UNITED
NATIONS

E

Economic and Social
Council

Distr.
GENERAL

EB.AIR/WG.1/1998/6
17 June 1998

Original: ENGLISH

ECONOMIC COMMISSION FOR EUROPE

EXECUTIVE BODY FOR THE CONVENTION ON
LONG-RANGE TRANSBOUNDARY AIR POLLUTION

Working Group on Effects
(Seventeenth session, 26-28 August 1998)
Item 6 (a) of the provisional agenda

MONITORING OF FOREST CONDITION IN EUROPE

Summary report prepared by the Coordinating Centre of
the International Cooperative Programme on Assessment and Monitoring
of Air Pollution Effects on Forests

Introduction

1. The International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) established two different monitoring systems to assess the changes in forest condition, and its relation to air pollution:

(a) An extensive large-scale monitoring programme on a systematically selected grid of 16 km x 16 km, to monitor annually the crown condition on some 5700 plots, and also to assess the forest soil and forest foliar condition (level I); and

(b) An intensive monitoring network for more detailed assessments, on some 860 permanent forest plots, to monitor tree crown, soil and foliar

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condition, and also assess tree growth, ground vegetation, and measure atmospheric deposition and meteorological conditions (level II).

The results of both are presented with special focus on level II assessments.

I. RESULTS OF THE INTENSIVE MONITORING OF FOREST ECOSYSTEMS IN EUROPE (LEVEL II)

1. Plots selected and surveys conducted

2. To better understand the effects of air pollution and other stress factors on forests, a Pan-European Programme for Intensive and Continuous Monitoring of Forest Ecosystems (level II) has been implemented. 863 observation plots have been selected. In the European Union (EU) 512 plots have been installed. In several non-EU countries, including Belarus, Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Norway, Poland, Romania, Russian Federation (St. Petersburg region), Slovakia, Slovenia and Switzerland, 351 plots have been selected, 250 of which have already been installed. In total 760 plots have been installed.

3. The intensive monitoring programme assesses crown condition, increment and the chemical composition of foliage and soil on all plots. On a limited number of plots (at least 10%), atmospheric deposition, meteorological parameters and soil solution chemistry are assessed. The surveys take place as follows:

- Crown condition assessment (at least once a year);
- Chemical analysis of the contents of needles and leaves (at least every 2 years);
- Soil analysis (every 10 years);
- Increment studies (every 5 years);
- Deposition measurements (continuous);
- Soil solution (continuous);
- Meteorology (continuous);
- Ground vegetation (every 5 years);
- Remote sensing/aerial photography (once).

4. Table 1 gives an overview of the number of selected plots for the main surveys. Several countries also plan to carry out additional surveys on, for instance, phytopathology, litterfall, lichens and/or mosses, mycorrhiza and/or fungi, intensive air quality measurements, etc.

Table 1. Overview of the number of selected plots for the main surveys

Country	Selected plots	Crown condit.	Soil analysis	Foliar analysis	Increm.	Atm. depos.	Meteor. param.	Soil solution	Ground veget.
Total EU	512	512	512	512	510	269	138	188	287[a/]
Non-EU	351	351	343	344	350	227	18	31	211
Total	863	863	855	856	860	496	156	219	498

[a/] Since ground vegetation assessment is mandatory in EU, the number will increase to 512 in the future.

2. Spatial distribution of plots

5. The most important stand characteristic of the forest ecosystem is the tree species. A standard clustering of tree species was used to obtain relatively homogeneous subsets with sufficient numbers of plots [1]. The spatial distribution of the tree species clusters shows (i) a strong concentration of pine (mostly Scots pine) and spruce in northern and central Europe (especially Poland); (ii) a rather even distribution of most broadleaves over Europe except for the northern part (Scandinavia); and (iii) a strong concentration of other conifers and broadleaves in southern Europe.

3. Strategy for a scientific evaluation

6. To evaluate the data in the intensive monitoring database, a strategy plan has been developed based on an evaluation of:

- Clear (long-term) objectives based on the potentially available data in the intensive monitoring database;
- Studies/activities needed to reach the objectives of the level II programme;
- Priorities for data evaluation, based on a review of key parameters, availability of data in time and available tools for data evaluation.

4. Objectives in view of the potentially available data set

7. The level II database will ultimately contain data on:

- Site factors: stand and site characteristics, stand history / management (all plots);
- Stress factors: meteorological data, air pollution/atmospheric deposition data and biotic stress/pests and diseases (a limited number of plots);
- "Ecological" ecosystem condition: crown condition, forest growth, ground vegetation (all plots);
- "Chemical" ecosystem condition: foliar chemistry and soil chemistry (all plots) and soil solution chemistry (a limited number of plots).

8. The ultimate objective of the intensive monitoring programme is to gain insight into the trends in and relationships between site/stress factors and ecosystem condition on a large, European scale. More specifically, the objectives focus on:

- Relationships between site and stress factors and the forest ecosystem condition (**correlative studies**);
- Trends in stress factors and/or ecosystem condition (**trend studies**);
- The fate of atmospheric deposition in the ecosystem in terms of accumulation, release and leaching (**budget studies**);
- Critical loads of atmospheric deposition, related to the chemical ecosystem condition, in relation to present loads (**critical load studies**);

- Future impacts of atmospheric deposition on the chemical ecosystem condition (**future impact studies**);
- The relevance of the results for all investigated plots (at many plots several data will be missing) and on a European scale (**upscaling studies**).

9. The studies needed to reach the objectives are in parentheses. Examples of such studies are presented in [1]. These examples are based on previously executed studies in various countries, using similar data as those obtained on level II. They include examples of (i) correlative studies with crown condition in Norway, the Netherlands and also on a European level; (ii) a trend study on deposition, soil and soil solution chemistry on the national level in Germany; (iii) input-output budget studies for forested sites in Netherlands; (iv) future impact studies related to soil chemistry of integrated monitoring sites in Europe; and (v) an upscaling study related to atmospheric deposition in Europe.

5. Provisional timetable for evaluations

10. A provisional timetable for evaluations has been developed covering the period 1998-2010, based on priorities in view of data availability and evaluation possibilities. As a general rule, studies will first be performed with measured data and the study will only take place when the data are adequate for a reliable study. In a second stage, studies with both measured data and extrapolated data, based on the results of upscaling studies, may be performed. Based on available data and the results from the past period(s) a new evaluation action plan will be defined each year. Priorities for data evaluation have been indicated for the short (1998-2000), medium (2000-2005) and long (2005-2010) term.

11. In the period 1998-2000, the impact of atmospheric deposition on soil solution chemistry may be investigated and preliminary investigations of relationships of site and stress factors with the available crown condition data can be performed. In the period 2000-2005 it will be possible to (i) perform correlative studies between the stress factors and the “ecological” ecosystem condition (crown condition, growth, ground vegetation); and (ii) assess preliminary trend studies based on data from annual surveys for crown condition, foliar chemistry (biannual), soil solution chemistry, meteorology and atmospheric deposition. In the period 2005-2010 it will be possible to (i) assess more in depth trend studies, including 10-year changes in forest growth (based on two repetitions over 5-year intervals) and soil condition (based on one repetition) and their relationship with site and stress factors; and (ii) validate and apply dynamic impact models to predict future trends in soil (solution) chemistry for many sites. These evaluations can only be carried out with the active participation of external institutes.

6. Relevant aspects for data evaluation

(a) Selection of key parameters

12. The number of parameters assessed within the surveys is large, therefore it is necessary to restrict the (first) evaluations to a number of selected key parameters. Key parameters are those parameters that give an adequate description of (i) the ecological and chemical condition of the ecosystem; and (ii) the stresses on that ecosystem. The parameters are all mandatory, except the contents of minor nutrients (Fe, Mn, Cu and Zn) in the foliage and the heavy metal contents in soil.

(b) Representativeness of the data for the intensive monitoring plots: the contents of the database

13. The representativeness of the data set for the variation of the key parameters over the level II plots depends on the coverage of the data and the spatial distribution of the plots. A summary of the plots for which data have been stored and evaluated (data coverage) for the five considered surveys is given in table 2.

Table 2. Review of the numbers of plots used in the evaluation of selected key parameters for the year 1995

Surveys	**Number of plots**	
	Mandatory data	**Optional data**
Crown condition	422	---
Soil (Organic layer)	312	112
Soil (Mineral layer)	310	174
Foliar composition	437	318
Increment	283	283
Deposition	91	---

14. The number of plots for which data have been stored and evaluated for the year 1995 varied from 283 to 422 in the surveys on crown and soil condition, foliar composition and increment. This implies that the results of selected mandatory (key) parameters within these surveys give a reasonable indication of the variation over the level II plots. The number of plots for the optional key parameters in the soil survey (humus layer and mineral topsoil: heavy metals) and the mandatory key parameters in the deposition survey is low (50-100), which hinders the interpretation in terms of effects of stand and site characteristics.

(c) Reliability of the data: the number of observations

15. The reliability of the data depends strongly on the data assessment methods. In this context, the number of observations or samples is very

important. In general, the number of observations needed to derive a reliable plot-mean value of a selected key parameter increases as the spatial variation over the plot increases. An indication of the variation, in terms of relative standard deviation, for the various surveys has been derived from the data on individual trees (crown and increment survey) and from the literature (soil, foliar and deposition survey). This information can be used to derive a plot-mean value with a certain reliability or margin of error.

16. A first comparison of the numbers of observations required to derive a reliable plot-mean value with a maximum standard error of 20% relative to the mean and the actual numbers used, showed that both ranges coincide very well for most of the surveys. For increment parameters, the standard error of the plot-mean value is generally lower (an error below 20%) due to the relatively large number of observation trees. More work, however, needs to be done to gain better insight into the adequacy of the number of observations or samples in each survey. This includes an evaluation of the relative standard deviation for the soil, foliar and deposition data, to improve the estimates of required sample numbers.

(d) Comparability of the data: the data assessment methods

17. The comparability of data is influenced by the comparability of data assessment methods in terms of, for instance, the definition of the assessable crown (defoliation, discolouration), the type (Kraft classes) of trees that were used for the assessments (crown, foliar, increment), the sampling devices (specifically deposition) and the digestion and analysis methods (specifically soil and foliar composition). There are clear differences in, for instance, the definition of the assessable crown, Kraft classes of trees and in sampling devices. It is, however, not always clear what the effects of these differences are on the comparability of data.

18. With respect to the digestion and analysis methods, in most cases reference methods were used, or methods that most likely will lead to comparable results. Results of interlaboratory comparisons for the soil, foliar composition and major ions in deposition generally indicate a reasonable to good transnational comparability of the digestion and analysis methods. Notable exceptions are the total contents of Ca, Mg, K and Na and heavy metals in soil and the foliar S content, for which the intercomparability appears to be problematic.

7. Results of key parameters in single surveys

19. For each of the five core surveys, the results of selected key parameters are presented. The results of soil solution and meteorology are not yet given, since the first data of these new assessments were submitted only at the end of 1997 and are now under validation. Ground vegetation has not yet been submitted as it only starts in 1998. It should be kept in mind that the results are based on part of the intensive monitoring plots. This holds specifically for the deposition data and the optional soil and increment data, which are mostly based on fewer than 100 plots (see table 2). Even though the

other data sets are more representative of the intensive monitoring plots, the results do not give a statistically representative overview of Europe.

(a) Crown condition

20. Table 3 presents the assessed defoliation in 1995 on plot level for broadleaves and conifers.

Table 3. Distribution of the plot-mean defoliation values over the traditional defoliation classes[a/]

Species	**Number of plots**	**Proportion per defoliation class (%)**			
		0-10%	**10-25%**	**25-60%**	**60-100%**
All conifers	346	32.4	48.3	18.5	0.9
All broadleaves	196	20.4	41.3	35.7	2.6
All trees	542	28.0	45.8	24.7	1.5

a/ The results may be affected by the differences in assessment standards in the various countries.

21. Most defoliation values (74%) occurred in the 0-25% range. Discolouration occurred only at ca. 10% of the plots. The percentage of plots with conifers with a defoliation >25% was 19.3, which is lower than the percentage observed in 1995 at the level I plots (25.5%). Inversely, the percentage of plots with broadleaves with a defoliation >25% stood at 38.3, which is higher than the percentage of the level I plots observed in 1995 (25.0%). These deviations show that the limited number of level II plots should not be used to obtain a Europe-wide perspective because of (i) the non-systematic character of intensive monitoring; and (ii) the different distributions of the plots over the various tree species and countries.

(b) Soil condition

22. The results that are presented focus on the major nutrient ratios (C/N and C/P), the acidity status (pH_{CaCl2} and base saturation) and the heavy metal contents (Pb, Cd, Cu and Zn) of the humus layer and mineral soil. C/N and C/P ratios give some indication of the availability of N and P by net mineralization. The acidity status is relevant in terms of the availability of base cation nutrients versus toxic aluminium. The heavy metal contents are relevant because of their potential toxic effects on soil organisms that are responsible for the decomposition of organic matter and the mineralization of nutrients, among other reasons.

23. The results are classified in terms of low, medium and high values for the various key factors in tables 4, 5 and 6. Approximately 40% of the humus layers had a C/N ratio above 30 (table 4). It is likely that N is largely

retained, and that N leaching is strongly limited at those sites. Inversely, the C/N ratio was less than 20 in approximately 15% of the sites, which implies a risk of high N leaching. Similar results were obtained for the level I plots [2].

Table 4. Percentage of sites in the classes 'low', 'medium' and 'high' of the C/N and C/P ratio in the humus layer

Class[a/]	**C/N ratio (N = 312)**		**C/P ratio (N = 161)**	
	Class	%	Class	%
Low	< 20	15.4	< 100	0.0
Medium	20 – 30	44.9	100 - 200	6.8
High	> 30	39.1	> 200	93.2

[a/] Low = high risk for NO_3 leaching; Medium = risk for NO_3 leaching; High = low risk for NO_3 leaching.

24. Approximately 22% of the soils are in a range where the acid input is mainly buffered by the release of toxic Al (base saturation < 10%). Another 29% of the soils are in a range with a high risk of Al buffering (10% < base saturation < 25%), whereas the risk of Al release is likely to be low in approximately half the soils (base saturation > 25%; table 5). Again, the results are comparable to those obtained for approximately 3000 level I plots [3].

Table 5. Percentage of observations in the classes 'low', 'medium' and 'high' of the pH_{CaCl2} and the base saturation in the mineral topsoil

Class[a/]	**pH($CaCl_2$) (N=310)**		**Base saturation (N=283)**	
	Class	%	Class	%
Low	< 3.5	13.2	<10%	21.6
Medium	3.5 - 4.5	59.0	10-25%	28.7
High	> 4.5	24.5	>25%	48.6

[a/] Low = high risk for toxic Al release; Medium = risk for toxic Al release; High = (very) low risk for toxic Al release.

25. Pb and Cu contents were high, compared to background levels, at more than 90% of the plots. For Cd and Zn, this number was lower: 59% and 83%, respectively. The area exceeding the critical value for effects on soil organisms was negligible for Cd but quite substantial for Cu (24%). There were also a few plots whose Pb and Zn contents exceeded the critical value (table 6). It has to be noted that sites of high leaching of heavy metals are not considered here. Specifically Cd and Zn may be mobile under acidic circumstances.

Table 6. Percentage of observations in the classes ‘low’, ‘normal’ and ‘high’ of the heavy metal contents in the humus layer

Class[a/]	**Pb (N = 91)**	**Cd (N = 69)**	**Cu (N = 89)**	**Zn (N = 86)**
Low	4.4	37.7	3.4	17.4
Normal	83.5	59.4	69.7	77.9
High	8.8	0.0	23.6	4.7

[a/] Low: background level; Normal: between background and critical level; High: above critical level.

26. The risk classes indicated above are just an indication as they depend on the critical levels used. Nevertheless, the results indicate that the data set contains plots for which it is worthwhile to study impacts of (i) N deposition on N cycling and leaching; (ii) acid deposition on the aluminium release; and (iii) metal inputs on the accumulation and release of heavy metals. These studies are also important because comparable results with respect to C/N ratios and acidity status were found at 3000 level I plots.

(c) Foliar composition

27. With the exception of P, the contents of all major nutrients (N, S, Ca, Mg and K) were generally higher in the broadleaves (beech, oak) than in the conifers (pine, spruce). This is a common observation, related to the higher nutrient demands of broadleaves compared to conifers. To classify the results of foliar contents of major nutrients in terms of low, normal or adequate and high availability for forest growth, use was made of criteria given in [3]. The results for the major nutrients show that:

- High N contents in foliage were observed in ca. 28% of the plots, whereas the N contents were low in ca. 14% of the plots. High values were more often observed in the broadleaves (46%) than in the conifers (15%);
- High S contents were hardly observed (4%). Instead, most S contents in the foliage of conifers (67%) appeared to be low;
- Low foliar contents of P and of the base cations Ca, Mg and K were observed in only 3-12% of all plots, depending on the element considered. Relative deficiencies were less frequent in conifers than in broadleaves.

28. High ratios of N compared to P, Ca, Mg and K were observed only in approximately 1-6% of all plots, depending on the ratio considered. Foliar contents of minor nutrients were predominantly normal (85-90%). These results are comparable for 1400 level I plots, except for the relatively large number of plots with high N contents. Because of this comparability, the results of studies of foliage on intensive monitoring plots might also be valuable for the level I monitoring programme.

(d) Deposition

29. Because most countries started their deposition monitoring in 1995 or even later, the number of plots with deposition data is limited (about 50-60). The computed element fluxes of S and N compounds in bulk deposition and throughfall are given in figure 1.

30. On most plots, the observed total N fluxes in bulk deposition were higher than the S fluxes. Even though for throughfall the reverse was true, this does not necessarily imply that total S inputs are generally higher than total N inputs, since both NH_4 and NO_3 are taken up by the forest canopy. In general, both N and S fluxes were relatively low (mostly below 25 kg . ha^{-1} . yr^{-1}), since most of the investigated plots were not located in high-deposition areas. It should be kept in mind that the data set for 1995 was limited to a small number of plots. More in-depth evaluations with respect to deposition can be made in the future when more data become available.

8. Relationships between selected parameters in various surveys

31. A first investigation was made of the influence of various stand and site characteristics on the selected key parameters in the five mandatory surveys. Its results supported the hypothesis that it is relevant to include those characteristics in any correlative study. Tree species appeared to be highly significant for all selected key parameters. The same is true for the climatic region, with the exception of certain foliar contents. The effect of soil type, altitude and stand age (when included) on the key parameters appeared to vary from insignificant to highly significant. As expected, the variation in key parameters that was explained by the considered stand and site characteristics was lower for crown condition (for defoliation approximately 25%) than for the chemistry of soil foliage and deposition (40-80%), since crown condition is influenced by many more stress factors.

32. N and S deposition appeared to be highly significant predictor variables for the foliar N and S contents and the N content on the humus layer. Unlike N and S, the influence of base cation (Ca, Mg, K) deposition on the base cation contents in foliage and in the humus layer was mostly insignificant or slightly significant. Instead, there was a highly significant relationship between the base cation contents in the foliage and in the humus layer. These findings indicate that N and S deposition have a strong influence on the availability of these nutrients, whereas the soil is a dominating source of base cations. This is consistent with the fact that most N and S in the soil is ultimately derived from the atmosphere.

II. RESULTS OF THE LEVEL I MONITORING OF FOREST CONDITION IN EUROPE

1. Soil

33. After the level I soil condition report of 1997 [4], data from more plots became available. These data were used for further evaluations of the

soil condition in Europe, and to analyse the relationship between soil and crown condition.

(a) Acidity status

34. The pH is an important parameter characterizing the acidity status of a soil, and the site quality for tree growth. Extremely acid topsoil conditions (pH < 3.0) occur mainly in the countries of central and eastern Europe, in Germany, Poland, in the mountains in the north of the Czech and Slovak Republics, in the Carpathian mountains in Romania and in southern Estonia. Acid conditions with pH between 3.0 and 3.5 are frequently found in the same regions but also in central Sweden and southern Norway. Almost half of the forest soils in Europe fall in the pH 3.5 - 4.5 range. Values between pH 4.5 and pH 6.0, indicating weathering of silicate minerals as the major source for buffering of acids [5] – produced internally or from deposition - are rare. This suggests that silicate weathering, although it constitutes a large pool for buffering of acids, is rarely the buffer mechanism that determines the pH in forest soils, due to its slow reaction. High pH values (pH≥ 6.0), indicating the presence of calcareous parent materials or semi-arid climatic conditions, are located mostly around the Alps, in southern France, eastern Spain and Italy, but also in Hungary, southeast Romania and near the Baltic coast of Estonia.

(b) Soil conditions in relation to tree species

35. For the evaluation of differences in soil conditions in relation to tree species, plots were selected which are common to the crown condition and soil condition databases, having Norway spruce (Picea abies), Scots pine (Pinus sylvestris), Common beech (Fagus sylvatica) or oak (Quercus robur and Q. petraea) as dominant species, covering at least 50% of the stand, and where the crown condition was monitored continuously between 1992 and 1997. This procedure ascertains a sufficiently large number of observations for statistical analysis.

Table 7. Availability of soil condition data at the common plots with > 50% of the main tree species

	pH			**Exchangeable base cations**		**C/N ratio**			**Total Mg**
Species	**O**	**M1**	**M2**	**M1**	**M2**	**O**	**M1**	**M2**	**O**
Fagus sylvatica	162	204	198	130	125	196	203	194	195
Q.robur, Q.petraea	98	189	182	150	141	180	189	181	179
Pinus sylvestris	554	573	551	516	496	578	559	535	420
Picea abies	539	576	558	524	507	554	565	548	448
Total common plots	**1353**	**1542**	**1489**	**1320**	**1269**	**1508**	**1516**	**1458**	**1242**
Total reference plots	**2802**	**3327**	**3315**	**2543**	**2446**	**3178**	**3388**	**3264**	**2738**

O: organic layer (consisting of litter and humus); M1: mineral surface layer (0-5 or 0-10 cm layer); M2: mineral subsurface layer (10-20 or 10-30cm layer)

36. The acid/base status in terms of pH values and exchangeable base cations (Ca, Mg, K and Na), and the Mg content and the C/N ratio are compared between these plot groups individually, and with the average European forest soil conditions, used as reference. Because national differences in assessment methods affect the data comparability, the average European situation is derived from results in those countries that are also represented in the common plots' data set (all EU countries except Sweden, and Czech Republic, Hungary, Lithuania, Norway, Poland, Romania, Slovakia, and Switzerland).

(c) Acidity

37. Inherent differences in base content of the litter of tree species have a marked influence on soil acidity. On the other hand, trees with higher nutrient requirements, like broadleaves, are planted on those sites where their demands can be met. In the surface mineral layer, but more so in the organic layer, significant differences in acidity between species become evident. For all layers the presentation according to buffer ranges was chosen for comparison purposes, although they are not valid for organic layers, where buffering occurs through dissociation of organic acids. About 80-90% of the organic layers of coniferous stands have a pH of 4.2 or less, while this level of acidity occurs only in 50% of the oak stands and in 39% of the beech stands. In conifer stands the 0-10cm layer of the mineral soil was similarly acidic, whereas in beech and oak stands the surface mineral layer was more acidic (60% < pH 4.2) than the organic layer. The distribution of pH values in subsurface mineral layers does not differ greatly among the species groups, but more or less corresponds to the average European situation.

38. The statistical significance of differences between the paired species groups was tested with the non-parametric Mann-Whitney test. Significant differences in organic layer pH could be detected between all paired groups except beech-oak and pine-spruce. In the subsurface layer only the oak-pine and pine-spruce pairs showed significant pH differences. Soil reaction at the soil surface is strongly influenced by the plant community.

(d) Base cations

39. Figure 2 indicates that beech and oak stands occur on soils with a wide range of base saturation (BS)(percentage of base cations at the exchange complex = BS in %) in the surface, as well as in the subsurface mineral layer. Median values are around 60-70% and 40-60%, respectively. Soils growing coniferous forests have generally a lower and narrower (50% of the values are within the box) range of base saturation, with medians around 20% BS. While the difference in BS between surface and subsurface mineral layers is negligible in coniferous stands, a considerable increase in BS towards the soil surface occurs in broad-leaved stands. Median values for oak stands increase from 37% in the subsurface layer to 70% in the surface layer (figure 2a). The differences in base saturation are always insignificant between the broadleaves and between the conifers, whereas broadleaf – conifer pairs differ significantly.

40. Also the contents of exchangeable base cations (base cation contents = BCE in $cmol_c \cdot kg^{-1}$) show highly significant differences among species, indicating the varying nutrient requirements of the species considered. Only the differences between beech and oak in the upper mineral layers are not significant. Median values of BCE in the subsurface layer steeply increase in the sequence: pine (0.6 $cmol_c \cdot kg^{-1}$) < spruce (1.4 $cmol_c \cdot kg^{-1}$) < oak (3.8 $cmol_c \cdot kg^{-1}$) < beech (5.7 $cmol_c \cdot kg^{-1}$). On conifer sites nearly no differences are found between upper mineral layer and subsurface layer, whereas under deciduous forest the base contents in the 0-10 cm layer tend to be slightly higher, which may be attributed to differences in base cation input through litterfall between broadleaves and conifers.

(e) Magnesium content in organic layer

41. The humus types differ between forests with broadleaves and conifers. Whereas pine and spruce sites have mostly unfavourable types like mor or moder, indicating a slower decomposition of organic materials, sites with beech and oak have more frequently mull humus. The magnesium contents of the organic layer reflect this relation. The influence of litter composition is demonstrated by differences observed in the range between 25th and 75th percentile values of plots clustered by vegetation type. Organic layers of beech stands (1200-2600 mg . kg^{-1}) are usually high in Mg, oak (1000-1900 mg . kg^{-1}) and spruce (650-1800 mg . kg^{-1}) stands occupy intermediate sections of the overall range, while organic layers of pine stands (450-1200 mg . kg^{-1}) are particularly poor in Mg. Occasionally values above 10,000 mg . kg^{-1} may occur at plots on Mg-rich parent materials.

(f) C/N ratio

42. The quality of the humus, described by a low C/N ratio, is the highest in beech stands, intermediate in oak and spruce stands and the lowest in pine forests. All species pairs show highly significant differences in distribution, except the oak-spruce pair for the organic layer and the beech-oak pair for the surface and subsurface mineral layer. It is remarkable that differences in humus quality between forest types, expected in the organic layer, also persist in the mineral soil.

Table 8. Comparison of percentile values of the C/N ratio in organic, surface and subsurface mineral layer under different vegetation types

	Percentile values of the C/N ratio (organic/surface/subsurface)				
Species	**5th**	**25th**	**50th**	**75th**	**95th**
Beech	10/9/7	18/13/11	22/15/13	27/18/17	40/23/26
Oak	15/11/8	20/13/11	24/16/13	32/19/18	40/30/27
Pine	20/12/9	25/18/15	31/23/21	40/29/28	53/45/47
Spruce	16/12/9	22/16/13	25/19/18	30/23/22	39/35/34

2. Forest foliar condition

43. After the Foliar Condition Report of 1997 [3], data of additional plots became available. These data were used to evaluate further the nutrient status of common beech (Fagus sylvatica). Since the foliar survey was carried out in the various countries in different years, only the nitrogen and magnesium concentrations in beech leaves for the years 1992-1995 were assessed.

44. The nitrogen and magnesium values for common beeches vary widely. The highest nitrogen contents, exceeding the class limit of 25 mg/g, are found in the United Kingdom, Germany (Lower Saxony) and partly in Spain; the lowest mostly in Bulgaria and Slovakia.

45. Low Mg concentrations were found in Belgium (Wallonia), Germany (Lower Saxony) and Spain (mean of these plots was < 1.3 mg/g; according to [6] optimum Mg supply can be assumed only if Mg contents of leaves exceed 1.5 mg/g). The lowest Mg concentrations are mostly combined with medium-range nitrogen contents. High nitrogen contents are in general connected to magnesium concentrations in the medium and higher ranges. Due to the low data availability, only tendencies can be discerned and any further interpretation is limited.

III. CONCLUSIONS AND RECOMMENDATIONS

46. The common monitoring of UN/ECE (ICP Forests) and EU aims to detect the impact of air pollution on forest condition. ICP Forests now represents one of the largest biomonitoring systems worldwide. The two levels of monitoring – the large-scale monitoring of relatively simple key parameters on the **systematic 16 km x 16 km grid net (level I)** like crown condition, soil condition and element contents in the trees’ needles and leaves, and the **intensive monitoring programme (level II)** – have different aims.

47. The large-scale extensive monitoring provides the identification of spatial-temporal trends in crown condition. The results of soil and foliar analyses on mostly the same plots provide additional possibilities for combining the information and relating the detected trends to certain environmental factor combinations. This yields a more **holistic picture** of the forest condition on the large scale and the probable processes involved. However, the quality of the relations found depends largely on the kind and quality of the data available, as well as on the spatial scale. All studies have in common that the dependency of crown condition on natural and/or anthropogenic **stressors** could be verified on each scale considered.

48. The presentation of the **1997 results of the crown condition survey** focused on time series. On the European scale, different developments of crown condition can be discerned, depending on regions, species, or various subsamples of species groups and ecological site conditions. All assessed species show a general deterioration in crown condition, even if recent recuperations were found for Scots pine (Pinus sylvestris) and Norway spruce (Picea abies) in parts of central Europe.

49. As regards the **foliar survey**, the highest N contents in common beech in the years 1992-1995 were found in the United Kingdom, Germany and Spain. The results from beech (1992-1995) are consistent with the results from the other tree species foliage report of 1997.

50. The **soil condition survey** reveals that a wide range of pH values in subsurface mineral layers is tolerated by both conifers and broadleaves, and that broad-leaved stands usually grow on soils rich in exchangeable basic cations. Naturally, the influence of vegetation on chemical soil characteristics is most apparent in the organic layer. The acidifying effect of organic matter on the soil surface is stronger for humus derived from conifers than for humus under broad-leaved stands, often leading to very acid conditions in organic layers at coniferous stands. Inputs of basic cations through litterfall result in relatively high base saturations in surface mineral layers as compared to subsurface layers, particularly in broad-leaved forests. Vegetation type affects humus quality in both organic and mineral layers. Beech forests seem to produce the highest humus quality, indicated by a low C/N value and a high Mg content, followed by oak and spruce forests. Organic layers of pine stands are usually associated with high C/N values and low Mg contents, pointing to low site quality.

51. In 1998 the first results of the **intensive monitoring (level II)** for the year 1995 were evaluated and presented. The major conclusions and recommendations can be summarized as follows:

(a) The intensive monitoring programme currently consists of 760 plots, which forms a good basis for future evaluation studies. Even for evaluations that include meteorological and soil solution a sufficient number of plots is likely to be available;

(b) The current evaluation strategy comprises several phases. Evaluations will include effects of site and stress factors on all relevant parts of the ecosystem such as forest growth, ground vegetation and the chemical status of soil and foliage. The evaluation plan will be subject to further development, depending on new insights and results from studies. It is important that key parameters are carefully selected and their comparability is ensured. Studies on comparability of methods by the relevant expert panels are important and recommended;

(c) Results from the soil survey indicate that (i) at least 15% of the plots have C/N ratios that indicate high N leaching; (ii) at least 20 to 50% of the plots are in a base saturation and pH range where the release of toxic Al may be significant; and (iii) 5-25% of the plots have contents of either Pb, Cu or Zn above a critical level related to effects on soil microbiota. This indicates that the data set contains plots for which it is worthwhile to study impacts of N deposition on N cycling and leaching and of acid deposition on the aluminium release. Furthermore, it is also relevant to consider the accumulation and release of heavy metals. These studies are also important because comparable results with respect to C/N ratios and acidity status were found at 3000 level I plots;

(d) The foliar contents of major nutrients are mainly (50%-90%, depending on the element) in the normal range. High values were relatively often observed for the foliar N, Ca and Mg contents and low values for the foliar S contents. Foliar contents of minor nutrients were predominantly in the normal range (85-90%). Results are comparable for 1400 level I plots except for the relative large number of plots with high N contents. Because of this comparability, results of studies with respect to foliage on intensive monitoring plots might also be valuable for the level I monitoring programme;

(e) The most important parameters for forest growth were assessed on 273-478 plots. On most plots, the observed total N fluxes in bulk deposition were higher than the S fluxes. Even though for throughfall the reverse was true. This does not necessarily imply that total S inputs are generally higher than total N inputs, since both NH_4 and NO_3 are taken up by the forest canopy. It should be kept in mind that the data set for 1995 was limited to a small number of plots. More in-depth evaluations with respect to deposition can be made in the future when more data become available;

(f) Results from the various surveys indicate a need to study the impact of N deposition on N availability in soil and foliage. This can be derived from (i) the comparatively high N deposition fluxes compared to S; (ii) the relatively high number of plots with C/N ratios indicating N saturation and elevated NO_3 leaching; and (iii) the significant impact of N deposition on foliar N contents. When soil solution data become available in the coming year, studies between N deposition and N output based on soil solution concentrations can be made. In this context, it is relevant to combine such studies with literature information on the relevance of increased N contents in foliage as an indicator of stresses on the ecosystem. Examples are: (i) increased sensitivity to drought, frost and fungal diseases; and (ii) adverse effects on the N metabolism;

(g) It is recommended that studies for the level II plots in the near future focus on the assessment of critical loads for S and N (acidity) based on the evaluation of the fate of these pollutants by means of input-ouput budgets. This implies the use of data from the surveys on atmospheric deposition, meteorology and soil solution.

IV. REFERENCES

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Note: These references are reproduced in the form in which they were received by the secretariat.

(a) (b)

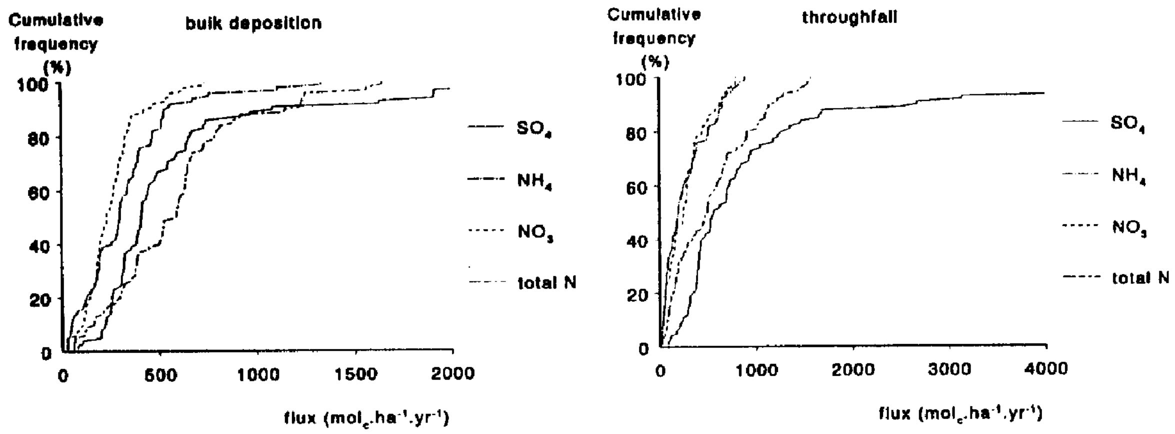

Figure 1. Cumulative frequency distributions of the bulk deposition (a); and throughfall fluxes (b), of SO_4, NH_4, NO_3 and total N

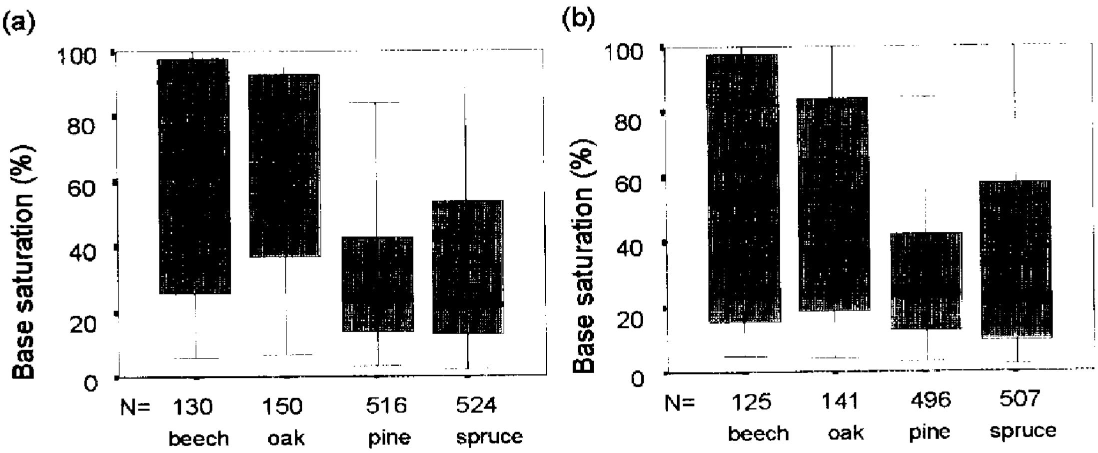

Figure 2. Base saturation of surface (a) and subsurface mineral layer (b) at different stands