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

United Nations
Economic Commision
for Europe

European Commission

Forest Foliar Condition in Europe

Results of large-scale foliar chemistry surveys 1995

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Abstract

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The present paper reports about the establishment of the foliar database, the data integrity checks, and the evaluation of the forest foliar chemistry surveys on level I. The report is based on the results from 16 European countries. The surveys were made in 1995, but data from previous year (1987-1994) were also included in the evaluation. On the basis of these results recommendations for the years to come are given.

Keywords: forest, foliar chemistry surveys, nutrients, sulphur, level I

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Preface

The concern about an increased observation of unknown forest damage in Europe lead in the 1980's to the establishment of two European programmes on the protection of forests against atmospheric pollution and other stress factor: The International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) and the European Union Scheme on the Protection of Forests against Atmospheric Pollution. In the framework of these two programmes a large-scale transnational monitoring network (level I) was established. On this grid, annual crown condition surveys have been carried out since 1986/87. In addition to these observations a survey of the forest soil condition and a survey of the chemical content of needles and leaves were carried out. 16 European countries participated in the foliar survey of the systematic grid and submitted their results to the Forest Foliar Coordinating Centre (FFCC) set up at the Austrian Federal Forest Research Centre (Vienna). The major activities of FFCC were the storage, quality control, evaluation and presentation of the received data. The preparation of the present report was made possible thanks to

- the submission of data and reports by the participating countries to FFCC
- financial support granted by the Austrian Government and the European Commission (EC)
- the advice given by the Foliar Expert Panel
- the scientific work carried out by FFCC.

Summary

This report summarizes the results of the first survey of the chemical content of needles and leaves carried out on the systematic grid (16x16 km; level I) in the framework of the International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) and the European Union Scheme on the Protection of Forests against Atmospheric Pollution.

The needle and leaf analytical data provide information on the actual nutrient state of forest trees on a European-wide basis, and also any possible nutrient imbalances that may be of importance in connection with *new-type forest damage*. In addition, such data can also be used as indicators to assess the site specific stress situation caused by air pollution and air-borne depositions. Correlative studies with other datasets within the ICP-Framework (Crown and Soil Condition datasets) is also possible.

The foliar database contains information on 1395 plots in 16 European countries (Austria, Belgium-*Wallonia*, Bulgaria, Croatia, Czech Republik, Finland, Germany, Ireland, Italy, Lithuania, Norway, Russia-*St. Petersburg Region*, Slovakia, Slovenia, Spain and United Kingdom). The survey was carried out using a common methodology. The comparability of the data was ensured by means of two intercalibration tests, which demostrated that macronutrients with a slight exeption for sulphur and some micronutrient concentrations could be compared across participating countries.

The first evaluation of the data showed that a wide range in foliar nutrient concentrations exists in the countries in Europe. Generally, most plots have an adequate nutrient status. In a relative high number of plots in Germany, Slovakia and from United Kingdom high levels of nitrogen and sulphur were found. The results of German Lands with high air pollution-related nitrogen and sulphur values give the evaluation of the nutrient and air pollution situation a different dimension than if only the results of 1995 (Germany-*Lower Saxony*) are considered. In contrast, in an important number of plots low nitrogen concentrations were observed especially in Bulgaria, Croatia, Finland, Lithuania, Norway and Russia - *St. Petersburg Region.*

1 INTRODUCTION

Since the first appearance of the symptoms of the new type of forest damage, disturbances in the tree nutrition were taken into account in the explanation attempts (BÄUMLER et.al. 1995, BONNEAU 1989a, 1989b, BONNEAU & LANDMANN 1988, BOSCH 1986, BOSCH et al. 1983, van den BURG 1990a, CAPE et al. 1990, van DIJK & ROELOFS 1988, DONAUBAUER 1989, FREER-SMITH et al 1989, FÜRST 1994, GRESZTA et al. 1989, HARTMANN & THOMAS 1993, HÜTTL 1985, 1987, HÜTTL & ZÖTTL 1985, HÜTTL & MEHNE 1988, ISERMANN 1985, KREUTZER & BITTERSOHL 1986, LANDMANN et al. 1987, LANDOLT et al. 1984, LIU & HÜTTL 1991, LEONARDI & FLÜCKIGER 1986, MATERNA 1988, 1989, MOHREN et al. 1986, ORTLOFF & SCHLÄPFER 1996, PRINZ et al. 1985, REHFUESS 1983, 1989, RIEBELING 1992, ROELOFS et al. 1985, STEFAN 1987, 1989, 1991a, 1992, 1993, 1994a, 1994b, 1995a, 1995b, ZECH et al. 1983, 1985, ZÖTTL 1985, ZÖTTL & MIES 1983, ZÖTTL & HÜTTL 1985, 1986). This assumptions were supported by the observations in many regions, that damaged tree shows low magnesium concentrations in leaves and needles, often combined with optimal or high nitrogen concentrations (EVERS 1994, HANTSCHEL et al. 1988, HÜTTL & WISNIEWSKI 1987, KAUPENJOHANN et al. 1987, REEMTSMA 1986, ZECH & POPP 1983). However, investigations on a larger European scale were lacking.
In order to improve the understanding of the role of atmospheric pollution in relation to crown condition and the nutritional status of the trees, the foliar and soil surveys were designed. In 1994 the methods of the harmonized sampling and analysis of foliage were agreed upon. The execution of the foliar survey was optional. Not all European countries were able to participate in the survey. This was mainly due the heavy work load at that time of the survey (the soil condition survey and the installation of intensive monitoring plots). The methods to be applied in the investigation were discussed in three meetings of Expert Panels on Foliar Analysis. Common methodologies were documented in the "Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests" (ICP-Forests) and in Regulation (EC) No.836/94 (European Union). The objectives of the foliar survey were:

- to establish a database for nutrient concentrations of the tree foliage of the level I plots and ensure comparability of the submitted data,
- to describe the nutrient status,
- to detect shortages, disturbances or imbalances in tree nutrition and
- to provide the basis for future correlative studies between the foliar data and other datasets (e.g. crown condition and soil).

2 METHODOLOGY

2.1 FOLIAR SURVEY METHODS

Leaf and needle analytical investigations on Level I plots were optional and participating countries are free to carry them out on the transnational 16x16 km network according to the ICP Programme Manual (UN/ECE,1994) and the Commission Regulation No. 836/94. The field and laboratory work of the programme was undertaken by the National Focal Centres (NFCs).

On the Level I plots the determination of the elements nitrogen, sulphur, phosphorus, calcium, and magnesium was mandatory; that of sodium, zinc, manganese, iron, copper, lead, aluminium, and boron was optional. The applied methods of analysis are given in Tables 2-1a and 2-1b.

Table 2-1a: Applied methods of pretreatment and analysis (methode code see Table 2-2)

Country	**S**	**N**	**P**	**K**	**Ca**	**Mg**
Austria	1/13	1/13	3.7/31	3.7/31	3.7/31	3.7/31
Belgium-*Wallonia*	3.3/50	8.1/70	6.1/31	6.1/31	6.1/31	6.1/31
Bulgaria		8.2/14	6.1/55	6.1/20	6.1/20	6.1/20
Czech Rep.	5.4/31	8.1/50	5.4/31	5.4/31	5.4/31	5.4/31
Finland	3.2/31	1/13	3.2/31	3.2/31	3.2/31	3.2/31
Germany-*Lower Saxony*	4.1/31	1/10	4.1/31	4.1/31	4.1/31	4.1/31
Ireland		8.3/52*	8.3/54*	8.3/20	8.3/20	8.3/20
Italy	1/10	1/13	5.4/54	5.4/20	5.4/20	5.4/20
Italy-*South Tyrol*	5.4/31**	1/11**	5.4/31**	5.4/31**	5.4/31**	5.4/31**
Lithuania	3.2/71	8.2/14	6/50	6/30	6/20	6/20
Russia-*St. Petersburg Reg.*	1/41***	0/70***	3.1/32	3.1/32	1/41***	3.1/32
Slovakia	1/13	1/13		3.5/20	3.5/20	3.5/20
Slovenia	6/72	8/70	3.3/54	3.3/30	3.3/20	3.3/20
Spain	1/13	1/13	5.5/31	5.5/30	5.5/31	5.5/31
United Kingdom	1/41***	8.3/51	3.8/51	3.8/31	3.8/31	3.8/31

* FFCC has no information about the analytical method used for the Level I survey.
** FFCC has no information about the method applied in the 2nd interlaboratory test.
*** There are different methods used for the 2nd interlaboratory test and the Level I survey.

In addition to these data, national reports were to be prepared, containing both general information about the investigation and details about sampling, preparation of samples, analyses, and evaluation of the data (see Annex A). Item 2.3 describes how and to which degree the analytical methods of the individual countries affected comparability across Europe. The data were to be provided in a uniform format, as described in the ICP Programme Manual (UN/ECE, 1994) and in the Commission Regulation No. 836/94. The deadline for submission of the data was June 30, 1996.

Table 2-1b: Applied methods of pretreatment and analysis for the optional parameters (methode code see Table 2-2)

Country	**Na**	**Zn**	**Mn**	**Fe**	**Cu**	**Pb**	**Al**	**B**
Austria		3.7/31	3.7/31	3.7/31				
Belgium-*Wallonia*								
Bulgaria		6.1/20	6.1/20	6.1/20	6.1/20	6.1/20		
Czech Rep.	5.4/31	5.4/31	5.4/31	5.4/31	5.4/31			
Finland		3.2/31	3.2/31	3.2/31	3.2/31		3.2/31	6/57
Germany-*Lower Saxony*	4.1/31	4.1/31	4.1/31	4.1/31	4.1/21	4.1/21	4.1/31	
Ireland								
Italy								
Italy-*South Tyrol*	5.4/31**	5.4/31**	5.4/31**	5.4/31**	5.4/31**	5.4/31**	5.4/31**	5.4/31**
Lithuania	6/30	6/20	6/20	6/20	6/20	6/20	6/20	6/20
Russia-*St. Petersburg Reg*.	3.1/32	3.1/32	3.1/32	3.1/32	3.1/32	3.1/32	3.1/32	3.1/32
Slovakia	3.5/20***	3.5/20	3.5/20	3.5/20	3.5/20	3.5/21	3.5/20	
Slovenia		3.3/20	3.3/20	3.3/20		3.3/21	3.3/21	
Spain		5.5/20	5.5/20	5.5/20				
United Kingdom		3.8/31	3.8/31	3.8/31	3.8/31		3.8/31	

* FFCC has no information about the analytical method used for the Level I survey.
** FFCC has no information about the method applied in the 2nd interlaboratory test.
*** There are different methods used for the 2nd interlaboratory test and the Level I survey.

Table 2-2: Code numbers of abbreviations of pretreatments and determinations

Code Nr.	Description of the method
0	No information
1	No pretreatment
3.1	Wet ashing, HNO_3
3.2	Wet ashing, HNO_3/H_2O_2
3.3	Wet ashing, $HNO_3/HClO_4$
3.5	Wet ashing, $HNO_3/HClO_4/H_2O_2$
3.7	Wet ashing, H_2SO_4/HNO_3
3.8	Wet ashing, H_2SO_4/H_2O_2
4.1	Pressure bomb, HNO_3
5.1	Microwave, HNO_3
5.4	Microwave, HNO_3/H_2O_2
5.5	Microwave, $HNO_3/H_2O_2/HCl$
6	Dry ashing, no more information
6.1	Dry ashing, dissolution with HCl
8	Kjeldahl, no more information
8.1	Kjeldahl, H_2SO_4/Se-catalyst
8.2	Kjeldahl, $H_2SO_4/K_2SO_4/CuSO_4$
8.3	Kjeldahl, H_2SO_4/H_2O_2
10	Element-analyser
11	Dumas
13	LECO
14	Kjeldahl-apperatus, Kjeltec/Tecator
20	AAS-flame technique
21	AAS-flameless technique
30	AES-flame technique
31	AES-ICP
32	AES-ICP+MS
41	RFA-wavelength dispersive
50	UV-VIS spectrophotometry
51	FIAS
52	Indophenol-blue-method
54	Molybdene-blue-method
55	Vanadium-molybdene-blue-method
57	Azomethin-H
70	Titration
71	Turbidimetric titration
72	Conductivity titration

2.2 DATA INTEGRITY CHECK

The data which were sent to us (95/96) were checked according to several different criteria:

- Checking of the disks for computer viruses;
- Visual checking of the data files - for correct file format;
    - for correct position of the data fields;
    - for values that were not plausible;
    - as far as possible, for correct units;
    - for the same number of datasets in the transmitted files; and
    - for illegal characters and undefined codes.

The involved NFCs were then contacted and asked to correct the errors, if any, and after that the data files were entered into the database (see 3.1).

- The communicated coordinates and plot numbers were compared to those of the crown condition monitoring (from PCC-West). In case of differences regarding the coordinates or names of plots the NFCs were contacted for comments.

- A final integrity check was performed to detect extreme values. For this check the limits of the Tables 2-3 and 2-4 were used. Values below or exceeding these limits were also sent to the NFCs for a check.

Table 2-3: Check values for Pinus and Picea (* optional parameter)

Element	lower limit	upper limit
N	8.0 mg/g	22.0 mg/g
P	0.5 mg/g	3.0 mg/g
K	2.0 mg/g	11.0 mg/g
Ca (Leaves type=0)	1.6 mg/g	9.6 mg/g
Ca (Leaves type=1)	1.6 mg/g	19.0 mg/g
Mg	0.3 mg/g	2.1 mg/g
S	0.2 mg/g	6.0 mg/g
Zn *	-	90 µg/g
Mn *	-	4000 µg/g
Fe *	-	250 µg/g
Cu *	1.0 µg/g	-

Table 2-4: Check values for other tree species (* optional parameter)

Element	lower limit	upper limit
N	8.0 mg/g	30.0 mg/g
P	0.5 mg/g	3.0 mg/g
K	2.0 mg/g	20.0 mg/g
Ca	1.6 mg/g	30.0 mg/g
Mg	0.3 mg/g	4.0 mg/g
S	0.2 mg/g	6.0 mg/g
Zn *	-	90 µg/g
Mn *	-	4000 µg/g
Fe *	-	250 µg/g
Cu *	1.0 µg/g	-

2.3 NEEDLE/LEAF INTERLABORATORY TEST 1995/1996

On March 8-9, 1994, the ICP-Expert Panel of Ås, Norway, recommeded to carry out an interlaboratory analytical test during running Level-I monitoring programme. It was organized by Dr. Ulrich Bartels, Landesumweltamt North Rhine-Westphalia (Germany), with the participation of 39 European laboratories. In July 1994 four unknown samples of pine needles from Slovakia, spruce needles from Slovakia and Germany, and oak leaves from Spain had been distributed to be analysed by 31th December 1995. The detailed data were reported separately in October 1996.
An extremely compressed evaluation of the ringtest data is given in Tables 2-5 and 2-6.

Table 2-5: Results of the 2nd Interlaboratory test

Element mandatory	Range mg/g	Interlab.var. %	Criticism
N	11.4-14.6	6.5-5.5	very good
S	1-1.4	18-13	problematic
P	0.7-1.4	12-6	good
Ca	4.5-12.5	13-5	good
Mg	0.5-1.3	13-5.5	good-acceptable
K	4-6.2	8.5-5.5	good

Element optional	Range µg/g	Interlab.var. %	Criticism
Na	20-80	130-30	not acceptable
Zn	23-39	17-10	acceptable
Mn	28-1560	10-7.7	very good
Fe	70-300	30-6	acceptable >120 µg/g
Cu	2.9-5.8	34-22	acceptable
Pb	1-3.2	100-30	not acceptable
Al	80-420	55-10	acceptable >200 µg/g
B	10-60	50-10	acceptable >25 µg/g

It contains a list of the mandatory and optional elements, the concentration ranges of the four samples, the determined interlaboratory variances (=standard deviations between the laboratories expressed in percent) and a short criticism by the ringtest leader.
The test between all 39 laboratories resulted for the elements nitrogen, phosphorus, calcium, magnesium, potassium, zinc, manganese, and copper to be very good, good or acceptable. The analyses of iron, aluminium and boron are acceptable under certain conditions, while those of sulphur are fairly problematic because many laboratories had some analytical problems. The results of sodium and lead were criticised as being unacceptable.
Table 2-6 gives an extract for only those 15 anonymous laboratories which parallel to the ring test analyzed plant material from the Level-I plots (survey 1995) and only for this foliar report evaluated nine elements. The results of the ringtest for the countries submitting data of 1995 and previous years are given in Annex B-Table B0. The tendency of outliers is given. A check of the individual results, specially for sulphur, of the laboratories who did not wish that their anonymity be detected, proved that it was not necessary to exclude one or more country from the Level-I evaluation. Their tendency of analytical deviations is principally not in contrast to the forest foliar condition report.
Nevertheless the interlaboratory analytical test demonstrates that a further Europe-wide improvement and harmonisation of the analytical methods is necessary. A repetition of the ring test with another set of unknown samples is recommended.

Table 2-6: ICP-Forests 2nd Needle/leaf Interlab-test 1995/96
Problematic parameters/laboratories

Lab. Code	N	S	P	Ca	Mg	K	Zn*	Mn*	Fe*
3									
7									
13								<<	
14	>>								
17		<							
18									
20				<<			>>		>
21							<		<<
23									
24		>>				<<			
25		>>							
26		>			>>				<>
27					<<		<		<
28									<>
44									

Criteria
1 value out of tolerance: no mention
2 values out of tolerance: < or >
3 or 4 values out of tolerance: << or >>
> = values higher than mean
< = values lower than mean
<>= no tendency

* optional element

2.4 DATA PROCESSING

2.4.1 Data Classification

To allow the mapping of the results of the needle and leaf-analytical tests, a classification of the data is required; this item was discussed for leaves type 0 on the occasion of the 3rd Expert Panel Meeting on Foliar Analysis. For the main tree genera beech, pine and spruce the required limits were determined for the mandatory parameters (S, N, P, K, Ca and Mg); for oak, classification limits could be fixed only for N, P, K, Ca und Mg. For leaves type 0, the lower and the upper limit for the respective tree species and element is obvious from Table 3-8. With the help of the classification limits, the results can be evaluated and classified into low, medium and high values.
The *harmonious* range of the nutrient ratios, which is used for the evaluation in Chapter 3.5.5., is also based on this classification.

2.4.2 Terciles

To allow a mathematically exact, objective form of mapping while at the same time permitting the mapping of the data for which no classification limits had been determined, the measured data of each main tree species were grouped into three classes of an equal number of data (terciles). An evaluation using terciles only allows statements about the distribution of the data in the area of investigation; as opposed to the classification values described in 2.4.1, they do not allow conclusions regarding the physiological significance of the values. In the case of leaves type 0, the tercile evaluation was used for S, N, P, K, Ca, Mg, Fe, Mn and Zn; in the case of leaves type 1 terciles were used for the evaluation of S, N, P, K, Ca, and Mg values.
The proportions between the element contents of leaves type 1 and those of leaves type 0 (see 3.3.6) could also be evaluated only with the help of the terciles.

2.5 STATISTICAL METHODS

An important rule of statistical analysis is firstly to inspect the descriptive characteristics, e.g. means, ranges, variances, quantiles. After this, inferential methods - usually for testing whether there are any differences between the population means - can be used. Finally techniques of explorative data analysis can be applied to find out questions or hypotheses for further investigations. The most popular test to analyse population differences is the so-called Analysis of Variance (ANOVA). This method requires a number of assumptions to be met:

- equal variances
- stochastically independent observations
- metric (continous) variables with approximately normal distribution

Most important is the assumption of equal variances. Since the classes are ordinal variables, a comparison of means of those quantities is not statistically acceptable. For the nutrient contents it was found that the variances were not equal, hence an analysis of variance was not be applied. Where the assumptions of ANOVA are not met, a Kruskal-Wallis test is a suitable alternative to detect differences between means of populations. Unfortunately, this test can show only whether or not there is a difference between populations, but not where such differences are to be found.

A method for finding out differences between pairs of populations is the Scheffé test. The authors recognise that, strictly speaking, equal variances are also needed for the Scheffé test, but this test is much less sensitive to violations of that requirement. With respect to the explorative data (analyses an unweighted pair) group arithmetic average (UPGMA) cluster - analyses and a principial coordinate analysis were performed both for the similarities between countries and for the similarities between the main tree species. These methods were chosen because they allow inspection of close together countries (respectively trees) are when all variables are considered simultaneously. To be able to explain why the actual results of these methods show a particular pattern, further investigations are necessary. The hypotheses to be tested must be formulated by forest scientists in this case; it is impossible to find that out by means of statistical methods. For the calculations, the statistical package GENSTAT V5.2 (registered trade mark of the Numerical Algorithms Group Ltd., Oxford, UK) was used.

3 RESULTS

3.1 PRESENTATION OF THE DATABASE

Data from the survey 1995 are available from 713 plots belonging to the transnational 16x16 km network of Austria, Belgium-*Wallonia*, Bulgaria, the Czech Republic, Finland, Germany-*Lower Saxony*, Ireland, Italy, Lithuania, Russia-*St. Petersburg Region*, Slovakia, Slovenia, Spain, and the United Kingdom, and were communicated to the FFCC for further evaluation until November 13 (967 data sets). Included were the results of 74 beech plots, 128 oak plots, 183 pine plots, 271 spruce plots, and 57 plots with other tree genera. In addition, older data (altogether 2,479 data sets) from 1987-1994 surveys were also transferred from Austria, Bulgaria, Croatia, Finland, Germany, Norway, Lithuania, and Spain, so that they could be integrated into this all-European evaluation.
After the data had been checked (see 2.3), they were filed on a VAX 4000 in an ORACLE database table. In this table, the following columns were set up:

Columnname	Discription
COUNTRY	code of the country
YEAR	year of sampling
PLOT	plotnumber
TREE_SPECIES	codenumber for the tree species
LEAVES_TYPE	for current(=0) and current+1(=1)
SAMPLING_DATE	date of sampling
COUNTRY_NAME	name of the country (in English)
REGIOGRAF	country-code for mapping
TREE_NAME	tree species (Reference Flora Europaea)
MAIN_SPECIES	main genera (e.g. OAK)
NJ	year of sprouting
LATITUDE	in +DDMMSS
LONGITUDE	in +DDMMSS
ALTITUDE	in 50 metre classes
LEVEL1	'X' for datas of the survey 95
N	content in mg/g
S	content in mg/g
P	content in mg/g
CA	content in mg/g
MG	content in mg/g
K	content in mg/g
NG	mass of 1000 needles or 100 leaves in g
NA	content in mg/kg, optional element
ZN	content in mg/kg, optional element
MN	content in mg/kg, optional element
FE	content in mg/kg, optional element
CU	content in mg/kg, optional element
PB	content in mg/kg, optional element
AL	content in mg/kg, optional element
B	content in mg/kg, optional element

Presently (February 1997) a total of 3446 data sets are available (see Table 3-1).

Table 3-1: Stored data sets till February 1997

Country	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**
Austria			171	169	167	163	163	163	159
Belgium-*Wallonia*									39
Bulgaria					5	85	61	93	28
Croatia								8	
Czech Rep.									80
Finland	56	56	56	12	30	58	58	58	58
Germany	155	155	6	23		99	12	150	42
Ireland									25
Italy									60
Lithuania							36		28
Norway						40			
Russia-*St.Petersburg Reg.*									28
Slovakia									116
Slovenia									39
Spain								171	166
United Kingdom									99
	211	**211**	**233**	**204**	**202**	**445**	**330**	**643**	**967**

3.2 SELECTION FOR EVALUATION

3.2.1 Survey 1995

The following three reasons were decisive for using the 1995 survey for the transnational evaluation: If a transnational evaluation of the national results from one sampling year is made, climate-related differences in the nutrient content of the needle and leaf samples within individual participating countries and among them are to a large extent excluded. The investigation of 1995 had with 14 countries the highest number of participants. While the samples of this period were analyzed, also the 2nd interlaboratory test (see 2.2) was also carried out, thereby checking the analytical quality of the data. The selected data sets were used for the following evaluations:

- Mean values and rages of major nutrients
- Terciles (Leaves type 0) of major and micro nutrients
- Terciles (Leaves type 1) of major nutrients
- Classification
- Nutrient ratios
- Nutrient content leaves type 1/ leaves type 0
- Statistical studies

3.2.2 Surveys 1987 - 1995

It was not possible to illustrate the development of the needle and leaf contents in Europe with the help of older data from identical sample points because only Austria (1989-1995) and Finland (1987-1995) delivered time series of identical plots over several years. However, to allow the inclusion of data from previous years in a transnational evaluation, the mean values of the plots were calculated for the period of the sampling years and separately evaluated in Chapter 3.4. This form of evaluation guarantees a better cover. In Bulgaria, Germany, Lithuania, and Spain considerably more plots are included in the evaluation. Croatia and Norway, which communicated only older data, can also be considered when applying this form of evaluation. The data were evaluated according to the classification values (see Table 3-8).

3.3 EVALUATION 1995

3.3.1 Mean Values and Ranges of the major Nutrients

The results of the 713 individual plots that were communicated to the FFCC were grouped according to tree species and individual countries and are documented in Annex D. The Annexes contain the minimum, maximum and mean values of the macro- and micronutrient elements of the tree species used in the investigation. For further evaluation, sample plots were grouped according to the genera of spruce, pine, beech and oak. About 92% of the sample material belonged to one of those four major tree species; apart from these, also hornbeam (13%) and eucalypt (11%) plots ranked relatively highly.

Spruce (Table 3-2)

As can be seen in Table 3-2, most of the national nitrogen means were between the lower and the upper classification value. Only in Finland and in Lithuania were the nitrogen means of the spruce samples below the lower classification value; the mean value of the United Kingdom was just below the upper classification value of 17.0 mg N/g.
In Belgium - *Wallonia*, Germany - *Lower Saxony*, Italy and Finland the upper classification value for nitrogen was not exceeded on any of the spruce plots. Only in the United Kingdom were the nitrogen values of all spruce plots higher than the lower classification value of 12.0 mg N/g.
In the case of phosphorus, potassium, calcium, and magnesium, the mean values of all countries with spruce plots were between the lower and the upper classification values. On individual plots in Ireland, Italy, Lithuania, Slovenia, and Austria, phosphorus values were observed below the lower classification value; in Austria and Lithuania this was also true for potassium. In the Czech Republic, individual plots showed potassium values that were lower

Table 3-2: Ranges and mean values of the nutrient content of *SPRUCE* plots in the individual countries (Leaves type 0 - mg/g)

Country	n	N	P	K	Ca	Mg	S
Austria	72	11.32-17.04	0.96-2.44	2.63-9.68	1.69-10.61	0.77-2.49	0.78-1.45
		13.60	**1.53**	**6.33**	**4.93**	**1.36**	**0.98**
Belgium-	7	11.30-16.21	1.39-2.19	4.71-7.04	2.06-4.34	0.64-1.23	0.72-0.94
Wallonia		**13.08**	**1.74**	**5.82**	**3.22**	**0.90**	**0.79**
Bulgaria	1						
			2.12	**9.29**	**4.14**	**1.82**	
Czech Rep.	34	11.15-18.43	1.30-2.18	2.89-9.44	2.29-7.30	0.57-1.51	0.75-1.53
		15.17	**1.60**	**6.27**	**4.23**	**0.99**	**1.04**
Finland	13	9.00-13.20	1.10-2.03	5.06-9.14	2.40-6.88	1.11-1.48	0.81-1.01
		11.49	**1.54**	**6.92**	**4.51**	**1.26**	**0.91**
Germany-	7	11.78-14.49	1.20-1.71	4.63-8.25	3.64-4.85	0.79-1.27	0.87-1.25
Lower Saxony		**12.96**	**1.42**	**6.18**	**4.23**	**0.97**	**1.01**
Ireland	16	10.31-18.23	0.81-1.68	3.93-9.89	2.77-7.76	0.77-1.32	
		14.78	**1.32**	**6.97**	**4.98**	**1.06**	
Italy	15	10.18-13.56	0.84-2.01	4.54-8.04	2.87-6.58	0.74-1.97	0.82-1.49
		12.13	**1.22**	**6.41**	**4.89**	**1.10**	**1.04**
Lithuania	13	4.20-18.00	0.40-1.70	1.40-8.40	1.50-7.90	0.90-2.70	0.40-1.40
		9.87	**1.13**	**5.36**	**5.26**	**1.78**	**0.85**
Slovenia	29	10.70-23.80	0.65-2.33	3.82-10.42	1.73-14.17	0.63-3.75	0.94-2.30
		14.07	**1.28**	**6.96**	**5.96**	**1.21**	**1.33**
United Kingdom	26	13.50-20.68	1.20-2.76	5.41-11.25	1.99-9.50	0.81-1.70	0.95-1.94
		16.93	**1.72**	**8.35**	**4.80**	**1.22**	**1.38**
SPRUCE	**233**	**4.20-23.80**	**0.40-2.76**	**1.40-11.25**	**1.50-14.17**	**0.57-3.75**	**0.40-2.30**
		13.89	**1.48**	**6.65**	**4.86**	**1.23**	**1.07**

than the lower classification value, which, in this country, applied also to the magnesium value of individual plots.
The mean sulphur content of the spruce samples of Belgium - *Wallonia*, Germany - *Lower Saxony*, the Czech Republic, Italy, Lithuania, Slovenia, and Finland fell below the lower classification value of 1.1 mg S/g. In Slovenia and in the United Kingdom, the mean values were between the two classification values of 1.1 mg S/g and 1.8 mg S/g and only in these two countries did individual plots show a sulphur content beyond the upper classification value.

Pine (Table 3-3)

In Russia - *St. Petersburg Region* and Finland the national nitrogen means of pine remained below the lower classification value, whereas national nitrogen means exceeded the upper classification value in Germany - *Lower Saxony* and in the United Kingdom. In the Czech Republic, in Germany - *Lower Saxony*, Spain, Lithuania, and in the United Kingdom the upper classification value was exceeded in pine plots. In Belgium - *Wallonia*, Ireland and Austria the nitrogen values of all pine plots remained between the upper and the lower classification values.
In all countries the phosphorus and potassium means were between the upper and the lower classification values. The upper limit of 2.0 mg P/g was exceeded by pine plots in Bulgaria, Lithuania, Russia - *St. Petersburg Region*, and the United Kingdom. In Belgium - *Wallonia*, the Czech Republic, Germany - *Lower Saxony*, Finland, and Austria the phosphorus values of all pine plots were between 1.0 and 2.0 mg P/g, the lower and the upper phosphorus classification values for pine. The upper potassium classification value of 10.0 mg K/g was exceeded only in Spain. In Belgium - *Wallonia*, the Czech Republic, Germany - *Lower Saxony*, Ireland, Finland, the United Kingdom, and Austria, the potassium values of all pine plots ranged between 3.5 and 10.0 mg K/g, i.e. between the lower and the upper classification values.
Lithuania was the only country where the mean calcium concentrations of all pine plots was higher than 4.0 mg Ca/g and therefore exceeded the upper classification value. Also individual pine plots in Bulgaria, in the Czech Republic, in Spain, Ireland, Russia - *St. Petersburg Region*, and Austria showed calcium values beyond the upper classification value. In Belgium - *Wallonia*, Germany - *Lower Saxony* and the United Kingdom the calcium values of the individual pine plots ranged between the lower (1.5 mg Ca/g) and the upper (4.0 mg Ca/g) classification values. In Bulgaria, Ireland, Russia - *St. Petersburg Region*, and Finland there were also pine plots with calcium values lower than 1.51 mg Ca/g. In most countries the magnesium means of the pine plots were also between the upper and the lower classification values; the exceptions were Bulgaria and Spain, where the national means for pine exceeded the limit of 1.5 mg Mg/g.
Apart from these two countries, pine plots with magnesium values higher than the upper classification value of 1.5 mg Mg/g were found in Lithuania and the United Kingdom. Germany - *Lower Saxony* was the only country where the magnesium values on pine plots remained below the lower classification value.
The national sulphur mean in pine plots exceeded 1.1 mg S/g only in Germany - *Lower Saxony* and in the United Kingdom; in all other countries the mean sulphur value of the pine plots was less than 1.1 mg S/g. Only in Spain, Russia - *St. Petersburg Region* and in the United Kingdom was the upper sulphur classification value of 1.8 mg S/g exceeded on individual pine plots. On pine plots in Belgium - *Wallonia*, the Czech Republic, Germany -

Table 3-3: Ranges and mean values of the nutrient content of *PINE* plots in the individual countries (Leaves type 0 - mg/g)

Country	n	N	P	K	Ca	Mg	S
Austria	5	9.71-15.23	1.24-1.58	5.23-6.73	3.17-4.72	1.03-1.43	0.73-1.12
		13.39	**1.35**	**5.69**	**3.72**	**1.18**	**0.97**
Belgium-	3	14.75-16.92	1.37-1.74	5.06-5.99	1.84-2.79	0.61-0.89	0.89-1.27
Wallonia		**15.55**	**1.57**	**5.59**	**2.33**	**0.79**	**1.05**
Bulgaria	12		0.89-2.54	3.03-8.82	0.62-7.14	0.79-2.65	
			1.48	**5.61**	**2.82**	**1.58**	
Czech Rep.	6	15.71-18.29	1.27-1.72	4.60-7.63	2.74-4.95	0.94-1.32	0.90-1.11
		16.52	**1.58**	**5.65**	**3.66**	**1.05**	**1.01**
Finland	16	9.30-13.80	1.38-1.96	4.65-6.06	1.49-3.13	0.90-1.30	0.85-1.07
		11.40	**1.54**	**5.42**	**2.02**	**1.10**	**0.96**
Germany-	18	15.19-21.12	1.06-1.98	4.58-6.79	1.65-3.43	0.57-1.29	1.08-1.61
Lower Saxony		**17.95**	**1.53**	**5.47**	**2.47**	**0.82**	**1.25**
Ireland	9	12.39-16.35	0.74-1.37	4.40-6.73	1.48-3.00	0.87-1.50	
		13.65	**1.02**	**5.53**	**1.98**	**1.12**	
Lithuania	15	8.20-17.80	0.80-8.70	2.30-7.30	2.50-8.00	0.90-2.40	0.60-1.70
		13.07	**1.78**	**4.20**	**5.74**	**1.35**	**0.99**
Russia	27	0.50-16.90	0.35-3.40	2.85-7.84	1.34-5.32	0.61-1.49	0.16-2.47
St. Petersburg Region		**6.47**	**1.14**	**5.82**	**2.62**	**0.96**	**1.09**
Slovenia	1						
		12.10	**1.30**	**6.19**	**5.19**	**1.49**	**1.13**
Spain	56	7.81-17.97	0.60-1.62	3.57-10.41	1.59-7.22	0.88-2.74	0.60-1.83
		12.56	**1.10**	**5.93**	**3.97**	**1.60**	**1.10**
United Kingdom	11	13.96-20.95	1.21-2.18	6.87-9.64	1.58-3.74	0.76-1.66	1.11-1.82
		17.79	**1.70**	**8.08**	**2.55**	**1.07**	**1.41**
PINE	**179**	**0.50-21.12**	**0.35-8.70**	**2.30-10.41**	**0.62-8.00**	**0.57-2.74**	**0.16-2.47**
		12.71	**1.34**	**5.75**	**3.29**	**1.26**	**1.11**

Lower Saxony, Lithuania, and Austria, the determined values fell below the lower classification values.

Beech (Table 3-4)

The upper nitrogen classification value of 25.0 mg N/g was exceeded only by the national mean of the United Kingdom. In costrast the national mean of Slovenia and the beech value of one single plot in Bulgaria fell below the lower nitrogen classification value for beech, 18.0 mg N/g. The upper nitrogen classification value was exceeded only on beech plots in Spain, Slovakia and the United Kingdom.
With the exception of Bulgaria, all national phosphorus mean values ranged between the lower and the upper classification values (1.0 mg P/g and 1.7 mg P/g, respectively). In Bulgaria, Spain, Italy, and in the United Kingdom individual beech plots showed values higher than 1.7 mg P/g.
The national potassium mean values of all countries were found to be between the upper and the lower classification values. In Italy and in Slovakia the upper classification value of 10.0 mg K/g was exceeded on some of the beech plots. However, in Slovakia, Slovenia and Belgium - *Wallonia*, the potassium values of individual plots remained below the lower classification value.
In Bulgaria, Spain, Italy, Slovakia and the United Kingdom, the national calcium means for beech were beyond the upper classification value of 8.0 mg Ca/g. Apart from those countries, exceedances of the upper classification value were observed also on some beech plots in Belgium and Slovenia.
In Belgium-*Wallonia*, the national magnesium means for beech proved to be lower than the lower classification value, whereas in Slovakia it exceeded the upper classification value. In Bulgaria, Italy and the United Kingdom some plots showed magnesium values higher than 2.0 mg Mg/g. The national sulphur mean of 2.0 mg S/g was exceeded only in Slovakia; in all other countries the mean value ranged between the upper and the lower classification values. Apart from Slovakia, the upper classification value for sulphur in beech was exceeded also on individual plots in Italy and the United Kingdom.

Oak (Table 3-5)

Only in the United Kingdom was the national nitrogen mean for oak higher than the upper classification value of 25.0 mg N/g; in all other countries with the national nitrogen means ranged between the upper and the lower classification values. Apart from the United Kingdom, individual plots with nitrogen values exceeding 25.0 mg N/g were found in Spain and Slovakia.
In Italy and Slovenia, the national phosphorus means fell below the lower classification value, while in the other countries means ranged between the upper and the lower classification values. Only in Spain and the United Kingdom had individual oak plots phosphorus values higher than the upper classification value.
Of all the national potassium means, only that of the United Kingdom exceeded the upper classification value. Individual oak plots with potassium values beyond the upper classification value of 10.0 mg K/g were also found in Belgium - *Wallonia,* Spain, Italy, and Slovakia.
The national calcium means exceeded the upper classification value of 8.0 mg Ca/g in Italy, Slovenia, Slovakia, and the United Kingdom. In addition, individual oak plots in Spain showed calcium values higher than 8.0 mg Ca/g. The national magnesium means all ranged

Table 3-4: Ranges and mean values of the nutrient content of *BEECH* plots in the individual countries (Leaves type 0 - mg/g)

Country	n	N	P	K	Ca	Mg	S
Austria	1						
		20.40	**1.05**	**7.92**	**14.50**	**1.42**	**1.39**
Belgium-	7	17.67-22.14	0.93-1.42	4.66-6.86	5.00-8.30	0.48-1.01	1.30-1.65
Wallonia		**19.68**	**1.15**	**6.09**	**6.01**	**0.67**	**1.48**
Bulgaria	2	16.80-16.80	1.56-3.90	6.95-8.12	7.33-11.91	1.02-2.29	
		16.80	**2.73**	**7.54**	**9.62**	**1.66**	
Italy	7	19.13-25.09	0.69-1.75	6.37-10.07	3.90-14.44	0.90-3.17	0.17-2.55
		23.70	**1.15**	**7.87**	**11.00**	**2.34**	**1.49**
Slovakia	38	12.80-39.80		4.85-16.32	1.41-26.56	1.22-3.96	1.31-4.35
		19.24		**9.08**	**12.61**	**2.04**	**2.37**
Slovenia	3	11.80-20.80	0.67-1.36	3.37-7.94	3.57-15.22	1.08-1.45	1.28-1.41
		15.33	**1.07**	**5.93**	**7.94**	**1.22**	**1.33**
Spain	5	22.39-28.98	1.11-1.82	8.00-10.00	7.62-11.82	0.85-1.84	1.62-1.86
		24.71	**1.31**	**8.90**	**10.05**	**1.33**	**1.78**
United Kingdom	11	22.20-29.00	1.18-1.90	5.77-9.51	7.21-21.24	0.94-2.25	1.61-2.13
		25.59	**1.49**	**8.14**	**12.06**	**1.77**	**1.82**
BEECH	**74**	**11.80-39.80**	**0.67-3.90**	**3.37-16.32**	**1.41-26.56**	**0.48-3.96**	**0.17-4.35**
		20.81	**1.36**	**8.35**	**11.34**	**1.80**	**2.02**

Table 3-5: Ranges and mean values of the nutrient content of *OAK* plots in the individual countries (Leaves type 0 - mg/g)

Country	n	N	P	K	Ca	Mg	S
Belgium-	8	18.50-23.91	0.87-1.52	5.87-15.82	3.64-6.34	0.77-1.77	1.16-1.59
Wallonia		**20.85**	**1.10**	**8.68**	**5.21**	**1.18**	**1.42**
Italy	8	12.33-22.89	0.56-1.78	5.72-11.30	4.43-14.14	0.88-4.45	0.83-1.86
		19.88	**0.91**	**7.30**	**9.43**	**2.31**	**1.32**
Slovakia	16	12.50-32.62		5.71-12.37	7.29-18.85	1.36-2.57	1.07-3.23
		21.13		**9.32**	**12.28**	**1.89**	**2.24**
Slovenia	2	13.80-19.20	0.70-1.16	5.44-6.23	8.18-12.16	1.02-2.37	1.13-1.54
		16.50	**0.93**	**5.84**	**10.17**	**1.70**	**1.34**
Spain	80	9.94-28.22	0.58-2.22	3.57-12.74	1.86-16.78	0.77-3.31	0.84-2.25
		15.38	**1.07**	**7.46**	**6.61**	**1.69**	**1.15**
United Kingdom	14	24.96-31.43	1.16-2.18	7.75-12.62	5.46-11.71	1.06-1.79	1.55-2.17
		27.86	**1.55**	**10.10**	**8.01**	**1.55**	**1.87**
OAK	**128**	**9.94-32.62**	**0.56-2.22**	**3.57-15.82**	**1.86-18.85**	**0.77-4.45**	**0.83-3.23**
		18.10	**1.12**	**8.02**	**7.62**	**1.71**	**1.40**

between the lower and the upper classification values (1.0 and 2.5 mg/g). In Spain, Italy and Slovakia the upper magnesium classification value was exceeded on individual oak plots.
As can be seen from Tables 3-2 to 3-5, the nitrogen means of all four main tree genera were highest in the United Kingdom, in the case of pine together with Germany - *Lower Saxony*. The lowest nitrogen mean values for spruce were found in Lithuania and Finland; for pine in Russia - *St. Petersburg Region* and Finland; for beech in Slovenia and Bulgaria; and for oak in Spain and Slovenia. However, Annex 1 and Annex 2 indicate that the nitrogen contents of *Quercus ilex* (holm oak) and *Quercus suber* (cork oak), which represent the biggest share of the oak samples from Spain, were considerably lower than those of the other oak species: *Quercus ilex* averaged 10.2 mg N/g, *Quercus suber* 11.5 mg N/g; compared with this, the nitrogen values of the other species average between 14.7 and 19.5 mg N/g. This raises the question whether evergreen and deciduous oak species should be evaluated as one single group, as was decided on the occasion of the Third Expert Panel.
The United Kingdom phosphorus, potassium and sulphur mean values were highest or second highest for all 4 main tree genera. In the case of beech and oak, the potassium, calcium, magnesium and sulphur means of Slovakia were always among the top group of the countries with the highest mean values. In the case of spruce and pine the mean calcium and magnesium values of Lithuania held this top position. The magnesium and calcium means of all four main tree genera were lowest in Belgium.

3.3.2 Terciles (Leaves Type 0)

3.3.2.1 Terciles - Macronutrient Content of the individual Plots

To check the country-related differences between the mean values using the results of the individual plots, the 4 main tree genera were subjected to an evaluation using terciles (33.3 percentile) for the different nutrients (see Annex B - Table B1). This allowed conclusions about the geographical distribution of plots characterized by high, medium, or low values.
The percentages given in the tables refer either to the number of plots of one of the main tree genera of a country (see Annex B - Tables B2 - B5) or to the total number of plots of the 4 main tree genera of the respective country.

Spruce

Table B2 (see Annex B) shows that in the United Kingdom the national percentage share for spruce was in the 3rd tercile (values of the 1st tercile < values of the 2nd tercile < values of the 3rd tercile) for nitrogen, phosphorus, potassium, and sulphur; according to the percentage evaluation the results of the United Kingdom also ranked above other countries. As regards calcium and magnesium, the same applied to Lithuania. In Germany-*Lower Saxony*, Italy and Finland, no nitrogen values of any spruce plots ranged in the 3rd tercile. The same applied to Belgium and Germany for calcium and nitrogen. No Belgium or Finish spruce plots showed any 3rd tercile sulphur values.
The highest national percentage share of spruce plots with nitrogen values in the 1st tercile (low nitrogen values) were found in Finland and Lithuania. The only country not having any spruce plots with 1st tercile nitrogen values was the United Kingdom. For phosphorus, the highest national shares of spruce plots with values in the 1st tercile were observed in Italy and Lithuania; for potassium, in Lithuania and Belgium; and for calcium and magnesium in Belgium, the Czech Republic and Germany - *Lower Saxony*. In Finland, no spruce plots showed magnesium values in the 1st tercile. The highest national percentage shares of spruce

plots with sulphur values in the 1st tercile were observed in Belgium and Finland, but in the United Kingdom no sulphur value was found in the 1st tercile in any spruce plots.

Pine

As can be seen from Table B3 (see Annex B), the situation for the pine plots was approximately the same as that for spruce. The highest shares of national pine plots with nitrogen values in the 3rd tercile were found in the Czech Republic and in Germany, followed by the United Kingdom. In Finland, no nitrogen values of any pine plot ranged in the 3rd tercile. The highest percentage shares of phosphorous values in the 3rd tercile were found in the Czech Republic and the United Kingdom. In Ireland no plots had any phosphorus values in the 3rd tercile. While all of the potassium values in the United Kingdom were in the 3rd tercile, none of the pine plots in Belgium-*Wallonia* or Finland showed any potassium values in the 3rd tercile.
The highest national percentage share of pine plots with calcium values in the 3rd tercile was found in Lithuania; the highest national percentage share of pine plots with 3rd tercile magnesium values was found in Spain. In Belgium, Germany - *Lower Saxony* and Finland no plots showed any calcium or magnesium values in the 3rd tercile; as regards calcium, this also applied to the United Kingdom.
The highest national percentage shares of 1st tercile plots, both for nitrogen and phosphorus, were observed Russia - *St. Petersburg Region*; in the case of nitrogen, Russia - *St. Petersburg Region* was followed by Finland, in the case of phosphorus by Spain and Ireland. None of the pine plots in Belgium - *Wallonia*, the Czech Republic, Germany - Lower Saxony, Ireland, or United Kingdom showed any phosphorus values in the 1st tercile.
In Lithuania the national proportion of low potassium values (1st tercile) is highest. In contast, none of the potassium values of any pine plot in United Kingdom or Austria ranged in the 1st tercile. The percentage of pine plots with low calcium values was highest in Finland, Ireland and Belgium. No calcium values in the 1st tercile were observed in the Czech Republic, in Lithuania and Austria. Looking at the high percentage shares of pine plots with magnesium values in the 1st tercile, the magnesium supply was most unfavourable in Belgium and Germany - *Lower Saxony*. The highest percentages of pine plots with sulphur values in the 3rd tercile were observed in the United Kingdom and Germany - *Lower Saxony*, whereas no pine plots in the Czech Republic, in Finland or Austria showed sulphur values in the 3rd tercile. The highest percentage shares of pine plots with low sulphur content (1st tercile) were found in Finland, Belgium, Lithuania and Austria.

Beech

Among the six countries with three or more beech plots, the United Kingdom was again the one with the highest percentage share of plots with 3rd tercile nitrogen values (see Annex B - Table B4); in contrast none of the nitrogen values of any beech plot in Belgium or Slovenia ranged in the 3rd tercile. The United Kingdom also had the highest percentages of plots in the 3rd tercile for phosphorus and calcium, in Spain this was true for potassium, and in Italy for magnesium. The highest national percentage shares of beech plots with low nitrogen values (1st tercile) were observed in Slovenia and Slovakia.
The highest percentages of beech plots with phosphorus values in the 1st tercile were found in Italy and Belgium. In Belgium all potassium, calcium and magnesium values in beech occured in the 1st tercile. However, in Belgium all beech plots had 1st tercile sulphur values only; high (3rd tercile) sulphur values were observed mainly in Slovakia.

Oak

As can be seen from Table B5 (see Annex B), oak sample plots in the United Kingdom also showed high (3rd tercile) nitrogen values most frequently. Similarly, the national percentages of 3rd tercile values for phosphorus, potassium and sulphur were highest in the United Kingdom The highest national percentage shares of calcium and magnesium values in the 3rd tercile were observed in Slovakia; in the case of magnesium also in Italy.
In Slovakia, the percentage of high sulphur values was even higher than that of the United Kingdom In Spain, more than half of the oak plots showed low (1st tercile) sulphur values.

Combined results of the 4 main tree genera *(see Figures 1-6)*

For the values given in Table 3-6 the results of all 4 main tree genera were combined:
As regards the nitrogen, phosphorus, potassium, and sulphur values, the United Kingdom had the highest national percentages of plots with values in the 3rd tercile (highest range). The same was true in Lithuania for calcium.
With respect to nitrogen values, the Czech Republic and Germany - *Lower Saxony* also had high national percentages in the 3rd tercile. In contrast Finland had no 3rd tercile nitrogen values in any plot. Apart from the United Kingdom, Bulgaria and the Czech Republic also had relatively high percentages of plots with 3rd tercile phosphorus values. The same applied to Russia - *St. Petersburg Region* and Slovakia in the case of the potassium values. In addition to Lithuania, Slovakia and Slovenia also showed high (3rd tercile) national percentage shares of calcium values; higher shares of magnesium values in the 3rd tercile were also found in Bulgaria and Austria. None of the plots in Germany - *Lower Saxony* or Belgium showed any calcium or magnesium values in the 3rd tercile.
The highest national percentage shares of plots with high (3rd tercile) sulphur values were observed in the United Kingdom, Slovenia and Slovakia. Finland was the only country without any plots with 3rd tercile sulphur values.
The highest national percentage shares of sample plots with low (1st tercile) nitrogen values occured in Russia - *St. Petersburg Region*, Finland and Lithuania; none of the United Kingdom plots showed nitrogen values in the 1st tercile range. The Russia - *St. Petersburg Region* had the highest national percentage share of 1st tercile phosphorous values, followed by Slovakia. The highest national percentages of low potassium values (1st tercile) were observed in Lithuania and Belgium. Belgium also had the highest national percentage shares of calcium and magnesium 1st tercile plots.
The highest national percentage shares of plots with a low sulphur content (1st tercile) were found in Finland, Belgium and Lithuania.

Figure 1

Figure 2

Figure 3

Figure 4

Figure 5

Figure 6

Table 3-6: Terciles - Macronutrient content of main tree genera/Individual countries
Percentage of plots of the 4 main tree genera in the individual countries according to the first and third tercile

Country	N		P		K		Ca		Mg		S	
	1./3	3./3	1./3	3./3	1./3	3./3	1./3	3./3	1./3	3./3	1./3	3./3
Austria	29.4	19.2	34.6	39.7	33.3	25.6	25.6	41.0	14.1	46.2	43.6	9.0
Belgium-*Wallonia*	20.0	32.0	20.0	36.0	64.0	8.0	76.0	0.0	92.0	0.0	64.0	8.0
Bulgaria			13.3	60.0	40.0	26.7	53.3	20.0	13.3	46.7		
Czech Rep.	5.0	65.0	2.5	20.0	42.5	22.5	45.0	25.0	60.0	17.5	40.0	27.5
Finland	69.0	0.0	6.9	44.8	13.8	13.8	62.1	13.8	10.3	17.2	75.9	0.0
Germany-*Lower Saxony*	12.0	72.0	12.0	56.0	40.0	16.0	48.0	0.0	76.0	0.0	12.0	44.0
Ireland	12.0	44.0	56.0	16.0	32.0	36.0	48.0	24.0	56.0	12.0		
Italy	33.3	23.3	53.3	10.0	46.7	26.7	26.7	40.0	43.3	40.0	30.0	20.0
Lithuania	50.0	25.0	46.4	21.4	71.4	10.7	10.7	67.9	28.6	50.0	60.7	25.0
Russia-*St. Petersburg Reg.*	88.9	3.7	63.0	7.4	25.9	48.1	55.6	14.8	55.6	7.4	51.9	33.3
Slovakia	44.4	25.9			18.5	48.1	13.0	53.7	25.0	44.4	11.1	64.8
Slovenia	45.7	20.0	54.3	5.7	31.4	40.0	25.7	45.7	57.1	22.9	11.4	71.4
Spain	41.8	15.6	48.2	17.7	38.3	29.1	28.4	34.0	24.1	49.6	43.3	18.4
United Kingdom	0.0	88.7	3.2	71.0	9.7	69.4	32.3	32.3	27.4	22.6	4.8	75.8

3.3.2.2 Terciles - Micronutrient Content of the individual Plots

An evaluation using terciles was also performed for the micronutrients of zinc, iron and manganese in a similar way to the macronutrients, because for these optional elements, data from a relatively high number of countries were available (see Annex B - Table B6). For the evaluations of the individual main tree genera only those countries were considered from which the results of at least 3 sample plots of the respective main tree genera were available.

Spruce

As can be seen from Table B7 (see Annex B), Austria and Germany - *Lower Saxony* had the highest shares of spruce plots with zinc values in the 3rd tercile, while none of the Czech spruce plots showed zinc values in such a high range. The highest iron and manganese contents (3rd tercile) were found in the United Kingdom and the Czech Republic. In Lithuania, none of the spruce plots had manganese values in the 3rd tercile.
The highest shares of spruce with a low (1st tercile) zinc content were in the Czech Republic and Lithuania, whereas in Italy none of the spruce plots showed a zinc content in the 1st tercile. Low iron values were observed most frequently in Finland and Austria. The highest share of spruce with a low manganese content (1st tercile) was found in Lithuania; relatively large numbers of spruce plots with a manganese content in the 1st tercile were also observed in Italy, Austria and Germany - *Lower Saxony*.

Pine

In the case of the pine plots, Spain had the highest share of plots with a higher zinc content (see Annex B - Table B8), whereas in the Czech Republic, Finland and Austria no pine plots with a 3rd tercile zinc content were observed. High iron values were found mainly on the pine plots of Bulgaria, Germany - *Lower Saxony* and the United Kingdom. No pine plots with an iron content in the 3rd tercile were observed in Lithuania. The highest shares of pine plots with high manganese values were found in the Czech Republic, in the United Kingdom, in Finland, and Austria. The highest shares of pine plots with a low zinc content were found in Finland; the same applied to Russia - *St. Petersburg Region* for iron values. The highest share of pine plots with a low manganese content was identified in Spain. In contrast none of the pine plots in the Czech Republic, Lithuania, Finland, United Kingdom, or Austria had a manganese content in the 1st tercile.

Beech

Compared to pine, there was little difference in the shares with higher zinc content between the 4 countries having at least 3 beech plots. In the United Kingdom, however, the share of the beech plots with a low (1st tercile) zinc content was considerably higher than it was in other countries (see Annex B - Table B9). With reference to the shares of high iron contents, values in Spain and Slovakia were higher than those of the two other countries. As regards the shares of high or low manganese contents of beech plots, there were only relatively small differences between the 4 countries, compared to the differences observed with the other main tree genera.

Oak

Among the 3 countries where micronutrient investigations were undertaken on oak, Spain and Slovakia showed higher zinc values (in the 3rd tercile) than the United Kingdom, which clearly had the highest share of oak plots with a low zinc content (see Annex B - Table B10). High (3rd tercile) iron values were observed mainly on the oak plots in Spain. The share of oak plots with a high manganese content was remarkably higher in Slovakia and in the United Kingdom compared to Spain.

Results combining the plots of all four main tree genera (Table 3-7)

Combining all 4 main tree genera, Bulgaria, Germany - Lower Saxony and Austria had the highest national percentage shares of high zinc values. The highest national shares of low zinc values were found in the Czech Republic, Russia - *St. Petersburg Region* and Lithuania. The highest national percentage shares of plots with high iron values was observed in Italy, the Czech Republic and Spain. The highest national percentage shares of low (1st tercile) iron values existed in Finland, Russia - *St. Petersburg Region* and Austria.

Table 3-7: Terciles - Micronutrient content of main tree genera/Individual countries
Percentage of plots of the 4 main tree genera in the individual countries
according to the first and third tercile (optional elements)

Country	Zn		Fe		Mn	
	1./3	3./3	1./3	3./3	1./3	3./3
Austria	19.2	42.3	56.4	12.8	44.9	19.2
Bulgaria	20.0	46.7	46.7	26.7	46.7	13.3
Czech Rep.	70.0	2.5	12.5	50.0	10.0	67.5
Finland	31.0	20.7	96.6	3.4	3.4	51.7
Germany-*Lower Saxony*	8.0	44.0	8.0	28.0	36.0	24.0
Italy	0.0	38.5	7.7	53.8	53.8	7.7
Lithuania	62.5	8.3	20.8	37.5	41.7	8.3
Russia-*St. Petersburg Reg.*	63.0	25.9	77.8	7.4	18.5	29.6
Slovakia	29.6	35.2	38.9	37.0	24.1	46.3
Slovenia	20.0	34.3	40.0	17.1	25.7	51.4
Spain	31.9	31.9	17.0	49.6	55.3	12.8
United Kingdom	53.2	22.6	24.2	33.9	9.7	66.1

3.3.3 Terciles (Leaves Type 1) - Macronutrient Content of the individual Plots

As there are no classification standards for the evaluation of the nutrient content of leaves type 1 (needles of the previous year), the values of spruce and pine were jointly evaluated by using terciles again (Annex B - Table B11). This was done firstly to check the results by means of a comparison of leaves type 0 (needles of the current year) and 1 and, secondly, to allow a country-related comparison in respect of the percentages of low, medium, and high values.

Nitrogen

As can be seen from Annex B - Table B12, the national percentages of high nitrogen values (3rd tercile) were by far highest in the United Kingdom and Slovakia (for Slovakia, conifer data were available only for leaves type 1). None of the conifer plots of Germany - *Lower Saxony,* Italy or Finland showed nitrogen values in the 3rd tercile. The highest percentages of nitrogen values in the 1st tercile were determined for Finland, Italy, Germany - Lower Saxony, and Austria. The highest national percentage of values in the 2nd (medium) tercile was calculated for Belgium (80%).

Phosphorus

The highest national percentages of conifer plots with phosphorus values in the 3rd tercile were found in Belgium-*Wallonia* and the United Kingdom. Only in Germany - Lower Saxony were there no plots with phosphorus values in the 3rd tercile. The countries with the highest percentages of phosphorus values in the 1st tercile (low values) were Bulgaria and Germany (more than 70% of the conifer plots of the respective country) as well as Italy (66.7%) and

Austria (approx. 46%). The highest national percentages in the 2nd (medium) tercile were observed for the Czech Rep. (60%) and Finland (approx. 48%).

Potassium

As in the case of phosphorus, also the national percentages of potassium values in the 3rd tercile were highest in the United Kingdom and in Belgium (78% and 60%, resp.). As opposed to nitrogen and phosphorus, at least one of the plots of each country had a potassium value in the 3rd tercile in leaves type 1. In addition to the United Kingdom and Belgium, relatively high national percentages of 3rd tercile potassium values were determined also for Slovenia (approx. 37%) and the Czech Rep. (approx. 28%). Low potassium values, documented by high percentages of plots classified in the 1st tercile, were found mainly in Bulgaria (approx. 77%) as well as in Italy (about 47%) and Austria (about 44%). The highest national percentages of 2nd tercile potassium values of leaves type 1 were observed in Germany - *Lower Saxony* (approx. 57%) and Finland (approx. 55%).

Calcium

As regards the calcium values of leaves type 1, the highest national percentage of 3rd tercile calcium values was determined for Italy. Relatively high national percentages of calcium values in the 3rd tercile existed also in Slovakia (approx. 46%), Austria (approx. 42%), and Bulgaria (about 39%). The highest national percentages of 1st tercile values were determined for Belgium-*Wall.* (60%), Germany - *Lower Saxony* (approx. 57%), Finland (approx. 52%), and the United Kingdom (about 51%). The country with the highest national percentage of 2nd tercile (medium) calcium values of leaves type 1 was Finland (approx. 45%), followed by Bulgaria (about 39%), Slovakia (about 37%), the Czech Rep. (approx. 35%), and Austria (approx. 34%).

Magnesium

The highest national percentages of 3rd tercile magnesium values of leaves type 1 were determined for Bulgaria (approx. 77.6%), Austria (approx. 51%), and Italy (approx. 47%). In the other countries, the national percentages of 3rd tercile values ranged between 10% (Belgium) and 27% (United Kingdom). The highest national percentages of low (1st tercile) magnesium values were observed for Germany - *Lower Saxony* (approx. 71%), Belgium (70%), Slovakia (approx. 59%), and the Czech Rep. (55%). The percentages of 1st tercile magnesium plots were lowest in Austria (13%), Finland (14%), and Bulgaria (15%). By far the highest national percentage of 2nd tercile magnesium values was determined for Finland (62%).

Sulphur

The countries with the highest national percentages of plots with a low (1st tercile) sulphur content were Belgium-*Wall.* (90%) and Finland (approx. 83%). Relatively high national percentages of 1st tercile sulphur values were observed also in Austria (approx. 44%), Italy (40%), and the Czech Rep. (30%). None of the conifer plots of Slovakia had any sulphur values of the 1st tercile, and only one plot of the United Kingdom had one. These two countries therefore showed the highest percentages of high (3rd tercile) sulphur values of needle set 2: about 88% in Slovakia and 75% in the United Kingdom. In the Czech Rep. 30%

of the conifer plots had 3rd tercile sulphur values, in Italy 13%, and in Austria 9%). None of the conifer plots of Belgium, Germany - *Lower Saxony* or Finland showed any sulphur values in the 3rd tercile.

3.3.4 Classification

The classification of the macronutrient content of the individual plots of the four main tree genera was performed using the classification values shown below in Table 3-8.

Table 3-8: Classification values in mg/g (fixed at the 3rd Forest Foliar Expert Panel Meeting)

	Class	**N**	**P**	**K**	**Ca**	**Mg**	**S**
Spruce	1	≤12.0	≤1.0	≤3.5	≤1.5	≤0.6	≤1.1
	2	-17.0	-2.0	-9.0	-6.0	-1.5	-1.8
	3	>17.0	>2.0	>9.0	>6.0	>1.5	>1.8
Pine	1	≤12.0	≤1.0	≤3.5	≤1.5	≤0.6	≤1.1
	2	-17.0	-2.0	-10.0	-4.0	-1.5	-1.8
	3	>17.0	>2.0	>10.0	>4.0	>1.5	>1.8
Beech	1	≤18.0	≤1.0	≤5.0	≤4.0	≤1.0	≤1.3
	2	-25.0	-1.7	-10.0	-8.0	-1.5	-2.0
	3	>25.0	>1.7	>10.0	>8.0	>1.5	>2.0
Oak	1	≤15.0	≤1.0	≤5.0	≤3.0	≤1.0	
	2	-25.0	-1.8	-10.0	-8.0	-2.5	
	3	>25.0	>1.8	>10.0	>8.0	>2.5	

Since very different terms are being used for the same values or fields of values in European countries (BERGMANN 1993, van den BURG 1985, 1990b), and in order to avoid misinterpretation or wrong conclusions, it was decided by the participants of the 3rd Expert Panel Meeting (Vienna 1995) that, for the evaluation at European level, classifications of only 3 classes and without more specific names or descriptions should be determined.

3.3.4.1 Main Tree Genera

It can be seen from Table 3-9 that plots were most frequently classified into Class 1 in the case of nitrogen (approx. 33 % of all plots), followed by phosphorus (approx. 22 % of all plots). Only 2 - 4 % of the plots ranged in Class 1 according to the potassium, calcium and magnesium classification values of Table 3-8.
High values (values of Class 3) were determined mainly for calcium (approx. 34 % of all plots) and magnesium (approx. 22 % of the plots). The lowest percentage share of Class 3 was determined for phosphorus.
Table 3-9 also illustrates that in the case of the 4 main tree genera, nitrogen was the element most frequently classified into Class 1 (i.e. values below the lower classification value of Table 3-8). For spruce, pine and beech, the shares of the phosphorus values of Class 1 fell clearly below the shares of the nitrogen values of Class 1. However the Class 1 shares of those two elements were almost identical in oak. The shares of plots with Class 1 classifications were for all 4 main tree genera considerably lower for potassium and calcium. While the percentages of Class 1 plots for magnesium were only about 1 percent for spruce and pine,

they amounted to approx. 14 percent for beech and 7 percent for oak respectively; in the case of beech, they reached about the same figures as the share of the beech plots in the Class 1 for phosphorus.
Concerning the percentages of plots to be classified in Class 1, relatively marked differences between the 4 main tree genera were also observed for the other macro-nutrients. Compared with the other main tree genera, the spruce plots showed the lowest Class 1 percentages for all 5 major nutrients (N, P, K, Ca, Mg).

Table 3-9: Classification of the nutrient content - Main tree genera
percentage of plots of the 4 main tree genera according to the 3 classes
(see Table 3-8)

	Class	**N**	**P**	**K**	**Ca**	**Mg**	**S**
Spruce	1	22.4	9.4	2.1	0.4	0.9	67.1
	2	67.2	83.3	89.7	77.3	83.3	31.5
	3	10.3	7.3	8.2	22.3	15.9	1.4
Pine	1	39.5	24.0	4.5	3.4	1.1	57.0
	2	49.1	73.2	95.0	69.3	76.0	40.5
	3	11.4	2.8	0.6	27.4	22.9	2.5
Beech	1	34.3	13.9	4.1	4.1	13.5	6.9
	2	43.8	72.2	77.0	16.2	25.7	50.0
	3	21.9	13.9	18.9	79.7	60.8	43.1
Oak	1	44.5	44.6	3.9	2.3	7.0	
	2	39.1	50.9	75.0	61.7	84.4	
	3	16.4	4.5	21.1	35.9	8.6	
Main Tree Genera	**1**	**33.3**	**21.4**	**3.4**	**2.1**	**3.7**	**53.8***
	2	**53.3**	**72.9**	**86.6**	**64.3**	**74.4**	**37.7***
	3	**13.3**	**5.7**	**9.9**	**33.6**	**21.8**	**8.5***

* For sulphur no oak values included.

Much greater differences than those between the percentages of Class 1 plots of the 4 main tree genera were observed for the percentages of Class 3 plots, with values exceeding the respective upper classification values. For nitrogen, the percentages of Class 3 values for the 4 main tree genera ranged between 11 and 22%; for potassium between 1 and 21%, for calcium between 22 and 80%, and for magnesium between 9 and 61%. For all elements except potassium, the highest percentages of Class 3 values, i.e. values exceeding the upper classification value, were always observed for beech.
Similarly, for sulphur, beech showed a considerably higher share of values above the upper classification value than spruce or pine did (namely 43.1% of the beech plots as compared to 1.4 and 2.5% for spruce and pine, respectively). Low sulphur values of Class 1 were observed on two thirds of the spruce plots and approximately 57% of the pine plots, but only 7% of the beech plots.

3.3.4.2 Classification Results: Country-specific Results for the Main Tree Genera

Tables 3-10 to 3-13 show that for the main tree genera there were relatively differences between countries in the class percentages of the individual elements and, consequently, also deviations from the results determined for the respective main tree genera.

Spruce (Table 3-10)

The percentages of spruce plots with nitrogen values of Class 1 (approx. 77%) ranged considerably above the corresponding mean (22%) and above the percentage of the other countries (0 - 43%) in Finland and in Lithuania; only in the United Kingdom did none of the spruce plots show nitrogen values of Class 1.
There was also a relatively large number of countries with Class 1 phosphorous values, topped by Lithuania with 54% of its spruce plots, Ireland (25%), Italy (20%), Slovenia (20%), and Austria (approx. 6%). Potassium values of Class 1 were found on the spruce plots of 3 countries (Czech Republic - approx. 3%, Lithuania - approx. 8%, Austria - approx. 4); calcium or magnesium values of Class 1 were found only in Lithuania (approx. 8) and in the Czech Republic (approx. 6% thereof) respectively.
In Belgium, Germany - *Lower Saxony*, Finland, and the United Kingdom no spruce plots had any Class 1 values for phosphorus, potassium, calcium, or magnesium (this applied also to one spruce plot in Bulgaria).
For nitrogen and potassium, relatively high percentages of Class 3 spruce plots (at least 20% of the national plots) were observed in the United Kingdom; for calcium in Ireland, Italy, Lithuania, Slovenia, Finland, the United Kingdom and Austria; and for magnesium in Lithuania and Austria.
Only in Slovenia and the United Kingdom did the percentage of Class 1 sulphur values (sulphur content remaining below the lower classification value) fall below 20%; in the other countries with sulphur data the percentage of plots with a low sulphur content ranged between 68 and 100%. Only Slovenia (1) and the United Kingdom (2) had individual spruce plots with sulphur values of Class 3.

Pine (Table 3-11)

The percentages of pine plots with nitrogen values in Class 1 in Russia - *St. Petersburg Region* and, Finland (approx. 93% and 75%, respectively) considerably exceeded the mean value of the pine plots (approx. 40%) and the values of the other countries (0 - 43%). Of the countries with three or more pine plots, no plots with nitrogen values in Class 1 (nitrogen values $\leq$ 12.0 mg N/g) were found in Belgium - *Wallonia*, the Czech Republic, Germany - *Lower Saxony*, Ireland, and the United Kingdom. Relatively high percentages of Class 1 phosphorus values were observed in the pine plots of Spain (approx. 43%), Russia - *St. Petersburg Region* (approx. 41%) and Ireland (33.3%). In addition, only Class 1 phosphorus values were found in Bulgaria and Lithuania.
Of the countries with three or more pine plots, Belgium - *Wall.*, the Czech Republic, Germany - *Lower Saxony*, Finland, the United Kingdom, and Austria had no plots with phosphorus values of Class 1 ($\leq$ 1.0 mg P/g).
High (Class 1) percentages of potassium values ($\leq$ 3.5 mg K/g) were observed only in the pine plots of Lithuania (33.3%) and Bulgaria (approx. 17%). Except for these two countries, only one single pine plot in Russia - *St. Petersburg Region* showed a potassium value below the lower classification value. In Belgium - *Wallonia*, the Czech Republic, Germany - Lower

Table 3-10: Classification of the nutrient content - *SPRUCE* / Individual countries
Percentage of spruce plots in the individual countries according to the 3 classes (see Table 3-8)

Country	Class	**N**	**P**	**K**	**Ca**	**Mg**	**S**
Austria	1	15.3	5.6	4.2	-	-	90.3
	2	83.3	83.3	93.1	77.8	73.6	9.7
	3	1.4	11.1	2.8	22.2	26.4	-
Belgium-*Wallonia*	1	42.9	-	-	-	-	100.0
	2	57.1	85.7	100.0	100.0	100.0	-
	3	-	14.3	-	-	-	-
Bulgaria	1		-	-	-	-	
	2		-	-	100.0	-	
	3		100.0	100.0	-	100.0	
Czech Rep.	1	2.9	-	2.9	-	5.9	67.7
	2	82.4	97.1	94.1	88.2	91.2	32.4
	3	14.7	2.9	2.9	11.8	2.9	-
Finland	1	76.9	-	-	-	-	100.0
	2	23.1	92.3	92.3	76.9	100.0	-
	3	-	7.7	7.7	23.1	-	-
Germany-*Lower Saxony*	1	28.6	-	-	-	-	85.7
	2	71.4	100.0	100.0	100.0	100.0	14.3
	3	-	-	-	-	-	-
Ireland	1	12.5	18.8	-	-	-	
	2	75.0	81.3	81.3	75.0	100.0	
	3	12.5	-	18.8	25.0	-	
Italy	1	33.3	20.0	-	-	-	80.0
	2	66.7	73.3	100.0	80.0	93.3	20.0
	3	-	6.7	-	20.0	6.7	-
Lithuania	1	76.9	53.9	7.7	7.7	-	76.9
	2	15.4	46.2	92.3	61.5	46.2	23.1
	3	7.7	-	-	30.8	53.9	-
Slovenia	1	27.6	17.2	-	-	-	17.2
	2	58.6	75.9	93.1	62.1	86.2	79.3
	3	13.8	6.9	6.9	37.9	13.8	3.4
United Kingdom	1	-	-	-	-	-	15.4
	2	57.7	92.3	65.4	73.1	84.6	76.9
	3	42.3	7.7	34.6	26.9	15.4	7.7
SPRUCE	**1**	**22.4**	**9.4**	**2.1**	**0.4**	**0.9**	**67.1**
	2	**67.2**	**83.3**	**89.7**	**77.3**	**83.3**	**31.5**
	3	**10.3**	**7.3**	**8.2**	**22.3**	**15.9**	**1.4**

Table 3-11: Classification of the nutrient content - *PINE* / Individual countries
Percentage of pine plots in the individual countries according to the 3 classes (see Table 3-8)

Country	Class	**N**	**P**	**K**	**Ca**	**Mg**	**S**
Austria	1	20.0	-	-	-	-	80.0
	2	80.0	100.0	100.0	80.0	100.0	20.0
	3	-	-	-	20.0	-	-
Belgium-*Wallonia*	1	-	-	-	-	-	66.7
	2	100.0	100.0	100.0	100.0	100.0	33.3
	3	-	-	-	-	-	-
Bulgaria	1		8.3	16.7	16.7	-	
	2		83.3	83.3	66.7	58.3	
	3		8.3	-	16.7	41.7	
Czech Rep.	1	-	-	-	-	-	83.3
	2	83.3	100.0	100.0	50.0	100.0	16.7
	3	16.7	-	-	50.0	-	-
Finland	1	75.0	-	-	12.5	-	100.0
	2	25.0	100.0	100.0	87.5	100.0	-
	3	-	-	-	-	-	-
Germany-*Lower Saxony*	1	-	-	-	-	11.1	11.1
	2	50.0	100.0	100.0	100.0	88.9	88.9
	3	50.0	-	-	-	-	-
Ireland	1	-	44.4	-	11.1	-	
	2	100.0	55.6	100.0	88.9	100.0	
	3	-	-	-	-	-	
Lithuania	1	26.7	20.0	33.3	-	-	66.7
	2	66.7	73.3	66.7	13.3	73.3	33.3
	3	6.7	6.7	-	86.7	26.7	-
Russia-*St. Petersburg Reg.*	1	92.6	40.7	3.7	3.7	-	55.6
	2	7.4	55.6	96.3	81.5	100.0	37.0
	3	-	3.7	-	14.8	-	7.4
Spain	1	42.9	42.9	-	-	-	64.3
	2	55.4	57.1	98.2	55.4	46.4	33.9
	3	1.8	-	1.8	44.6	53.6	1.8
United Kingdom	1	-	-	-	-	-	-
	2	36.4	81.8	100.0	100.0	81.8	90.9
	3	63.6	18.2	-	-	18.2	9.1
PINE	**1**	**39.5**	**24.0**	**4.5**	**3.4**	**1.1**	**57.0**
	2	**49.1**	**73.2**	**95.0**	**69.3**	**76.0**	**40.5**
	3	**11.4**	**2.8**	**0.6**	**27.4**	**22.9**	**2.5**

Saxony, Spain, Ireland, Finland, the United Kingdom, and Austria, no Class 1 potassium values were found.
In Bulgaria, the percentage of plots with Class 1 calcium values ($\leq$ 1.5 mg Ca/g) reached approximately 17%, in Finland 12.5%, in Ireland about 11%, and in Russia - *St. Petersburg Region* approximately 4%. Of the countries with at least 3 pine plots, again Belgium - *Wallonia*, the Czech Republic, Germany - *Lower Saxony*, Spain, the United Kingdom, and Austria as well as Lithuania had no calcium Class 1 plots. Of the 179 pine plots, only 2 in Germany - *Lower Saxony* had magnesium values in Class 1 ($\leq$ 0.6 mg Mg/g).
The highest percentage shares of pine plots with nitrogen values in Class 3 (> 17.0 mg N/g) occured in the United Kingdom (approx. 64%) and Germany - *Lower Saxony* (50%). Apart from these two countries, only individual pine plots in the Czech Republic, Spain and Lithuania had nitrogen values in Class 3. Class 3 phosphorus values (> 2.0 mg P/g) were observed only in the United Kingdom (approx. 18%), Bulgaria (about 8%), Lithuania (approx. 7%) and Russia - *St. Petersburg Region* (approx. 4%). Potassium values in Class 3 (> 10.0 mg K/g) were observed only in one plot in Spain.
With respect to calcium, many more countries than those concerned in the cases of nitrogen, phosphorus and potassium had pine plots that were classified into Class 3 (> 4.0 mg Ca/g).
The highest percentages of pine plots with Class 3 calcium values were observed in Lithuania, the Czech Republic and Spain; pine plots of Bulgaria, Ireland, Russia - *St. Petersburg Region*, and Austria also reached calcium values of Class 3. The plots in Belgium-*Wallonia*, Germany *Lower Saxony*, Finland and the United Kingdom did not show any Class 3 calcium values.
The highest percentages of pine plots with magnesium values in Class 3 (> 1.5 mg Mg/g) were found in Spain and Bulgaria (approx. 54 and 42%, respectively); magnesium values of Class 3 were also found in Lithuania and in the United Kingdom.
Of the countries with three or more pine plots, Belgium - *Wallonia*, the Czech Republic, Spain, Lithuania, Russia - *St. Petersburg Region*, Finland and Austria had Class 1 sulphur values ($\leq$ 1.1 mg S/g) on 56 - 100% of their pine plots. For contrast, only 11% of the pine plots in Germany and none of the pine plots in the United Kingdom had sulphur values in Class 1. Only in the United Kingdom, in Russia - *St. Petersburg Region* and Spain was the upper limit for sulphur in pine plots (1.8 mg S/g) exceeded.

Beech (Table 3-12)

Of the countries with three or more beech plots, Slovenia and Slovakia had the highest percentages of beech plots with nitrogen values in Class 1 ($\leq$ 18.0 mg N/g). Apart from these two countries, a nitrogen value of Class 1 was observed on one beech plot of Belgium - *Wallonia*. In Italy, Spain and the United Kingdom there were no beech plots with nitrogen values in Class 1. Phosphorus values in Class 1 ($\leq$ 1.0 mg P/g) existed on beech plots in Belgium - *Wallonia*, Slovenia and Italy. No phosphorus values in Class 1 were in Spain and in the United Kingdom. No phosphorus values were available from Slovakia.
Potassium values in Class 1 ($\leq$ 5.0 mg K/g) were found on the beech plots of Belgium - *Wallonia*, Slovenia and Slovakia; no plots with Class 1 potassium values were found in the beech plots of Spain, Italy or the United Kingdom. Calcium values in Class 1 ($\leq$ 4.0 mg Ca/g) were observed only in Slovenia, Slovakia and Italy. Beech plots with Class 1 magnesium values were found ($\leq$ 1.0 mg Mg/g) especially in Belgium, but also in Spain, Italy and the United Kingdom. This was not the case for any plots in Slovenia and Slovakia.

Table 3-12: Classification of the nutrient content - *BEECH* / Individual countries
Percentage of beech plots in the individual countries according to the 3 classes (see Table 3-8)

Country	Class	**N**	**P**	**K**	**Ca**	**Mg**	**S**
Belgium-*Wallonia*	1	14.3	28.6	14.3	-	85.7	14.3
	2	85.7	71.4	85.7	85.7	14.3	85.7
	3	-	-	-	14.3	-	-
Italy	1	-	28.6	-	14.3	14.3	28.6
	2	85.7	57.1	85.7	-	14.3	57.1
	3	14.3	14.3	14.3	85.7	71.4	14.3
Slovakia	1	55.3		2.6	2.6	-	-
	2	26.3		63.2	5.3	23.7	26.3
	3	18.4		34.2	92.1	76.3	73.7
Slovenia	1	66.7	33.3	33.3	33.3	-	66.7
	2	33.3	66.7	66.7	33.3	100.0	33.3
	3	-	-	-	33.3	-	-
Spain	1	-	-	-	-	40.0	-
	2	60.0	80.0	100.0	20.0	20.0	100.0
	3	40.0	20.0	-	80.0	40.0	-
United Kingdom	1	-	-	-	-	9.1	-
	2	45.5	81.8	100.0	9.1	18.2	81.8
	3	54.6	18.2	-	90.9	72.7	18.2
BEECH	**1**	**34.3**	**13.9**	**4.1**	**4.1**	**13.5**	**6.9**
	2	**43.8**	**72.2**	**77.0**	**16.2**	**25.7**	**50.0**
	3	**21.9**	**13.9**	**18.9**	**79.7**	**60.8**	**43.1**

High nitrogen values in Class 3 (> 25.0 mg N/g) were observed on beech plots in the United Kingdom (approx. 55%); individual beech plots also showed nitrogen values of Class 3 in Spain, Slovakia and Italy.
Phosphorus values in Class 3 (> 1.7 mg P/g) existed on all plots in Spain, Italy and the United Kingdom. Potassium values in Class 3 (> 10.0 mg K/g) were observed on more than one third of the 38 beech plots in Slovakia and on one Italian beech plot.
Class 3 calcium values (> 8.0 mg Ca/g) existed in all countries offering results for beech plots; the highest percentages were found in Slovakia, the United Kingdom, Italy and Spain. Of the countries with three or more beech plots, no magnesium values in Class 3 (> 1.5 mg Mg/g) were found in Belgium - *Wallonia* and Slovenia. The highest percentages of Class 3 magnesium values, were determined for Slovakia, the United Kingdom and Italy (more than 70%). Only in Belgium - *Wallonia*, Slovenia and Italy did beech plots show sulphur values in Class 1 (≤ 1.3 mg S/g). In Spain, Slovakia and the United Kingdom such values were not observed. Sulphur values had to be classified in Class 3 (> 2.0 mg S/g) in Slovakia, Italy and the United Kingdom.

Oak (Table 3-13)

Three of the five countries with more than three oak plots had nitrogen values in Class 1 ($\leq$ 15.0 mg N/g). While in Italy and in Slovakia one quarter of the oak plots showed nitrogen values in Class 1, this percentage was 62.5% in the case of Spain; this result might, however, be a consequence of the high percentage of evergreen oaks in Spain. In Belgium - *Wallonia* and the United Kingdom no oak plots showed any Class 1 nitrogen values.

Table 3-13: Classification of the nutrient content - *OAK*/ Individual countries
Percentage of oak plots in the individual countries according to the 3 classes
(see Table 3-8)

Country	Class	**N**	**P**	**K**	**Ca**	**Mg**
Belgium-*Wallonia*	1	-	37.5	-	-	25.0
	2	100.0	62.5	75.0	100.0	75.0
	3	-	-	25.0	-	-
Italy	1	25.0	75.0	-	-	12.5
	2	75.0	25.0	87.5	37.5	50.0
	3	-	-	12.5	62.5	37.5
Slovakia	1	25.0		-	-	-
	2	50.0		56.3	12.5	87.5
	3	25.0		43.8	87.5	12.5
Spain	1	62.5	50.0	6.3	3.8	7.5
	2	32.5	46.3	83.8	72.5	85.0
	3	5.0	3.8	10.0	23.8	7.5
United Kingdom	1	-	-	-	-	-
	2	7.1	85.7	35.7	57.1	100.0
	3	92.9	14.3	64.3	42.9	-
OAK	**1**	**44.5**	**44.6**	**3.9**	**2.3**	**7.0**
	2	**39.1**	**50.9**	**75.0**	**61.7**	**84.4**
	3	**16.4**	**4.5**	**21.1**	**35.9**	**8.6**

Except for the United Kingdom, all countries had phosphorus values of Class 1 ($\leq$ 1.0 mg P/g), with the highest percentages being observed in Italy (75%) and Spain (50%). No phosphorus data were available from the Slovakian oak plots.
Potassium and calcium values in Class 1 ($\leq$ 5.0 mg K/g; $\leq$ 3.0 mg Ca/g) were observed on only five, and three of the Spanish oak plots respectively. Magnesium values in Class 1 ($\leq$ 1.0 mg Mg/g) were found in Spain (on 7.5% of the oak plots), Italy (12%) and Belgium - *Wallonia* (25%).
High (Class 3) nitrogen values (> 25.0 mg N/g) existed in some 93% of the oak plots in the United Kingdom and on approximately 25% of the Slovakian oak plots: In contrast, only 5% of the Spanish oak plots showed any Class 3 values and none of the oak plots in Belgium - *Wallonia* or Italy. Class 3 phosphorus values (> 1.8 mg P/g) were found on three of the Spanish oak plots and on 2 oak plots in the United Kingdom, which corresponds to approx. 4% (Spain) and approx. 14% (United Kingdom), respectively.
Potassium values in Class 3 (> 10.0 mg K/g) existed in all of the 5 countries with three or more oak plots. The highest percentage of national oak plots with Class 3 potassium values

was observed in the United Kingdom (approx. 64%); in Slovakia this percentage was around 44%, and in Spain about 10%.
Calcium values in Class 3 (> 8.0 mg Ca/g) were found in all countries except for Belgium - *Wallonia*. The highest percentage of national oak plots for this element (88%) was found in Slovakia, in Italy the respective percentage was about 63%, in the United Kingdom about 43% and in Spain approximately 24%. Magnesium values in Class 3 (> 2.5 mg Mg/g) were observed in Italy (approx. 38% of the national oak plots), Slovakia (12.5%) and Spain (7.5%). In Belgium - *Wallonia* and the United Kingdom, no plots showed any magnesium values in Class 3.

3.3.4.3 Classification Results referring to the individual Countries

For a comparison of the countries, the classification results of the 4 main tree genera were combined and the percentages of the national plots classified in Classes 1 to 3 for the major nutrients and for sulphur are shown in Table 3-14.

Nitrogen *(see Figure 7)*

As can be seen from Table 3-14, Class 1 values (values falling below the lower classification values) for nitrogen were observed in all countries except the United Kingdom. The highest percentages of areas with Class 1 nitrogen values were found in Russia - *St. Petersburg Region* (92.6%), Finland (78.9%), Spain (52.5%) and Lithuania (50%). As well as the United Kingdom, relatively low Class 1 nitrogen percentages were also observed in the Czech Republic (2.5%), Germany - *Lower Saxony* (8.0%) and Ireland (8.0%). Among the plots with a particularly high nitrogen content (exceeding the upper classification value), the United Kingdom took the leading position with approx. 60%, followed by Germany - *Lower Saxony* (36.0%), Slovakia (20.4%), the Czech Republic (15.0%) and Slovenia (13.9%). In Belgium - *Wallonia*, Russia - *St. Petersburg Region* and Finland, none of the sample plots showed Class 3 nitrogen values with any of the four main tree genera.

Phosphorus *(see Figure 8)*

The highest percentage shares of Class 1 phosphorus values were observed in Spain (45.4%), Russia - *St. Petersburg Region* (40.7%), Italy (36.7%) and Lithuania (35.7%). No United Kingdom sample plots showed phosphorus values in Class 1; the same applied to the Czech Republic, to Germany - *Lower Saxony* and Finland. The percentages of Class 1 phosphorus values were also low in Bulgaria (6.7%) and Austria (5.1%).
The high (Class 3) phosphorus values (those exceeding the upper classification value) reached a maximum of 20% in Bulgaria. Only in the United Kingdom and in Austria were the 10% limit for the Class 3 phosphorus values exceeded (12.9% and 10.3%, respectively). No phosphorus values in Class 3 were observed on any of the plots of Germany - *Lower Saxony* or Ireland. No phosphorus analysis data were available for Slovakia.

Potassium *(see Figure 9)*

In the case of potassium, none of the plots of the United Kingdom were classified into Class 1; the same applied to Germany - *Lower Saxony*, Ireland, Italy and Finland. The highest percentages of plots with potassium values in Class 1 were observed in Lithuania (21.4%) and

Bulgaria (13.3%). In Belgium - *Wallonia*, Slovakia and Austria the percentages of potassium values in Class 1 ranged between 1.9% and 4.0%.
No Class 3 potassium values were determined in Germany - *Lower Saxony*, Lithuania and Russia - *St. Petersburg Region*. The highest percentages of Class 3 potassium values existed in Slovakia (37.0%) and the United Kingdom (29.0%). In all other countries having Class 3 potassium values, the respective percentages ranged between 2.5% (Czech Republic) and 12.0% (Ireland).

Calcium *(see Figure 10)*

Bulgaria (13.3%) and Finland (6.9%) were the only countries where the share of plots with calcium values in Class 1 exceeded 5 percent. In Belgium - *Wallonia,* the Czech Republic, Germany - *Lower Saxony*, the United Kingdom and Austria, none of the sample plots showed any Class 1 calcium values; in the other countries, percentages ranged between 1.9 and 4.0 percent.
Except for Germany - *Lower Saxony*, there was at least one sample plot with calcium values in Class 3 in all countries. The highest percentages of plots with Class 3 calcium values were observed in Slovakia (90.7%), Lithuania (60.7%), Italy (46.7%), Slovenia (41.7%), the United Kingdom (37.1%) and Spain (34.0%).

Magnesium *(see Figure 11)*

The highest percentage share of Class 1 magnesium values was found in Belgium - *Wallonia* (32%); magnesium values of Class 1 were also observed in Germany - *Lower Saxony* (8.0%), Italy (6.7%), Spain (5.7%), the Czech Republic (5.0%) and the United Kingdom (1.6%). Magnesium values in Class 1 were not found in Bulgaria, Ireland, Lithuania, Russia - *St. Petersburg Region*, Slovenia, Slovakia, Finland, and Austria. The highest percentages of plots with Class 3 magnesium values were found in Slovakia (57.4%), Bulgaria (46.7%) and Lithuania (39.3%). In Spain, Italy, the United Kingdom and Austria, the percentages of plots with magnesium values in Class 3 ranged between 22.6 and 30 percent. No magnesium values in Class 3 were found in Belgium - *Wallonia*, Germany - *Lower Saxony*, Ireland, Russia - *St. Petersburg Region* and Finland; in the Czech Republic this applied to one plot only.

Table 3-14: Classification of the nutrient content - *MAIN TREE GENERA* / Countries
Percentage of plots of the 4 main tree genera in the individual countries according to the 3 classes (see Table 3-8)

Country (n)	Class	**N**	**P**	**K**	**Ca**	**Mg**	**S ***
Austria	1	15.4	5.1	3.8	-	-	88.5
(78)	2	83.3	84.6	93.6	76.9	75.6	11.5
	3	1.3	10.3	2.6	23.1	24.4	-
Belgium-*Wallonia*	1	16.0	20.0	4.0	-	32.0	58.8
(25)	2	84.0	76.0	88.0	96.0	68.0	41.2
	3	-	4.0	8.0	4.0	-	-
Bulgaria	1		6.7	13.3	13.3	-	
(15)	2		73.3	80.0	66.7	53.3	
	3		20.0	6.7	20.0	46.7	
Czech Rep.	1	2.5	-	2.5	-	5.0	70.0
(40)	2	82.5	97.5	95.0	82.5	92.5	30.0
	3	15.0	2.5	2.5	17.5	2.5	-
Finland	1	75.9	-	-	6.9	-	100.0
(29)	2	24.1	96.6	96.6	82.8	100.0	-
	3	-	3.4	3.4	10.3	-	-
Germany-*Lower Saxony*	1	8.0	-	-	-	8.0	32.0
(25)	2	56.0	100.0	100.0	100.0	92.0	68.0
	3	36.0	-	-	-	-	-
Ireland	1	8.0	28.0	-	4.0	-	
(25)	2	84.0	72.0	88.0	80.0	100.0	
	3	8.0	-	12.0	16.0	-	
Italy	1	23.3	36.7	-	3.3	6.7	63.6
(30)	2	73.3	56.7	93.3	50.0	63.3	31.8
	3	3.3	6.7	6.7	46.7	30.0	4.5
Lithuania	1	50.0	35.7	21.4	3.6	-	71.4
(28)	2	42.9	60.7	78.6	35.7	60.7	28.6
	3	7.1	3.6	-	60.7	39.3	-
Russia-*St. Petersburg Region*	1	92.6	40.7	3.7	3.7	-	55.6
(27)	2	7.4	55.6	96.3	81.5	100.0	37.0
	3	-	3.7	-	14.8	-	7.4
Slovakia	1	46.3		1.9	1.9	-	-
(54)	2	33.3		61.1	7.4	42.6	26.3
	3	20.4		37.0	90.7	57.4	73.7
Slovenia	1	31.4	20.0	2.9	2.9	-	21.2
(35)	2	57.1	74.3	91.4	54.3	88.6	75.8
	3	11.4	8.6	5.7	42.9	11.4	3.0
Spain	1	52.5	45.4	3.5	2.1	5.7	59.0
(141)	2	42.6	51.8	90.1	63.8	67.4	39.3
	3	5.0	2.8	6.4	34.0	27.0	1.6
United Kingdom	1	-	-	-	-	1.6	8.3
(62)	2	40.3	87.1	71.0	62.9	75.8	81.3
	3	59.7	12.9	29.0	37.1	22.6	10.4

* For sulphur no oak values included.

Sulphur *(see Figure 12)*

Of the 12 countries from which sulphur data were available, Slovakia was the only one without any plot with Class 1 sulphur values. The highest percentages of plots with sulphur values of Class 1 (values remaining below the lower classification value) were determined for Finland (100%), Austria (88.5%), Lithuania (71.4%) and the Czech Republic. Percentages of plots with Class 1 sulphur values exceeding 50 percent were observed also in Belgium - *Wallonia*, Italy and Russia - *St. Petersburg Region*. In Germany - *Lower Saxony*, Spain and Slovenia, between 20.6 and 32% of the plots had sulphur values of Class 1; the same applied to only 8.3% of the plots of the United Kingdom, which is the second worst result after that of Slovakia. With 73.7%, Slovakia clearly had the highest percentage of sulphur values in Class 3 (values exceeding the upper classification value), whereas in Spain, Italy, Russia - *St. Petersburg Region*, Slovenia, and the United Kingdom the percentages of plots with Class 3 sulphur values were still between 1.6 and 10.4%. No Class 3 sulphur values were observed in Belgium - *Wallonia*, the Czech Republic, Germany - *Lower Saxony*, Lithuania, Finland or Austria.

If we combine the percentages of the plots with sulphur values of Class 2 and Class 3 (above the lower classification value), Slovakia still takes the lead with its 100%, but the difference between the Slovakian results and those of other countries such as the United Kingdom (91.7%), Slovenia (79.4%) or Germany - *Lower Saxony* (68.0%) gets less marked. In Belgium - *Wallonia*, the Czech Republic, Italy, Lithuania, and Russia - *St. Petersburg Region*, more than one quarter of the plots also had sulphur values in Classes 2 and/or 3. In Finland, however, none of the plots showed any sulphur values in Class 2 or 3; and in Austria only 11.5% of the plots had sulphur values in Class 2 or 3.

Figure 7

Figure 8

Figure 9

Figure 10

Figure 11

Figure 12

3.3.5 Nutrient Ratios

Beside the nutrient contents especially the nutrient ratios can show if there are any disturbances of tree nutrition (BENGTSON & HOLSTENER-JORGENSEN 1971, FIEDLER & THAKUR 1984, FÜRST 1992, GEBAUER 1991, HOFFMANN & FIEDLER 1962, MOHREN et al. 1986, STEFAN 1991b, 1991c, 1993, 1995c, WEISSEN et al. 1990, ZÖTTL et al. 1989). For the evaluation of the relevant nutrient situations, the nutrient contents were classified according to the values given in Table 3-8. It was investigated to what extent (acc. to the determined nutrient ratios) nutrition was *harmonious* and whether, or how significantly, the results of the individual main tree genera or of the individual countries differed.
For the evaluation of the nutrient ratios, the lower and upper classification values were used to determine medium (= Class 2), *harmonious* ranges for the 4 main tree genera:

	Spruce	**Pine**	**Beech**	**Oak**
S/N	0.065-0.150	0.065-0.150	0.052-0.111	-
N/P	6.0-17.0	6.0-17.0	10.59-25.00	8.33-25.0
N/K	1.33-4.86	1.2-4.86	1.8-5.0	1.5-5.0
N/Ca	2.0 -11.33	3.0-11.33	2.25-6.25	1.88-8.33
N/Mg	8.0 -28.33	8.0-28.33	12.0-25.0	6.0-25.0
K/Ca	0.58-6.00	0.88-6.67	0.63-2.50	0.63-3.33
K/Mg	2.33-15.0	2.33-16.67	3.33-10.0	2.0-10.0
Ca/Mg	1.0 -10.0	1.0-6.67	3.67-8.00	1.2-8.0

Values falling below these medium ranges were classified into Class 1; ratios exceeding the respective limit value were classified into Class 3.
The nutrient ratios were calculated using the mean values of the plots.

3.3.5.1 Main Tree Genera

Considering the entire data for the N/P, N/K, K/Mg, and Ca/Mg ratios Table 3-15 shows that, more than 90 percent of the plots were in Class 2; taking the K/Ca ratio, about 88 percent of the plots were to be classified in Class 2. As regards the N/Ca and N/Mg ratios, only about 73 and 76%, of the plots had Class 2 ratios respectively. The percentage of (spruce, pine and beech) plots with a Class 2 S/N ratio was 76.5%.
Only 0.5 - 2.4% of all sampled plots had N/P, N/K, N/Ca, or N/Mg ratios in Class 3, whereas the percentages of plots in Class 1 (too low values of nitrogen) for these four ratios ranged between 5.3 and 26.2%.
Thus, supply with calcium and magnesium was usually good, which can be also concluded from the fact that the percentages of plots in Class 1 were found to be higher than the percentages of Class 3 plots with respect to the K/Ca and K/Mg ratios.
However, Table 3-15 also shows that in some cases there were considerable differences between the 4 main tree genera and, consequently, also marked deviations from the whole set of the sample material.
Taking the N/P and N/K ratios, for instance, and considering all tree species, only some 80% of the plots were in Class 2, whereas this share amounted to more than 90% when only spruce and oak were considered. 85 - 97 % of the spruce, pine and oak plots had K/Ca ratios in Class 2, but only about 60% of the beech plots. Similarly, only 71%, respectively 67%, of the beech plots had K/Mg and Ca/Mg ratios in Class 2, which is considerably less than in the case of the

other 3 main tree genera (K/Mg ratios in Class 2: 93 - 97%; Ca/Mg ratios of Class 2: 93 - 98%). The most significant species-related differences were determined for the N/Ca and N/Mg ratios. For these two ratios, 87% and 86% of the spruce plots ranged in Class 2 respectively, and 78% and 90% of the oak plots; but only about two thirds of the pine plots were in Class 2 for these two ratios. Only one third of the beech plots showed N/Ca ratios in Class 2, and only 41% of the beech plots had N/Mg ratios in Class 2.

Table 3-15: Classification of nutrient ratios - Main tree genera
Percentage of plots of the 4 main tree genera according to the 3 classes (Class 1 lower range; Class 2 medium range/*harmonious* range; Class 3 upper range)

Ratio	Class	SPRUCE	PINE	BEECH	OAK
N/P	1	4.7	9.6	5.7	0.9
	2	93.5	87.4	88.6	94.6
	3	1.7	3.0	5.7	4.5
N/K	1	2.6	12.0	17.8	9.4
	2	96.1	86.2	80.8	90.6
	3	1.3	1.8	1.4	-
N/Ca	1	11.6	31.7	58.9	22.7
	2	88.4	67.7	38.4	77.3
	3	-	0.6	2.7	-
N/Mg	1	13.8	31.7	47.9	7.0
	2	86.2	66.5	41.1	90.6
	3	-	1.8	11.0	2.3
K/Ca	1	2.1	10.6	35.1	13.3
	2	97.9	88.8	63.5	84.4
	3	-	0.6	1.4	2.3
K/Mg	1	3.0	6.7	24.3	3.1
	2	97.0	93.3	71.6	94.5
	3	-	-	4.1	2.3
Ca/Mg	1	0.4	3.4	2.7	-
	2	98.7	93.3	68.9	93.0
	3	0.9	3.4	28.4	7.0
S/N	1	19.9	10.1	2.8	
	2	78.7	80.4	65.3	
	3	1.4	9.5	31.9	

With one exception (beech, N/Mg, 11.3%), between 0 and 6% of the plots had N/P, N/K, N/Ca, or N/Mg ratios in Class 3. For spruce, between 2.7 (N/K) and 13.6% (N/Mg) of the plots had nitrogen ratios in Class 1; for oak, between 0.9 (N/P) and 21.9% (N/Ca); for pine, between 9.5 (N/P) and 31.5% (N/Ca and N/Mg); and for beech, between 0 (N/P) and 63.4% (N/Ca).
Whereas for spruce, pine and oak, the percentages of plots with K/Ca, K/Mg, and Ca/Mg ratios in Class 1 and Class 3 were relatively low (for spruce 0-3.2%, for pine 0 - 10.6%, for oak 0 - 12.5%), 38% of the beech plots had K/Ca ratios and 25% had K/Mg ratios in Class 1; and 30% of the beech plots had Ca/Mg ratios in Class 3.

For S/N ratios, the results of the beech plots deviated substantially from those of the spruce and pine plots. 77.5% and 80.5% of the spruce and pine plots had S/N ratios of Class 2 respectively, but only 65% of the beech plots. The percentages of plots with Class 1 S/N ratios were considerably higher for pine and spruce than they were for beech; on the other hand, the percentage of beech plots with Class 3 values (N content too low as compared to S content) ranked considerably above the results from the conifers.

3.3.5.2 Classification of Nutrient Ratios - Country-specific Results

For the following part of the evaluation, the results of the classification of all main tree genera from the individual countries were combined (Table 3-16).

N/P ratio

In the 12 countries for which N/P ratios are known, between 48.1 and 100% of the plots had N/P ratios of Class 2 (medium range). The share of Class 2 plots remained below 80 percent (48.1%) only in Russia-*St. Petersburg Region*. In the Czech Rep. and the United Kingdom, the N/P ratios of all plots occupied in Class 2.
In Italy 0 - 16.7% of the plots had to be classified in Class 3 (nitrogen values exceeding the upper classification value). With the exception of Russia-*St. Petersburg Region*, the percentages of Class 1 plots were between 0 and 10.7%.

N/K ratio

In the 13 countries where N/K ratios were determined, between 44.4 and 100% of the plots had medium N/K ratios in Class 2. In Germany - *Lower Saxony*, Italy, Slovenia and the United Kingdom the N/K ratios of all plots were found in Class 2. In Belgium-*Wall.*, the Czech Rep., Spain, Ireland, Finland and Austria, more than 90% of the plots had N/K ratios in Class 2, but only slightly more than 70% of the plots in Lithuania and Slovakia. For this ratio, too, the percentage of plots occurring in Class 2 was lowest in Russia-*St. Petersburg Region*.
The percentages of plots in Class 3 ranged between 0 and 14.3% in Lithuania. The highest percentage of Class 1 plots was found in Russia-*St. Petersburg Region* with 55.6%, followed by Slovakia (25.9%) and Lithuania (14.3%). For the other countries, the percentages of plots with Class 1 results ranged between 0 and 8.5%.

N/Ca ratio

As regards the percentages of plots with Class 2 N/Ca ratios, much more significant differences were determined between the 12 countries with N/Ca ratios than in the case of the ratios previously discussed. Between 22.2 and 100% of the plots ranged in Class 2. In Germany - *Lower Saxony* and in the Czech Rep., the N/Ca ratios of all plots were classified into the medium (Class 2) range, whilst in Belgium-*Wall.* and Ireland 96% were. In Italy, Finland, the United Kingdom and Austria, between 80 and 90% of the plots had N/Ca ratios in Class 2, in Spain about 74%, and in Slovakia approximately 64%. In Russia-*St. Petersburg Region*, only 37% of the plots had Class 2 N/Ca ratios; in Lithuania, this percentage was only about 29%, and in Slovakia only 22%. Only two plots in Slovakia and one in the United Kingdom showed extraordinarily high (Classs 3) N/Ca ratios. In accordance with their low percentages of Class 2 plots, Slovakia, Lithuania and Russia-*St. Petersburg Region* showed the highest percentages of plots with Class 1 (exceptionally low) N/Ca ratios out of all countries. The percentages were lowest in the Czech Rep., in Germany - *Lower Saxony*, Belgium, Ireland, and the United Kingdom (between 0 and 9.7%).

Table 3-16: Classification of the nutrient ratios - Main tree genera/Individual countries
Percentage of plots in the individual countries according to the three classes

Country	N/P 1	N/P 2	N/P 3	N/K 1	N/K 2	N/K 3	N/Ca 1	N/Ca 2	N/Ca 3	N/Mg 1	N/Mg 2	N/Mg 3
Austria	5.1	94.9	-	-	98.7	1.3	12.8	87.2	-	17.9	82.1	-
Belgium-*Wallonia*	4.0	96.0	-	8.0	92.0	-	4.0	96.0	-	-	72.0	28.0
Bulgaria												
Crech Rep.	-	100.0	-	-	97.5	2.5	-	100.0	-	-	100.0	-
Finland	10.3	89.7	-	6.9	93.1	-	10.3	89.7	-	10.3	89.7	-
Germany-*Lower Saxony*	-	96.0	4.0	-	100.0	-	-	100.0	-	-	88.0	12.0
Ireland	-	96.0	4.0	4.0	96.0	-	-	100.0	-	-	100.0	-
Italy	-	83.3	16.7	-	100.0	-	20.0	80.0	-	26.7	70.0	3.3
Lithuania	10.7	85.7	3.6	14.3	71.4	14.3	71.4	28.6	-	57.1	42.9	-
Russia-*St.Petersburg Reg.*	51.9	48.1	-	55.6	44.4	-	63.0	37.0	-	70.4	29.6	-
Slovakia				25.9	72.2	1.9	74.1	22.2	3.7	50.0	48.1	1.9
Slovenia	5.7	80.0	14.3	2.9	97.1	-	34.3	65.7	-	14.3	85.7	-
Spain	1.4	96.5	2.1	8.5	91.5	-	26.2	73.8	-	24.8	74.5	0.7
United Kingdom	-	100.0	-	-	100.0	-	9.7	88.7	1.6	3.2	95.2	1.6

Country	K/Ca 1	K/Ca 2	K/Ca 3	K/Mg 1	K/Mg 2	K/Mg 3	Ca/Mg 1	Ca/Mg 2	Ca/Mg 3	S/N 1	S/N 2	S/N 3
Austria	3.8	96.2	-	5.1	94.9	-	-	97.4	2.6	17.9	82.1	-
Belgium-*Wallonia*	4.0	96.0	-	-	84.0	16.0	-	80.0	20.0	35.3	64.7	-
Bulgaria	20.0	73.3	6.7	20.0	80.0	-	33.3	53.3	13.3			
Crech Rep.	-	100.0	-	-	100.0	-	-	100.0	-	50.0	50.0	-
Finland	-	100.0	-	-	100.0	-	-	100.0	-	-	100.0	-
Germany-*Lower Saxony*	-	100.0	-	-	100.0	-	-	100.0	-	24.0	76.0	-
Ireland	4.0	96.0	-	-	100.0	-	-	100.0	-			
Italy	13.3	86.7	-	16.7	83.3	-	-	93.3	6.7	9.1	86.4	4.5
Lithuania	39.3	60.7	-	17.9	82.1	-	3.6	85.7	10.7	28.6	57.1	14.3
Russia-*St.Petersburg Reg.*	3.7	96.3	-	-	100.0	-	-	96.3	3.7	3.7	48.1	48.1
Slovakia	38.9	59.3	1.9	20.4	79.6	-	3.7	75.9	20.4	-	42.1	57.9
Slovenia	8.6	91.4	-	2.9	97.1	-	-	91.4	8.6	-	100.0	-
Spain	9.9	87.9	2.1	7.1	91.5	1.4	0.7	94.3	5.0	-	98.4	1.6
United Kingdom	8.1	91.9	-	3.2	96.8	-	-	96.8	3.2	8.3	91.7	-

N/Mg ratio

Between 29.6 and 100% of the N/Mg ratios of the plots of the individual countries occured in Class 2. All plots of the Czech Rep. and of Ireland had medium N/Mg ratios. In Germany - *Lower Saxony*, Slovenia, Finland, the United Kingdom and Austria, 82 - 95% of the plots had N/Mg ratios in Class 2; in Belgium-*Wall.*, Spain and Italy ranged from 70 to approx. 75%. In contrast, only about 43 and 48%, of the plots of Lithuania and Slovakia had N/Mg ratios of Class 2 respectively, and only about 30% of the plots of Russia-*St. Petersburg Region*.
In Germany-*Lower Saxony* and particularly in Belgium-*Wall.*, a relatively large number of plots showed exceptionally high (Class 3) N/Mg values. Russia-*St. Petersburg Region*, Lithuania and Slovakia had the highest percentages (50 - 70%) of exceptionally low (Class 1) N/Mg ratios.

K/Ca ratio

Between 59.3 and 100% of the plots had K/Ca ratios in Class 2. The K/Ca ratios of all plots in Czech Rep., Germany - *Lower Saxony* and Finland were medium (Class 2). More than 90% of the plots in Belgium-*Wall.*, Ireland, Russia-*St. Petersburg Region*, the United Kingdom and Austria occured in Class 2; in Spain, Italy and Slovenia more than 80% were. In Bulgaria, this was true for only about 73%; in Lithuania for about 61%; and in Slovakia for approximately 59%.
Only three of the Spanish plots and one in Bulgaria and Slovakia had K/Ca ratios in Class 3. The highest percentages of plots with Class 1 K/Ca ratios were found in Lithuania and Slovakia (approx. 39%).

K/Mg ratio

The differences between the percentages of plots with K/Mg ratios in Class 2 determined for the 14 countries concerned were not as significant as they were for nutrient ratios previously discussed; the results of 80 - 100% of the plots ranged in Class 2. In the Czech Rep., Germany - *Lower Saxony*, Ireland, Russia-*St. Petersburg Region* and Finland, the K/Mg ratios of all plots belonged to Class 2; in Spain, Slovenia, the United Kingdom and Austria, more than 90% did. The lowest percentages of medium K/Mg ratios were determined for Slovakia and Bulgaria.
Only four plots in Belgium-*Wall.* and two in Spain had Class 3 K/Mg; in Belgium, however, even this low number corresponds to a 16% share. The highest percentages of Class 1 K/Mg plots were calculated for Slovakia, Bulgaria, Lithuania and Italy (between approx. 17 and 20%).

Ca/Mg ratio

In 13 out of the 14 countries concerned, the percentages of plots with medium (Class 2) Ca/Mg ratios were similar to those for the K/Mg ratios: with the exception of Bulgaria, 76 - 100% of the plots of the individual countries had Ca/Mg ratios of Class 2. In Bulgaria, only slightly more than half of the investigated plots showed Ca/Mg ratios of Class 2.
Compared to the results for the other ratios, many more countries had Ca/Mg ratios of Class 3. The highest Class 3 percentages were determined for Slovakia and Belgium-*Wall.* (approx. 20% in each case). Bulgaria was the only country having a relatively high percentage of plots with Ca/Mg ratios in Class 1.

S/N ratio

Less data were available for the S/N ratio than for the other nutrient ratios, firstly because there were no sulphur classification values for oak, which means it was not possible to calculate the medium range for the oak plots; and secondly because in some of the countries the sulphur and/or nitrogen content had not been determined.
Between 42.1 and 100% of the (spruce, pine, beech) plots had S/N ratios in Class 2. In Slovenia and Finland the S/N ratios of all plots occured in Class 2; in Spain and the United Kingdom more than 90% did. The percentages of plots in Germany - *Lower Saxony*, Italy and Austria with Class 2 ratios were still relatively high (76 - 86%). The lowest percentages of plots with S/N ratios in Class 2 were calculated for Slovakia, the Czech Rep. (42 - 50%) and Lithuania (57%).
Slovakia and Russia-*St. Petersburg Region* showed relatively high percentages in Class 3 S/N ratios (58 and 48%, respectively). Between 0 and 50% of the plots of the individual countries had exceptionally low (Class 1) S/N ratios; the highest percentages of plots with Class 1 S/N ratios were found in the Czech Rep. (50%), Belgium-*Wall.* (35%), Lithuania (29%) and Austria (18%).

3.3.6 Nutrient Content of Leaves Type 1 compared to that of Leaves Type 0

The results of the nutrient content of leaves type 0 and 1 were compared to check whether, where, and to which degree deviations from the usual leaves type-related results had occurred. The content of nitrogen, phosphorus and potassium, for instance, usually decrease with increasing needleage; the calcium content usually increases in the older needles; and for magnesium, there are usually no distinct age-specific changes (HÖHNE 1968, REEMTSMA 1966, STEFAN 1995c).
Table 3-17 shows that, except for the nitrogen ratio in pine, the averages of the ratios of the two leaves types do correspond to the information about the leaves type-related differences provided in the technical literature. However, Table 3-17 also shows that considerable deviations from the *normal leaves type-related development* occur on individual plots.

Table 3-17: Minima, maxima and averages of the ratios of leaves type 1 and 0 (=1.00) in respect of the spruce and pine plots

		N1:N0	P1:P0	K1:K0	Ca1:Ca0	Mg1:Mg0	S1:S0
Spruce	Min.	0.809	0.486	0.414	0.831	0.541	0.760
(n=175)	Max.	1.218	1.804	1.699	3.133	1.352	1.550
	Avg.	0.961	0.832	0.866	1.393	0.905	1.051
Pine	Min.	0.526	0.491	0.414	0.399	0.461	0.795
(n=54)	Max.	2.333	1.343	1.465	3.342	1.420	1.384
	Avg.	1.067	0.926	0.883	1.790	0.882	1.064

With regard to the individual results Tables B13 and B14 (Annex B) illustrate that, deviations from the data given in the technical literature occurred in almost all countries. The following list shows that there were also a few deviations from literature in the case of the national mean values:

Spruce - N Belgium-*Wall.* (1.030), Italy (1.026)
K Belgium-*Wall.* (1.160)

Pine - N Belgium-*Wall.* (1.069), Finland (1.007), United Kingdom (1.048), Austria(1.158)
P Belgium-*Wall.* (1.009), Austria (1.010)
K Belgium-*Wall.* (1.012)

Taking individual plots, the deviations from the expected results for the two tree species were most significant in the following countries (nitrogen, phophorus, potassium > 1.00; calcium < 1.00):

Spruce - N - Belgium (1.218)
P - Italy (1.804)
K - Belgium (1.699)
Ca - United Kingdom (0.831)

Pine - N - Austria (1.338)
P - Belgium (1.343)
K - Bulgaria (1.465)
Ca - Bulgaria (0.399)

To determine whether the nutrient ratios of the two leaves types generally tended to be high or low, terciles were also used for the evaluation in this case and the percentages of high, medium and low ratios were calculated for the plots of the individual countries (Annex B - Table B15)
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Spruce (Annex B - Table B16)

For nitrogen, the highest percentages of 1st tercile values were found in the Czech Republic and Austria. In contrast, in Italy, Belgium-*Wall.* and Germany - *Lower Saxony* at least half the spruce plots had values in the 3rd tercile, their ratios simply indicating that, the nitrogen content determined for leaves type 1 had decreased insignificantly or not at all compared to leaves type 0 (this may also be due to nitrogen air pollution).
In the case of phosphorus, the highest percentages of 1st tercile results were determined for Germany-*Lower Saxony* and Austria. Italy and Austria had the highest percentages of 1st tercile ratios for potassium. Similarly to nitrogen, Italy and Belgium-*Wall.* were the countries with the highest percentages of phosphorus values in the 3rd tercile. In the case of potassium, the same applied to the spruce plots of Belgium-*Wall.* and the Czech Republic.
The highest percentages of plots with calcium ratios in the 1st tercile (no or only insignificant increase of the calcium content of leaves type 1 as compared to leaves type 0) were observed on spruce plots in the United Kingdom and Germany - *Lower Saxony*. On the other hand, the highest percentages of plots with 3rd tercile ratios were found in Italy, Belgium-*Wall.* and Austria.
The United Kingdom and Germany - *Lower Saxony* are the two countries where relatively significant decreases of the magnesium content of leaves type 1 as compared to that of leaves type 0 occurred most frequently. No or only minor decreases of the magnesium values of leaves type 1 as compared to leaves type 0 were mainly observed in Italy and Austria.
The highest percentages of spruce plots with 3rd tercile sulphur values (indicating a sulphur accumulation in the previous year) were determined for the Czech Rep., for Belgium-*Wall.*

and Germany - *Lower Saxony*. In contrast Finland had the highest percentage of plots with sulphur ratios in the 1st tercile (92%) and the lowest rate of plots with sulphur values in the 3rd tercile (8%).

Pine (Annex B - Table B17)

The highest percentages of pine plots with nitrogen ratios in the 3rd tercile (no or insignificant decrease of the nitrogen values in leaves type 1 as compared to those of leaves type 0) were found in the United Kingdom and Austria. Decreases of the nitrogen content of leaves type 1 as compared to that of leaves type 0 were most frequent in the Czech Republic.
As far as phosphorus and potassium ratios of leaves type 1 and 0 were concerned, no or only minor decreases of the relevant measured values of leaves type 1 as compared to leaves type 0 (documented by the highest percentages of 3rd tercile values) were observed in Austria and Belgium-*Wall.*
The highest percentages of plots with calcium and magnesium ratios in the 3rd tercile (significant increase of the results of leaves type 1 as compared to those of leaves type 0) were found in Belgium-*Wall.* and Bulgaria.
As to the sulphur ratio of leaves type 1 and leaves type 0, the percentages of plots with 3rd tercile values were highest in Austria, the United Kingdom and the Czech Rep., whilst they were lowest in Finland.

3.3.7 Results of the inferential Data Analysis (see Annex C1)

3.3.7.1 Kruskal - Wallis - Test

Significant differences were determined both between the individual countries and between the main tree genera. Of course it is not very surprising or outstanding that there are any diferences between countries and trees. But before one can try to find out differences between pairs of countries it is necessary to know there are *any* significant differences.

3.3.7.2 Scheffé - Test

Only countries showing significant differences will be mentioned.

Spruce

For nitrogen, the major contrast was formed by high values in the United Kingdom, the Czech Rep., Ireland, Slovenia and Austria, and low values in Germany, Belgium-*Wallonia*, Italy, Finland and Lithuania. In addition, the value from the United Kingdom was so high that there are also significant differences compared to Slovenia and Austria. In the case of sulphur high values were observed for the United Kingdom and Slovenia compared to low values determined for the Czech Rep., Italy, Germany, Austria, Finland, Lithuania and Belgium-*Wallonia*. The high magnesium value of Lithuania differed from the low values of the Czech Rep., the United Kingdom, Slovenia, Italy, Ireland, Germany and Belgium-*Wallonia*. Another significant difference existed between Austria (with a high) and the Czech Rep. (with a low) value.

Pine

In the case of nitrogen, high values were observed for the United Kingdom and for the Czech Rep., and comparatively low values for Lithuania, Finland, Russia-*St. Petersburg Region* and Spain. The lowest value was found in Russia-St. Petersburg Region which differed significantly from those in Belgium-*Wallonia*, Ireland, Austria, Lithuania and Finland. For sulphur, a significant difference existed between the United Kingdom, with a high value, and Finland, with a low value. In the case of magnesium, high values were determined for Spain and Bulgaria, whereas the values of Finland, Russia-*St. Petersburg Region* and Germany proved to be low.

Beech

For nitrogen, there was a marked difference between the high value measured in the United Kingdom and the low value of Slovakia. In the case of sulphur the high value of Slovakia differed considerably from the low values of Italy and Belgium-*Wallonia*. Belgium-*Wallonia* was separated from the United Kingdom by a low magnesium value, and from Slovakia and Italy by high values.

Oak

In the case of nitrogen there was a remarkable difference between the high value of the United Kingdom and the comparatively low values of Slovakia, Belgium-*Wallonia*, Italy, Slovenia and Spain. The low value determined for Spain also formed a contrast to the high values of Slovakia and Belgium-*Wallonia*. The high sulphur values of Slovakia and the United Kingdom contrasted with the low values of Belgium-*Wallonia*, Italy and Spain; Belgium-*Wallonia* differed significantly only from Slovakia. For magnesium, the high value of Italy was in contrast with the low one of Belgium-*Wallonia*.

3.3.8 Results of the explorative Data Analysis (see Annex C2)

3.3.8.1 Cluster Analysis with Respect to the Content of Calcium, Magnesium and Potassium

Countries

Results proved similar for Belgium-*Wallonia*, Ireland, the Czech Rep., Germany, Russia-*St. Petersburg Region*, Finland and Bulgaria. Another group of countries was represented by Italy, Spain, Austria, and Slovenia. The United Kingdom, Lithuania and Slovakia, were distinct from these.

Main tree genera

Beech, oak and others (generally the other deciduous trees) on the one hand, and pine and spruce (conifers) on the other form two relatively homogeneous groups.

3.3.8.2 Principal Coordinate Analysis with Respect to the Content of Calcium, Magnesium and Potassium

The results of the principal coordinate analysis were in good accordance with those of the cluster analysis. For further investigations, the coordinates can be compared with the geographical coordinates of the plots.

3.3.8.3 Cluster Analysis with Respect to the Classes for Nitrogen, Calcium, Magnesium, Potassium, and Their Ratios

Countries

First group: Belgium-*Wallonia*, Germany, Italy, Ireland, Austria, Czech Rep., Slovenia, Spain and Finland;
Second group: Slovakia, Lithuania and, at some distance, Russia-*St. Petersburg Region*

The United Kingdom takes a centre position between the two groups, but is more closely allied to the first group.

Main tree genera

Beech is clearly isolated, whereas oak, pine and spruce form a uniform group.

3.3.8.4 Principal Coordinate Analysis with Respect to the Classes for Nitrogen, Calcium, Magnesium, Potassium and their Ratios

The outcome of the ordination showed good accordance with the cluster analysis. It would be interesting to find out in further investigations if there are any other ecological variables not yet considered, which cause the similarities between the countries and/or tree genera.

3.4 EVALUATION OF DATA FROM PREVIOUS YEARS

If the results of investigations carried out before 1995 are also to be considered, data from almost 1,300 plots of the main tree genera are available for an evaluation of the period 1987 to 1995. To classify the values of several years for a plot, the means of the elements (N, P, K, Ca, Mg, S), which from 1987-1995 were investigated between one and nine times, were calculated and, like in Chapter 3.3.4, assigned to the three classes according to the classification values of Table 3-8. In some countries, however, not all of the above-mentioned elements were determined so that the number of plots differ for the 6 elements.

3.4.1 Main Tree Genera

As can be seen from Table 3-18, nitrogen values were most frequently classified into Class 1 (nitrogen values ≤ lower classification value) similarly to the results of 1995. About one third of all plots turned out to be in Class 1, and of the 4 main tree species, spruce had the lowest share of Class 1 plots (25 %); for the other 3 main tree genera, these percentages were 36 - 39 %. In contrast, only about 10 % of the plots had nitrogen values in Class 3 (> upper classification values). In the case of elevated nitrogen values there were again marked differences between the 4 main tree genera. Only 7 % of the spruce plots, and 10 and 12 % of the pine and oak plots respectively showed values in Class 3, but about 20 % of the beech plots did.

Table 3-18: Classification of the nutrient content - Main tree genera
percentage of plots of the 4 main tree genera according to the 3 classes
(see Table 3-8)

	Class	**N**	**P**	**K**	**Ca**	**Mg**	**S**
Spruce	1	25.3	6.3	6.0	1.1	1.7	63.8
	2	68.0	88.8	89.6	80.1	86.0	34.4
	3	6.7	5.0	4.3	18.8	12.3	1.8
Pine	1	38.7	17.5	3.2	3.2	0.9	42.3
	2	51.8	74.9	96.1	73.1	72.4	48.1
	3	9.5	7.6	0.7	23.7	26.7	9.6
Beech	1	35.8	5.7	4.0	4.0	13.6	5.7
	2	44.7	57.5	77.6	25.6	28.8	51.1
	3	19.5	36.8	18.4	70.4	57.6	43.2
Oak	1	37.3	34.3	4.0	2.0	4.0	
	2	50.8	48.7	77.4	56.0	86.1	
	3	11.9	16.9	18.7	42.1	9.9	
Main Tree Genera	**1**	**33.2**	**15.6**	**4.5**	**2.3**	**3.1**	**49.4***
	2	**56.8**	**73.9**	**88.2**	**67.6**	**75.8**	**41.5***
	3	**9.9**	**10.5**	**7.3**	**30.1**	**21.2**	**9.1***

* For sulphur no oak values included.

The percentage of the plots with phosphorus values in Class 3 reached 10.5 %, i.e. approximately the same percentage as the nitrogen values of this class, but the share of the phosphorus values of Class 1 ($\leq$ lower classification value) was only about 16 %. Compared with nitrogen, the differences for Class 1 and Class 3 of the main tree genera were much more pronounced in the case of phosphorus. 6 % of the spruce and beech plots had phosphorus values in Class 1, compared with 17.5 % of the pine plots and 34 % of the oak plots. Similarly large differences between the 4 main tree genera existed also for the percentage shares in Class 3. The lowest shares were observed for spruce (5 %) and pine (8 %); twice as many (approx. 17 %) of the oak plots and about 37 % of the beech plots showed phosphorus values in this class.

With respect to potassium, calcium and magnesium, the shares in Class 1 for the 4 main tree genera reached only 2 to 4.5 %. The Class 1 shares of these 3 elements varied only between 1 and 14 % (potassium: 3-6%; calcium: 1-4 %; magnesium: 1-14%) for the individual main tree genera. Only 7 % of the plots showed potassium values in Class 3; for calcium and magnesium these percentages (> upper classification values) were approx. 30 and 21 % respectively and therefore highest among all major nutrients.

The main tree genera showed considerable differences also for the shares of plots having potassium, calcium and magnesium values in Class 3. Potassium values in Class 3 were observed for only 4 and 1 % of the spruce and pine plots respectively, but for 18 and 19 % of the beech and oak plots respectively. Also in the case of calcium the spruce and pine plots showed with 19 and 24 % respectively considerably lower shares of Class 3 plots than the oak plots with 42 % and the beech plots with 70 % did. As to magnesium, about 10 % of the oak plots, 12 % of the spruce plots, and 27 % of the pine plots had values of Class 3; the highest share in Class 3 magnesium values was determined for beech plots with 58 %.

Almost half of the spruce, pine and beech plots showed low sulphur values in Class 1; just over 40 % of the plots of these three tree species were classified in Class 2, and 9 % had elevated sulphur values in Class 3. The highest shares of plots with low sulphur values (≤ lower classification values) were found for spruce (64 %) and pine (42 %). The beech plots, on the other hand, had only 6 % of plots with sulphur values in Class 1. The shares of plots with sulphur values in Class 3 also varied considerably: 2 % in the case of spruce and 10 % for pine, but more than 40 % for beech.

3.4.2 Classification Results: Country-specific Results for the Main Tree Genera

Tables 3-19 to 3-22 show that, referring to one specific main tree genus, the plots of the individual countries differ more or less significantly in respect of the elements and, consequently, also deviate from the results given for that main tree genus in Table 3-18.

Spruce (Table 3-19)

Nitrogen values in Class 1 were observed on more than half of the spruce plots particularly in Bulgaria, but also in Lithuania and Norway. On the other hand in the Czech Republic only one spruce plot with nitrogen values in Class 1 was detected, and in the United Kingdom none. In the case of the spruce plots, high nitrogen values in Class 3 existed mainly in the United Kingdom (42.3 %) and in Ireland (12.5 %). In Germany and Lithuania about 4% had nitrogen values in Class 3. No spruce plots with nitrogen values of Class 3 were found in Austria, Belgium-*Wall.*, Bulgaria, Finland, Italy and Norway.

Low phosphorus values in Class 1 were most frequently observed on spruce plots in Lithuania (almost 40 %). In Ireland, Italy and Slovenia between 17 - 20 % of the plots showed Class 1 values. No spruce plots with phosphorus plots in Class 1 were found in Belgium-*Wall.*, the Czech Republic, Finland and the United Kingdom. In the other 4 countries where spruce plots existed, between 1 and 10 % of the plots showed phosphorus values in Class 1. In Ireland and Norway no spruce plots with elevated phosphorus values in Class 3 were detected and even in the Czech Republic, Finland, Germany, Italy, Lithuania, Slovenia and the United Kingdom this share varied only between 0.5 and 8 %. With 30 %, Bulgaria had the highest percentage share of plots with phosphorus values in Class 3, followed by Belgium-*Wall.* (14 %) and Austria (13%).

In 8 out of 12 countries no spruce plots showed low potassium values in Class 1. In Austria and the Czech Republic, this percentage only reached 1 to 3 %; in Lithuania it was 11 and in Germany 12 %. About one third of the spruce plots in the United Kingdom showed elevated potassium values in Class 3, compared to 19 % in Bulgaria and 20 % in Ireland. In Belgium-*Wall.*, Finland, Italy, Lithuania and Norway, none of the spruce plots had elevated potassium values.

Only in Germany, the Czech Republic and Lithuania did spruce plots show calcium and/or magnesium values in Class 1. Higher percentages of plots (more than 25 %) with elevated calcium values were observed in Lithuania, Slovenia and the United Kingdom; higher percentages of plots with elevated magnesium values were found in Lithuania and Bulgaria.

Table 3-19: Classification of the nutrient content - *SPRUCE* / Individual countries
Percentage of spruce plots in the individual countries according to the 3 classes (see Table 3-8)

Country	Class	**N**	**P**	**K**	**Ca**	**Mg**	**S**
Austria	1	17.7	1.3	1.3	-	-	88.6
	2	82.3	86.1	96.2	83.5	78.5	11.4
	3	-	12.7	2.5	16.5	21.5	-
Belgium-*Wallonia*	1	42.9	-	-	-	-	100.0
	2	57.1	85.7	100.0	100.0	100.0	-
	3	-	14.3	-	-	-	-
Bulgaria	1	88.9	10.0	-	-	-	
	2	11.1	60.0	80.0	100.0	70.0	
	3	-	30.0	20.0	-	30.0	
Czech Rep.	1	2.9	-	2.9	-	5.9	67.6
	2	82.4	97.1	94.1	88.2	91.2	32.4
	3	14.7	2.9	2.9	11.8	2.9	-
Finland	1	38.5	-	-	-	-	100.0
	2	61.5	92.3	100.0	92.3	100.0	-
	3	-	7.7	-	7.7	-	-
Germany	1	21.5	2.2	12.4	1.6	3.2	55.1
	2	74.2	97.3	87.1	81.7	90.9	42.2
	3	4.3	0.5	0.5	16.7	5.9	2.7
Ireland	1	12.5	18.8	-	-	-	
	2	75.0	81.3	81.3	75.0	100.0	
	3	12.5	-	18.8	25.0	-	
Italy	1	33.3	20.0	-	-	-	80.0
	2	66.7	73.3	100.0	80.0	93.3	20.0
	3	-	6.7	-	20.0	6.7	-
Lithuania	1	64.3	39.3	10.7	7.1	-	78.6
	2	32.1	57.1	89.3	53.6	46.4	21.4
	3	3.6	3.6	-	39.3	53.6	-
Norway	1	65.0	5.0	-	-	-	100.0
	2	35.0	95.0	100.0	90.0	95.0	-
	3	-	-	-	10.0	5.0	-
Slovenia	1	27.6	17.2	-	-	-	17.2
	2	58.6	75.9	93.1	62.1	86.2	79.3
	3	13.8	6.9	6.9	37.9	13.8	3.4
United Kingdom	1	-	-	-	-	-	15.4
	2	57.7	92.3	65.4	73.1	84.6	76.9
	3	42.3	7.7	34.6	26.9	15.4	7.7

The share of spruce plots with low sulphur values in Class 1 was in Slovenia and in the United Kingdom only about 17 and 15 % respectivily; in Germany low sulphur values were found on 55 %, and in the Czech Republic on about two thirds of the spruce plots; in the other countries on between 79 and 100 % thereof. High sulphur values in Class 3 for spruce plots were only found in Germany and Slovenia (3 % in either case) and the United Kingdom (approx. 8 %).

Pine (Table 3-20)

The percentage of pine plots with nitrogen values in Class 1 exceeded the respective mean of 38.7 % of the pine plots mainly in Croatia, but also in Russia-*St. Petersburg Region*, Bulgaria, Lithuania, and Spain. Of the countries with 3 or more pine plots, Belgium-*Wall.*, the Czech Republic, Ireland and the United Kingdom did not have any with nitrogen values in Class 1. Higher percentages of plots with Class 3 nitrogen values were found in the United Kingdom (64 %), Germany (28 %) and the Czech Republic (17 %). In Austria, Belgium-*Wall.*, Croatia, Finland, Ireland and Russia-*St. Petersburg Region*, none of the pine plots showed nitrogen values in Class 3.
Low phosphorus values in Class 1 were observed mainly in Croatia (62.5 %), Ireland (44 %), Russia-*St. Petersburg Region* (41 %) and Spain (30 %). No phosphorus values of Class 1 were determined for the pine plots in Austria, Belgium-*Wall.*, the Czech Republic, Finland and the United Kingdom. Larger percentages of plots with elevated phosphorus values in Class 3 were found in Bulgaria (31 %) and the United Kingdom (18 %).
Low potassium values in Class 1 were observed only on pine plots in Bulgaria (5 %), Germany (1 %), Lithuania (17 %), Russia-*St. Petersburg Region* (4 %) and Spain (2 %). High potassium values were detected on one pine plot in Bulgaria, Germany and Spain.
Low (Class 1) calcium values existed only on pine plots in Bulgaria, Ireland and Russia-*St. Petersburg Region*. Higher percentages of elevated calcium values in Class 3 were found on pine plots in Croatia (10 %), Lithuania (53 %), the Czech Republic (50 %), and Spain (41 %).
Low magnesium values in Class 1 existed on only 3 pine plots in Germany and one in Lithuania. High Class 3 magnesium values were determined on pine plots in Bulgaria (15 %), Germany (3 %), Lithuania (36 %) and Spain (41 %).
The percentage share of pine plots with low sulphur values in Class 1 varied in the 10 countries where sulphur had been included in the investigations of 3 or more pine plots in a wide range. The lowest percentages of pine plots with Class 1 sulphur values were observed in the United Kingdom (0 %) and in Germany (2 %). In all other countries the percentage of sulphur values in Class 3 reached at least 55 %. High sulphur values in Class 3 were found on one quarter of the pine plots in Germany. In contrast the other 4 countries with sulphur values in Class 3 had only between 3 and 9 % of such pine plots.

Beech (Table 3-21)

In Belgium-*Wall.*, Germany, Italy, Spain, United Kingdom none showed low nitrogen values in Class 1. In contrast, the share of beech plots with low nitrogen values was between 55 and 67 % in Bulgaria, Slovakia and Slovenia. The highest percentages of beech plots with an elevated nitrogen content were determined in the United Kingdom (55 %), in Spain (44 %) and in Germany (42 %). Only in Belgium-*Wall.* and Slovenia none of the beech plots had any nitrogen values in Class 3.

Table 3-20: Classification of the nutrient content - *PINE* / Individual countries
Percentage of pine plots in the individual countries according to the 3 classes (see Table 3-8)

Country	Class	**N**	**P**	**K**	**Ca**	**Mg**	**S**
Austria	1	20.0	-	-	-	-	60.0
	2	80.0	100.0	100.0	100.0	100.0	40.0
	3	-	-	-	-	-	-
Belgium-*Wallonia*	1	-	-	-	-	-	
	2	100.0	100.0	100.0	100.0	100.0	
	3	-	-	-	-	-	
Bulgaria	1	62.7	8.6	4.9	14.8	-	66.7
	2	34.3	60.5	93.8	72.8	85.2	33.3
	3	3.0	30.9	1.2	12.3	14.8	-
Croatia	1	100.0	62.5	-	-	-	75.0
	2	-	37.5	100.0	-	100.0	25.0
	3	-	-	-	100.0	-	-
Czech Rep.	1	-	-	-	-	-	83.3
	2	83.3	100.0	100.0	50.0	100.0	16.7
	3	16.7	-	-	50.0	-	-
Finland	1	37.5	-	-	-	-	100.0
	2	62.5	100.0	100.0	100.0	100.0	-
	3	-	-	-	-	-	-
Germany	1	1.0	3.0	1.0	-	3.0	2.0
	2	71.0	97.0	98.0	96.0	94.0	73.0
	3	28.0	-	1.0	4.0	3.0	25.0
Ireland	1	-	44.4	-	11.1	-	
	2	100.0	55.6	100.0	88.9	100.0	
	3	-	-	-	-	-	
Lithuania	1	50.0	16.7	16.7	-	2.8	69.4
	2	47.2	80.6	83.3	47.2	61.1	27.8
	3	2.8	2.8	-	52.8	36.1	2.8
Russia-*St. Petersburg Reg.*	1	92.6	40.7	3.7	3.7	-	55.6
	2	7.4	55.6	96.3	81.5	100.0	37.0
	3	-	3.7	-	14.8	-	7.4
Spain	1	47.0	30.7	1.5	-	-	54.5
	2	52.3	66.7	97.7	59.1	34.8	42.4
	3	0.8	3.0	0.8	40.9	65.2	3.0
United Kingdom	1	-	-	-	-	-	-
	2	36.4	81.8	100.0	100.0	81.8	90.9
	3	63.6	18.2	-	-	18.2	9.1

Low phosphorus values in Class 1 existed only in Belgium-*Wall.*, Italy and Slovenia, with percentages between 29 and 33 %. High phosphorus values in Class 3 were found on 73 % of the Bulgarian beech plots. Phosphorus values in Class 3 also existed in Germany, Italy, Spain, and the United Kingdom, but their shares were only between 8 and 18 %.
Low (Class 1) potassium values were found on beech plots in Belgium-*Wall.*, Bulgaria, Slovakia and Slovenia. No potassium values in Class 1 were determined for any beech plots in Germany, Italy, Spain and the United Kingdom. High potassium values in Class 3 existed on more than one third of the beech plots in Slovakia, and on plots in Bulgaria, Germany, Italy and Spain.

Table 3-21: Classification of the nutrient content - *BEECH* / Individual countries
Percentage of beech plots in the individual countries according to the 3 classes (see Table 3-8)

Country	Class	**N**	**P**	**K**	**Ca**	**Mg**	**S**
Belgium-*Wallonia*	1	-	28.6	14.3	-	85.7	14.3
	2	100.0	71.4	85.7	85.7	14.3	85.7
	3	-	-	-	14.3	-	-
Bulgaria	1	57.1	-	5.4	2.7	5.4	
	2	40.0	27.0	75.7	37.8	29.7	
	3	2.9	73.0	18.9	59.5	64.9	
Germany	1	-	-	-	8.3	33.3	-
	2	58.3	91.7	91.7	50.0	33.3	50.0
	3	41.7	8.3	8.3	41.7	33.3	50.0
Italy	1	-	28.6	-	14.3	14.3	28.6
	2	85.7	57.1	85.7	-	14.3	57.1
	3	14.3	14.3	14.3	85.7	71.4	14.3
Slovakia	1	55.3		2.6	2.6	-	-
	2	26.3		63.2	5.3	23.7	26.3
	3	18.4		34.2	92.1	76.3	73.7
Slovenia	1	66.7	33.3	33.3	33.3	-	66.7
	2	33.3	66.7	66.7	33.3	100.0	33.3
	3	-	-	-	33.3	-	-
Spain	1	-	-	-	-	33.3	-
	2	55.6	88.9	88.9	22.2	44.4	88.9
	3	44.4	11.1	11.1	77.8	22.2	11.1
United Kingdom	1	-	-	-	-	9.1	-
	2	45.5	81.8	100.0	9.1	18.2	81.8
	3	54.5	18.2	-	90.9	72.7	18.2

In contrast high calcium values in Class 3 were found in all countries with beech plots, with national percentages ranging between 14 and 92 %. The highest shares of beech plots with elevated calcium values were observed in Slovakia (92 %), the United Kingdom (91 %), Italy (80 %) and Spain (78 %).
The highest share of beech plots with low magnesium values in Class 1 occured in Belgium-*Wall.* with approximately 86 %. In the other 5 countries with magnesium values in Class 1,

this share varied between 5 and 33 %. No Class 1 plots were found in Slovakia and Slovenia and no Class 3 plots were found in Belgium-*Wall.* and Spain. The highest percentage shares of beech plots with magnesium values in Class 3 were observed for Slovakia, the United Kingdom and Italy.
Only in Belgium-*Wall.*, Italy and Slovenia a total of 5 beech plots (in these countries) showed low sulphur values in Class 1. Sulphur values for beech plots had to be classified into Class 3 particularly in Slovakia (74 %), in Germany, Italy, Spain, and the United Kingdom.

Oak (Table 3-22)

Half of the 6 countries with more than 2 oak plots had low nitrogen values in Class 1 (Italy, Slovakia, Spain). While in Italy and Slovakia one quarter and in Spain half of the oak plots showed low nitrogen values, no values were found on any in the oak plots in Belgium-*Wall.*, Bulgaria or the United Kingdom. Elevated nitrogen values in Class 3 were observed on approximately 93 % of the plots in the United Kingdom, but on only 25 % in Bulgaria and on less than 10 % of the Spanish plots. Of the 5 countries of which phosphorus data were available, only Bulgaria and the United Kingdom showed no low phosphorus values. In Belgium-*Wall.*, Italy and Spain, the shares of plots with low phosphorus values varied between 38 and 75 %. High phosphorus values existed mainly in Bulgaria, where 54 % of the oak plots showed values in Class 3; in the United Kingdom, this applied to only 14 % and in Spain to 7 % of the plots. In Belgium-*Wall.* and Italy no plots had any elevated phosphorus values in Class 3.

Table 3-22: Classification of the nutrient content - *OAK* / Individual countries
Percentage of oak plots in the individual countries according to the 3 classes
(see Table 3-8)

Country	Class	**N**	**P**	**K**	**Ca**	**Mg**
Belgium-*Wallonia*	1	-	37.5	-	-	25.0
	2	100.0	62.5	75.0	100.0	75.0
	3	-	-	25.0	-	-
Bulgaria	1	-	-	2.2	-	-
	2	97.3	45.7	67.4	37.0	89.1
	3	2.7	54.3	30.4	63.0	10.9
Italy	1	25.0	75.0	-	-	12.5
	2	75.0	25.0	87.5	37.5	50.0
	3	-	-	12.5	62.5	37.5
Slovakia	1	25.0		-	-	-
	2	50.0		56.3	12.5	87.5
	3	25.0		43.8	87.5	12.5
Spain	1	50.0	45.5	5.1	2.6	4.5
	2	42.9	47.4	85.9	65.4	85.9
	3	7.1	7.1	9.0	32.1	9.6
United Kingdom	1	-	-	-	-	-
	2	7.1	85.7	35.7	57.1	100.0
	3	92.9	14.3	64.3	42.9	-

Low potassium values in Class 1 were found on a single plot in both Bulgaria and Germany and on 8 plots in Spain (5 %). The highest share of plots with elevated potassium values was determined for the United Kingdom (64 %); Slovakia (44 %), Bulgaria (30 %), in Belgium-*Wall.* (25 %), and in Italy (12.5 %). In Spain, the country with the most oak plots, only 9 % showed elevated potassium values.
Low calcium values were measured on only 4 of the Spanish oak plots. All countries had plots with calcium values in Class 3 except for Belgium-*Wall.*. Of the national oak plots, elevated calcium values were determined for about 84 % in Slovakia, 63 % in Bulgaria and Italy, 43 % in the United Kingdom and 32 % in Spain.
Low magnesium values in Class 1 were detected in Belgium-*Wall.*, Italy and Spain; their shares varied between 4.5 and 25 %. High magnesium values in Class 3 were observed in Bulgaria (11 %), Italy (38 %), Slovakia (13 %), and Spain (10 %). In Belgium-*Wall.* and the United Kingdom no plots showed any magnesium values in Class 3.

3.4.3 Classification Results referring to the individual Countries

To compare countries, the classification results of the 4 main tree genera were combined and the percentages of the national plots classified in Classes 1 to 3 for sulphur and the major nutrients are illustrated in Table 3-23.

Nitrogen *(see Figure 13)*

Tables 3-23 and 3-24 show that all countries except the United Kingdom had some Class 1 nitrogen values. The highest percentages of sample plots with low nitrogen values were found in Croatia (100 %), Russia-*St. Petersburg Region* (93 %), Norway (65 %), Lithuania (56 %), and Bulgaria (50 %). Comparatively low percentages of plots with nitrogen values in Class 1 were determined not only in the United Kingdom, but also in the Czech Republic (2.5 %), Ireland (8 %), Germany (14 %), Belgium-*Wall.* (16 %) and Austria (18 %). The United Kingdom had approx. 60 % of plots with high nitrogen values of Class 3 by far the highest figures (see Tables 3-23 and 3-25). The group of countries with the results most similar to those of the United Kingdom was formed by Slovakia, Czech Republic, Germany, and Slovenia, but their percentage shares of sample plots with high nitrogen values ranged only between 11 and 20 %. However, between 1987 and 1995 individual parts in Germany (Länder) showed higher percentages of plots with elevated nitrogen values, sometimes with equally high results as in the United Kingdom. In Austria, Belgium-*Wall.*, Croatia, Finland, Norway and Russia-*St. Petersburg Region*, none of the sample plots of the 4 main tree genera had any elevated nitrogen values in Class 3.

Phosphorus *(see Figure 14)*

In the United Kingdom, the Czech Republic and Finland none of the sample plots had low phosphorus values in Class 1 and even in Austria, Germany, Bulgaria, and Norway the share of plots with low phosphorus values only varied between 1 and 5 %. The highest shares of sample plots with low phosphorus values were found in Croatia (63 %), Russia-*St. Petersburg Region* (41 %), Italy (37 %) and Spain (37 %). Low phosphorus values were observed on more than one quarter of the sample plots in Ireland and Lithuania.
Bulgaria had the most plots with elevated phosphorus values in Class 3 (46%), followed by Austria (12 %) and the United Kingdom (13 %). In Belgium-*Wall.*, the Czech Republic,

Table 3-23: Classification of the nutrient content - *MAIN TREE GENERA* / Individual countries
Percentage of plots in the individual countries according to the 3 classes (see Table 3-8)

Country	Class	**N**	**P**	**K**	**Ca**	**Mg**	**S**
Austria	1	17.6	1.2	1.2	-	-	85.9
	2	82.4	87.1	96.5	83.5	80.0	14.1
	3	-	11.8	2.4	16.5	20.0	-
Belgium-*Wallonia*	1	16.0	20.0	4.0	-	32.0	56.3
	2	84.0	76.0	88.0	96.0	68.0	43.8
	3	-	4.0	8.0	4.0	-	-
Bulgaria	1	50.3	4.6	4.0	7.5	1.1	
	2	47.1	49.4	82.2	57.5	73.6	
	3	2.5	46.0	13.8	35.1	25.3	
Croatia	1	100.0	62.5	-	-	-	75.0
	2	-	37.5	100.0	-	100.0	25.0
	3	-	-	-	100.0	-	-
Czech Rep.	1	2.5	-	2.5	-	5.0	70.0
	2	82.5	97.5	95.0	82.5	92.5	30.0
	3	15.0	2.5	2.5	17.5	2.5	-
Finland	1	37.9	-	-	-	-	100.0
	2	62.1	96.6	100.0	96.6	100.0	-
	3	-	3.4	-	3.4	-	-
Germany	1	13.7	2.3	8.3	1.7	4.3	35.0
	2	72.3	96.3	90.7	85.0	89.7	52.9
	3	14.0	1.3	1.0	13.3	6.0	12.1
Ireland	1	8.0	28.0	-	4.0	-	
	2	84.0	72.0	88.0	80.0	100.0	
	3	8.0	-	12.0	16.0	-	
Italy	1	23.3	36.7	-	3.3	6.7	60.9
	2	73.3	56.7	93.3	50.0	63.3	30.4
	3	3.3	6.7	6.7	46.7	30.0	8.7
Lithuania	1	56.3	26.6	14.1	3.1	1.6	73.4
	2	40.6	70.3	85.9	50.0	54.7	25.0
	3	3.1	3.1	-	46.9	43.8	1.6
Norway	1	65.0	5.0	-	-	-	100.0
	2	35.0	95.0	100.0	90.0	95.0	-
	3	-	-	-	10.0	5.0	-
Russia-*St.Petersburg Reg.*	1	92.6	40.7	3.7	3.7	-	55.6
	2	7.4	55.6	96.3	81.5	100.0	37.0
	3	-	3.7	-	14.8	-	7.4
Slovakia	1	46.3		1.9	1.9	-	-
	2	33.3		61.1	7.4	42.6	26.3
	3	20.4		37.0	90.7	57.4	73.7
Slovenia	1	31.4	20.0	2.9	2.9	-	21.2
	2	57.1	74.3	91.4	54.3	88.6	75.8
	3	11.4	5.7	5.7	42.9	11.4	3.0
Spain	1	47.1	37.4	3.4	1.3	3.4	51.1
	2	47.5	57.2	91.2	61.3	62.0	45.4
	3	5.4	5.4	5.4	37.4	34.7	3.5
United Kingdom	1	-	-	-	-	1.6	8.3
	2	40.3	87.1	71.0	62.9	75.8	81.3
	3	59.7	12.9	29.0	37.1	22.6	10.4

Table 3-24: Percentage of plots (4 main tree genera) with class 1 results in the individual countries (class 1 ≤ lower classification value)

Percentage	**N**	**P**	**K**	**Ca**	**Mg**	**S**
0 %	United Kingdom	Czech Rep. Finland United Kingdom	Croatia, Finland Ireland, Italy Norway United Kingdom	Austria Belgium-Wallonia Croatia, Czech Rep. Finland, Norway United Kingdom	Austria, Croatia Finland, Ireland Norway Russia-St.P. Reg. Slovakia, Slovenia	Slovakia
1-10 %	Czech Rep. Ireland	Austria Bulgaria Germany Norway	Austria Belgium-Wallonia Bulgaria, Czech Rep. Germany Russia-St. P. Reg. Slovakia, Slovenia Spain	Bulgaria, Germany Ireland, Italy Lithuania Russia-St. P. Reg. Slovakia Slovenia Spain	Bulgaria Czech Rep. Germany Italy Lithuania Spain United Kingdom	United Kingdom
11-25 %	Austria Belgium-Wallonia Germany, Italy	Belgium-Wallonia Slovenia	Lithuania			Slovenia
26-50 %	Finland Slovakia Slovenia Spain	Ireland, Italy Lithuania Russia-St. P. Reg. Spain			Belgium-Wallonia	Germany
51-75 %	Bulgaria Lithuania Norway	Croatia				Belgium-Wallonia Croatia, Czech Rep. Italy, Lithuania Russia-St. P. Reg. Spain
>75 %	Croatia Russia-St. P. Reg.					Austria Finland Norway

Table 3-25: Percentage of plots (4 main tree genera) with class 3 results in the individual countries (class 3 > upper classification value)

Percentage	**N**	**P**	**K**	**Ca**	**Mg**	**S**
0 %	Austria Belgium - *Wallonia* Croatia, Finland Norway Russia-*St. P. Reg.*	Croatia Ireland Norway	Croatia Finland Lithuania Norway Russia-*St. P. Reg.*		Belgium - *Wallonia* Croatia Finland Ireland Russia-*St. P. Reg.*	Austria Belgium - *Wallonia* Croatia, Czech Rep. Finland Norway
1-10 %	Bulgaria Ireland Italy Lithuania Spain	Belgium - *Wallonia* Czech Rep., Finland Germany, Italy Lithuania Russia-*St. P. Reg.* Slovenia Spain	Austria Belgium - *Wallonia* Czech Rep. Germany Italy Slovenia Spain	Belgium - *Wallonia* Finland Norway	Czech Rep. Germany Norway	Italy Lithuania Russia-*St. P. Reg.* Slovenia Spain
11-25 %	Czech Rep., Germany Slovakia Slovenia	Austria United Kingdom	Bulgaria Ireland	Austria, Czech Rep. Germany, Ireland Russia-*St. P. Reg.*	Austria Slovenia United Kingdom	Germany United Kingdom
26-50 %		Bulgaria	Slovakia United Kingdom	Bulgaria, Italy Lithuania, Slovenia Spain United Kingdom	Bulgaria Italy Lithuania Spain	
51-75 %	United Kingdom				Slovakia	Slovakia
>75 %				Croatia Slovakia		

Finland, Germany, Italy, Lithuania, Russia-*St. Petersburg Region*, Slovenia and Spain, the share of sample plots with high phosphorus values in Class 3 ranged between 1 and 7 %. In Croatia, Ireland and Norway no plots showed any Class 3 phosphorus values.

Potassium *(see Figure 15)*

United Kingdom, Croatia, Finland, Ireland, Italy, and Norway had no low potassium values in Class 1. Lithuania had the highest percentage of sample plots (14 %) with low potassium values in Class 1. In Austria, Belgium-*Wall.*, Bulgaria, Czech Republic, Finland, Germany, Russia-*St. Petersburg Region*, Slovakia, Slovenia and Spain, the percentage share of national plots with potassium values in Class 1 ranged from 1 to 8 %.
No high Class 3 potassium values were observed on the sample plots Croatia, Finland, Lithuania, Norway and Russia-*St. Petersburg Region*. Slovakia with 37 % and the United Kingdom with 29 % showed the highest percentages of plots with elevated potassium values in Class 3. In Bulgaria and Ireland, national sample plots had high potassium values of 14 and 12 % respectively; in Austria, Belgium-*Wall.*, the Czech Republic, Germany, Italy, Slovenia, and Spain this ranged between 1 and 8 %.

Calcium *(see Figure 16)*

Bulgaria was the only country where the number of sample plots with low calcium values in Class 1 exceeded 5 %. In Austria, Belgium-*Wall.*, Croatia, the Czech Republic, Finland, Norway and the United Kingdom, no sample plots showed any low Class 1 calcium values.
In contrast, calcium values in Class 3 were found in all countries, but with very different shares (3 - 100 %) of the national plots. The highest percentages of plots found in Croatia (100 %) and Slovakia (approx. 91 %). In Bulgaria, Italy, Lithuania, Slovenia, Spain, and the United Kingdom this percentage exceeded 25 %. The lowest shares of plots with calcium values in Class 3 were observed in Belgium-*Wall.*, Finland and Norway (3 - 10 %).

Magnesium *(see Figure 17)*

The highest percentage share of plots with low magnesium values was found in Belgium-*Wall.* with 32 %. Of the remaining 15 countries, 8 (Austria, Croatia, Finland, Ireland, Norway, Russia-*St. Petersburg Region*, Slovakia, Slovenia) did not have any plots with magnesium values in Class 1. In 7 countries (Bulgaria, Czech Republic, Germany, Italy, Lithuania, Spain, United Kingdom) these percentages ranged between 1 and 7 %.
The highest percentage shares of magnesium values in Class 3 were found in Slovakia (57 %), Lithuania (44 %), Spain (37 %), Italy (30 %), and Bulgaria (25 %). Percentages higher than 10 % were also found in the United Kingdom (23 %), Austria (20 %), and Slovenia (11 %). No elevated magnesium values in Class 3 were observed on the plots of Belgium-*Wall.*, Croatia, Finland, Ireland, and Russia-*St. Petersburg Region*.

Sulphur *(without consideration of the oak plots-see Figure 18)*

In Finland and Norway 100 %, and in Austria 86 %, of the plots had low sulphur values in Class 1 which exclude the impact of S-pollutants. In 7 of the other countries the national plots with low sulphur values still represented more than 50 %, namely Croatia (75 %), Lithuania (73 %), the Czech Republic (70 %), Italy (61 %), Belgium-*Wall.* (56 %), Russia-*St. Petersburg Region* (56 %), and Spain (51 %). In Germany, sulphur values in Class 1 were

found on 35 % of the plots, in Slovenia on 21 %, and in United Kingdom on 8 % of the plots; none of the sample plots of Slovakia showed any sulphur values in Class 1.
By far the highest share of plots with elevated sulphur values in Class 3 was determined for Slovakia (73.7 %). In Germany and the United Kingdom, 12 % and 10.4 % of the national plots showed high sulphur values in Class 3 respectively. This percentage was only about 7%, for Russia-*St. Petersburg Region*, 9% for Italy, and 2 - 4 % for Spain, Slovenia, and Lithuania. Several parts of Germany (Länder) before 1995 showed large percentages of plots with elevated sulphur values. In Austria, Belgium-*Wall.*, Croatia, the Czech Republic, Finland, and Norway, no plots had any sulphur values in Class 3.
However, it is to be pointed out in this context that plots classified in Class 2 may be affected by the impact of S-pollutants.

Figure 13

Figure 14

Figure 15

Figure 16

Figure 17

Figure 18

3.4.4 Classification Values of identical Plots over several Years in Austria and Finland

When evaluating the investigations before 1995 using the mean plot values, it should be taken into account that considerable deviations from the mean of a longer period may occur for elements in individual years, as is indicated by the results of Austria and Finland. Table 3-26 shows annual fluctuations regarding the percentage of plots with a certain content of major nutrients. This is probably a result of weather factors (HEINSDORF 1966, 1973, HUNGER 1970, SCHMIDT 1985, WEHRMANN 1961) and air pollution.

Table 3-26: Classification Results 1987-1995 (leaves type 0)
Percentages of plots of the 4 main tree genera in Finland and Austria according to class 1 and class 3 (see Table 3-8)

Element	Country	Class	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**
N	Austria	1			13.1	17.9	39.0	52.5	21.3	48.8	15.4
		3			1.2	0.0	0.0	0.0	0.0	0.0	1.3
	Finland	1	50.0	21.4	46.4	50.0	40.0	55.2	27.6	37.9	75.9
		3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
P	Austria	1			3.6	2.4	3.6	8.8	3.8	7.5	5.1
		3			11.9	15.7	17.1	13.8	13.8	13.8	10.3
	Finland	1	0.0	0.0	0.0	0.0	0.0	3.4	3.4	0.0	0.0
		3	14.3	17.9	3.6	0.0	6.7	3.4	3.4	6.9	3.4
K	Austria	1			1.2	2.4	2.4	5.0	0.0	2.5	3.8
		3			3.6	1.2	2.4	6.3	2.5	2.5	2.6
	Finland	1	0.0	0.0	0.0	0.0	0.0	3.4	0.0	0.0	0.0
		3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.4
Ca	Austria	1			0.0	0.0	0.0	0.0	1.3	0.0	0.0
		3			13.1	6.0	9.8	38.8	16.3	21.3	23.1
	Finland	1	3.6	0.0	0.0	0.0	0.0	6.9	0.0	3.4	6.9
		3	0.0	3.6	21.4	0.0	0.0	6.9	17.2	3.4	10.3
Mg	Austria	1			1.2	1.2	1.2	1.3	0.0	0.0	0.0
		3			13.1	19.3	29.3	22.5	13.8	27.5	24.4
	Finland	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		3	0.0	3.6	3.6	0.0	0.0	3.4	0.0	0.0	0.0
S	Austria	1			72.6	87.8	87.7	88.8	80.0	91.3	88.5
		3			0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Finland	1	75.0	39.3	78.6	100.0	93.3	96.6	96.6	100.0	100.0
		3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

The most significant differences were observed for nitrogen. Between 1987 and 1994 the percentage of plots with nitrogen values in Class 1 ($\leq$ lower classification value) varied between 21 and 55 % in Finland and reached 76 % 1995. The situation was similar in Austria, where the percentage of plots with nitrogen values in Class 1 varied between 13 and 52.5 % from 1989 to 1994, but (contrary to Finland) decreased in 1995. For phosphorus, potassium and magnesium, only minor fluctuations between the individual stages of investigation occurred in these two countries, but for calcium and sulphur the annual differences were more marked.

4 CONCLUSIONS

- After agreement on the harmonized methods the foliar survey was carried out successfully. 16 countries carried out the survey and the data were submitted to the FFCC.

- The comparability of the data was ensured by the means of two intercalibration tests. These intercalibration exercises demonstrated that macronutrients and some micronutrient concentrations could be compared across participating countries: 39 laboratories were participating in the ring test.

- A database with the results of the foliar surveys, and available data from earlier surveys, was setup. This will allow correlative studies with other data sets.

- A preliminary evaluation of the data showed that a wide range in foliar nutrient concentrations and nutrient ratios exist in European countries participating in the Level I investigation 1995 (n = 14). It should be noted, however, that some of the country-related differences might be due to the methods of chemical analysis used.

- Most plots appear to have adequate status of nutrient concentrations. In a relative large number of plots in Germany, Slovakia and the United Kingdom, high levels of nitrogen and sulphur were found**;** in the so called 'black triangle' - the area near the border of Poland, Czech Republic and Germany - was not covered very well by the investigation of 1995. In Czech Rep. and Slovenia, high levels of nitrogen were also found in many plots. On the other hand, low nitrogen concentrations were found in an important number of plots especially in Bulgaria, Croatia, Lithuania, Norway and Russia - *St. Petersburg Region*.
  While the sulphur input in Germany in the last years was decreasing compared to the results of previous years, the nitrogen input did not. Nevertheless the sulphur content of foliage shows regional differences, with mostly higher values in the eastern part of Germany.

- Investigations of nutrient element ratios suggested that a *harmonious* ratio in many species existed. However, in comparison to other countries, the percentages of plots in the *harmonious* range of the nitrogen-ratios (N/P, N/K, N/Ca, N/Mg, S/N) in Russia - *St. Petersburg Region*, Lithuania and Slovakia were low.

- Investigations of cause-effect relations for these findings are now possible combining the data from the different databases (foliar data with crown- and/or soil-condition data).

5 RECOMMENDATIONS

The Forest Foliar Database is a valuable source of information on the nutrient state of forest trees. In addition, it can be used for investigations that may provide a better insight in the cause-effect relationship associated with the observed loss of vitality of European forests. In this context the following recommendations are made:

- the value of a repetition of the Level I foliar survey be considered, taking account of its role in explaining forest (ecosystem) conditions,
- better representation of areas through the participation of all European countries,
- investigation of all plots in the same year,
- in order to allow annual fluctuations and possible trends in foliage chemistry to be identified, the need for shorter periods of time between successive assessments, possibly on a sub-sample of the Level I Network (in addition to the assessments made on Level II plots) should be evaluated,
- results of earlier foliar surveys should be examined in relation to spatial and temporal trends in foliage nutrient status and entered in the FFCC database (according to the existing guidelines),
- analysis of the optional parameters on as many plots as possible (also considering the results of the soil investegation),
- a critical review of the submanual should be prepared to determine whether any of the optional parameters should become mandatory,
- regular interlaboratory tests and standardisation of analytical procedures (in case that individual parameters cannot be determined or if, knowing the results of the interlaboratory tests, problems regarding the analysis of certain elements occur in any country, the samples of the latter should be examined in a different, optimally working laboratory to ensure large-scale representation),
- a further evaluation of the foliar data may be improved substantially by including other data assessed on Level I as stand site characteristics, crown condition and results of the soil survey.

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