 77:280-296.

Kazda, M. & Zvacek, L. 1989. Aluminium and manganese and their relation to calcium in soil solution and needles in three Norway spruce (Picea abies L. Karst.) stands of Upper Austria. Plant and Soil 114:257-267.

Koeppe, D.E. 1981. Lead:Understanding the minimal toxicity of lead in plants. In: Lepp, N.W. (Ed.). Effects of heavy metal pollution on plants. Effects of trace metals on plant nutrition. Applied Science Publishers. London, New Jersey. Pollution Monitoring Series Vol. 1:55-75.

Kolari, K.K. 1979. Hivenravinteiden puute metsäpuilla ja männyn kasvuhäiriöilmiö Suomessa. Kirjallisuuskatsaus. Summary: Micro.nutrient deficiency in forest trees and dieback of Scots pine in Finland. A review. Folia Forestalia 389:1-37.

Kreutzer, K. & Heil, K. 1989. Untersuchungen zum Stoffhaushalt in einem Fichtenbestand (Picea abies Karst.) der Hochlagen des Bayerischen Waldes. 1. Statusseminar PBWU Forschungsschwepunkt „Waldschaden". GSF-Bericht 6789:51-60.

Kreutzer, K., Knorr, A., Brosinger, F. & Kretzschmar, P. 1983. Scots pine – dying within the neighbourhood of an industrial area. In: Ulrich, B. & Pankrath, J. (Eds.). Effects of accumulation of air pollutants in forest ecosystems. D. Riedel, Dordrecht. Pp. 343-357.

Kukkola, E. 1999. Effects of copper and nickel on subarctic Scots pine needles. Acta Universitatis Ouluensis, Scientiae Rerum Naturalium A 336. 46 p. + Appendexes.

Landmann, G., Hunter, I. & Hendershot, W. 1997. Temporal and spatial development of magnesium deficiency in forest stands in Europe, North America and New Zealand. In: Hüttl, R.F. & Schaaf, W. (Eds.). 1997. Magnesium deficiency in forest ecosystems. Kluver Academic Publisher, Dordrecht, Boston, London. Nutrients in Ecosystems Vol 1:23-64.

Landolt, W., Guecheva, M. & Bucher, J.B. 1989. The spatial distribution of different elements in and on the foliage of Norway spruce growing in Switzerland. Environmental Pollution 56:155-167.

Lazof, D.B. & Bernstein, N. 1999. The NaCl induced inhibition of shoot growth: The case for disturbed nutrition with special concideration of calcium. Advanc. Bot. Res. 29:113-189.

Lehto, T. & Mälkönen, E. 1994. Effects of liming and boron fertilization on boron uptake of Picea abies. Plant and Soil 163:55-64.

Lepp, N.W. 1981. Copper. In: Lepp, N.W. (Ed.). Effects of heavy metal pollution on plants. Effects of trace metals on plant nutrition. Applied Science Publishers. London, New Jersey. Pollution Monitoring Series Vol. 1:111-143.

Linder, S. 1995. Foliar analysis for detecting and correcting nutrient imbalances in Norway spruce. Ecological Bulletins 44:178-190.

Liu, J.-C. & Hütl, R.F. 1991. Relations between damage symptoms and nutritional status of Norway spruce stands (Picea abies Karst.) in southwestern Germany. Fertilizer Research 27:9-22.

Malcolm, D.C. & Garforth, M.F. 1977. The sulphur:nitrogen ratio of conifer foliage in relation to atmospheric pollution with sulphur dioxide. Plant and Soil 47:89-102.

Mankovská, B. 1988. The accumulation of atmospheric pollutants by Picea abies Karst. Ekológia (CSSR) 7:95-108.

Manninen, S. 1995. Assessing the critical level of SO2 for Scots pine (Pinus sylvestris L.) in northern Europe on the basis of needle sulphur fractions, sulphur/nitrogen ratios and needle damage. Acta Universitatis Ouluensis, Scientiae Rerum Naruralium A273.47 p + Annexes.

Marschner, H. 1995. Mineral nutrition of higher plants. 2nd ed. Academic Press, London.889 p.

Materna, J. 1982. Concentration of sulphur dioxide in the air and sulphur content in Norway spruce seedlings (Picea abies Karst.). Communicationes Institutale Forestalis Cechosloveniae 12:137-146.

Mengel, K. 1984. Ernährung und Stoffwechsel der Pflanze. 6th ed., Gustav Fischer Verlag, Stuttgart. 431 p.

Miller, H.G., Miller, J.D. & Cooper, J.M. 1981. Optimum foliar nitrogen concentration in pine and its change with stand age. Can. J. For. Res. 11.3:563-572.

Merilä, P., Lindgren, M., Raitio, H. & Salemaa, M. 1998. Relationships between crown condition, tree nutrition and soil properties in the coastal Picea abies Forests (Western Finland). Scan. J. For. Res. 13:413-420.

Morrison, I.K. 1985. Effect of crown position on foliar concentrations of 11 element in Acer saccharum and Betula alleghaniensis trees on a till soil. Can. J. For. Res. 15:179-183.

Mälkönen, E., Derome, J. & Kukkola, M. 1990. Effects of nitrogen inputs on forest ecosystems. Estimation based on long-term fertilization experiment. In: Kauppi, P., Anttila, P. & Kenttämies, K. (Eds.). Acidification in Finland. Springer-Verlag, Berlin. pp. 325-347.

Page, A.L., Bingham, F.T. & Chang, A.C. 1981. Cadmium. In: Lepp, N.W. (Ed.). Effects of heavy metal pollution on plants. Effects of trace metals on plant nutrition. Applied Science Publishers. London, New Jersey. Pollution Monitoring Series Vol. 1:77-109.

Raitio, H. 1979. Boorin puutteesta aiheutuva männyn kasvuhäiriö metsitetyllä suopelolla. Oireiden kuvaus ja tulkinta. Summar: Growth disturbancee of Scots pine caused by boron deficiency on an afforested abandoned peatland field. Description and interpretation of symptoms. Folia Forestalia 412:1-16.

Raitio, H. 1983. Growth disturbance of Betula pendula in the Torajärvi experimental area. Communicationes Instituti Forestalis Fenniae 116:104-110.

Raitio, H. 1992. The foliar chemical composition of Scots pines in Finnish Lapland and on the Kola peninsula.Arctic Centre Publications 4:226-231.
Raitio, H. 1993. Calcium and magnesium deficiency in young pines and stand structure on affected habitats. In: Huettl, R.F. & Mueller-Dombois, D. (Eds.). Forest decline in the Atlantic and Pacifi regions. Springer-VerlagBerlin, Heidelberg, New York. Pp.132-143.
Raitio, H. 1995a. Chemical needle analysis as a diagnostic and monitoring method. In: Nilsson, L.O., Hüttl, R.F., Johansson, U.T. & Mathy, P. (Eds.). Nutrient uptake and cycling in forest ecosystems. Proceedings of a symposium held in Halmstad, Sweden, 7-10 June 1993. EC Ecosystem Res. Rep. No 21:197-206.
Raitio, H. 1995b. Influence of sample washing on the foliar chemical composition. A review. 3rd Meeting of the Forest Foliar Expert Panel. International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests – ICP Forests, 6-8, November 1995 Vienna. 8 p.
Raitio, H. 1999. Needle chemistry. In: Raitio, H. & Kilponen, T. (Eds.). Forest condition monitoring in Finland. National report 1998. The Finnish Forest Research Institute, Research Papers 743:51-69.
Raitio, H. & Merilä, P. 1998. Seasonal variation in the size and chemical composition of Scots pine and Norway spruce needles in different weather conditions. Pilot project No 96.60.SF.003.0, Technical report. 44 p.
Raitio, H., Tuovinen, J.-P. & Anttila, P. 1995. Relation between sulphur concentrations in the Scots pine needles and the air in northernmost Europe.Water, Air and Soil Pollution 85:1361-1366.
Reddy, G.N. & Prasad, M.N.V. 1990. Heavy metal-binding proteins/peptides:Occurrence, structure, synthesis and functions. A rieview. Environ. Exp. Bot. 30:251-264.
Reemtsma, J.B. 1966. Untersuchungen über den Nährstoffgehalt der Nadeln verschiedenen Alters an Fichte und Nadelbaumarten. Flora 156:105-121.
Robson, A.D. & Pitman, M.G. 1983. Interactions between nutrients in higher plants. Inorganic plant nutrition. Encyclopedia of Plant Physiology 15A:147-180.
Rolfe, G.L. & Reinbold, K.A. 1977. Environmental contamination by lead and other heavy metals. Inst. Environ. Studies, Urbana, Illinois. 143 p.
Rzeznik, Z. & Nebe, W. 1987. Wachstum und Ernährung von Buchen-Provenienzen. Beitr. Forstwirtsch. 21:106-111.
Shear, C.B., Crane, H.L. & Myers, AT. 1948. Nutrient-element balance:application of the concept to the interpretation of foliar analysis. Am. Soc. Hort. Sci. 51:1-319.
Shkolnik, M.Y. 1984. Trace elements in plants. Elsevier, Amsterdam, New York. 463 p.
Snowdon, P & Waring, H.D. 1984. Composite samples for foliar analysis. Aust. For. Res. 14:235-242.
Spiecker, H., Mielikäinen, K., Köhl, M. & Skovsgaard, J.P. (Eds.). 1996. Growth trends in European forests.Springer Verlag. Berlin, Heidelberg.European Forest Institute Research Report No. 5. 372 p.
Strebel, O. 1960. Mineralstoffernährung und Wuchsleistung von Fichtenbeständen (Picea abies) in Bayern. Forstwiss. Cbl. 79:17-42.
Tamm, C.O. 1956. Studier över skogens näringsförhållanden IV. Medd. Stat. Skogsforskningsinst. 46:1-27.
Tamm, C.O. 1991. Nitrogen in terrestrial ecosystems. Ecological Studies 81. Springer-Verlag.
Timmer, V.R. 1991. Interpretation on seedling analysis and visual symptoms. In: van den Driessche, R. (Ed.). Mineral nutrition of conifer seedlings. CRC Press, Boca raton Ann Arbor Boston. Pp. 113-134.

Turvey, N.D. & Grant, B.R. 1990. Copper deficiency in coniferous trees. Forest Ecology and Management 37:95-122.

Ulrich, B. 1989. Effects of acidic precipitation on forest ecosystems in Europe. In: Adriano, D.C. & Johnson, A.H. (Eds.). Acidic precipitation. Vol 2: Biological and Ecological Effects. Spriger Verlag, New York. Pp. 189-272.

Ulrich, B., Mayer, R. & Khanna, P.K. 1980. Chemical changes due to acid precipitation in a loess-derived soil in central Europe. Soil Science 130:193-199.

Ulrich, B. & Sumner, M.E. (Eds.). 1991. Soil acidity. Springer Verlag, Berlin.

Zimdahl, R.L. & Hassett, J.J. 1977. Lead in soil. In: Boggess, W.R. (Ed.). Lead in the environment. National Science Foundation, Washington, D.C. pp.93-98.

Zech, W. & Popp, E. 1983. Magnesiummangel, einer der Gründe für das Fichten- und Tannensterben in NO-Bayern. Forstwiss. Centralbl. 102:50-55.

Zvacek, L. 1988. Mikronährstoffe und toxische Metalle an Waldstandorten. Dissertation, Universität Wien, Austria. 237 p.

Zöttl, H.W. 1985. Waldsterben und Nährelementversorgung. Düsseldorfer Geobotanisches Kolloquium 2:31-41.

Van Praag, H.J. & Weissen, F. 1986. Foliar mineral composition, fertilization and dieback of Norway spruce in the Belgian Ardennes. Tree Physiol. 1:169-176.

Wells, C.G. 1969. Foliage sampling guides for loblolly pine. USDA For. Serv. Res. Note SE-113.

Wikner, B. 1985. The biogeochemistry of boron and its role in forest ecosystems. In: Caldwell, D.E., Brierley, J.A. & Brierley, C.L. (Eds.). Planetary ecology. Van Nostrand Company, New York. Pp. 522-536.

Will, G.M. 1985. Nutrient deficiencies and fertilizer use in New Zealand exotic forests. FRI Bulletin 97:1-54.

Wyttenbach, A., Bajo, S & Tobler, L. 1993. Spruce needles:standards and real samples. Fresenius J. Anal. Chem. 345:294-297.

4.6 Forest Growth

4.6.1 Summary

Tree sizes were first measured on Level II plots in the winter 1994/1995. With the remeasurement currently undertaken (1999/2000), the first five-year tree growth data for diameter and basal area will be available shortly. From the review conducted, the following conclusions can be drawn:

- Forest growth data and knowledge on forest structure are prerequisites for the analysis of many other parameters assessed on Level II plots.
- Forest measurements are relatively inexpensive and in the case of diameter or circumference measurements also very precise. In the next 5 – 10 years (i.e. following the next two sampling periods) the analysis should thus be focused on basal area increment or diameter increment, which will provide valuable information on stress responses.
- As height changes are less influenced by stand density and management activities, analysis of height growth (i.e. site index change) will become even more important. However, only within 10 to 20-year intervals height growth can be estimated with a sufficiently high precision and only after 20 years of observation significant changes in height growth may be detected.
- As it is more difficult to reach the required accuracy within height measurements than for diameter measurements, it is recommended to measure tree height and height to crown base on as many trees as possible (ideally all trees of the Level II plots or a subplot with a sufficient number of trees).
- Forest growth is influenced by internal factors (stand age, density and inter-tree competition) and external factors (weather conditions, available nutrients and water). In order to eliminate internal factors growth models need to be applied.
- For the evaluation of annual growth changes permanent girth bands can be used on a subset of trees.
- The selection of useful growth models needs further evaluation and should be a priority of the Expert Panel on Forest Growth in the future. This requires a close co-operation with the other Expert Panels as many of these models depend or require various stand and site variables.
- The data on forest growth will gain increased value in case that the objectives of ICP Forests are widened towards fields such as biodiversity, criteria and indicators for sustainable forest management or climatic change.

Table 4.6.1.-1: Key parameters[1)] of the forest growth survey (Level II)

Parameter	Current state	Proposal
tree stem diameter	M	M
tree height	O	**M**
height to crown base	O	**M**
crown width	O	O

1) Abbreviations, codes : M = mandatory parameter, O = optional parameter, **blue** = excluded from survey, **red** = new optional or new mandatory parameter, **green** = change from optional to mandatory or from mandatory to optional

4.6.2 Introduction

Recently, a controversy about whether forest growth should be used as an indicator of forest decline or forest vitality has been sparked among scientists and among foresters following the report of widespread growth increases (Spiecker et al., 1996). With the 'Waldsterben debate' the usage of tree growth (usually radial stem growth, less frequently height growth) as an indicator of tree or forest vitality had become a standard procedure. Beginning with the observation of silver fir (Abies alba) decline in the late 1970s in Germany, growth comparison between trees judged as 'healthy' or 'damaged' were made (Kenk, 1983; Kiennen and Schuck, 1983; Kenk et al., 1985; Gerecke, 1986; Schöpfer and Hradetzky, 1986). Usually tree crown defoliation was used as indicator of 'damage'. In many cases growth reductions of the 'damaged trees' in comparison with the 'undamaged trees' were found to have occurred as far as several decades ago. Similar growth decreases were soon confirmed for other species (Athari, 1983; Dong, 1985; Pretzsch, 1985; Eichkorn, 1986; Dong and Kramer, 1987; Lorenz and Eckstein, 1988; Standovár and Somogyi, 1998). As the national survey of many countries indicated still increasing crown defoliation, the attempt to quantify growth loss was evident. However, the scenarios of a general decline in forest growth have not materialized. On the contrary, since the early 1990s several reports of higher growth of forest stands in comparison with previously derived yield tables were published (Pretzsch, 1992a; Spelsberg et al., 1995; Spiecker et al., 1996; Schöpfer et al., 1997). The report by Spiecker et al. (1996) found growth increases for the Central European countries, while the studies on growth in the Nordic countries were not conclusive. However, neither the possible causes nor the consequences of the findings could be analysed. One emphasis of this review is therefore on whether tree growth measured on Level II plots can help to find possible causes of growth changes.

The view of the importance and the proposed methods for assessment of data on forest growth within ICP Forests has gradually changed. At the beginning a large scale survey of increment was planned on Level I, but at the 5th Task Force Meeting (Tampere, 1989) it was decided to concentrate on the assessment on the permanent observation plots of Level II. During the 1st Expert Panel Meeting (Farnham, 1991) proposed methods of assessment and evaluation were revised in detail, but no agreement could be reached. The measurement of dbh, as the most basic parameter and unavoidable prerequisite, should be carried out on the whole plot on trees above 5 cm, while other measures may be restricted to a sub-sample. The 2nd Expert Panel (Sopron, 1993) intended to contribute to data analysis methods. However, as no striking new methods were presented the chapter on data analysis remained rather short. At the third and fourth Expert Panel Meetings (1997, Birmensdorf; 1999, Igls-Vill) a revised Manual was drafted, specifying measurement and sampling methods in greater detail and making tree height measurements mandatory.

In addition, in 1998 a survey of the participating countries had ranked forest growth on Level II plots as one of the most important parameters to be assessed. In addition, in 1999 the majority of external requests for data from ICP Forests had been for stand and growth data, a clear indication of the importance of forest growth data for the ICP Forests Programme.

4.6.3 Objectives

The primary objective of the monitoring of forest growth in Level II plots is

– to provide an additional assessment of tree and stand condition. These assessments, together with others undertaken at Level II plots, will form the basis for comparisons of particular forest types throughout the ECE-region (ICP Forests Manual, Sub-Manual on Forest Growth).

Tree size and standing volume and their change (i.e. forest growth) are indicators of forest stand condition and of the reaction of a forest stand to various external and internal factors. Therefore, tree size and its changes can be used both as response variables and as explanatory variables in statistical analysis.

Three objectives for tree size measurements can be distinguished.

– to obtain information about the stand structure or single tree properties as explaining variables for other measurements carried out on Level II plots.
– to estimate single tree and stand growth as a response variable of environmental and stress factors
– to provide data for an economically orientated evaluation of effects of various stresses.

4.6.4 Parameters

Currently, the following parameters for tree and stand size and its changes are considered key parameters by the Expert Panel on Forest Growth:

– Measured key parameters are:

tree stem diameter (at least two perpendicular measurements required) or circumference at breast height on all trees above the diameter limit on the plot or sub-plot.

The following parameters may be restricted to a sub-sample:
tree height
height to crown base
crown width

– Calculated key parameters:

tree basal area
tree and stand volume (provided that information on tree taper exists, i.e. form factors or upper diameters are determined)
crown dimensions (overtopped area, surface or volume, provided that information on crown form exists)
stand basal area (provided that the single tree assessment can be related to area)
stand top or dominant height, stand mean height (provided that the sample design is appropriate)
inter-tree competition and several structural measures can be calculated (provided that x, y-co-ordinates for each tree are available)

Changes in tree or stand sizes
periodical current increment (diameter or basal area, tree height, tree volume) for single trees or the stand level (provided that at least two consecutive assessments are carried out)
changes of current increment (diameter or basal area, tree height, tree volume) for single trees or the stand level (provided that at least two estimates of periodical increment are available)

– On felled trees the following parameters can be measured optionally, if annual rings are detectable:

tree-ring width (enabling estimates on retrospective annual increment of diameter and basal area increment)
periodical height increment (most recent growth provided that terminal shoot length can be measured; past growth provided that a stem analysis has been carried out and that a sufficient number of stem discs has been sampled at different tree heights)
volume increment on the basis of the retrospective diameter and height increment measurements.

4.6.5 Methods and Sampling Design

Tree and stand growth have been assessed in Europe for two centuries (Hartig, 1795) and experimental growth and yield plots were established more than a hundred years ago (Ganghofer, 1881). Therefore, a large amount of information on methods and evaluation methods on forest growth is readily available in textbooks (e.g. Prodan, 1965, Kramer and Akca, 1987) or within the institutions in charge of forest inventories or growth research. In the following section only a rough review can be given on measurements and sampling methods.

4.6.5.1 Quality of measurements

All measurements and assessments are prone to error. Errors will reduce the interpretability of the data and therefore need to be minimised. We can distinguish between sampling and measurement errors (Cochran, 1977). Sampling errors arise when only a portion (sample) of the population is assessed. Observation errors arise when measurements or observations deviate from the true value. For forest growth measurements, knowing the accuracy of the measurements is particularly important, because many of the measured variables will be used in combination to compute additional values.
Cochran (1977) defines accuracy as the size of deviations from the true mean. Precision refers to the size of deviations from the mean value obtained by repeated applications of the sampling and assessment procedure. Accuracy estimates can be obtained from the supplier of the instruments as well as from the literature. In addition, it is possible to test the accuracy of instruments and the assessment method in calibration exercises against a true value (known height of an object, for instance). The actual precision of field data collection can be expected to be less than the derived accuracy. The precision of collected data is a function of sampling and measurement errors. Again, estimates of precision can be obtained from the literature.

However, assessment conditions and the quality of the observer may vary substantially. Therefore, it is recommended to measure the actual precision under field conditions with independent control assessments. Therefore, a detailed suggestion of implementing quality control has been added to the revised draft version of the Sub-Manual on Forest Growth.

Stem diameter and circumference

Tree diameter and stem circumference measurements are probably the easiest and most accurate measurements of all tree measurements on Level II plots. Tree diameter at breast height is either measured with a calliper, averaging two perpendicular measurements, or with a diameter band. Both methods are relative precise (Cluzeau et al., 1998; Kaufmann pers.com). However, if diameter is calculated from circumference one assumes that the stem cross-section is a circle and measurements are systematically higher than diameters calculated from two calliper measurements (see also Prodan, 1965; Gregoire et al., 1990). In the Swiss National Inventory measured diameters with a tape were on average 6 mm larger than the measured diameters with a calliper (Kaufmann, pers. com.). Therefore, it is necessary to report the measurement method and it is advised to continue with the same method.

Tree height

The accuracy of tree height measurements depends very much on the method used (Prodan 1965; Kramer and Akca, 1987; Skovsgard et al. 1998; Neumann, 1999). Using Christen and Suunto measurement equipment in the Swiss National Forest Inventory the precision suggested by Kramer and Akca (1987), as well as the quality standard set by Tallent-Halsell (1994) were both not achieved (Kaufmann, 1999). Similar results were obtained by Cluzeau at al. (1998) using various instruments. Hasenauer and Monserud (1997) found in Austria that the height measurement error was so high that the estimation of the growth for a five-year period was questionable (coefficient of determination = 0.14). Using laser height measurements the precision increases, as Skovsgard et al. (1998) achieved measurement errors of +/- 2% of the true height. With tripods theses errors were further reduced to +/- 1%. However, the authors point out that improved precision will not prevent measuring bias. Therefore a quality assuring procedure should be established (see suggestions in the Sub-Manual on Forest Growth).
We can conclude that height measurements should be performed in connection with an accurate measurement of the distance to the tree and if the site condition permits using a tripod. The error of tree height measurement increases with the angle to the tree top. Problematic is the height measurement on trees with flat crowns (i.e. broadleaves and Scots pine (Pinus sylvestris), see results by Cluzeau et al., 1998). However, even with the best methods and under optimal stand condition (i.e. visibility of the tree top) we can only expect the measurement errors to be +/- 1 % of the tree height.

Height to crown base

Measurements of the height to crown base are usually less precise than tree height measures. The reason is that in addition to the measurement error the definition of the crown base is subject to observer interpretation, while tree height is clearly defined (Cluzeau et al., 1998). However, as discussed later, the crown percentage derived from tree height and height to crown base measurements is an important explanatory variable used in most single-tree growth models. For missing measurements Hasenauer and Monserud (1996) have developed a model for Austria to estimate crown ratio and using tree and site variables, with height-diameter ratio being the most important predictor.

Crown width

The outline of the crown can be determined using a perpendicular and measuring the radii as distances from the tree. Four to eight crown radii may be measured, but measurements are very time consuming. An alternative is to measure only two radii, this seems sufficient if only the crown width is of interest and not the shape of the crown projection. Little information on the precision of measuring methods is available. Crown width in connection with crown length is used to relate tree growth to crown size parameters (Dong, 1985, Dong and Kramer, 1987) and in competition indices of individual tree growth models (Wensel et al., 1987; Biging and Dobbertin, 1992, 1995; Pretzsch, 1992b).

4.6.5.2 Methods to calculate tree and stand characteristics and their changes

Tree and stand basal area

Tree basal area is usually computed as a circle with a radius of half the measured tree diameter at breast height. The accuracy of the basal area measurement depends therefore on the precision of the diameter measurements and the eccentricity of the stem. Stand basal area is computed as the sum of the basal area of all trees per unit area. This has been used for at least 200 years as the most important variable to describe a forest stand and its change over time. Basal area is almost always included in yield tables, growth models, and other models describing stand condition and biological relations in stands. However, various definitions for mean stand basal area are available (Prodan, 1965; Kramer and Akca, 1987).

Stand height

Several different measures of stand height exist (Kramer and Akca, 1987; Eckmüllner, 1999). Examples are dominant or top stand height and Lorey's mean height. Eckmüllner (1999) compared the influence of various thinning methods on various calculated top heights. He

suggests using Assmann's definition of top height as the height of the 100 thickest trees as it is least influenced by management activities.
The accuracy of the estimated stand height depends also on the sampling design used to select the measured trees. Zingg (1999) compared various sampling methods to estimate stand top height with the actual top stand height and found in some cases substantial discrepancies between estimated and actual top height and that the standard deviations of the estimated top heights were smaller than the actual values. Therefore, he suggested to measure all tree heights of the thickest trees.

Tree and stand volume

Tree stem volume can be estimated using measured diameter at breast height and tree height and some information on the stem form. The information on the stem form is usually derived from felled trees either in form of taper conversion numbers or taper equations (Kramer and Akca, 1987). It should be noted that following the law of error propagation the measurement errors for diameters and tree height and the uncertainty of the taper equation will reduce the accuracy of the volume estimate (see Kaufmann, 1999). Stand volume can be estimated if the height and the basal area/diameter is measured/estimated. Each country has yield tables or models to estimate stand volume when the diameter and the height are known. It is important to use local tables/models that include local variations of the taper equations and diameter/height relations.
When describing the stand, sometimes stand volume is preferred instead of basal area. However, priority should be to first present stand basal area, then stand height and then stand volume following the accuracy of the estimates. Because many models (growth models, planning models etc.) need both height and diameter/basal area, it is important to measure both parameters. Volume can be derived from these two parameters.

Changes in diameter and basal area

Tree diameter and basal area increment is derived as the difference between two subsequent measurements. On Level II plots five-year periods are used. For slow growing trees the measurement errors may be higher than the actual growth (see previous sections). However, in most cases tree and stand growth can be reliably estimated for five-year periods. For stand growth, it is important to include the ingrowth (the trees that have surpassed the threshold of 5 cm diameter at breast height), tree removal and tree mortality.

Mean values for five-year periods are however too coarse to allow estimating the effects of short-term stresses, such as a late frost, summer drought, insect defoliation, etc. The in-depth evaluation of the growth reactions of trees as influenced by biotic and abiotic factors needs more detailed and accurate information on the current course of growth. The ad hoc Expert Meeting on Phenological Observations on Intensive Monitoring Plots (Level II - Plots) in Punkaharju, Finland, 21 to 23 September 1997, recommended to use girth bands for the permanent recording of diameter increment. This method of assessment would not only be important for growth and yield studies, but also for phenological observations. This technique can provide precise measurements of, for example, the onset and cessation of growth and the response of trees to stress phenomena across a number of species. Continuous measurement using automatic equipment is preferable (Vogel, 1994; Preuhsler, 1995; Naleppa, 1995), but weekly recordings on a fixed day of the week could be used if performed using manually read girth bands (Spelsberg, 1990). At the very least, it is suggested to obtain annual increment from girth bands on a sub-sample of trees.

Changes in tree and stand height

Like diameter, tree height increment is estimated as the difference between two subsequent measurements. For tree height however the measurement error is considerably higher (see above, Hasenauer and Monserud, 1997). In addition, wind or snow breakage of the tree top may make an estimate of tree increment impossible.
The change of stand mean height and the dominant tree height between subsequent periods may not allow to estimate the actual growth as it depends on various other factors. Eckmüllner (1999) showed that the forest management influenced the obtained top height considerably independent of the definition used for top height.
For five-year height growth estimates a height measurement error will sum up to an error of around 20% of the actual growth (Sterba, 1999). For a 20% change in growth between two subsequent periods this would mean an error of 150% of the actual growth change, rendering height growth comparisons between two growth periods nearly impossible. The period to reliably estimate tree height increment will therefore be at least five years, in cases of slow growing mature stands 10 to 20 years or more.

Changes in tree and stand volume

For the calculation of tree and stand volume changes see the sections above. Whether the volume growth and changes in volume growth and can be reliably estimated for five-year periods depends very much on the basal area growth. Although volume growth is the least reliable measure, stand volume growth and stand volume growth changes may be more reliably estimated than top stand height changes, if the basal area growth is high enough.

Directly measured increment on felled trees

On felled trees on the plot and in the surroundings of the plot it is possible to obtain stem discs and to measure ring width on different directions (four or eight radii are usually measured). On standing trees outside of the plot it is possible to take tree cores and to measure ring width. For trees outside the plot no area-related growth can be computed and the growth obtained from felled or fallen trees is certainly not representative of the stand. Therefore, quantitative information on current growth cannot be obtained from these measurements. However, ring-width measurements allow to reconstruct past stand history where forest management plans are missing or not detailed enough (Cherubini et al., 1996, 1998; Lebourgeois, 1997). Ring-width

measurements of dominant and codominant trees are also suitable to obtain climate-growth relationships (Fritts, 1976; Cook and Kairiukstis, 1990; Schweingruber, 1993, 1996).
The determination of annual terminal shoot increment may be possible on felled trees, either by using stem analysis or by measuring internodal length. For some species and in some situations the determination of internodal length is either impossible or at least very time consuming and costly. Otherwise, the same restrictions apply as in the case of ring-width measurements.

4.6.5.3 Sampling design

It is well documented that less precise but non-biased measurements need a larger sample size to achieve the same overall error of the estimate of the mean than more precise methods (Cochran, 1977). For the two mandatory tree size variables at Level II plots this would mean that more height measurements are required to achieve the same relative errors as diameter measurements. However, tree-height measurements are substantially more time consuming. Therefore, height measurements were not made mandatory on all trees in the Sub-Manual on Forest Growth. Instead a minimum sampling design was defined that allows estimating the stand top height and the stand mean height. However, as shown previously height measurements on more trees are necessary. Therefore, it is recommended to measure tree height on all trees.
In addition to tree size estimation, the increment of trees as the difference between two subsequent measurements is of highest importance. Errors for increment follow the law of error propagation (Sterba, 1999). Thus the relative error for increment is always higher than the relative error of the size measurement. Therefore, for a given sample size and time interval between two measurements, diameter increment will be more reliable than height increment. Diameter increment in a five-year period can usually be estimated for stands with a sufficiently small error. For a reliable estimate of height increment periods of 10 to 30 years may be necessary depending on the growth rate and number of measured trees.
As stated in the Manual it is important that individual trees are identified and that remeasurements are done on the same trees. This way the sampling error of increment variables reduces substantially and possible measurement errors can be more easily identified (Cochran, 1977, Cluzeau et al., 1998).

4.6.6 Analyses methods and growth models

If the tree size measurements are only used for stand description, no models are necessary. However, if tree growth is used as a response variable, any confounding effects on growth need to be eliminated. Similar to crown defoliation estimates, where the assessment is carried out directly against a typical reference tree, or in chemical foliage analysis, where a threshold for normal trees is defined, tree or stand increment need to be compared to some expected or normal value. References are derived from models (i.e. the reference tree is a simplified model of a typical tree). In the following section only a brief discussion on modelling techniques can be given. For a recent textbook on tree-growth modelling with emphasis on mixed-species stands, the reader is referred to Vanclay (1994).

4.6.6.1 Use of growth models

Models are a simplified representation of reality. Models can be grouped into models for prediction (also called empirical models) and models for understanding (examples are process models). Process models for tree growth attempt to model the processes of growth and help to provide a better understanding of growth and stand dynamics (Vanclay, 1994). Models for prediction sacrifice details of growth processes to achieve greater efficiency and accuracy. As most readers of this review will be more familiar with models for prediction, the focus will be on these. However, in the future the various expert panels should work together in evaluating models suitable for the aims of ICP Forests, in particular as more and more hybrid models between empirical and process models become available (Kimmins et al., 1990; Sievänen and Burk, 1993; Baldwin et al., 1993).
Ideally, the forest growth models used for ICP Forest have to include all the factors influencing tree or stand growth, but not direct stress factors. Such factors are tree age, tree size, competition (stand density, inter-tree competition), tree species and site fertility. If these factors can be accounted for, the effects of stress factors can be estimated using multivariate statistics. The difficulty is to separate the non-stress from stress factors. All models are determined by the environmental conditions of the time of establishment. Therefore changes in environmental factor not accounted for by the models are influencing or biasing the results.

4.6.6.2 Empirical models

The most commonly used models for prediction of forest growth are yield tables. Other prediction models are empirically derived stand tables and single-tree models (Vanclay, 1994). The difference between these three classes of models is the cohorts of trees being used to model growth. The amount of information needed and the costs increases from stand models to single-tree models. For even-aged, single storey and single species stands stand models are usually sufficient. With increasing stand heterogeneity single-tree models are needed for adequate growth models.

Yield tables

Yield tables are interpolated growth estimates of typical stands for a given region usually derived from long-term experimental plots or chronosequences (i.e. stands at different ages on presumably identical sites are measured or stem analysis. Many regional or local yield tables exist in Europe (for Austria: Guttenberg, 1915; for Germany: Wiedemann, 1936/42; Assmann and Franz, 1965; Schober 1975, for England: Bradley, 1967, for Hungary: Kiss et al., 1987; Béky and Somogyi, 1996)

Single-tree models

Single-tree growth models allow incorporating available tree specific information such as defoliation or crown size. While yield tables were the common approach to forestry in Europe, stand table models and single-tree models had been favoured in North America. Some models used in North America are Prognosis (Stage, 1973), FOREST (Ek and Monserud, 1974), CACTOS (Wensel et al., 1987). In Europe recently developed models for uneven-aged mixed-species include SILVA in southern Germany (Pretzsch, 1992; Kahn and Pretzsch, 1997), Prognaus in Austria (Sterba, 1995; Monserud and Sterba, 1996) a model for Norway spruce-Scots pine-common beech mixed stands in Austria (Hasenauer, 1994) and BWIN in north-western Germany (Nagel, 1999). Models differ in respect to parameters used, some take into account the specific spatial situation, others do not. For a comparison of spatially independent and spatially dependent competition indices see (Biging and Dobbertin, 1992, 1995; Bachmann, 1998).

4.6.6.3 Models and goodness-of-fit statistics

If models are developed, it is important to consider the underlying measurement errors that will influence the fit of the model. Imprecise measurements will reduce the goodness-of-fit statistics, while biased but precise measurements will yield a high goodness-of-fit statistics although the fit model may be wrong. Often some non-measured variables are estimated with regression techniques. If these estimated data are used in subsequent model fitting the goodness-of-fit statistic will give misleading high values (Hasenauer and Monserud 1997). Therefore, modelling should be done using the actual measured data and not estimated data. Currently new more efficient modelling methods using simultaneous fitting of equations have been developed, which be implemented on Level II plots (Hasenauer et al., 1998)

4.6.7 Resources Required

Circumference measurement, as the most important growth measure, is also one of the easiest and fastest measurements. In addition, it can be considered fairly accurate. Tree height measurements take more time and require usually a team of two assessors. Depending on stand conditions, between 150 and 300 tree sizes per day and stand can be measured. Tree height measuring instruments costs vary substantially, with higher costs for more precise instruments. However, considering that tree-height measurements will only be carried out every five years these costs are comparably low. While height-to-crown base is only one additional measurement to tree height and therefore a cheap additional measure, the measurement of crown width is substantially more time consuming and therefore costly and at the same time less accurate. One alternative to terrestrial measuring of crown width would be the use of aerial photographs. However, this method may only be cost-effective if the remote sensing technology is available and also used for other studies on level II plots.

4.6.8 Needed Additional Information and Link to other Surveys Carried out

4.6.8.1 Crown condition and observed causes

The amount of foliage needed for photosynthesis in relation to the parts of the trees that respire determines the growth of a tree (Kozlowski and Pallardy, 1996). There have been many studies that found that trees with higher defoliation grew less than trees with lower defoliation (Murri and Schlaepfer, 1987; Sterba and Eckmüllner, 1988; Dobbertin, 1998a; Kozlowski and Pallardy, 1996). Steyrer (1996) found that trees with low defoliation grew better than predicted, while trees with higher defoliation grew less than predicted. Using a step-wise linear regression Dobbertin (1996) found for Norway spruce (Picea abies) and silver fir that following tree diameter, defoliation was the next significant variable to explain tree growth. It is therefore important to have the information on defoliation of the trees measured for forest growth to find the relationship and to account for it in models.

4.6.8.2 Climatic information

Tree growth obtained in any five-year period is highly depended on the weather conditions during that period. Growth models fit using one period (even when climate is incorporated) may not apply if the weather conditions during the following period have substantially changed (Wensel and Turnblom, 1998). It is therefore important to have on- or near-site information on weather conditions. In addition, if annual, weekly of hourly circumference measurements are taken (see section 8.2.), climatic information, preferably measures on or next to the plot will be of high importance to develop growth models.

4.6.8.3 Phenology

As had been mentioned in Chapter 4.6.5.2 there is a strong correlation between phenological observation of the trees and a) the onset and cessation of tree growth and b) the reported biotic or abiotic damages to leaves/needles. It is therefore very useful to install girth bands on trees selected for phenological observations.

4.6.8.4 Soil characteristicsc

Nutirent and water availability are two of the most important limiting factors for tree growth. On the other hand tree growth - through nutrient and water uptake - is influencing soil properties. Soil toxisticity is another limiting factor for tree growth. Therefore, tree growth can only be analysed in connection with the information obtained in the soil surveys.

4.6.8.5. Deposition

Of course, the input into the forest through deposition is also influencing tree growth. In particular N-deposition are thought to be one cause of the most recently observed growth increases in western and central Europe (Spiecker et al., 1996). To test this hypothesis deposition must be measured and compared with the actual tree growth.

4.6.8.6 Tree mortality

As explained above, gross stand growth is composed of the growth of the surviving trees, the growth of the trees that died or were removed and ingrowth. It is possible that the gross growth of a stand is negative if the basal area (or volume) lost due to mortality is higher than growth of surviving trees plus ingrowth. The surviving trees are likely to profit from mortality of their neighbours and may actual increase in growth. It is therefore crucial to have the information on tree mortality, which up to now has only been supplied as part of the crown assessments on the plots.

In addition, tree mortality itself is an indicator of the health of the forest stand. It is therefore only reasonable to evaluate the tree mortality rates of the Level II sites. As tree mortality rates due to competition (self-thinning) are usually low (mostly below 1% per year, Neumann and Stemberger, 1990; Dobbertin, 1998b) a sufficient long time interval is needed to estimate and model tree mortality rates. Mostly mortality models based on tree size, inter-tree competition and tree vigour (crown length and crown defoliation) are used to predict mortality (Dobbertin and Biging, 1998; Monserud and Sterba, 1999; Dobbertin and Brang, in press).

In addition, the information on tree mortality will become increasingly important in the future, if the objectives of the programme will be widened. For example for the assessment of biodiversity, and the sustainability of forest management the quantification of standing or fallen dead trees and mortality rates is necessary. Such analyses have already been done on Level II plots (Bretz Guby and Dobbertin, 1996).

4.6.9 Uses of the Growth Data if the Objectives of the ICP Forests Programme are Extended

The information collected as part of the ICP Forest Programme is becoming increasingly important for other fields of interest. Forest growth and stand and tree size structure is important for following fields of interest: monitoring biodiversity, assessing the sustainability of forest management, assessing the impact of climate change, carbon sequestration and certification of forests. Zeide (1997) points out that while ecosystem health and biodiversity are regarded as highly important and in need of monitoring, the concepts are often not clearly understood.

Biodiversity has either been divided into ecosystem diversity, species diversity and genetic diversity or into compositional diversity, structural diversity and functional diversity (Kaennel, 1998). It is known that tree size structure is important for certain mammals (Carey, 1995), while the distribution of size of dead and alive trees is in particular important for arthropod and bird diversity (Bühlmann and Pasinelli, 1996; Fernandez and Azkona, 1996; Hammond, 1997). Tree species diversity and tree structure are therefore key indicators of forest biodiversity. Models have been developed in order to study stand structure of boreal forests from the standpoint of biological diversity (Kolström, 1998). Data obtained from Level II plots are ideal to test these models. Neumann and Starlinger (in press) found little correlation between spatial stand structure and ground vegetation diversity at Austrian Level II plots. Spatial tree structure can therefore not be substituted by vegetation diversity indices.

The measures of structural diversity, species diversity, and forest growth in connection with other assessed parameters on Level II (such as soil parameters and fluxes) are essential to study the sustainability of management practices (Lindenmayer and Franklin, 1997). In addition, stand structure, including deadwood, and forest growth can be used as indicators for certification of the sustainability forest management.

Information on susceptibility of trees and forest to changes in climate and disturbance regimes gathered on Level II plots can help to fill the gaps of knowledge in climate change research (Dale and Rauscher, 1994).

Another important current issue of interest is the global carbon cycle. Carbon sequestration in forests is one of the key elements in the global carbon budget. Measures of tree size and forest growth can be used to estimate the above-ground biomass of a forest and therefore a large portion of its above-ground carbon storage (Karjalainen, 1996; Solberg, 1997).

4.6.10 References

Assmann, E., Franz, F., 1965. Vorläufige Fichten-Ertragstafel für Bayern. Forstwiss. Cbl. 84:13-43.

Athari, S., 1983. Zuwachsvergleich von Fichten mit unterschiedlich starken Schadsymptomen. Allg. Forstz. 38(26/27):653-655.

Bachmann M., 1998. Indizes zur Erfassung der Konkurrenz von Einzelbäumen. Methodische Untersuchungen in Bergmischwäldern. Forstliche Forschungsberichte München 171.

Baldwin, V.C., Burkhart, H.E., Dougherty, P.M., Teskey, R.O., 1993. Using a growth and yield model (PTAEDA2) as a driver for a biological process model (MAESTRO). Research Paper SO 276, New Orleans, LA, USDA Forest Service, Southern Forest Experiment Station.

Béky, A., Somogyi, Z. 1996. Yield table for hornbeam-sessile oak stands of optimal structure. (Fatermési tábla optimális szerkezet q gyertyános-kocsánytalan tölgyesekre.) Erdészeti Kutatások 85:49-78. (In Hungarian.).

Biging, G.S., Dobbertin, M., 1992. A comparison of distance-dependent competition measures for height and basal area growth of individual conifer trees. Forest Science 38(3): 695-720.

Biging, G.S., Dobbertin, M., 1995. Evaluation of competition indices in individual-tree growth models. Forest Science 41(2): 360-377.

Bradley, R.T. 1967: Thinning control in British Woodlands. Forestry Commission Booklet No. 17.

Bretz Guby, N.A., Dobbertin, M., 1996. Quantitative estimates of coarse woody debris and standing dead trees in selected Swiss forests. Global Ecology and Biogeography Letters 5(6): 327-341.

Bühlmann, J., Pasinelli, G., 1996. Beinflussen kleinflächige Waldnutzung und Wetter die Siedlungsdichte des Mittelspechts Dendrocopos medius?. Der Ornithologische Beobachter 93: 267-276.

Carey, A.B., 1995. Sciurids in Pacific Northwest managed and old-growth forests. Ecological Applications 5(3): 648-661.

Cherubini, P., Piussi, P., Schweingruber, F.H., 1996. Spatiotemporal growth dynamics and disturbances in a subalpine spruce forest in the Alps: a dendroecological reconstruction. Canadian Journal of Forest Research 26: 991-1001.

Cherubini, P., Dobbertin, M., Innes, J.L., 1998. Potential sampling bias in long-term forest growth trends reconstructed from tree rings: A case study from the Italian Alps. Forest Ecology and Management 109: 103-118.

Cluzeau, C., Urich, E., Lanier, M., Garnier, F., 1998. RENECOFOR - Interprétation des mesures dendrométriques de 1991 à 1995 des 102 peuplements du réseau. Fontainebleau, Office National des Forêts - Département des Recherches Techniques.

Cochran, W.G. , 1977. Sampling techniques. John Wiley & Sons, New York, 3. Ed.

Cook, E.R. and Kairiukstis, L.A. 1990. Methods of dendrochronology. Applications in the environmental sciences. Kluwer Academic Publishers, Dordrecht.

Dale, V.H., Rauscher, H.M., 1994. Assessing impacts of climate change on forests: the state of biological modeling. Climatic Change 28(1-2): 65-90.

Dobbertin, M., 1996. Relationship between basal area increment, tree crown defoliation, and tree and site variables. In: Proceedings, IUFRO Conference on Effects of environmental factors on tree and stand growth, Berggiesshübel near Dresden, September 23-27, 1996. Dresden, Technische Universität, pp. 33-44.

Dobbertin, M., 1998a. Ergebnisse der Sanasilva-Inventur: Zuwachs und Kronenverlichtung. Berichte der Eidg. Forschungsanstalt für Wald, Schnee und Landschaft, Birmensdorf (P. Brang (Redaktion), Sanasilva-Bericht 1997. Gesundheit und Gefährdung des Schweizer Waldes – eine Zwischenbilanz nach 15 Jahren Waldschadenforschung) 345: 27-28.

Dobbertin, M., 1998b. Ergebnisse der Sanasilva-Inventur: Sterberate, Nutzungsrate und Einwuchsrate. Berichte der Eidg. Forschungsanstalt für Wald, Schnee und Landschaft, Birmensdorf (P. Brang (Redaktion), Sanasilva-Bericht 1997. Gesundheit und Gefährdung des Schweizer Waldes – eine Zwischenbilanz nach 15 Jahren Waldschadenforschung) 345: 24-27.

Dobbertin, M., Biging, G.S., 1998. Using the non-parametric classifier CART to model forest tree mortality. Forest Science 44(4): 507-516.

Dobbertin, M., 1999. Relating defoliation and its causes to premature tree mortality. In Proceedings of the Second Workshop of the IUFRO WP 7.03.10, April 20-23, 1999, Sion-Châteauneuf, Switzerland. Methodology of Forest Insect and Disease Survey in Central Europe. Edited by Beat Forster, Milos Knízek, and Wojciech Grodzki. Birmensdorf, Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) 215-220.

Dobbertin, M., Brang, P., in press. Crown defoliation improves tree mortality models. Forest Ecology and Management.

Dobbertin, M., Baltensweiler, A., Rigling, D., in press. Tree mortality in an unmanaged mountain pine (Pinus mugo var. uncinata) stand in the Swiss National Park impacted by root rot fungi. Forest Ecology and Management.

Dong, P.H., 1985. Beziehungen zwischen Zuwachs und Kronenparametern in immissionsgeschädigten Nadelholzbeständen. Dt.Verb. Forstl. Forsch. Anst., Kaerlbronn, 15: 1-15.

Dong, P.H., Kramer, H., 1987. Zuwachsverlust in erkrankten Fichtenbeständen. Allg. Forst-Jagdtztg. 158 (7/8):122-125.

Eckmüllner, O., 1999. Unerwünschte Einflüsse auf Oberhöhen. Cbl. f. d. ges. Forstw. 116(1/2): 17-24.

Eichkorn, T., 1986. Wachstumsanalysen an Fichten in Südwestdeutschland. Allg. Forst-Jagdtztg. 157 (7):125-139.

Ek, A.R., R.A: Monserud 1974: FOREST: A Computer model for simulating the growth and reproduction of mixed species forest stands. Res.Rep. R2635, University of Wisconsin, College of Agriculture and Life Science.

Fernandez, C., Azkona, P., 1996. Influence of forest structure on the density and distribution of the White-backed woodpecker Dendrocopos leucotos and black woodpecker Dryocopus martius in Quinto Real (Spanish western Pyrenees). Bird Study 43(Part 3): 305-313.

Fritts, H.C. 1976. Tree rings and climate. Academic Press, New York.

Ganghofer, A., 1881. Das forstliche Versuchswesen. Vol. 1, Augsburg.

Gerecke, K.L., 1986. Zuwachsuntersuchungen an vorherrschenden Tannen aus Baden-Württemberg. Allg. Forst-Jagdtztg. 157(3/4):59-68.

Gregoire T.G., Zedaker S.M., Nicholas N.S., 1990. Modeling relative error in stem basal area estimates. Canadian Journal of Forest Research 20(5): 496-502.

Guttenberg, A.1915: Wachstum und Ertrag der Fichte im Hochgebirge. Franz Deuticke, Wien und Leipzig.

Hammond, H.E.J., 1997. Arthropod biodiversity from Populus coarse woody material in north-central Alberta: A review of taxa and collection methods. Canadian Entomologist 129(6): 1009-1033.

Hartig, G.L., 1795. Anweisung zur Taxation der Forste oder zur Bestimmung des Holzertrages der Wälder. Gießen.

Hasenauer, H., 1994. Ein Einzelbaumwachstumssimulator für ungleichaltrige Fichten-Kiefern- und Buchen-Fichtenmischbestände. Forstliche Schriftenreihe / Universität für Bodenkultur 8.

Hasenauer, H., Monserud, R.A., 1996. A crown ratio model for Austrian forests. Forest Ecology and Management 84(1-3): 49-60.

Hasenauer, H., Monserud R.A., 1997. Biased predictions for tree height increment models developed from smoothed data. Ecological Modelling 98(1): 13-22.

Hasenauer, H., Monserud R.A., Gregoire T.G., 1998. Using simultaneous regression techniques with individual-tree growth models. Forest Science 44(1): 87-95.

Innes, J.L. (ed), 1994. Assessment of increment in permanent monitoring plots established to determine the effects of air pollution on forests. Proceedings of the Sopron workshop. August 28 to September 1, 1993, Sopron, Hungary. Birmensdorf, Swiss Federal Institute for Forest, Snow and Landscape Research.

Kaennel, M., 1998. Biodiversity: a diversity in definition. In: P. Bachmann, M. Köhl, R. Päivinen (eds), Assessment of biodiversity for improved forest planning. Dordrecht, Kluwer, pp. 71-81.

Kahn, M., Pretzsch, H., 1997. Das Wuchsmodell SILVA - Parametrisierung der Version 2.1 für Rein- und Mischbestände aus Fichte und Buche. Allgemeine Forst- und Jagdzeitung 168(6-7): 115-123.

Karjalainen, T., 1996. Dynamics and potentials of carbon sequestration in managed stands and wood products in Finland under changing climatic conditions. Forest Ecology and Management 80(1-3): 113-132.

Kaufmann, E., 1999. Baumhöhenerfassung undEinfluss von Messfehlern im schweizerischen Landesforstinventar. Cbl. f. d. ges. Forstw. 116(1/2): 129-140.

Kenk, G., 1983. Zuwachsuntersuchungen in geschädigten Tannenbeständen in Baden-Württemberg. Allg. Forstz 38: 650-652.

Kenk, G., Kremer, W., Bonaventura, D., Gallus, M., 1985. Jahrring- und zuwachsanalytische Untersuchungen in erkrankten Tannenbeständen des Landes Baden-Württemberg. Mitt. Forst. Vers. u. Forsch. Anst. Bad.-Württemb. 112.

Kiennen, L., Schuck, H.J., 1983. Untersuchungen über die Zuwachsentwicklung bei erkrankten Tannen. E European Journal of Forest Pathology 13 (5/6):289-295.

Kimmins, J.P., Scoullar, K.A., Apps, M.J., Kurz, W.A., 1990. The FORCYTE experience: a decade of model development. In: B.J. Boughton, J.K. Samoil (eds), Forest Modeling Symp. Saskatoon, Saskatchewan, Canada, 1989/03/13-15 :60-67.

Kiss, R., Somogyi, Z., Juhász, Gy. 1987. Yield table for pedunculate oak (Quercus robur L.) (Kocsányos tölgy fatermési tábla, 1985). Erdészeti Kutatások 75: 265-282.

Kolström, M., 1998. Ecological simulation model for studying diversity of stand structure in boreal forests. Ecological Modelling 111(1): 17-36.

Kozlowski, T.T., Pallardy. S.G., 1996. Physiology of woody plants. 2nd ed.. San Diego, Academic Press.

Kramer, H., Akca, A. 1987. Leitfaden für Dendrometrie und Bestandesinventur. 2. Auflage. Sauerländer's Verlag Frankfurt.

Lebourgeois, F., 1997. RENECOFOR - Etat dendrochronologique des 102 peuplements du réseau. Fontainebleau, Office National des Forêts - Département des Recherches Techniques.

Lindenmayer, D.B., Franklin, J.F., 1997. Managing stand structure as part of ecologically sustainable forest management in Australian mountain ash forests. Conservation Biology 11(5): 1053-1068.

Lorenz, M., Eckstein, D., 1988. Wachstumsreaktionen von Einzelbäumen in Douglasien-, Fichten- und Kiefernbeständen in norddeutscher Waldschadensgebieten. Forst und Holz 43(1):8-12.

Monserud, R.A., H. Sterba 1996: A basal area increment model for individual trees growing in even- and uneven-aged forest stands in Austria. For.Ecol.Manage. 80:57-80.

Monserud, R.A., Sterba, H., 1999. Modeling individual tree mortality for Austrian forest species. Forest Ecology and Management 113(2-3): 109-123.

Murri, M., Schlaepfer, R., 1987. Zusammenhänge von Kroneneigenschaften und Duchmesser- bzw. Grundflächenzuwachs von Fichte auf zwei Gebirgsstandorten. Forstwiss. Centralbl. 106:328-340.

Nagel, J, 1999. Konzeptuelle Überlegungen zum schrittweisen Aufbau eines wachstumskundlichen Simulationssystem für Nordwestdeutschland. Schr. Forstl. Fak. Univ. Göttingen a. Nieders. Forstl. Vers. Anst. No. 128.

Naleppa, M., 1995. Entwurf und Eignungsprüfung eines DMS-Aufnehmers für eine permanente und hochauflösende Messung des Umfangzuwachses von Bäumen. Diplomarbeit. Fachhochschule München.

Neumann, M., 1999. Die Bedeutung der Baumhöhe im Wandel der Waldwachstumsforschung. Cbl. f. d. ges. Forstw. 116(1/2): 3-16.

Neumann, M., Stemberger, A., 1990. Über Ausmass und Verteilung der Mortalität: Gegenüberstellung von Ergebnissen der Waldzustandsinventur mit früheren Untersuchungen. Forstwiss. Centralbl. 107(2):63-99.

Neumann, M., Starlinger, F., in press. The expressiveness of different indices for stand structure and diversity. Forest Ecology and Management.

Pretzsch, H., 1985. Wachstumsmerkmale Oberpfälzer Kiefernbestände in den letzten 30 Jahren. Vitalitätszustand Strukturverhältnisse - Zuwachsgang. Allg. Forstz. 42:1122-1126.

Pretzsch, H., 1992a. Zunehmende Unstimmigkeit zwischen erwartetem und wirklichem Wachstum unserer Waldbestände. Forstwiss. Centralbl. 111:366-382.

Pretzsch, H., 1992b. Konzeption und Konstruktion von Wuchsmodellen für Rein- und Mischbestände. Forstl. Forsch.ber. München. 115.

Pretzsch, H., 1996. Strukturvielfalt als Ergebniss waldbaulichen Handelns. Allgemeine Forst- und Jagdzeitung 167(11): 213-221.

Pretzsch, H., 1997. Analysis and modeling of spatial stand structures. Methodological considerations based on mixed beech-larch stands in Lower Saxony. Forest Ecology and Management 97(3): 237-253.

Preuhsler. T. (ed), 1995. Methoden der Permanent-Zuwachsmessung. Seminar der Bayer. Landesanstalt für Wald und Forstwirtschaft. Forstliche Forschungsberichte München 153.

Prodan, M., 1965: Holzmesslehre. Sauerländer's Verlag Frankfurt.

Schober, R., 1975. Ertragstafeln wichtiger Baumarten. 2. Ed., Frankfurt a. M.

Schöpfer, W., Hradetzky, J., 1986. Zuwachsrückgang in erkrankten Fichten- und Tannenbeständen - Auswertungsmethoden und Ergebnisse. Forstwiss. Centralbl. 105:446-470.

Schöpfer, W., Hradetzky, J., Kublin, E., 1997. Wachstumsvergleiche von Fichte und Tanne in Baden-Württemberg. Forst und Holz 52(16):443-448.

Schweingruber, F.H. 1993. Trees and wood in dendrochronology. Springer-Verlag, Berlin.

Schweingruber, F.H. 1996. Tree rings and environment. Paul Haupt, Bern.

Sievänen, R., Burk, T.E., 1993. Adjusting a process-based growth model for varying site conditions through parameter estimation. Can. J. For Res. 23: 1837-1851.

Skovsgaard, J.P., Johannsen, V.K., Vanclay, J.K., 1998. Accuracy and precision of two laser dendrometers. Forestry 71(2): 131-139.

Solberg, B., 1997. Forest biomass as carbon sink - Economic value and forest management/policy implications. Critical Reviews In Environmental Science And Technology (SI): S323-S333.

Spelsberg, G. 1990: Erfahrungsbericht über fünf Jahre Zuwachsmessung per Dauerumfangmeßband. (In KENK: DeutscherVerband Forstlicher Forschungsanstalten, Sektion Ertragskunde - Jahrestagung 1990 Verden/Aller; Freiburg 1990).

Spelsberg, G., Teske, H., Graner, M., Suntrup, U., 1995. Hohes Zuwachsniveau der Fichte in Nordrhein-Westfalen. Allgemeine Forst-Zeitschrift 50(20): 1097-1098.

Spiecker, H., Mielikäinen K., Köhl M., Skovsgaard, J.P., (eds.) 1996: Growth Trends in European Forests. EFI Res. Rep. 5. Springer. Berlin.

Stage, A.R., 1973 Prognosis model for stand development. USDA For. Ser. , Res. Pap. INT-137.

Standovár, T., Somogyi, Z. 1998. Corresponding patterns of site quality, decline and tree growth in a sessile oak stand. European Journal of Forest Pathology 28:133-144.

Sterba, H., 1995. PROGNAUS - ein abstandsunabhängiger Wachstumssimulator für ungleichaltrige Mischbestände. Tagungsbericht der Sektion Ertragskunde des DVVFA. Joachimstal 29.-31.5 1995: 173-183.

Sterba, H., 1999. Genauere Höhenmessungen - Bedeutung des Höhenzuwachses in der Waldwachstumtheorie. Cbl. f. d. ges. Forstw. 116(1/2): 141-154.

Sterba, H., Eckmüllner, O., 1988. Nadelverlust - Zuwachsrückgang: doch eine Beziehung. Österreichische Forstzeitung 10: 52-53.

Steyrer, G., 1996. Auswahl und Prüfung von Zuwachsparametern als Waldzustandsindikatoren - Einfluss des Kronenzustandes auf den Zuwachs. FBVA-Berichte / Forstliche

Bundesversuchsanstalt Wien (M. Neumann (ed), Österreichisches Waldschaden-Beobachtungssystem) 96: 121-135.

Tallent-Halsell, N. G., 1994. Forest Health Monitoring 1994. Field Methods Guide. EPA/620/R-94/027. U.S. Environmental Protection Agency, Washington, D. C.

Vanclay, J.K., 1994. Modelling Forest Growth and Yield - Applications to Mixed Tropical Forests. CAB International.

Vogel, M., 1994. Automatische Radialzuwachsfeinmessung in einem Fichtenaltbestand und Möglichkeiten der Interpretation kurzfristiger Schwankungen der Zuwachsmesswerte. Allgemeine Forst und Jagdzeitung 165(2): 34-40.

Wiedemann, E., 1936/1942. Fichten-Ertragstafel. In: Schober, R. 1975: Ertragstafeln wichtiger Baumarten. 2. Ed., Frankfurt a. M.

Wensel, L.C., Meerschaert W.J., G.S. Biging, 1987. Tree height and diameter growth models for Northern California Conifers. Hilgardia. 55(8).

Wensel, L.C., Turnblom, E.C., 1998. Adjustment of estimated tree growth rates in northern California conifers for changes in precipitation levels. Canadian Journal of Forest Research 28(8): 1241-1248.

Zeide, B., 1997. Assessing biodiversity. Environmental Monitoring and Assessment 48(3): 249-260.

Zingg, A., 1999. Genauigkeit und Interpretierbarkeit von Oberhöhen. Cbl. f. d. ges. Forstw. 116(1/2): 25-34.

4.7. Deposition

4.7.1 Summary

During the past years an extensive network for deposition measurements has been established within the Intensive Monitoring Programme and a large dataset is now available. Measurements are presently carried out at approximately 500 sites all over Europe.
The results of the review show that the deposition parameters measured are mainly those that are considered necessary, thus there is no big need for changes.

Yet, there are still two types of uncertainties in the measurements:
– In some cases, countries do not follow all recommendations and precautions in the manual. Also, data checks are not always carried out as recommended. One resulting problem is that ion balances in the analyses still have to be improved. Some of these uncertainties in the data, will gradually disappear, when skill is improved and lessons are learned.
– On the other hand there are uncertainties, which can not totally be avoided due to lack of knowledge and due to lack of well-founded recommendations. One important example is the sampling of snow. No good solution is yet available. However, on-going studies may result in recommendations for improved equipment.

Data quality improvements are also in the future of particular importance. Presently the following three different actions are undertaken or planned:
– Analytical intercomparions
– Field intercomparison of the sampling procedure.
– Analytical training workshops.

A new component which should be included into the deposition monitoring is the definition of interpretation procedures. It is recommended to develop harmonized modelling approaches for the estimation of total deposition from throughfall, bulk deposition, air quality and meteorological data. The programme would derive greater benefit if all countries could use their data for estimating total deposition to their forest plots.

The deposition Submanual of ICP Forests has been updated in 1999, thus there is no need for changes in the parameters.

Table 4.7.1-1: Key parameters of the deposition survey

Sample solution	Mandatory	Optional
Throughfall, stemflow	pH, conductivity	
	Base cations; Na^+ K^+ Mg^{2+} Ca^{2+}	Al^{3+}, Mn^{2+}, Fe^{3+}
	Other cations; NH_4^+	Heavy metals such as Cu, Zn, Hg, Pb,Cd, Co, Mo
	Anions; Cl^-, NO_3^- SO_4^{2-}	Total - P, PO_4^{3-}
	Total alkalinity	Total alkalinity
	N_{total}	S_{total} ,$C_{tot\ org}$ (TOC) $C_{dissolved\ org}$ (DOC)
Wet deposition*	pH, conductivity	
	Base cations; Na^+ K^+ Mg^{2+} Ca^{2+}	Al^{3+}, Mn^{2+}, Fe^{3+}
	Other cations; NH_4^+	Heavy metals such as Cu, Zn, Hg, Pb, Cd, Co, Mo
	Anions; Cl^-, NO_3^- SO_4^{2-}	Total - P, PO_4^{3-}
	Total alkalinity	Total alkalinity
		S_{total},, N_{total}
Fog, frozen fog (rime)		pH, conductivity
		Base cations; Na^+ K^+ Mg^{2+} Ca^{2+}
		Other cations; NH_4^+
		Anions; Cl^-, NO_3^- SO_4^{2-}, Total – P
		Alkalinity
		Al^{3+}, Mn^{2+}, $Fe^{3+}$and heavy metals

* measured as wet-only or bulk deposition

4.7.2 Introduction

Pollutants emitted to the atmosphere are dispersed by wind over large distances. During this process, chemical reactions take place. Many of the pollutants are oxidised in the atmosphere, and gaseous compounds are also transformed into particulates. The pollutants in the atmosphere are further subject to sink processes, such as washout by precipitation and also gravity and impaction. In this way, they are transferred from the atmosphere to soil, vegetation and water surfaces. This pollution input may cause adverse effects to ecosystems, with the size of the effects related to both the sensitivity of the ecosystem and the magnitude of the pollutant input.

Some compounds, such as sulphur and nitrogen species have a relatively long residence time in the atmosphere, typically several days to one week, and can be transported over distances of 1000 - 2000 km. Emissions in one region of Europe can therefore contribute to effects in other regions. To study and combat the long-range transport of air pollution, the Convention on Long-Range Transboundary Air Pollution (CLRTAP) was established in 1979 under the framework of UN ECE.

Within the ICP Forests Level II programme, measurements of air pollution deposition were initiated on forest plots in order to study the input of these pollutants as a basis for further exposure-effects relationships. The monitoring programme contains mandatory measurements of major ions in precipitation and throughfall.

Exposure levels, which may cause damage to ecosystems, are defined as critical loads and critical levels (Grennfelt & Nilsson, 1985?; Task Force on Mapping, 1996). As a result of a lack of more detailed dose-effect relationships, critical levels and critical loads are used for damage assessment in Europe.

An improvement in the pollution environment within Europe will be observed if control measures are undertaken through to 2010, according to agreed limits set in the Multi-protocol, and to National Ceiling Emissons that are currently under discussion in the EU. Decreased deposition will eventually decrease the need for pollution measurements, but measurements will need to continue from 2000 to 2010, and beyond, to follow the progress of reductions in deposition. Consideration of the recovery process of forest ecosystems may require special attention.

4.7.3 Objectives

The objective of deposition monitoring at the Level II plots is to produce deposition data relevant for the assessment of possible effects on forests and representative for the specific sites on which intensive monitoring of forest parameters is performed.

4.7.4 Sampling design

There are different methods to measure or estimate deposition to forests. However, only one of them, the throughfall method, meets the requirements of being relatively simple and economically feasible for most countries. Throughfall is the precipitation collected within the forest under the canopy. It contains a mixture of ions from precipitation (wet deposition), from compounds deposited onto leaves and branches and washed off during precipitation events (dry deposition) and ions introduced or lost by internal canopy processes (uptake and leaching).

Using throughfall measurements, it is possible to estimate the total deposition of all ions which are not subject to any significant internal cycling within the canopy (i.e. those ions which do not exhibit uptake or leaching processes). Sulphur, sodium and chloride fulfil these criteria at deposition levels observed over most of Europe. However, canopy exchange of nitrogen compounds occurs, whilst base cations, such as calcium, magnesium and potassium, are leached from the canopy. The deposition of these compounds cannot be estimated via throughfall measurements, unless there are data available on the magnitude of canopy processes.

An advantage of throughfall measurements is that they can be used for estimating deposition in complex terrain, such as forested areas and on exposed and slopes. A further advantage is that wet as well as dry deposition, including contributions from fog and cloud water (occult deposition), is measured.

In addition to throughfall, wet deposition (deposition via precipitation) in the open field near the forest should be measured and, at least for some forest types, stemflow should be assessed. The difference between throughfall and wet deposition for sulphur indicates the importance of dry deposition contributions. The difference between throughfall and wet deposition for nitrogen will indicate the nitrogen balance of the plot. In areas experiencing low nitrogen deposition, the wet deposition of nitrogen is larger than the throughfall flux. Where nitrogen deposition is high, the throughfall nitrogen flux considerably exceeds wet deposition.

The choice of method for sampling precipitation and throughfall is optional, as long as the principal procedures and precautions described within the manual are followed. A number of different types of sampler can be used and the number of samplers, as well as the siting of the samplers in or near the plot, may be defined by the individual countries. The performance of the samplers must, however, be assessed.

According to the manual, stemflow should be measured in beech stands as a minimum. In beech stands, stemflow contributes up to 25-30% of total deposition. In mature spruces stands stemflow is considered to contribute less than 5%. An assessment of the contribution is recommended at all plots, but few countries have reported on such studies, to date.

To relate effects to exposure, it is essential that deposition monitoring is site specific. It is recommended that measurements should be made on all Level II sites and not only at 10 % of the plots. If deposition is however measured at a selection of plots only, it is recommended to choose the plots in such a way that they are spatially well distributed over the country.

4.7.5 Parameters

Parameters chosen for analysis are the following:

- Sulphate, nitrate and ammonium in throughfall and precipitation are measured to study the input of acidifying compounds.
- The pH of precipitation and throughfall provide information on the acid input and on the influence of acidification at the plot.
- Base cations are essential nutrients to forests and they are important factors for the determination of the critical load of an ecosystem.
- Chloride and sodium are less important for the assessment of risks for effects, but data on these ions are necessary to study the ion charge balance of the sample.
- Bicarbonate is measured in samples with a pH>5. At such pH ranges, the contribution of bicarbonate to the ion balance is considerable.
- Conductivity is a QA/QC parameter. Measured and calculated data should match.

The parameters measured are relevant. Additional parameters may be valuable. However, little information is available on the value to introduce new parameters in an extensive network, without pilot studies.

4.7.6 Analyses

The major ions in precipitation and throughfall are selected for analysis. The manual contains advice and recommendations on how to avoid contamination of the sample and how to perform the analysis in accordance with good laboratory practice.

Countries are free to select analytical methods as long as good quality is assured. It is however recommended, that standardized methods are used, preferably ISO methods or the methods used in the EMEP and Integrated Monitoring programmes. Analyses should be carried out in accordance with procedures in the manual.

Throughfall samples often indicate a surplus of cations. The criterias set-up for data check are not fulfilled by a large number of data submitted to the FIMCI data base. It is expected that part of this deficit of anions is due to the fact, that not all essential parameters are measured. Anions of organic acids are suspected to be present in significant amounts. Analyses of TOC or DOC could to add to the knowledge, but it is not believed possible to use to improve the ion balance. There is not enough knowledge today to give useful recommendations on improvements in this aspect.

4.7.7 Deposition estimates from available data

The deposition of sulphur (and Na and Cl) can be estimated with good accuracy from throughfall measurements when procedures outlined in the manual are followed. Estimates of nitrogen and base cation deposition, require considerable interpretation and modelling procedures following the collection of wet deposition and throughfall data. These modelling approaches benefit from data on air quality and meteorology at the plot. The manual does not include any detailed descriptions of such procedures, largely because there are no standardised procedures, but also because slightly different calculations are made in different parts of Europe, due to individual characteristics of pollution, climate, and forest type. Only principal recommendations are included in the manual at present.

More emphasis needs to be placed on interpretation procedures in the future, using either a standardised protocol for all countries (*e.g.* within a special project), or by producing a framework of guidelines within which individual countries develop their own protocols. The Programme would derive greater benefit if all countries could use their data for estimating total deposition to their forest plots.

4.7.8 Quality control

Quality assurance of the sampling procedure

Manuals on deposition monitoring and on air pollution measurements have been elaborated to provide harmonised procedures within the ICP Forests monitoring network to create comparable data-sets. The manuals describe procedures for sampling and analysis, as well as for quality assurance, data reporting and data interpretation. Comparable and high quality deposition data are important in order to guarantee correct assessments of the input to forest ecosystems.

Sampling must be carried out in accordance with the descriptions and recommendations in the manual. Actions described in the manual for quality assurance and quality control (QA/QC) must be followed.

Uncertainties in the sampling procedure derive mainly from the following points:

- The number of samplers in the forest plot is not always sufficient to cover the spatial variability of deposition in the plot. The manual urges the countries to study the impact on results of the number of samplers. At present, few countries can provide data from such assessments.
- The wet deposition is not always collected efficiently. Open field samplers are subject to more influence from wind than the samplers within the forest. Estimates of wet deposition are thus expected to be more uncertain those of throughfall deposition. Duplicate samplers should be used to prevent data loss in the event of contamination of one of the samplers. A bulked sample from two or three samplers in the open field may decrease uncertainty.
- Wet deposition can be measured with samplers open all the time (bulk collector) or open only during periods of precipitation (wet-only collector). The bulk collector will sample not only wet deposition but to some extent, dry deposition is also sampled. The dry deposition contribution depends on the pollution climate; in clean areas the contribution is small, whilst in polluted areas and in areas subject to impact from Saharan dust, the contribution may be significant. Individual countries are free to choose between bulk and wet-only collectors. There must be some information available on the relative contribution of dry deposition and on the differences observed between wet-only and bulk collectors. Such information could be available either from earlier monitoring projects, or from preliminary studies where the two types of sampler are run in parallel at the same site. Most countries have an idea of regional differences between bulk and wet-only deposition, but results from studies are probably not available for all countries.
- Special uncertainties are introduced when precipitation is sampled in the form of snow. Snow collection in the open field is even more difficult than rain collection. The selection of an efficient snow sampler is essential, but to date, information on improved methods of snow sampling is scarce. However, on-going studies may result in recommendations for improved equipment.
- Stemflow is expected to make a small contributions to deposition estimates, and since its measurement and interpretation is complex, it is usually only measured in beech stands. A recommended preliminary study can identify the importance of stemflow measurements, whether it should be included in the sampling programme and if so, how many and which types of trees should be sampled.
- Uncertainties in total deposition estimates are also introduced via the selection of equipment. Different samplers have different sampling characteristics and the sampling efficiency varies due to differences in aerodynamic design, and are differently affected by evaporation, algae growth etc. To study the performance of the samplers used in the different countries, a field intercomparison is presently (October 1999 - June 2000) being carried out in the Netherlands. The outcome of the study is expected to provide indications

on any considerable deviations by some samplers. If that can be shown, it will be recommended to replace those samplers. The study will also give a view of the overall uncertainty within coniferous stands, with a similar crown design as Douglas fir, on a European level.

The manual recommends that the total accuracy of sampling should be estimated.
The overall accuracy of the measurements needed for estimating deposition to the forest plots is ±30%. This accuracy is not reached for all parameters and at all plots and only a few countries can present data on the accuracy of their measurements.

Quality assurance of the analytical procedure

Data checks, as specified in the manual, should be made as soon as data are available at the laboratory, sample by sample. If the quality criteria set up in the manual for the data check are not fulfilled, and there is no obvious reason for deviations, samples should be reanalysed. Criteria set up in the manual may have to be further discussed and modified to be relevant for all parts of Europe. The ion balance criteria of throughfall samples is in many cases not possible to reach even if the analyses of all parameters are of high quality. However, the necessity of data checks and quality control/quality assurance deserves to be repeated!

The laboratories performing the analyses for ICP Forests deposition monitoring have - which is acknowledged with gratitude - been invited to take part in AQUACON intercomparisons. The outcome has been that many laboratories perform analyses with sufficient accuracy. Some countries, which use methods not recommended for the purpose, have not performed well. Recommendations on not to use these methods have been made. Such quality assurance activities on a European level should be carried out yearly or every second year. It is believed that repeated intercomparisons will gradually improve laboratories that initially show poor performance and to maintain the level of quality at the other laboratories. The Expert Panel wish to support the group leading the AQUACON project in their efforts of establishing a continuation of this activity.

Further activities to improve the analytical part oft he monitoring are analytical training workshops. This activity is planned to take place in late autumn 2000, via JRC Ispra and Istituto Idrobiologico in Pallanza.

4.7.9 Resources required

Monitoring programmes are expensive to run, and sometimes due to lack of money, limitations are introduced in the programme and in quality assurance and control procedures. Savings can be made by:

- increasing the sampling periods (for example from weekly to monthly sampling), which in turn may increase the risk for contamination, and loss of data.
- not performing any stemflow measurements, which may introduce uncertainties in the total deposition, for some tree species.

- decreasing the intensity of quality assurance actions, which may hazard the credibility of data.

Such savings can of course be made, but it should be assessed via for example a measurements campaign the magnitude of uncertainties introduced. The saved work (and money) must be weighed against the value of receiving less accurate data. If there is a problem to keep up quality due to lack of resources, it is recommended rather to reduce the number of sites, and improve the quality of the deposition measurements at the remaining sites. Site number reduction can e.g. be based on tree species. A decision should be made for which tree species dose-effect relationships need to be assessed (e.g. only for the main tree species in Europe).

4.8 Ambient air quality

Air concentrations of some pollutants such as sulphur dioxide and ozone may cause direct effects to vegetation, including forest trees. An assessment of the risk of air pollution damage to forests will thus require data on the air concentration of these pollutants as well as their deposition.

Measurements of air concentrations within the Level II Programme have been optional to date. However, work is currently on-going to introduce passive sampling in the forest plots. These measurements will add to the available information and be of value for further effects risk assessments and for improved deposition estimates. It is anticipated that that individual countries will initiate air pollution measurements in a number of forest plots.

The following air concentrations are recommended to be measured to enable exposure - effects assessments:

- Ozone should be measured to assess ozone effects on forest trees - possible influence on defoliation, growth etc.
- Nitrogen compounds in the air should be measured to provide a basis for estimating the dry nitrogen deposition contribution.
- Nitrogen dioxide and sulphur dioxide should be measured in areas with suspected high concentrations to assess the risk for direct effects to forest trees.

In addition it is foreseen to introduce mandatory assessments of visible ozone injury at the Intensive Monitoring Plots. A first Intercalibration Course for ozone injury will take place in September 2000 in Spain. A test phase in the individual countries will then follow in 2001 and the experience as well as first results are foreseen to be compiled and discussed in the year 2002.

4.9 Meteorology

4.9.1 Summary

Meteorological variables comprise the most decisive and variable parameters affecting structure, growth, health and stability of forest ecosystems. Thus they are important basic variables in order to explain the basic conditions of trees and stands as well as their changes over time. Meteorological variables have a key function in the entire monitoring programme of Level II.

Meteorological monitoring at Level II plots has only started within the last few years, the phase of installation and beginning of the monitoring is not completed. Until now most member states are still in the phase of gathering experience in the techniques.

Automatic stations with quasi-continuous sensing are recommended; the necessary investment amount for it with about 15,000.- EURO and by that the danger of vandalism in some european regions may be a handicap.
The usability of meteorological data from e.g. the national weather service networks will be an important item in the future work of the expert panel, as well as quality control and the handling of missing data.

The worth of the database is expected to increase during the coming years, when initial difficulties of the monitoring have been overcome and time series are longer and therefore more expressive.

As meteorological monitoring has only begun recently at many Level II plots, there is no need for changes neither in the sampling procedure nor in the parameter set.

Table 4.9.1-: Key parameters of the meteorological survey

Mandatory	Optional
precipitation	UV-b radiation
air temperature	soil temperatures
air humidity	soil moisture:
wind speed *	(matric potential, water content)
wind direction *	stand precipitation:
solar radiation *	(quantity of throughfall and stemflow)

*) In case of local technical problems at level II plots the variables wind speed, wind direction and solar radiation may be omitted on these plots.

4.9.2 Introduction

Meteorological variables comprise the most decisive and variable parameters affecting structure, growth, health and stability of forest ecosystems and also contain the main factors guiding deposition into the forests. Thus they have a key function in the entire monitoring programme of Level II.

Meteorological monitoring at Level II plots has only started within the last few years, the phase of installation and beginning of the monitoring is not completed. The responsible Expert Panel is therefore still defining and formulating this part of the programme. Important activities are the gathering and exchange of experience in techniques and basic evaluations.

4.9.3 Objectives

The objectives described in the Manual of ICP Forests for Intensive Monitoring Plots have only recently been formulated and are still of actuality:
Main objective of the meteorological monitoring at the Level II plots is to contribute to the explanation of actual forest condition and its change over time, and notably to

- describe the climatic characteristics of Level II plots.
- supply explanations for the state of health, growth and development of trees at the plot in relationship to meteorological conditions.
- identify and investigate stress factors for trees on the plots.
- identify driving variables for modelling of ecosystem responses under actual and changing environmental conditions (e.g. water budget, water availability for the stand, growth, nutrient cycling.)

4.9.4 Sampling design, methods and parameters

Woodland has specific climatic condition, therefore in general the measurements should be carried out inside the forest area, i.e. above the plot stand or at least at an open field station within the forest area in close proximity to the stand of the Level II plot.

The mandatory required variables to be obtained are the minimum necessary and comprise

- precipitation
- air temperature
- air humidity
- wind speed
- wind direction
- solar radiation.

Additional optional variables are

- UV-b radiation
- soil temperature
- soil moisture
- stand precipitation (to be measured inside of the stand)

The technical equipment and placement should be in accordance to the international World Meteorological Organization standard; automatic stations with quasi-continuous sensing are recommended. The actual price for a complete automatic station with all sensors for the above mentioned mandatory and optional variables, including solar panel and an adequat data logger is about 15,000.- EURO. As this price and the risk of vandalism may be a handicap for a sufficient number of well distributed stations allover Europe, the integration of surrounding meteorological stations of e.g. the national sercices needs to be proved.

Evaluation

Soil moisture and stand precipitation are important at least for water budget evaluations and for the defining and evaluation of stress parameters for trees and stands in connection with the mandatory meteorological variables. Therefore special reference is made to the soil solution survey (stem flow and soil moisture meaqsurement).

For the modelling of ecosystem responses the use of continuously measured data (at automatic stations) is necessary . However, until now only at a small number of Level II plots throughout Europe meteorological stations are installed and their data are submitted to FIMCI. It is therefore absolutely necessary to at least complete the installation of the foreseen meteorological stations. It might even turn out to be necessary to increase the number of stations in some parts of Europe.

For plots that will not be equipped with meteorological stations the usability of meteo-data of nearby stations of the national service networks has to be proved.

4.9.5 Quality assessment and quality control

Problems will arise by missing data (e.g. by reason of technical sensor problems); in respect of the big quantity of data and the need of complete time series for modelling purposes an effective and immetiate automatic chek for plausibility is necessary.

The use of external meteo-data will need in many cases transfer functions or at least correlative studies of the data series of different sources.

One item of the next combined Meteo-Pheno-workshop will deal with quality assessment and quality control.

4.9.6 Analyses and benefits

Meteorological variables are important basic variables in order to explain the basic conditions of trees and stands as well as their changes over time. Until now most member states are still in the phase of gathering experience in the techniques. Thus the evaluation of meteorological data of level II plots is very often in the initial phase only. Therefore results and methods of member states or institutions that have already gained deeper experience should be made available. Main fields of interest are methods for the presentation of results as well as the definition of key parameters for the explanation of the state of health, growth and development of trees (e.g. begin and cessation of growing season, meteorological extreme values and period). It also includes results on the influence of meteorological stress factors (e.g. drought or frost stress).

In some member states first integrated evaluations of Level II data are in work. The respective results should be used for the development of standardized definitions and further programme tools.

4.10 Phenology

4.10.1 Summary

The phenological part of the monitoring programme has been established very late compared to other surveys and was thus restricted by financial limitations. Due to this fact all phenological observations under ICP Forests are reduced to be optional. This is a pitty, as phenology (in close connection with meteorological data) has an important key function in respect of biodiversity, growth and structure of the stands and climate changes as well as of biotic and abiotic stress factors and damages.

Phenological observations comprise extensive observations at plot level which can be conducted by technical staff as well as intensive phenological monitoring on individual trees which need well trained and specialised staff.

As the observations have only recently begun there is of importance to gain experience with phenological observations on the transnational scale. Thus there is presently no need for changes neither in the assessment procedures nor in the parameter sets. All assessments are optional.

Table 4.10.1-1: Key parameters of the phenological observations (Level II)

extensive monitoring at plot level	**intensive monitoring at tree level**
Flushing	Conifers:
Colour changes	Needle appearance
Leaf/needle fall	Lammas shoots
Significant signs of leaf or crown damage (e.g., eaten leaves or bare crown parts)	Flowering
Other damage (breakage, uprooted trees)	Broad-leaved species
	Leaf unfolding
	Secondary flushing
	Flowering
	Autumn colouring
	Leaf death and leaf fall

4.10.2 Introduction

Phenological monitoring at Level II plots has only started within the last few years, the phase of installation and beginning of the monitoring is not completed. The responsible Expert Panel is therefore still defining and formulating this part of the programme. Important activities are the gathering and exchange of experience in techniques and basic evaluations.

Within the aims of the Level II monitoring program, Forest Phenology is defined as the systematic observation and recording of:

- the biotic and abiotic (e.g. damaging) events and phenomena
- the yearly development stages of forest trees.

4.10.3 Objectives

The objectives described in the Manual of ICP Forests for Intensive Monitoring Plots have only recently been formulated and were adopted by the ICP Forests Task Force in 1999.
The main objective of phenological observation at the Level II plots is to provide supplementary and complementary information on the status and development of forest tree condition during the year.
Additional objectives of phenological monitoring are:

- to determine the course of the annual development stages of forest trees on the intensive monitoring plots, in order
- to explain possible changes in the timing of these stages (starting time, length of period and magnitude) in relation to environmental factors of natural and/or anthropogenic origin,
- to utilise this knowledge in interpreting observed changes in tree condition (e.g. crown condition, growth, nutritional situation).

4.10.4 Sampling design, methods and parameters

The observations are optional and will be extensive at a plot level and intensive at an individual tree level. They are recommended in general at least for those Level II plots where continuous measurements (e.g. meteorological observations, deposition or soil solution measurements) are being carried out.

The extensive observations at plot level are limited to the most obvious effects of biotic (pests and/or diseases) and abiotic damage (e.g. frost, wind, hail) and to the occurrence of flushing, colour change and leaf/needle fall. According to the already existing experience in some member states the observations can be conducted by technical staff in a cursory examination and will need aproximately 15 minutes per plot per weekSpecial in depth training is not required.

The intensive phenological observation is based on visual observations on individual trees at the plots or the buffer zones, with priority given to the main tree species. Here the most important phases are to be monitored and are for conifers: needle appearance, appearance of Lammas shoots and flowering; and for broad-leaved trees: leaf unfolding, secondary flushing, flowering, autumn colouring, leaf death and leaf fall. These assessments are time consuming (depending on the number of observed trees, e.g. for 20 trees approximately 30 minutes per week during the observed phenological phases) and need well trained staff.

Additional technics are the assessment of litterfall (reference is made mainly to the EPs of Crown Condition, Soil Chemistry and Soil Solition, Foliage and the Ad Hoc Working Group on Litterfall, where the methods will be hamonized in close cooeration), girth bands (reference is made mainly to the EPs of Forest Growth and Crown Condition), and the use of pollen information.
For the observation of damaging events reference is made to the Ad Hoc Working Group on Phytopathology.

Evaluation

The phenological part of the monitoring programme has been established very late compared to other surveys and was thus restricted by financial limitations. Due to this fact the phenological observations are reduced

- to be optional,
- to a minimum of phenological phases to be observed,
- to the plots with continuous measurements,
- and they are concentrated on European main species.

Only the first results of phenological assessments and of integrated evaluations will prove their sufficiency. As the observation is decided to be optional, the documentation of many important information will be lacking at many plots. An example is the amount of broken tips of branches after the storm of December 1999. This parameter might influence the results of the crown condition assessment in the year 2000, the increment of at least the year 2000 as well as the nitrogen situation.

In view of the limited financial resources, in depth observations on a small number of plots are rather recommended than low intensity observations on a bigger number of plots.

4.10.5 Quality assurance and quality control

The extensive observation on plot level will be done in a cursory way, a good explanation of the aims and the possibilities of their use might be very helpful for the technical staff, who should do it.

The intensive phenological observation will need a good training in sense of an intercalibration course; reference is made to the EP of Crown Condtion.

4.10.6 Analysis and benefits

Phenological observations focus on the trees of forest stands and their response to environmental stress. Besides completing the "one time per year" crown condition assessment, phenological observations allow insight in the reaction of trees to various anthropogenic and natural influences during the course of the year. Moreover the determination of the physiological status of the trees during the year can give quite strong information on their sensibility to environmental stress. Thus the observations enable a better understanding and explanation of forest condition as well as of the complex mechanisms of balanced as well as imbalanced forest ecosystems.

The assessments provide information on regional characteristics of phenological events and phases. The value of the assessments is enhanced when phenological data are evaluated in combination with additional data collected at Level II plots. Integrated evaluations of meteorological, deposition, soil solution, crown condition and increment data together with phenological data are of particular interest. They are in work in those member states were phenological assessments at Level II plots have already been carried out. Such evaluations should also start on a pan-European scale as soon as the respective phenological surveys have been carried out.

4.11 Ground Vegetation

4.11.1 Summary

Vegetation is an essential component of forest ecosystems and contains a major part of the plant diversity in forests. The assessment of ground vegetation at Level II plots and its sub manual is however, a rather young part of the Intensive Monitoring Programme, and therefore the need for a review is premature. Minor corrections and updates have been done by the Expert Panel on Ground Vegetation, including management of species lists. However, when experience from the Level II is gained, the Expert Panel will consider this topic in more detail.

4.11.2 Introduction

Vegetation is a major component of forest ecosystems. Vegetation layers contain a large part of total forest biological diversity, and play a direct role in water or nutrient cycling, and strongly interact with other biotic components (insects, game, etc.). Vegetation is a good bioindicator of environmental changes (pollution, climate etc.). Knowledge of the ecological niche of numerous plant species allows to deduce changes in underlying environmental factors from vegetation changes. Thus, the long-term study of vegetation dynamics can provide information on changes in the forest ecosystem.

It is mandatory to assess the ground vegetation every five years. (Heavy disturbances caused by management operations (e.g. thinning) preceding or occurring during the sampling year should be avoided. Whenever possible, it is recommended to sample the vegetation at least the year before these operations, in addition to the normal frequency.)

4.11.3 Objectives

The main objectives of the vegetation assessment are:
characterisation of the current state of the forest ecosystems on the basis of their plant composition;
monitoring of the vegetation changes due to natural and anthropogenic environmental factors.

The characterisation will allow plots to be positioned within identifiable vegetation types. The aims of studies of vegetation dynamics are to describe, explain and model succession, by an analysis of pathways, and elucidating causes and mechanisms of vegetation changes.

4.11.4 Sampling design and methods

The area selected for vegetation assessment must be representative for the plot, in order to allow the comparison with other parameters recorded on the same plot. Several sampling units can be used in order to obtain statistical replication.

Two different sampling designs may be used, which either lead to a more qualitative or to a more quantitative characterisation:

Design I – large sampling area
In this case, the dynamics are assessed by monitoring changes in the species composition of a large number of species over a large area, utilising sampling units greater than 100 m2, with a low to medium accuracy in estimates of changes in cover for each of these species;

Design II – several small sampling units
In this case, the study concentrates on population dynamics (expansion or regression) on a smaller area. Small sampling units (in general under 10 m2) are used for a more accurate estimation of species cover.

Specific details for the design is given in the Manual

4.11.5 Parameters

Species
All phanerogams, vascular cryptogams and terricolous mosses will be taken into account. It is recommended to identify and note terricolous lichens as far as possible. All the species are coded due to the species list that has been work out on the basis of the Flora Europaea list (Pankhurst / the Royal Botanic Garden, Edinburgh) and due to the list of Mr. F. Starlinger (Austria), based on “Frey W., Frahm J. -P., Fischer E. & Lobin W. 1995: Die Moos- und Farnpflanzen Europas. In: Kleine Kryptogamenflora. Vol. IV. 6th ed. The The Expert Panel Meeting on Ground Vegetation will execute continous updating of these lists according to species observed in the Level 2 plots across Europe.

A minimum of two people must assess all of the sampling units. At least one must be a trained expert ensuring the quality needed.

A separate record must be made for each species in the different vertical strata. The limits of each stratum are not fixed, but depend on the physiognomy of the stand. The minimum requirement is to record each species separately in the following layers:

- a bottom layer; terricolous mosses and lichens (if they are present)
- a field layer; including herbs and ligneous species under a certain height limit
- a shrub layer
- a tree layer which might be divided into several strata

It is recommended to visually estimate the percentage cover of each layer (separating between mosses, lichens, herbs, shrubs and trees), as well as the cover of bare soil and litter.

A detailed record of saplings and seedlings of tree species is recommended (e.g. number, coverage, etc.).

Species cover

Species cover is reported as percentage ground cover. Countries are free to choose their own scales as far as they can be directly converted into percentage cover (a table for conversion between various scales and percentage cover values is given in the Manual)

A more accurate estimation of cover can be obtained using small sampling units (in general under 10 m2), those possibly divided into smaller sub-units (0.01 m2), with visual estimates of individual species cover in these smaller sub-units. In the finest scale grid, a presence-absence assessment can be made and then transformed into a percentage cover estimate. It is also possible to use line intercept methods to obtain a quantitative cover estimate.

Additional information

- If separate spring and summer assessments are done, the input data must be separated.
- Data from fenced and unfenced plots must be clearly separated in the database.
- The information on ground vegetation shall be submitted on plot level (aggregated data) by using the arithmetic mean (with a minimum accuracy of 0.01%).
- NFC's should keep the results of separate sub-plots in their national database.

4.11.6 Analysis

A number of statistical methods, including multivariate statistics, should be executed on the dataset as soon as the data are available. Calculation of biological indices may be valulable. The data on vegetation might be an important platform for integrated analyses. The Expert Panel on Ground Vegetation should initiate such analyses.

4.11.7 Benefits of the parameters

The Level II database on ground vegetation will give valuable information about plant diversity from a large number of forest plots in Europe, as clearly stated by the Expert Panel on Ground Vegetation in Brussels 1999. The data on vegetation is also a good bioindicator of environmental changes (including air pollution and climate)

4.11.8 Resources required for the assessments

The cost of the vegetation assessment is mostly due to the cost of man-hours. The cost of equipment, storage and analyses are limited.

4.12. Remote Sensing

4.12.1 Summary

The application of remote sensing techniques is optional within the ICP-Forests/EU Level I and Level II-programme. Thus, no common results - including all countries - can be presented for the review period. However, based on the council regulation 3528 more than 50 projects have tested and applied remote sensing-based inventory methods and - among with the development of newly available technologies - it has become obvious that the use of earth observation data will become even more important in the future. Remote sensing (including satellite and airborne data) has a number of advantages over terrestrial surveys, however, it is clear that remote sensing will never fully replace terrestrial surveys. Remote sensing data supplement terrestrial data and therefore provide a more coherent picture of the ecosystem.

In order to harmonize the remote sensing techniques, the Working Group on Remote Sensing Applications for Forest Health Assessment of the European Commission defined standards for the application of remote sensing for forest health assessment (EEC, 2000). During the review period the work concentrated on the application of Colour Infra Red (CIR) aerial photographs within the Level II-programme, resulting in an amendment of the remote sensing manual concerning special remote sensing techniques and data evaluation methods for the Intensive Monitoring Programme (Level II). All reported assessments on Level II-plots and most of the those on Level I were carried out according to this manual which shows the high acceptance of the standards and is a guarantee for high quality of the information derived from earth observation data.

The EU Working Group strongly recommends the application of remote sensing within the EU/ICP Forests monitoring programme for large scale approaches (Level I) as well as for intensive monitoring (Level II).

Table 4.12.1-1:
Key parameters of remote sensing applications (Level I and Level II)

tree parameters	stand parameters
localisation (x,y,z-coordinates, 3D-view)	delineation of boundaries
tree height	representativeness
crown length	natural age class
crown polygon	crown closure
tree crown models	forest health condition
discolouration	management practice
crown condition	digital canopy model
special phenomena	digital terrain model
social class	

4.12.2 Introduction

Remote Sensing presents the opportunity to assess qualitative and quantitative information on objects using a sensor that is fixed on a remote platform. A variety of different sensors with specific capacities are available. Based on the council regulation 3528 more than 50 projects have tested and applied remote sensing-based inventory methods (including satellite and airborne data While developing newly available technologies, it has become obvious that the use of earth observation data will become even more important in the future. Remote sensing has a number of advantages over terrestrial surveys, however, it is clear that remote sensing will never fully replace terrestrial surveys. Remote sensing data supplement terrestrial data and therefore provide a more coherent picture of the ecosystem. There are a number of factors that make remote sensing, and especially aerial photography, a suitable medium for monitoring forest ecosystems:

- Remote sensing provides information that is not accessible through other media, e.g. the use of near-infrared, mid-infrared and laser. Such observations provide essential information on plant physiological processes (e.g. drought stress).
- Remote sensing provides a view of forest ecosystems that is not obtainable from the ground. This birds eye view allows data to be collected on the canopy itself (e.g. discolouration, crown structue, insect damages).
- Remote sensing provides a permanent record of the condition of important parts of an ecosystem at any given time (documentation). These records accurately document the current state of the forest for a given day and can be repeated in the future to provide an historical perspective of the past (time series). They can easily be evaluated at a later date and used as legal evidence if necessary (reproducibility).
- Remote sensing provides spatial geo-referenced data which can be easily implemented in a Geographical Information System (GIS) for integrated use within the forest sector or other user communities.
- Remote Sensing provides spatial georeferenced data not only about the monitoring plots but gives additional information about the surrounding area (e.g. structure of surrounding stands, distance to stand boundaries or other impact factors).

To harmonize the remote sensing techniques on the European level the Working Group on Remote Sensing Applications for Forest Health Assessment has defined standards for the application of remote sensing for forest health assessment (EEC, 2000). During the review period it was amended e.g. by a chapter concerning special remote sensing techniques and data evaluation methods for Level II. All reported assessments on Level II-plots and most of the those on Level I were carried out according to the manual which shows the high acceptance of the standards and is a guarantee for high quality of the information derived from earth observation data.

4.12.3 Objectives

Remote sensing is one tool among others that can contribute to forest health monitoring.

The main objectives of remote sensing within the EU/ICP Forests Programme are:

- assessment of a composition of reflected wavelengths that are not accessable through other media but provide essential information on plant physiological processes (e.g. indication of drought stress);
- collecting of crown data for different surveys (e.g. growth, deposition, crown condition, ground vegetation) by measurements or interpretation on the canopy itself (e.g. location, length, width, polygon, structure, health status of crowns);
- documentation of the properties of the inventory plot (e.g. stand structure, canopy closure, canopy roughness, health condition);
- permanent record of the properties of the surrounding area (e.g. representativness concerning age class, stand height, stand structure, health condition)
- reference for the comparison of terrestrial surveys from different interpreters (e.g. time series of identical plots) or different countries (e.g. detection, quantification and management of "country effects")
- provision of georeferenced data which can easily be linked to other systems via GIS (e.g. for the evaluation of comparability of deposition measurements or ground vegetation assessments in connection with canopy structure)

4.12.4 Methods and Parameters

Methods and parameters concerning remote sensing techniques for forest health assessments are documented in the EU-Manual written by the *EU-Working Group on Remote Sensing Applications for Forest Health Assessment* (EEC, 2000). Within the review period the manual was updated for the following topics:

- new chapters (photogrammetrie, GPS)
- film material (new Kodak CIR edition)
- flight parameters (helicopter, GPS)
- inventory concept (permanent plots, Level II-programme)
- statistics (revision)
- keys for standwise assessments
- interpretation (keys for new species).

In general, observations by satellites are more suitable for large scale inventories or investigations at regional scale. Aerial photography has proved to be an important tool for small scale assessments, e.g. on intensive monitoring plots. Besides qualitative data from the visual photo-interpretation also quantitative data can be derived by photogrammetric measurements within aerial photographs (see Tab. 4.12.1.-1). Therefore five levels of intensity have been defined for the possible application of aerial photography within the Level II-programme (Tab. 4.12.4.-1). They range from option 1, where photos will be taken purely for documentation purposes, to basic visual interpretations (option 2 and 3) and advanced photogrammetric analysis of single tree crowns or canopy models in option 4 and 5.

Table 4.12.4.-1: **Options for including aerial photography as part of the Level 2 Programme**

Op-tion	Application	Repetition	Output (simplified)
1	CIR aerial photographs taken for documentation purposes only, no interpretation or photogrammetric measurements.	at least once, at the beginning of the survey	documentation
2	As for Option 1, but photographs are also interpreted to assess the representativeness of each plot in relation to the surrounding forest, no other interpretation or photogrammetric measurements are carried out. Simple photogrammetric instruments are sufficient.	repetition will vary depending on forest management intensity and rate of change (e.g. 3 - 10 year cycle)	representativeness
3	As for Option 2, but including various assessments of individual trees using appropriate interpretation keys (e.g. species, age class, crown condition, social class and special phenomena), no photogrammetric measurements are carried out. Simple photogrammetric instruments are sufficient.	at the start of the survey then at a suitable cycle	qualitative tree data
4	As for Option 3, but including a number of photogrammetric measurements such as obtaining the x, y, z co-ordinates of every tree, tree height, and the production of crown polygons etc. High precision photogrammetric instruments will be required.	as above	quantitative tree data
5	As for Option 4, but including detailed photogrammetric analysis such as the production of digital terrain models and digital canopy models etc. High precision photogrammetric instruments will be required.	as above	complex models

4.12.5 Costs

In accordance to the EU Manual the costs for the application of aerial photography on intensive monitoring plots varies - depending on the inventory intensity between 1000 and 5000 ECU/plot:

Option 1	1000 ECU/plot
Option 1,2	1300 ECU/plot
Option 1,2,3	1700 ECU/plot
Option 1,2,3,4	4000 ECU/plot
Option 1,2,3,4,5	5000 ECU/plot.

These estimates are very rough, however. Depending on the number of inventory plots that are assessed, the number of trees per plot, the stand structure, the technical equipment and the experience of the interpreter the costs may vary. In Germany the medium costs per plot proved to be less than estimated. They ranged from 1300 ECU for option 1 to 2750 ECU for option 5 (Wolff et al. 1999).

4.12.6 Recommendations

The application of remote sensing data will provide a powerful and cost efficient monitoring tool. It will facilitate improved statistical representativity of the data at a regional and pan-European scale. This is due to the flexibility in the inventory design and marginal costs for very dense sampling grids. Therefore, the Working Group (WG) recommends the use of remote sensing data in the monitoring programme.

Based on the wide experience accrued over the past years, digital classification of space and air-borne data approaches have been developed to provide regional and European-wide information which meet requirements from the forestry and environmental user communities.

- The WG recommends the application of remote sensing because it provides an objective and harmonized assessment and monitoring of forest health condition over large regions (without "country effect").
- The WG recommends the application of remote sensinsing data in parallel with the terrestrial observations on Level I plots and denser national grid systems for forest condition assessment and monitoring. Currently, for some cases, a cost reduction of up to 80% can be expected if terrestrial data from Level II-plots are used for calibration.
- The WG recommends the regular documentation of all Level II plots with large scale CIR photographs. Visual interpretation, photogrammetric measurements as well as digital image processing procedures can be applied according to the EU Manual. In this way, new and complementary information on the crown layer can be obtained at a cost that equals only a low percentage of the mean plot costs.
- The WG recommends the verification of the location of all Level-I plots as well as the corners of Level-II plots, preferably using DGPS measurements.

- Remote sensing and GIS techniques provide the tools to link the different levels of the monitoring programme, and to up-scale the information for landscape and regional analyses.
- Newly available remote sensing technologies should be continuously evaluated and tested for their contribution to the objectives of the monitoring programme.

4.12.7 Remote Sensing Applications within an extended ICP Forests Programme

In terms of extension of the ICP Forest Programme remote sensing approaches could contribute data on different scales in time and space. They can provide information about changes over time in different ecosystems which may signal changes in the environmental conditions.

Remote sensing can supplement to monitoring the impacts of climate change on forest ecosystems by providing large area (small scale) estimates of forest cover and its changes over time (*e.g.,* changes at forest boundaries in boreal ecosystems, shifts in the tree-line in mountainous regions and the encroachment of desertification. Above-ground biomass of different forest types can be estimated at the European (trans-boundary) level using remote sensing techniques. Remote sensing therefore offers the opportunity to estimate the carbon storage of European forests at the regional and continental scale.

Regarding the issue of bio-diversity, remote sensing can supply information about the structure and composition of forests in relation to surrounding land cover types making up the landscape. Techniques could be developed to derive indicators of the condition of forest habitats and their sensitivity to change, which could be linked to biodiversity at the landscape scale.

4.12.8 References

EEC, 2000: Remote Sensing Applications for Forest Health Staus Assessment.

Wolff, B. et al., 1999: Evaluierung des Luftbildeinsatzes im Rahmen des deutschen Level II-Monitorings. Arbeitsbericht BFH, Inst. f. Forstökolgie und Walderfassung, 99/3, Eberswalde.

5. Strategy in view of Integrated Evaluations

5.1 Introduction

The revised objectives mentioned in Chapter 2 still necessitate to keep the approach of so-called Level I plots, that are systematically arranged in a 16 x 16 km grid, and where crown condition soil and foliar surveys are conducted and Level II plots where “Intensive and Continuous Monitoring of Forest Ecosys-tems"” takes place. The Level I plots allow the upscaling of relationships observed at the Level II plots to the European scale and are indispensable for the assessment of changes in forest crown condition at that scale. With the increasing number of surveys and data and with the growing length of the existing time series, the options for integrated evaluations relying on several surveys are now strongly expanding. As up to the present time the causes of observed forest damages have been identified as a complex of multiple stress factors, these kind of evaluations are indispensable tools in order to fulfil the objectives (a), (b), (c) and (d) mentioned in Chapter 2.

5.2 Objectives

Integrated approaches include statistical evaluations applied to data collected within different fields of forest ecosystem research. They aim at the elucidation of relations between tree condition features as response parameters and anthropogenic as well as natural stress factors as predictors. It also includes modelling approaches related to:

- The fate of elements in the forest ecosystem, e.g. the occurrence of N saturation or Al release
- The long term impact of atmospheric inputs and nutrient cycling on soil and soil solution chemistry and thereby on soil and forest sustainability
- The impacts of meteorological factors, soil factors and deposition on tree growth and species diversity of the ground vegetation.

All those modelling approaches, requiring information from surveys related to deposition, meteorology, growth, foliar, ground vegetation, soil and soil solution, are indispensable tools for assessing the impacts of policy decisions regarding deposition reductions.

Another important objective of the

5.3 Methods

Beyond uni- and bivariate statistics, a variety of multivariate methods may be applied to data collected on Level I and Level II plots (cf. LORENZ et al. 1999, DE VRIES et al. 1999) as well as from other sources like e.g. the EMEP project. Multiple regression and ordination were up to now the most often applied methods within the last 10 years (SEIDLING 2000). They will continue to play a considerable role within further studies, by indicating the influencing predictors. If strong interactions between predictors do occur, a combination with principal component or factor analysis is indicated in order to eliminate intercorrelation effects. The application of further multivariate methods (cluster analysis, discrimant analysis, canonical correlation and redundancy analysis and others) might be rectified within the frame of integrated studies and may deliver valuable insights into the complex dependencies of crown condition of forest trees. In this respect the exploration of maximum likelihood methods and other approaches of advanced statistical modelling has to be taken into closer consideration.

Apart from those modelling approaches it is necessary to apply a range of available models relted to soil hydrology, soil chemistry and tree growth. An overview of possible models has been given in the strategy plan for the Intensive Monitoring plots (De Vries, 1999).

5.4 Results

Up to now Integrated evaluations have mostly been carried out at national or regional levels. A recently conducted overview on 23 integrated studies focusing on crown condition (Seidling, 2000) revealed that in the large majority of the available studies either the trans-national systematic Level I gridnet or other mostly national grids were used for the evaluations. Main factors that are statistically influencing defoliation were tree age, herbivore insects and fungi, climatic extremes, air pollutants like sulphur and nitrogen compounds and ozone, as well as acidified or dried out soils.
With the ongoing implementation and data evaluation, integrated evaluations also became feasible at the Intensive Monitoring Plots. For the Level II evaluations, in contrast to Level I, measured instead of modelled data are available on a relative large number of plots. In the latest report (De Vries et al., 2000a) results of regression analyses clearly show that the chracteristics of the forested site and the measured environmental factors (meteorology and atmospheric deposition) at Level II are influencing the condition of the forest ecosystem. The amount of the variance that could be explained by measured data amounted up to 30 – 50% for crown condition, 33 – 71% for chemical foliar contents and 17 – 44% for soil solution.
Modelling studies have also been carried out already. This included a study focusing on N and C sequestration in European forests. The interesting feature of that study is that it includes the generalisation of results obtained at Intensive Monitoring studies to the European scale using level I plot data, thus illustrating the value of both approaches. This was done by combining (i) relationships between the N sequestration in forests versus N deposition and forest floor C:N ratio, based on results following from Intensive Monitoring studies (level II plots), with (ii) available and modelled data N deposition and C:N ratio at level 1 plots (De Vries et al., 2000b)..

5.5 Evaluation and further needs

A general problem within the context of statistical modelling is the discrepancy of plots that can be aggregated to a more or less homogeneous sample and the high number of potential predictors which influence tree condition. On one side the inclusion of additional plots will add further known or unknown sources of variation within the population of plots, on the other side, a reduction of predictors might lead to a significant loss of information. A thorough plot and parameter selection according to functional consideration in ecological terms (e.g. HENDRIKS et al. 1997) or statistical methods like PCA, might partly overcome this discrepancies. Also a clear and distinct structure of hypotheses might gain an increasing weight within further integrated approaches. It can be based on the general knowledge on ecosystems and on the results from process-based models.

Whereas the integrated evaluation of the data can be managed by individual scientists or evaluating teams, the co-ordination of the surveys and harmonisation of parameters which has to be achieved in advance is mostly the task of several Experts and Expert Panels within the Programme Co-ordinating Group of ICP Forests. It does not only include the use of same standards and methods across country borders but has in addition to guarantee that parameters are measured in such a way that they are expressive in various types of evaluations.

In order to work on specific questions arising in recent times two ad hoc groups have been established to elaborate methods for the assessment of (i) litterfall and (ii) biotic and abiotic damage types. Both surveys will assess parameters that contribute to several different evaluations:

- Litterfall sampling will on one hand provide information on the time of needle and leaf shedding. Thus it provides data input for phenological evaluations. On the other hand the amount of shed leaves is connected to the leaf biomass of trees and thus to defoliation estimates. In addition the collected leaf and needle material can be chemically analysed and consequently provides necessary information for the calculation of nutrient and element fluxes in the ecosystem. Finally, a combination of those data with estimates on mineralisation (e.g by interested scientists) allows the estimation of current carbon sequestration, being a key issue with repect to climate change (see objective…)
- Also biotic and abiotic damages are of concern under several aspects. A more detailed survey will firstly be valuable as such, as it will result in information on the presence extend and duration of forest pests and diseases. Secondly information on leaf and needle influencing factors (e.g. leaf eating insects) are a prerequisite not only for the interpretation of crown condition but also for forest growth data as they influence the growth and increment of trees. The biotic and abiotic damages like e.g. storm, hail or fungi attacks will thirdly influence the phenological appearance of forest trees and respective information is thus necessary for the interpretation of phenological observations.

At plots where all surveys are already carried out, it is considered worthwhile to include some additional measurements that allows the adequate assessment of critical loads, such as total soil analyses to derive weathering rates, element contents in stems and braches to derive net uptake rates and soil physical properties to calculate leaching rates.

5.6 Conclusions

Level I and Level II plots with their defined sets of parameters and their widespread spatial distribution over large parts of Europe as well as the increasing length of time series deliver a valuable source for integrated empirical studies. The application of process-based soil, tree or stand related models to the empirical data will provide deeper insight into cause effect relations. The transfer of local or regional findings to larger areas (up-scaling) might also become increasingly possible in the course of those analytical processes (see Chapt. 3.2.).
The integrated evaluation of the existing data as well as of newly generated ones will however require an intensified co-operation of the responsible bodies. In this respect the installation of a permanent subgroup tackling questions of parameter harmonisation and integrated evaluations is considered worthwhile. Such a group should also manage the links to other other research networks, such as those related to biodiversity and carbon sequestration (IPCC, CARBO-EUROPE etc).
The integrated evaluations will also in the future require the necessary funding for specialised statisticians in the evaluating data centres. The complex results will have to be interpreted with caution in such a way that they provide understandable information for the public as well as for policy makers.

5.7 References

DE VRIES, W., REINDS, G.J., DEELSTRA, H.D., KLAP, J.M., VEL, E.M., 1999: Intensive Monitoring of forest ecosystems in Europe. Technical Report 1999. UN/ECE and EC, Geneva, Brussels, 173 p.

DE VRIES, W. G.J. REINDS, M. KERKVOORDE, C.M.A. HENDRIKS, E.E.J.M. LEETERS, C.P. GROSS, J.C.H. VOOGD AND E.M. VEL, 2000a: Intensive Monitoring of Forest Ecosystems in Europe. Technical Report 2000. UN/ECE and EC, Geneva and Brussels, 188 pp.

DE VRIES, W., G.J. REINDS, P. GUNDERSEN AND J.KLAP, 2000B. A CRITICAL REVIEW OF DIFFERENT ESTIMATES FOR THE CURRENT CARBON SEQUESTRATION IN EUROPEAN FOREST SOILS. NATURE (TO BE SUBMITTED)

HENDRIKS, C.M.A., VAN DEN BURG, J., OUDE VOSHAAR, J.H., VAN LEEUWEN, E.P., 1997: Relations between forest condition and stress factors in The Netherlands in 1995. DLO WINAND STARING CENTRE FOR INTEGRATED LAND, SOIL AND WATER RESEARCH, Wageningen, Report 148, 134 p.

LORENZ, M., MÜLLER-EDZARDS, C., BECHER, G., FISCHER, R., DIBBERN, B., 1999: Forest condition in Europe. 1999 Technical Report. UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE, EUROPEAN COMMISSION, Geneva, Brussels, 84 p. + Annexes.

SEIDLING, W., 2000: Multivariate methods within integrated studies on tree crown condition in Europe - an overview. UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE, EUROPEAN COMMISSION, Geneva, Brussels, 56 p. + Annexes

6. Outlook

The successful finalization of the internal review of ICP Forests leads to a revision of the programme scheme. Although important recommendations for improvements of the work of ICP Forests have been gained, reviewing the programme will remain a permanent tasks.

Assessments and quality assurance

In the **field assessments**, concrete projects have been initiated. For example, in the deposition measurements a comparison of the samplers is currently carried out by The Netherlands. A similar study is planned for the comparison of snow samplers. As regards crown condition assessments, a new concept for intercalibration courses is foreseen. Crown condition assessments will be accompanied by quantification of effects of different damage causes to leaves and needles and by the assessment of litterfall. Ad-hoc working groups have been entrusted with the development of adequate methods. To estimate Ozone injuries, a training course will be conducted in September 2000 in Spain. Future ambient air quality measurements will be of increasing importance.

In order to further improve quality assurance in the **laboratories**, several interlaboratory comparisons have been carried out in the past. This important work will be continued. A fourth interlaboratory comparison for foliage chemistry is currently organized by Germany. In the field of water chemistry Italy has offered a second comparison within the AQUACON work. In addition, a workshop for the leaders of the laboratories will be organized in order to further harmonize methods. Finally, an interlaboratory comparison for soil samples will have to be organized prior to the next soil survey. All theses activities will lead to recommendations for proper reference methods and equipment.

The European **data centres** will continue to assure by means of adequate plausibility checks that only tested and correct data will be added to the data bases. In this context, any changes in the methods applied or special events should be reported by the participating countries to the centres by means of data accompanying reports.

Data evaluation

Whilst the **evaluation** of the Level II monitoring results is directed towards identifications of cause-effect relationships at the ecosystem level, the continuation of crown condition, soil and foliar surveys at Level I remains indispensable for further integrated evaluations of large-scale data. For holistic views of the complex interrelationships between the manifold causes and effects characterizing forest condition at the small and at the large scale, the evaluations must not remain confined to the data of ICP Forests and EU, but must make use of all further data and information sources available by other programmes. Specifically, the execution of integrated evaluations of Level I crown, soil and foliar data and relevant external data from other large-scale survey as well as extrapolations of relationships identified for Level II with available data at Level I plots and further improvement of the understanding of cause-effect relationships by means of in-depth studies including literature reviews are important tasks for the future.

Policy implications and co-operation

ICP Forests has until today contributed substantially to the progress achieved within the **Working Group on Effects**. This will remain of major importance also in future.
Also the **co-operation with the European Union** scheme on the protection of forests against atmospheric pollution is of vital interest for ICP Forests and should be continued. ICP Forests should carry on its **co-operation with other programmes under the CLRTAP**, in particular with ICP Integrated Monitoring for ecosystem research, with ICP Mapping for calculating Critical Loads, with ICP Vegetation in the field of ozoneinjury and EMEP in the field of air concentration measurements.

Thus, the pan-european monitoring system of ICP Forests and EU will also in the future offer a unique source of information on the condition of forest ecosystems. The data gathered in this programme and their evaluation will be of fundamental interest for the public, for policy making processes and for the scientific community not only in the field of environmental protection but also for forest policy items, such as sustainable forest management, biodiversity in forests or the effects of climate change on forest ecosystems.

Reporting

The improvement over the last years in presenting the results to the public has been recognised. In particular the **Executive Report** is an important tool to spread the monitoring results obtained. This annual report should remain the basic document for the public. A suggestion to reduce co-ordinating costs would be, that the **Technical Reports** on the results of the crown condition survey at Level I alternate yearly with the Technical Reports on the Level II results.
In comparison to printed media, the Internet will gain increasing importance for the dissemination of results to all target groups. Besides continuously updated basic information on the programme, PCC should regularly provide the latest findings of all surveys on its website.

As a result of the internal and the external review, the new strategy of ICP Forests ensures that the programme will continue to correspond to the long-term priorities of CLRTAP and to play a key role in the monitoring of forest condition in Europe.