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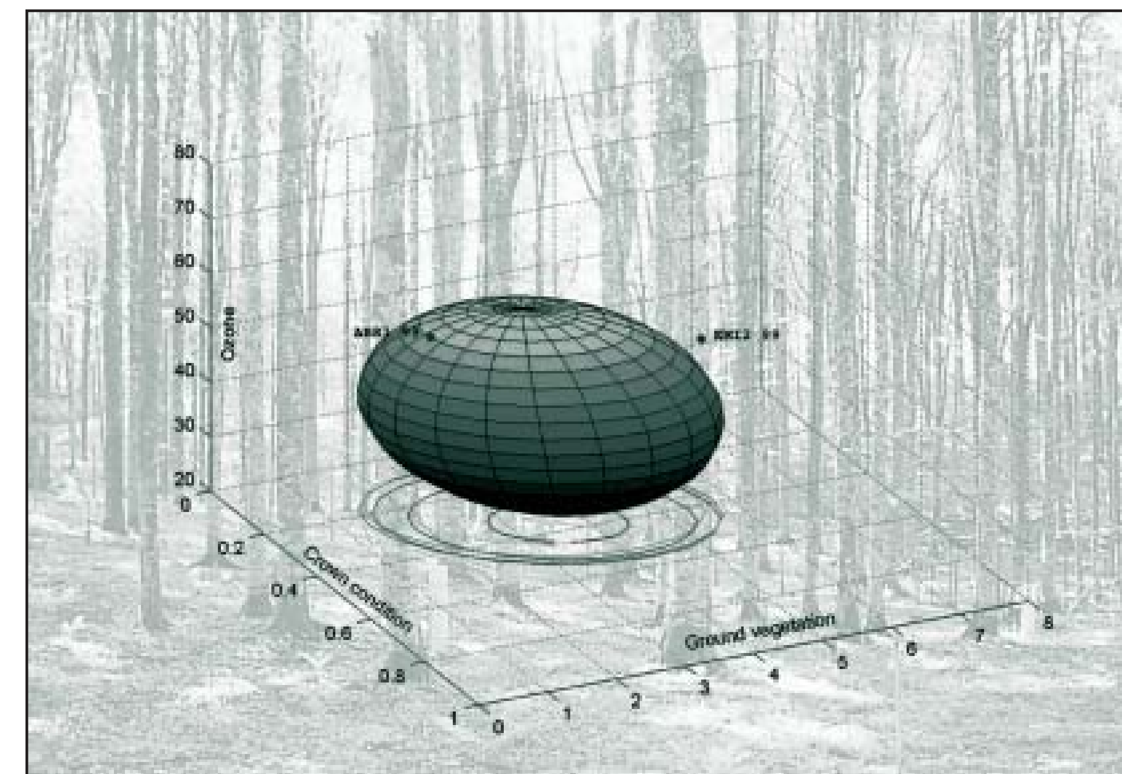

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A N N A L I

ISTITUTO SPERIMENTALE PER LA SELVICOLTURA

Special Issue on

INTEGRATED AND COMBINED (I&C) EVALUATION OF INTENSIVE MONITORING OF FOREST ECOSYSTEMS IN ITALY

CONCEPTS, METHODS AND FIRST RESULTS

First Report of the Task Force on Integrated and Combined (I&C) Evaluation of the CONECOFOR programme

CONECOFOR *(CONtrollo ECOsistemi FORestali)* is the intensive monitoring programme of forest ecosystems in Italy.
The programme is framed within the Pan-European Level II Monitoring of Forest Ecosystems. It is co-sponsored by the European Commission (EC) and co-operates with the UN/ECE ICP-Forests and the UN/ECE ICP-Integrated Monitoring.
CONECOFOR is managed by the Ministero delle Politiche Agricole e Forestali (MiPAF), D.G. Risorse Forestali, Montane ed Idriche, Divisione V acting also as National Focal Center (NFC) of Italy within the EC and UN/ECE programme.

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Premessa

Lo studio delle condizioni delle foreste su base sistematica è stato compiutamente avviato in Italia da circa quindici anni per iniziativa del Ministero delle Politiche Agricole e Forestali (allora Ministero dell'Agricoltura e delle Foreste), attraverso le strutture e il personale del Corpo Forestale dello Stato, a livello centrale e periferico. Da un primo approccio di tipo essenzialmente descrittivo, basato su semplici osservazioni dello stato delle chiome degli alberi, si è passati negli ultimi anni ad un'impostazione dichiaratamente ecologica e funzionale, che considera l'ecosistema forestale come un sistema biologico altamente organizzato e quindi fortemente reattivo rispetto a cause di alterazione ambientale, quali l'inquinamento atmosferico ed i cambiamenti climatici su scala continentale.
Il programma paneuropeo di controllo delle condizioni delle foreste a lungo termine avviato dalla Commissione Economica per l'Europa delle Nazioni Unite e dall'Unione Europea nel 1994, così come il Programma italiano per il Controllo degli Ecosistemi Forestali (CONECOFOR), introducono una dimensione considerata finora solo raramente negli studi ecologici, quella temporale. Tali Programmi sono infatti basati sullo studio delle caratteristiche ecologiche fondamentali delle comunità forestali presenti su di una rete di aree permanenti e sulla continua verifica, nell'arco di almeno vent'anni, degli scostamenti dei parametri biotici ed abiotici dallo stato di riferimento iniziale. Un tale tipo di approccio appare l'unico idoneo per valutare in modo oggettivo ed accurato gli effetti a lungo termine dell'inquinamento atmosferico e dei cambiamenti climatici sulle foreste.
Questo numero speciale degli "Annali dell'Istituto Sperimentale per la Selvicoltura" è interamente dedicato al Programma CONECOFOR, ed in particolare alla valutazione integrata dei dati prodotti nel suo ambito. Ciò si deve alla disponibilità dell'Istituto Sperimentale per la Selvicoltura, che collabora al Programma CONECOFOR fin dalla sua nascita, ed in particolare a quella del suo Direttore Dr. Augusto V. Tocci. CONECOFOR, giunto ormai al suo settimo anno di attività, è un programma di monitoraggio intensivo degli ecosistemi forestali basato su osservazioni e misurazioni di numerosi indicatori ed indici dello stato dell'ecosistema, condotte attualmente in 27 aree permanenti distribuite dal Nord al Sud d'Italia. Le misurazioni coprono vari compartimenti dell'ecosistema (suolo, vegetazione erbacea ed arbustiva, alberi, atmosfera) in vari ecosistemi forestali (faggete, peccete, cerrete e querceti decidui misti, leccete) e la banca di dati generata dal programma è quindi particolarmente complessa.
Il volume, attraverso il contributo di tutti i gruppi di ricercatori che cooperano in CONECOFOR, descrive l'approccio concettuale ed i metodi con i quali – in questa prima fase - è stata affrontata la valutazione integrata dei dati. Nella sezione 1 (Introduzione), sono presentate le basi concettuali della valutazione integrata e le caratteristiche del programma CONECOFOR. Nella sezione 2 (Metodi) sono affrontati e discussi i metodi di valutazione, la disponibilità, la qualità e l'affidabilità dei dati e le possibilità di aggregazione dei dati stessi. Nella sezione 3 (Risultati) ciascun gruppo di ricercatori responsabile per ogni indagine espone i risultati ottenuti nei primi anni di funzionamento del programma. L'esposizione dei risultati segue una traccia comune tra i vari gruppi e mira ad identificare – tra quelle portate avanti sulle aree di studio – alcune misurazioni particolarmente utili agli scopi della valutazione integrata e/o alla costruzione di indici sintetici. Chiude la sezione un lavoro dedicato ad una prima effettiva integrazione e combinazione dei risultati. La sezione 4 (Conclusioni) propone infine una sintesi del lavoro svolto nei primi sei anni di attività ed una prospettiva per il proseguimento a breve e medio termine.

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Foreword

Studies on forest conditions on systematic national grids started in Italy fifteen years ago, by the Ministry for Agriculture and Forestry Policy, through the National Forest Service. Monitoring activities, formerly based on descriptive parameters such as tree crown transparency scores, are now set up taking into account the forest ecosystem as a complex biological system, highly reactive to environmental disturbances.
The Pan-European Intensive Programme for Long-term Forest Ecosystem Monitoring, established in 1994 by the Economic Commission for Europe of the United Nations (UN/ECE) and the European Union, as well as the Italian Forest Ecosystem Monitoring Programme (Italian acronym: CONECOFOR), explore a new dimension generally underestimated in applied ecology: the temporal dimension. These programmes aim to study in detail the spatial and temporal variation of forest ecosystem parameters and the relationships between them, air pollution, climate change and other stress factors.
This Special Issue of the "Annali dell'Istituto Sperimentale per la Selvicoltura" focuses on the CONECOFOR Programme, with a particular attention to the integrated evaluation of monitoring data. We are grateful to this Institute, which is involved into the CONECOFOR since it was born, and in particular to the Director Dr. Augusto V. Tocci. CONECOFOR is an intensive-monitoring programme based upon measurements/observations of a variety of indicators and indices of ecosystem status currently being carried out on 27 permanent plots throughout Italy. The measurements cover various ecosystem compartments (soil, ground vegetation, trees, atmosphere) in various forest ecosystems (beech, spruce, mixed deciduous oaks, holm oak as main tree species): accordingly, the database generated by the programme is complex.
With contributes from all the research teams involved in the programme, the present volume would describe the conceptual approach and the method adopted in Italy for the integrated evaluation of intensive monitoring data. Section 1 (Introduction) presents the conceptual basis of the integrated evaluation and some basic features of the CONECOFOR programme. Section 2 (Methods) addresses evaluation methods, data availability, quality and reliability and data aggregation. Under section 3 (Results) each research team presents the results obtained within the first years of monitoring. Results are presented in the light of selecting indicator and indices suited for the aim of the integrated evaluation and/or to derive synthetic indices. Also, a paper is devoted to present some first results obtained by the integration of data from different investigations. Section 4 (Conclusions) provides a synthesis of the major achievements obtained in the first six years of activity and a provisional short-to-medium term work schedule.

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INTEGRATED AND COMBINED (I&C) EVALUATION OF INTENSIVE MONITORING OF FOREST ECOSYSTEMS IN ITALY

CONCEPTS, METHODS AND FIRST RESULTS

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An introduction to the Integrated and Combined (I&C) evaluation system designed for the intensive monitoring of forest ecosystems in Italy§

Marco Ferretti[1]

Accepted 11 December 2000

Abstract - Integrated evaluation of forest intensive monitoring data is being attempetd at European level, where the multiple regression approach has been adopted together with other multivariate statistical techniques. However, problems arising at national levels can be substantially different from those at European level, thus leading to the need for different technical solutions. This paper describes the conceptual basis adopted for the Integrated and Combined (I&C) evaluation of intensive monitoring data in Italy. The I&C considers three major approaches: (*i*) the evaluation of risk status in relation to air pollution, (*ii*) the quantification of the ecosystem's status and changes and (*iii*) the evaluation of the relationship between pressure and status indicators through time. Different levels of evaluation (based on the number of indicators considered) and time windows (based on the sampling regimes of the different investigations) are defined. Both the level of evaluation and the time windows determine the iterative nature of the I&C.

Key words: *forest ecosystem, integrated evaluation, intensive monitoring, risk, status and changes.*

Riassunto - Introduzione al sistema di valutazione integrato e combinato (I&C) progettato per il monitoraggio intensivo degli ecosistemi forestali in Italia. La valutazione integrata dei dati derivanti dal monitoraggio intensivo delle foreste a livello europeo è essenzialmente basata su regressioni multiple ed altre tecniche multivariate. Tuttavia, i problemi che una valutazione integrata può porre a livello nazionale possono essere sostanzialmente diversi da quelli presenti a livello europeo, per cui può essere necessario ricorrere a differenti soluzioni tecniche. Questo articolo descrive le basi concettuali adottate per la definizione della valutazione integrata e combinata (I&C) dei dati in Italia. I&C considera tre approcci principali: (*i*) la valutazione dello stato di rischio in relazione ai contaminanti atmosferici, (*ii*) la quantificazione delle stato dell'ecosistema e dei suoi cambiamenti e (*iii*) la valutazione nel tempo delle relazioni tra agenti di stress ed indicatori di stato. Vengono considerati differenti livelli di valutazione (basati sul numero di indicatori considerati) e finestre temporali (basate sui regimi di campionamento) che – assieme – definiscono la natura iterativa del processo di valutazione I&C.

Parole chiave: *ecosistemi forestali, valutazione integrata, monitoraggio intensivo, analisi di rischio, stato e cambiamenti.*

F.D.C. 524.61:180:(450)

European forests are being intensively monitored by hundreds of Permanent Monitoring Plots (*PMPs*) where data relating to a number of ecosytem status indicators are collected (*e.g.* EC – UN/ECE 2000). The high cost of this activity coupled with the important political and scientific value of the collected data makes it necessary to address the problem of an integrated evaluation of the data sets generated by the intensive monitoring program. This is important in order to be able to submit an easily understandable and - at the same time - scientific synthesis of these data to politicians, decision-makers and resource managers who are often asked questions like: does air pollution affect our ecosystems? Are our ecosystems changing? At which rate and where are they changing? (Johnson 1988).

Integration of data can be performed considering the dimensions of both time (data from the same site at different times) and space (data from different plots at the same time). Time and space are well known important issues when analysing ecological trends (*e.g.* Magnuson *et al.* 1991; Findlay and Zheng 1997; Innes 1998). However, decisions as to the most suitable dimension in which to analyse data generated by monitoring programs are dependent on the sampling strategy adopted to select the monitoring sites - which controls the inferential process – (Edwards 1998) and the data availability (again in both space and time) - which controls the actual evaluation possibilities. At European level, an evaluation strategy was adopted which gives priority to the space dimension (De Vries 1999). The strategy is based on a conceptual model where the different indicators considered by the monitoring program are reported in terms of predictor and response variables and mutual relationships

§ Paper prepared within the CONECOFOR programme, by the contract with the Ministry for Agriculture and Forestry Policy - National Forest Service, Italy. CONECOFOR is part of the Pan-European Level II Intensive Monitoring of Forest Ecosystems and is co-sponsored by the European Commission.

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(*e.g.* EC – UN/ECE 2000, p. 21 and p. 29). Relationships are then formally explored by multivariate analysis, *e.g.* ordination techniques (Principal Component Analysis, Redundancy Analysis, Project to Latent Structure Analysis, Correspondence Analysis, Canonical Correspondence Analysis) and/or multiple regression techniques (EC – UN/ECE 2000) where *PMPs* are used as cases. Multivariate analysis has been acknowledged for some time as a quantitative approach to the study of community ecology (*e.g.* Gauch 1982). However, multiple regression does not provide quantitative data on the extent and rate of changes occurring in the ecosystem as a whole, a goal that is important when attempting to identify those monitoring plots which "deviate" from expected trends. In addition, there are some conceptual and technical problems to be considered when attempting to analyse intensive monitoring data. Conceptual problems come from the nature of the monitoring sites. Level II *PMPs* were not selected on a design basis or on a model basis: they are case studies selected with preferential sampling (Ferretti 2000a), and this places a strong limitation on the inferential process (*e.g.* Stevens 1994; Edwards 1998). In practice, it means that *PMPs* are not comparable to each other and that conclusions cannot be extrapolated to sites other than those being monitored. Although this is not expected to invalidate the outcome of *e.g.* multiple regression analyses, it has important consequences on the strength of the conclusions that the program will be able to draw.

The technical problems come from the nature of the monitoring program which gives priority to the intensity of monitoring (roughly defined by the number of investigations carried out at a site) rather than to sampling density (roughly defined by the number of sites). For example, the typical ratio between intensive (Level II) and extensive (Level I) monitoring plots is 1:5 (*e.g.* EC Regg. 1091/94), while the ratio between the number of investigations carried out at Level II and Level I ranges from 7:3 to 7:1. In addition, several investigations on Level II produce data on many variables (*e.g.* foliar chemistry requires measurements of 5 chemical parameters plus the weight of 100/1000 leaves/needles). Although this may make sense in the overall concept of the European forest monitoring program, it has been recognized that the ratio between variables (the number of measured parameters at *PMPs*) and cases (the number of *PMPs*) often becomes unfavourable for e.g. multiple regression, as for many multivariate analyses (Tables 1-2) (EC-UN/ECE 1999, p. 35). This problem becomes even greater when attempting to stratify the *PMPs* to obtain more homogeneous sub-datasets and/or when individual countries are considered (Tables 1-3). Actually, the integrated evaluation carried out at individual country level may encounter considerable problems in adopting the European approach, especially in those countries – like Italy - with a relatively small number of intensive *PMPs* and where the ratio between variables and cases becomes even worse (Table 2-3). This makes it problematic to perform multi-

Table 1 - Number of cases (number of *PMPs*) in Europe (1996 data) and Italy (1999) for the most frequent tree species.
Numero di casi (numero di aree di saggio permanenti) in Europa (1996) ed Italia (1999) per le specie più frequenti.

Main forest species	Europe	Italy
Scot pine	205	0
Norway spruce	162	4 (5)
beech	84	7 (10) a
deciduous oaks	77	6b
evergreen oaks	19	2 (4) c
other	148	1d

in brackets: number of plots inclusive of those selected/incorporated in 1999 and/or not operational yet.
a: *Fagus sylvatica*
b: *Quercus cerris* (4), *Q. pubescens* (1), *Q. robur* (1)
c: *Q. ilex*
d: *Carpinus betulus+Q. robur*

Table 2 - Number of variables (number of mandatory indicators) according to the intensity level of monitoring.
Numero di variabili (numero di indicatori richiesti su basi legali) secondo l'intensità di monitoraggio.

Core surveys	+ deposition	+ meteo
Crown condition: 2(a)	Deposition: 12 (e)	meteo: 6 (f)
Foliar condition: 7 (b)	Gases: 3	
Soil condition: 14 (c)	Soil solution: 8	
Ground vegetation: 1(d)		
Tree growth: 1		
Total: 25	23	6
Grand total: 25	48	54

(a) only considered: defoliation, discoloration
(b) for each of two age classes
(c) for each soil layer
(d) for each species and layer
(e) for each open field, throughfall and stemflow (when measured)
(f) open field and under canopy.

Table 3 - Number of *PMPs* in Italy according to the species and to the surveys. Core surveys: crown condition, soil condition, foliar condition, growth and yield, ground vegetation.
Numero di aree di saggio permanenti in relazione alla specie ed alle varie indagini. Indagini core: condizione delle chiome, condizione del suolo, condizione del fogliame, accrescimenti, vegetazione erbacea.

Main species	Number of plots				
	Total	with core surveys	with ozone	with deposition	with meteo
Beech	7 (10)	7 (10)	7	6	2
Norway spruce	4 (5)	4 (5)	4	3	4
Turkey oak	4	4	4	2	1
Holm oak	2 (3)	2 (3)	2	1	1
European oak	2	2	2	1	1

in brackets: number of plots inclusive of those selected/incorporated in 1999 and/or not operational yet.

ple regression analysis in Italy, where even simple regression seems to be problematic: for example the maximum number of *PMPs* with the same major tree species and deposition measurements is 6 (Table 3) and this makes any possible result of regression analysis very weak.

When integration of data over space is difficult, integration of data over time may represent an alternative. However, in this case the different sampling regimes adopted by the various investigations can mean that a considerable amount of time is needed to collect data on a sufficient number of cases of data. For example, the relationship between deposition and growth needs 20-25 years to obtain data on 5 cases for a simple regression analysis (Table 4). The unfavourable ratio between variables and cases is something that will influence the analysis of intensive monitoring data also in the future. This is one of the most undesired results of the weakness of the design phase of the whole European program (Ferretti 2000a). At the end the situation is such that it would be difficult – if at all possible – to have any robust integrated analysis of intensive monitoring data at national level before several years and this creates the need for exploring alternatives. This paper intends to outline the conceptual basis adopted to identify an Integrated and Combined (I&C) evaluation system of intensive monitoring data in Italy. Information and considerations on the I&C have been also reported elsewhere (Ferretti *et al.* 2000a).

Aims of the whole report

The aim of this first report of the I&C Task Force is to provide an overview of the concepts and the methods needed for an integrated and combined (I&C) evaluation of forest monitoring data provided by the permanent plots in Italy (Allavena *et al.* 1999). Concepts and methods are those that have been agreed upon by the various experts involved in the CONECOFOR program. The report considers some basic aspects of the CONECOFOR program and how its characteristics will influence the I&C evaluation (Section 1, Introduction), the nature of the various I&C analyses suggested and issues related to data quality, completeness, precision, as well as temporal and spatial aggregation (Section 2, Methods), the indicators adopted by each individual investigation and some first results (Section 3, Results). Section 4 (Conclusions) will provide final considerations and suggestions for future work.

Table 4 - Time series needed to explore relationship between deposition (assumed as stressor) and various response entities.
Serie temporali necessarie per esplorare le relazioni tra deposizioni atmosferiche (assunte come agenti di stress) e varie entità/indicatori di risposta.

Stressor	Response	Sampling regime of response	Time series needed to have 5 points on a scatterplot
Deposition	Soil	10 y	1995-2035a
	Growth	5 y	2000-2020a
	Foliage	2 y	1999-2007
	Ground vegetation	1 y	1998-2003
	Crown	1 y	1998-2003

a: in many plots, deposition data starts in 1998, while soil- and growth survey are always in 1995 and 1996, respectively.

Overall approach of the I&C evaluation

Nature and position of the I&C evaluation system within the CONECOFOR program

The need to address an integrated and combined (I&C) evaluation of intensive monitoring data was expressed several times during the internal meetings of the CONECOFOR program and was the main consideration that led the National Focal Center (NFC) of Italy to establish the I&C Task Force (TF). The I&C TF includes the team leaders of the various investigations carried out at the *PMPs* and has met four times to discuss the proposals coming from its coordinator and agree upon its terms of reference and concepts. It is important to consider the position of I&C evaluation within the CONECOFOR program (Fig. 1). The I&C is based on the work of existing Specific Investigation Teams (SITs) which remain responsible for the development of manuals and standard operating procedures (SOPs), training and intercalibration (T&I), data collection (DC), quality control (QC), validation and storage of data (V&S), Specific Investigation Data Submission (SIDS), Specific Investigation Analysis (SIA), and Specific Investigation Reporting (SIR). This is a further difference compared to the European evaluation system, where there is the need to report the results obtained by individual investigations. This issue is not addressed within the I&C evaluation since each survey has its own SIR. On the other hand, SITs have the duty to provide a Specific Investigation Contribution (SIC) to the I&C by a process of Indicator Development Evaluation and Update (IDEU) which

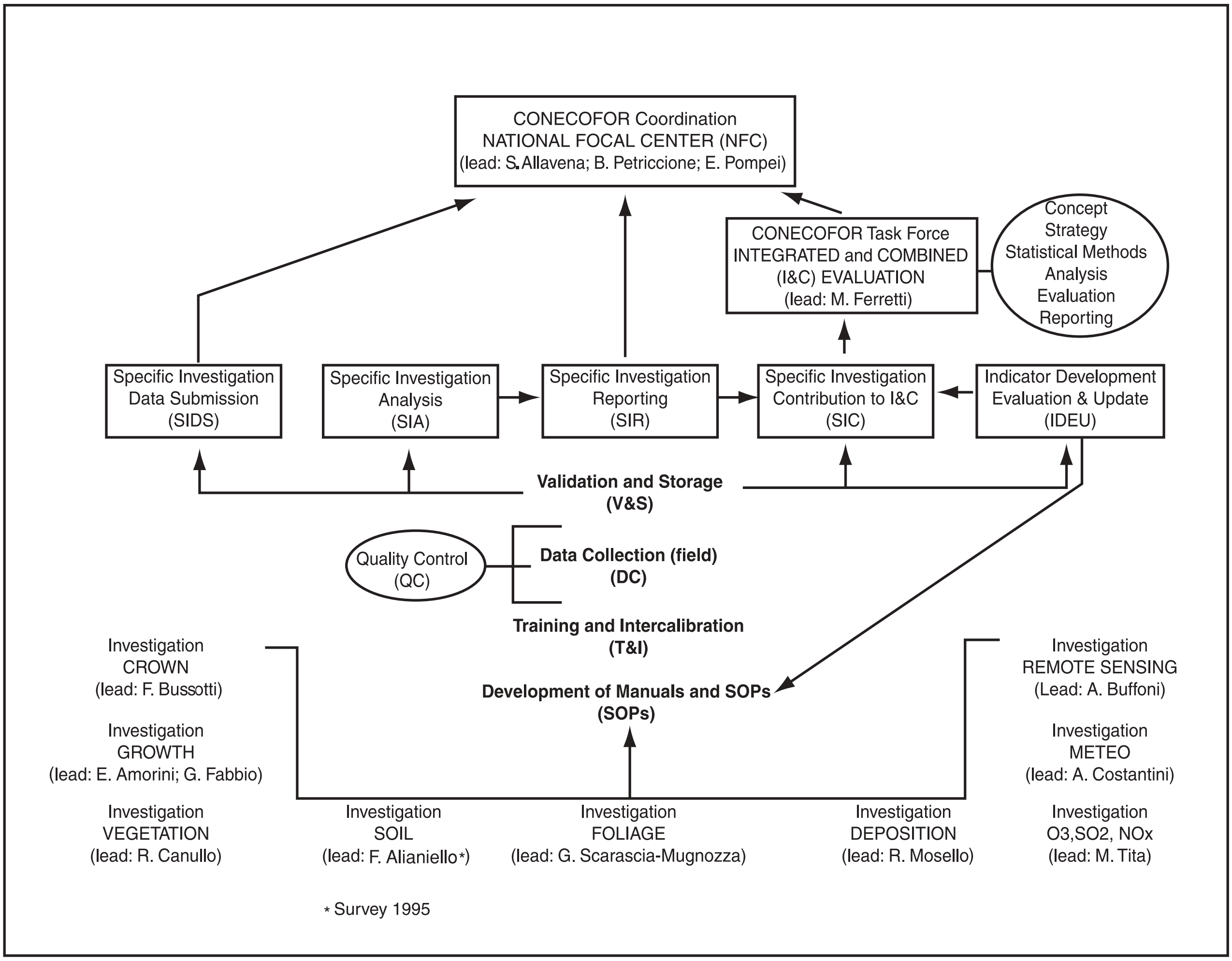

Figure 1 - The operational structure of the CONECOFOR program and the position of the I&C evaluation system.
La struttura operativa del programma CONECOFOR e la posizione del sistema di valutazione I&C.

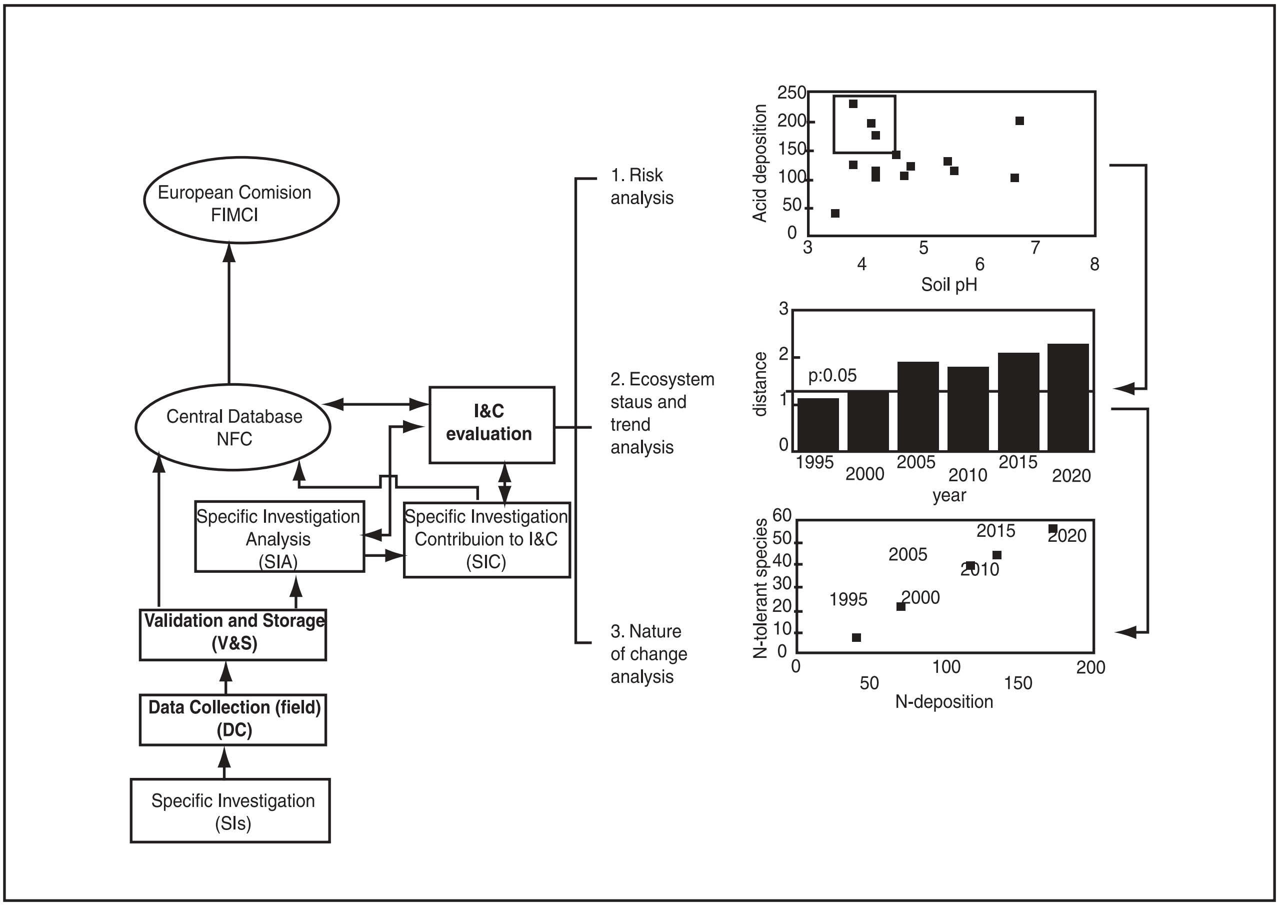

Figure 2 - The three analyses incorporated in the I&C evaluation. See text for further explanations.
I tre tipi di analisi incorporati nella valutazione I&C. Si veda il testo per ulteriori spiegazioni.

can have a clear feedback on the SOPs. IDEU also plays an important role in trying to reduce the number of variables that can be used in the statistical analysis, thus improving the ratio between variables and cases. This has been attempted following both conceptual and statistical approaches; and data relating to a number of indicators and indices are provided by various contributors in the Section on Results.

Given its structure, the I&C is not intended to replace the evaluation of data collected by individual surveys and it is not concerned with problems like, *e.g.* the relationship between N-NH_4 and S-SO_4 in the deposition, or insect damage and tree condition. This kind of problem will remain the responsibility of the individual investigations. Rather, I&C will consider both generic and specific questions which need to use data generated by different surveys: for example, in order to assess the biological status of the vascular plant community of the ecosystem, data on ground vegetation, tree condition and tree growth are necessary; to assess the evolution of the chemical status of the ecosystem, overall data on inputs via deposition, soil and foliage are essential. In this respect it is essential that any investigation team develop its work according to the current status of science: this will allow the incorporation of updated findings in the I&C process.

The I&C evaluation system

The I&C TF agreed on the fact that a full use of monitoring data needs different approaches. This calls for an evaluation system open to emerging issues of concern, but of course must be driven by priorities. In this context, different kinds of analysis were identified to set up the I&C evaluation system (Fig 2). Three kinds of analysis are considered: (*i*) risk analysis, (*ii*) ecosystem status and changes analysis and (*iii*) nature of change analysis. Additional kinds of analysis will be explored in the future, with meta-analysis being of particular interest (*e.g.* ADAMS *et al.* 1997).

Risk analysis (RA) has been suggested and designed taking into account the objective of the monitoring program. At the time the I&C process was undertaken, air pollution was the major concern of the European regulation under which the whole monitoring program is funded. Therefore, risk analysis is aimed at understanding the actual risk of the target forest ecosystems in relation to air pollution (FERRETTI *et al.* 2000a), *i.e.* to identify whether the actual or potential exposure to pollutants can be actually or potentially dangerous to the concerned forests ecosystem. A collateral advantage is the potential to identify *PMPs* where some investigations are redundant (*e.g.* deposition measurements in highly buffered sites with low deposition loads) or lacking (*e.g.* deposition measurement in desaturated soil under potentially high deposition inputs). The I&C TF agreed to concentrate on the following issues: direct and indirect effects of atmospheric deposition (acidification, eutrophication), direct and indirect effects of ozone, effects of weather and climate. Details are given by FERRETTI *et al.* (this volume, "Methods of Analysis of the I&C Evaluation System").

The aim of ecosystem status and change (S&C) analysis is to *quantify* the ecosystem status and changes. This analysis will consider indicators and indices from as many investigations as possible, taking into account the existing differences occurring in sampling regimes and spatial allocations. This approach refers to a multidimensional scaling (MDS), a non-parametric multivariate analysis where individual communities/ecosystems are represented in a *n*-dimensional space: differences between communities/ecosystems are represented by the distance between the points, and changes in the status can be tracked by the trajectory of the point in such a space. This approach could be followed either in relation to an ecosystem's "mean status" over several years in order to collect baseline data to identify size and direction of change (FERRETTI *et al.* 2000a), or in relation to a defined target condition or management objective (*e.g.* LUNDQUIST and BEATTY 1999). With different methods, the approach of using a concept of distance between points in a multidimensional space was first developed for aquatic ecosystems (*e.g.* FIELD *et al.* 1982, quoted by LUNDQUIST and BEATTY 1999; JOHNSON 1988) and then for forests (LUNDQUIST and BEATTY 1999). As a first attempt, the approach adopted here is based on the use of the concept of Mahalanobis distance, while other statistical techniques (*e.g.* the kernel density estimation, LUNDQUIST and BEATTY 1999) will be tested in the future. The use of Mahalanobis distance is not new in forest condition monitoring: for example, INNES *et al.* (1996) have used this method to identify trees with unusual foliage color. For the S&C analysis, the objective is to know the Mahalanobis distance of the ecosystem status $X=(X_1, X_2,\ldots, X_n)$ at a given year, from a reference "mean status" computed over a time window (see below). The data generated by the *n* indicators $X_1, X_2,\ldots, X_n$ are used to identify the ecosystem status $Y_1, Y_2,\ldots Y_k$ at any given year $t_1, t_2,\ldots t_k$ and the distance between the status identified by the mean vector μ and each relevant year $Y_1, Y_2,\ldots Y_k$ is then computed. As the time series increases, subsequent data are added to the model, thus strengthening the value of the mean status for those variables subjected to high short-term random fluctuation. With this approach, anomalous ecosystem status in a time series can be identified at the analytical stage by further statistical analysis of the distance values. Details are given by FERRETTI *et al.* (this volume, "Methods of Analysis of the I&C Evaluation System").

Nature of change analysis (NoC). The S&C analysis will provide information about changes, but not about the reason of change, nor about its direction (*e.g.* improvement, worsening). This issue will be covered by the nature of change (NoC) analysis, in which time series data at plot level will be used to identify relationships between stressors and response indicators. This analysis will be used to integrate the data from individual *PMPs* through time and will need time in order to collect a sufficient number of cases to allow proper correlation (Table 4).

All the above analyses can be performed independently, although it is easy to recognize their connection: for example risk analysis may identify those plots expected to be sensitive to acidification and/or eutrophication, S&C may provide quantitative estimation of the changes occurring in those ecosystems and NoC can identify relationships between the observed changes in stressors and response variables (*e.g.* number of nitrophilous species and deposition of N-compounds). Details will be given by Ferretti *et al.* (this volume, "Methods of Analysis of the I&C Evaluation System").

Indicators and indices

As reported by Hunsaker (1993), an indicator is a characteristic or an entity that can be measured or estimated in order to assess the status and trend of the target environmental resource. In the context of the CONECOFOR program, forest is the target resource and trees, soil, ground vegetation, atmosphere are all possible indicators. However an indicator can be measured for different characteristics: for example the atmosphere can be measured in relation to its chemical (*e.g.* ozone) and physical (*e.g.* solar radiation) characteristics. Therefore, an index can be defined as a characteristic that describes the status of a given indicator (Ferretti 1997). Accordingly, ozone concentration is here considered as an index of the chemical condition of the atmosphere, while solar radiation as an index of the physical condition.

The number of indicators and indices adopted at a given *PMP* defines the intensity level of monitoring. Taking into account the above definitions, indicators and indices can be classified in relation to the compartment of the ecosystem they are related to (biological, chemical, physical) or their role (*e.g.* stressor, response). These categories will be used several times in this report.

Variables and cases

A strong limitation to the whole I&C system is the unfavourable ratio between variables (many) and cases (few). A value of 4-5 is considered the minimum acceptable ratio between cases and variables. It is therefore important to define variables and cases explicitly. Within the framework of the I&C evaluation system a "variable" coincides with the index (either measured or calculated) describing the status of a given indicator at a given *PMP*. Usually, the variables are expressed in terms of statistical descriptors (sum, mean, maximum,…): examples can be the deposition (kg•ha^{-1}) of N-NH_4, the median crown transparency, the maximum O_3 concentration, the Shannon index, and so on. On the other hand, a "case" is an individual *PMP* at an individual year: for example *PMP* CAL1 at year 1998 is one case. Deposition of N-NH_4 at *PMP* CAL1 at years 1998, 1999, 2000 is 1 variable: 3 cases ratio. As for many analyses of ecological trends, there is some risk in this approach due to the temporal dependence of the data, which may introduce some disturbance in the data series, and to the multicollinearity of the data (*e.g.* N and N/Mg ratio in the foliage) which violates the assumption of independency between variables. Especially the latter will be considered when attempting to select the indices to be used as response/ predictors in the model.

Data availability, data quality, evaluation levels, time windows

The basic requirement of integrated analysis is to have high quality (*i.e.* consistent, precise, complete) data sets (Ferretti *et al.* 2000a). Details on these issue will be given by Ferretti and Nibbi (this volume). Besides data quality, there are also other problems. For example, not all surveys are carried out at all *PMPs*, nor do all the surveys start at the same time, nor do they have similar sampling regimes (Ferretti *et al.* 2000a). These facts have clear effects on the possibility of spatial and temporal aggregation of available data. To deal with this problem, different evaluation levels and time windows were suggested. The "evaluation level" (EL) is defined by the investigations carried out at the *PMPs:* three major EL levels are considered, namely EL1 (which includes the *PMPs* where all the core surveys are carried out), EL2 (*PMPs* with core surveys + deposition) and EL3 (core surveys + deposition + meteorological measurements). Details about ELs are given by Ferretti *et al.* (this volume, "Spatial and Temporal Aggregation of the CONECOFOR Data").

The "time window" is defined by the sampling regimes and/or data aggregation of the different investigations, namely 1 year (crown, ground vegetation, ozone, deposition, meteo), 2 years (foliage chemistry), 5 years (growth) and 10 years (soil). These different time schedules imply that different data can be available for the analysis, and this is particularly relevant for the S&C. Details on time windows are given by Ferretti *et al.* (this volume, "Spatial and Temporal Aggregation of the CONECOFOR Data").

Data aggregation

The aggregation of data will vary in relation to data availability (see above) and the analysis of concern. For RA, *PMPs* will be investigated individually since the aim is to identify the condition of risk for any *PMP*. The same will be done for the NoC analysis, where the response of individual *PMPs* to a given stressor is of interest. The S&C analysis will require a different aggregation of data in order to cope with the unfavourable ratio between cases and variables. For the S&C, *PMPs* will be grouped according to the most important species (*e.g.*: beech, Norway spruce, Turkey oak and holm oak) and this will improve the chances for multivariate statistics: for example, beech *PMPs* will generate 78 cases by 2010, thus supporting 15 variables to be used simultaneously in multivariate analysis (Table 5). As is obvious from Table 5, species with few plots like Turkey oak and holm oak will be difficult to investigate with multivariate statistics unless the time series becomes very long. This reflects again some basic problems with the design of the whole monitoring program where the problems associated with data analysis were not taken into account.

Evaluation process

The previous sections may have provided an idea of the complex system within which the I&C evaluations will work. The full process will require a lot of time (Ferretti *et al.* this volume, "Spatial and Temporal Aggregation of the CONECOFOR Data") but it does not mean that results will be not available before dozens of years. This is thanks to the nature of the I&C, which allows different kinds of analysis to be undertaken simultaneously. For example, RA for the identification of risks attributable to ozone can be undertaken as soon as five years of ozone data are available (year 2000). Proper assessment of risks due to deposition will be addressed after five years of deposition data are collected (year 2002), and so on. At the same time, the continuous collection of data will allow a first run of the S&C for beech *PMPs* by the year 2005. Thus, the I&C system should be seen as a process where different kinds of analysis are undertaken according to the availability of data and/ or expressed needs and priority.

Conclusions

The I&C evaluation system designed for Italy is based on the recognition that a proper assessment of intensive monitoring data needs to consider carefully the way in which data are collected, namely the monitoring site selection procedure, the spatial allocation of individual investigations, their different sampling regimes and the ratio between the number of variables and the number of cases which is a drawback in the application of multivariate statistical techniques. An additional need is to make maximum use of currently available and future data as soon as they become available. The I&C system is based on three kinds of analysis aimed at providing answers to questions about the potential sensitivity of selected forest ecosystems to air pollutants, to quantify the status and changes of

Table 5 - *PMPs* equipped with deposition collectors. Number of cases that will become available in the period 1998-2010. The number of variables that can be used in multivariate statistics (with 5:1 as cases: variables ratio) is reported in brackets.
Aree permanenti equipaggiate per la misura delle deposizioni atmosferiche. Numero di casi che saranno disponibile nel periodo 1998-2010. Il numero di variabili che potranno successivamente essere usate per analisi multivariata è riportato tra parentesi, tenendo come riferimento il rapporto 5:1 tra casi e variabili).

Species	1998	1999	2000	2001	2002	2003	2004	2005	2010
Fagus sylvatica	6(1)	12 (2)	18 (3)	24 (4)	30 (6)	36 (7)	42 (8)	48 (9)	78 (15)
Picea abies	3	6 (1)	9 (1)	12 (2)	15 (3)	18 (3)	21 (4)	24 (4)	39 (7)
Quercus cerris	2	4	6 (1)	8 (1)	10 (2)	12 (2)	14 (2)	16 (3)	26 (5)
Quercus ilex	1	2	3	4	5 (1)	6 (1)	7 (1)	8 (1)	13 (2)

the selected ecosystems, and to identify the nature of changes. The I&C analyses are mostly concerned with changes occurring at individual *PMP* level, and explicitly avoid comparing the actual data from different *PMPs*. On the other hand, comparison between size and direction of changes are considered of value, although they do not allow classical statistical inference. The implementation of the analyses is necessarily based on data availability which defines the level at which the analysis can be carried out and the time window the analysis can cover. Thus, an important feature of the I&C evaluation designed for Italy is represented by its iterative nature where the same level of analysis can be implemented for subsequent time windows. In this context, data availability is therefore a strong driver of the entire evaluation plan.

References

Adams D. C., Gurevitch J., Rosemberg M. W., 1997-*Resampling test for meta-analysis of ecological data*. Ecology, 78 (5): 1227-1283.

Allavena S., Isopi R., Petriccione B., Pompei R., 1999 - *Programma Nazionale Integrato per il controllo degli ecosistemi forestali*. Ministero delle Politiche Agricole, Roma, Italia, 220 p.

De Vries W., 1999 -*Intensive monitoring of forest ecosystems in Europe. Evaluation of the programme in view of its objectives and proposal for the scientific evaluation of the data. A strategy document*. Unpublished paper distributed for the 4th SAG/NFCs/EPs combined meeting of the EU-UN/ECE ICP-Forests Level II, Heerenven, The Netherlands, September 1999: 42 ps.

EC-UN/ECE, 1999; De Vries W, Reinds G. J., Deelstra H.D., Klap J. M., Vel E. M. – I*ntensive Monitoring of Forest Ecosystems in Europe, 2000 Technical Report*. EC, UN/ECE 1999, Brussels, Geneva. 173 ps.

EC-UN/ECE, 2000; De Vries W, Reinds G. J., Van Kerkvoorde M. S., Hendricks C. M. A., Leeters E. E. J. M., Gross C. P., Voogd J. C. H., Vel E. M. – *Intensive Monitoring of Forest Ecosystems in Europe, 2000 Technical Report*. EC, UN/ECE 2000, Brussels, Geneva. 191 ps.

Edwards D., 1998 - *Issues and themes for natural resources trend and change detection*. Ecological Applications, 8 (2): 323-325.

Ferretti M., 1997 - *Forest health assessment and monitoring. Issues for consideration*. Environmental Monitoring and Assessment, 48: 45-72.

Ferretti M., 2000a – *Sampling design*. Paper prepared for the internal review of the ICP – Forests available by the author.

Ferretti M., 2000b - *Spatial and temporal aggregation of the CONECOFOR data for the Integrated and Combined (I&C) analyses*. In: Ferretti M. (ed.), "Integrated and Combined (I&C) evaluation of intensive monitoring of forest ecosystems in Italy – Concepts, Methods and First Results" Annali dell'Istituto Sperimentale per la Selvicoltura, Special Issue, anno 1999, 30: 59-66.

Ferretti M., Bussotti F., Giordano P., Mazzali C., Nibbi R., 2000a - Program CONECOFOR – *Integrated and Combined (I&C) Evaluation of Risk, Status and Changes of Forest Ecosystems*. In: SISEF, Atti, 2: 435-440.

Ferretti M., Giordano P., Mazzali C., 2000b - *Methods of analysis of the Integrated and Combined (I&C) evaluation system*. In: Ferretti M. (ed.), "Integrated and Combined (I&C) evaluation of intensive monitoring of forest ecosystems in Italy – Concepts, Methods and First Results", Annali dell'Istituto Sperimentale per la Selvicoltura, Special Issue, anno 1999, 30: 33-42

Ferretti M., Nibbi R., 2000 - *Procedures to Check Availability, Quality and Reliability of Data Collected at the CONECOFOR Permanent Monitoring Plots*. In: Ferretti M. (ed.), "Integrated and Combined (I&C) evaluation of intensive monitoring of forest ecosystems in Italy – Concepts, Methods and First Results" Annali dell'Istituto Sperimentale per la Selvicoltura, Special Issue, anno 1999, 30: 43-57.

Field J.G., Clarke K. R., Warwick R.M., 1982 – *A practical strategy for analysing multispecies distribution patterns*. Marine Ecol. Prog. Ser. 8: 37-52.

Findlay C.S., Zheng L., 1997 - *Determining characteristics stressor scales for ecosystem monitoring and assessment*. Journal of Environmental Management 50: 265-281.

Gauch H.G., JR, 1982 – *Multivariate analysis in community ecology*. Cambridge University Press: 298 ps.

Hunsaker C.T., 1993 - *New Concepts In Environmental Monitoring: The Question Of Indicators*. The Science of the Total Environ., Suppl.: 77-95.

Innes J.L., 1998 - *Measuring Environmental Change*. In: Peterson D. L., Parker V. T. (Eds.) Ecological Scale: 429-457.

Innes J.L., Ghosh S., Schwytzer A., 1996 – *A method for the identification of trees with unusually colored foliage.* Can. J. For. Res., 26: 1548-1555.

Lundquist J.E., Beatty J. S., 1999 - *A conceptual model for defining and assessing condition of forest stands.* Environmental Management, 23 (4): 519-525.

Johnson A. R., 1988 - *Diagnostic variables as predictors of ecological risk*. Environmental Management 12 (4): 515-523.

Magnuson J.J., Kratz T.K., Frost T.M., Bowser C.J., Benson B.J., Redwood N., 1991 - *Expanding the temporal and spatial scales of ecological reserach and comparison of divegent ecosystems: roles for LTER in the United States*. In: Risser P.G. (Ed.), 1991 “Long-term Ecological Research. An International Perspective”. John Wiley & Sons.

Stevens D., 1994. - *Implementation of a national monitoring program*. Journal of Environmental Management, 42: 1-29.

The CONECOFOR Programme§

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Abstract - The Ministry for Agriculture and Forestry Policy (National Forest Service) has since 1995 sponsored the "National Integrated Programme for Forest Ecosystems Monitoring" *(CONECOFOR)*, implemented to study the effects of atmospheric pollution and climate change on forest ecosystems. The Programme operates within different international inititives including the Convention on Long Range Transboundary Air Pollution *(L.R.T.A.P. U.N.-E.C.E.,* ratified by Italy in 1982), the European Union Scheme on the Protection of Forests against Atmopsheric Pollution and the Resolutions of the Ministerial Conferences on the protection of forests in Europe. The Programme supplement the so-called "Level I" monitoring. Level I investigations have been in progress since 1987 on a European grid made up of 16x16 km. At present there are in Italy 260 monitoring plots distributed over the whole country, where annual assessment of the tree crown status are made. At selected plots within the same network, in 1995/6, pedological investigations were carried out and the chemical content of the leaves analysed. The Level II CONECOFOR Programme is currently based on 27 permanent plots. Nine different researches have been in progress since 1996 in the permanent plots, including geology and geomorphology (preliminary), vegetation (yearly), crown condition (yearly), chemical content of leaves (every two years), soil (every 10 years), variations in tree growth (every 5 years), atmospheric depositions (continuously), meteorology (continuously), atmospheric pollutants (continuously). The National Forest Service co-ordinates the seven participating research Institutes, which are responsible for the analyses. The information achieved by the Programme will broaden our knowledge of forests, in particular as regards cause/effect relationships between various interacting factors.

Keywords: *CONECOFOR, EU Regulations, Permanent plots, Forest ecosystems.*

Riassunto - Il Programma *CONECOFOR.* Il Ministero delle Politiche Agricole e Forestali (Corpo Forestale dello Stato), in base al Regolamento U.E. n. 1091/94, ha avviato dal 1995 il "Programma Nazionale Integrato per il Controllo degli Ecosistemi Forestali" *(CONECOFOR),* per studiare gli effetti dell'inquinamento atmosferico e dei cambiamenti climatici sugli ecosistemi forestali. Il Programma s'inquadra anche nell'ambito di iniziative internazionali come la Convenzione di Ginevra sull'inquinamento atmosferico trans-frontaliero *(L.R.T.A.P. U.N.-E.C.E.),* ratificata dall'Italia nel 1982, lo Schema Europeo sulla Protezione delle Foreste contro l'Inquinamento Atmosferico e le Risoluzioni delle Conferenze dei Ministri sulla protezione delle foreste in Europa. Il Programma costituisce l'evoluzione delle indagini (cosiddette di Livello I) condotte, già dal 1987, su di una rete europea costruita su una maglia 16x16 km, consistente attualmente in Italia in circa 260 punti di rilevamento distribuiti sul tutto il territorio nazionale. In questi punti sono effettuate annualmente valutazioni dello stato delle chiome degli alberi. Su di una selezione dei punti della stessa maglia sono state condotte, nel 1995/6, indagini a carattere pedologico ed analisi del contenuto chimico delle foglie. Il Programma CONECOFOR di Livello II è attualmente basato su 27 aree permanenti. Nelle aree permanenti sono svolte nove diverse indagini, avviate dal 1996: analisi geologica e geomorfologica (preliminare), analisi della vegetazione (ogni anno), analisi delle condizioni delle chiome (ogni anno), analisi del contenuto chimico delle foglie (ogni due anni), analisi dei suoli (ogni 10 anni), analisi delle variazioni di accrescimento degli alberi (ogni 5 anni), analisi delle deposizioni atmosferiche (in continuo), analisi meteorologiche (in continuo), analisi degli inquinanti atmosferici (in continuo). Il Corpo Forestale dello Stato è il centro di coordinamento di sette Istituti di ricerca responsabili delle indagini. Le analisi condotte nei primi quattro anni di attuazione del Programma CONECOFOR hanno consentito di realizzare una base di conoscenza sullo stato dei sistemi sotto osservazione, con particolare riguardo alle relazioni causa/effetto tra i fattori esaminati.

Parole chiave: *CONECOFOR, Regolamenti UE, Aree permanenti, Ecosistemi forestali.*

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Studies of forest conditions on systematic national grids were started in Italy fifteen years ago, by the Ministry for Agriculture and Forestry Policy, through the National Forest Service. Monitoring activities, formerly based on descriptive parameters such as tree crown transparency scores, are now set up taking in consideration quantitative analyses of the processes occurring in forest ecosystems as complex biological systems, highly reactive to environmental disturbances. This new ecological approach is the basis of the "National Integrated Programme for Forest Ecosystems Monitoring" (Programma Nazionale Integrato per il CONtrollo degli ECOsistemi FORestali, CONECOFOR), which was born in 1995 in the framework of the United Nations/Economic Commission for Europe (UN/ECE) and European Union (EU) activities, and since 1997 has been fully developed, with most of the foreseen analyses carried out.

The present paper provides information on

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set out of the Programme, on forest biocoenosis characterisation and on data collected until now.

Forest monitoring was born in Italy in the framework of several international activities:

- the *International Co-operative Programme on the Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests)* and the *International Co-operative Programme on Integrated Monitoring of Air Pollution Effects (ICP-IM)*, which were established by the UN/ECE under its *Convention on Long Range Trans-boundary Air Pollution (CLRTAP)*, ratified by Italy in 1982;
- the EU Scheme for forests protection against atmospheric pollution, started in 1986 by the first *ad hoc* Regulation n. 3528/86;
- the Resolutions of the Ministerial Conferences on the protection of forests in Europe.(n. 1, Strasbourg 1990, n. H4, Helsinki 1993).

Since 1987, tree crown assessment including the occurrence of a series of damaging events were recorded in Europe by the joint EU and UN/ECE systematic sample survey on forest condition (Level I), carried out according to a nominal 16x16 grid. More recently, a series of permanent plots for intensive forest monitoring (Level II), was established within the same programme in order to collect data on various indicators and processes in the forest ecosystems.

Criteria for monitoring and the evaluation strategy of the Level I and II are given by several Regulations of the European Commission (Regulations EC nn. 3528/86, 2157/92, 1091/94, 307/97 *etc*.). Actions at international level are co-ordinated by the ICP Forests Programme Centre and the DG VI of the European Commission. Technical details and protocols for surveying are also included in international manuals based upon a general international agreement (UN/ECE 1998a, 1998b). The international monitoring activity after 2001 (expiration date of the Regulation EC n. 307/97) will be probably based on a more global and complex approach aimed at investigating ecosystem response to disturbances sources such as pollution, climate change and not proper management.

Until now, the monitoring results have been documented by a wide range of reports (KLEEMOLA and FORSIUS 1999, UN/ECE and EC 1997a, 1997b, 1997c, 2000a, 2000b) and constitute part of the scientific basis for the development of international protocols on air pollution abatement under CLRTAP of UN/ECE.

The Pan-European Intensive Programme of Forest Ecosystem was started in 1994. The general aim of the Intensive Monitoring Programme is to contribute to a better understanding of the impact of air pollution and other factors on forest ecosystems. At the present, the programme covers 864 plots in 30 participating Countries (513 plots in the EU and 351 plots in non-EU countries). Due to its non-systematic character the intensive monitoring data set is not representative for Europe in the statistical sense, but it does give information on stress and effects on a European-wide scale. Some surveys are carried out on all plots (crown condition, soil and leaves chemistry, and tree growth). At part of those plots, assessments of atmospheric deposition (494 plots), meteorology (188 plots), soil solution chemistry (252 plots), ground vegetation (637 plots) and remote sensing (approx. 150 plots) are carried out. Totally 784 intensive monitoring plots have been installed. All data and information on the methods applied has been validated and stored, for most of the plots (approx.85%), by the Forest Intensive Monitoring Co-ordinating Institute (FIMCI), a contractor of the European Commission.

Forest Monitoring in Italy

In Italy, an extensive monitoring at the European scale (Level I) on the international grid (16x16 km), as well as an intensive monitoring on a national network of permanent plots named CONECOFOR network (Level II), is carried out under the co-ordination and responsibility of the General Direction of Forestry, Mountain and Water Resources (5th Unit, National Forest Service) of the Ministry for Agriculture and Forestry Policy.

Level I

The systematic sample grid (nominal density: 16x16 km) (Level I) is representative of the total forest area which covers almost 8.675.100

ha (source: National Forest Inventory, MAF-ISAFA 1988). Of these, 6.147.000 ha (70,9%) are semi-natural forests, 2.239.200 ha (25,8 %) are *macchia* and degraded stands and 288.900 ha (3,3%) are productive artificial stands. From the 8.675.100 ha of the total forest area (28,8 % of the country's total area), 79,9 % are broadleaves (*macchia* included), 20,1 % are conifers. From 1989 to 1995, crown condition was monitored in 220 observation plots with a total of 5.614 trees evaluated. A decrease of the observation plots due to forest fires and felling occurred during the last years. After a review carried out in 1999, in the year 2000 the total observation plots are 261 and the evaluated trees 7.161. From 1985 to 1995 crown condition assessment had been carried out also on a plot grid 3x3 km (National Forest Inventory - "Indagine Nazionale sul Deperimento delle Foreste", *INDEFO*) in almost 9.600 sites covering a total forest area of 6.733.800 ha. Since the comparison between the data coming from the INDEFO and the Level I data did not show any significant difference, in 1996 the INDEFO assessment was interrupted, while more detailed and careful observations on the Level I grid are now being carried out.

In 1995 and 1996 soil and foliar surveys were carried out respectively in 89 and 57 plots. Results and data were submitted to the Forest Soil Co-ordinating Centre (FSCC) of Gent (Belgium) and to the Forest Foliar Co-ordinating Centre (FFCC) in Wien, which co-ordinate these analyses at international level.

Monitoring works are under the responsibility of the Ministry for Agriculture and Forestry Policy (National Forest Service), which is in charge of validation and submission of national data and results to the European Commission and to the ICP Forest and ICP IM. The Ministry also collaborates with the research laboratories of the Department of Forest Environment and Resources of the Tuscia University (Viterbo) and of the Department of Plant Biology of the University of Firenze, which are responsible for scientific co-ordination, data collection, training people from National and/or Regional Forest Services involved in field work and for the control and inspection of the surveys.

Defoliation and discoloration are the main parameters evaluated in crown condition assessment. Among species affected by defoliation, *Pinus spp.*, *Abies alba*, *Fagus sylvatica* and *Castanea sativa* showed the highest values of crown transparency. Concerning soil analysis, the C/N ratio seemed to decrease regularly with depth, ranging from 30.8 to 15.6 in the organic layer and from 30.2 to 8.0 in the lowest mineral layer (10-20 cm); the highest values were found in *Picea abies* plots. Acidity values ranged from a pH 3.0 to 7.2; the lowest values were found in *Picea abies* plots. Concerning leaves analyses, data referred to a single species in different sites did not show any significant result.

Level II

The National Programme for Forests Ecosystems Monitoring CONECOFOR (Petriccione and Isopi 1996, Allavena *et al.* 1999) started in 1995 within the framework of the Level II forest monitoring (Regulation EC n. 1091/94) and to answer the new questions in this field. Formerly structured as a national network including 20 permanent plots, the CONECOFOR Programme covers at the moment 27 plots (Fig. 1 and 2). Since 1997, ten of them are also included in the European Network for Integrated Monitoring of Ecosystems established under the International Co-operative Programme on Integrated Monitoring of Air Pollution Effects (ICP-IM, Fig. 3).

Analyses include crown condition assessment, chemical content of soil and leaves, deposition and air pollutants, tree growth assessment, climate and ground vegetation assessment.

The establishment of a national network allowed to unify and integrate in one project all the investigations on forest condition in Italy. In this respect the CONECOFOR Programme is both an extension and integration of projects already existing at regional or national level co-financed by the European Commission under the same Regulations.

Field work is carried out, on each plot, by the staff of decentralised structures of the National Forest Service, by Regional Administrations or by scientists of involved research Institutions and local laboratories. Inter-calibration courses and updating meetings are annually organised to make field work easier and to improve

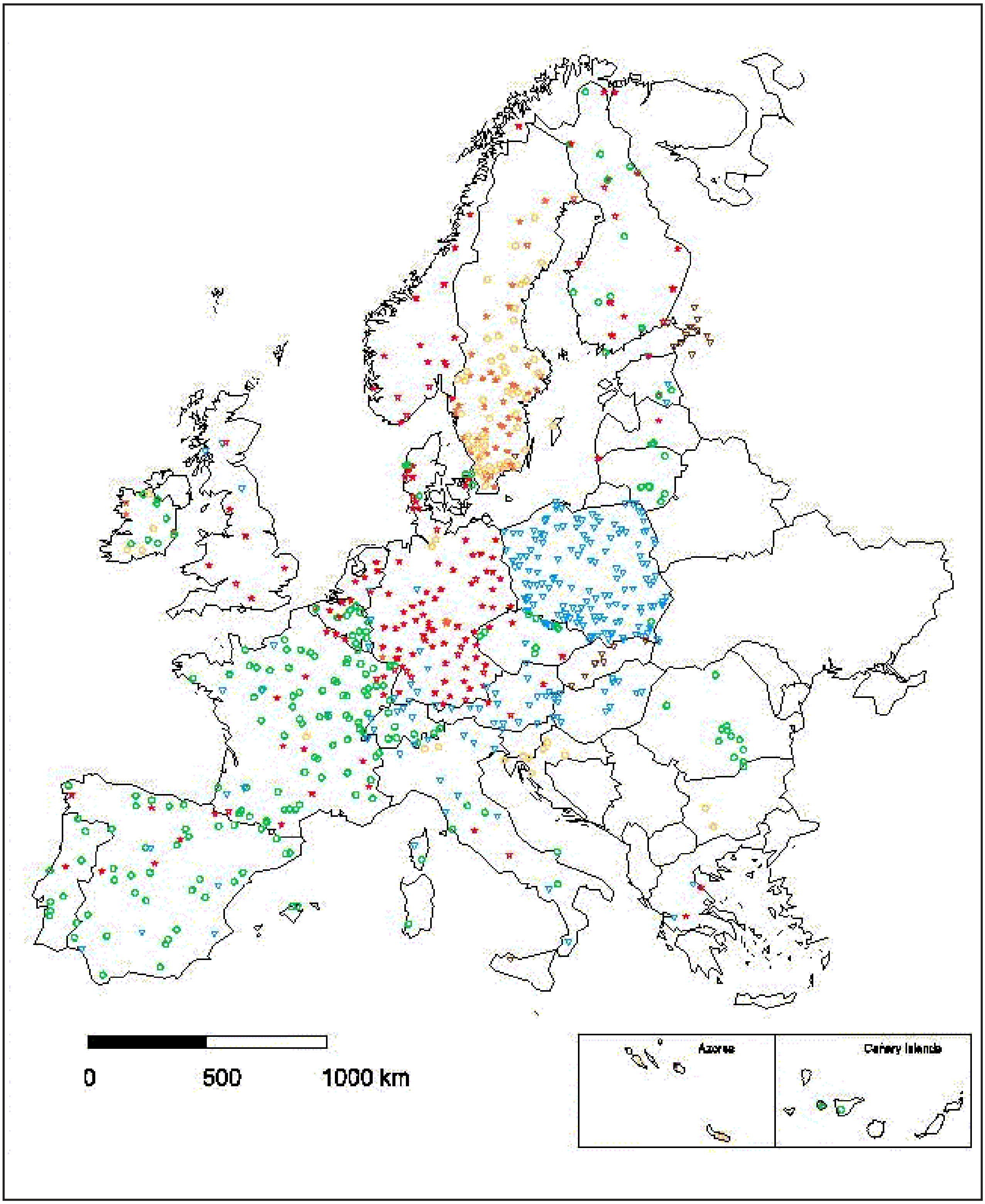

Figure 1 - Geographical location of permanent plots of the Pan-European Intensive Monitoring Network EU/ICP Forests (source: EC & UN-ECE, 2000)
Localizzazione geografica delle aree permanenti della Rete pan-europea di 2° livello EU/ICP-Forests.

Figure 2 - Geographical location of the National Network CONECOFOR permanent plots.
Localizzazione geografica delle aree permanenti della Rete Nazionale CONECOFOR.

data quality. In the following chapter, details are given on various aspects of the CONECOFOR Programme.

The CONECOFOR programme

Organisational structure of the CONECOFOR programme

The CONECOFOR Programme is included in the activities on forest monitoring co-ordinated at international level by the European Commission and by the Co-ordinating Centre of ICP Forests and ICP IM. The European Commission is also supported by a Scientific Advisory Group (SAG), with relevant experts of forestry items, coming from the different Countries participating to the international programmes on forest monitoring. SAG is responsible for setting up guidelines of monitoring activities and for evaluating agreements reached by the Experts Groups on activities as well as for taking decisions on future strategy.

The Forest Intensive Monitoring Co-ordinating Institute (FIMCI) is the advisory institution responsible for international data management. Data collected and results obtained, submitted by Countries at the end of every year, are stored in an international data bank and processed by FIMCI. In the framework of European Commission, Expert Panels or Working Groups (EP/WG) have been also created to address activities on analyses foreseen by EC Regulations on Level II. EP/WG include experts in charge of the analyses at national level. At the moment Expert Panels on deposition (including air pollutants analysis), crown condition, meteorology, ground vegetation, phenology, tree growth, soil and foliar analysis and remote sensing are active. At national level, National Focal Centres (NFCs) have been established to co-ordinate activities concerning forest monitoring programmes. NFCs are also responsible for programmes to be submitted at the end of every year to the European Commission for the financial support, as well as for validation of technical and financial achievement. In Italy NFC is represented by the General Direction for Forestry, Mountain and Water Resources (5th Unit, National Forest Service) of the Ministry for Agriculture and Forestry Policy, where a scientific staff has been working full time. The NFC underwrite annually contracts with national Research Institutes responsible for the scientific co-ordination of the analyses, data collection, analysis of samples and evaluation at National level.

Financial resources for the National Programme, including Level I and II (approx. 1.000.000 Euro per year), are ensured by a 50% contribution of EC.

A tutor, who has the responsibility for plot management and for field works (including sampling of water, leaves and air pollutants), has been appointed for each permanent plot. Tutors are staff from National Forest Service or from Regional Administrations in the case that plots are located in Regional property lands.

The Network of Permanent Monitoring Plots (PMPs)

Selection of the PMPs

In 1994, 40 permanent plots have been visited to select 20 plots, on the basis of criteria reported in the Regulation EC n. 1091/94, in particular taking into account several priorities fixed at National level, such as the inclusion of plot in a pre-existing network, rates of ecological homogeneity, regional or national representation, land ownership, land protection type, site location (far from pollution sources) and availability of local supporting teams. The same criteria were followed for enlarging the CONECOFOR network to 26 plots in 1998.

Figure 3 - Geographical location of the ICP-IM (Integrated Monitoring of Ecosystems) sites (source: Kleemola & Forsius, 1998).
Localizzazione geografica dei siti della Rete ICP-Integrated Monitoring of Ecosystems.

Installing the PMPs

The establishment procedure of CONECOFOR Network in 1995 was the following:

- selection of a 100.000 m^2 large homogeneous area as plot (as a minimum);
- establishment within each plot of two 2500 m^2 square areas (analysis and control areas);
- localisation of an open field site;
- establishment of 25 subplots 10 x 10 large within the analysis area;
- localisation in the field and on a map of 5 sites for soil sampling within the analysis area;
- localisation in the field and on a map of 5 trees per dominant species for foliar sampling within the analysis area;
- tree selection for crown condition assessment within the analysis area;
- numbering of all trees existing within the analysis area in the field and on a map at a 1:250 scale (Fig. 4);
- micro-topographic sampling of the analysis area;
- fencing of the analysis and control area.

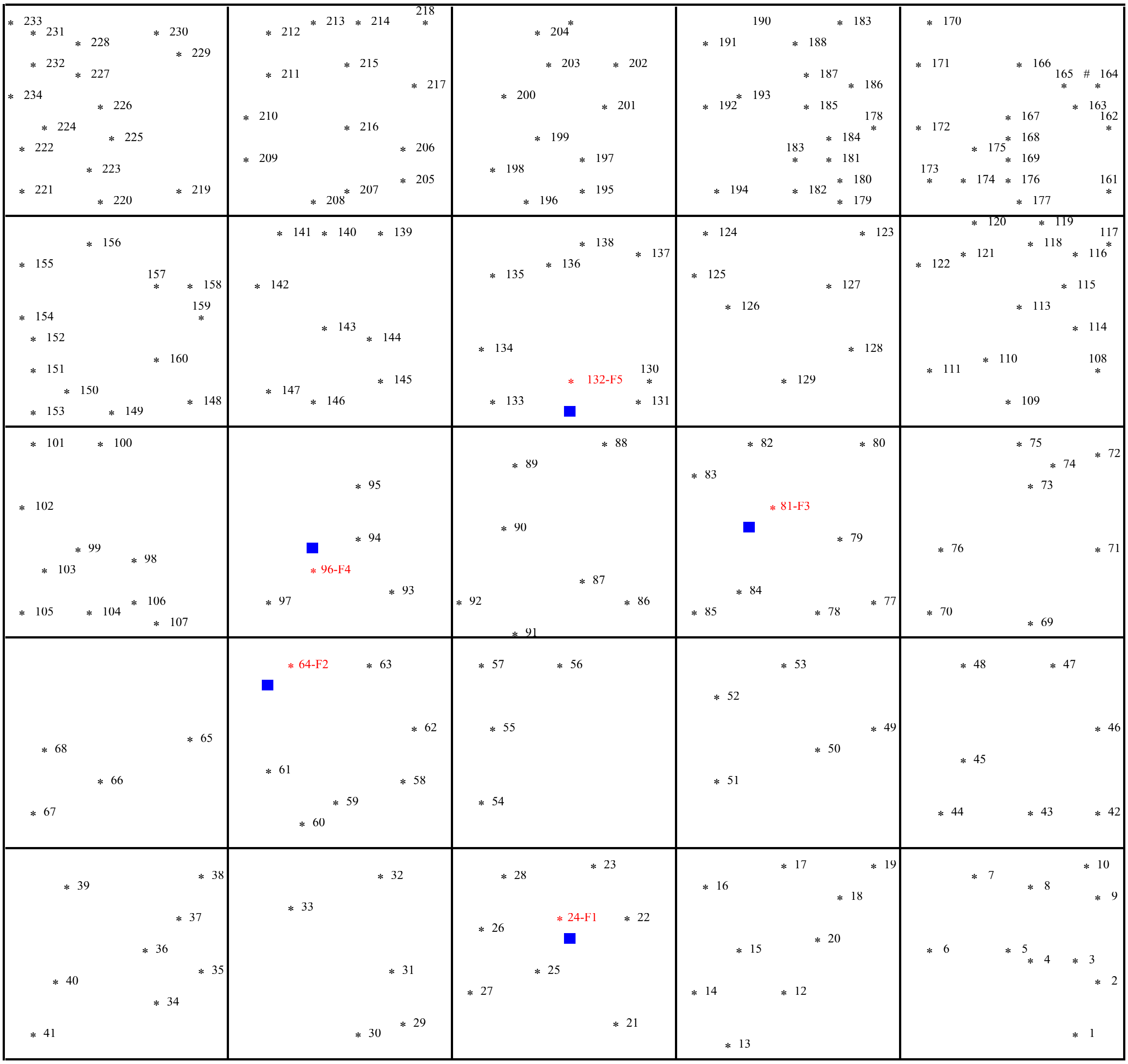

Figure 4 - Permanent plot *UMB1*: trees map of the analysis area, splitted into 25 subplots of 10 m^2 (original at 1:250 scale), with each tree numbered.
Area permanente UMB1*: mappa degli alberi dell'area di analisi, suddivisa in 25 subaree di 10 m^2 ciascuna (originale in scala 1:250), con ogni albero numerato.*

A permanent plot is made up by two contiguous 2500 m^2 areas: one area was established to carry out analyses and the other one was chosen as control; the latter one being used only to give data on vegetation as indicator of biocenosis condition (Fig. 5). The layout of a typical analysis area including buffer zone, service areas, perimeter fence, meteorological station fence, bulk/litter/stemflow collectors is shown in Figs. 6 and 7.

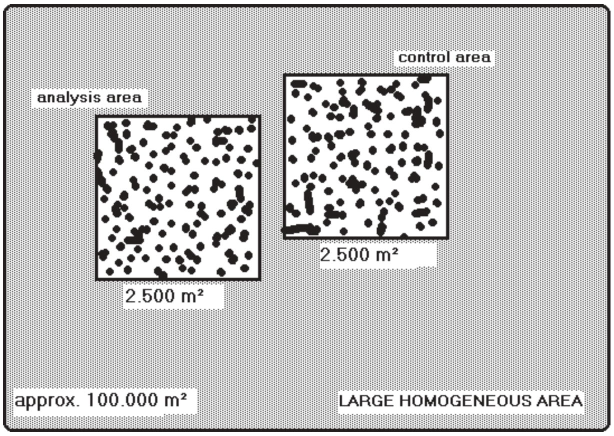

Figure 5 – Layout of a typical CONECOFOR permanent plot.
Schema di una tipica area permanente CONECOFOR.

Procedures to avoid disturbances

In order to reduce the impact of sampling activities, several general procedures have been appointed. For each permanent plot, 4 categories of sampling areas have been defined according to protection rates used (analysis area, con-

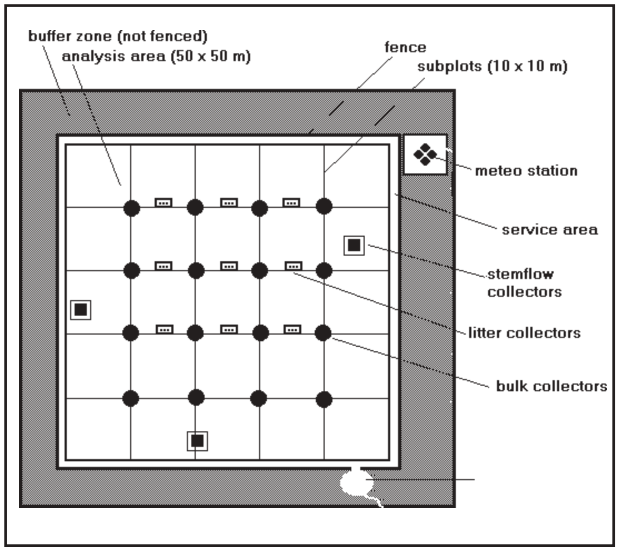

Figure 6 - Layout of a typical analysis area included into the CONECOFOR plots.
Schema di una tipica parcella di analisi compresa nelle aree permanenti CONECOFOR.

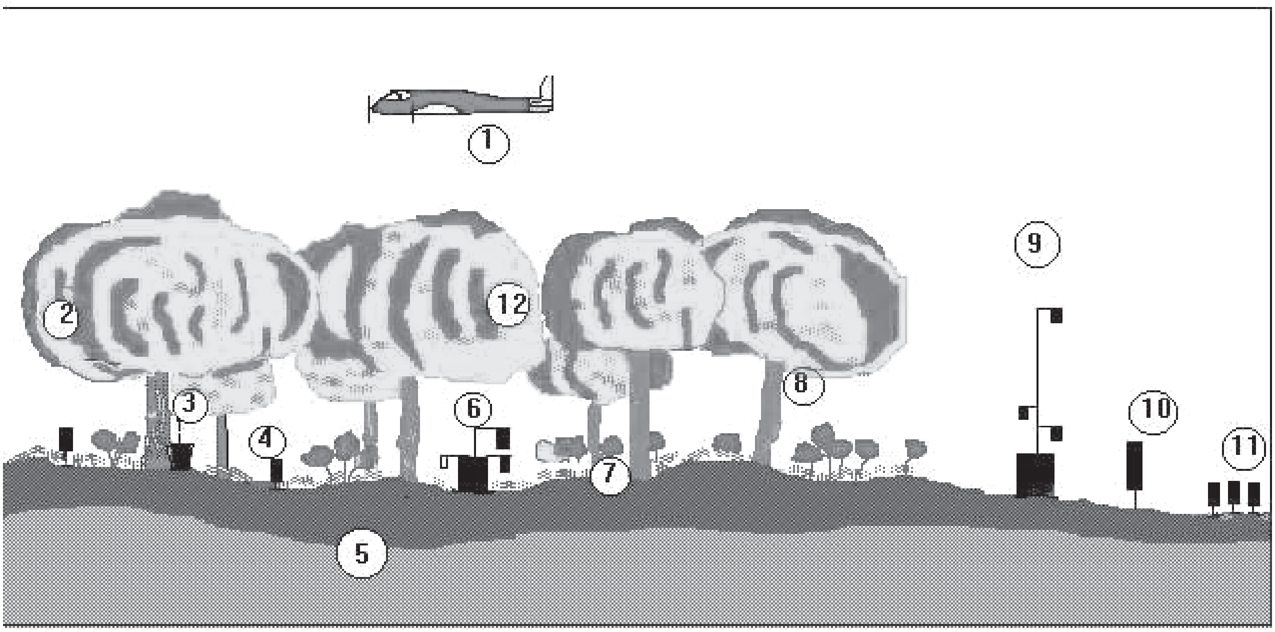

Figure 7 - Scheme of analysis setup in permanent plots (1: remote sensing; 2: chemical content of leaves; 3: deposition - stemflow; 4: deposition - throughfall; 5: soil; 6: meteo - in the plot; 7: ground vegetation; 8: tree growth; 9: meteo - open field; 10: atmospheric pollutants; 11: deposition - open field; 12: crown conditions).
Schema delle ricerche condotte nelle aree permanenti (1: telerilevamento, 2: chimica delle foglie; 3: deposizioni - lungo il fusto; 4: deposizioni - sottochioma; 5: chimica dei suoli; 6: meteo - parcella di analisi; 7: vegetazione; 8: accrescimenti arborei; 9: meteo - fuori bosco; 10: inquinanti atmosferici; 11: deposizioni - fuori bosco; 12: condizioni delle chiome).

trol area, buffer zone and service area). Furthermore, during field work, in particular during phases linked to deposition surveys, many shrewdness are adopted such as to empty out stem flow collectors outside the analysis area, to reduce the number of people staying in the analysis area during surveying and to avoid trampling on subplots for vegetation assessment.

Location and characteristics of the PMPs

The selected permanent plots (Tab. 1) are distributed overall the national territory and are located within the most important forest biocoenosis (*Fagus sylvatica* - beech woods: 10 plots; *Quercus cerris* - Turkey oak woods: 5 plots, *Picea abies* - spruce woods: 6 plots; *Quercus ilex* - holm oak woods: 4 plots; *Quercus robur* – peduncolate oak or *Quercus petraea* - European oak woods: 2 plots). Most of the 27 plots are located on hill or mountain slopes at altitudes between 500 and 1500 m (Fig. 8); only three plots are on alluvial plains (EMI1 e FRI1) or in proximity of sea front (TOS2). Lithological substrate (Fig. 9) is mostly sedimentary while only very few plots are on alluvial, metamorphic or volcanic soils. Most of soils are acid (with the exception of UMB1 where soil appears to be neutral), being Cambisols and Luvisols.

Due to the existing differences in altitude and latitude, plots show diversity in climate conditions. In fact, many plots have a climate characterised by annual rainfall ranging from 1000 to 1500 mm and temperatures ranging from 10 to 12°C. On the other hand, two plots (FRI1 and TOS2) are located in very dry sites with 500-650 mm of annual rainfall, while EMI2 and VEN1 show very wet conditions with values included between 1800 and 1900 mm/year.

Plots are distributed over two bio-climatic Regions: 10 plots are located in the Central European Region and 14 of them in Mediterranean one. They are spread out over four altitude belts (Fig. 10) from the Mediterranean belt to the Boreal one, even if most of plots are cored into intermediate belts (Subatlantic, 12 plots and Central European, 6 plots).

Table 1 - Permanent plot list (ICP-Forests, ICP-IM and National code, conventional name, Administrative location, elevation in m a.s.l., dominant tree species).
Lista delle aree permanenti (sigla ICP-Forests, ICP-IM e nazionale, nome convenzionale, localizzazione amministrativa, altitudine in m s.l.m., specie arboree dominanti).

For.	IM	Nat.	*Name* (Adm. location)	m a.s.l.	*Dominant tree species*
01	**IT05**	**ABR1**	*Selva Piana* (Collelongo - AQ)	1500	*Fagus sylvatica*
02	**—**	**BAS1**	*Monte Grosso* (Potenza)	1125	*Quercus cerris*
03	**IT06**	**CAL1**	*Piano Limina* (Giffone - RC)	1100	*Fagus sylvatica*
04	**—**	**CAM1**	*Serra Nuda* (Corleto Monforte - SA)	1175	*Fagus sylvatica*
05	**IT07**	**EMI1**	*Carrega* (Sala Baganza- PR)	200	*Quercus petraea*
06	**IT08**	**EMI2**	*Brasimone* (Camugnano - BO)	975	*Fagus sylvatica*
07	**—**	**FRI1**	*Bosco Boscat* (Castion di Strada - UD)	6	*Carpinus betulus, Quercus robur*
08	**—**	**FRI2**	*Tarvisio* (Tarvisio-UD)	820	*Picea abies*
09	**IT09**	**LAZ1**	*Monte Rufeno* (Acquapendente - VT)	690	*Quercus cerris*
10	**IT10**	**LOM1**	*Val Masino* (Val Masino - SO)	1190	*Picea abies*
11	**IT11**	**MAR1**	*Roti* (Matelica - MC)	0775	*Quercus cerris*
12	**—**	**PIE1**	*Val Sessera* (Bioglio - BI)	1150	*Fagus sylvatica*
13	**—**	**PUG1**	*Foresta Umbra* (VicoGargano - FG)	800	*Fagus sylvatica*
14	**—**	**SAR1**	*Marganai* (Iglesias - CA)	700	*Quercus ilex*
15	**—**	**SIC1**	*Ficuzza* (Godrano - PA)	940	*Quercus cerris*
16	**IT12**	**TOS1**	*Colognole* (Livorno)	150	*Quercus ilex*
17	**IT03**	**TRE1**	*Passo Lavazè* (Trento)	1775	*Picea abies*
18	**—**	**UMB1**	*Pietralunga* (Pietralunga - PG)	725	*Quercus cerris*
19	**IT13**	**VAL1**	*La Thuile* (La Thuile - AO)	1740	*Picea abies*
20	**—**	**VEN1**	*Pian di Cansiglio* (Vittorio Veneto - TV)	1100	*Fagus sylvatica*
21	**—**	**ABR2**	*Rosello* (Rosello - CH)	980	*Fagus sylvatica*
22	**—**	**LAZ2**	*Monte Circeo* (S. Felice Circeo - LT)	190	*Quercus ilex*
23	**—**	**LOM2**	*Giovetto* (Borno - BS)	1150	*Picea abies*
24	**—**	**LOM3**	*Valsassina* (Moggio - LC)	1250	*Fagus sylvatica*
25	**—**	**TOS2**	*Cala Violina* (Scarlino - GR)	30	*Quercus ilex*
26	**—**	**TOS3**	Vallombrosa (Reggello - FI)	1170	*Fagus sylvatica*
27	**IT01**	**BOL1**	*Renon* (Bolzano)	1740	*Picea abies*

Most of plots are property of local Administrations, with the State owning only four plots (Fig. 11). Fifteen plots are included into protected areas (Fig. 12), while, for 7 of them, the only protection type is the one foreseen by CONECOFOR Programme.

Average age of dominant trees shows a wide variation among plots (Fig.13); number of trees per plot is directly related to the specific composition (Fig. 14) and structure of biocoenosis.

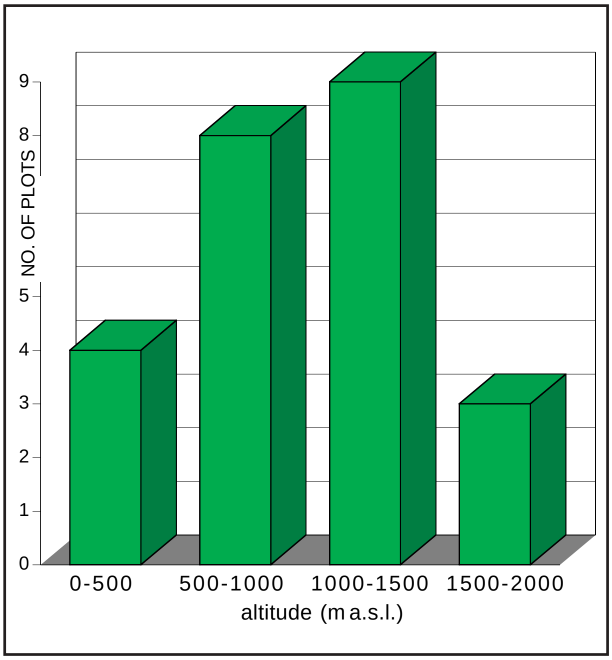

Figure 8 - Distribution of CONECOFOR plots according to altitude (m a.s.l.).
Distribuzione delle aree CONECOFOR secondo l'altitudine.

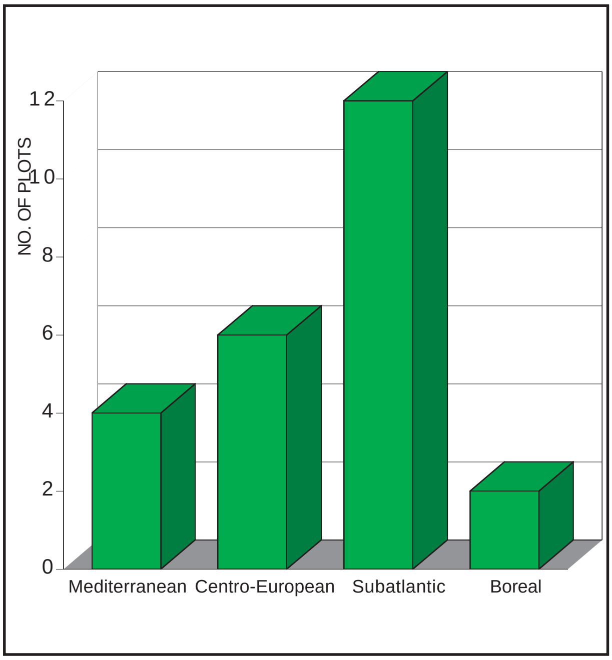

Figure 9 - Distribution of CONECOFOR plots according to altitudinal belts.
Distribuzione delle aree CONECOFOR secondo le fasce altitudinali.

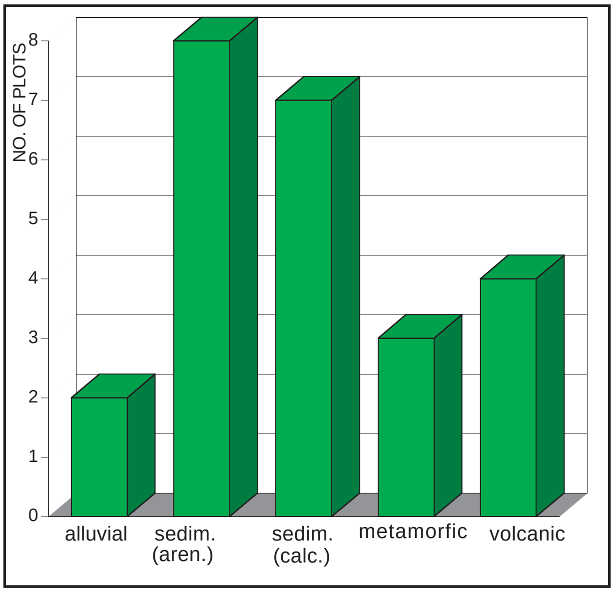

Figure 10 - Distribution of CONECOFOR plots according to lithological substrate.
Distribuzione delle aree CONECOFOR secondo il substrato litologico.

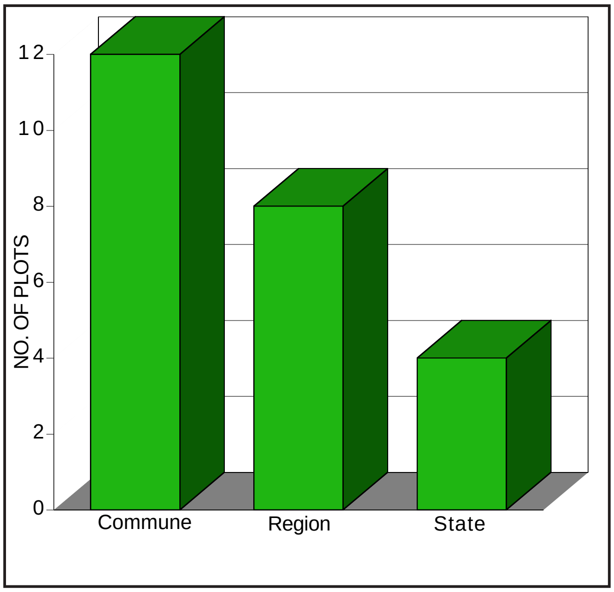

Figure 11 - Distribution of CONECOFOR plots according to land owner type.
Distribuzione delle aree CONECOFOR secondo il tipo di proprietà dei terreni.

Analyses carried out at the PMPs

Analyses carried out at the permanent plots are, as recalled above, under the responsibility and scientific co-ordination of Research Institutes and University Departments. Methods and frequency per each analysis are reported in Regulations of the European Commission regarding monitoring activities on Level II, in ICP Forests and IM manuals and in National manuals on deposition, ground vegetation and tree crowns. As for most of National programmes overall Europe, the starting year of analysis, their going on and data collection over long term in all the established plots, appeared to be very difficult because of the long distances among them. In the following paragraph, a brief description of the various investigations is given. Because of that, two levels of intensity were defined within the network according to the number of analyses set up per each plot. More detailed information can be found in Allavena *et al.* (1999) and in several papers of this volume (see Section 3, Results).

Ground vegetation

The main objective of the assessment of ground vegetation is the determination of the changes in vegetation due to the natural dynamics and macro-disturbance factors (air pollution, climate changes, *etc.*). Vegetation assessment is active in all CONECOFOR plots, since 1996/7. Assessment is planned every three years (14 plots) or annual (10 plots), according to two different approaches: (1) phytosociological (plant community level) and (2) dynamic (population

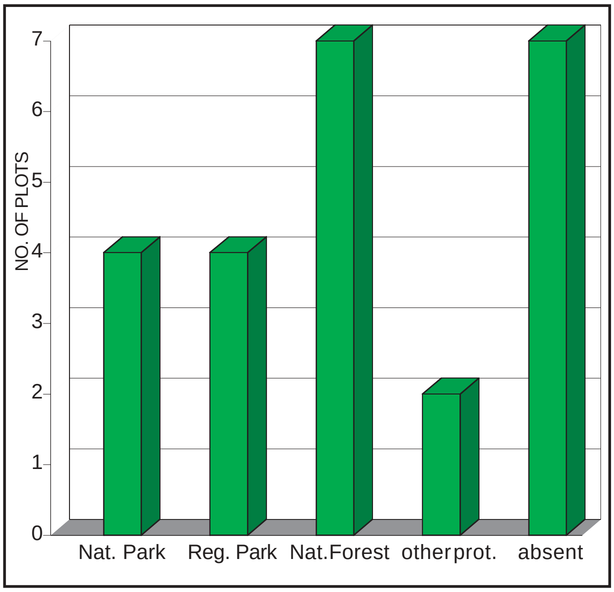

Figure 12 - Distribution of CONECOFOR plots according to protection type (National Park, Regional Park, Public Forest, various, no protection).
Distribuzione delle aree CONECOFOR secondo il regime di protezione.

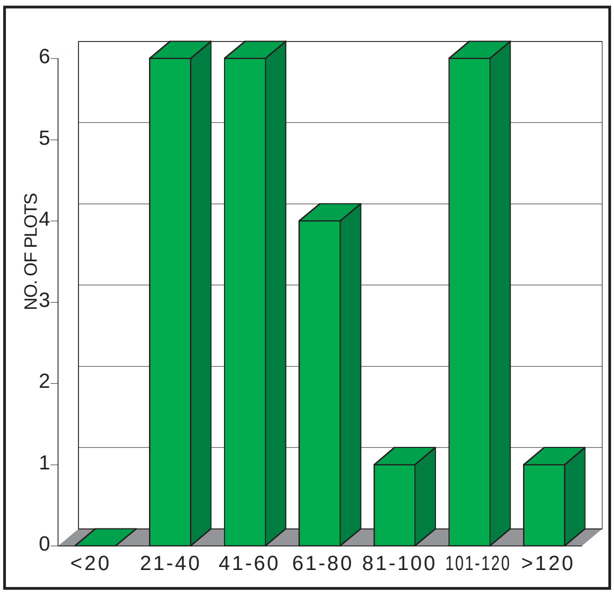

Figure 13 - Distribution of CONECOFOR plots according to average age of dominant trees.
Distribuzione delle aree CONECOFOR secondo l'età media degli alberi del piano dominante.

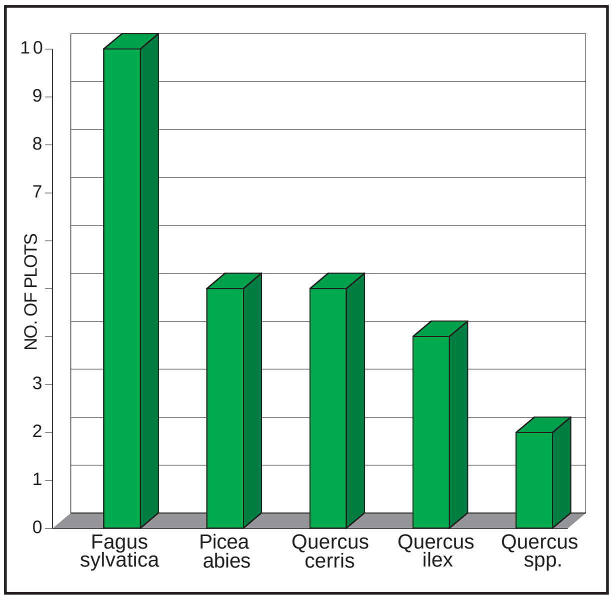

Figure 14 - Distribution of CONECOFOR plots according to dominant species into the biocoenosis.
Distribuzione delle aree CONECOFOR secondo la specie dominante nella biocenosi.

level). According to the first approach, Braun-Blanquet data collection method (coverage scale for each species) is applied on the analysis area and on the large surrounding area, divided into 24 sample units 100 m^2 large. The second approach is based on 100 smaller sample units (0,25 m^2), where species coverage is studied in a more accurate way; a detailed map of plant populations *(synusies)* or functional individuals occurring in the analysis area is also to be made. A systematic and syntaxonomical outline of plant communities represented in the CONECOFOR permanent plots is reported in Tab. 2.

Crown conditions

The tree condition survey is aimed at identifying status and changes of the forest trees at the monitoring plots. The survey is based on a visual assessment of 30 trees per plot, each tree being scored according to a series of indicators. The surveyed plots were 17 in 1996, 19 in 1997 20 in 1998, 24 in 1999 and 25 in 2000. Quality Assurance procedures (SOPs, training audits, QC reporting) are formally part of the same main species. As an example of the results, beech plots display consistent increase of transparency only between 1996 and 1997, but not between 1997-1998. On the other hand, Turkey oak plots show consistent changes since 1996. However, in both cases the majority of the observed changes fall within accuracy limits of the survey method.

Soil analysis

Aim of the research is the definition of a basic information on the chemical condition of soils and on properties that determinate its vulnerability to air pollution. The main information

Table 2 - Systematical and syntaxonomical outline of plant communities represented in the CONECOFOR permanent plots.
Prospetto sistematico sintassonomico delle fitocenosi presenti nelle aree CONECOFOR.

SYNTAXON (**CLASS**, ORDER, ALLIANCE, •*Association*)	*PERMANENT PLOT*
QUERCETEA ILICIS Br.-Bl. 1936	
QUERCETALIA ILICIS Br.-Bl. 1936	
ERICO-QUERCIOON ILICIS Brullo, Di Martino & Marcenò 1977	
•*Quercetum gussonei* Brullo & Marcenò '84	*SIC1*
QUERCION ILICIS Br.-Bl. 1936	
•*Viburno-Quercetum ilicis* Br.-Bl. 1936	*SAR1, TOS2*
•*Orno-Quercetum ilicis* Horvatic 1956, 1958	*TOS1*
QUERCO-FAGETEA Br.-Bl. et Vlieger 1937	
QUERCETALIA PUBESCENTIS Br.-Bl. 1931, 1932	
QUERCION PUBESCENTIS Knapp 1942	
•*Rubio-Quercetum cerridis* Pignatti E. & S. 1968, Bas Pedroli et al. 1988	*LAZ1*
•*Aceri obtusati-Quercetum cerridis* Ubaldi & Speranza 1982	*MAR1, UMB1*
QUERCION FRAINETTO Horvat 1954	
•*Physospermo verticillati-Quercetum cerridis* Aita et al. 1977	*BAS1*
FAGETALIA SYLVATICAE Pawl. 1928	
CARPINION Issl. 1931, Oberd. 1953	
•*Ornithogalo pyrenaici-Carpinetum* Marincek et al. 1982	*FRI1*
•*Physospermo cornubiensi-Quercetum petraeae* Oberdorfer & Hofmann 1967	*EMI1*
FAGION SYLVATICAE Luquet 1926, Pawl. 1928	
•*Polysticho-Fagetum* Feoli & Lagonegro '82	*ABR1*
•*Aquifolio-Fagetum* Gentile 1969	*CAL1, CAM1, PUG1*
•*Trochiscantho-Fagetum* Gentile 1974	*EMI2*
•*Luzulo pedemontanae-Fagetum* Oberdorfer & Hofmann 1967	*PIE1, TOS3*
•*Luzulo albidae-Fagetum* Meusel 1937	*VEN1*
•*Cardamini pentaphyllae-Fagetum* Mayer & Hofmann 1969	*LOM3*
VACCINIO-PICEETEA Br.-Bl. 1939	
PICEETALIA ABIETIS Pawl. 1928	
PICEION ABIETIS Pawl. 1928	
•*Homogyno-Piceetum* Zukrigl 1973	*BOL1, TRE1, VAL1*
ABIETI-PICEION Br.-Bl. 1939	
•*Veronico urticifoliae-Piceetum* Ellenberg & Klotzli 1972	*FRI2, LOM1, LOM2*

requested is the ability of soils to withstand to atmospheric depositions, specifically acidification, nutritional unbalances and heavy metals contamination. The analyses were carried out in 1995/6 by the methods of the Programme Coordinating Centre (1994). Twenty sites were studied, distributed over all the Country. First results show the following general characteristics of the soils: they have a rather low organic carbon content and show a good capacity of resistance to acidification.

Chemical content of leaves

Analysis of chemical contents of leaves and needles aimed at investigating nutritional conditions of trees. In general an unbalance of mineral contents could be one of the causes of forest ecosystems decline. In the permanent plots samples from 5 different trees, representatives of ecosystem health conditions, have been collected. Sampling has been made in 1995, 1997 and 1999 in all plots, during Autumn-Winter for evergreen species and during August-September for deciduous, before leaves yellowing.

Tree growth, LAI and litterfall

Tree growth was assessed in winter 1996/97 and 1999/2000 by the survey of basic growth variables, of tree species composition and of individual social class. This approach allowed to elaborate a complete frame of reference for each plot, the analysis of the standing crop being feasible at individual, at social layer and at tree population level. The implementation of annual ring analysis by tree coring in the buffer area made the evaluation of past growth possible and to highlight the presence of growth changes. The estimate of annual litter production and of Leaf Area Index (LAI) provided further elements of judgement on stand productivity in each forest type observed.

Deposition analysis

Measurements of atmospheric deposition chemistry have been carried out in 17 permanent plots of the CONECOFOR network. Sampling methods and the mailing and treatment of the samples are in close agreement with those used in the European network. Three laboratories are involved in measurements. Analytical quality controls include inter-comparison exercises as well as criteria for data validation based on the ionic balance and the comparison between measured and calculated conductivity.

Meteorological monitoring

Climate research is very important to study and classify areas and it represents the starting point for all other researches about CONECOFOR Programme. Data collected in 8 plots, with 13 stations located *in the plot* and *in open field*, were stored in a database composed of two sections, which describe geographical characteristics of the areas, measured parameters and their elaboration and contains acquired measurements for observed parameters. A classification on four areas for 1998 by three models (De Martonne, Gaussen, Thornthwaite) has been tried in order to characterise a climate through some indices.

Gaseous atmospheric pollutant

Following the appearance of forest decline phenomena air pollution in remote areas has received an increasing attention. Information about air pollution in forest areas is often scarce and fragmentary. Passive samplers are monitoring devices based on the diffusion of air pollutants onto an absorbing medium and can provide basic exposure information regarding air pollution. They are inexpensive and do not require electricity or highly skilled personnel on site. In the period 1996 - 2000 ozone passive samplers were exposed at all the plots of the CONECOFOR network. Tests performed on the adopted sampler type show a statistically high correlation between the samplers and continuous measurements.

Results of the monitoring activities highlight relevant ozone concentrations (weekly averages) in several areas, especially in the South of Italy and show that concentrations are clearly influenced by weather conditions. Correlation between monitoring sites suggests a regional occurrence of ozone episodes.

Remote sensing

Colour InfraRed (CIR) aerial photographs are a well-tested tool to collect information about the characteristics and the health condition of forest stands and trees. During 1996 and 1997 high scale (1:5.000) CIR air photographs of 20 plots of the CONECOFOR network were taken. The same approach was adopted in other European countries (*e.g.* Austria, Ireland and Germany) according to a work programme prepared by the EU Working Group on remote sensing and forest health assessment. Maps describing the plots (Fig. 15) and its representativeness regarding land use, tree species, natural age and crown condition were developed by photogrammetric means. Air photographs were subsequently interpreted to define crown conditions (defoliation and yellowing) in the plot and in the buffer zone. Measurements of canopy surface were carried out on a regular grid (1x1 m) and data collected were processed to develop a digital canopy model and to show canopy illumination and roughness.

Conclusions

Forests have invaluable values and a great care should be devoted to save their health. To preserve conservation conditions and ecological efficiency of these ecosystems a great consideration should be paid to the knowledge on how and at which rate forest health can be endangered either by "traditional" (pests, pathogens, weather condition) or "new" factors (air pollution, climate changes) and their combination. The first four years of the CONECOFOR Programme implementation allowed an in depth description of different forest biocoenosis in Italy, ranging from the Alps to Sicily. They have been studied in all the most important components such as soil, ground vegetation, macro- and micro-climate, atmospheric pollutants. Information has been collected on the health of forests and their structure and functioning: this is an important contribution to the pool of information which has come, and will come over the next few years, from all the monitoring programmes on European forests. Desirably, in the future Level II analysis should be supported by experiments of the Level III, which operate ecosystem manipulation and are already active in several European Countries and in USA. The assessment and monitoring of forest health represent a key point for environmental policy-makers and for the management of environmental resources in the frame of sustainable development.

References

Allavena S., Isopi R., Petriccione B., Pompei E., 1999 - *Programma Nazionale Integrato per il Controllo degli Ecosistemi Forestali. Primo rapporto. 1999.* Ministero per le Politiche Agricole (Roma).

Kleemola S., Forsius M. (eds.), 1999 - *8th Annual Report 1999. UN/ECE ICP, Integrated Monitoring.* The Finnish Environment, 325. Finnish Environment, Institute. Helsinki.

MAF-ISAFA, 1988. *Inventario Forestale Nazionale 1985. Sintesi metodologica e risultati.* Ministero Agricoltura e Foreste. Istituto Sperimentale per l'Assestamento Forestale e l'Alpicoltura, Trento.

Petriccione B., Isopi R., 1996 - *The Italian National Integrated Network for Forest, Ecosystems Monitoring (CON.ECO.FOR.).* In: Proceedings of the 17th International Meeting for Specialists in Air Pollution Effects on Forest. Ecosystems (Sept. 14-19, 1996, Florence, Italy).

UN/ECE, 1998a - *Convention On Long-Range Transboundary Air Pollution.* International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests. Manual on methods and

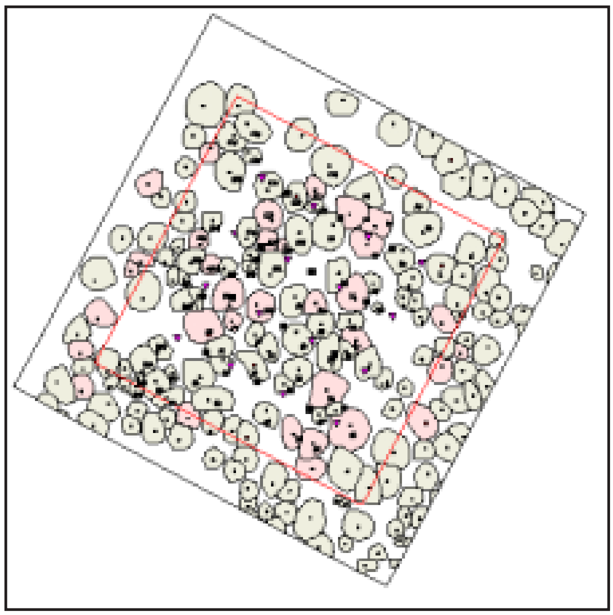

Figure 15 - Permanent plot *VAL1*: crown map derived by aerophotographs.
Area permanente VAL1*: carta delle chiome realizzata da foto aeree.*

criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on *forests*. BFH, Hamburg.

UN/ECE, 1998b - *Convention On Long-Range Transboundary Air Pollution*. International Co-operative Programme on Integrated Monitoring of Air Pollution. *Effects on Ecosystems. Manual for integrated monitoring*. ICP IM Programme Centre, Helsinki

UN/ECE & EC, 1997a - *Forest Foliar Condition in Europe. Results of a large scale foliar chemistry surveys (survey 1995 and data from previous years)*. Brussels, Geneva and Vienna.

UN/ECE & EC, 1997b - *Forest Soil Condition in Europe. Result of a Large-Scale Soil Survey*. Brussels and Geneva.

UN/ECE & EC, 1997c - *Ten Years of Monitoring Forest Condition in Europe*. Brussels and Geneva.

UN/ECE & EC, 2000a - *Forest Condition in Europe: Results of the 1999 survey. 2000 Technical Report*. Geneva and Brussels.

UN/ECE & EC, 2000b - *Intensive monitoring of Forest Ecosystems in Europe. Technical Report 2000*. Brussels and Geneva.

Methods of analysis of the Integrated and Combined (I&C) evaluation system§

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Abstract - The Integrated and Combined (I&C) evaluation system is based on three different kinds of analysis: Risk Analysis (RA), Status and Changes analysis (S&C) and Nature of Change analysis (NoC). The aim of RA is to identify the actual or potential risk of individual *PMPs* in relation to three kinds of stressors: input via deposition of nitrogen and acidifying compounds, ozone, and weather and climate stress. The aim of S&C analysis is to quantify the ecosystem status at a given time in comparison to its mean status over defined time windows, thus allowing the formal identification of those *PMPs* deviating from the overall dynamics. NoC analysis will try to associate stressor and response indicators through time in order to provide indications as to determinants of changes in the various *PMPs.* This chapter will outline the methods adopted by the various kinds of analysis.

Key words: *exposure-sensitivity, risk, status and changes, nature of changes, Mahalanobis distance, stressor-response relationships.*

Riassunto - Metodi di analisi nel sistema di valutazione Integrata e Combinata. Il sistema di valutazione Integrata e Combinata (I&C) è basato su tre diverse analisi: l'analisi di rischio (RA), l'analisi di stato e cambiamenti (S&C) e l'analisi della natura dei cambiamenti (NoC). L'analisi di rischio ha lo scopo di identificare il rischio effettivo o potenziale delle varie aree permanenti in relazione a tre categorie di agenti di stress principali: le immissioni dei composti dell'azoto e acidificanti, l'ozono e gli stress connessi alle fluttuazioni ed ai cambiamenti climatici. L'analisi di stato e cambiamenti ha lo scopo di quantificare lo stato dell'ecosistema ad un dato momento in paragone al suo stato medio su una definita finestra temporale in modo da permettere una identificazione formale di quelle aree permanenti che deviano dalla dinamica generale. L'analisi della natura dei cambiamenti tenterà di associare agenti di stress e di risposta nella serie temporale dei dati in modo da avere indicazione sui principali determinanti di cambiamento nelle varie aree permanenti. In questo capitolo vengono delineati i metodi di analisi.

Parole chiave: *esposizione-sensibilità, rischio, stato e cambiamenti, natura dei cambiamenti, distanza di Mahalanobis, relazione agenti di stress e risposta.*

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Intensive monitoring of forest ecosystems provides data which can be explored in many different ways depending on the objective of the analysis. In order to try and design an evaluation system, the Task Force on Integrated and Combined (I&C) evaluation of intensive monitoring data began by discussing these issues (Ferretti *et al.* 2000). An immediate conclusion reached in the discussion was that any evaluation of intensive monitoring data sets must be related to the objectives of the program. There is a general agreement that the aim of the intensive monitoring program is "to contribute to a better understanding of the impact of the atmospheric pollution and other factors which may influence the forest ecosystems" (EC-UN/ECE 1998). This definition establishes priorities (atmospheric pollution), but also incorporates the basis for other studies (the other factors). Recently, objectives were reviewed and - while air pollution remains of central interest - a number of different issues have been tentatively targeted, including many of those related to the UNCED (*e.g.* biodiversity), the Helsinki process (*e.g.* sustainable forest management, forest protection) and the Kyoto protocol (*e.g.* carbon sequestration) (De Vries 1999). When a program changes from a single-objective program to a multi-objective one, data analysis strategy must be kept under continuous review (Parr *et al.* 2001). In addition, it is obvious that there can be different approaches in relation to different questions. Based on these considerations, the discussion within the I&C Task Force (I&C TF) pointed out the need to have an open evaluation system that can adapt to changing priorities (Gruppo di esperti CONECOFOR-I&C, 1998). However, the I&C TF recognized three major is-

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sues of concern for the evaluation system: (*i*) the need to evaluate and identify the actual and potential risk status of the various Permanent Monitoring Plots (*PMPs*) in relation to air pollution, atmospheric deposition and meteorological stress; (*ii*) the need to evaluate, identify and quantify changes in biological, chemical, and physical ecosystem status and (*iii*) the need to evaluate and identify the determinants of changes. All together, the above issues constitute the framework within which the I&C evaluation system was designed. Operatively, three categories of analysis were identified, each dealing with one of the issues reported above: Risk Analysis (RA), Status and Changes analysis (S&C) and Nature of Change analysis (NoC). These three kinds of analysis clearly need different conceptual approaches, different data and different statistical techniques. They are obviously not the only analyses the I&C will consider in the future, but they are the first ones on which the system will concentrate. Other themes (*e.g.* biodiversity, sustainable forest management, carbon sequestration,..) and other techniques (*e.g.* meta-analysis, use of external datasets, integration with Level I for upscaling,..) will be considered in the future.

Risk Analysis (RA)

The Risk Analysis suggested here has similarities with the Risk Assessment widely adopted and debated in the U.S. (Suter II 1990; Hunsaker *et al.* 1990; Power and Adams 1997). Broadly, RA is defined as a process aimed at evaluating "the effects of an environmental change on a valued natural resource and interprets the significance of those effects in the light of uncertainties identified in each component of the assessment process" (Hunsaker *et al.* 1990). An important step of the process is to identify disturbance scenarios of concern. RA is based on the definition of three categories of potentially dangerous stressors and their possible action on the forest ecosystem, which can be evaluated considering various exposure and response indicators and indices. Deposition of nitrogen and acidifying compounds, ozone concentrations and doses, as well as climate and weather fluctuations and changes were identified as stressors of interest (Ferretti *et al.* 2000). For each of them, both acute and chronic effects are considered (Table I). These three issues of concern are closely related: for example, the effects of climatic changes and nitrogen fertilization can be difficult to separate and they can easily affect each other (*e.g.* Innes 1994; Chappelka and Freer-Smith 1995). Table I provides an overview of the stressors, examples of their expected actions, indicators of exposure to the given stressors and indicators of response. The following definitions were adopted:

Stressor is the environmental driving force expected to have an adverse effect on the forest ecosystem (*e.g.* deposition of acidifying compounds);

Action is the expected category of action exerted by a given stressor (*e.g.* induction of changes in ecosystem chemistry);

Indicator is the target environmental entity that can be measured or estimated either to evaluate the *exposure* to the stressor (*e.g.* precipitation chemistry) or the *response* to the stressor (*e.g.* soil chemistry)

Index is a characteristic that describes the status of a given exposure/response indicator (*e.g.* amount of deposition of H^+, exchangeable acidity in the soil).

Table 1 - Stressor, type of effect, expected actions (examples), exposure and response indicators (examples) adopted for Risk Analysis.
Agenti di stress, tipo di effetto, azione attesa (esempi) ed indicatori di esposizione e risposta (esempi) adottati per l'analisi di rischio.

Stressor/effect	Exposure Indicator	Action on	Response Indicator
N, H+ Deposition			
Acute	precipitation chemistry	tree foliage, herbs	Trees, herbs
Chronic	precipitation chemistry	ecosystem chemistry, productivity, dynamics	Trees, soil, herbs
Ozone			
Acute	atmospheric chemistry	tree foliage, herbs	Trees, herbs
Chronic	atmospheric chemistry	tree cond./growth/chemistry; vegetation dynamics	Trees, herbs
Climate			
Acute	atmospheric physics	tree cond/growth; herbs	Trees, herbs
Chronic	atmospheric physics	tree cond./growth/phenology; vegetation dynamics	Trees, herbs

Table 2 - Stressor, type of effect, exposure and response indices (examples) adopted for Risk Analysis and feasibility of the evaluations taking into account the data collected by existing investigations.
Agenti di stress, tipo di effetto, indici di esposizione e risposta (esempi) adottati per l'analisi di rischio e fattibilità in relazione ai dati attualmente raccolti dalle varie indagini.

Stressor/effect	Exposure Indices	Response Indices	Feasibility
N, H^+ Deposition			
Acute	H^+ conc. of each precipitation	foliar symptoms	Unfeasible
Chronic	long-term H^+, N dep.	crown cond., basal area, foliar N-ratios,..	Feasible
Ozone			
Acute	max O_3 hour, AOT40	foliar symptoms	Unfeasible
Chronic	AOT40, mean O_3 summer	crown cond., basal area, species assemblage	Feasible
Climate			
Acute	P, T, W extremes	tree condition, species coverage,..	Feasible
Chronic	P, T, W long-term mean	increment, timing/duration of pheno-phases,.	Feasible

P: precipitation; T: temperature; W: wind

Table 2 reports examples of exposure and response indices for each stressor/effect category and the actual feasibility of the various RAs in relation to the characteristics of the data collected and to the methods of collection. There are several methods to carry out an RA: for example, while risk assessment in the U.S. follows a formalized approach (U.S. EPA 1992), Smidt (1998) refers to risk analysis mainly as the exceedance of the air pollutant concentration/deposition/doses standards established by different organizations. A problem with this latter approach is that any ecosystem is unique in its sensitivity, thus a number of modifying factors need to be taken into account (*e.g.* Mills *et al.* 2000). In the I&C system, the process of RA will be similar for all three stressor categories: first, actual exposure of the *PMP* to the given stressor will be quantified; second, the influence of the modifying factors on the various response indicators will be considered; third, the actual sensitivity of the *PMP* will then be identified and/or quantified and any exceedance reported. This is more similar to the Level II approach of the Critical Load concept (*e.g.* Posch *et al.* 1999). When exposure to the stressors is found to exceed the sensitivity of the various response indicators, a potential risk will be identified; thus, focused analysis on biological and chemical response indicators will be carried out. Details about data requirements and statistical methods will be given below.

Deposition of nitrogen and acidifying compounds

The aim of this analysis is to provide information on the potential risk due to depositions in the various *PMPs*. Deposition of air pollutants varies throughout Italy according to latitudinal, longitudinal and altitudinal patterns. The same occurs to forest ecosystems in terms of e.g. historical management practices, species assemblage and soil condition. This variability in both stressor and target resource makes it very difficult to evaluate the real effects of the stressor itself unless information about exposure can be coupled with information about a suite of both chemical and biological response indicators and indices. Deposition studies have received some attention in Europe for some time (Decet and Mosello 1997). Taking into account the data available for Italy, both acute (*e.g.* Barbolani *et al.* 1986; Gravano *et al.* 1999) and chronic (Mosello and Marchetto 1996; Novo *et al.* 1997; Posch *et al.* 1999) effects can be theoretically expected for the Italian forests. However, it will not be possible to have a proper RA of the acute effects. This is because weekly sampling of bulk depositions do not allow the detection of peak values of H^+ concentration: on the one hand, bulk samples are often buffered by the dry deposition fraction; on the other, weekly sampling will result in a leveling out of peak values which are often associated to low-volume, single-event precipitation (*e.g.* Barbolani *et al.* 1986). For these reasons, the RA will consider only the chronic effects of deposition of N- and acidifying compounds (Table 2). A first need for this analysis is to have a robust set of data about precipitation chemistry (which is affected by marked intra- and inter-annual variations) and data about soil chemical and physical properties. At least 5 years

Table 3 - Data needed for a first assessment of risk due to deposition of nitrogen and acidifying compounds, ozone and climate stress.
Dati necessari per una prima valutazione del rischio dovuto a deposizioni, ozono e stress climatici.

Stressor	Stressors data	Stand and soil data
N, H^+ Deposition	5 years H^+, N deposition	Species, age, soil type, AcExch, BaseSat, C/N, pH , hydr. cond.
Ozone	5 years O_3 data	Species, age, phenology, water availability, evapotranspiration
Climate	5 years P, T, W data	Species, age, phenology, soily type, water availability

P: precipitation; T: temperature; W: wind

of data are usually considered in order to calculate deposition loads. Deposition data needed are: deposition of acidifying compounds, deposition of total nitrogen, deposition of sulphur, after corrections for marine contribution. Initial information concerning the potential risk due to deposition can be obtained either by coupling deposition rates, soil characteristics and chemistry, with stand characteristics (Table 3) and/ or by calculating Critical Loads (CLs) and any exceedance recorded in each individual *PMP*. These data will allow us to identify where high exposure (*e.g.* high deposition rates) is coupled with highly sensitive soils (*e.g.* low base saturation, unfavourable C/N ratio,…) and with highly sensitive stands (*e.g.* conifers). This can be done using different techniques, from simple regression (*e.g.* plotting soil C/N ratio versus N deposition for any *PMP*) to ordination. Soil data needed for this purpose may vary, as different criteria are adopted to calculate critical loads for acidity: for example, critical pH values, BC:Al ratio and Al:Ca ratio are all used in the Simple Mass Balance method by different countries (Hall *et al.* 1999). In this context, the construction of the Critical Load function for each individual *PMP* will be of interest. The function is based on the calculation of four parameters, namely the maximum critical load for Sulphur deposition (CL_{max}(S)), the minimum critical load for nitrogen deposition (CL_{min}(N)), the maximum critical load for nitrogen deposition (CL_{max}(N)), and the critical load for nutrient nitrogen (CL_{nut}(N)) (Posch *et al.* 1999) (Fig. 1). The calculation/estimation of these parameters needs a number of entries: for example, maximum critical load for sulphur deposition can be calculated as follows (Posch *et al.* 1999):

$$CL_{max}(S)=BC_{dep}-Cl_{dep}+BC_{w}-Bc_{u}-ANC_{le(crit)}$$

thus including the estimation of net base cation input (corrected for seasalt contribution) and of the critical leaching of acid neutralization capacity. Similarly, the calculation of CL related to N is complex, as it includes estimation of N uptake and immobilization.

The critical load function parameters were already estimated for Italy at 1x1 km grid resolution (Posch *et al.* 1999; Buffoni, com. pers.), but – given the complexity of the process - estimation is based on a number of assumptions and on data extrapolated from available cartography and statistics, which makes this estimation subject to many uncertainties. Therefore there is the need for site-specific calculations for the CONECOFOR *PMPs*.

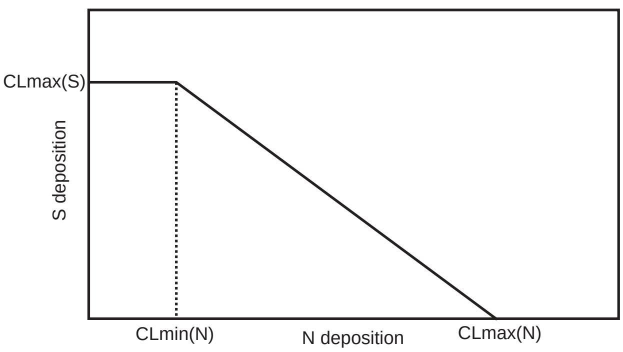

Figure 1 - Example of generic critical load function for S and acidifying N. The meaning of the various CLs is explained in the text. The function is site specific, and needs to know both S and N deposition. Every point falling below the bold line is considered as identifying sites where deposition of S and N does not exceed the critical load for that site.
Esempio di una generica funzione di carico critico per S ed N (acidificazione). Il significato dei vari CL è spiegato nel testo. La funzione è necessariamente specifica per ogni sito e necessita della conoscenza della deposizione di azoto e zolfo. Ogni punto che cade sotto la linea in grassetto è considerato non eccedere il carico critico per quel dato sito.

Ozone

Ozone is acknowledged as the most dangerous regional air pollutant for forest ecosystems in Europe (*e.g.* Karenlampi and Skarby 1996; Fuhrer *et al.* 1998; Matyssek and Innes 1999). This is particularly true for southern Europe, especially in relation to the marked latitudinal gradient of ozone (Dollard *et al.* 1995; Mills *et al.* 2000) and to some peculiar local dynamics (Millan *et al.* 2000). Visual symptoms caused by ozone have been observed and confirmed in parts of Greece, Italy, Spain and Ticino (Switzerland) (*e.g.* Velissariou *et al.* 1992; Skelly *et al.* 1999; Sanz *et al.* 1999; Cozzi *et al.* 2000).

In Italy there is a situation conducive to both acute and chronic ozone effects, with O_3 peak values reaching about 200 ppb (*e.g.* Ferretti *et al.* 1998) and the AOT40 Level I threshold of 10 $ppm{\cdot}h^{-1}$ being frequently exceeded (Angiolino *et al.* 1997; Bussotti and Ferretti 1998). However, at the same time high ozone values can be counteracted by a suite of factors likely to reduce the sensitivity of trees and natural vegetation to ozone: among others, low soil moisture and drought can be very important modifying factors. Similarly to deposition analysis, the way in which data are collected (passive samplers - see Buffoni and Tita, this volume) allows only weekly averages, making it impossible both to detect peak concentrations (usually occurring over a period of an hour or just a few hours) and to calculate accurately the AOT40 (which depends on the shape of the series of hourly concentrations). Thus, the risk due to acute effects of ozone cannot be evaluated properly (Table 2). Chronic effects are difficult to evaluate fully, too, unless weekly ozone data can be processed further. However, there are promising attempts even in this respect and it is likely that in the near future there will be interesting opportunities (Grünhage *et al.* 2001).

Exposure to ozone may affect different ecosystem compartments (trees, ground vegetation) and attributes (*e.g.* biodiversity, growth) (Braun *et al.* 1999; Mills *et al.* 2000). Data needed for a proper evaluation of the risk due to chronic ozone exposure are reported in Table 4. Ozone measurements over a 5 year period (in order to cope with the high variability of ozone data), data on evapotranspiration and water availability (which affect the ozone uptake) and data on the species composition and age structure are important factors in determining sensitivity (Table 4). Thus, the process will be similar to the one reported for deposition, i.e. identification of the *PMPs* where higher exposure – expressed in terms of O_3 concentration and/or doses (average or maximum weekly value and seasonal sum) - is associated with high sensitivity - expressed in terms of most frequent tree species and possibly weather and soil condition.

Climate fluctuations and changes

The effects of climate changes on forest ecosystems is of major concern, with a number of predicted scenarios available for different ecoregions (*e.g.* Krauchi 1993). Temperate forests have been recognized as potentially sensitive to climate fluctuations and changes, with a number of findings showing changes in growth trends and health status (Innes 1994). Although now the concern is almost always placed on the effects of long-term climate change, short-term fluctuations in one or more meteorological parameters are one of the most important determinants of forest condition. For example, the hurricanes of December 1999 caused some of the most severe damage ever on the French forests (Badeau *et al.* 2000; Ulrich 2000). Although less severe, early or late frost events have a long history as a cause of forest damage, and the same occurs with drought stress (Innes 1994). This makes it essential to consider meteorological stress in RA. Both acute and chronic effects can be potentially evaluated (Table 3), although in

Table 4 - Data needed for a full assessment of risk due to ozone (after Mills *et al.* 2000) and their present availability .
Dati necessari per una completa valutazione del rischio dovuto a ozono (da Mills et al. 2000) e loro attuale disponibilità.

Parameters needed	Availability
ozone concentrations	yes
ozone doses	not yet
soil moisture	not yet
soil nutrients	yes
community structure	yes
species	yes
genotypes	not yet
mycorrhizal intercations	no
deposition of N	in part of PMPs
phenology	in part of PMPs
atmospheric conductivity	no
Vapour Pressure Deficit	not yet
Evapotraspiration	in part of PMPs
Drought indeces	in part of PMPs
other pollutants	in part of PMPs

this case the number of *PMPs* equipped with meteorological stations represents the limiting factor. A first requirement of the data set is to have at least 5 years of data (Table 3). This is because, although meteorological stress can occur at any time, it is of interest to find out whether a particular *PMP* is more subject to this kind of event. Thus, several years of information are necessary, particularly when there is the possibility of comparing the data with historical records. The risk due to climate fluctuations and changes can be first evaluated using measured and calculated meteorological stress indices (see Amoriello and Costantini, this volume) and coupling them with data relating to the timing of phenological phases, soil (type, moisture, water availability) and site information (altitude, slope, aspect). Additionally, deviations from historical records are of interest, although consistency and comparability of meteo data from external sources need to be evaluated carefully.

Status and Changes (S&C)

The purpose of S&C analysis is to quantify changes in ecosystem's status. The ecosystem's status can be defined using an *n*–tuple of indices which refer to the different investigations characterizing the study of the ecosystem itself. In the following sections, we will show a mathematical method which can be used to try and quantify these changes, describing its pros and cons.

Basic definitions

If we consider *n* variables which identify the ecosystem's status, then the status at a given time *t* will be a point in a *n*–dimensional space; subsequent status at different times will form a cloud of points in that space (see Johnson 1988). Let us suppose that we have observed the indices which define the ecosystem's status over a certain number of years, then we can describe the variations of the status over time as the distance of each observation from the mean of all the observations. We can choose different notions of distance, but the Mahalanobis one permits us to consider the structure of variance and covariance connecting the observed variables. As already reported, it is important to note that Mahalanobis distance doesn't provide information as to the reason of change, nor its direction (improvement or worsening), but it simply gives information about the deviation from a mean condition in the short–middle–long term. Further information about the quality of changes cannot be investigated with this method but rather by using different techniques.

The minimal condition necessary to apply this method is obviously to have at least three years of data for a given *PMP* and the same set of indices over time. Firstly, let us recall the definition of Mahalanobis distance, and then we will start to describe the pros and cons of this approach. Let $\underline{X} = (X_1, K, X_n)$ be the vector random variable which represents the indices of our ecosystem's status. Suppose further that for each variable X_i we have the observations χ_{il}, K, χ_{ik} over a time-window set up by the times t_1, K, t_k. We can consider the expected value of each variable $\mu_i = E(X_i)$, which can be estimated by means of the previous observations. Therefore $\mu_{\underline{X}} = E(\underline{X}) = (\mu_1, K, \mu_n)$ is our mean status. The square of Mahalanobis distance is so defined as

$$d^2(\underline{X}, \mu_{\underline{X}}) = (\underline{X} - \mu_{\underline{X}}) \cdot \Sigma^{-1} \cdot (\underline{X} - \mu_{\underline{X}})^T$$

where

$$\Sigma = [\mathrm{cov}\,(X_i, X_j)]_{i,j}$$

is the covariance matrix. Note that if $n=1$, that is we have only one variable, such a distance is still meaningful and simply becomes the absolute value of the standardized variable, that is $d = |X - \mu_X| / \sigma_X$.

Pros and cons of the method

A useful property of Mahalanobis distance is that it doesn't depend on the units of measure of the various indices $\underline{X}$; that is, if $\alpha \neq 0$ is a scalar and we set $\underline{Y} = (\alpha \cdot (X_1, K, X_n)$, then

$$d^2(\underline{X}, \mu_{\underline{X}}) = d^2(\underline{Y}, \mu_{\underline{Y}})$$

Using this property we can observe that there is no difference between the distance computed with the variable X_1 or with $X_1/M \cdot 100$ (where M is the maximum value of X_1). A proof of this equality follows.

Let $\alpha \neq 0$ be any number and consider the new vector random variable $\underline{Y}=(\alpha\cdot(X_1,\ldots,X_n)$. Hence $\mu_{\underline{Y}}=(\alpha\cdot\mu_{X1},\mu_{X2}\ldots,\mu_{Xn})$and the distance for $\underline{Y}$ becomes

$$d'^2=(\underline{Y}-\mu_{\underline{Y}})\cdot(\Sigma')^{-1}\cdot(\underline{Y}-\mu_{\underline{Y}})^T$$

where $\Sigma'=(\sigma'_{ij})_{ij}$ is the covariance matrix of $\underline{Y}$. From the definition of $\underline{Y}$ this matrix is given by

$$\Sigma' = \begin{bmatrix} \alpha^2\sigma_{11} & \alpha\sigma_{12} & \cdots & \alpha\sigma_{1n} \\ \alpha\sigma_{21} & \sigma_{22} & & \sigma_{2n} \\ \vdots & & \ddots & \\ \alpha\sigma_{n1} & \sigma_{n2} & & \sigma_{nn} \end{bmatrix}$$

where σ_{ij} are the elements of the covariance matrix Σ.of $\underline{X}$. Using the linearity of the determinant we obtain that $|\Sigma'| = \alpha^2 \cdot |\Sigma|$, and

$$(\Sigma')^{-1} = \frac{1}{\alpha^2}\begin{bmatrix} \sigma^{-1}_{11} & \alpha\sigma^{-1}_{12} & \alpha\sigma^{-1}_{13} & \cdots & \alpha\sigma^{-1}_{1n} \\ \alpha\sigma^{-1}_{21} & \alpha^2\sigma^{-1}_{22} & \alpha^2\sigma^{-1}_{23} & \cdots & \alpha^2\sigma^{-1}_{2n} \\ \sigma^{-1}_{31} & \alpha\sigma^{-1}_{32} & \alpha\sigma^{-1}_{33} & \cdots & \alpha^2\sigma^{-1}_{3n} \\ \vdots & & & & \\ \sigma^{-1}_{n1} & \alpha^2\sigma^{-1}_{n2} & \alpha^2\sigma^{-1}_{n3} & \cdots & \alpha^2\sigma^{-1}_{nn} \end{bmatrix}$$

Where σ^{-1}_{ij} are obviously the elements of Σ^{-1}. Now we can finally calculate d'^2 obtaining

It is necessary to make some considerations about the numerical calculation of this distance. First of all it is self-evident to note that it doesn't exist if any of the variables has zero variance, but – in the long-term - this would not be a serious problem for the CONECOFOR data set.

A more concrete problem could be determined by the fact that, if the coefficient of correlation ρ of two variables X_i and X_j is ±1, then the covariance matrix Σ is not invertible and the distance doesn't exist (this property simply follows from the linearity of the expected value). There could be some problems also if ρ is close to ±1, because the matrix Σ could be ill-conditioned. In this case, to find its inverse may be a non trivial problem of numerical calculation, which can be addressed by using the appropriate software packages. In practice, we didn't have any problem using the LINPACK® library in MATLAB®, even with $\rho=0.93$.

In our situation the real problem is the great number n of variables. In fact if we have more variables than outcome values k, the data matrix will be singular. This implies singularity of the estimated covariance matrix, too, and Mahalanobis distance cannot be calculated

$$n>k \Rightarrow |\Sigma|=0$$

This is probably the most important prob-

$$d^2=(\underline{Y},\mu_{\underline{Y}})= d'^2=(\underline{Y}-\mu_{\underline{Y}})\cdot(\Sigma')^{-1}\cdot(\underline{Y}-\mu_{\underline{Y}})^T=$$

$$=\frac{1}{\alpha^2}\left(\alpha\cdot X_1-\alpha\cdot\mu_{X_1},X_2-\mu_{X_2},\ldots,X_n-\mu_{X_n}\right)\cdot\begin{bmatrix} \sigma^{-1}_{11} & \alpha\sigma^{-1}_{12} & \alpha\sigma^{-1}_{13} & \cdots & \alpha\sigma^{-1}_{1n} \\ \alpha\sigma^{-1}_{21} & \alpha^2\sigma^{-1}_{22} & \alpha^2\sigma^{-1}_{23} & \cdots & \alpha^2\sigma^{-1}_{2n} \\ \alpha\sigma^{-1}_{31} & \alpha^2\sigma^{-1}_{32} & \alpha^2\sigma^{-1}_{33} & \cdots & \alpha^2\sigma^{-1}_{3n} \\ \vdots & & & & \\ \alpha\sigma^{-1}_{n1} & \alpha^2\sigma^{-1}_{n2} & \alpha^2\sigma^{-1}_{n3} & \cdots & \alpha^2\sigma^{-1}_{nn} \end{bmatrix}\cdot\left(\underline{Y}-\mu_{\underline{Y}}\right)=$$

$$=\frac{1}{\alpha^2}\left(\alpha\cdot\sum_{k=1}^{n}\left(X_k-\mu_{X_k}\right)\sigma^{-1}_{k1},\ \alpha^2\cdot\sum_{k=1}^{n}\left(X_k-\mu_{X_k}\right)\sigma^{-1}_{k2},\ldots,\ \alpha^2\cdot\sum_{k=1}^{n}\left(X_k-\mu_{X_k}\right)\sigma^{-1}_{kn}\right)\cdot\begin{pmatrix}\alpha X_1-\alpha\mu_{X_1}\\ X_2-\mu_{X_2}\\ \vdots \\ X_n-\mu_{X_n}\end{pmatrix}=$$

$$=\frac{1}{\alpha^2}\alpha^2\sum_{i=1}^{n}\sum_{k=1}^{n}\left(X_k-\mu_{X_k}\right)\sigma^{-1}_{ki}\left(X_i-\mu_{X_i}\right)=\left(\underline{X}-\mu_{\underline{X}}\right)\cdot\Sigma^{-1}\cdot\left(\underline{X}-\mu_{\underline{X}}\right)^T=d^2(\underline{X},\mu_{\underline{X}})$$

q.e.d.

lem in using Mahalanobis distance for our purposes, and it is so important because the indices $\hat{X}_i$ come from investigations with different targets (*e.g.* trees, ground vegetation, precipitation, atmosphere..), and – within the same target - with different aims and different sample sizes. For example, in the case where trees are the target, foliage is sampled on 5 trees per *PMP*, growth is estimated from more or less all the trees in the *PMP*, and crown condition is assessed on a subsample. Therefore, these data usually cannot be collected in a single data matrix with the purpose of increasing the value of the ratio *k/n*.

Evaluation of changes

All the Specific Investigation Teams (SITs) contributing to the I&C evaluation were requested to provide a certain number of synthetic indices, which identify the ecosystem's status for that particular investigation (see section on "Results"). The request was made for a better interpretation of the survey results, but also in order to reduce the number of variables used to describe the ecosystem's status. Nevertheless we have to deal with a great number of indices (variables), which represent the components of the *n*–tuple $\underline{X}$, status of the ecosystem. In the previous paragraph we stressed the importance of having a number of observations greater than the dimension of the *n*–tuple $\underline{X}$, to calculate the Mahalanobis distance. So we propose to consider together the *n*–tuples coming from all the *PMPs* belonging to the same species (*e.g.* beech) and from all the available years, to calculate the mean status, origin of the Mahalanobis distance. In this way we can consider for each *PMP* and every year the distance from the mean value and it will be possible to follow the changes experienced by the single *PMP* over the years, in comparison to the overall mean.

To identify formally those *PMPs* which are markedly "far" from the average status, different methods can be used. For example, with large samples sizes (*n* always higher than 370) Innes *et al.* (1996) used the 99th percentile of the empirical distribution function of the Mahalanobis distances to identify trees with anomalous foliage color. Otherwise, possible outliers in univariate distribution can be identified adopting a "cut-off" value equal to the 75th percentile plus 1.5 times the interquartile range (Jobson 1991). Alternatively, the minimum volume estimate may be used (Rousseauw and Van Zomeren 1990, quoted in Innes *et al.* 1996). In our case it seems to be better to avoid the term "outlier" and concentrate on identifying values which are "far" from the average. With a limited sample size, it is perhaps more useful to identify "anomalous" values using the mean and the standard deviation of the Mahalanobis distance values and setting a cut off point equal to the mean plus 1.5 times the standard deviation.

Nature of Change (NoC)

While RA and S&C analyses are aimed at identifying risks and quantifying changes, NoC will address the relationship occurring between stressors and response indicators and indices through time. Thus, the analysis will consider individual *PMPs*. For example, the response of the ecosystem to atmospheric inputs can be evaluated using different indicators, both biological (crown condition, increments, vegetation dynamics) and chemical (changes in soil and soil solution chemistry, stream flow chemistry, foliar chemistry). The simplest example is something like the regression between the concentration of N in the deposition and the foliar concentration of N through time. As the time series increases and more cases become available, new predictors can be added to the model, thus evolving towards multiple regression. There are many exposure/predictors and response indicators/variables and the choice about which to use will be done according to the time series availability and specific questions that the collection of data and the other two analyses (RA and S&C) will raise.

Other techniques

The monitoring program is based on a series of individual case studies which in some cases have very little in common and which in any case do not allow formal inferential statistics from which general conclusions can be drawn. This limitation can be partly overcome by exploring different analytical techniques such as meta-analysis. Traditionally, the results of different experiments were compared using subjective, narrative methods or – at the best – with a "vote-counting" approach. In Italy, an example of this informal procedure can be found in Ferretti (1997). Meta-analysis provides a rigorous framework for the quantitative synthesis of the results of independent studies (Adams *et al.* 1997). This seems particularly attractive as the case of the CONECOFOR program seems suitable and future discussion within the I&C Task Force will consider this approach.

Conclusions

There is no single analytical approach that can cover all the information needs related to the interpretation of data generated by the intensive monitoring of forest ecosystems. That is why the I&C evaluation system was based on different types of analysis designed in order to provide answers to different questions about potential and actual risks due to air pollution, deposition and climate fluctuations and changes, quantification of changes and identification of the nature of the observed changes. The three kinds of analysis need different approaches, data sets and statistical techniques. Although they probably cover the major issues related to the intensive monitoring program, changing environmental priorities, as well as links with other programs and future data availability make it necessary to continuosly review the system.

References

Adams D. C., Gurevitch J., Rosemberg M. W., 1997 - *Resampling test for meta-analysis of ecological data.* Ecology, 78 (5): 1227-1283.

Angiolino E., Bedogni M., Bravetti E., Lanzani G., Lavecchia C., Musitelli A., Valentini M., 1997 - *Studio dell'inquinamento da ozono nel territorio delle province di Milano, Varese, Como e Bergamo.* Provincia di Milano, Studi Monografici sulla Qualità dell'Aria, 91 pp.

Badeau V., Landmann G., Nagelaisen M. 2000 - *Apprèciacion des dègats au niveau national a l'aide du resau europèen du suivi des dommages forestiers (16x16km).* Department de la Santè des Forets: 4ps.

Barbolani E., Del Panta S., Ferretti M., Pantani F., 1986 - *Survey on acid deposition in coastal areas of Tuscany.* Annali di Chimica, 76: 365-374.

Braun S., Rihm B., Schindler C., Flückiger W., 1999 – *Growth of mature beech in relation to ozone and nitrogen deposition: an epidemiological approach.* Water Air and Soil Pollution, 116: 357-364.

Bussotti F., Ferretti M., 1998 - *Air Pollution, Forest Condition and Forest Declines in Southern Europe. An Overview.* Environmental Pollution, 101: 49-65.

Chappelka A., Freer-Smith P., 1995 - P*redisposition of trees by air pollutants to low temperatures and moisture stress.* Environmental Pollution, 87: 105-117.

Cozzi A., Ferretti M., Innes J.L., 2000 - *Sintomi fogliari attribuibili ad ozono sulla vegetazione spontanea in Valtellina.* Monti e Boschi, 3-4: 42-49.

Decet F., Mosello R., 1997 – *Studies on the chemistry of atmospheric deposition in eighteenth and nineteenth centuries.* Ambix, 44: 57-82.

De Vries W., 1999 – *Intensive monitoring of forest ecosystems in Europe. Evaluation of the programme in view of its objectives, studies to reeach the objectives and priorities for the scientific evaluation of data.* Heerenven, The Netherlands, FIMCI, A strategy document: 40 pp.

Dollard, G., Fowler, D., Smith, R.I. and Hjellhrekke, A.-G., Uhse, K., Wallasch M., 1995 - *Ozone measurements in Europe.* Water Air and Soil Pollution, 85, 1949-54.

EC-UN/ECE, 1998; De Vries W, Reinds G. J., Deelstra H. D., Klap J. M., Vel E. M. – *Intensive Monitoring of Forest Ecosystems in Europe, 2000 Technical Report.* EC, UN/ECE 1998, Brussels, Geneva. 193 ps.

Ferretti M., 1997 - *Conclusioni*. In: "Rapporto Finale Progetto CE 93.60.IT.008.0, ARF Regione Lombardia, Milano". Unpublished. Available from ARF Regione Lombardia, Milano.

Ferretti M., Gavilli G., Grossoni P., Lorenzini G., Pellegrini M., 1998 - *Biomonitoraggio di ozono, metalli in traccia, zolfo e cloro a Firenze nel 1996*. In: M. Ferretti, M. Pellegrini, (a cura di) 1998 – "Vegetali come bioindicatori di inquinamento atmosferico in città italiane. Risultati, problemi prospettive". Provincia di Firenze, Comune di Bologna, Meta Spa-Modena: 21-33.

Ferretti M., Bussotti F., Giordano P., Mazzali C., Nibbi R., 2000 - *Program CONECOFOR – Integrated and Combined (I&C) Evaluation of Risk, Status and Changes of Forest Ecosystems.* In: SISEF, Atti, 2: 435-440.

Führer J., Skärbi L., Ashmore M. R., 1997. *Critical levels for ozone effects on vegetation in Europe.* Environmental Pollution 97: 91-106.

Gravano E., Ferretti M., Bussotti F., Grossoni P., 1999. *Foliar symptoms and growth reduction of Ailanthus altissima Desf in an Area with high ozone and acidic deposition in Italy.* Water Air Soil Pollution, 116: 267-272.

Grünhage L., Krause G.H.M., Köllner B., Bender J., Weigel H-J., Jäger H-J., Guderian R., 2001 – *A new flux-oriented concept to derive critical levels for ozone to protect vegetation*. Environmental Pollution, 111: 355-362.

Gruppo di esperti CONECOFOR-I&C, 1998. *Valutazione integrata e combinata (I&C) dei dati raccolti nelle aree permanenti di monitoraggio (APM) intensivo degli ecosistemi forestali in Italia. Rapporto 0*. Internal report adoped at the meeting in Rome, 24 November 1998.

Hall J., Cooper J., Hornung M., Morton D., Reynolds B., Ulyett J., Warr T., 1999 - *UK help-in-kind to the Mapping Programme*. In: Posh M., de Smet P.A.M., Hettelingh J.-P., Downing, "Calculation and mapping of critical thresholds in Europe". RIVM Report No. 259101009: 35-44.

Hunsaker C. T., Graham R. L., Suter II G. W., O'Neill R.V., Barnthouse L.W., Gardner R.H., 1990 – *Assessing ecological risk on a regional scale*. Environmental Management, 14 (3): 325-332.

Innes J.L, 1994 – *Climatic sensitivity of temperate forests*. Environmental Pollution, 83: 237-243.

Innes J.L., Ghosh S., Schwyzer A, 1996 - *A method for the identification of trees with unusually colored foliage*. Can. J. For. Res., 26: 1548-1555.

Jobson J.D., 1991 - *"Applied multivariate data analysis"*. Springer, 1991

Johnson A.R., 1988 - *Diagnostic variables as predictors of ecological risk*. Environmental Management, 12, n. 4, 512-523, 1988

Kärenlampi L., Skärbi L., 1996 - *Critical levels for Ozone in Europe. Testing and finalizing the concepts*. UN-ECE Workshop report, published by the University of Kuopio, Dept. Ecology and Environmental Science, 363 pp.

Kräuchi N., 1993 - *Climate change and forest ecosystems - an overview*. In : "Long term implications of climate change and air pollution on forest ecosystems" ed. R. Schlaepfer. Vienna, IUFRO; Birmensdorf, WSL, IUFRO World Series Vol. 4, 53-76.

Matyssek R, Innes J.L., 1999 – *Ozone – a risk factor for trees and forests in Europe?* Water Air and Soil Pollution, 116: 199-226.

Millàn M. M., Mantilla E., Salvador R., Carratalà A., Sanz M. J., Alonso L., Gangoiti G., Navazo M., 2000 - *Ozone cycles in the western Mediterranean Basin: interpretation of monitoring data in complex coastal terrain*. Journal of Applied Meteorology, 39: 487-508.

Mills G., Hayes F., Buse A., Reynolds B., 2000 - *Air pollution and vegetation. UN/ECE ICP Vegetation*. Annual Report 1999/2000. Centre for Ecology and Hydrology: 48 ps.

Mosello R., Marchetto A., 1996 – *Chemistry of Atmospheric wet deposition in Italy: results from a five-year study*, Ambio, 25 (1): 21-25.

Novo A., Brusasca G. and Buffoni A., 1997 - *Deposizioni di inquinanti in Italia: trend, modellistica e carichi critici*. In: "Deposizioni atmosferiche totali ed ecosistemi forestali. Lo stato della ricerca nell'areale alpino" Cimolais (PN) 6-7/11/1996, 27-45.

Parr T.W., Ferretti M., Simpson I.C. , Forsius M. and Kovács-Láng E . (Submitted Jan 2001). *Towards a long-term integrated monitoring programme in Europe: network design in theory and practice*. Environmental Monitoring and Assessment.

Posch M., De Smet P.A.M., Hettelingh J.-P., Downing R. J., 1999 - *Calculation and mapping of critical thresholds in Europe*. RIVM Report No. 259101009: 165 ps.

Power M., Adams S.M. (Eds), 1997 – *Perspective of the scientific community on the status of ecological risk assessment*. Environmental Management, 21 (6): 803-830.

Sanz M. J., Calatayud V., Calvo E., 2000 - *Spatial pattern of ozone injury in Aleppo pine related to pollution dynamics in a coastal-mountain region in eastern Spain*. Environmental Pollution, 108: 239-247.

Skelly J.M., Innes J.L., Savage J.E., Snyder K.R., Vanerheyden D.J.,. Zhang J.W., Sanz M. J., 1999 - *Observation and confirmation of foliar ozone symptoms of native plant species Switzerland and south Spain*. Water Air Soil Pollution, 116: 227-234.

Smidt S., 1998 - *Risk assessment of air pollutants for forested areas in Austria, Bavaria and Switzerland*. Environ.Sci. & Pollut.Res., Special Issue No.1: 25-31.

Suter II G. W., 1990. *Endpoints for regional Risk Assessment*. Environmental Management, 14, 1: 9-23.

Ulrich E., 2000 - *Renecofor – 8ème Bilan technique et financier et bilan des degats des tempetes de dècembre 1999*. Office National des Forets: 30 ps.

US EPA (United States Environmental Protection Agency), 1992 – *Framework for ecological risk assessment*. EPA/630/R-92001. Washington, DC.

Velissariou D., Davison A.W., Barnes J.D., Pfirmann T., Mac Lean D.C., Holevas C.D., 1992 - *Effects of air pollution on Pinus halepensis Mill.: pollution levels in Attica, Greece*. Atmospheric Environment, 26, 373-80.

Procedures to check availability, quality and reliability of data collected at the CONECOFOR Permanent Monitoring Plots[§]

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Abstract – Every evaluation of data from intensive monitoring programs must consider what data are available, when and where they were collected, the extent to which they meet the desired quality and their reliability. This is particularly important in the case of integrated evaluations where there is a serious risk of error propagation into models. This paper reports on the action undertaken within the Integrated and Combined (I&C) evaluation system to evaluate availability, quality and reliability of the data collected at the Permanent Monitoring Plots of the CONECOFOR programme.

Key words: *data availability, data quality, errors at plot level.*

Riassunto – Procedure di controllo della disponibilità, qualità e affidabilità dei dati raccolti sulle aree permanenti del programma CONECOFOR. Ogni approccio alla valutazione di dati derivati da programmi di monitoraggio intensivo non può prescindere da considerare quali dati siano disponibili, dove e quando, a che livello essi soddisfino la desiderata qualità e quale sia la loro affidabilità. Questi aspetti sono particolarmente importanti nel caso della valutazione integrata dei dati dove esiste un rischio serio di propagazione degli errori nel modello di valutazione adottato. Questo articolo riferisce delle azioni intraprese all'interno del sistema di valutazione Integrata e Combinata (I&C) per valutare disponibilità, qualità e attendibilità dei dati raccolti sulle aree permanenti del programma CONECOFOR.

Parole chiave: *disponibilità dati, qualità dei dati, errori a livello di area permanente.*

F.D.C. 524.634:(450)

Every operational hypothesis concerning integrated and combined evaluation (I&C) of intensive monitoring data depends on their availability, their quality level and their reliability. In addition, the extent to which data from different surveys can be actually integrated should explicitely addressed (Ferretti *et al.* 2000). These characteristics must be known and adequate procedures need to be designed and implemented before undertaking any data analysis. This is particularly true when the data are to be evaluated in an integrated and combined way, when a propagation of the error in the model adopted is a serious risk.

Each step of the investigation – from data collection to data analysis - is subjected to error (Table 1) (Wagner 1995, Köhl *et al.* 2000). In addition, monitoring itself has always an impact on the target area and consequently there is the potential for biased results. When different surveys should be undertaken on the same, relatively small area with high intensity of sampling is fundamental to keep at minimum or at least to know inter- and intra-survey disturbances (Ferretti *et al.* 1998).

Table 1 - Errors potentially associated to the various steps of the investigations currently being undertaken at the plots of the intensive monitoring. R: random errors; S: systematic errors. Bold: high risk of serious error; italics: moderate risks of serious error; normal: low risks of serious errors (based on Wagner 1995).
Errori potenzialmente associati ai vari stadi in alcune indagini portate avanti nelle aree di monitoraggio intensivo. R: errori random; S: errori sistematici. In grassetto alto rischio di errori seri; corsivo: rischio medio di errori seri; carattere normale: basso rischio di errori seri (basato su Wagner 1995).

	Step						
Survey	**Sampling strategy**	**Sampling tactics**	**Sample collection**	**Transport, conservation**	**Sample preparation**	**Measurement/ Assessment**	**Data Analysis**
Crown condition	**R - S**	**S**	-	-	-	**S**	S
Soil inventory	**R - S**	**S**	**R - S**	**S**	S	S	S
Foliar analysis	**R - S**	**S**	**R - S**	**S**	S	S	S
Deposition	**R - S**	**S**	**R - S**	**S**	S	S	S
Meteorology	**R - S**	**S**	-	-	-	S	S
Increments	**R - S**	**S**	*R - S*	S	S	S	S
Ground Vegetation	**R - S**	**S**	-	-	-	**S**	S

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Table 2 - Issues related to the intensive monitoring data, their areas of interest and evaluation methods.
Aspetti connessi ai dati derivati dal monitoraggio intensivo, loro area di interesse e metodi di valutazione.

Issue	Area of interest	Method
Data availability	Spatial and temporal availability of the data	Questionnaire/ Investigation report
Data completeness	Actual vs. expected records	Questionnaire/ Computation
Reproducibility	Spatial and temporal comparability of data	Questionnaire/ Quality evaluation
Reliability	Relative margin of error at PMP level	Questionnaire/ Computation of error
Representativity	Sampling design at PMP level	Evaluation of sampling strategy
Integrability	Connections between investigations	Evaluation of links
Disturbances	Disturbances associated to the monitoring activity	Control plot

Given their potential impact on the results, all the above issues are matter of concern of the I&C evaluation system and will be considered step-by-step. In particular, this paper has the aim to provide information and data about the procedures adopted within the I&C evaluation system to check data availability, completeness, reliability and representativity (Table 2) (Ferretti *et al.* 1999 a, b, c). As an example we will use the monitoring years 1995-1998. Similar procedures were and are being applied also for the subsequent years.

Definitions

Data availability

Data availability is defined for each specific investigation (SI) at each individual Permanent Monitoring Plot (*PMP*) and year. However, it is always possible that a planned investigations can not be actually undertaken, at least in part. This is particularly the case of those investigations using automatic devices, because malfunctioning or damage from whatever reason can results in a loss of data. Therefore a first need is an overview of what kind of data is available for each *PMP* and for each year and at which level of completeness (see below). It will than be possible to identify the potential analyses allowed by each plot and how many plots and with which characteristics will be available for each analysis in each year.

Data quality

Data quality is a general term under which several attributes of data need to be clarified, namely accuracy, precision, reproducibility, reliability and completeness. While accuracy and precision are addressed by each specific investigation, in this paper we will concentrate on reproducibility, reliability and completeness.

Reproducibility

Reproducibility can be defined by the degree at which two operators (or the same operator at different times) achieve the same results (in a defined acceptable range, *e.g.* ± 10% of the control/reference value) when using the same method and equipments.

Reliability

Necessarily, the I&C evaluation will be based on various statistical descriptors (*e. g.* mean, mode, sum, percentiles, extremes) of the various datasets generated by each survey at each *PMP*. Being based on a sample, the reliability of the above descriptors depends on the number of observations at plot level and on the variability of the data. While the number of observation is in general costant between *PMPs* (*e.g.* deposition collectors are generally 16; sample trees for crown condition are generally 30), data variability is plot-specific. Since the standard error (and consequently the relative margin of error of the mean) depends on both the above terms, different level of reliability can be expected for each *PMP* and data set.

Completeness

The completeness of the data set is defined by the ratio between the actual and the expected number of records. For example, if crown condition is to be carried out on 30 trees per *PMP*, the expected number of records for crown transparency is 30. Lower numbers will indicate incomplete datasets.

Representativity

Representativity is defined by the way in which observations at *PMP* level were carried out, *e.g.* by the way in which sub-samples were selected within each *PMP*. Representativity usually means that sample selection is free from subjectivity and this makes the inferential process possible. Representativity can be ensured by three different characteristics of sampling: casuality, independence, and known probability of each element of the population to be sampled. While the complete achievement of these characteristics is possible with a fully randomized sampling design, other schemes (*e.g.* systematic sampling) are generally accepted . It is therefore important to know how the sampling is carried out at plot level.

Integrability, disturbances

Data can be representative and of good quality, but the extent to which they can be actually integrated depends again on the original design of the *PMP*. Table 3 reports disturbances that may occur between and within monitoring activity. As it is obvious, some investigations may cause problems to some others: in particular, deposition sampling and ground vegetation assessment seem largely conflicting because the high frequency of deposition sampling, the considerable effects of the actions associated to that sampling and the high sensitivity of ground vegetation to such disturbances.

Methods

Data availability, quality and reliability

In order to obtain an overview of the data collected during the surveys performed on the network's *PMPs*, an explorative questionnaire was drawn up. Consisting of three specific sections common to all investigations (available data, their quality and reliability), which must be filled in for each year and each *PMP*, this questionnaire has been sent to the leader of each working group. Each section was then tailored to each individual investigation according to the parameters measured in the *PMPs* and to the specific needs agreed upon by the experts in the working groups, in accordance with the methods proposed by FIMCI (EC-UN/ECE 1998). As an example, we include here the questionnaire sent to the working group on Estimation of Growth and Yield (Figs. 1-3).

The first section of the questionnaire is devoted to ascertain what data are available at what *PMP*. Section 2 deals with data quality, either in general terms (use of SOPs *etc.*) and in detail (*e.g.*

Table 3 - Investigations carried out at the CONECOFOR PMPs and associated potential disturbances. Ozone is not considered since the measurements are always carried out outside the *PMP*. "Frequency of visits": the frequency of the visits associated to each activity; "Action": the actual action associated to each survey; "Disturbance": effects associated to the activity; "Impact on": the investigation affected by the one under consideration; "Possible solution": some suitable solutions (after Ferretti *et al.* 1998).
Indagini in svolgimento sulle aree permanenti CONECOFOR e potenziali tipi di disturbo che esse possono provocare. Il rilevamento di ozono non viene considerato perchè le misurazioni vengono svolte esclusivamente all'esterno dell'area permanente. "Frequency of visits": la frequenza delle visite associate a ciascuna indagine; "Action": effettive azioni associate alle varie indagini; "Disturbance": effetti associati all'azione considerata; "Impact on": indagine influenzata da quella considerata; "Possible solution": alcune possibili soluzioni per evitare il disturbo (da Ferretti et al. *1998).*

Investigation	Frequency of visits	Action	Disturbance	Impact on	Possible solution
Crown condition	every year	observation	trampling	ground vegetation	maximum care; different sub-plots
Soil inventory	every 10 years	opening of pits; soil cores	digging;trampling	ground vegetation	different sub-plots
Foliar analysis	every 2 years	collection of foliage samples	removal of branchlets from trees; trampling	crown condition; ground vegetation	different trees; different sub-plots
Increment	every 5 years	tree measurements; collection of wood cores/disks	damage to trees; trampling	crown condition; ground vegetation	different trees; different sub-plots
LAI (1)	every year	LAI measurements	trampling	ground vegetation	maximum care; different sub-plots
Litterfall (1)	every month	Litterfall collection	trampling	ground vegetation	maximum care; different sub-plots
Deposition	every week	collection of throughfall	trampling;	ground vegeatation	different sub-plots;
Meteorology (in the plot)	every week or month	installing measurement devices	disturbance trampling	ground vegetation	different sub-plots
Ground vegetation	every year	observation	trampling	ground vegetation	only maximum care

(1) undertaken only in 1997 and 1998.

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Valutazione Integrata e Combinata (I&C) dei dati raccolti sulle Aree Permanenti di Monitoraggio Intensivo (APMI)

Indagine: accrescimenti
Anno: **specificare (riempire un foglio per ciascun anno)**

1. DATI DISPONIBILI PER SINGOLA AREA
(Grassetto: OBBLIGATORI; corsivo: OPZIONALI; grassetto + corsivo: ALTRI)

N. prog.	APMI	**DBH**	*Dendrocronologia*	*Spessore corteccia*	*Altezza*	*Area basimetrica*	*Profondità chioma*	*Larghezza chioma*	***LAI***	***Litterfall***
1	ABR1									
2	BAS1									
3	CAL1									
4	CAM1									
5	EMI1									
6	EMI2									
7	FRI1									
8	FRI2									
9	LAZ1									
10	LOM1									
11	MAR1									
12	PIE1									
13	PUG1									
14	SAR1									
15	SIC1									
16	TOS1									
17	TRE1									
18	UMB1									
19	VAL1									
20	VEN1									

Riempire con:
0 = dati non disponibili
1 = dato disponibile

Figure 1 - Example of the explorative questionnaire. Growth and Yield estimation. Section 1: available data.
Esempio del questionario esplorativo. Stima degli accrescimenti. Sezione 1: dati disponibili.

Data Quality Limits, data completeness). Section 3 is devoted to find out the reliability of the data in terms of % error of the mean. This has been done using the following:

$$E\ \% = t_{\alpha} \frac{CV}{\sqrt{n}}$$

E = error margin within the plot relative to mean value (%);
t_{α} = Student t value for a specific probability level (with normal distribution, for α=0.05, t =1.96);
CV= coefficient of variation (%);
n = number of observations within the plot.

The data used in this paper relating to the 20 *PMPs* for the years 1995, 1996, 1997 and 1998 include crown condition, soil and foliar chemistry, atmospheric deposition, tree growth studies, LAI and litterfall, ground vegetation, meteorology and gaseous pollutants.

Representativity, integrability, disturbances

Up to date, these issues were covered only partially and in some cases only conceptually. Further work is needed in this direction. Representativity was first estimated by scrutinizing the sampling design at the level of *PMPs*. Type of observation (how observations at *PMP* level were actually carried out), sampling tactics (spatial allocation of the observations) and sampling strategy (design-based, model-based, preferential sampling) were considered.

As far as integrability is concerned, I&C considers “integrable” two data sets which are linked either conceptually and/or spatially. Disturbances and interferences between co-located surveys (*e. g.* ground vegetation and deposition) should be considered carefully.

The extent to which monitoring activity impact the *PMP* will be assessed by means of a control plot installed nearby the sampling plot. It is of course important to ensure homogeneity between the two plots.

Results

Available Data

As an example, the availability of the data is given in Table 4 and 5 for each investigation

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Valutazione Integrata e Combinata (I&C) dei dati raccolti sulle Aree Permanenti di Monitoraggio Intensivo (APMI)

Indagine: accrescimenti
Anno: **specificare (riempire un foglio per ciascun anno)**

2. QUALITÀ DEI DATI

2. 1 QUALITÀ DEI DATI - ASPETTI GENERALI

	Misurazioni dendrom.	LAI	Litterfall
Uso di manuali operativi standard			
Corso di istruzione effettuato			
Effettuazione di controlli di campagna			
Completezza dei dati verificata			
Plausibilità dei dati verificata			

Riempire con:
0 = no
1 = si

2. 2 QUALITÀ DEI DATI - ASPETTI DI DETTAGLIO

		Litterfall		LAI	
N. prog.	APMI	campioni ricevuti (1)	campioni misurati (2)	Misurazioni richieste (3)	Misurazioni effettuate (4)
1	ABR1				
2	BAS1				
3	CAL1				
4	CAM1				
5	EMI1				
6	EMI2				
7	FRI1				
8	FRI2				
9	LAZ1				
10	LOM1				
11	MAR1				
12	PIE1				
13	PUG1				
14	SAR1				
15	SIC1				
16	TOS1				
17	TRE1				
18	UMB1				
19	VAL1				
20	VEN1				

Riempire indicando:
(1) numero di campioni ricevuti da ciascuna APMI
(2) numero di campioni effettivamente misurati
(3) numero di misurazioni richieste per singola APMI
(4) numero di misurazioni effettuate per singola APMI

Figure 2 - Example of the explorative questionnaire. Growth and Yield estimation. Section 2: data quality.
Esempio del questionario esplorativo. Stima degli accrescimenti. Sezione 2: qualità dei dati.

and each *PMP* at any given year 1995, 1996, 1997, 1998.

Crown Condition

As far as crown condition is concerned, in 1996 17 *PMPs* (503 trees) were evaluated, in 1997 19 *PMPs* (558 trees), in 1998 all 20 *PMPs* (594 trees) (Table 3). The same occurred in 1999 and 2000 (not reported here). Indices used in the investigation were all the mandatory and optional indices suggested by Eichhorn *et al.* (1996): Removal and mortality, Social position, Crown compression, Visibility, Crown dieback – extent, Crown dieback – type, Leaf loss – intensity, leaf loss – pattern, Crown transparency, Flowering, Fructification, Leaf colour – extent, Leaf colour – type, Leaf colour – leaf position, Leaf colour – crown position, Age of affected leaves, Leaf size, Leaf malformation - type, Leaf malformation – extent, Leaf damage – extent, Leaf damage – type, Ramification structure, Regeneration, Epiphytes and other growths, Ramification damage – type, Ramification damage – position, Stem damage – type and Stem damage – position. De-

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Valutazione Integrata e Combinata (I&C) dei dati raccolti sulle Aree Permanenti di Monitoraggio Intensivo (APMI)

Indagine: accrescimenti
Anno: **specificare (riempire un foglio per ciascun anno)**

2. AFFIDABILITÀ DEI DATI PER SINGOLA AREA

Errore relativo accettabile: DBH: [ ] LAI: [ ] Litterfall: [ ]
Si prega di indicare il limite di errore percentuale ritenuto accettabile per ottenere dati attendibili

N. prog.	APMI	n. camp.	StD DBH	n. camp.	StD LAI	n. camp.	StD Litterfall
1	ABR1						
2	BAS1						
3	CAL1						
4	CAM1						
5	EMI1						
6	EMI2						
7	FRI1						
8	FRI2						
9	LAZ1						
10	LOM1						
11	MAR1						
12	PIE1						
13	PUG1						
14	SAR1						
15	SIC1						
16	TOS1						
17	TRE1						
18	UMB1						
19	VAL1						
20	VEN1						

Riempire con: n. camp= numero di campioni per APMI; StD DBH, ..., StD Litterfall=deviazione standard della media per ciascun parametro.
DBH e Litterfall vanno riferiti alla specie principale dell'APMI.
Per ogni chiarimento:
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Figure 3 - Example of the explorative questionnaire. Growth and Yield estimation. Section 3: data reliability.
Esempio del questionario esplorativo. Stima degli accrescimenti. Sezione 3: affidabilità dei dati.

tails about the use of the above indices are given by BUSSOTTI *et al.* (this volume).

Analysis of Soils

Chemical analysis of soils was performed in 1995 on all the *PMPs* (Table 4). It included: soil classification according to FAO nomenclature, pH and total concentration of N, C, P, K, Mg and Ca (with pH>6.0) for the organic layer and pH, Exchangeable Acidity, Basic Saturation, Cationic Exchange Capacity and total concentrations of N, C, Ca, Mg, K for mineral layers.

Analysis of Needles and Leaves

Chemical analysis of leaves was performed in 1995, 1997 and 1999 (not reported here) on all 20 *PMPs* (Table 4). In each plot the following elements were determined: weight of a sample of 100 leaves or 1000 needles, total P, S, N, Ca, Mg and K. Some further optional tests were also carried out to determine the values of other micronutrients such as Na, Mn, Zn, Fe, Cu, B and Al.

Estimation of Growth and Yield (Increment), LAI and litterfall

For Growth and Yield in all 20 *PMPs* the following data were recorded in 1996 (Table 4): diameter at 130 cm, bark thickness, basal area and height. The same parameters were recorded in the winter 1999-2000 (data not reported here). On some individuals in each *PMP* a wood core was taken for growth trend studies. Data on the main dendrometric variables as well as crown depth and width were collected on a sub sample of trees.

Investigations on LAI began in 1997, although the data from that year are partial (Table 5). The investigation was performed on *15 PMPs* (no data for BAS1, CAL1, CAM1, SAR1 and

Table 4 - Mandatory investigations carried out at each *PMP* between 1995 and 1998. 0= no; 1= yes.
Effettuazione indagini obbligatorie; 0=no, 1=si.

		Crown				Soil				Foliar analysis				Increment				Ground vegetation (1) and (2)				Deposition				Meteo			
N.	PMP code	95	96	97	98	95	96	97	98	95	96	97	98	95	96	97	98	95	96	97	98	95	96	97	98	95	96	97	98
1	*ABR1*	0	1	1	1	1	0	0	0	1	0	1	0	0	1	0	0	0	1	0	1	0	0	0	1	0	0	1	1
2	*BAS1*	0	0	0	1	1	0	0	0	1	0	1	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0
3	*CAL1*	0	1	1	1	1	0	0	0	1	0	1	0	0	1	0	0	0	1	0	1	0	0	0	1	0	0	0	0
4	*CAM1*	0	1	1	1	1	0	0	0	1	0	1	0	0	1	0	0	0	1	0	1	0	0	0	1	0	0	0	0
5	*EMI1*	0	1	1	1	1	0	0	0	1	0	1	0	0	1	0	0	0	1	0	1	0	0	0	1	0	0	0	1
6	*EMI2*	0	1	1	1	1	0	0	0	1	0	1	0	0	1	0	0	0	1	0	1	0	0	0	1	0	0	0	0
7	*FRI1*	0	0	1	1	1	0	0	0	1	0	1	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0
8	*FRI2*	0	1	1	1	1	0	0	0	1	0	1	0	0	1	0	0	0	1	0	1	0	0	0	1	0	0	0	1
9	*LAZ1*	0	1	1	1	1	0	0	0	1	0	1	0	0	1	0	0	0	1	0	1	0	0	0	1	0	0	0	1
10	*LOM1*	0	1	1	1	1	0	0	0	1	0	1	0	0	1	0	0	0	1	0	1	0	0	0	1	0	0	1	1
11	*MAR1*	0	1	1	1	1	0	0	0	1	0	1	0	0	1	0	0	0	1	0	1	0	0	0	1	0	0	0	0
12	*PIE1*	0	1	1	1	1	0	0	0	1	0	1	0	0	1	0	0	0	1	0	1	0	0	0	1	0	0	0	0
13	*PUG1*	0	0	1	1	1	0	0	0	1	0	1	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0
14	*SAR1*	0	1	1	1	1	0	0	0	1	0	1	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0
15	*SIC1*	0	1	1	1	1	0	0	0	1	0	1	0	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0
16	*TOS1*	0	1	1	1	1	0	0	0	1	0	1	0	0	1	0	0	0	1	0	1	0	0	1	1	0	1	1	1
17	*TRE1*	0	1	1	1	1	0	0	0	1	0	1	0	0	1	0	0	0	1	0	1	0	0	0	1	0	0	0	1
18	*UMB1*	0	1	1	1	1	0	0	0	1	0	1	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0
19	*VAL1*	0	1	1	1	1	0	0	0	1	0	1	0	0	1	0	0	0	1	0	1	0	0	0	0	1	1	1	1
20	*VEN1*	0	1	1	1	1	0	0	0	1	0	1	0	0	1	0	0	0	1	0	1	0	0	0	1	0	0	0	0

SIC1). In 1998 the investigation was done in 17 *PMPs* (no data for BAS1, CAM1 or PUG1).

Litterfall investigations began in 1997 in 18 *PMPs* (no data available for CAM1 and UMB1) (Table 5). As in the case of LAI, the litterfall investigations performed in 1997 were incomplete, whereas in 1998 the investigation was performed on *19 PMPs* and data are available for all *PMPs* except UMB1.

Ground Vegetation

As far as Ground Vegetation is concerned, we have available vegetation data for the years 1996 and 1998 at population level (referred to as ground vegetation (1)) including seedlings/saplings up to 2 m in height, and for 1996 at a community level (referred to as ground vegetation (2)) (Table 4). Further investigations have been carried out in 1999 and 2000 (no reported here). In 1996 and 1998 we have data on all the *PMPs* relative to: mosses; height, extent and number of weeds; basal diameter; functional types; estimated regeneration damage; and an investigation on the functional types of weeds.

Atmospheric depositions

Data relating to atmospheric depositions were recorded for 1997 and 1998 (Table 4). Further investigations were carried out in 1999 and 2000 (data not showed here). In 1998 deposition data refer to 14 *PMPs* (no data available for BAS1, FRI 1, PUG1, SAR1, UMB1 and VAL1), whereas for 1997 a complete dataset is available only for TOS1. Detailed data are shown in Table 6 and 7, which illustrate the status of all *PMPs* in the period 1997-98. In both study years the data collected were: mm of rainfall, pH, K, Ca, Mg, Na, $N\text{-}NH_4$, $N\text{-}NO_3$, N_{tot}, Cl, SO_4 and alkalinity. Total N was not measured in TOS1 in 1998.

Table 5 - Optional investigations carried out at each *PMP* between 1995 and 1998. 0= no; 1= yes.
Effettuazioni indagini non obbligatorie; 0=no, 1=si.

		LAI				Litter				Ozone			
N.	PMP code	95	96	97	98	95	96	97	98	95	96	97	98
1	ABR1	0	0	1	1	0	0	1	1	0	1	1	1
2	BAS1	0	0	0	0	0	0	1	1	0	1	1	1
3	CAL1	0	0	0	1	0	0	1	1	0	1	1	1
4	CAM1	0	0	0	0	0	0	0	1	0	1	1	1
5	EMI1	0	0	1	1	0	0	1	1	0	1	1	1
6	EMI2	0	0	1	1	0	0	1	1	0	1	1	1
7	FRI1	0	0	1	1	0	0	1	1	0	1	1	1
8	FRI2	0	0	1	1	0	0	1	1	0	1	1	1
9	LAZ1	0	0	1	1	0	0	1	1	0	1	1	1
10	LOM1	0	0	1	1	0	0	1	1	0	0	1	1
11	MAR1	0	0	1	1	0	0	1	1	0	1	1	1
12	PIE1	0	0	1	1	0	0	1	1	0	1	1	1
13	PUG1	0	0	1	0	0	0	1	1	0	1	1	1
14	SAR1	0	0	0	1	0	0	1	1	0	1	1	1
15	SIC1	0	0	0	1	0	0	1	1	0	1	1	1
16	TOS1	0	0	1	1	0	0	1	1	0	1	1	1
17	TRE1	0	0	1	1	0	0	1	1	0	1	1	1
18	UMB1	0	0	1	1	0	0	0	0	0	1	1	1
19	VAL1	0	0	1	1	0	0	1	1	0	1	1	1
20	VEN1	0	0	1	1	0	0	1	1	0	1	1	1

Table 6 - Deposition sampling in 1997-1998
Campionamento delle deposizioni nel 1997 e nel 1998.

PMP	1997	1998
ABR1	Start May '97, SF August '97	Start January '98
BAS1	Not available	Not available
CAL1	Start August '97	Start January '98
CAM1	Not available	Start March '98
EMI1	Start May '97, StemFlow July '97	Start January '98
EMI2	Start May '97	Samples from January to March missing
FRI1	Not available	Start July '98
FRI2	Start June '97, StemFlow July '97	Start January '98
LAZ1	Start May '97, StemFlow August '97	Start January '98
LOM1	Start July '97	Start January '98
MAR1	Start May '97	Start January '98
PIE1	Start May '97	StemFlow start October '98
PUG1	Not available	Not available
SAR1	Not available	Not available
SIC1	Start August '97	Start January '98
TOS1	Start January '97	Start January '98
TRE1	Start May '97	StemFlow start July '98 (n° 5 analysis)
UMB1	Not available	Not available
VAL1	Not available	Not available
VEN1	Start May '97, SF July '97	Start January '98

Air Pollution Measurements

Pollutants measured in the *PMPs* were: ozone (O_3) during summer months (starting in 1996); sulphur dioxide (SO_2) during winter (1997-98 and 1998-1999; nitrogen oxides (NO_x) during summer (starting in 1998). These measurements were performed in the following *PMPs* (Table 5): in 19 in 1996 (all except LOM1); in all 20 in 1997 and 1998 in the case of ozone; in 6 *PMPs* (EMI1, FRI1, PUG1, SAR1, TOS1, VAL1) for sulphur dioxide for both 1997 and 1998.

Meteorological measurements

The meteorological variables recorded during the periods of activity were: mm of rainfall, air temperature, air moisture, wind speed, wind direction and solar radiation. For 1996 data are available only for TOS1 e VAL1 (Table 4). For 1997 we have data on 3 *PMPs* (LOM1, TOS1, VAl1); in 1998 the survey included 7 *PMPs* (the same as in 1997 plus ABR1, FRI2, LAZ1, TRE1) (Table 4).

Details about functioning are in Table 8. Besides measurements carried out in the openfield, there are also available data provided by some meteorological monitoring installations located inside some *PMPs* (In the Plot), as follows: for 1997, *ABR1*, *EMI1* and *LAZ1*; for 1998, *ABR1*, *EMI1*, *FRI2*, *LAZ1* and *TRE1*.

Quality of the data

General Quality Assurance (QA) procedures

As far as the use of Standard Operating Procedures (SOPs) and the participation and/or organization of training-calibration courses are concerned, these procedures were adopted in the case of investigation on crown condition, soil, leaf/needle, ground vegetation, atmospheric depositions, meteorological monitoring and gaseous pollutants (in this last case, however, no training course was organized for 1997 and 1998) (Table 9).

Field checks were carried out in the cases of crown condition, growth, LAI, litterfall, ground vegetation, deposition, meteo and ozone. No field checks were done in 1996 for ground vegetation at population level (1) and in 1998 for ground vegetation at community level (2). Checks of the plausibility of the data were carried out for most of the investigations.

Detailed Procedures

Examples of quality of the data from each

Table 7 - Detailed data about deposition sampling for each openfield, throughfall and stemflow up to 31/12/1998 0= no; 1= yes.
Dati dettagliati sul campionamento delle deposizioni openfield, throughfall e stemflow al 31/12/1998; 0=no, 1=si.

PMP	Openfield	Throughfall	Stemflow
ABR1	1	1	1
BAS1	0	0	0
CAL1	1	1	1
CAM1	1	1	0
EMI1	1	1	1
EMI2	1	1	1
FRI1	1	1	0
FRI2	1	1	1
LAZ1	1	1	1
LOM1	1	1	0
MAR1	1	1	0
PIE1	1	1	1
PUG1	0	0	0
SAR1	0	0	0
SIC1	1	1	0
TOS1	1	1	1
TRE1	1	1	1
UMB1	0	0	0
VAL1	0	0	0
VEN1	1	1	1

Table 8 - Meteorological measurements in 1997 and 1998.
Misurazioni meteorologiche nel 1997 e nel 1998.

	1997						1998					
PMP	start	end	start	end	start	end	start	end	start	end	start	end
ABR1	01-dic.	31-dic.					01-jan	21-oct	01-nov	31-dic.		
BAS1												
CAL1												
CAM1												
EMI1	01-nov.	31-dic.					01-jan	31-dic.				
EMI2												
FRI1												
FRI2							05-jun	31-dic				
LAZ1	01-may	17-nov	25-nov	31-dic			01-jan	31-dic				
LOM1	01-jan	31-dic					01-jan	24-may	23-oct	31-dic		
MAR1												
PIE1												
PUG1												
SAR1												
SIC1												
TOS1	01-jan	02-oct	22-nov	16-dic			01-jan	14-apr	20-jun	31-dic		
TRE1	01-jan	31-mar	21-apr	10-may	26-set	06-dic	01-jan,	31-mar	21-apr	10-may	26-set	06-dic
UMB1												
VAL1	01-jan	04-jun	10-jun	31-dic			01-jan	31-dic				
VEN1												

investigation relative to each *PMP* is illustrated in Tables 10-12.

Crown Condition – Data reported here refers to crown transparency (an index oftenly termed defoliation or crown vigour) and the extent to which the Measurement Quality Objective (MQO) were achieved by the various field crews. MQO was set at 90% of the records falling within the control score ± 10% (Bussotti *et al.* 1999). This MQO was seldomly achieved: observance ranges from 68 to 90% in 1996, from 30 to 83% in 1997 and from 33 and 100% in 1998. This suggests that there is a problem with the reproducibility of data. As far as other indices are concerned, control surveys performed in the period 1996-1998 highlight that there are problems related to data on ramification structure, leaf colour type, the action of insects and of meteoric agents (Ferretti *et al.* 1999).

Analysis of Soils and Analysis of Needles and Leaves - No data were provided for Soil chemistry analysis or for Foliar chemistry analysis.

Estimation of Growth and Yield - In the case of Growth and Yield estimation, no detailed information on data quality was collected.

LAI – Data about the LAI refers to data completeness. For LAI in 1997 all requested measurements were performed (and some extra ones as well). In 1998, on the other hand, fewer measurements than requested were done.

Table 9 - General QA procedures and their adoption in the various investigations. 0= no; 1= yes; NA: not available.
Procedure generali di controllo della qualità dei dati implementate nelle varie indagini; 0=no, 1=si; NA: informazione non fornita.

	Crown			Soil	Foliar		Growth	LAI		Litter		Ground (1)		Ground (2)		Deposition		Meteo		Ozone		
	96	97	98	95	95	97	96	97	98	97	98	96	98	96	98	97	98	97	98	96	97	98
Use of SOPs	1	1	1	1	1	1	0	0	0	0	0	1	1	0	0	1	1	1	1	1	1	1
Training & Intercalibration	1	1	1	1	1	1	0	0	0	0	0	1	1	0	0	1	1	1	1	1	0	0
Field checks	1	1	1	NA	NA	NA	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1
Data completeness	1	1	1	NA	NA	NA	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
Data plausibility	1	1	1	NA	NA	NA	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1

Table 10 - Example of quality control data for the year 1996. Achievements of MQOs for crown transparency, completeness of measurements for groud vegetation at the population and community level, and ozone.
Esempio di dati dei controlli di qualità per il 1996. Raggiungimento degli obiettivi di qualità per la trasparenza della chioma, completezza delle misurazioni per le indagini sulla vegetazione a livello di popolazione e comunità, completezza delle misurazioni per ozono

	Crown trasparency		Ground (1)		Ground (2)		Ozone
PMP code	MQO	Actual agreement	Expected measured squares	Actual measured squares	Expected measured squares	Actual measured squares	Samples Completeness (%)
ABR1	90	86	100	100	25	25	100
BAS1	90	NM	100	100	25	25	93,75
CAL1	90	NC	100	100	25	25	100
CAM1	90	NC	100	100	25	25	93,75
EMI1	90	NC	100	100	25	25	100
EMI2	90	NC	100	100	25	25	100
FRI1	90	NM	100	100	25	25	93,75
FRI2	90	NC	100	100	25	25	87,5
LAZ1	90	86	100	100	25	25	100
LOM1	90	NC	100	91	25	25	NM
MAR1	90	NC	100	100	25	25	87,5
PIE1	90	68	100	100	25	25	93,75
PUG1	90	NM	100	100	25	25	100
SAR1	90	NC	100	98	25	25	100
SIC1	90	NC	100	91	25	25	100
TOS1	90	NC	100	100	25	25	100
TRE1	90	93	100	100	25	25	100
UMB1	90	NC	100	100	25	25	100
VAL1	90	NC	100	100	25	25	100
VEN1	90	90	100	100	25	25	100

NA: Not available; NC: not subjected to field check; NM: not measured.

Litterfall - Data about the litterfall refers to data completeness. In the case of litterfall data, all samples received were measured both in 1997 and in 1998. However, there is some uncertainty about sampling at the level of individual *PMP*, where sampling frequencies were not always the same. ABR1 and TOS1 are not included in Tables 11-12 because other agencies are in charge of performing the measurements.

Table 11 - Example of quality control data for the year 1997. Achievements of MQOs for crown transparency, completeness of measurements for LAI (no. of repetitions x no. of observations), litterfall and meteo measurements, completeness for ozone and sulfur dioxide.
Esempio di dati dei controlli di qualità per il 1997. Raggiungimento degli obiettivi di qualità per la trasparenza della chioma, completezza delle misurazioni per le indagini su LAI (nr. ripetizioni x nr. osservazioni) e litterfall; completezza e plausibilità dei dati meteo; completezza delle misurazioni per ozono e anidride solforosa.

	Crown trasparency		LAI		Litterfall		Meteo		Gaseous Air Pollutants	
PMP code	MQO	Actual agreement	Request measured	Actual measured	Received samples	measured samples	Completeness (%)	plausibility (%)	Completeness 0_3 (%)	Completeness SO_2 (%)
ABR1	90	NC	2X9	3X9	NA	NA	99	100	100	NM
BAS1	90	NM	2x9	NM	1	1	NM	NM	75	NM
CAL1	90	NC	2x9	NM	72	72	NM	NM	100	NM
CAM1	90	NC	2X9	NM	NM	NM	NM	NM	35	NM
EMI1	90	83	2X9	2X9	72	72	100	100	100	100
EMI2	90	NC	2X9	2X9	84	84	NM	NM	81,25	NM
FRI1	90	NC	2X9	3X9	70	70	NM	NM	100	100
FRI2	90	NC	2X9	4X9	48	48	NM	NM	100	NM
LAZ1	90	NC	2X9	4X9	80	80	96	100	100	NM
LOM1	90	63	2X9	3X9	51	51	100	100	100	NM
MAR1	90	NC	2X9	3X9	72	72	NM	NM	100	NM
PIE1	90	NC	2X9	2X9	61	61	NM	NM	100	NM
PUG1	90	NC	2X9	4X9	72	72	NM	NM	93,75	100
SAR1	90	NC	2X9	NM	84	84	NM	NM	100	100
SIC1	90	NC	2X9	NM	NA	NA	NM	NM	100	NM
TOS1	90	NC	2X9	2X9	NA	NA	92	100	100	100
TRE1	90	NC	2X9	2X9	60	60	81	100	100	NM
UMB1	90	30	2X9	2X9	NM	NM	NM	NM	100	NM
VAL1	90	NC	2X9	2X9	36	36	99	100	100	65
VEN1	90	NC	2X9	4X9	60	60	NM	NM	100	NM

NA: Not available; NC: not subjected to field check; NM: not measured.

Table 12 - Example of quality control data for the year 1998. Achievements of MQOs for crown transparency, completeness of measurements for ground vegetation at the population level, LAI (no. of repetitions x no. of observations) and litterfall; percentage of openfield samples falling in class 1 and 2 (ionic balance, conductivity) for deposition; completeness and plausibility for meteo; completeness for ozone and sulfur dioxide.
Esempio di dati dei controlli di qualità per il 1998. Raggiungimento degli obiettivi di qualità per la trasparenza della chioma, completezza delle misurazioni per le indagini sulla vegetazione a livello di popolazione per LAI (nr. ripetizioni x nr. osservazioni) e litterfall; percentuale di campioni che ricadono nelle classi 1 e 2 di bilancio ionico e conducibilità; completezza e plausibilità delle misurazioni meteo; completezza delle misurazioni di ozono ed andride solforosa.

	Crown trasparency		LAI		Litterfall		Ground (1)		Deposition		Meteo		Gaseous Air Pollutants	
PMP code	MQO	Actual agreement	Request measur.	Actual measur.	Received samples	Measur. samples	Expected measur. squares	Actual measur. squares	B.I.	K20 calc. vs. measur.	Complet. (%)	Plausib. (%)	Samples complet. O_3	Samples complet. SO_2
ABR1	90	NC	3X9	3X9	NA	NA	100	100	93	100	90	100	100	NM
BAS1	90	43	NM	NM	144	144	100	100	NM	NM	NM	NM	83,2	NM
CAL1	90	33	3X9	3X9	142	142	100	100	87	100	NM	NM	100	NM
CAM1	90	43	NM	NM	84	84	100	99	87	100	NM	NM	83,2	NM
EMI1	90	NC	3X9	2X9	180	180	100	100	93	100	99	100	100	100
EMI2	90	NC	3X9	2X9	126	126	100	100	89	100	NM	NM	94,4	NM
FRI1	90	90	3X9	2X9	151	151	100	100	82	100	NM	NM	100	100
FRI2	90	100	3X9	2X9	36	36	100	100	86	100	100	100	100	NM
LAZ1	90	NC	3X9	2X9	72	72	100	99	100	100	99	100	100	NM
LOM1	90	NC	3X9	3x9	90	90	100	81	91	100	50	100	100	NM
MAR1	90	77	3X9	2X9	108	108	100	100	82	97	NM	NM	100	NM
PIE1	90	NC	3X9	3x9	128	128	100	100	84	100	NM	NM	100	NM
PUG1	90	NC	NM	NM	120	120	100	100	NM	NM	NM	NM	100	100
SAR1	90	NC	3X9	3x9	156	156	100	99	NM	NM	NM	NM	100	100
SIC1	90	NC	3X9	3x9	156	156	NM	NM	90	94	NM	NM	100	NM
TOS1	90	100	3X9	2X9	NA	NA	100	99	33	96	78	100	100	100
TRE1	90	NC	3X9	2X9	96	96	100	100	58	100	84	100	100	NM
UMB1	90	NC	3X9	3x9	NM	NM	100	99	NM	NM	NM	NM	100	NM
VAL1	90	47	3X9	3x9	58	58	100	100	NM	NM	NA	NA	100	84.2
VEN1	90	NC	3X9	3x9	110	110	100	100	74	100	NM	NM	94,4	NM

NA: Not available; NC: not subjected to field check; NM: not measured.

Ground Vegetation - Data about ground vegetation refers to data completeness. In the ground vegetation study at population level (1), in 1996 the requested measurements on the specified grid squares were performed in 85% of *PMPs*: fewer grid squares than requested were measured in LOM1, SAR1 and SIC1. In 1998 the quality level target was achieved in 65% of *PMPs*, and fewer grid squares than requested were measured in CAM1, LAZ1, LOM1, SAR1, TOS1 and UMB1 (no survey was carried out at all in SIC1). For the community level survey (2), the quality target was achieved in 100% of *PMPs*.

Atmospheric deposition - No data on atmospheric depositions for 1997 were provided, since the survey did not cover the entire year; for 1998 there are no data on the intercalibration of analysis laboratories (although the majority of tests for all *PMPs* are performed in a single lab) nor on the reliability of the sampling, whereas there are data available on the percentage of openfield samples with an ionic balance in classes 1 and 2 and the percentage of openfield samples in conducibility classes 1 and 2. Details about Ionic Balance and Conductivity as methods to estimate data quality can be found in several reports (*e.g.* EC and UN/ECE, 1999). In the case of both these parameters percentage values are consistently above 70% (the only exceptions being TOS1 and TRE1, with 33% and 58% respectively of samples with ionic balance in classes 1 and 2).

Air Pollution Measurements - Data provided for the study of gaseous pollutants relate to completeness (percentage of valid records during the given period), quality and reliability of sampling in the ozone and sulphur dioxide surveys. Completeness values relating to ozone data range from 87 to 100% in 1996, from 35 to 100% in 1997, from 83 to 100% in 1998; whereas those relating to sulphur dioxide range from 65 and 100% for 1997 and from 84 to 100% for 1998.

Meteorological measurements - Completeness (percentage of actual records relative to expected records) and the plausibility (percent-

Table 13 - Reliability of data at *PMP* level. Relative margin of error in % of the mean value for each *PMP* and parameter.
Precisione dei dati a livello di singola area permanente. Margine di errore relativo sulla media (%) per ciascuna area e ciascun parametro.

Investigation	Crown	Foliar analysis							Growth		Ground (1)				Ground (2)		Deposition	
Index	Trasparency	Weigth	N	S	P	Ca	Mg	K	DBH	LAI	n species	H*	C	n regen.	n species	C	TF snow	TFrain
Reference period	1996 1998	1995	1995	1995	1995	1995	1995	1995	1996	1997 1998	1996 1998	1996 1998	1996 1998	1996 1998	1996	1996	1998	1998
ABR1	13,6	11,0	5,0	18,8	15,6	2,6	6,5	6,8	6,8	3,1	16,0	29,4	34,0	39,3	11,5	35,4	11,2	8,6
BAS1	16,9	14,7	2,9	10,5	5,6	11,2	23,5	8,1	6,5		7,1	14,8	11,3	14,7	5,0	0,4		
CAL1	12,7	7,5	3,3	5,7	10,5	3,1	8,2	6,3	10,7	5,7	6,9	77,6	9,7	120,8	7,8	10,0	13,3	11,4
CAM1	16,6	15,1	9,6	16,2	9,2	9,4	11,8	9,4	6,7		13,5	54,7	26,0	64,7	7,9	11,7		6,3
EMI1	35,3	14,9	8,4	5,3	14,5	9,2	18,2	40,5	5,4	4,7	12,0	24,8	26,9	33,5	7,5	24,5		10,8
EMI2	15,6	14,4	12,4	8,7	18,9	15,6	25,2	26,5	2,8	1,3	16,1	48,1	33,2	41,5	9,9	15,0		12,3
FRI1	35,5	14,8	11,7	8,3	23,5	10,8	13,2	6,7	5,4	1,2	7,7	9,0	15,5	21,2	7,5	9,4		9,2
FRI2	21,3	27,8	10,3	44,3	26,7	29,8	16,9	15,7	4,8	5,2	12,4	14,9	22,8	28,5	14,3	20,6	13,8	14,4
LAZ1	13,0	7,8	6,4	5,8	9,9	26,9	18,7	9,1	2,9	9,1	7,7	19,1	19,3	19,9	7,1	14,7		5,4
LOM1	31,2								7,5	16,0	9,7	30,6	18,3	38,7	7,5	11,1		
MAR1	19,6	17,0	6,0	6,8	26,0	20,1	47,5	20,8	3,5	4,0	11,1	14,7	23,7	23,6	6,2	13,9		8,1
PIE1	20,6								4,9	5,9	18,1	32,1	74,0	156,9	11,5	28,3	3,1	6,1
PUG1	28,4	13,2	4,9	8,1	14,6	20,8	24,0	15,8	6,4	1,5	6,7	12,5	10,5	28,4	8,8	5,1		
SAR1	11,7	36,2	9,5	15,3	12,3	17,9	12,7	8,0	5,2	0,8	16,3	39,6	29,7	43,4	12,8	31,8		
SIC1	7,9	10,2	2,2	10,3	3,0	4,4	17,0	9,0	2,6	2,5	6,5	10,3	11,1	15,5	7,0	8,6		6,4
TOS1	15,5	19,3	3,7	8,2	18,1	16,7	3,3	15,4	5,0	1,3	7,2	17,4	10,9	24,9	9,9	22,0		
TRE1	15,8	34,3	7,4	10,4	8,3	8,3	4,9	7,6	6,9	4,5	5,7	57,3	9,5	72,1	8,9	9,7	17,5	33,8
UMB1	13,5	6,8	18,9	18,3	8,5	16,2	35,0	11,9	5,4	2,4	10,6	8,4	13,8	12,3	13,1	21,4		
VAL1	17,6								6,2	12,0	12,6	31,8	19,7	68,7	12,3	24,5		
VEN1	18,5	17,9	8,0	11,3	23,4	10,1	17,4	7,7	5,3	5,8	8,7	52,5	20,5	120,8	8,2	20,4	15,4	5,2
Min	7,9	6,8	2,2	5,3	3,0	2,6	3,3	6,3	2,6	0,8	5,7	8,4	9,5	12,3	5,0	0,4	3,1	5,2
Mean	19,0	16,6	7,7	12,5	14,6	13,7	17,9	13,2	5,5	4,8	10,6	30,0	22,0	49,5	9,2	16,9	12,4	10,6
Max	35,5	36,2	18,9	44,3	26,7	29,8	47,5	40,5	10,7	16,0	18,1	77,6	74,0	156,9	14,3	35,4	17,5	33,8

age of plausible records relative to total records) of acquired data range between 81 and 100% for 1997 and between 50 and 100% for 1998 for completeness, and values always of 100% in both years for plausibility (Tables 11-12).

Reliability of the estimates of mean values

An overall picture of reliability of mean values at *PMP* level is given in Table 13. The mean relative margin of error varies between the different investigations.

Crown condition estimated by crown transparency

The findings are conditioned by the skewed distribution of crown transparency data (TESI *et al.* 1997). At present, the mean percentage error for each *PMP* ranges between 7.9 and 35.5% in the three years considered.

Analysis of Soils

Information on soil chemistry cannot be obtained, since there are no replicates within the *PMPs*.

Analysis of Needles and Leaves

Percentage errors in foliar chemistry analysis range from 6.8 to 36.2 % for the weight of 100 leaves/1000 needles, from 2.2 to 18.9 % for total N, from 5.3 to 44.3 % for total S, from 3 to 26.7 % for total P, from 2.6 to 29.8 % for total Ca, from 3.3 to 47.5 % for total Mg, from 6.3 to 40.5 % for total K.

Estimation of Growth and Yield and LAI

Standard deviation of DBH (all species) ranges from 15.1 to 64.7%. Considering the number of observations this implies percentage errors between 2.6 and 10.7% for 1996.

In the case of LAI, standard deviation in 1997 only occasionally reaches 10%, and this suggests that the data are homogeneous. In 1998 data variability appears to increase, with standard deviation values that in two cases are above 20%. Based on the number of observations, percentage errors range from 0.8 to 16 % in the years 1997-98.

Ground Vegetation

As far as Ground vegetation studies are

Table 14 - Nature of sampling, sampling tactics, location of observations and type of observations at *PMP* level for the different investigations carried out within the CONECOFOR programme.
Natura del tipo di campionamento, tattica di campionamento, localizzazione delle osservazioni e tipo di osservazioni livello di singola PMP per le varie indagini condotte nell'ambito del programma CONECOFOR.

Investigation	Nature of sampling design	Sampling tactics	Location	Type of observations
Crown condition	objective(1)	30 trees nearest to the centre of the PMP(1)	PMP	individual, estimate of variability possible
Soil inventory	objective	5 samples (centre plus corners of the PMP)	PMP	pooled, estimate of variability not possible
Foliar analysis	subjective	5 trees belonging to mean defoliation class	buffer zone	individual, estimate of variability possible
Increment/Basal area	objective	All trees above 3cm (coppice) or 5 cm (high forest) DBH	PMP	individual, estimate of variability possible
Increment /Height	objective	Random sampling within DBH class		
LAI	objective	9 measurement according to a 10x10 m grid	PMP	individual, estimate of variability possible
Litterfall	objective	9-16 collectors according to a 10x10 m grid	PMP	individual, estimate of variability possible
Deposition openfield	subjective	3 collectors placed in the nearest open area	within 2 km from PMP	individual, estimate of variability possible
Deposition throughfall	objective	9-16 collectors according to a 10x10 m grid	PMP	(only for precipitation volume)
Meteorology	subjective	1 device placed in the nearest open area	within 2 km from PMP	--
Ozone	subjective	1-5 devices placed in the nearest open area	within 2 km from PMP	individual, estimate of variability possible (in 1996 and 1997)
Ground vegetation	objective	25 quadrats (10x10m each)	PMP	individual, estimate of variability possible

(1) not applicable for TOS1, where trees were selected subjectively.

concerned, percentage errors range on average (in the 1996 and 1998 surveys) from 5.7 to 18.1 % in the case of number of species; from 8.4 to 77.6% for height; from 9.5 to 74 % for canopy cover; from 12.3 to 156.9 % for number of individuals undergoing regeneration.

In the community level study (2), percentage error for 1996 ranges from 5 to 14.3 % for number of species and from 0.4 to 35.4 % for canopy cover.

Atmospheric depositions

The percentage error was calculated for the volume of precipitation, the only parameter measured for each collector. Errors ranges from 3.1 to 17.5% for snow samples and from 5.2 to 33.8% for rain samples. One can observe that in more than 60% of *PMPs* the rain sample under the canopy displays a percentage error below 10%, and TRE1 is the only *PMP* that is markedly different from the others with a 33.80% error.

Air Pollution Measurement

Data about the reliability of air pollution measurements refer to pooled standard deviation, which was always very low (*e.g.* < 2.5 ppb) (data not showed here).

Meteorological measurements

Given the nature of these measurements, data were not specifically requested for meteorological measurements.

Representativity of data at PMP level

Table 14 summarizes some characteristics of the sampling design adopted by the various investigations at the level of each *PMP*. Most of the investigations were carried out according to an objective sampling design with the use of different locational methods: particularly, systematic and random sampling were adopted. In one case, the survey on growth and yield (basal area), all trees above a given DBH threshold were measured, thus avoiding the need of sampling. In all the above cases, the sample can be considered representative of the *PMP*, since the bias in sample selection is theoretically avoided by the scheme adopted and the probability of sampling can be theoretically known for each element of the population. This is true also for tree condition assessment where however probability of sampling is higher for those trees close to the centre of the *PMP* (*e.g.* HEINONEN and LINDGREN 2000). In the above cases, inferences at the *PMP* level are free of subjectivity: thus it is possible to say that *e.g.* mean nitrogen deposition rates at *PMP* ABR1 are 10 kg per hectar per year.

Sampling for foliar analysis (where the trees were subjectively selected), and the openfield measurements of deposition, meteo and ozone (for which the most suitable site was selected without undertaking any formal selection procedure) are the exceptions. In those cases, the sample cannot be considered representative of the sampled population and inferences at the

PMP level are subjected to a number of assumption. Statements like, “mean nitrogen concentration in beech leaves at *PMP* ABR1 is 2.2 % d.w.” can be questioned.

A final question that deserve to be considered is the way in which data are actually collected at *PMP* level. For example, most of the investigations collects data for each individual sub-sample and this allows estimates of within-*PMP* variability which is essential to evaluate *e.g.* changes between two subsequent sampling occasions. Other investigations used pooled samples. Although it is useful to reduce costs, it makes it impossible to evaluate within - *PMP* variability and therefore to estimate the significance of changes.

Conclusions

Availability, quality and reliability of the data collected at the *PMPs* of the CONECOFOR program are important issues when attempting to carry out an integrated evaluation.

Data availability has increased considerably since the 1995. Up to date, all the 20 *PMPs* installed in 1995 are covered for the investigations on tree condition, soil, foliar chemistry, growth/increment, ground vegetation, LAI, litterfall and ozone. According to the European guidelines, deposition and meteorology are carried out on a more limited number of *PMPs*.

Different data quality issues were considered. Data completeness is high in general for all the investigations, although some problems exists expecially with meteorological measurements at certain *PMPs*, where technical constraints caused some gaps in the data series. Reproducibility of data is not always satisfying, with problems being particularly important for crown condition. Reliability of data varies within and between investigations and the margin of error relative to the mean exceed 20% for many indicators and indices. This reveals that – in many cases - current sampling densities are inadequate. In addition, there could be considerable consequences in the frame of the integrated evaluation as there is a risk for error propagation. This makes important to develop an error model.

Approaches to integrated evaluations oftenly use statistical descriptors (*e.g.* mean, median,..) calculated at *PMP* level. However, the degree at which mean values at *PMP* level can be considered an unbiased estimate of the true value of the index considered depends on the sampling strategy adopted. When sampling is carried out objectively, representativity can be considered safe. In general, sampling strategies at the *PMP* of the CONECOFOR program were found to be objective, the only exception being the investigations on foliar chemistry and all those using equipments in the openfield (deposition, ozone, meteo). While for investigations using equipments is always difficult to have a probabilistic sampling design, the investigation on leaf/needle chemistry will receive considerable benefits in adopting a more suited sampling design. This will have beneficial consequences also on the whole integrated and combined evaluation system.

References

Bussotti F., Ferretti M., Cozzi A., Cenni E., 1999 - *Condizione delle chiome degli alberi. Valutazione nelle aree permanenti di livello 2°.* MANUALE DI CAMPAGNA. (Maggio 1999, Revisione 1). Pubblicato da Ministero per le Politiche Agricole, Roma: pp. 92.

Bussotti F., Ferretti M., Giordano P., Mazzali C., 2000. *A synthetic index to estimate tree condition in the Permanent Monitoring Plots of the CONECOFOR program.* In: Ferretti M. (ed.), “Integrated and Combined (I&C) evaluation of intensive monitoring of forest ecosystems in Italy – Concepts, Methods and First Results” Annali dell’Istituto Sperimentale per la Selvicoltura, Special Issue, anno 1999, 30: 67-72.

EC-UN/ECE, 1998 -De Vries W, Reinds G. J., Deelstra H. D., Klap J. M., Vel E. M. – *Intensive Monitoring of Forest Ecosystems in Europe, 1998 Technical Report.* EC, UN/ECE 1998, Brussels, Geneva. 193 ps.

EC-UN/ECE, 1999 - De Vries W, Reinds G. J., Deelstra H. D., Klap J. M., Vel E. M. – *Intensive Monitoring of Forest Ecosystems in Europe, 1999 Technical Report.* EC, UN/ECE 1999, Brussels, Geneva. 173 ps.

Eichhorn J., Ferretti M., Innes J.L., Roskams P., Vel E., 1996 - *Visual assessment of tree condition.* UN/ECE ICP-Forests, Manual on method and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests. 4th edition.

Ferretti M., Cozzi A., Cenni E., Bussotti F., 1998 - *Forest Ecosystem Monitoring. The "How" and the "How Not" in Multidisciplnary Monitoring Programs.* Atti I° Congresso SISEF, Padova, Agripolis, Giugno 1997: 293-298.

Ferretti M., Bussotti F., Cenni E., Cozzi A., 1999- I*mplementation of Quality Assurance procedures in the Italian programs of forest condition monitoring.* Water Air Soil pollution, 116: 371-376.

Ferretti M., Bussotti F., Giordano P., Mazzali C., Nibbi R., 2000 - *Program CONECOFOR – Integrated and Combined (I&C) Evaluation of Risk, Status and Changes of Forest Ecosystems.* In: SISEF, Atti, 2: 435-440.

Ferretti M., Giordano P., Mazzali C., Nibbi R.,1999 a - *Valutazione integrata e combinata (I&C) dei dati raccolti nelle aree permanenti di monitoraggio (APM) intensivo degli ecosistemi forestali in Italia.* Rapporto Fase 1. Università di Firenze, Dipartimento di Biologia Vegetale, Laboratorio di Botanica Forestale ed Applicata, Aprile 1999: 19 ps + Annexes 1-7.

Ferretti M., Giordano P., Mazzali C., Nibbi R.,1999b - V*alutazione integrata e combinata (I&C) dei dati raccolti nelle aree permanenti di monitoraggio (APM) intensivo degli ecosistemi forestali in Italia.* Rapporto Fase 2. Università di Firenze, Dipartimento di Biologia Vegetale, Laboratorio di Botanica Forestale ed Applicata, Luglio 1999: 30 ps.

Ferretti M., Giordano P., Mazzali C., Nibbi R., 1999c - *Valutazione integrata e combinata (I&C) dei dati raccolti nelle aree permanenti di monitoraggio (APM) intensivo degli ecosistemi forestali in Italia.* Rapporto Fase 3. Università di Firenze, Dipartimento di Biologia Vegetale, Laboratorio di Botanica Forestale ed Applicata, Aprile 1999: 27 ps.

Heinonen J., Lindgren M., 2000 - *Comparison of sampling methods for crown condition surveys.* In: Ukonmaanaho L., Raitio H., Forest Condition in Finland National Report 1999, The Finnish Forest Reasearch Institute, Research Paper 782, 2000: 90-97.

Köhl M., Traub B., Päivinen R., 2000 - *Harmonization and standardization in multi-national environmental statistics – mission impossible?* Environmental Monitoring and Assessment, 63: 361-380.

Tesi, G., Cenni E., Ferretti M., 1997 - *Normalizzazione dei dati di trasparenza delle chioma per l'analisi statistica dei risultati dei rilevamenti delle condizioni degli alberi.* Monti e Boschi, 3: 54-58.

Wagner G., 1995 - *Basic approaches and methods for quality assurance and quality control in sample collection and storage for environmental monitoring.* The Science of Total Environment, 176: 63-71.

Spatial and temporal aggregation of the CONECOFOR data for the Integrated and Combined (I&C) analyses[§]

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Abstract - This paper describes some issues which are important in the implementation of the analyses of the Integrated and Combined (I&C) evaluation system. Aggregation of data for the various I&C analyses depends on the analysis to be undertaken, on the investigations carried out at the various *PMPs* and on the sampling regimes of the various investigations. Different analyses require different data sets: for example a Risk Analysis (RA) aimed at evaluating the potential exposure to ozone will need at least five years of ozone data, while association between variables to detect trends will require 10 years as a minimum. The spatial allocation of individual investigations resulted in different monitoring intensity levels for individual plots. Accordingly, different levels of evaluation may be necessary. Sampling regimes vary between specific investigations and this makes it necessary to identify suitable "time windows" in order to make maximum use of existing data. The combination of evaluation levels with time windows places serious limitations to the whole evaluation system.

Key words: *data availability, data analysis, evaluation levels, time windows.*

Riassunto - Aggregazione spaziale e temporale dei dati CONECOFOR per le analisi Integrate e Combinate (I&C) - L'articolo descrive alcuni aspetti di importanza per la definizione della valutazione Integrata e Combinata (I&C). L'aggregazione dei dati dipende dal tipo di analisi che si vuole intraprendere, dalle misurazioni effettuate nelle singole indagini e dal regime di campionamento delle singole indagini. Tipi di analisi diverse richiedono diverse aggregazioni di dati: ad esempio la valutazione del rischio da una potenziale esposizione ad ozono richiede almeno 5 anni di dati per singola area permanente, mentre per stimare trend temporali ed associazioni tra variabili nel migliore dei casi sono necessari almeno 10 anni. La disponibilità di indagini a livello di singola area permanente è diversa e ciò determina la necessità di utilizzare livelli di valutazione differenziati. Il regime di campionamento e/o di aggregazione dei dati è variabile tra le varie indagini e ciò rende necessario identificare "finestre temporali" adatte per consentire il massimo uso dei dati esistenti. La combinazione di livelli di valutazione differenziati e di finestre temporali condiziona seriamente l'intero sistema di valutazione.

Parole chiave: *analisi dei dati, disponibilità dei dati, livelli di valutazione, finestre temporali.*

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There are many possible ways of integrating and combining the data generated by the various Specific Investigations (SIs) carried out within the CONECOFOR program. However, the actual possibilities are directly connected to the analysis to be undertaken and the data availability in space (*i.e. PMPs* covered by a given investigation) and time (*i.e.* years in which a given *PMP* is covered by a given investigation) – (Ferretti and Nibbi this volume). These factors are the major determinants of data aggregations (Table 1), and include other more subtle issues like the completeness of data series (which is directly connected with both the spatial and temporal availability of the data). Different spatial allocations and different sampling regimes and/or different time aggregations may lead to substantial problems when attempting to integrate data from different investigations.

In this chapter, the questions raised by the different monitoring intensities and the different sampling regimes and/or time aggregations are discussed in relation to the analysis to be undertaken within the Integrated and Combined (I&C) evaluation system.

Materials and methods

The range of actual possibilities of aggregating, integrating or combining data from different SIs is explored considering four categories of data aggregation determinants (Table 1).

Table 1 - Factors determining the actual chances of aggregating the data generated by different SIs.
Fattori che determinano le effettive possibilità di aggregare i dati generati da diverse indagini specifiche.

Data aggregations determinants	Effects on data aggregation
Type of I&C analysis	control the nature of the data to be used
Spatial coverage of SIs	control the number of cases for any given analysis
Time coverage of SIs	control the timing of different data sets and the number of cases
Ecological coverage of SIs	control the ecosystem compartments that can be evaluated

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Table 2 - Specific investigations, the year they were begun , number of *PMPs* covered, sampling regimes, repetition available and traditional reporting time unit in Italy.
Indagini specifiche, anno di inizio, aree interessate, regime di campionamento, ripetizioni disponibili e unità di tempo a cui vengono riportati i dati in Italia.

Investigation	First Year	No. of PMPs	Sampling regime	Repetition available(1)	Reporting time unit
Soil chemistry	1995	20	10y	95	1y
Growth and yield	1996	20	5y	96, 00	1y
Foliage chemistry	1995	20	2y	95, 97, 99	1y
Ground vegetation	1996	20	1y	96, 98, 99, 00	1y
Crown condition	1996	20	1y	96, 97, 98, 99, 00	1y
LAI	1997	20	1y	97, 98	1y
Litterfall	1997	20	1m	97, 98	1y
Ozone	1996	20	1w	96, 97, 98, 99, 00	1y (summer)
Deposition	1998	13	1w	98, 99, 00	1y
Soil solution	1999	2	1w	99, 00	1y
Streamflow	1998	2	1w	98, 99, 00	1y
Meteo	1998	9	continuous	98, 99, 00	1y

Y: year; m: month; w: week; (1): update: August 2000.

For each type of I&C analysis (first determinant – see FERRETTI this volume), the effects of the other determinants on the actual data availability are discussed taking into account the kind of data needed and the ratio between variables and cases. On this basis, forecasts are provided about the time at which the various I&C analyses will become possible.

Results

The three categories of analysis of the I&C system (Risk Analysis, Status and Change analysis and Nature of Change analysis) have clearly different requirements in terms of data needed.

Needs related to Risk Analysis (RA)

The Risk Analysis will be undertaken in relation to atmospheric deposition (acidifying compounds and nitrogen), ozone and meteorological stresses. Although it is always possible to use modelled data, it is obvious that RAs will be carried out better with data actually collected at the various *PMPs*. Therefore, RAs are possible when and where measurements of deposition, ozone and meteo are undertaken (Tables 2- 3). In addition, for a full understanding and evaluation of *e.g.* ozone risk we shall need to know data on some parameters closely connected with meteo stresses, especially those indicating the potential of water stress (MILLS *et al.* 2000). This may reduce considerably the number of *PMPs* where the RA can be fully implemented. An additional point is that data on stressors like deposition and ozone are subject to marked inter- and intra-annual variations (for examples see MOSELLO and MARCHETTO this volume; BUFFONI and TITA this volume) and this makes it necessary to concentrate the work on average values calculated over 5 years (*e.g.* POSCH *et al.* 1999). Thus, RAs will be possible only once 5 years of deposition, ozone and meteo data are available. This will occur soon for all three investigations (Table 4).

Table 3 - Number of *PMPs* which can provide data to certain RAs. See text for further details
Numero di aree permanenti che possono fornire dati a varie analisi di rischio. Ulteriori dettagli nel testo.

Main species	Acidification eutrophication	Risk Analysis Ozone	Meteo
Fagus sylvatica (n: 7)	6	7(2)	2
Picea abies (n: 4)	3	4(4)	4
Quercus cerris (n: 4)	3	4 (1)	1
Quercus ilex (n: 2)	1	2 (2)	1
Quercus petraea+robur (n: 2)	2	2 (1)	1

in brackets: the number of PMPs with both ozone and meteo data.

Needs related to Status and Changes (S&C) analysis

Since it aims to make a combined use of all the datasets generated by the CONECOFOR program, the S&C analysis is the most complex analysis of the I&C evaluation system. S&C needs to identify at which level the analysis is possible for individual *PMPs*, and at which time.

Defining the Evaluation Levels (ELs)

The monitoring program is based on a series of investigations which define the intensity level of monitoring: roughly, the more numerous the investigations, the more intensive the moni-

Table 4 - Data needed for RA and expected time of feasibility for RAs.
Categorie di dati che possono essere utilizzati e prevedibile epoca in cui potrà essere possibile effettuare le varie RA.

Risk Analysis	Data planned to be used	First possible
Deposition of N and acidifying compounds	soil, deposition, site and stand data	2002-2003
Ozone	ozone, phenology, meteo, site and stand data	2001-2002
Meteorological stress	meteo, phenology, site and stand data	2002-2003

Table 5 - Investigations that provide data for the various Evaluation Levels (ELs) of the S&C analysis. In brackets those data collected by specific side-projects which may be discontinued.
Indagini che forniscono dati utilizzati ai vari livelli di valutazione (EL) per l'analisi S&C. Tra parentesi le indagini portate avanti come progetti collaterali a CONECOFOR e la cui prosecuzione è incerta.

Evaluation Level I	Evaluation Level II	Evaluation Level III
Crown condition, Growth and yeld, Soil chemistry, Foliage chemistry, Ground vegetation (Ozone), (LAI), (Littertrap)	Deposition chemistry (soil solution) (streamflow)	Meteo measurements
	+ EL I	+ EL I and II
Total 20 PMPs	Total 15 PMPs	Total 9 (8) PMPs (a)

(a) PMPs with meteo measurements does not coincide with deposition measurements (see Table 6).

toring. An overview of the set-up of the CONECOFOR program is provided by ALLAVENA *et al.* (1999), while details about specific investigations are given in the papers under the section on Results of this volume. Unfortunately, investigations are not always replicated at all *PMPs* (see FERRETTI and NIBBI this volume). The immediate consequence is that the S&C evaluation cannot be performed at the same level for every *PMP*. Thus, it seems necessary to identify different evaluation levels (ELs) to be defined according to the intensity level of monitoring. The I&C Task Force agreed upon the following ELs (Table 5):

Evaluation Level 1, which is the basic evaluation level. It concerns all the *PMPs* where the so-called core measurements are undertaken. The core measurements are those that are mandatory for all the *PMPs* according to the EU regulations, supplemented by those investigations carried out within specific CONECOFOR side-projects (*e.g.* ozone). A major limitation for this EL is represented by the sampling regimes of certain investigations, like soil, which require extended time series.

Evaluation Level 2, which concerns the *PMPs* where core measurements plus deposition measurements are carried out. This EL is influenced by the fact that deposition measurements are carried out in *15 PMPs* (which is a high number in relation to the total number of *PMPs* in Italy), but with 4 different major species (see FERRETTI this volume).

Evaluation Level 3, which concerns the *PMPs* where core measurement plus deposition and plus meteorological measurements are carried out. As for EL2, EL3 is influenced by the few possible "replicates" (see FERRETTI this volume).

Some questions may concern data provided by those investigations which were extensively carried out in the past (ozone, LAI, litterfall) but with an uncertain future. This may affect some part of the RA and of the NoC analysis but it is expected to be of little importance for the S&C. In fact, it is always possible to perform the S&C analysis with or without those data. Similar questions – and similar answers – apply to data provided by soil solution and streamflow measurements which are carried out only on very few *PMPs*. *PMPs* that can contribute data to the different ELs are listed in Table 6.

Possible time windows for the S&C analysis

The questions raised by the different sampling regimes (Table 2) adopted by the specific investigations need to be considered carefully especially in the light of the S&C analysis. For

Table 6 - *PMPs* that can contribute data for different Evaluation Levels. Time windows covered by the data are listed. NF: Not Feasible.
Schema dei possibili livelli di analisi per singola APM in funzione della disponibilità dei dati. Viene indicato il periodo per cui i dati necessari a ciascun livello di analisi sono disponibili. NF: Non Fattibile

PMP	EL1	EL2	EL3
ABR1	1995-2000	1998-2000	1997-2000
BAS1	1998-2000	NF	NF
CAL1	1995-2000	1998-2000	NF
CAM1	1995-2000	1998-2000	NF
EMI1	1995-2000	1998-2000	1998-2000
EMI2	1995-2000	1998-2000	1999-2000
FRI1	1995-2000	1999-2000	NF
FRI2	1995-2000	1998-2000	1998-2000
LAZ1	1995-2000	1998-2000	1998-2000
LOM1	1995-2000	1998-2000	1997-2000
MAR1	1995-2000	1998-2000	NF
PIE1	1995-2000	1998-2000	NF
PUG1	1995-2000	NF	NF
SAR1	1995-2000	NF	NF
SIC1	1995-2000	1998-2000	NF
TOS1	1995-2000	1998-2000	1996-2000
TRE1	1995-2000	1998-2000	1998-2000
UMB1	1995-2000	NF	NF
VAL1	1995-2000	NF	1995-2000
VEN1	1995-2000	1998-2000	NF

example, soil data are available every 10 years, while a number of other investigations will provide data on an annual basis. There are two possible options in order to deal with this:

- assume the soil data valid for a time window of 10 years, adopting a conventional shift and centre the ten year period on the year of sampling. Then, assign the measured value to every year of the 10 year period. This way, soil data can be used every time the S&C analysis is carried out. On the other hand, this is a strong assumption and violates one of the conditions needed for calculating the Mahalonobis distance;
- define an iterative procedure that will not use all the data all the time, but only use data when they are actually available. This way a full run of the analysis is subject to the timing between the least frequent investigation and the annual ones. For example, soil data will be available every 10 years: thus, when attempting to relate soil data to crown condition data (collected every year), crown condition data will be used once every 10 years. In addition, the number of variables added to the whole will increase and this will create the need for longer time series to increase the number of cases. On the other hand, this option can keep all the datasets generated by the various investigations consistently connected to each other, without the need of assumptions.

The I&C Task Force agreed upon this latter option, especially in relation to the fact that some variables (like *e.g.* the soil data) will have variance equal to zero in the former approach and this is not allowed by the statistical method adopted (see Ferretti *et al.* this volume). Thus the following time windows (TWs) for the S&C analysis can be considered:

TW1, *annual* evaluations: they will involve all the investigations that can provide data for every year (biological status: crown condition, ground vegetation; chemical status: ozone, deposition; physical status: meteo). Note that the indicators of biological status are also response indicators and that the indicators of the chemical and physical status are also stressor indicators.

TW2, *biennial* evaluation: here the foliage chemistry is incorporated in the evaluation.

TW5, *five* years evaluation: the growth and yield data are added to the evaluation.

TW10, *ten* years evaluation. Every 10 years a full run of the system is potentially possible, with new soil data becoming available.

It is important to recognize that the most important limiting factors of these schedules are two core surveys like growth and soil. It follows that the full implementation of EL I will be the most difficult to be covered by the S&C analysis (see below).

Evaluation levels and time windows: feasibility of S&C analysis

In the previous chapters three evaluation levels and four evaluation time windows were identified. The overlapping between the two is only partial because some core surveys like soil are not available for every year. Conversely, deposition and meteo (which are not core surveys) are available every year. This means that the evaluation plan needs to consider both evaluation level and time windows in order to identify what can be actually feasible. Table 2 reports the current availability of data in relation to the investigations, while Table 7 reports the specific data availability for each possible evaluation level (as defined above) and each possible time window (as defined above). It is obvious that the actual possibilities of combining and integrating data are far fewer than those the number of investigations may suggest. This is particularly true for the 1 year evaluations on those plots where neither deposition nor meteo measurements are carried out. In these situations, only crown condition, ground vegetation and ozone can be evaluated together.

Taking into account Table 7, Table 8 lists the number of *PMPs* for each individual species that can contribute to the S&C analysis of the I&C evaluation system. Again, the numbers are rather low, and they become lower as the EL increases. Thus, according to the definition of cases given by Ferretti (this volume), to have a sufficient number of cases to carry out a proper S&C analysis it is necessary to identify a minimum number of years. Obviously, the minimum number of years (data series) needed for the S&C

Table 7 - Investigations (subdivided into those contributing response and stressor indicators) that can be adopted at each EL (see Table 1) and their possible periodicity in the evaluation system.
Indagini (suddivise tra quelle che possono fornire indicatori di risposta ed indicatori di stress) che possono essere adottate per ciascun livello di valutazione (vedi Tabella 1) e possibile periodicità nel sistema di valutazione.

Time	Evaluation Level					
	EL1		EL2		EL3	
	Response	Stressor	Response	Stressor	Response	Stressor
Every 1 year	CC, GV	O3	CC, GV	O3, Dep	CC, GV	O3, Dep, Mt
Every 2 year	CC, GV, F	O3	CC, GV, F	O3, Dep	CC, GV, F	O3, Dep, Mt
Every 5 year	CC, GV, F, G	O3	CC, GV, F, G	O3, Dep	CC, GV, F, G	O3, Dep, Mt
Every 10 year	CC, GV, F, G, S	O3	CC, GV, F, G, S	O3, Dep	CC, GV, F, G, S	O3, Dep, Mt

CC: crown condition, GV: ground vegetation, F: foliage chemistry, G: growth, S: soil; O3: ozone;
Dep: deposition; Mt: metorological measurements.

Table 8 - Number of *PMPs* for each major species that can be evaluated in relation to the ELs and time as they are reported in Table 4 and 7.
Numero di aree permanenti per ciascuna specie principale che possono essere valutate in relazione al livello di valutazione ed al tempo secondo le definizioni date in Tabella 4 e 7.

Time	Evaluation		
	EL1	EL2	EL3
Every 1 year	7Fs, 4Pa, 4Qc, 2Qi, 2Qp	6Fs, 2Pa, 3Qc, 1Qi, 2Qp+r	2Fs, 4Pa, 1Qc, 1Qi, 1 Qp
Every 2 year	7Fs, 4Pa, 4Qc, 2Qi, 2Qp	6Fs, 2Pa, 3Qc, 1Qi, 2Qp+r	2Fs, 4Pa, 1Qc, 1Qi, 1 Qp
Every 5 year	7Fs, 4Pa, 4Qc, 2Qi, 2Qp	6Fs, 2Pa, 3Qc, 1Qi, 2Qp+r	2Fs, 4Pa, 1Qc, 1Qi, 1 Qp
Every 10 year	7Fs, 4Pa, 4Qc, 2Qi, 2Qp	6Fs, 2Pa, 3Qc, 1Qi, 2Qp+r	2Fs, 4Pa, 1Qc, 1Qi, 1 Qp

Fs: Fagus sylvatica, Pa: Picea abies, Qc: Quercus cerris, Qi: Quercus ilex,
Qp+r: Quercus petraea+ Quercus robur.

analysis varies with the EL (which controls the number of variables) and the species considered (which controls the number of cases). To have at the least a number of cases 5 times greater than the number of variables, very long time series are needed especially, when trying to use any existing repetitions of soil surveys. Table 9 reports an example for beech, the species with the highest number of *PMPs*. The number of repetitions is calculated taking into account the need to have at least 5 cases for each variable. For example, with 3 variables, at least 15 cases are needed. Having 7 beech *PMPs* for EL1, at least three repetitions of the investigations will be needed. If we consider annual surveys under the EL1-TW1 hypothesis (crown condition, ground vegetation and ozone – see Table 5), they all started in 1996 (see Table 2) so it is possible to implement the S&C analysis after the collection of three years of data, which is 1998. Following this method, it is possible to foresee when the various combinations between ELs and TWs will make S&C analysis feasible. From Table 9 it is possible to see that – if the aim is to use all available data together - growth data (characteristic of time window 5) cannot be used before 2025, and soil data (time window 10) before 2065. On the other hand, by 2007 it will be possible to evaluate the status and changes of beech plots using data from annual and biennial surveys at EL 2: crown condition, ground vegetation, foliar chemistry, ozone and deposition. In cases other than beech, where the number of *PMPs* is smaller, some S&C analysis will not be possible. Again, the influence of the program design is strong in determining the actual possibilities of data analysis.

Table 9 - Possible implementation of S&C analysis according to the time window covered by the available data, the Evaluation Level and the ratio between cases and variables. See the text for further details.
Possibile implementazione dell'analis S&C in relazione alla finestra temporale coperta dai dati disponibili, al livello di valutazione possibile ed al rapporto tra casi e variabili. Ulteriori dettagli nel testo.

Time window	Evaluation Level	Beech			
		Cases	Variables (1)	Repetition needed	First possible
1	1	7	3(a)	3	1998
2	1	7	7(b)	5	2003
5	1	7	8 (c)	6	2025
10	1	7	10(d)	8	2065
1	2	6	5 (e)	5	2002
2	2	6	9	7	2007
5	2	6	10	9	2040
10	2	6	12	10	2085
1	3	2	9(f)	23	2020
2	3	2	14	35	2065
5	3	2	15	38	2190
10	3	2	17	43	2425

(1)under the hypothesis to cumulate the variables.
(a): considering only one variable for each crown, ground vegetation and ozone.
(b): plus 4 variables for foliage chemistry (N-ratios)
(c): plus 1 variables about increments (basal area)
(d): plus 2 variables for soil (C/N and AcExch)
(e): as in (a) plus 2 variables for deposition (H^+ and N dep.) (apply also to the other EL 2)
(f): as (e) plus 4 variables for meteo measurements (apply also to other EL3).

Table 10 - Possible implementation of S&C analysis when the aggregation of data is carried out taking into account their ecological coverage. The example refers to beech *PMPs*. See the text for further details.
Possibile implementazione dell'analis S&C in relazione all'aggregazione dei dati rispetto alla loro copertura ecologica. L'esempio si riferisce alle aree di saggio a prevalenza di faggio. Ulteriori dettagli nel testo.

	Ecosystem conditions		
	Biological	Chemical	Physical
Specific Investigations	CC, GV, G	F, S, Dep, O_3	Mt
Nr. of variables	3	9	4
Repetition needed	3	8	7
Limiting SI	G	S	-
First possible	2010	2065 (2003)	2004

CC: Crown condition; GV: ground vegetatition; G: forest growth;
F: foliar chemistry; S: soil chemistry; D: deposition, O_3: ozone; Mt: meteo
in brackets: the year when chemical conditions would be evaluable without soil data.

Aggregation of data in relation to their ecological coverage

The above problems forced us to consider alternative aggregation of data for the S&C analysis. Data can be evaluated in order to identify status and changes of the biological, chemical and physical conditions of the target ecosystems. This approach reduces the number of variables and therefore needs shorter time series (Table 10). However, the use of soil data remains a problem.

Needs in relation to the Nature of Change Analysis (NoC)

NoC analyses will concentrate on time series at individual *PMPs*. In this context, the only problem of data aggregation is related to the different sampling regimes adopted by the various investigations. In practice, the more frequent the investigations, the earlier it will be possible to build up a sufficient dataset. With this background, many of the points raised for the RA and S&C analyses are relevant also to NoC. However, NoC has some peculiarities since its aim is to identify cause-effects of the changes in response indicators as soon as they are detected. In this context, multiple regression techniques can be of help in identifying relationships between response and stressor indicators. While simple correlations between *e.g.* foliar nitrogen and nitrogen deposition can be explored in a relatively short time (Table 11), others will require a lot of time. However, the use of multiple regression will require much longer time series, according to the number of stressor (predictors) that are used.

Conclusions

The I&C evaluation systems need to consider carefully the kind of analysis to be undertaken, what data are available, where and when they are available. Different intensity level of monitoring and different sampling regimes for individual investigations make it difficult to streamline the whole I&C process, especially in relation to its S&C analysis. In this paper, issues related to the actual possibility of integrating data from different SIs were discussed for each kind of I&C analysis.

RA seems to be feasible in a relatively short time, given the fact that most of the data needed are currently being collected, although not at all *PMPs*.

S&C analysis is clearly the most complex analysis. Different evaluation levels (ELs) and time windows (TWs) were defined in order to understand what are the actual chances of performing an integrated analysis of ecosystem status and changes. The combination of ELs and TWs allows the identification of which investigations can contribute data for the S&C analysis. Considerations on the ratio between variables and cases allows us to predict the time when S&C analysis will be possible, again in relation to a specific EL.

The outcome of this process clearly indicates that – even under the most favourable conditions provided by the relatively high number of beech plots - there could be some problems with the increment and the soil data, which cannot be fully used in the S&C until 2025 and 2065, respectively. These problems risk becoming

Table 11 - Example of time series needed in order to have 10 cases on a scatterplot for each individual *PMP* and each stressor-response combination.
Esempio delle serie temporali necessarie per avere almeno 10 casi su un diagramma di dispersione di punti per ogni PMP *ed ogni combinazione stressor-response.*

	Stressor			
Response	Deposition	Ozone	Meteo	Biotic agents
Crown	1998-2007	1996-2005	1998-2007	1996-2005
Foliar chemistry	1999-2017	1997-2013	1999-2017	1997-2013
Ground vegetation	1998-2007	1996-2005	1998-2007	-
Forest growth	2000-2045	2000-2045	2000-2045	2000-2045
Soil	1995-2085	-	1995-2085	-

insoluble for those *PMPs* with less frequent species, the worst situation being for holm oak plots.

NoC analysis needs to be carried out at individual *PMPs* and will be based on regression and ordination techniques. Simple regression between individual stressor-response combinations will be feasible in a relatively short time, while more complex, multiple regression and ordination will require longer time series to cope with the unfavourable ratio between cases and variables.

The ratio between cases and variables is clearly the most problematic issue of the whole I&C system. This reflects once again the relatively little attention paid by the whole European program in addressing the design issues raised by the needs of an effective monitoring system. At the same time, programs at a national level should consider carefully whether it is wise to disseminate plots and/or measurements over a variety of ecosystem conditions or rather if it is not better to concentrate investigations on plots with similar characteristics, *e.g.* dominant species, soil type and so on (*e.g.* KÖHL *et al.* 1994). Although the value of collecting information on a variety of ecosystems must not be underestimated, it is equally important to consider that data collected must be put to effective use and analysed in order to investigate relationships and draw conclusions as to factors affecting ecosystem status and changes. The example of soil data is of particular interest: while sampling and analysis of the solid phase of soil is important in describing the actual ecosystem condition, the use of soil data for trend analysis is being seriously questioned, especially where (like Italy) the sampling carried out in 1995 does not provide samples capable of evaluating within-plot variability. In addition, the relatively low sensitivity of soil to changes has determined a low intensity of sampling (10 years) which obviously affects the feasibility of any trend analysis that considers soil data, with decades or centuries necessary before having a sufficient data set.

References

ALLAVENA S., ISOPI R., PETRICCIONE B., POMPEI E., 1999 - *Programma nazionale integrato per il controllo degli ecosistemi forestali*. Primo rapporto – 1999. Ministero per le Politiche Agricole, Direzione generale delle Risorse Forestali, Montane ed Idriche, Corpo Forestale dello Stato: 167 ps.

BUFFONI A., TITA M., 2000 - *Ozone measurements by passive samplers at Italian forest sites*. In: Ferretti M. (ed.), “Integrated and Combined (I&C) evaluation of intensive monitoring of forest ecosystems in Italy – Concepts, Methods and First Results” Annali dell’Istituto Sperimentale per la Selvicoltura, Special Issue, anno 1999, 30: 121-127.

FERRETTI M., 2000 - *An introduction to the integrated and combined (I&C) evaluation system designed for the intensive monitoring of forest ecosystems in Italy*. In: Ferretti M. (ed.), “Integrated and Combined (I&C) evaluation of intensive monitoring of forest ecosystems in Italy – Concepts, Methods and First Results” Annali dell’Istituto Sperimentale per la Selvicoltura, Special Issue, anno 1999, 30: 7-16.

FERRETTI M., GIORDANO P., MAZZALI C., 2000 - *Methods of analysis of the I&C evaluation system*. In: Ferretti M. (ed.), “Integrated and Combined (I&C) evaluation of intensive monitoring of forest ecosystems in Italy – Concepts, Methods and First Results” Annali dell’Istituto Sperimentale per la Selvicoltura, Special Issue, anno 1999, 30: 33-42.

FERRETTI M., NIBBI R., 2000 - *Procedures to check availability, quality and reliability of data collected at the CONECOFOR Permanent Monitoring Plots*. In: Ferretti M. (ed.), “Integrated and Combined (I&C) evaluation of intensive monitoring of forest ecosystems in Italy – Concepts, Methods and First Results” Annali dell’Istituto Sperimentale per la Selvicoltura, Special Issue, anno 1999, 30: 43-57.

KÖHL L. M., SCOTT C. T., ZING G. A., 1994 - *Permanent monitoring plots: potential and limitations*. In: Innes, J. L. (Ed), “Assessment of increment in permanent sample plots established to determine the effects of air pollution on forests”, Proceed. of the Sopron workshop, August 28 to September 1, 1993, Sopron, Hungary, WSL/FNP: 17-24.

MILLS G., HAYES F., BUSE A., REYNOLDS B., 2000 - *Air pollution and vegetation*. UN/ECE ICP Vegetation, Annual Report 1999/2000. Centre for Ecology and Hydrology: 48 ps.

MOSELLO R., MARCHETTO A., 2000 – *Atmospheric deposition and streamflow chemistry at the Permanent Monitoring Plots of the CONECOFOR program*. In: Ferretti M. (ed.), “Integrated and Combined (I&C) evaluation of intensive monitoring of forest ecosystems in Italy – Concepts, Methods and First Results" Annali dell'Istituto Sperimentale per la Selvicoltura, Special Issue, anno 1999, 30: 117-120.

Posch M., De Smet P.A.M., Hettelingh J.-P., Downing R. J., 1999 - *Calculation and mapping of critical thresholds in Europe.* RIVM Report No. 259101009: 165 ps.

A synthetic index to estimate tree condition in the Permanent Monitoring Plots of the CONECOFOR programme[§]

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Abstract – Tree condition is assessed by many indices which create the need for synthesis. Formal statistical approach (Factor Analysis) and conceptual approach were used to identify a synthetic index of tree condition. FA failed to provide a consistent answer because data are subjected to marked variations through time and space, with some indices being important determinants of the common variance in a given year at a given Permanent Monitoring Plot (*PMP)* and some others in another year or *PMP*. The conceptual approach was based on the assumption that tree condition worsens when the score of selected indices increases and when the number of positive indices increases. This makes it possible to identify a subset of indices to be combined into a new one. Although the new index is still dependent on data availability, it allows a meaningful synthesis of data when there is the need to have a simple index of the tree status at a given plot and year.

Key words: *tree condition, Factor Analysis, synthetic index.*

Riassunto – Un indice sintetico per stimare le condizioni degli alberi nelle aree permanenti CONECOFOR. La condizione degli alberi è valutata attraverso molti indici, cosa che crea la necessità di una sintesi. Allo scopo di definire un indice di sintesi sono stati usati sia un approccio formale di natura statistica (Analisi Fattoriale) sia un approccio concettuale. L'analisi fattoriale non ha permesso di definire nessun indice coerente tra i vari anni e le varie aree di studio. Questo perché il contributo dei vari indici alla varianza comune varia da area ad area e di anno in anno. L'approccio concettuale si è basato sugli assunti che le condizioni degli alberi peggiorano all'aumentare dei punteggi di certi indici ed all'aumentare degli indici positivi. Ciò ha reso possibile identificare un sottoinsieme di indici da combinare matematicamente in un nuovo indice sintetico. Sebbene anche il nuovo indice sia soggetto alla disponibilità di dati, esso permette una sintesi dei dati che ha un chiaro significato quando sia necessario un indice semplice per definire lo stato degli alberi in una determinata area e ad un determinato anno.

Parole chiave: *condizione degli alberi, analisi fattoriale, indice sintetico.*

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The visual assessment of tree condition is part of forest monitoring methods in Europe since the early 1980s (*e.g.* INNES 1993). In particular, it has been carried out to collect data relating to two indices, defoliation and discoloration, and – in this respect - it has provided vast data sets, although of doubtful quality (*e.g.* DURRANT *et al.* 2000). These efforts were part of the implementation of so-called Level I monitoring of forest condition. With the establishment of the Level II system, many and detailed monitoring activities were begun, making it important to undertake a more in-depth assessment of tree condition. In Italy, the assessment of tree condition on Level II Permanent Monitoring Plots (*PMPs*) started in 1996. At that time, no official manual, specifically designed for Level II, was adopted at international level. However, there were methods and manuals developed for regional monitoring programs in Italy (CENNI *et al.* 1995), and they were adopted at national level. In 1997, the Task Force of the ICP- Forests approved the sub-manual on crown condition (EICHHORN *et al.* 1996) and in 1998 the same manual was adopted in Italy to replace the previous one (BUSSOTTI *et al.* 1998 and 1999). Thus, all "mandatory" and "optional" tree condition indices are being assessed in Italy since 1998 and – to a lesser extent – since 1996 (Table 1).

When many indices are used, the problem arises of how to synthesize them into a more simple expression while maintaining intact the value of the original indices. This is a common problem in many fields, from air pollution indices (*e.g.* SWAMEE and TYAGI 1999), to foliar symptoms (MUIR and MCCUNE 1987) to tree condition (MCLAUGHLIN *et al.* 1992). Obviously, there are different ways of combining several indices into a single one and they mostly depend on the objective the synthetic index aims to achieve. In this paper, we will consider the following objectives: (*i*) to provide an index that may allow a quantification of tree condition at the level of individual Perma-

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Table 1 - Indices of tree condition according to the ICP-Forests Manual and their use in the CONECOFOR program since 1996. O: EU mandatory; F: optional.*: same scoring system as in the ICP-Forests Manual; +:scoring system consistent with the ICP-Forests Manual.
*Indici della condizione degli alberi proposti nel Manuale ICP-Forests e la loro applicazione in CONECOFOR dal 1996. O: obbligatorio per la regolamentazione UE; F: facoltativo; *: indicatore valutato in maniera analoga al Manuale ICP-Forests; +: indicatore valutato in maniera compatibile al Manuale ICP-Forests.*

Indices	Code	Status	1996	1997	1998	1999
Removals-Mortality	R&M	0			*	*
Visbity	Vsb	0		*	*	*
Social class	PSc	0	*	*	*	*
Canopy closure	Cmp	0	*	*	*	*
Defoliation-Extent	PdF	0	+	+	*	*
Discoloration-Extent	CdF-D	0	*	*	*	*
Defoliation-Patterns	PdF-P	F			*	*
Foliage trasparency-Extent	Trp	F	*	*	*	*
Crown dieback-Type	MrC-T	F			*	*
Crown dieback-Extent	McR-D	F			*	*
Discoloration-Type	CdF-T	F	+	+	*	*
Discoloration-Location of leaves/needles	CdF-LT	F			*	*
Discoloration-Location of crown	CdF-LC	F			*	*
Discoloration-Age of foliage	CdF-E	F			*	*
Leaf/Needles damage-Type	DnF-T	F	+	+	*	*
Leaf/Needles damage-Extent	DnF-D	F			*	*
Leaf/Needles size	DF	F	+	+	*	*
Leaf malformation-type	MF-T	F	+	+	*	*
Leaf malformation- Extent	MF-D	F			*	*
Crown form	Str	F	+	+	*	*
Damage to leaving branches-Type	Dr-T	F			*	*
Damage to leaving branches-Location	Dr-L	F			*	*
Regeneration of the crown	RgC	F	+	+	*	*
Epiphyta	Epf	F	+	+	*	*
Flowering	Fra	F	+	+	*	*
Fruiting	Fre	F	+	+	*	*
Damage to the stem-Type	Dt-T	F	+	+	*	*
Damage to the stem-Location	Dt-L	F			*	*

nent Monitoring Plots (*PMPs*) and (*ii*) to provide an index useful for the Status and Change (S&C) analysis of the Integrated and Combined (I&C) evaluation system (Ferretti this volume).

Materials and Methods

Data sets

The data used for the various analyses presented here are those collected on the various *PMPs* with beech (*Fagus sylvatica* L.) between 1996 and 1999. For each *PMP* the 30 trees nearest to the centre of the *PMP* were selected and scored for each of the indices reported in Table 1. Data were collected according to Standard Operating Procedures (SOPs) (Müller and Stierlin 1990, Ferretti 1994, Cenni *et al.* 1995, Bussotti *et al.* 1998 and 1999) and the whole survey was subjected to a Quality Control (QC) program (Ferretti *et al.* 1999). As two different Manuals were adopted in 1996-97 and 1998-99, only those indices in common between the two manuals were considered (Table 1). When the two manuals used different scoring systems for the same indices, 1996-97 data were re-scaled to be in line with the scoring system provided by Eichhorn *et al.* (1996). Only variables allowing a ranking of effects from a minimum to a maximum were used.

Approaches

Attempts to derive synthetic indices followed two approaches: one was statistical, and used Factor Analysis (FA); the second was conceptual, and followed a less formal approach.

The statistical approach is based on Factor Analysis which allows for a description of the variance of many variables in terms of a few ones, referred to as “factors”. Ideally, those factors would then allow for the elaboration of a synthetic index.

The conceptual approach is based on an arbitrary selection of those variables considered to be important in identifying and quantifying the status of a given tree and - consequently – of a given plot. This approach needs an expert opinion to select variables and is therefore more subjective than the statistical one.

Results

Factor Analysis does not allow variables with variance equal to 0. Thus, a first step was to identify such variables for each *PMP* and to eliminate them from the analysis. In some cases, the variables with null variance were so many that any further FA was impossible (Table 2). A further problem comes from the fact that variables with variance equal to 0 were (actually or potentially) different for each *PMP* and for each year. This has the major drawback that different *PMPs* and/or the same *PMP* at different years were (actually or potentially) described by different indices. Consequently, any synthetic index built up in this way risks being based on dif-

Table 2 - Results of the Factor Analysis for the various *PMP* with beech in 1997 and 1998.
Risultati dell'analisi fattoriale per le varie aree permanenti a faggio nel 1997 e 1998.

PMP	Year	Variables with variance ≠ 0	Index espression or comments	Explained variance (%)	
				Factor 1	All
ABR1	1998	PSc, CmP, TrP, CdF-D, MF-D, DnF-D, Str, RgC	Too small variation - FA not possible		
	1997	Cmp, TrP, CdF-D, CdF-T, Str	Too few variables - FA not feasible		
CAL 1	1998	PSc, Cmp, Trp, Fre, DnF-D	Too few variables - FA not feasible		
	1997	PSc, Cmp, Trp	Too few variables - FA not feasible		
CAM 1	1998	CmP, TrP, CdF-D, CdF-T, Fre, Str, RgC	F1=0, 47*Trp+0,53*CdF-D+0,48*CdF-T-0,015*DnF-D	24%	24%
	1997	CmP, TrP, Str	Too few variables - FA not feasible		
EMI 2	1998	TrP, CdF-D, CdF-T, MF-D, DnF-D, RgC	F1=0,1*CdF-D+1,09*CdF-T	29,32%	29,32%
	1997	CmP, CdF-D, CdF-T, MF-D, DnF-D, Str	F1=0,42*Cmp+0,39*Trp+0,28*CdF-T; F2=0,16*Cmp+0,99*CdF-D	29,20%	49,84%
PIE 1	1998	Psc, Cmp, Trp, CdF-D, CdF-T, MF-D, DnF-D, Str, RgC	F1=0,47*Trp*1,86*Str; F2=0,25*CdF-D-1,29*CdF-T;F3=1,49*DnF-D-0,7*Cmp	35,11%	70%
	1997	Cmp, Trp, CdF-D, CdF-T, MF-D, DnF-D, Str	F1=0,46*Trp+0,27*MF-D+0,2*Str; F2=0,35*CdF-D-1,35*DnF-D	27.28%	46,23%
PUG 1	1998	PSc, Cmp, Trp, MF-D, DnF-D, Str, RgC	Too small variation - Fa not possible		
	1997	PSc, Cmp, Trp, Str	Too few variables - FA not feasible		
VEN 1	1998	PSc, Cmp, Trp, DnF-D	Too few variables - FA not feasible		
	1997	Trp, CdF-T	Too few variables - FA not feasible		

ferent original variables, thus providing poor comparability. Further, FA is no longer possible when only a few variables remain. In our case, we started with 11 variables and FA was no longer possible with 5 or less variables. Table 2 reports the results of the FA: in many cases, it was not possible simply to perform FA, either because of null variance or because of the limited number of remaining variables; in some cases, limited variance does not allow for a meaningful FA; in other cases FA was fully carried out with varying results. In these latter cases, the portion of variance explained ranges from 24 to 70% on the whole, while Factor 1 itself explained between 24 and 35%. These results were similar to those obtained by Pardo (1997) for *PMPs* of the MONITO program in Tuscany (central Italy). What is obvious from Table 2 is that the outcomes of the FA change year by year and plot by plot.

The results of FA provide evidence that in many cases and for many variables there is little or no variance. This suggest that, for a given variable, its actual value is more important than its contribution to the total variance. For example, it could be important that crown transparency in a given *PMP* is 50 % even if all trees in the *PMP* have similar values. In this case, a conceptual approach to select those variables needed to build up a synthetic index may be more appropriate. A conceptual approach was adopted *e.g.* by McLaughlin *et al.* (1992) for broadleaves in Canada, while indices based on detailed assessment and measurement of branches and dieback is reported by Innes (1998). Here, the approach is based on the simple idea that (*i*) the condition of a tree can be considered as getting worse as the score of certain indices increases and (*ii*) that if a tree has a "positive" score (*i.e.* > 0) for more than one index, such a tree is likely to be in a worse condition than a tree with 0 or only one index with a positive score. In selecting those indices that are most suitable for use in constructing a synthetic index, the following elements should be taken into consideration :

- The objectives for which the index is needed. This is in relation to the analyses designed for the I&C evaluation system (*cfr.* Ferretti *et al.* this volume): for example, the Status and Changes (S&C) analysis would require an index providing information about the overall tree condition; on the other hand, the different scenarios of Risk Analysis (acidic and nitrogen deposition, ozone, meteo stress) would need different, more specific, indices (*e.g.* about foliar symptoms).
- Their unambiguous connection with expression of tree condition;
- Their scoring system, which must be unambiguous and of known reliability.

Among the indices formerly and currently used for tree condition assessment the following ones were considered: crown transparency (Italian code: Trp), extent of discoloration (CdF-D), discoloration type (CdF-T), extent of leaf/needle damage (DnF-D) (all tree species), plus crown form (Str) and extent of leaf malforma-

Table 3 - Indices considered for a cumulative tree condition score and the information they can provide.
Indici considerati per il calcolo di un indice cumulato ed il tipo di informazione da essi fornita.

Original Index	Information provided
Crown Trasparency (all species)	Overall tree appearance, indirect estimate of defoliation
Crown form (only broadleaves)	Branch development, dieback phenomena
Discoloration type (all species)	Directional change of foliage color
Discoloration extent (all species)	Amount of discoloration on the crown
Leaf/needle damage, extent (all species)	Amount of damage on the crown
Leaf malformations (only broadleaves)	Amount of leaf with anomalous shape (e.g. curling in beech)

tions (MF-D) (only for broadleaves) (Table 3). Crown transparency and crown form may provide information about overall tree condition. They are non-specific indices, with a number of biotic and abiotic stress factors potentially playing an important role as determinants. Discoloration type and extent may be related – although not exclusively – to abiotic stressors like nutritional disturbances, climate extremes, drought, gaseous air pollutants. However, scaling discoloration type into an ordered series from a minimum to a maximum is not easy; thus only discoloration extent will be actually considered. Extent of leaf/needle damage and leaf malformations can be related to the action of biotic agents, with hail, wind, drought and temperature stress being other important determinants.

To calculate a synthetic index starting from the original ones, an important consideration concerns the different scoring systems of the various original indices. For example, crown transparency is scored according to a 0-100% transparency scale, with 5% classes. On the other hand, crown form in beech is scored by 4 major types, starting from vigorous apical and lateral growth and finishing with growth stopped and dieback occurring. Thus, all the scores were relativized to be a-dimensional. This was done by subtracting the minimum possible score from the actual value and then dividing by the possible maximum score:

$$I_{jrel} = \frac{I_{j\ actual} - I_{j\ min}}{I_{j\ max}}$$

where
$I_{j\ rel}$= relativized index j(a-dimensional)
$I_{j\ actual}$= actual score for the original index j
$I_{j\ min}$= minimum possible score for the original index j
$I_{j\ max}$= maximum possible score for the original index j

The above calculation was done for each of the selected indices j (j_1, j_2, j_n) and for each tree t (t_1, t_2, t_n). Then, the total score of the Crown Condition Index (CCI) for individual trees was calculated by:

$$CCI_{tree} = \sum_{j=1}^{j=n} I_{rel}$$

where
CCI_{tree}= Crown Condition Index for individual trees
I_{rel} = relativized index for the various original indices

and the score for the *PMP* was calculated by means of the CCI_{tree} values:

$$CCI_{PMP} = \frac{1}{n} \sum_{t=1}^{t=n} CCI_{tree}$$

where
CCI_{PMP}= Crown Condition Index for the *PMP*
CCI_{tree}= Crown Condition Index for individual trees
n = number of trees assessed

A similar weight was given to each original index: this is because it is difficult to determine whether for a tree it is better to have high transparency or high discoloration. In this context, the CCI can provide only a global and rough score of the overall tree condition in the plot, but cannot be used to distinguish between the various symptoms. This should be done by a detailed investigation of crown data and - in any case - when a more detailed score is needed, individual indices are still available. It is also nec-

Table 4 - Availability of the various original indices at the *PMP* with beech as main species. Full means availability from 1996 to 1999. Otherwise the years for which data area available are reported.
Disponibilità dei vari indici originali per le aree a prevaslenza di faggio. "Full" indica la completa disponibilità dal 1996 al 1999. Diversamente vengono indicati gli anni per cui i dati sono disponibili.

Original index	ABR1	CAL1	CAM1	EMI2	PIE1	PUG1	VEN1
Crown trasparency	full	full	full	full	full	97,98,99	full
Crown form	full	full	full	full	full	97,98,99	full
Discoloration type	full	full	full	full	full	97,98,99	full
Discoloration extent	full	full	full	full	full	97,98,99	full
Leaf/needle damage, extent	full	full	full	full	full	97,98,99	96,98,99
Leaf malformation	full	full	full	full	full	97,98,99	96,97

essary to go back to original index scores or to a subset of I_{rel} when – for whatever reason – data are not available for all the original indices at all *PMPs* for every year. For example, data for leaf damage and malformations are not always available (Table 4). This is a clear problem when the synthetic index is based on a sum. In this case, a subset of indices can be used. For example, in the case of beech *PMPs*, only the following indices were consistently scored at each *PMP* and actually used for calculations presented here: crown transparency, crown form, extent of discoloration. CCI data for *PMPs* with beech are in Table 5. In all cases it is crown transparency which has the major weight on the CCI score: only in the case of the plot PUG1 does the crown form (Str) have a comparatively high weight.

A further problem associated to integrated indices of crown condition is the reliability of the data with which the CCI index is calculated. According to Ferretti *et al.* (1999) in some cases the reliability of crown condition data is rather low, especially for crown form and crown transparency, two of the indices adopted here to calculate the CCI. While the reliability of crown data remains a major problem that asks for improved quality assurance, an important challenge for the future will be to estimate the error associated to the use of integrated indices.

Conclusions

When a number of indices are used to assess tree condition it is also important to be able to synthetize the data collected in a simple way that can allow statements about the actual tree condition of a given site. Unfortunately, the nature of crown condition data implies marked spatial and temporal variability, with some indices being important recorders of tree condition at a given time and not important at all at another time. This limitation appears obvious when attempting to use a formal statistical approach to construct a synthetic index of tree condition: scarce or no variance of a considerable number of original indices, changes in the indices showing variance between years and plots makes it impossible to have a consistent outcome from Factor Analysis. The consequence is that it was not possible to identify a common synthetic index for all plots and all years by FA. On the other hand, it must be noted that – to identify the tree condition of a given *PMP* – the actual values of the original indices are as important as their variance, if not more. Thus, a simple index based

Table 5 - Mean values of the cumulated crown condition index (CCI) at the various *PMP* with beech as main species for the various survey years and on the whole. The contribution of the various original indices on the overall mean is also reported.
Media dell'indice cumulato di condizione della chioma alle varie aree a prevalenza di faggio, ai vari anni ed in totale. E' riportato il contributo dei vari indici originali alla media totale.

PMP	ABR1	CAL1	CAM1	EMI2	PIE1	PUG1	VEN1
CCI_{PMP} 1996	0,31	0,47	0,46	0,25	0,40		0,13
CCI_{PMP} 1997	0,32	0,49	0,41	0,51	0,55	0,41	0,14
CCI_{PMP} 1998	0,31	0,43	0,40	0,26	0,31	0,31	0,19
CCI_{PMP} 1999	0,25	0,38	0,28	0,34	0,30	0,28	0,29
Mean CCI_{tree}	0,30	0,44	0,39	0,34	0,39	0,33	0,19
Mean I_{rel}Trp	0,22	0,36	0,27	0,22	0,29	0,19	0,16
Mean I_{rel} CdF-D	0,04	0,02	0,06	0,09	0,05	0,02	0,03
Mean I_{rel}Str	0,03	0,06	0,06	0,02	0,04	0,013	0

on arbitrary selected original values has been calculated. The index is based on the consideration that the more symptoms a tree shows, the worse its condition is. Data for beech *PMPs* were used as an example. Usually the contribution of crown transparency to the total score is the most important, although in some cases also crown form has proved to be a strong driver of the final score. The value of such an index can be questioned as it does not allow detailed analyses about the nature of tree condition status at a given plot. In addition, the reliability of crown condition data may affect strongly the results obtained by the CCI and this make it necessary to quantify the error associated to such an index. However, when the objective is to have an immediate synthetic picture of the actual situation, the index can be of value. This is especially true in the light of the Status and Change (S&C) analysis of the I&C evaluation system, where there is an urgent need to get a meaningful reduction of the total number of variables and – at the same time – to mantain the maximum amount of information.

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References

Bussotti F., Ferretti M., Cozzi A., Cenni E., 1998 - *Condizione delle chiome degli alberi. Valutazione nelle aree permanenti di livello 2°.* MANUALE DI CAMPAGNA. (Maggio 1998, Revisione 0). Pubblicato da Ministero per le Politiche Agricole, Roma: pp. 80.

Bussotti F., Ferretti M., Cozzi A., Cenni E., 1999 - *Condizione delle chiome degli alberi. Valutazione nelle aree permanenti di livello 2°.* MANUALE DI CAMPAGNA. (Maggio 1999, Revisione 1). Pubblicato da Ministero per le Politiche Agricole, Roma: pp. 92.

Cenni E., Cozzi A., Ferretti M., Bussotti F., 1995 - *Valutazione delle condizioni degli alberi-Manuale per le aree di Livello I,* Regione Toscana-Giunta regionale, 126 pp.

Durrant D., Ferretti M., Solberg S., 2000 - *Quality Assurance.* Unpublished paper prepared for the internal review of the ICP-Forests.

Eichhorn J., Ferretti M., Innes J.L., Roskams P., Vel E., 1996 - *Visual assessemnet of tree condition.* UN/ECE ICP-Forests, Manual on method and criteria for harmonized sampling, assessemnt, monitoring and analysis of the effects of air pollution on forests. 4th edition.

Ferretti M., (Ed.), 1994 - *Mediterranean Forest Trees. A Guide For Crown Assessment,* CEC - UN/ECE, Brussels, Geneva.

Ferretti M., 2000 - *An introduction to the integrated and combined (I&C) evaluation system designed for the intensive monitoring of forest ecosystems in Italy.* In: Ferretti M. (ed.), “Integrated and Combined (I&C) evaluation of intensive monitoring of forest ecosystems in Italy – Concepts, Methods and First Results” Annali dell’Istituto Sperimentale per la Selvicoltura, Special Issue, anno 1999, 30: 7-16.

Ferretti M., Bussotti F., Cenni E., Cozzi A., 1999- Implementation of Quality Assurance procedures in the Italian programs of forest condition monitoring. *Water Air Soil pollution,* 116: 371-376.

Innes, J.L., 1993 - *Forest Health: Its Assessment And Status.* Commonwealth Agricultural Bureau, Wallingford, 677 pp.

Innes J.L., 1998 - *An assessment of the use of crown structure for the determination of the health of beech (Fagus sylvatica).* Forestry, 71 (2): 113-130.

McLaughlin D., Gizyn W., Mcilveen W., Kinch C., 1992 - *A quantitative tree crown rating system for deciduous forest health surveys: some results for Ontario.* In: Manion, P. D., and Lachance, D. (Eds), “Forest decline Concepts” APS Press; The American, Phytopatological Society, St. Paul, Minnesota: 137-154.

Muir, P. S., McCune, B., 1987 - *Index Construction for Foliar Symptoms of Air Pollution Injury.* Plant Disease, 71, 558-565.

Müller, E., Stierlin, H. R., 1990 - *Sanasilva. Tree crown photos.* Swiss federal Institute for Forest, Snow and Landscape Research, Birmensdorf, pp.129.

Pardo E., 1997 – *Studio combinato dei dati prodotti dal programma MONITO (Toscana, Italia centrale).* Tesi di laurea. Università di Firenze-Politecnico di Madrid.

Swamee P. K., Tyagi A., 1999 - *Formation of an Air pollution Index.* Journal of the Air and Waste Management Association, 49: 88-91.

Plant biodiversity as an indicator of the biological status in forest ecosystems: community and population level indices§

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Abstract - The vegetation survey in the permanent plots of the CONECOFOR National Network contributes to the goal of characterizing the biological status of the forest ecosystems following their species and structural composition; the status definition can be used to evaluate the changes in the system related to natural phenomena or anthropogenic factors. In this context specific diversity is an important parameter as much as it is closely connected to the ecosystem dynamics and "environmental quality". This work presents indices of diversity that have proven most useful in contributing to overall definition of the forest system status within each plot of the CONECOFOR Network. Vegetation assessment was done in each plot on a *community* level, considering the specific covers by stratum, and on a *population* level, with details on cover and specific density within the lower stratum of vegetation. Data from the first level were used to calculate the Shannon-Wiener index of diversity (H'), while data from the another were used for calculation of Fisher's α index. Both indices generally demonstrate an increase in the considered period; for data gathered on a community level this can be due to the increased precision in the taxonomic attribution, while the α values could lead to some hypothesis in relation with the information on the different intensity of the dynamism within the phytocoenoses, or on particular weather events. The conifer formations demonstrate a greater abundance-specific diversity than the broadleaf forests, among which the beech wood systems show the lower values. Considering the specific-individual diversity of the understorey, the deciduous forests seem more complex. This aspect can be linked to the greater variability in understorey environmental conditions of such systems, on which one can expect a more intense dynamism in relation to the peculiar past sylvicultural management. The two different estimates of plant diversity can contribute to the definition of the initial status of the system, underlining both the role of the species as primary producers and their contribution to the structure of the system. The extension of this latter aspect to the entire system, utilizing the data produced by tree stand growth studies, is foreseen. In addition to integrating the indices described with data from other study groups in the CONECOFOR project, it would be interesting to introduce functional groups of plant species as indicators of possible stressors, disturbances and dynamic processes.

Key words: *monitoring, vegetation assessment, Shannon-Wiener, Fisher's α.*

Riassunto - La diversità vegetale come indicatore dello stato biologico in ecosistemi forestali: indici a livello di comunità e di popolazione. Il rilevamento della vegetazione all'interno delle aree permanenti della Rete Nazionale CONECOFOR risponde allo scopo di caratterizzare lo stato e le variazioni degli ecosistemi forestali sulla base della loro composizione floristica e strutturale e di monitorare eventuali variazioni in funzione di fenomeni naturali o fattori antropogeni. In tale contesto la diversità specifica è un parametro rilevante in quanto strettamente connesso alla dinamica dell'ecosistema ed alla "qualità ambientale". Vengono presentati gli indici di diversità che sono risultati maggiormente adeguati a contribuire alla definizione complessiva dello stato del sistema forestale all'interno di ciascun *plot* della Rete CONECOFOR. Il rilevamento della vegetazione è stato effettuato in ciascun plot a livello di *comunità*, considerando le coperture specifiche di tutti gli strati verticali, e a livello di *popolazione*, rilevando in modo fine le coperture e le densità specifiche nello strato inferiore della vegetazione. Con i dati del primo livello si è calcolato l'indice di diversità di Shannon-Wiener (H'), mentre il secondo ha consentito di elaborare l'indice α di Fisher. Entrambi gli indici mostrano generalmente un incremento nel periodo considerato; se per i dati raccolti a livello di comunità ciò può essere imputabile alla maggior definizione nel rilevamento delle specie, i valori di α sembrano più condizionati da particolari eventi meteorici e segnalano l'ipotesi di un legame con la diversa intensità del dinamismo interno alla fitocenosi. Le formazioni di conifere mostrano una maggiore diversità specifica basata sulla copertura, rispetto alle formazioni di latifoglie (con le faggete ai valori minimi). Considerando la diversità specifica su base individuale, il sottobosco dei sistemi di specie caducifoglie sembra più complesso. Tale aspetto può essere legato alla maggiore variabilità delle condizioni ambientali in queste formazioni, per le quali ci si può attendere un più intenso dinamismo in relazione alla peculiare gestione selvicolturale passata. Le due diverse stime di diversità vegetale possono contribuire alla definizione dello stato iniziale del sistema sottolineando sia il ruolo delle specie come produttori primari che il loro contributo strutturante. Si suggerisce di estendere quest'ultimo aspetto all'intero sistema utilizzando anche i dati prodotti dalle ricerche sull'accrescimento del popolamento arboreo. Oltre ad integrare gli indici descritti con i dati provenienti da altri gruppi di ricerca del progetto CONECOFOR, sembra opportuno prevedere l'introduzione di gruppi funzionali di specie vegetali quali indicatori di possibili agenti di stress, di disturbo e di processi dinamici.

Parole chiave: *monitoraggio, rilevamenti della vegetazione, Shannon-Wiener, α di Fisher.*

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Vegetation is the main component of forest ecosystem structure: the stratification of the plant biomass not only has a functional meaning but also involves a significant portion of forest biodiversity. Plant organisms play a key-role in the water and nutrients cycling, interacting strongly with other biotic components. In addition, the plant system can be considered as a synthetic expression of environmental factors and their variation.

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The ground vegetation assessment within the permanent plots in the CONECOFOR National Network is relevant in characterizing the current status of forest ecosystems by assessing their composition and structure and by monitoring some changes in vegetation due to natural phenomena or anthropogenic factors (Canullo *et al.* 1999b). In this context specific diversity is a pertinent parameter in describing the structure of a plant community. It is strictly connected to ecosystem dynamics and environmental quality: measurements and estimates of diversity are frequently considered as indicators of the “health” of ecological systems (Magurran 1988) and their changes are often used as indicators of disturbances of anthropic origin (Liu and Brakenhielm 1996, Mackey and Curie 2000).

In particular, given that plant communities are generally found in a status of non-equilibrium (number of species depends on environmental time changes: Dobbertin 1998) variation of the specific diversity in a forest system can depend on both internal processes and disturbances. Thus, understanding and quantifying the variability of the specific diversity in relation to natural and anthropic ecological factors, is an aspect of extreme interest for the CONECOFOR Intensive Monitoring program.

In strictly theoretical terms, species diversity tends to increase in presence of a frequent casual disturbance, with intermediate competition and stress and a mid-low availability of resources (Grime 1979, Tilman 1982). On the basis of such theories, Liu and Brakenhielm (*op. cit.*) (confirmed by Schulze and Gerstberger 1993, Bobbink and Willels 1987, Hogg *et al.* 1994, De Vries *et al.* 1995) allow that an eventual surplus of atmospheric depositions of S and N can change the status of nutrients and thus alter interspecific relationships towards competitive exclusion and consequent reduction of biological diversity. However, further research in forest systems have underlined opposite trends (Falkengren - Grerup, 1986 Thimonier *et al.* 1992).

It is also worthwhile to recall that biodiversity does not only consider species richness but also the relationships of abundance between species Magurran (*op. cit.*).

This contribution describes the indices of diversity that have been considered most useful in synthesizing the parameters available in the context of the *Ground Vegetation Assessment*. The aim of the elaborations is to contribute to the overall definition of the forest system's status within each plot of the CONECOFOR Network, according to the methods of Integrated and Combined evaluation proposed elsewhere in this volume.

Materials and methods

The vegetation of each plot was surveyed according to two fundamental approaches detailed in the Manual compiled by the *Expert Group on Ground Vegetation Assessment* (Dupouey 1998):

- at the *community* level (12 sampling units, 10x10 m) the specific cover per layer was assessed;
- at the *population* level (100 sampling units, 50x50 cm) the herb layer (up to 1.30 m) of the vegetation was surveyed, recording the number of functional individuals per species as well (for further details see Canullo *et al.* 1999 a, b).

The data matrices differ qualitative and quantitative ways. In the first case the species richness refers to the entire system and abundance is estimated less accurately; in the second case, the number of species is reduced to understorey, and by a different sampling design, while counting concrete individual units assesses abundance.

Consequently, diversity was evaluated separately: the Shannon-Wiener (H’) index was considered for data at the community level while Fisher’s α index was applied for data at the population level (Fisher *et al.* 1943). The descriptive relevance and utility of these indices was exhaustively tested in the literature (Taylor 1978, Kempton and Taylor 1974, 1978, Peet 1974, Condit *et al.* 1998).

The Shannon-Wiener index is calculated with the following formula:

$$H' = -\Sigma p_i \ln(p_i)$$

Where p_i is the relative cover of the species *i*, estimated using $c_i/(c_1 + c_2 + \dots c_a)$ in which c_i is the average cover of the species *i* in the twelve quadrates sampled. The use of the relative cover values enables consideration of the total cover distribution between species. H' can be defined as abundance-specific diversity.

From the data at the population level an index of diversity could be obtained, based on Fisher's logarithmic series (*op. cit.*):

$$S = \alpha \ln (1 + N/\alpha)$$

The index of diversity is given by the value of α (specific-individual diversity) obtained as follows:

$$A = N(1-x)/x$$

in which x is derived from the iterative solution of the following equation:

$$S/N = (1-x)/x[-\ln(1-x)]$$

where S is the total number of species and N is the number of functional individuals. This is one of the most widely used indices which remains very stable with the variation of the dimension of the sampled area, has a good discriminate power, and can be calculated quite easily MAGURRAN (*op.cit.*).

Reference to understorey vegetation is consonant with numerous experiences according to which this stratum is the most sensitive to the impact of atmospheric depositions (KELLNER 1993, VAN DOBBEN 1993, NORDIN *et al.* 1998, MAKIPAA 1998).

The ground vegetation assessment within the CONECOFOR program has been active since 1996, and thus it was possible to calculate the Shannon-Wiener index only for the data gathered in the 1996 and 1999 surveys (for 1997 and 1998 only community-level data were available).

The results of the indices are currently used for the integrated and combined evaluation of the data from the Permanent Monitoring Plots (*PMPs*) of the CONECOFOR program, aimed at a synthesized evaluation of the forest ecosystem.

Results and discussion

Table 1 illustrates the general information about the sites (*PMPs*) where the vegetation was monitored. The emplacement of the plots covers various typologies of forest communities that are held to be representative of the ecological diversity present in Italy. The total number of species in each plot, and precisely in the twelve 10x10-sampling units, goes from a minimum of 20 (SAR1) to a maximum of 75 (BAS1) and is extremely variable between the 15 areas.

The results of the index of diversity (H'), calculated on the community level data, are represented in Table 2. The value of the index is extremely variable for data of both 1996 and

Table 1 - General information of the *PMPs* (CONECOFOR network) used for vegetation monitoring in Italy.
Informazioni generali dei siti (rete CONECOFOR) utilizzati per il monitoraggio della vegetazione.

No.	Site name	Latitude	Longitude	Altitude m a.s.l.	No. of species	Forest type
1	ABR1 - Selvapiana	+415051	+133523	1500	24	beech forest
2	BAS1 - Monte Grosso	+403638	+155225	1125	75	oak forest
3	CAL1 - Piano Limina	+382538	+161047	1100	34	beech forest
4	CAM1 - Serra Nuda	+402558	+152610	1175	31	beech forest
5	EMI1 - Carrega	+444306	+101213	200	30	oak forest
6	EMI2 - Brasimone	+440631	+110700	975	34	beech forest
7	FRI1 - Bosco Boscat	+454958	+131004	6	56	mixed deciduous forest
8	FRI2 - Tarvisio	+462928	+133536	820	68	spruce (and fir) forest
9	LAZ1 - Monte Rufeno	+424950	+115410	690	60	oak forest
10	LOM1 - Val Masino	+461416	+093316	1190	60	spruce (and fir) forest
11	MAR1 - Roti	+431738	+130424	775	65	oak forest
12	PIE1 - Val Sessera	+454055	+080402	1150	23	beech forest
13	PUG1 - Foresta Umbra	+414910	+155900	800	30	beech forest
14	SAR1 - Marganai	+392056	+083408	700	20	holm-oak forest
15	SIC1 - Ficuzza	+375432	+132415	940	*	oak forest
16	TOS1 - Colognole	+433034	+102119	150	39	holm-oak forest
17	TRE1 - Passo Lavazè	+462137	+112942	1775	33	spruce forest
18	UMB1 - Pietralunga	+432757	+122757	725	63	oak forest
19	VAL1 - La Thuile	+454326	+065555	1740	58	spruce forest
20	VEN1 - Pian di Cansiglio	+460326	+120156	1100	28	beech forest

* = missing data

Table 2 - Estimate of the H' index (Shannon-Weiner) calculated on the community level vegetation data.
Stima dell'indice H' (Shannon-Weiner) calcolato sui dati della vegetazione a livello di comunità.

sites	1996			1999			99 - 96
PMP	No. of units	No. of species	H'	No. of units	No. of species	H'	difference on H'
1	12	18	0.215	12	24	0.549	0.334
2	12	66	2.004	12	75	1.661	-0.343
3	12	28	1.424	12	34	1.662	0.238
4	12	30	0.862	12	31	1.059	0.197
5	12	26	1.183	12	30	1.706	0.523
6	12	26	0.553	12	34	0.37	-0.183
7	12	40	2.268	12	56	2.297	0.029
8	12	41	1.368	12	68	1.911	0.543
9	12	41	0.992	12	60	1.053	0.061
10	11	49	2.232	11	60	2.555	0.323
11	12	57	1.81	12	65	2.318	0.508
12	12	14	0.396	12	23	0.419	0.023
13	12	27	1.795	12	30	1.724	-0.071
14	12	33	0.903	12	20	0.945	0.042
15	*	*	*	*	*	*	*
16	12	38	2.117	12	39	2.222	0.105
17	12	12	1.437	12	33	2.365	0.928
18	12	47	1.561	12	63	2.113	0.552
19	12	21	1.342	12	58	2.229	0.887
20	12	32	0.871	12	28	0.499	-0.372

* = missing data

Table 3 - Estimate of Fisher's Alpha index calculated on population level vegetation data.
Stima dell'indice Alpha di Fisher calcolato sui dati della vegetazione a livello di popolazione.

sites	1998				1999				99 - 98
PMP	No. of units	No. of species	No. of individuals	alpha	No. of units	No. of species	No. of individuals	alpha	difference on alpha
1	100	14	763	2.433	100	13	764	2.224	-0.209
2	100	41	1542	7.735	100	59	1708	11.853	4.118
3	100	25	3236	3.687	100	28	4213	4.026	0.339
4	99	20	522	4.124	99	21	1262	3.578	-0.546
5	100	16	607	3.010	100	11	442	2.043	-0.967
6	100	16	209	4.033	100	17	102	5.822	1.789
7	100	36	2851	5.808	100	35	2399	5.908	0.1
8	100	40	2458	6.785	100	38	3131	6.084	-0.701
9	99	47	2773	8.039	100	47	1988	8.634	0.595
10	81	38	1917	6.716	100	45	1717	8.462	1.746
11	100	38	714	8.568	100	44	640	10.714	2.146
12	100	7	80	1.845	*	*	*	*	*
13	100	21	2976	3.050	100	21	2318	3.186	0.136
14	99	18	325	4.105	100	17	210	4.365	0.26
15	*	*	*	*	*	*	*	*	*
16	99	30	752	6.252	100	25	774	4.937	-1.315
17	100	15	3720	1.991	*	*	*	*	*
18	99	50	1160	10.635	100	49	979	10.858	0.223
19	100	20	6623	2.542	100	25	8286	3.177	0.635
20	100	25	2754	3.793	100	15	967	2.519	-1.274

* = missing data

1999. The number of species in some cases presents a fairly marked variation between the two study years; this is due to the fact that, in 1999 (when the standard definitive procedure was adopted), bryophytes and lichen were also taken into consideration. Also, to a lesser degree, it is due to improvement in the identification of the *taxa*. The temporal variation, however, is generally positive, with consequent increase in the index of diversity; only in the cases of BAS1, EMI2 and PUG1 did this increase of the number of species not lead to an increase of the level of diversity. This aspect is not contradictory, since the index is weighted towards average abundance of cover, rather than simply reflecting the specific richness.

Regarding the diversity at the population level using Fisher's α (Table 3), it would be well to note that the data gathered in the two years (1998 and 1999) are fully comparable, referring only to vascular species.

At the community level, the variation of the number of species is not markedly univocal: in fact, in addition to the considerations mentioned above, the more detailed survey system implies an underestimate of less frequent species.

The extreme variability of the number of individuals can be explained both by the different incidence of renewal of woody species and by the count of functional units that reflects the morphological-evolutive characteristics of the herbaceous species (Falinska 1991).

One can note the extreme variability of the index and its generally positive variations. In order to show the sensitiveness of the index, some cases are underlined: in ABR1 site, after a year, the number of species is reduced by one unit and there is an increase of one individual, with a variation of -0.2 points of the index; CAM1 shows one species more and the doubling of the number of individuals which caused the index to decrease by over half a point; in MAR1, the presence of six new species produced an increase of the index by over 2 points.

The maximum values for α are due to sites with evident signs of recent disturbance (as in BAS1, MAR1, LAZ1 and UMB1). In the first two plots there are notable increases in diversity. In BAS1 the increase of over four points (essentially due to the strong increase in the number of species) is due to fencing that excluded grazing, after the first survey. On the other hand, in MAR1 the positive variation of the index could be due to the intense regeneration of phytocoenoses after the last, recent, coppice treatments (Canullo and Pedrotti 1993). In VEN1, very violent hail dramatically reduced the number of species and of individuals in the understorey vegetation with a consequent reduction of the α value.

These considerations further confirm the sensitivity and adequacy of the α index for the goals of the intensive monitoring program.

Grouping the observed *PMPs* into simple categories (Table 4), the average and the coefficient of variation were calculated (only for the 1999 data) for both indices; as a preliminary approach, the values were tested by non-parametric Mann-Whitney U-test.

The results at the community level demonstrate that the systems with the higher abundance-specific diversity are represented by the formations of conifers (2.265) which differ significantly from the complex of the broadleaved trees and in particular from the beech woods (0.897). Considering the understorey diversity, there are no significant differences, even though the systems of deciduous species seem more complex than other systems. This aspect can be linked to the greater variability in the understorey environmental conditions generated in these types of formations, which lead one to expect a more intense dynamism in relation to the peculiar past sylvicultural management.

The two estimates of plant diversity complement each other in contributing to the definition of the initial status of the system, underlining two distinct aspects of the phytocoenoses. The H' index considers diversity from the point of view of the role of the species as primary producers (approximate to cover), while the α index describes the species' contribution from a more functional point of view (approximate to epigeal structures produced). The extension of the latter aspect to the entire plant system could be evaluated, combining the data gathered on a population level with that produced by research on tree stand growth, given that, since 1999 the survey methodologies have been harmonized by common consensus.

Regarding the evaluation of the effects derived from atmospheric depositions, the indices described could be easily integrated with the data from chemical analyses of the atmospheric depositions and the soil status done in this project by other research groups.

On the other hand, the acidification and eutrophication of the forests has been studied for quite some time in Northern Europe, together with data on depositions with the values of the indices of the indicator species (Diekmann and Dupre 1997, Van Dobben *et al.* 1999, Rust 2000). Several experiences have demonstrated that the decrease of soil pH and the increase in N availability foster the development and expansion of nitrophylous species, which have proven more competitive than indicator species for acidity (Schmidt 1993, Röder *et al.* 1996, Diekmann and Dupre *op.cit.*).

In our case, analogous situations could result in non-coupled variations of the indices proposed, precisely because of the different nature of the complementary information they express. Therefore, it might be useful to combine these indices with evaluation of functional groups as indicators of possible stressors, disturbances and dynamic processes, likewise was done for indicator values of vascular plants (Ellenberg 1979).

Table 4 - Average values and coefficient of variation of the indices of diversity in function of the principal categories of forests (1999 data).
Valori medi e coefficiente di variazione degli indici di diversità in funzione delle principali categorie di foreste (dati 1999).

Forest type	coniferous	beech	oak-deciduous	holm-oak
H' (mean)	2.265	0.897	1.858	1.583
CV	0.119	0.656	0.261	0.571
Alpha (mean)	5.907	3.559	8.335	4.651
CV	0.448	0.362	0.448	0.086

References

Bobbink R., Willems J.H., 1987 - *Increasing dominance of Brachypodium pinnatum (L.) Beauv. in chalk grassland: a threat to a species-rich ecosystem.* Biological Conservation 40: 301-314.

Canullo R., Allegrini M.C., Nicoletti G., Campetella G., Allavena S., Isopi R., Petriccione B., Pompei E., 1999a - *Analisi della vegetazione all'interno delle aree permanenti della Rete Nazionale Integrata CONECOFOR. 1999/2000. Manuale Nazionale di Riferimento per il* *coordinamento, i rilevatori ed i responsabili di zona.* Università degli studi di Camerino.

Canullo R., Campetella G., Allegrini M.C., Petriccione B., 1999b - *Studio della vegetazione.* In "Programma Nazionale Integrato per il Controllo degli Ecosistemi Forestali". Ministero per le Politiche Agricole, Corpo Forestale dello Stato p.:107-115.

Canullo R., Pedrotti F., 1993 - *The cartographic representation of the dynamical tendencies in the vegetation: a case study from the Abruzzo National Park, Italy.* Oecologia Montana 2: 13-18.

Condit R., Foster R.B., Hubbell S.P., Sukumar R., Leigh E.G., Manokaran N., Loo De Lao S., Lafrankie J.V., Ashton P.S., 1998 - *Assessing forest diversity on small plots: calibration using species-indvidual curves from 50 - ha plots.* In: F. Dallmeier and J.A. Comiskey (*Editors*) "Forest biodiversity research, monitoring and modeling". Man and the biosphere series Vol 20, Unesco p.: 247-268.

De Vries W., Leeters E.E.H.J.M., Hendriks C.M.A., Van Dobben H., Van Den Burg J., Boumans L.J.M., 1995 - *Large scale impact of acid deposition on forests and forest soils in the Netherlands.* In : G.J. Heij, J.W. Erisman (*Editors*) "Acid rain research: Do we have enough answers?", Elsevier, Amsterdam p.: 261-277.

Diekmann M., Dupre C., 1997 - *Acidification and eutrophication of deciduous forests in northwestern germany demonstrated by indicator species analysis.* Journal of Vegetation Science 8(6): 855-864.

Dobbertin M.K., 1998 - *Indicators for forest biodiversity in Europe: proposal for terms and definitions.* Technical Report, 4 (version 1.0), Birmensdorf.

Dupouey J.-L., 1998 - *Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests. Part VIII, assessment of Ground Vegetation.* UN-ECE, ICP-Forests, Hamburg.

Ellenberg H., 1979 - *Zeigerwerte der Gefäßpflanzen Mitteleuropas.* Scripta Geobotanica IX, 122 p.

Falinska K., 1991 - *Plant demography in vegetation succession.* Tasks for vegetation science 26, Kluwer Academic Publisher, Dordrecht, 220 p.

Falkengren-Grerup U., 1989 - *Soil acidification in deciduous forest in southern Sweden.* Oecologia (Berlin) 70: 339-347.

Fisher R.A., Corbet A.S., Williams C.B., 1943 - *The relation between the number of species and the number of individuals in a random sample of an animal population.* Journal of Animal Ecology 12: 42-58.

Grime J.P., 1979 - *Plant strategies and vegetation processes.* Wiley, New York, 222 p.

Hogg P., Squires P., Fitter A.H., 1994 - *Acidification, nitrogen deposition and rapid vegetation change in a small valley mire in Yorkshire.* Biological Conservation 71: 143-153.

Kellner O., 1993 - *Effects on associated flora of sylvicultural nitrogen fertilisation repeated at long intervals.* Journal of Applied Ecology 30: 563-574.

Kempton R.A., Taylor L.R., 1974 - *Log-series and log-normal parameters as diversity determinants for the Lepidoptera.* Journal of Animal Ecology 43: 381-399.

Kempton R.A., Taylor L.R., 1978 - *The Q-statistic and the diversity of floras.* Nature 275: 252-3.

Liu Q., Brakenhielm S., 1996 - *Variability of plant species diversity in Swedish natural forest and its relation to atmospheric deposition.* Vegetatio 125: 63-72.

Mackey R.L., Currie D.J., 2000 - *A re-examination of the expected effects of disturbance on diversity.* Oikos 88(3): 483-493.

Magurran A.E., 1988 - *Ecological diversity and its measurments.* Croom Helm London, 179 p.

Makipaa R., 1998 - *Sensitivity of understorey vegetation to nitrogen and sulphur deposition in a spruce stand.* Ecological Engineering 10(1): 87-95.

Nordin A., Nasholm T., Ericson L., 1998 - *Effects of simulated N deposition on understorey vegetation of a boreal coniferous forest.* Functional Ecology 12(4): 691-699.

Peet R.K., 1974 - *The measurement of species diversity.* Annals and Review of Ecology and Systematics 5: 285-307.

Röder H., Fischer A., Klock W., 1996 - *Waldentwicklung auf Quasi-Dauerflächen im Luzulo-Fagetum der Buntsandteinrhön (Formstamt Mittelsinn) zwischen 1950 und 1990.* Fortwiss. Cbl. 115: 321-335.

Rust S., 2000 - *The effect of nitrogen input on drought stress in pine ecosystems in northern Germany.* Allgemeine Forst und Jagdzeitung 171(4): 61-67.

Schmidt P.A., 1993 - *Veränderung der Flora und Vegetation von Väldern unter Immissionseinfluß.* Fortwiss. Cbl. 112: 213-224.

Schulze E.-D., Gerstberger P., 1993 - *Functional aspects of landescape diversity: a Bavarian example.* In: E.-D. Schulze, H.D. Mooney (*Editors*) "Biodiversity and ecosystem functions". Springer-Verlag, Berlin p.: 453-465.

Taylor L.R., 1978 - *Bates, Williams, Hutchinson - a variety of diversities*. In: "Diversity of Insect Faunas" 9th Symposium of the Royal entomology Society. Balckwell, Oxford, pp.: 1-18.

Thimonier A., Dupouey J.L., Timbal J., 1992 - *Floristic changes in the herb-layer vegetation of a deciduous forest in the Lorraine Plain under the influence of atmospheric deposition*. Forest Ecology and Management 55: 149-167.

Tilman D., 1982 - *Resource competition and the community structure.* Princeton University Press, Princeton, 296

Van Dobben H.F., 1993 - V*egetation as monitor for deposition of nitrogen and acidity*. PhD thesis, Status University of Utrecht.

Van Dobben H.F., Ter Braak C.J.F., Dirkse G.M., 1999 - *Undergrowth as a biomonitor for deposition of nitrogen and acidity in pine forest.* Forest Ecology & Management 114(1): 83-95.

Tree growth survey and increment assessment
Contribution to the integrated evaluation of ecosystem's status§

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Abstract - The paper deals with the mandatory action "tree growth survey" framed into the integrated and combined (I&C) evaluation joining together the different tasks acting in the National Programme on Intensive Monitoring of Forest Ecosystems CON.ECO.FOR. Aims of the paper are: (i) to outline the contents of growth survey implemented on Level II plots; (ii) to recall the qualities of basic growth indicators (basal area, mean and top height) selected for the elaboration of ecosystem status indexes in the I&C assessment; (iii) to test, in addition to the common European protocol which links the outcome of growth mensuration to the comprehensive tree population in the unit area (plot or subplot), a working hypothesis aimed at improving growth indicators consistency *i.e.* their ability to highlight growth rates acting inside each *PMP*. The proposal, especially addressed to explain the high in-and-between variability typical of forest structures tested in Italy, is founded on the evaluation of individual social class and on the arrangement of trees into well-discernible vegetation layers. The expected goals are both the assessment of internal growth structure and its variations throughout subsequent inventories. The analysis applied to beech stands, a forest type showing a high heterogeneity, is discussed. Results highlight the contribution of each layer to basal area increment and the different average rates as a function of tree density and stand structure within each *PMP.* Average values in the upper tree layer *vs.* average comprehensive values are then compared among *PMPs.* The comparison highlights similar growth rates per layer *vs.* different total allocation rates, these values incorporating the variability across stand structures. The arrangement of trees per basal area increment classes and per layer allowed then the examination of distributive pattern inside each *PMP.* On this basis, the proposal to find out, at each inventory and in each plot, a sub-set of *growth-indicator trees* sorted out among dominant trees showing the prevailing allocation rates (modal *b.a.i.* classes), is made. Such a choice relies on the assumptions that growth response is more easily detected in dominant trees these being less sensitive to competition, and that trees close to modal increment classes are reliable growth tendency descriptors as well. The relationship between average *dbh* of trees pooled into mode and close to mode *b.a.i.* classes and dominant *dbh* in each *PMP,* is finally analysed.

Key words: *forest monitoring, tree growth, response indicators, increment assessment.*

Riassunto - Il monitoraggio delle variazioni di accrescimento.Contributo alla valutazione integrata dello stato dell'ecosistema. Il lavoro riferisce su una delle azioni obbligatorie nell' ambito della valutazione integrata & combinata che riunisce le diverse ricerche in atto nel Programma Nazionale di Monitoraggio Intensivo degli Ecosistemi Forestali CON.ECO.FOR. Obiettivi del lavoro sono (i) la definizione dei contenuti del rilievo dendrometrico eseguito nelle aree di II livello; (ii) il richiamo delle proprietà delle variabili di base (area basimetrica, altezza media e altezza dominante) selezionate per l' elaborazione di indici di stato dell' ecosistema nella valutazione I&C;(iii) la presentazione di un'analisi, supplementare al protocollo comune condiviso a livello europeo che collega il risultato delle misure di accrescimento all' intera popolazione arborea sull' unità di superficie, mirata ad aumentare la coerenza di risposta degli indicatori dendrometrici, vale a dire la loro capacità di distinguere i diversi ritmi di accrescimento in atto nel soprassuolo. La proposta ha l'obiettivo particolare di spiegare la elevata variabilità nelle e tra le aree, tipica delle strutture studiate in Italia, e si basa sulla valutazione del rango sociale individuale e sull'ordinamento degli alberi per piano di vegetazione. Gli obiettivi attesi sono la determinazione della struttura interna dell'accrescimento e delle sue variazioni nei successivi inventari. L'analisi è applicata alle aree realizzate in popolamenti di faggio, una tipologia forestale importante che presenta un'ampia variabilità dendrometrica. I risultati pongono in evidenza il contributo di ciascun piano di vegetazione all' accrescimento complessivo in area basimetrica ed i differenti ritmi incrementali medi tra i piani in ciascuna area, funzione della densità e della differente aggregazione della struttura verticale del bosco. La comparazione dei valori di accrescimento medi espressi nel piano superiore con quelli totali medi per area tra le cinque aree, rivela come ad accrescimenti omogenei per piano corrispondono valori diversi nel totale per l'influenza della variazione trasversale alle strutture delle popolazioni osservate. Ordinate le frequenze arboree per classi incrementali e per piano ed esaminata la distribuzione dei valori, si propone di individuare per ciascuna area ed a ogni inventario un subcampione di alberi indicatori dell' accrescimento scelti tra gli alberi dominanti compresi nell'intorno dei valori modali. La scelta è basata sull' assunto che la risposta in termini di accrescimento degli alberi dominanti sia più immediatamente percettibile perché questi sono meno sensibili alla competizione, e che gli alberi componenti le frequenze modali siano anche descrittori affidabili della tendenza di accrescimento nel periodo. Si analizza infine la relazione tra il diametro medio degli alberi così individuati ed il diametro dominante calcolato per ciascuna area.

Parole chiave: *monitoraggio, accrescimento arboreo, indicatori di risposta, incremento.*

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Tree growth may be accounted both within the context of its dynamics and as an autogenous process. According to the first viewpoint, it is supported by external elements *i.e.* the bio-chemical and physical properties of the growth medium, the ecological environment, the site-class; it is conditioned by the organization of life *i.e.* the spatial aggregation pattern; it is affected by the health status and influenced by temporarily disturbing factors. The compliance or counteraction of the above elements and factors determines actual growth rate.

But tree growth is also an autogenous

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process driven by native qualities of the component species such as the individual genotype, the eco-physiological properties and the adaptive ability. It is the first mover which causes the stand structure, determines the rhythm and time of competition, the course of regular mortality, modifies to a certain extent the ecological conditions inside the standing crop, acting itself as a controller of the allocation rate, at tree as well as at stand level.

Natural growth trend is not linear either for the tree or its components (crown, stem, root system), but is made up of a sequence of well-discernible growth phases over tree lifespan. In addition, individual growth rate increases or drops according to the establishment of a social hierarchy, to the recurrent inter-individual competition cycles, to the occurrence of external disturbances or positive inputs overlapping the natural growth course (FABBIO and AMORINI 1999).

Materials

At the first inventory (winter 1996/97), our frame of reference was a network of 20 (2500 m^2) permanent monitoring plots (*PMPs*) representing the most widespread forest types over Italian peninsula from the Mediterranean-mountain area to the upper vegetation belt in the Apennines and in the Alps. Each plot was established into an homogeneous forest stand (10 hectares as a minimum) representative for local growing conditions (ALLAVENA *et al.* 1999). In accordance with PRODAN (1968), it makes the set of trees surveyed in the unit area a sample of the population under investigation but, depending on the general design, each *PMP* has to be considered as a case-study and inference is problematic (FERRETTI *et al.* 2000).

Subjects of analysis are *the forest stand*, *i.e.* the spatially continuous set of trees showing a similar structure and growing under similar enviromental conditions, *the stand structure*, *i.e.* the physical distribution of trees in the growing space (aggregate and per species), *the individual trees* (HARA 1986, OLIVER and LARSON 1990).

Stand origin is a main differentiating factor, 11 being high forests and 9 stands managed under the coppice system (stored coppices and transitory crops) (FABBIO 1997). Such a difference implies a number of consequences as average age classes, tree densities and related structural patterns; in general terms, it means an increase of formerly existing variability in all descriptive parameters (Table 1), due to the number of types tested too. The established *PMPs*' distribution reflects closely the actual share of the management systems in Italy.

A further source of variability within the same type (see for instance tree densities at similar ages in beech stands) is caused by the irregular silvicultural practice characterizing most Italian high forests. This is both an historical background due to the prevailing mountain location (economically marginal areas) and more recently to the generalized suspension of harvesting in the public domain because of the conservative policy acting also on forests previously oriented to wood production.

Methods

At the first inventory (AMORINI *et al.* 1999) a detailed description of site and tree population in each *PMP* was carried out. Standing crops were determined by the basic growth variables: dbh of all living trees above 3 cm in coppice forests and 5 cm in high forests; tree height by random sampling over the dbh range. Basal area, mean and top dbh as well as standing volume were calculated. Mean and top height were estimated by height *vs.* dbh relationship. Standing volume was derived from the two-entry tables elaborated per species and stand type (National Forest Inventory 1985). Core sampling of trees living in the main storey allowed the estimate of stand age and the assessment of past radial stem growth. The survey of tree height, height to crown base and crown width on the same trees selected for coring in the buffer area, made data available to fit the crown width *vs.* dbh allometric relationship.

The estimate of social class according to KRAFT made an accurate description of vertical stand structure possible and pointed out both the role played by each tree species in mixed stands and the contribution of each storey (stem frequency and basal area distributions *vs.* dbh per species and layer). The former assessment at stand (sampled population) level was there-

Table 1 - Summary of dendrometrical parameters surveyed in each *PMP* at the inventory 1996/97.
Parametri dendrometrici riassuntivi delle aree all' inventario 1996/97.

PLOT CODE	MAIN SPECIES	MANAG. SYSTEM	AGE (1) yrs	STEMS (2) n ha^{-1}	BASAL AREA m^2 ha^{-1}	MEAN DBH(3) cm	DOM DBH(4) cm	MEAN HEIGHT(5) m	TOP HEIGHT(5) m
ABR1	*Fagus sylvatica*	high forest	110	899	40,06	23,8	41,1	20,1	24,8
BAS1	*Quercus cerris*	trans. crop(6)	65	917	41,05	23,9	43	16,8	19,7
CAL1	*Fagus sylvatica*	high forest	110	333	40,02	39,1	57,2	24,2	27,4
CAM1	*Fagus sylvatica*	high forest	100	228	47,57	51,5	60,3	26,8	28,0
EMI1	*Q.petraea Q.cerris*	stored coppice	45	2057	25,76	12,6	30	14,2	20,0
EMI2	*Fagus sylvatica*	stored coppice	40	4540	37,10	10,2	22,2	10,1	15,2
FRI1	*Carpinus bet.Q.robur*	stored coppice	45	1126	24,40	16,6	27,5	17,2	20,8
FRI2	*Picea abies*	high forest	110	532	52,92	35,6	43,3	29,5	30,8
LAZ1	*Quercus cerris*	stored coppice	35	1629	23,99	13,7	22,9	13,5	15,8
LOM1	*Picea abies*	high forest	80	1043	40,02	22,1	45,7	18,5	25,8
MAR1	*Quercus cerris*	stored coppice	35	4233	35,88	10,4	21,9	12,8	19,3
PIE1	*Fagus sylvatica*	trans. crop	55	1213	29,07	17,5	21,8	16,1	19,2
PUG1	*Fagus sylvatica*	high forest	85	940	44,31	24,5	45,7	23,1	27,2
SAR1	*Quercus ilex*	stored coppice	50	1710	40,80	17,4	28,5	13,7	16,3
SIC1	*Quercus cerris*	trans. crop	50	855	25,23	19,4	26,3	14,5	16,8
TOS1	*Quercus ilex*	stored coppice	50	2380	26,21	11,8	31,9	11,1	15,2
TRE1	*Picea abies*	high forest	120-200	393	54,16	41,9	55,7	28,2	30,7
UMB1	*Quercus cerris*	trans. crop	75	739	34,85	24,5	36,2	25,5	30,0
VAL1	*Picea abies*	high forest	150	745	50,83	29,5	45,8	21,4	28,3
VEN1	*Fagus sylvatica*	high forest	110	345	34,69	35,8	46,6	24	25,4

(1) average age in the dominant storey in those *PMPs* where, due either to the irregular silvicultural practice or to the applied management system (group selection system), more than one age class is present in the main crop;
(2) living trees. Minimum dbh surveyed = 3 cm in coppice forests; = 5 cm in high forests and transitory crops;
(3) dbh of average basal area tree;
(4) average dbh of 100 largest trees per hectare;
(5) height values corresponding to mean and dominant dbhs read on the height-dbh curve;
(6) stored coppices undergoing conversion into high forest. One or more thinnings carried out in the original stored crops.

The number of forest types monitored and the different stand origin & management systems in progress are shown in the Table. Tree densities at similar ages and related growth parameters per type highlight the additive effect of quoted factors and of irregular practice of forestry on variability across *PMPs.*
La Tabella evidenzia l'elevato numero di tipi forestali monitorati, la diversa origine dei soprassuoli e le forme di governo attualmente in corso. Le densità unitarie ad età simili ed i parametri dendrometrici correlati per ciascun tipo, evidenziano l'effetto additivo dei fattori citati e della pratica non regolare della selvicoltura sulla variabilità tra le aree.

fore ranked into the component sub-populations and the allocation of growth per storey was determined.

Identification of indicators

The contents of the first inventory outline the actual status of tree populations in each *PMP* and establish the reference database for the planned surveys. The outcomes from the different mandatory and optional research actions undertaken on level II plots are the basis of the present I&C evaluation aimed at identifying the current ecosystems status by relevant indicators able to synthesize the information related to their designed use. Variations of ecosystem status (baseline condition at the beginning of the monitoring programme) will be identified by size and direction changes of elaborated descriptors (Ferretti *et al. op.cit.*). The I&C action in progress is in accordance with the statements of the Expert Panel on Forest Growth (Dobbertin *et al.* 2000), which quotes: *forest growth data and knowledge of forest structure as prerequisites for the analysis of many other parameters assessed on level II plots.... tree size and its change can be used both as response variables* *and as explanatory variables in the analysis.*

The goal is therefore the identification of indicators tightly interactive to the general understanding of dynamics in progress.

According to OCSE (1999 in Benedetti and De Bertoldi 2000), the characteristics of an indicator are to be simple, easily comprehensible, able to show a time trend, reactive to environmental changes, to be enforceable to themes of general concern, allowable for comparisons, theoretically well-founded and based on international standards, easily available at a reasonable cost/benefit ratio, well-documented and quality certified, periodically updateable.
In short, the qualities of an indicator may be summarized as follows:
representativeness: i.e. the indicator should be clearly related to the phenomenon and highly correlated to the effect to test with a minimal statistical dispersion; easily recognizable from background noises; sufficiently extensible to analogous but not identical situations;
accessibility: i.e. easily measurable and easy to be sampled, being accessible with standard techniques;
reliability: i.e. minimal bias occurrence;
effectiveness: i.e. directly usable to quantify interventions, costs and benefits (Gamba and Martignetti 1995 in Benedetti *et al. op.cit.*).

Under these assumptions, the following variables were tested: *basal area* (m^2ha^{-1}) *i.e.* the summation of circular areas at 1.3m of all living trees in the plot from the measurement of individual tree girth; *mean height* (m) *i.e.* the height of mean basal area tree; *top height* (m) *i.e.* the height of mean basal area tree among 100 largest stems per hectare. At the moment these variables are only indexes of stand status; but they will become significant indicators when more surveys will be implemented and current increment in the relative intervals will be determined.

Features and qualities of these classical forest mensurational indexes may be recalled as follows:

- basal area:
- responsive, within the boundaries of silvicultural treatment (periodical removal), of site carrying capacity;
- function of tree density, *i.e.* index of the distance between actual and potential status, if a reference stand (control) is available;
- highly related with standing volume and biomass, it follows the same distributive pattern but is more reliable as an outcome of a calculation instead of an estimate;
- summation of individual values; it may be disaggregated into different layers; both the weight of each sub- population and its descriptive statistics may be thus assessed;
- qualifies stand growth as an addition of different, well-discernible growth rates acting in the tree population;
- consistent with actual stand structure;

- mean height:
- dependent from tree density and from the arrangement of vertical stand structure, *i.e.* from stand origin and silvicultural treatment (thinnings);
- expression of growth environment;
- responsive to changes as a function of a growth variation on a relatively large set of trees living under average site conditions;

- top height:
- independent to a great extent from past and current tree density, *i.e.* from applied silvicultural treatment;
- well-founded descriptor of a reference status as a qualified index of site class, *i.e.* physical environment conditions (soil and climate) as compared with the bio-ecological boundaries of tree species concerned;
- reliable index of productive capacity (potential production); it suggests both a foreseeable growth level and pattern; it allows as a consequence the estimate of possible deviations from an expected growth trend (*e.g.* yield tables);
- less sensitive than mean height in the short term because less depending on current growth environment. More sensitive in the long run; see at the purpose the *falling off of site quality class* (Assmann 1970).

A few remarks on the quoted forest mensurational variables may be recalled as follows: their response ability depends also on the specific sensitivity or complacency to positive inputs or stresses originated by site or environmental factors. Species sensitivity is related to site quality too, given its possible range from the optimum to the specific bio-ecological boundaries. *PMPs*' location into typical vegetation areas provided with a wide homogeneous cover should reduce this further element of uncertainty.

As far as basal area and mean height are concerned, the condition of no-management in progress in most *PMPs* in Italy bounds the effect of removals, at least for the foreseen duration of the project (20 yrs).

Data analysis

The availability of a second dataset since the inventory 1999/2000, makes it possible the calculation and first comparisons of individual and population growth in terms of mean and dominant dbh, basal area, mean and top height, standing volume.

The increment in the period provides the quantitative variation of the main growth parameters; the assessment of tree mortality and ingrowth supplies further information on the dynamics in progress in each *PMP*.

In accordance with statements of common European protocol (ICP Manual 1998), which links the outcome of growth mensuration to the comprehensive tree population living in the unit area (plot or subplot), the analysis provides data updating at *PMP* level. In addition, and with a special reference to the observed forest structures which show a high in-and-between variability, a working hypothesis aimed at improving growth indicators consistency, *i.e.* their ability to explain the growth rates acting inside each tree population, has been tested. The approach is consistent with the statements of the "Growth Panel" (Dobbertin *et al. op. cit.*) which quotes: *among the objectives for tree size measurements,*

- to obtain information about stand structure or single tree properties as explaining variables for other measurements carried out on level II plots;

- to estimate single tree and stand growth as a response variable of environmental and stress factors.

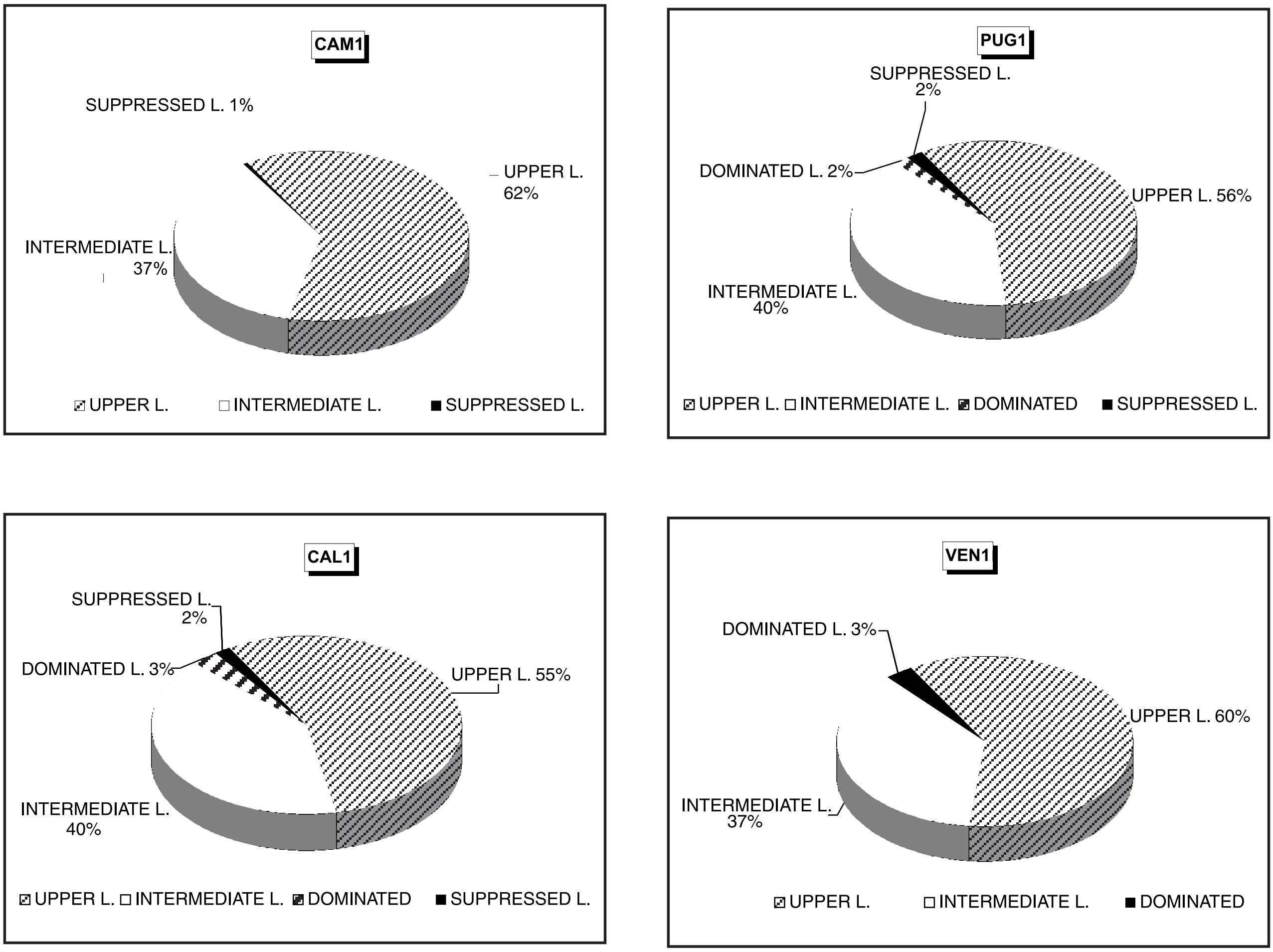
The analysis is based on the evaluation of individual social class and on the stratification of trees into well-discernible layers in order to reduce to a great extent the subjectivity of individual social attribution. Aiming at both the assessment of internal growth structure and its variations throughout subsequent inventories. The analysis applied to beech *PMPs*, a target forest type in the European network showing a high heterogeneity in Italy, is here presented. According to local yield tables, four *PMPs* are classified as a 2nd (ABR1, CAL1, PUG1, VEN1) and one as a 1st (CAM1) site class.

Each population has been stratified into the upper, intermediate, dominated and suppressed layer to quantify their contribution and qualify comprehensive stand growth. The percentage distribution of basal area increment (*b.a.i.*)in each *PMP* is outlined in Figure 1; a quite similar proportion of the upper layer on 4 *PMPs* (55-62%), but a much greater share of the same layer in ABR1 (87%) - this plot showing a peculiar stand structure - is highlighted.

The values of *b.a.i.* and relative averages are reported in Table 2. *Within PMPs*: values per layer compared with growth per plot highlight the different contribution of social classes as a function of actual tree density and physical arrangement of standing crop. The differences between average *b.a.i.* per layer and per plot point out the growing pattern and highlight the reduced information of the comprehensive value. *Among PMPs*: similar average growth rates in the upper tree layer (ABR1 excepted) match different average growth per plot, the latter value incorporating the variability across stand structures.

Trees in each layer have been then stratified into *b.a.i.* classes (Figure 2). As far as the relationship *growth environment change / tree increment variation* (underlying hypothesis) is concerned, the distributive pattern provides further information on the structure of actual growth and gives the graphic evidence of the prevailing allocation rates. Modal values per layer may be considered as the reliable expression of incremental tendency over the observed time window; in these terms they link up *b.a.i.* distributions originated in each plot by different ranges, number of trees and spatial aggregation patterns, in accordance with stand development.

On this basis, the median of the upper layer highlights sets of possible *growth-indicator trees*, under the assumption they produce a more



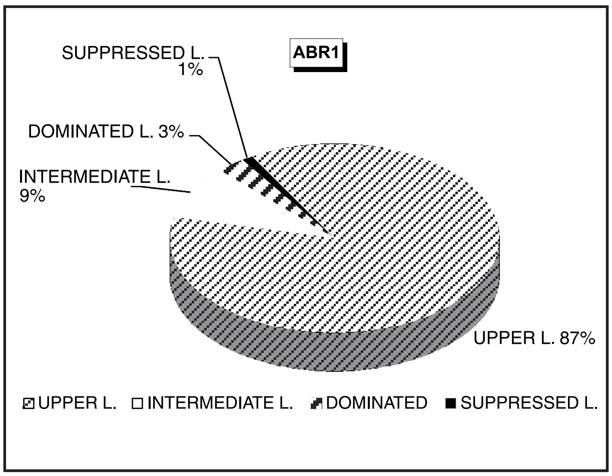


Figure 1 - Percentage distribution of Δg among layers over the time $t_0 \rightarrow t_1$ (beech high forest *PMPs*).
Distribuzione percentuale dell' accrescimento in area basimetrica tra i piani sociali nell' intervallo tra i due inventari nelle aree di faggeta.

consistent response in terms of growth. The working hypothesis is that trees living in the upper layer contribute a major share of current basal area increment (Roberts *et al.* 1993, Hamilton 1969, Kozlowski and Peterson 1962, in Hamilton *op. cit.*); they are less sensitive to internal stresses such as inter-individual competition (Harper 1967) and more responsive to growth environment conditions being able to fulfil current site capacity (Ker 1953 e Kira *et al.* 1953, in Oliver and Larson *op. cit.*). Their location over dbh range is predictable to be placed on the right side of the distribution, close to the bounds of average dominant trees. The size of the subset will vary from plot to plot according to stand structure and tree density.

In order to verify size-consistency between *dbh* of trees originating in each plot modal and close to modal *b.a.i.* classes and dominant *dbh* calculated in each plot, the corresponding values at the first and second inventory are reported

Table 2 - Values of Δg in the main and subordinate storey over the time $t_0 \rightarrow t_1$ inside the surveyed beech high forests (5 *PMPs*). These *PMPs* cover the latitudinal range of beech cover in Italy from Southern Apennines to the Alps. (Values referred to plot area = 2500 m^2).
Valori totali e medi di accrescimento in area basimetrica per piano di vegetazione nell'intervallo tra i due inventari nelle 5 aree di faggeta. Queste coprono la variazione latitudinale della specie in Italia, dall' Appennino meridionale alle Alpi. (Valori riferiti alla superficie dell'area = 2500 m^2).

TREE LAYER	PMP									
	CAL1		CAM1		PUG1		ABR1		VEN1	
	ΔG 96-99 cm^2	Δg ± se cm^2	ΔG 96-99 cm^2	Δg ± se cm^2	ΔG 96-99 cm^2	Δg ± se cm^2	ΔG 96-99 cm^2	Δg ± se cm^2	ΔG 96-99 cm^2	Δg ± se cm^2
UPPER L. (predom.+dom.trees)	1720 *(20)*	86 ± 11.6	2270 *(30)*	76 ± 7.7	3426 *(47)*	73 ± 4.9	4874 *(88)*	55 ± 2.6	2509 *(32)*	78 ± 5.8
INTERMEDIATE L. (subdominant+ subdominated trees)	1249 *(30)*	42 ± 4.7	1368 *(24)*	57 ± 7.7	2379 *(79)*	30 ± 3.2	523 *(30)*	17 ± 2.8	1545 *(49)*	32 ± 2.7
DOMINATED L. (overtopped trees)	92 *(9)*	10 ± 4.1	-	-	99 *(30)*	3 ± 0.6	148 *(32)*	5 ± 0.8	128 *(8)*	16 ± 2.1
SUPPRESSED L. (trees subordinated to the main crop stratification)	49 *(12)*	4 ± 1.7	20 *(1)*	-	116 *(36)*	3 ± 0.3	66 *(45)*	1 ± 0.2	-	-
TOTAL	3110 *(71)*	44 ± 5.3	3658 *(55)*	66 ± 5.5	6020 *(192)*	31 ± 2.6	5611 *(195)*	29 ± 2.2	4182 *(89)*	47 ± 3.6

ΔG = basal area increment per layer in the period.
( ) n° of trees in each layer.
Δg = average tree basal area increment.

The set of trees in each *PMP* includes all trees surveyed at the first and second inventory, [ingrowth (*i.e.* trees overcoming the min. threshold dbh in the interval 1996-99) + mortality in the period + trees showing a not consistent dbh variation (*i.e.* measurement or transcription & recording error at the time of the first inventory, detected and checked at the second round of measurement)] excepted.
L'insieme di alberi in ciascuna area comprende tutti quelli misurati al primo e secondo inventario, con esclusione delle piante entrate a misura nel periodo, della mortalità e dei valori non coerenti dovuti ad errori di misura al primo rilievo.

in Table 3. The hypothesis is verified under regular age-related densities (CAL1, CAM1, VEN1) whilst former dbh is, as expected, lower in overstocked plots (PUG1 and ABR1).

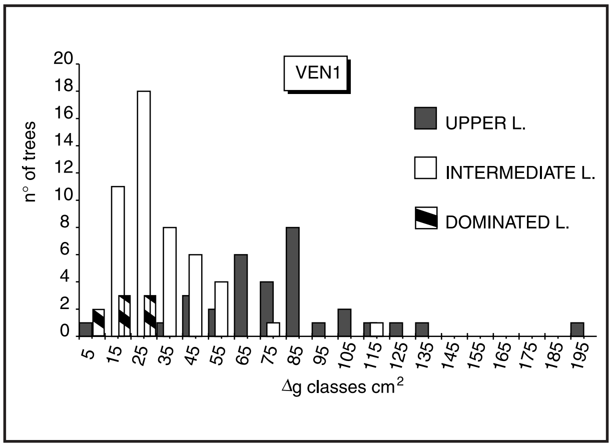
Conclusive remarks

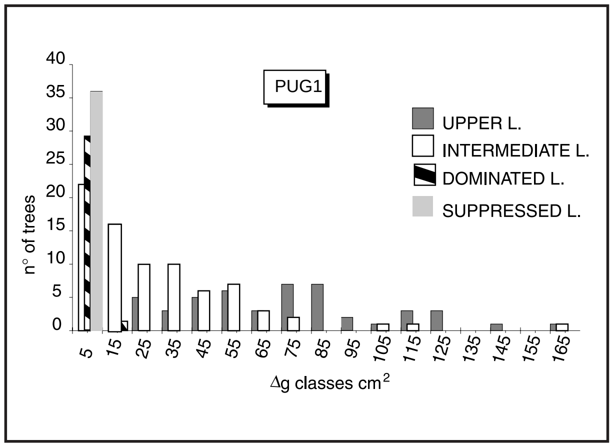
Under the general statement that dynamics within forest ecosystems takes place over different spatial and temporal scales (Innes 1998), there is a special evidence that growth allocation over time (growth dynamics) is basically an individual (tree) attribute showing a high intertree variation throughout the dbh range. Such a variability may be reduced sorting similar tree positions occurring in each structural aggregate. It makes possible to highlight expected, different growth trends, the social class becoming the major determinant in grown-up, storeyed stand structures. The assessment of differentiated growth patterns produces an improved response

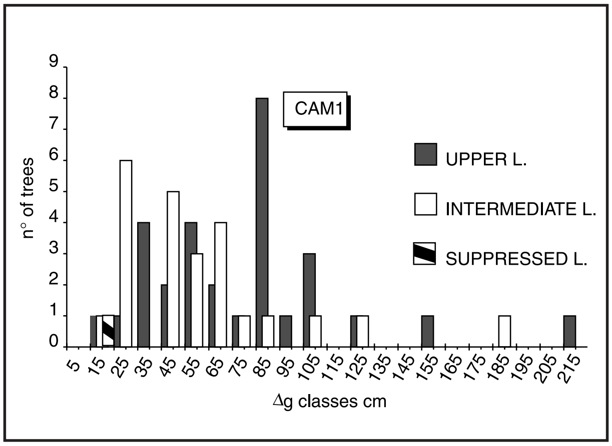
Table 3 - Relationship between the average *dbh* [1] of trees pooled in modal and close to modal Δg classes in the upper layer (see Figure 2) and the dominant *dbh* [2] surveyed in each *PMP*, at the times of the first and second inventory.
Relazione tra il diametro medio degli alberi componenti le classi modali e contigue di accrescimento in area basimetrica nel piano superiore (vedi Figura 2) ed il diametro dominante calcolato per ciascuna area, al primo e secondo inventario.

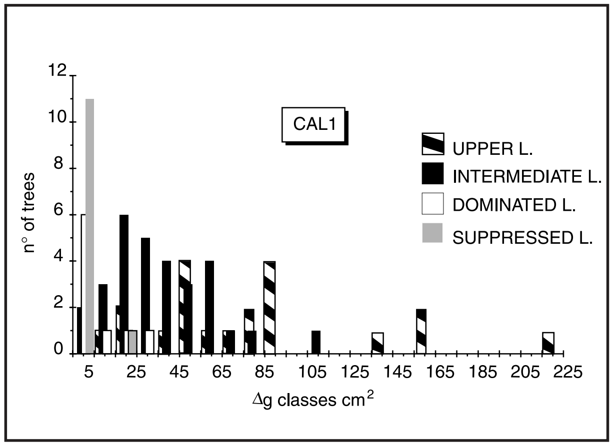
	DBH		
	[1]	**[2]**	
CAL1 (12)			333 trees ha^{-1}
1996	56.3 ± 2.3	57,2	
1999	57.1 ± 2.3	57,9	
CAM1 (8)			228 trees ha^{-1}
1996	57.1 ± 3.6	60,3	
1999	58.0 ± 3.6	61,2	
PUG1 (14)			940 trees ha^{-1}
1996	40.2 ± 1.8	45,7	
1999	41.4 ± 1.7	46,7	
ABR1 (41)			899 trees ha^{-1}
1996	33.4 ± 0.8	41,1	
1999	34.4 ± 0.8	42,1	
VEN1 (18)			345 trees ha^{-1}
1996	45.6 ± 0.7	46,6	
1999	46.7 ± 0.7	47,4	

( ) n° of trees in the selected Δg classes.
[1] Values in cm ± se
[2] average dbh of 100 thickest stems ha^{-1} (cm).









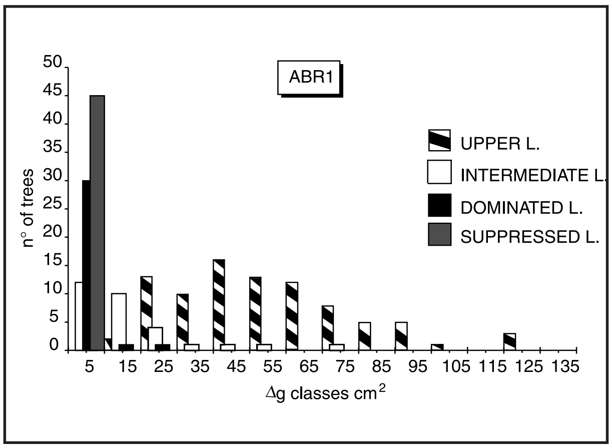


Figure 2 - Distribution of trees per basal area increment classes and per layer over the time $t_0 \rightarrow t_1$ (beech high forest *PMPs;* frequencies referred to plot area = 2500 m^2).
Distribuzione degli alberi per classi di incremento in area basimetrica e per piano sociale nell' intervallo tra i due inventari (aree di faggeta; valori riferiti alla superficie delle aree = 2500 m^2).

consistency of growth indicators because their actual sensitivity to external stressors or positive inputs is in this way arranged as well. Intermediate and dominated layers are in fact more sensitive to internal constraints (*e.g.* inter-tree competition), whilst trees living in the upper main storey are more responsive in the short run independently from their sensitivity to competition.

The proposed analysis may provide therefore a basis to *qualify* the comprehensive growth - *function of the different growth rates acting in the tree population* - and makes it possible to follow its internal variations or recognize emerging trends throughout subsequent inventories. It increases the available opportunities in the examined context where, due both to stand origin and irregular silvicultural management, most of plots show a complex arrangement of vertical stand structure which heavily contributes to inner variability.

References

Allavena S., Isopi R., Petriccione B., Pompei E.(eds) 1999 – *Programma Nazionale Integrato per il Controllo degli Ecosistemi Forestali*, Ministero per le Politiche Agricole, Roma,167 p.

Amorini E., Fabbio G., Cutini A., 1999 – *Studio degli accrescimenti arborei*. In: Programma Nazionale Integrato per il Controllo degli Ecosistemi Forestali. MiPA-CFS Roma:131-136.

Assmann E., 1970 – *The principles of forest yield study*. Pergamon Press, Oxford 506p.

Benedetti A., De Bertoldi S., 2000 – *Qualità del suolo: criteri di definizione*. Relazione al Convegno Accademia Nazionale delle Scienze 29 marzo, Roma.

Dobbertin M., Andreassen K., Neumann M., Somogyi Z., 2000 – *Forest Growth*. Report of the Expert Panel on Forest Growth. 17 p.

Fabbio G., 1997 – *Assessment of increment in coppice forests*. Report to the Expert Panel on Forest Growth, Zurigo.

Fabbio G., Amorini E., 1999 – *Studio dell' accrescimento arboreo in ecosistemi forestali*. Relazione al VIII Congresso Nazionale Società Italiana di Ecologia, Lecce.

Ferretti M., Bussotti F., Giordano P., Mazzali C., Nibbi R., 2000 - *CONECOFOR-Integrated and combined (I&C) evaluation of risk, status and changes of forest ecosystems*. In: Atti (2) S.I.S.E.F. :435-440.

Hamilton G.J., 1969 – *The dependence of volume increment of individual trees on dominance, crown dimensions and competition*. Forestry (42): 133-144.

Hara T., 1986 – *Growth of individuals in plant populations*. Ann. Bot. London, (57): 55-68.

Harper J.L., 1967 – *A Darwinian approach to plant ecology*. J. Ecol. (55): 247-270.

ICP Manual, 1998 – *Part V Estimation of Growth and Yield*. (J. Innes ed.) Federal Research Centre for Forestry and Forest Products (BFH): 1-20.

Innes J.L., 1998 – *Measuring environmental change*.In: Peterson D.L., Parker V.T., (Eds.) Ecological Scale. Columbia University Press: 429-457.

Ker J.W., 1953 - *Growth of immature douglas-fir by tree classes*. Forest Chronicle (29): 367-373.

Kira T., Ogawa H., Sakazaki N., 1953 - *Intraspecific competition among higher plants: I competition-density-yield interrelationship in regularly dispersed populations*. Journal of the Institute of Polytechnics, Osaka City University (1): 1-16.

Kozlowski T.T., Peterson T.A., 1962 - *Seasonal growth in pine*, Botanical Gazette 124 (2).

MAF-ISAFA 1988 – *Inventario Forestale Nazionale 1985. Sintesi metodologica e risultati*. 461p.

Oliver C.D., Larson B.C., 1990 – *Forest stand dynamics*. Mc Graw Hill, New York 467p.

Prodan M., 1968 – *Forest biometrics*. Pergamon Press, Oxford 447p.

Roberts S.D., Long J.N., Smith F.W., 1993 – *Canopy stratification and leaf area efficiency: a conceptualisation*. For. Ecol. Manage. (60):143-156.

Properties and productivity of crowns and canopy
Contribution to an integrated analysis of forest ecosystem's status§

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Abstract - Starting from the evidence that crowns and canopy are more sensitive and react more promptly to abiotic and biotic disturbances than other stand structural components, Italy, as other European countries, decided to undertake surveys on properties and productivity of crowns and canopy in addition to the mandatory surveys planned in the EC-UN/ECE program "Intensive Monitoring (Level II) of Forest Ecosystems". Annual litter production and LAI were chosen as suitable variables for monitoring properties and productivity of crowns and canopy. Surveys involved 20 plots, covering the most diffuse forest types in Italy. The collected data provided a first reference point on properties and productivity of crowns and canopies for the selected stands and allowed to make comparisons with data from similar stands already available in literature. The meaning and the potential use of litter production, LAI and of other indexes related to crowns and canopy characteristics is discussed on the basis of the available data as a whole and of a more detailed analysis carried out on a case of study represented by *Quercus cerris* plots. The importance of implementing a complete database to increase indexes representativeness and reliability and to perform an integrated analysis of results, which takes into account the outcomes of other research actions, is recognised as an indispensable requirement for the achievement of the monitoring program goals.

Key words: *intensive monitoring, leaf area index, litter production, response indicators, integrated analysis.*

Riassunto - Caratteristiche e produttività delle chiome e della copertura forestale. Contributo ad un'analisi integrata dello stato dell'ecosistema forestale. Le chiome degli alberi e la copertura forestale nel suo complesso, di fronte a eventi perturbanti di natura abiotica e biotica, sono maggiormente sensibili e hanno tempi di risposta più immediati rispetto alle altre componenti di un ecosistema forestale. Per questo motivo l'Italia, così come altri paesi europei, ha avviato una serie di indagini facoltative, oltre a quanto stabilito dal programma EC-UN/ECE "Intensive Monitoring (Level II) of Forest Ecosystems", finalizzate ad analizzare le caratteristiche e la produttività delle chiome e della copertura forestale. In particolare la produzione annuale di lettiera e l'indice di area fogliare (LAI) del popolamento sono stati individuati come indicatori utili al raggiungimento degli obiettivi del programma di monitoraggio. I rilievi hanno interessato venti aree sperimentali rappresentative delle principali tipologie forestali italiane. Per la stima della produzione annuale di lettiera si è proceduto attraverso il metodo della raccolta, posizionando con criterio sistematico dodici trappole all'interno di ciascuna area. Per la stima del LAI in popolamenti di conifere è stato utilizzato un *Plant Canopy Analyser LAI 2000;* nel caso delle latifoglie si è proceduto anche a stimare il LAI con il metodo delle trappole. Il presente lavoro, dopo aver fornito un quadro generale dei dati raccolti, illustra più in dettaglio i risultati relativi ai popolamenti di *Quercus cerris*. L'analisi di questo caso di studio costituisce lo spunto per soffermarsi sul significato ecologico e funzionale degli indicatori presi in considerazione (produzione annuale di lettiera e LAI) e di altre variabili o indici ad essi collegati quali l'area fogliare specifica e la composizione della lettiera (lettiera fogliare, parti legnose, frutti) e di valutarne le potenzialità di impiego. La continuità dei rilievi nel tempo e l'integrazione dei dati raccolti con i risultati di altre azioni di ricerca (valutazione dello stato delle chiome, variazioni di accrescimento, dati meteorologici, vegetazione, fenologia) si configurano come condizioni necessarie per garantire da un lato una maggiore rappresentatività e accuratezza degli indicatori presi in considerazione e, dall'altro, il raggiungimento degli obiettivi del programma di monitoraggio.

Parole chiave: *monitoraggio intensivo, indice di area fogliare, produzione di lettiera, indicatori di risposta, analisi integrata.*

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Tree and stand growth is a process supported by external elements such as the physical environment, the bio-ecological conditions, by temporarily acting factors such as disturbances, and, on the other hand, by native qualities of the component species such as the genotype, the physiological properties and the adaptive ability (Fabbio and Amorini 2000). In this context, studies on properties and productivity of crowns and canopy are important in order to evaluate the quality of an ecosystem and its functional status (Waring 1983, Romane 1995). Leaves and crowns are indeed the active interface of energy, carbon and water exchanges between forest canopies and the atmosphere and deal with a major pathway for both energy and nutrients transfer in this type of ecosystem (Bray and Gorham 1964). In addition, crowns and canopy are more sensitive and react more promptly than other stand structural components to abiotic and biotic disturbances. Monitoring their characteristics is therefore a crucial issue for intensive and continuous monitoring programs of forest ecosystems status. That is the reason why Italy, as other European Countries, decided to undertake surveys on properties and

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productivity of crowns and canopies in addition to the mandatory surveys planned in the EC-UN/ ECE program "Intensive Monitoring (Level II) of Forest Ecosystems".

Annual litter production and LAI were chosen as valid variables for monitoring properties and productivity of crowns and canopies. They indeed matched almost all the main requirements of a good indicator such as to be rather simple, comprehensible, able to show time trends, reactive to environmental constraints, enforceable to themes of general concern, allowable for comparisons, and characterised by a good representativeness, accessibility, reliability and effectiveness (Benedetti and De Bertoldi 2000). In addition, they were able to interact with the outcomes of other mandatory surveys (*i.e.* meteorology monitoring, crown condition assessment, increment studies) in order to implement a general analysis and understanding of the phenomena under observation.

This paper gives a general description of the research activity carried out during the first three years of observation and currently in progress. A more detailed analysis, carried out on a case study represented by Turkey oak (*Quercus cerris* L.) plots, is presented in order to show the suitability of variables and indexes chosen to analyse properties and productivity of crowns and canopy, their meaning and potential use, with reference to the general aims of the monitoring program.

Materials and Methods

Surveys started in the second half of 1997 and involved 20 plots, covering the most diffuse forest types in Italy. Details about sampling strategy, representativeness and stand characteristics are given in Fabbio and Amorini (*op. cit.*).

Twelve 0.25 m^2 litter-traps were positioned systematically in each plot to estimate the total annual litter production (dry biomass) and its main components (leaves, woody parts and fruits) according to the method described by Cutini (1992). Litter was collected every fifteen days during fall and once a month during the other seasons, sorted into the main components and then dried in a forced air stove at 85°C ±2 up to reach the constant dry weight.

LAI (one-sided projected area) of broadleaved stands was estimated from the measure of total annual litter production using, as a conversion factor, the specific leaf area (SLA, leaf area per unit of leaf dry weight) calculated each year on a sub-sample of leaves chosen systematically. At each litter collection, all the undamaged leaves, collected from one trap at rotation, were sampled up to a total of 100 leaves for each plot. Leaves were measured before drying with a leaf area meter (Delta T Devices, Burwell, UK) and weighed after drying for 24 hours at 85°C±2. Mean SLA value was used to estimate stand leaf area index from leaf litter component (LAI_{LT}). LAI values were corrected using a shrinkage coefficient, previously calculated on a sub-sample of green leaves, in order to avoid underestimates due to a SLA calculated from partly shrunk fallen leaves (Vanseveren 1969).

Furthermore, in order to provide LAI estimates also for coniferous forests and in a less labour-intensive way, indirect estimates of LAI with a LAI 2000 Plant Canopy Analyzer (LAI 2000 PCA, Li-Cor, Lincoln, NE, USA) have been carried out on a sub-sample of fifteen plots. LAI was measured during the period of maximum leaf expansion (July-August). Measurements were taken over the litter-traps according to an already described protocol (Cutini *et al.* 1998). The instrument uses diffuse light interception to provide estimates both of quantitative characteristics of canopy as LAI (LAI_{PCA}) and of foliage arrangement and distribution in the space, and can be successfully used to assess both temporal and spatial variations and to compare different stands (Cutini *et al. op. cit.*).

Results

A summary of the type of data available on properties and productivity of crowns and canopy for the plots of the EC-UN/ECE program "Intensive Monitoring (Level II) of Forest Ecosystems" is given in table 1.

In order to show the potential use of the collected data, preliminary results from plots where Turkey oak is the main or one of the main component species (BAS 1, EMI 1, LAZ 1, MAR 1, SIC 1), are here shortly reported as an example.

Table 1 - Overview of data available (+) on properties and productivity of crowns and canopy in level II intensive monitoring plots in Italy.
Sintesi dei dati disponibili (+) su caratteristiche e produttività delle chiome e della copertura forestale nelle aree di monitoraggio intensivo (II livello) in Italia.

plot code	main species	forest type	1997					1998					1999				
			LT*	LTC*	LF	LAI_{LT}	LAI_{PCA}	LT	LTC	LF	LAI_{LT}	LAI_{PCA}	LT	LTC	LF	LAI_{LT}	LAI_{PCA}
ABR 1	*F. sylvatica*	high forest	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
BAS 1	*Q. cerris*	transitory crop	+	+			+	+	+	+	+		+	+	+	+	
CAL 1	*F. sylvatica*	high forest						+	+	+	+	+	+	+	+	+	
CAM 1	*F. sylvatica*	high forest						+	+	+	+						
EMI 1	*Q. cerris- Q.petraea*	stored coppice	+	+			+	+	+	+	+	+	+	+	+	+	
EMI 2	*F. sylvatica*	stored coppice	+	+			+	+	+	+	+	+					
FRI 1	*C. betulus*	stored coppice	+	+			+	+	+	+	+	+	+	+	+	+	
FRI 2	*P. abies*	high forest	+	+			+	+	+			+					
LAZ 1	*Q. cerris*	stored coppice	+	+			+	+	+	+	+	+	+	+	+	+	
LOM 1	*P. abies*	high forest	+	+			+		+	+			+		+	+	
MAR 1	*Q. cerris*	stored coppice	+	+			+	+	+	+	+	+	+	+	+	+	
PIE 1	*F. sylvatica*	transitory crop	+	+			+	+	+	+	+	+	+	+	+	+	
PUG 1	*F. sylvatica*	high forest	+	+			+	+	+	+	+		+	+	+	+	
SAR 1	*Q. ilex*	stored coppice	+	+				+	+	+		+	+	+	+		
SIC 1	*Q. cerris*	stored coppice	+	+				+	+	+	+	+	+	+	+	+	
TOS 1	*Q. ilex*	stored coppice	+	+			+	+	+	+		+	+	+	+		+
TRE 1	*P. abies*	high forest	+	+			+	+	+			+	+	+			
UMB 1	*Q. cerris*	transitory crop					+					+					
VAL 1	*P. abies*	high forest	+	+			+	+	+			+					
VEN 1	*F. sylvatica*	high forest	+	+			+	+	+	+	+	+	+	+	+	+	

LT = litter ; **LTC** = litter sorted in fractions (leaves, woody, fruit); **LF** = leaf size and leaf area measurments (mean leaf area and dry weight, SLA=specific leaf area) of main species
LAI_{LT} = LAI from litter traps; **LAI_{PCA}** = LAI from Plant Canopy Analyzer LAI-2000
***** = data not available on an annual basis

Leaves sub-samples collected from litter traps allowed to calculate some interesting leaf morphometric indexes such as mean leaf area, mean leaf dry weight and SLA. Figure 1 highlights the differences among sites and the changes occurred in Turkey oak SLA between the years. The tendency of Turkey oak to show a lower SLA in 1999 than in 1998 is rather evident.

The amount of litter production accounted both for differences among sites and between years. The extreme values were recorded in LAZ 1 and SIC 1 plots. LAZ 1 was the plot showing the lowest productivity (total litter 3.5 Mg ha^{-1}; leaf litter 3.0 Mg ha^{-1}) while SIC 1 the most productive (total litter 7.8 Mg ha^{-1}; leaf litter 4.9 Mg ha^{-1}). Litter production was higher in 1998 than in 1999 in total, while leaf and acorn production in some cases (figure 2). As regards litter composition, leaves were the most important fraction representing, on average, 68% of total litter.

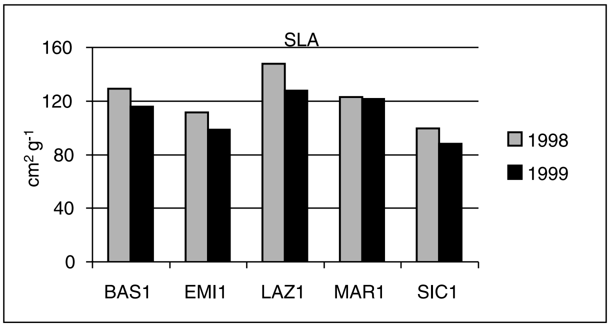

Figure 1 - Changes of specific leaf area (SLA) in *Q. cerris* level II intensive monitoring plots.
Cambiamenti dell'area fogliare specifica (SLA) in aree di monitoraggio intensivo (II livello) a prevalenza di Q. cerris.

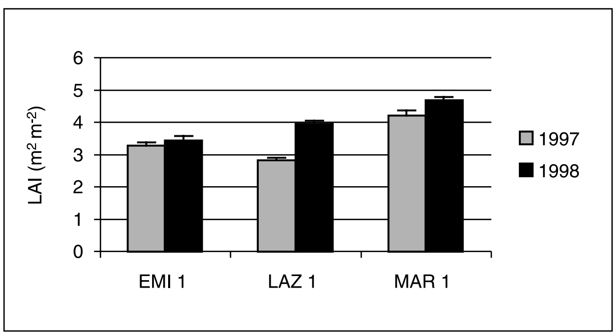

Figure 3 - LAI estimates (mean ± 1se) with LAI 2000 PCA in *Q. cerris* level II intensive monitoring plots.
Valori di LAI (media ± 1 es) misurati con lo strumento LAI 2000 PCA in aree di monitoraggio intensivo (II livello) a prevalenza di Q. cerris.

Figure 3 shows differences in LAI measurements from PCA LAI 2000 among sites and between years. LAI ranged from 3 to 5.5 $m^2 m^{-2}$ with values in 1998 higher than in 1997.

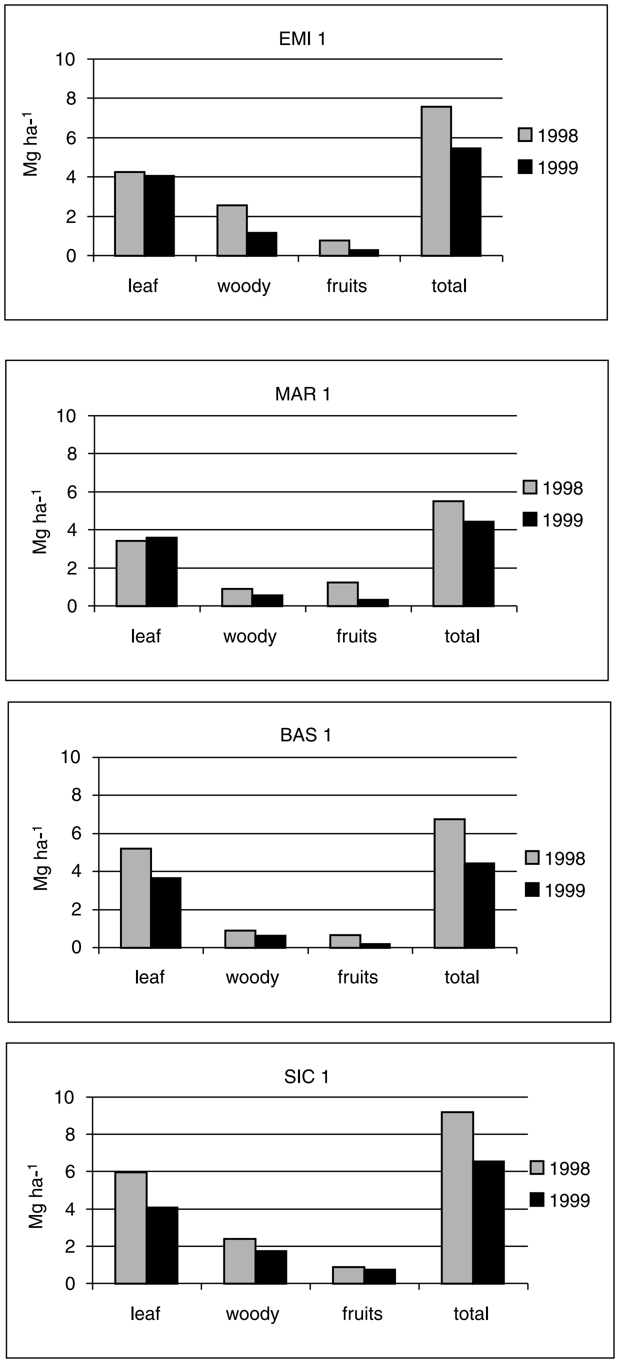

Figure 2 - Annual (total and main fractions) litter production in *Q. cerris* level II intensive monitoring plots.
Produzione annuale di lettiera (totale e per componenti) in aree di monitoraggio intensivo (II livello) a prevalenza di Q. cerris.

Discussion and conclusions

Temporal intermittence in litter and LAI data collection or the lack of data in some cases, are the consequences of financial constraints which led to the modification of the original data collection plan, *i.e.* to progressively reduce the number of surveyed plots or to re-arrange or simplify data collection procedures. This aspect, together with the shortness of monitoring period, does not allow at present a satisfactory analysis of results. Nevertheless, the collected data will provide a first reference point on properties and productivity of crowns and canopy for a considerable part of the selected stands and will allow to make comparisons with data already available in literature for similar stands.

With reference to the case study analysed, results highlighted some interesting trends. Sites were characterised by differences in leaf morphometric characteristics (SLA), productivity (total and leaf litter production) and canopy structure (LAI). Moreover, common trends in year-to-year changes were observed. SLA was lower in 1999 than in 1998. Litter has the same trend with higher values in 1998 than in 1999, as a consequence of a more important production both of leaves and acorns in 1998. These aspects could be ascribed both to native qualities of the main species such as genotype (productivity, endogenous cycles) or to external means such as physical environment and climate course. However, there are not enough data available at present to carry out a detailed analysis to discriminate the role of each factor involved.

In terms of productivity, mean values of leaf-litter (4.2 Mg ha^{-1}) and total litter (6.2 Mg ha^{-1}) were rather high if compared with data reported in literature (BRAY and GORHAM 1964, O'NEIL and DE ANGELIS 1981). This is in accordance with LAI values from PCA LAI 2000 which, although generally underestimating LAI, provided values rather high.

The amount of leaf fraction is consistent with the structure of the selected stands, which are generally in a juvenile phase of stand dynamics and far from maturity, typically characterized by a lower importance (50%) of leaf litter (KIRA and SHIDEI 1967).

Results from this first phase of monitoring period confirm the choice of undertaking the action on properties and productivity of crowns and canopy. The observed trends seem to confirm litter production and LAI as variables able to detect changes in forest ecosystem status due to the influence of external means such as physical environment, bio-ecological conditions, and, on the other hand, of native qualities of the component species such as genotype and then, physiological properties and adaptive ability. Besides, close relationships between them and important processes such as evapotranspiration, photosynthesis, light and rain interception (HEWELETT 1982, RUNNING *et al.* 1989), stand structure, growth, productivity, microclimatic condition and, hence, forest ecosystem dynamics as a whole are well-documented in literature (GHOLZ 1982, WARING 1983, TADAKI 1986, BOLSTAD and GOWER 1990).

Therefore, the continuous quantitative analysis of litterfall and LAI over time could provide a better understanding of stand productivity and functional status and of the role of external means and native qualities. This makes easier the achievement of one of the main targets of the monitoring program that is to discriminate in a precise time healthy ecosystems recovering from a natural disturbance from ecosystems having lost their resilience due to anthropogenic stress (RAPPORT *et al.* 1998).

As well as litterfall and LAI, chosen as reference indicators of crowns and canopy characteristics, a continuous monitoring of other variables such as mean leaf area, mean leaf dry weight, SLA (leaf morphometric characteristics) and, on the other hand, leaf litter, leaf biomass of main and accompanying species, woody parts and fruits/seeds (litter fractions) could provide useful information to a better understanding of stand structure (increasing/decreasing importance of a species/component) and functional status. So, it will be possible to implement a general analysis aimed at improving knowledge of the real impact of the atmospheric pollution and other factors which may influence the forest ecosystems.

In order to achieve this objective, it will be necessary to interact and combine the results of this action with the outcomes of other mandatory surveys. Among others, it could be crucial to integrate the observations on properties and productivity of crowns and canopy with:

- crown condition assessment, in order to establish relationships between crowns transparency and leaf biomass or LAI estimate;
- increment studies, to improve the knowledge on stand structure and productivity and provide a reasonable evaluation of stand functional status by calculating indexes commonly used in growth analysis as leaf weight ratio (ratio of leaf biomass to aboveground dry biomass) and net assimilation rate or growth efficiency (ratio of volume/biomass increment to leaf area/biomass) (WARING 1983, CHIARELLO *et al.* 1989, SCHULZE 2000);
- meteorological data, to assess the influence of environmental constraints on qualitative and quantitative aspects of crowns and canopy characteristics;
- soil and ground vegetation analyses, in order to evaluate the influence and the role of canopy characteristics on abiotic and biotic components and processes at ground level;
- phenology, to complement observations on the different phases with quantitative estimates on the intensity of processes such as flushing, shedding, fruiting.

Essential requirement of this evaluation strategy is to ensure the continuous survey, in all plots or in a sub-sample, of the variables and indexes chosen as crucial for the aims of the monitoring program. A complete database for each selected plot will increase indexes representativeness and reliability thus limiting erroneous or incomplete evaluations of their meaning. At now, because of financial constraints, this is the most critical point, but a decision on the matter cannot be further delayed.

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References

BENEDETTI A., DE BERTOLDI S., 2000 – *Qualità del suolo: criteri di definizione.* Relazione al Convegno Accademia Nazionale delle Scienze, 29 marzo, Roma.

BOLSTAD P.V., GOWER S.T., 1990 - *Estimation of leaf area index in fourteen southern Wisconsin forest stand using a portable radiometer.* Tree Physiology (7): 115-124.

BRAY J.R., GORHAM E., 1964 - *Litter production in forest of the world.* Adv. Ecol. Res. (2): 101-157

CHIARELLO N.R., MOONEY H.A., WILLIAMS K., 1989 - *Growth, carbon allocation and cost of plant tissue.* In "Plant physiological ecology". Pearcy R.W. *et al.* (eds), Chapman and Hall, London: 327-365.

CUTINI A., 1992 - *Indice di area fogliare, produzione di lettiera ed efficienza di un ceduo di cerro in conversione.* Ann. Ist. Sper. Selv., Arezzo (Italy), XXIII: 147-166.

CUTINI A., MATTEUCCI G., SCARASCIA MUGNOZZA G., 1998 - *Estimation of leaf area index with the Li-Cor LAI 2000 in deciduous forests.* For. Ecol. Manage. (105): 55-65.

FABBIO G., AMORINI E., 2000 – *Tree growth survey and increment assessment.Contribution to the integrated evaluation of ecosystem's status.* Ann. Ist. Sper. Selv., Arezzo (Italy), 30: 81-89.

GHOLZ H.L., 1982 - *Environmental limits on aboveground net primary production, leaf area and biomass in vegetation zones of the Pacific Northwest.* Ecology (63): 469-481.

KIRA T., SHIDEI T., 1967 - *Primary production and turnover of organic matter in different forest ecosystems of the western Pacific.* Jpn. J. Ecol. (17): 70-87.

HEWELETT J.D., 1982 - *Principles of forest hydrology.* University of Georgia Press.

O'NEIL R.V., DE ANGELIS D.L., 1981 - *Comparative productivity and biomass relations of forest ecosystems.* In "Dynamic properties of forest ecosystems", Reichle D.E. (ed.). Cambridge University Press, London: 441-449.

RAPPORT D.J., WITHFORD W.G., HILDÉN M., 1998 - *Common patterns of ecosystem breakdown under stress.* Environ. Monit. Assess., 51: 171-178.

ROMANE F., 1995 - *Introduction and objectives.* In: "Sustainability of Mediterranean ecosystems. Case study of the chestnut forest", Romane F. (ed.), European Commission, Brussels, Ecosystem research report n. 19: 1-5.

Running G. S.W., Ramkrishnar R.N., Peterson D.L., Band L.E., Potts D.F., Pierce L.L., Spanner M.A., 1989 - *Mapping regional forest evapotranspiration and photosynthesis by coupling satellite data with ecosystem simulation*. Ecology (70): 1090-1101.

Schulze E.D. (ed.), 2000 – *Carbon and nitrogen cycling in European forest ecosystems*. Ecological Studies 142. Springer Verlag, Berlin. 498pp.

Tadaki Y., 1986 – *Productivity of forests in Japan*. In proceedings of International Workshop: "Crown and canopy structure in relation to productivity", Fujimori T. and Whitehead D. (eds.), Forestry and Forest Products Research Institute, Ibaraki, Japan: 7-25.

Vanseveren J.P., 1969 - *Recherches sur l'écosysteème foret. Série B: La chenaie mélangée calcicole de Virelles-Blaimont*. Contribution n. 30: L'index foliaire et sa measure par photoplanimétrie. Bull. Soc. Roy. Bot. Belg. (102): 373-385.

Waring R.H., 1983 - *Estimating forest growth and efficiency in relation to canopy leaf area*. Adv. Ecol. Res. (13): 327-354.

Forest soil conditions at the Permanent Monitoring Plots in Italy§

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Abstract - The study of health conditions of forests may not set aside the assessment of soil status. Soil role in the forest ecosystem is very important and often underestimated. The monitoring of Italian forest soils was performed on twenty Italian sites under different pedological and climatic conditions. The main objective was the evaluation of the effect of acid depositions on soils and nutrients availability. The FAO classification has been determined on all soils. Other analyses were carried out on four mineral layers and on the organic layer. Although the number of sites is too small to consider the monitoring perfectly representative of the status of Italian forest soils, some generic information can be achieved. Soils with very low pH values are very few. The parameters which give information on soil sensitivity to acidification, as base saturation and sum of exchangeable base cations in the mineral layers, and the amount of potassium, calcium and magnesium in the organic layer, do not demonstrate almost any alarming situations. Large part of the Italian soils demonstrate, as compared to the other European soils, lower content of organic matter, but this is due to the Mediterranean climatic conditions, very different from those occurring in the central and northern Europe. The presence and availability of nutrients (particularly nitrogen and phosphorus) are generally considered sufficient.

Key words: *forest soil, acid depositions, monitoring, nutrients.*

Riassunto – Le condizioni del suolo nelle aree permanenti di monitoraggio in Italia. Lo studio delle condizioni dello stato di salute delle foreste non può prescindere dalla valutazione dei suoli, il cui ruolo nell'ecosistema forestale è fondamentale e spesso poco riconosciuto. Il monitoraggio dei suoli forestali italiani è stato effettuato su venti siti dalle diverse caratteristiche pedologiche e climatiche. Lo scopo principale era la valutazione dell'effetto delle deposizioni acide sui suoli e sulla disponibilità dei nutrienti. È stata effettuata la classificazione di ogni suolo secondo il sistema FAO, mentre altre determinazioni sono state eseguite su quattro strati minerali e sullo strato organico. Anche se il numero dei siti è troppo piccolo per essere considerato del tutto rappresentativo della situazione delle foreste italiane, è possibile intravedere delle tendenze. Pochissimi sono i suoli che dimostrano bassi valori di pH, mentre quei parametri che indicano sensibilità all'acidificazione, quali la saturazione basica, la quantità di cationi basici scambiabili negli strati minerali, e la presenza nello strato organico di potassio, calcio e magnesio, non evidenziano in quasi nessuno dei siti degli stati allarmanti. Una buona parte dei suoli italiani ha, rispetto a quelli europei, contenuto di sostanza organica inferiore, ma questo è dovuto alle condizioni climatiche mediterranee, diverse da quelle della media europea. La presenza e la disponibilità dei nutrienti (e in particolare azoto e fosforo, oltre a potassio, calcio e magnesio) vengono considerate in genere sufficienti.

Parole chiave: *suolo forestale, deposizioni acide, monitoraggio, nutrienti.*

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The assessment of forest conditions should also comprise the study of soils. Soil functions are multiple, but not always a sufficient attention has been placed to its role in the forest ecosystems and to its health status: in fact humans and even the scientific world always supposed it is unlikely to change or deteriorate. It is considered immobile and always ready to provide its services to the environment.

The role of soil in the forests is multiform, and some of its functions could be summarised as follows:

- It is suitable to be rooted by plants for their nutrition and solid statics.
- It receives and gives nutrients back to plants. Clays and humic substances contained in it represent the essential materials for ion exchange, a mechanism able to collect nutrients and give them back for the use of plants and micro-organisms.
- It is the habitat where micro-organisms operate to transform organic residues into humic substances, whose role for physical, chemical and nutritional purposes is fundamental; soil micro-organisms offer also many other services to plants and to micro-fauna.
- It represents the habitat of an important part of the micro and meso-fauna, which are essential constituents of the balance of the forest environment. Soil influences interest also the macro-fauna.
- It provides a buffer to acidification, immobilises inorganic contaminants and favours the degradation of the organic ones. But these capacities are not unlimited.

Changes produced by human activity to the environment affect also forest soils. One of the major phenomena due to environmental pollu-

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tion emerged in forest ecosystems is the acid deposition. And this is the main object of study of the European programme of forest monitoring, named CONECOFOR in Italy.

The parameters to study in order to know the effects of acid depositions are those that provide information of their immediate impact on forest soils and those that can state something on the possibility of resistance of soils to acidification. The most significant of such parameters were chosen for the monitoring programme.

Not only the possible consequences of acid depositions, but also other parameters necessary for the assessment of forest soils conditions, were investigated.

The fundamental information for soils knowledge, the soil classification, was determined on all sites with the FAO system (Food and Agriculture Organization of the United Nations 1994).

An important parameter is the organic matter, whose presence is fundamental for many reasons, like resistance to soil erosion, storage of nutrients, ionic exchange, nutrient support to microflora: total carbon was determined on all the soil layers and also the quantity ($kg \cdot m^{-2}$) of the organic layer.

Presence of nutrients was also measured: total nitrogen was determined on all the layers, while total phosphorus, potassium, calcium and magnesium were determined on the organic layer.

Other determinations regarding ionic exchange were performed, which are useful to assess also the availability of nutrients.

The Italian data regarding the CONECOFOR sites of pH, $CaCO_3$, total C and total N on all layers, total K, Ca, Mg and P on the organic layer, were available by the Editors, but not published in the report prepared by the Forest Soil Co-Ordinating Centre (1997), due to an error after the draft correction. This error has never been repaired, to our knowledge.

Materials and methods

Forest soils from 20 Permanent Monitoring Plots (*PMPs*) distributed all over Italy were studied. They are shown in Table 1.

Sampling and analysis methods are those of the Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests (1994).

Sampling was carried out in 5 replicates on the organic horizon and on 4 layers of the mineral horizon, as follows:

- 0-10 cm
- 10-20 cm
- 20-40 cm
- 40-80 cm.

The 5 replicates were mixed together to obtain one combined sample. The

Table 1 - Main characteristics of the forest soils.
Caratteristiche principali dei suoli.

PMP no.	PMP code	Altitude (m)	FAO classification	Dominant tree species
1	Abr1	1500	Acrisols	*Fagus sylvatica*
2	Bas1	1125	Luvisols	*Quercus cerris*
3	Cal1	1100	Podzols	*Fagus sylvatica*
4	Cam1	1175	Acrisols	*Fagus sylvatica*
5	Emi1	200	Luvisols	*Quercus cerris + Quercus petraea*
6	Emi2	975	Cambisols	*Fagus sylvatica*
7	Fri1	6	Phaeozems	*Quercus robur + Carpinus betulus*
8	Fri2	820	Luvisols	*Picea abies*
9	Laz1	690	Cambisols	*Quercus cerris*
10	Lom1	1190	Cambisols	*Picea abies*
11	Mar1	775	Luvisols	*Quercus cerris*
12	Pie1	1150	Podzols	*Fagus sylvatica*
13	Pug1	800	Acrisols	*Fagus sylvatica*
14	Sar1	700	Cambisols	*Quercus ilex*
15	Sic1	940	Phaeozems	*Quercus cerris*
16	Tos1	150	Cambisols	*Quercus ilex*
17	Tre1	1775	Podzols	*Picea abies*
18	Umb1	725	Cambisols	*Quercus cerris*
19	Val1	1740	Leptosols	*Picea abies*
20	Ven1	1100	Luvisols	*Fagus sylvatica*

determinations carried out were:
On all the layers:

- pH ($CaCl_2$)
- Total Carbon (dry combustion)
- Total Nitrogen (dry combustion)
- $CaCO_3$ (only if pH in $CaCl_2$>6)

Only on the organic layers:

- Total Phosphorus
- Total Potassium
- Total Calcium
- Total Magnesium
- Amount of the organic layer

Only on the mineral layers:

- Exchangeable acidity (EA)
- Exchangeable acid cations (EAC)
- Exchangeable base cations (EBC)
- Cation exchange capacity (CEC)
- Base saturation (BS)

FAO classification was determined to all soils. To do that, many other important parameters were determined, such as soil texture, but with different sampling criteria as those of the other determinations.

Results

In the discussion of results we will follow the lines of the report prepared by the Forest Soil Co-Ordinating Centre (1997). 20 Italian sites is a very small number to give general results statistically valid, principally if we wish to compare smaller groups with similar properties (soil type, exchangeable acid cations (EAC), climatic conditions, vegetation cover, *etc.*). However in some cases we will also try the explanation of the results in this way, discharging too small groups.

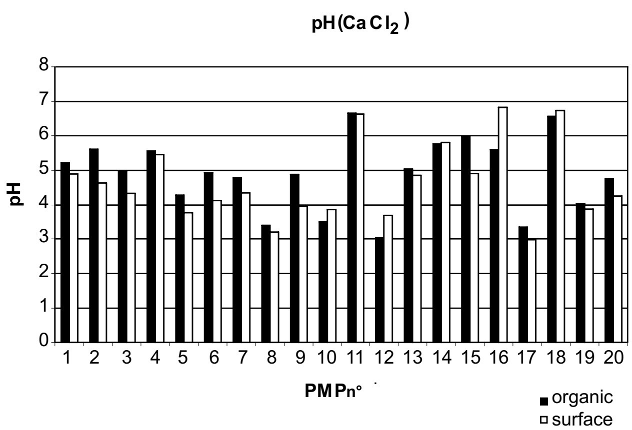

Figure 1 - pH ($CaCl_2$) of the organic layers and of the surface mineral layers.
pH ($CaCl_2$) degli orizzonti organici e degli strati minerali superficiali.

FAO classification

The results are shown in Table 1. There are 6 cambisols, 5 luvisols, 3 acrisols, 3 podsols, 2 phaeozems and 1 leptosol.

pH

Perhaps it is necessary to remind that soil pH values measured in $CaCl_2$, as in this research, result lower than those measured in water. Optimal pH values for plant growth are generally between 5.0 and 7.0. Lower values (4.0-5.0) are recommended for conifers (Rikala and Jozefk 1990). pH values in $CaCl_2$ on the organic layers and on the mineral surface layers are shown in Fig. 1. Extremely low values (below 3.0) were not found. Values below 3.5 were found on 4 organic layers (20%) and on 2 surface layers (10%). They are located in 3 plots under *Picea abies* and on 1 plot under *Fagus sylvatica*. They are all mountain sites, higher than 800 m a.s.l.

More than pH, the sensitivity to acidification is important for the knowledge of health status of soils. An indication of that is provided by the pH difference between the mineral surface and the organic layer. If it is very high (more than 1 pH unit), than also the sensitivity to acidification is high. This value was found higher than 1 only on site 16 (1.2), but on that site the mineral surface layer shows a high pH value (6.8).

Other criteria are used for the sensitivity to acidification, and they are based on different parameters: presence of $CaCO_3$, pH, hydraulic conductivity (whose value is established on the basis of soil type), base cations availability, base saturation and sum of total contents of Ca, Mg and K in the organic layer. The values of base cations and of base saturation are reported in Table 2 together with the other data regarding ionic exchange (CEC, exchangeable acidity and AEC). We must remind that for the European soils (data from the Report of the Forest Soil Co-Ordinating Centre 1997) more than 50% of sites were found to have values of BCE below 2, and

Table 2 - Exchangeable acidity (EA [c*M* kg^{-1}]), Exchangeable base cations (EBC [c*M* kg^{-1}]), Exchangeable Acid Cations (EAC [c*M* kg^{-1}]), Base saturation (BS [%]) on the first two mineral layers.
Acidità scambiabile (EA [cM kg^{-1}]), cationi basici scambiabili (EBC [cM kg^{-1}]), cationi acidi scambiabili (EAC [cM kg^{-1}]), saturazione basica (BS [%]) sui primi due strati minerali.

PMP code and region	Soil layers	Exchangeable Acidity (EA)	Exchangeable Base Cations (EBC)	Exchangeable Acid Cations (EAC)	Cation Exchange Capacity (CEC)	Base saturation (BS)
1 Abruzzo	Surface	1	11.7	1	12.5	93
	Subsurface	1	7.9	1	9.1	86
2 Basilicata	Surface	1	5.9	1	6.6	89
	Subsurface	1	5.0	1	5.9	86
3 Calabria	Surface	4	5.1	4	8.9	58
	Subsurface	3	3.2	3	6.7	48
4 Campania	Surface	nd	nd	nd	nd	nd
	Subsurface	nd	nd	nd	nd	nd
5 Emilia1	Surface	4	2.2	4	6.4	34
	Subsurface	5	0.9	5	5.5	17
6 Emilia2	Surface	2	3.8	3	6.3	60
	Subsurface	2	2.6	2	5.0	51
7 Friuli1	Surface	2	8.2	2	10.0	82
	Subsurface	1	8.6	1	9.8	88
8 Friuli2	Surface	11	2.1	12	13.6	15
	Subsurface	2	3.8	2	5.7	67
9 Lazio	Surface	4	1.9	4	6.0	33
	Subsurface	3	2.1	4	5.7	36
10 Lombardia	Surface	5	2.5	5	7.4	34
	Subsurface	4	0.5	4	4.2	12
11 Marche	Surface	0	7.7	0	7.9	97
	Subsurface	0	7.7	0	7.9	98
12 Piemonte	Surface	7	0.5	7	7.7	6
	Subsurface	nd	nd	nd	nd	nd
13 Puglia	Surface	1	7.5	1	8.2	92
	Subsurface	1	6.0	1	6.8	88
14 Sardegna	Surface	0	9.3	0	9.5	98
	Subsurface	0	5.2	0	5.6	94
15 Sicilia	Surface	0	8.5	1	9.1	94
	Subsurface	0	6.7	1	7.3	92
16 Toscana	Surface	0	19.7	0	19.9	99
	Subsurface	0	14.3	0	14.5	99
17 Trentino	Surface	3	14.0	4	17.8	79
	Subsurface	7	7.2	7	14.7	49
18 Umbria	Surface	nd	nd	nd	nd	nd
	Subsurface	nd	nd	nd	nd	nd
19 Val d'Aosta	Surface	nd	nd	nd	nd	nd
	Subsurface	nd	nd	nd	nd	nd
20 Veneto	Surface	3	4.3	3	7.2	60
	Subsurface	3	3.4	4	7.1	48

about 70% below 4. About 50 % of the European soils were found to have values of base saturation below 30. Italian soils on average show values higher than the European ones. Few sites, 8, 10 and 12, show low values of base cations availability and of base saturation, and at the same time low values of pH.

Ca CO_3

Only on site 11 calcium carbonate was found (4g.kg-1) on the organic layer. On two other sites it was found in deeper mineral layers.

Total carbon

Results of total carbon on the organic layer and on the surface mineral layer are given in Fig. 3. All mineral surface layers (0-10 cm) show to-

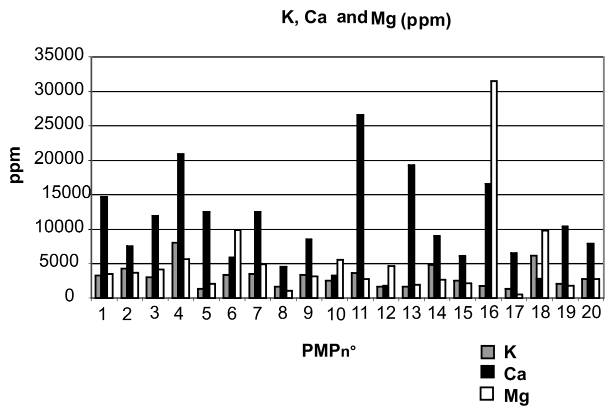

Figure 2 - Total content (ppm) of potassium calcium and magnesium on the organic layers.
Contenuto totale (ppm) di potassio, calcio e magnesio negli strati organici.

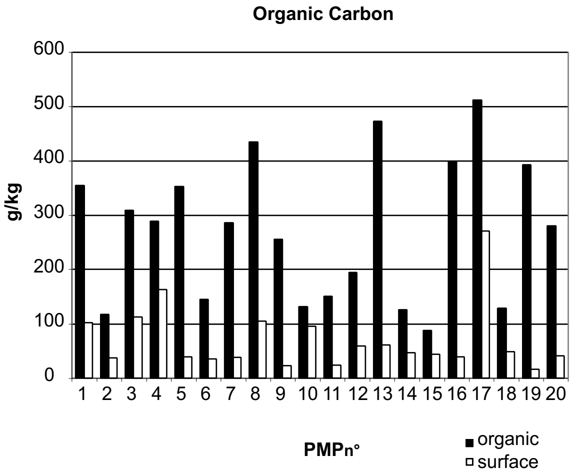

Figure 3 - Total carbon (g/kg) of the organic layer and of the surface mineral layer.
Carbonio totale (g/kg)dello strato organico e dello strato minerale superficiale.

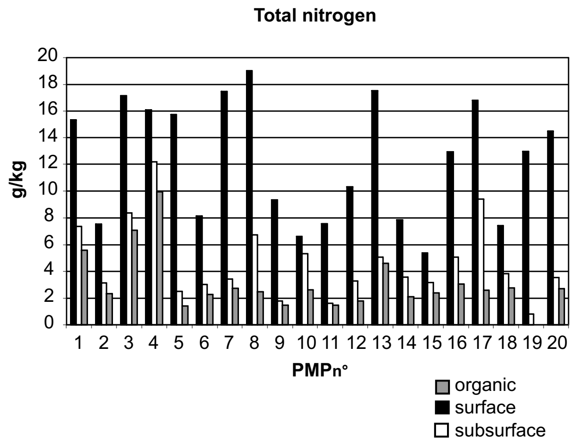

Figure 4 - Total nitrogen (g/kg) on the organic layers and of the two mineral superior layers.
Azoto totale (g/kg) degli strati organici e dei due strati minerali superiori.

tal carbon values lower than those of organic layers. Carbon concentration always decreases with depth (data not shown).

Total carbon of the organic layer is below 100 g·kg^{-1} on 1 site and below 200 g·kg^{-1} on 7 sites. Generally the organic matter content of the organic layer is considered low, if compared with the soils of Europe. In fact European soils with organic carbon concentration on the organic layer below 180 g·kg^{-1} represent less than 10%, while on our *PMPs* they are 35%. Furthermore, there are 70% European observations above 280 g·kg^{-1}, *vs.* 45 % in Italy. It could be explained considering that European data are mainly from northern and central Europe, and climatic conditions cause to organic matter of Italian soils a higher mineralisation level than in colder climates. Also the total amount of the organic layers (data not shown) is generally lower than the European average.

Total Nitrogen and C/N

Nitrogen is the most important nutrient for plants. In Fig. 4 the values of total nitrogen of the organic layer and of the surface and subsurface mineral layers are shown. In the organic layer no sites were found with N concentration above 20 g·kg^{-1}. In 6 cases N concentration was found below 8 g·kg^{-1}. Generally the values are lower than the mean values of Europe, where values below 6 g·kg^{-1} represent less than 10 %, and more than 10 % are the observations above 20 g·kg^{-1}. The explanation should be found in the high mineralisation rates of Mediterranean soils. However within the CONECOFOR sites it is not possible to find out a correlation between nitrogen content and climatic conditions, but some correlation is found with the dominant tree. Higher values were observed under *Fagus sylvatica* and *Picea abies*, lower values under *Quercus cerris*. In mineral surface and subsurface layers, by contrast, values of total nitrogen were found higher than the mean values of Europe, where for more than 50% of observations

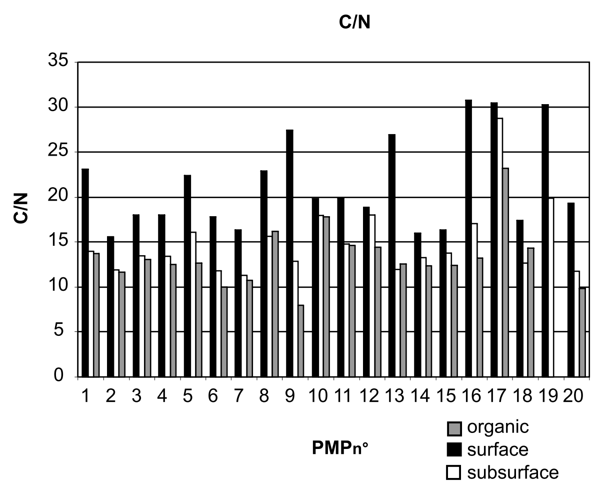

Figure 5 - Carbon/nitrogen ratio of the organic layers and of the two mineral superior layers.
Rapporto carbonio/azoto degli strati organici e dei due strati minerali superiori.

were found values above 28, *vs.* 15 % of the Italian *PMPs*.

A low value of the C/N parameter on the organic layer indicates a rapid mineralisation of the organic matter, and hence a higher availability of nitrogen (BARBER 1995). The C/N parameter everywhere decreases from the organic to the mineral layer (Fig. 5). A different trend would be indication of an anomalous addition of nitrogen, possibly due to atmospheric depositions. Organic layers of 12 plots demonstrate values of C/N lower than 20. Only on 3 plots they are a bit higher than 30. Generally it is possible to state that the C/N parameter on the organic layers of *PMPs* (between 10 and 31) is lower than the mean values of Europe, where the majority of C/N values are between 20 and 40.

Phosphorus and C/P

Phosphorus is one of the most important nutrients, together with nitrogen and potassium. More than in the case of nitrogen, its availability is determined by the rate of decomposition of the organic matter (WARING and SCHLESINGER 1985), indicated by the C/P ratio (Fig. 6). A low C/P ratio is an indication of high phosphorus availability. Other parameters, like pH, concentration of some cations (calcium, aluminium, iron) and climatic zone, give indications for the evaluation of phosphorus availability. Calcium phosphate is principally present in alkaline soils, iron and aluminium phosphate in acid soils, and they are all relatively insoluble. In the Italian sites only two *PMPs* (6 and 11) show values of total phosphorus below 700 ppm, while 6 *PMPs* (30%) are above 1000 ppm. In the European soils it happens only in less than 20% of sites. In some cases the C/P ratio of Italian *PMPs* is high (sites 5, 8, 16 and 17).

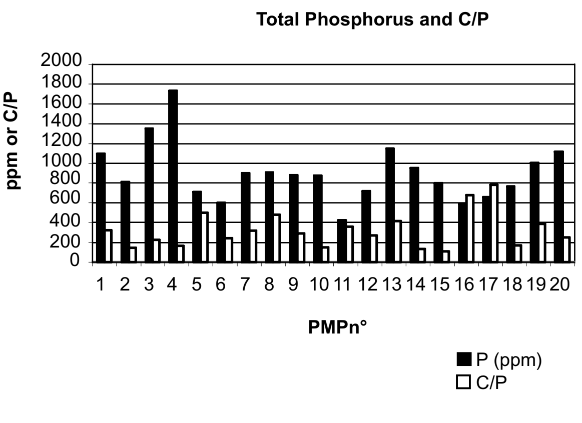

Figure 6 - Total phosphorus (ppm) and C/P ratio on the organic layers. The measure units on the ordinates of the two groups of values are different (ppm and pure number), but the scale on the axis is the same.
Fosforo totale (ppm) e rapporto C/P degli strati organici. Le unità di misura sulle ordinate delle due grandezze sono diverse (ppm e numeri puri), ma i valori assoluti della scala sull'asse y sono gli stessi.

Conclusions

The number of sites observed is too small to achieve general conclusion regarding the health status of the Italian forests, but they are enough to have elements of evaluation. Only few sites of the Italian forests were found in danger of acidification, and the overall situation about this problem looks better than in the rest of Europe. Also the availability of nutrients can be considered generally sufficient. A problem could be found in the organic carbon content, which shows values generally lower than the European average. This is caused by the Mediterranean climatic conditions, different from those of the central and northern Europe, which are most represented in the European report.

More reliable results could be achieved after a new monitoring to be performed after a period long enough to detect possible differences.

References

FOREST SOIL CO-ORDINATING CENTRE 1997 - *Forest soil condition in Europe.*

INTERNATIONAL CO-OPERATIVE PROGRAMME ON ASSESSMENT AND MONITORING OF AIR POLLUTION EFFECTS ON FORESTS 1994 - *Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests.* Hamburg and Prague, Coordinating Centre.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS 1994 - FAO – *World reference Base for Soil Resource*

RIKALA R., H. J. JOZEFEK 1990 - *Effect of dolomite lime and wood ash on peat substrate and development of tree seedlings.* Silva Fennica 24: 323-334.

BARBER S. A. 1995 - *Soil nutrient bioavailability. A mechanistic approach,* 2nd ed. Wiley, New York, 414 p.

WARING R. H., SCHLESINGER W. H. 1985 - *Forest ecosystem. Concepts and management.* Academic Press, Orlando, 340 p.

Foliar nutrient concentrations as possible indicators for the status and changes of Permanent Monitoring Plots§

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Abstract - Within the CON.ECO.FOR monitoring programme, the analysis of main nutrients (Nitrogen, N; Sulphur, S; Phosphorous, P; Calcium, Ca; Magnesium, Mg; Potassium, K) has been performed in 20 Permanent Monitoring Plots *(PMPs*). Data from three surveys, made in 1995, 1997 and 1999 are now available. A first attempt to determine if significant changes in the nutritional status have occurred along the years, trying to identify which factors are more important in causing the possible changes, is presented in the paper. The analysis of data evidenced that, over the time of investigation (five years), the variability is mainly linked to *PMP*-based factors. Furthermore, when the sampling of foliar material is done outside the optimal periods or when the distance between sampling dates for the same *PMP* is large, other factors may shadow or confound possible long-term changes. In the Italian environment, *Quercus ilex* L. behaves differently than deciduous oaks and it is appropriate to treat separately this species in data analysis.

Key words: *Forest monitoring, Foliar nutrients,* Picea abies *L.,* Fagus sylvatica *L.,* Quercus *spp.,* Quercus ilex *L.*

Riassunto – Le concentrazioni di nutrienti fogliari come possibili indicatori per l'analisi di stato e cambiamenti delle aree permanenti. Nel programma di monitoraggio CON.ECO.FOR, l'analisi dei nutrienti principali (Azoto, N; Zolfo, S; Fosforo, P; Calcio, Ca; Magnesio, Mg; Potassio, K) è stata realizzata per 20 Aree di monitoraggio permanente *(PMPs*). Sono disponibili i dati di tre campionamenti. Nel lavoro viene presentato un primo tentativo di determinare se siano avvenuti cambiamenti significativi nel tempo, provando anche ad identificare quali fattori siano più importanti nel causare gli eventuali cambiamenti. L'analisi dei dati ha evidenziato che sinora, su cinque anni, la variabilità è maggiormente causata da fattori legati alle singole *PMP*. Quando inoltre i campionamenti del materiale fogliare avvengono al di fuori dei periodi ottimali definiti per le singole specie o quando la distanza tra campionamenti successivi su di una stessa *PMP* è ampia, altri fattori possono oscurare i possibili cambiamenti di più lungo termine. Nell'ambiente italiano, il leccio mostra differenze dalle querce decidue e l'analisi di questa specie dà migliori risultati se effettuata separatamente.

Parole chiave: *monitoraggio delle foreste, nutrienti fogliari,* Picea abies *L.,* Fagus sylvatica *L.,* Quercus *spp.,* Quercus ilex *L.*

F.D.C 524.634:160:161: (450)

Plant macronutrients are involved in a large part of the physiological and biochemical processes in forest ecosystems (Bauer *et al.* 2000). Nitrogen (N), is a primary constituent of the protein Rubisco and of chlorophylls. Both are key elements for photosynthesis, therefore N is one of the most important resources for plants (Evans and Seeman 1989, Hikosaka and Terashima 1995). A number of studies have reported a close relationship between nitrogen content and leaf photosynthesis that, ultimately, determines plant production (Field and Mooney 1986, Evans 1989, Reich *et al.* 1995). Phosphorous (P) is a component of ATP, nucleic acids and cell membranes; Sulphur (S) is found in many plant proteins and specific roles for potassium (K, in stomatal cells), Calcium (Ca, in cell walls) and Magnesium (Mg, in chlorophyll) are well established. These nutrients also stimulate the rate of enzymatic reactions (Waring and Schlesinger 1985).

Differences in leaf nutrient concentrations provide the basis for the use of foliar analysis to recognize nutrient deficiencies or imbalances in forest ecosystems. However variation in nutrient concentrations due to species, season, canopy position, relative growth rate and nutrient supply must be known before the technique is of valuable use in forest management (Waring and Schlesinger 1985). The analysis of nutrient

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concentrations and contents of tree needles and leaves is one important tool for the assessment of plant and ecosystem status (Marschner 1986, Bonneau 1988, Linder 1995, Bauer *et al.* 2000) and analysis of foliage can indicate conditions in which nutrients are limiting to forest growth (Waring and Schlesinger 1985) and can be used to detect imbalances (Linder 1995).

Natural or human-induced differences in nutrient availability alter foliar nutrient concentrations and rates of nutrient reabsorption, circulation and subsequent loss in litter. In Europe, the majority of forest stands have been intensively managed involving wood but also litter use, causing nutrient deprivation. Furthermore, European forests have experienced deposition of acids, nitrogen and sulphur in the last 50 years, which resulted in nutrient imbalances affecting growth (Bauer *et al.* 2000). In this respect, leaf nutrient analysis could be a useful tool to monitor the effects of environmental changes on tree nutrition (Dusquenay *et al.* 2000).

Recently, the European Commission, starting from the positive results of the International Cooperative Programme on Integrated Monitoring (ICP-IM), issued a Regulation (1091/94) on the long-term monitoring of forests (ICP-Forests). Among the various parameters to be monitored, leaf nutrient concentrations are considered fundamental and biennial sampling is compulsory for six macronutrients (N, P, K, Ca, Mg, K and S) and optional for some micronutrients.

Each European country has built a network of Permanent Monitoring Plots (*PMP*, EC UN/ECE Stefan *et al.* 1997, Allavena *et al.* 1999, Croise *et al.* 1999) which are used to monitor a number of crucial parameters. Those plots are considered a level-II in a monitoring scheme that starts from an extensive network of level-I sites, where crown conditions are monitored since a number of years. Currently, in Italy, 24 level-II monitoring plots have been established and two more will be added in the near future (Allavena *et al.* 1999).

Here we present a preliminary report on the foliar nutrient conditions of the Italian *PMPs* that have been sampled three times, in 1995, 1997 and 1999, attempting to detect if changes have been occurring in this relatively short period.

Reports on foliar conditions are available at European (EC UN/ECE Stefan *et al.* 1997) and national (Croise *et al.* 1999) scale and thresholds have been estabilished to define low, medium and high nutritional levels. Presenting the data, we will refer to those thresholds in the peculiar situation of our country and tree species.

Materials and Methods

The survey of 1999

The applied protocols of collection, preparation and analysis of leaves and needles for the 1999 sampling were among those recommended by the annex V to the EC Regulation 1091/94.

Most of the analyses have been performed in the laboratories of the Consortium AGRITAL Ricerche, while the material collected in the *PMPs* located in Tuscany and Lombardy (TOS1-3 and LOM1-3) have been analysed in regional-based laboratories.

The collection of samples was under the responsibility of local-based National and Regional Forest Service offices, which, for 1999, collected and sent material for analyses to our laboratories for 20 out of the 24 *PMPs*. No samples were available for *Quercus cerris* L. (Turkey oak) plots 02 and 11 (BAS1, MAR1) and for *Fagus sylvatica* L. (beech) plots 03 and 13 (CAL1, PUG1). Hence analyses are available for 7 *PMPs* with beech, 5 *PMPs* with *Picea abies* L. (Norway spruce) and 3 *PMPs* for both *Quercus ilex* L. (holm oak) and Turkey oak. For deciduous oaks, analyses of one *PMP* with *Quercus robur* L. (pedunculate oak) and one with *Quercus petraea* L. (sessile oak) are also available. In the former *PMP* also *Carpinus betulus* L. (hornbeam) was present and sampled.

In all *PMPs*, leaves and needles have been collected from upper part of the crown of five trees. Samples were air-dried and then sent to the laboratory. To check for site variability and preserve the possibility to perform statistical analyses, the samples have been collected, shipped and analysed separately for each of the five trees. For sampling and analysis, the Tuscany (*PMPs*: TOS1, TOS2 e TOS3) and Lombardy Regions (*PMPs:* LOM1, LOM2 e LOM3) have followed the protocols listed in annex V to the European Commission Regulation n. CE 1091/94 and the same was done by the *AGRITAL Ricerche* Consortium.

The protocol followed by the latter institution is briefly described.

Once arrived in the laboratory, each sample, put in paper bag, was oven dried at 80°C for 48 hours and then the weight of 100 leaves or 1000 needles was determined. Afterwards, the entire sample was grounded with a Thomas-Wiley intermediate mill (Thomas Scientific, Swedesboro, NJ, USA) and the residual humidity was determined at 105°C in three repetitions. The nutrient concentration (Nitrogen, N; Sulphur, S; Phosphorous, P; Calcium, Ca; Magnesium, Mg; Potassium, K; all in mg g^{-1}) was referred to the dry weight at 105°C.

For the analysis of S, P, Ca, Mg and K, each sample was acid-treated in a microwave oven with 3ml HNO_3 and 1 ml H_2O_2. Ca, Mg, and K concentrations were determined by flame atomic absorption spectrometry, while S and P concentrations by Inductively-Coupled Plasma atomic emission spectrometry (ICP) without ultrasonic nebulization. Total N concentration was determined with a Carlo Erba 1108 CHNS Elemental Analyser (Carlo Erba, Italy). Each analysis was performed in three replicates and the single nutrient values are the average of the three repetitions.

In this report, the *PMPs* averages are presented, generally accompanied by their standard deviations, both calculated on the five sample trees.

Indicators of the status and changes of the PMS

The analysis of the status of *PMPs* was performed starting from the main nutrients (N, P, K, Ca, Mg, S). The nutrient concentrations, expressed in milligrams of nutrient per gram of dry weight (mg g^{-1}), were compared with the threshold proposed at European level for the monitoring of forest foliar condition in Europe (EC-UN/ECE, Stefan *et al.* 1997). As the absolute nutrient concentration can be often of limited value in signalling possible nutrient imbalances (Linder 1995, Bauer *et al.* 1997, Dusquenay *et al.* 2000), we have also calculated nutrient ratios (N/P, N/K, N/Ca, N/Mg, K/Ca, K/Mg, Ca/Mg and S/N). As no limits were set for sulphur concentrations for the genus *Quercus*, the data on S/N ratio will not be presented and discussed.

For each nutrient and ratio, the thresholds fixed at European level identify three classes that determine low, medium and high nutrient concentrations. For nutrient ratios, the middle class is referred to as “harmonious” conditions for nutrition, while the other two are indicating possible imbalances (EC-UN/ECE, Stefan *et al.* 1997). The European guidelines set the thresholds for the main tree genera monitored in Europe, which included spruce, beech, pine and oak. Hence, in two cases (spruce and beech) the limits refer to a single species, while in the other two cases (pine and oak) the limits are set for a number of species, at least 3 or 4 pines and 5-6 oaks. In this respect, it is possible that for pines and oaks, the comparison between site- or country-based data and the thresholds may not be always straightforward, as the limits may hold better for a species than for another one. In Italy, no *PMPs* have been established in pine stands, but 10 oak stands are monitored, 5 with Turkey oak, 3 with Holm oak and 1 each with sessile and pedunculate oak. While the nutrient concentrations of the three deciduous oak species seem to differ significantly only for P and K, with Turkey oak having an average P and K content 1.7 times higher than the other two oaks, Holm oak stands appear to be completely different from the deciduous oaks stands. Compared to deciduous oaks, Holm oak shows, on average (all three years), lower concentrations of N, S, Ca and K respectively of 0.58, 0.70, 0.52 and 0.64 times, while Mg is 1.36 times higher and P concentration is similar to that of deciduous oaks (0.83).

For this reason, we will present and discuss the nutrient concentrations and ratios for oaks divided in deciduous (Turkey, sessile and pedunculate oak) and evergreen (holm oak) species. In order to compare our results with the data presented in already published reports (EC-UN/ECE, Stefan *et al.* 1997), we will also report the comprehensive data.

To look for possible indications of changes, the results of the three surveys (1995, 1997 and 1999) have been compared at the *PMP*- and at the species-based level.

The *PMP*-based comparison was not possible for all *PMPs* and years, because new *PMPs* were established in 1997 and 1999, some *PMPs* were not sampled all years and, in some cases, *PMPs* were also moved to other sites of the same region with the same species (*e.g.* LOM3 from Pian dei Resinelli to Valsassina). The sampling was repeated in the same *PMPs* in 14 cases for the three surveys, in 16 cases for the surveys 1997 and 1999, in 15 cases for 1995 and 1999 and in 18 cases in 1995 and 1997. A pure between-years statistical comparison could be made for 11 *PMPs* for 1995 and 1999 (2 *PMPs* with Norway spruce, 4 with beech, 4 with deciduous and 1 with evergreen oaks) as for 1997 only the *PMP* averages values were available and not the data of single trees, thus limiting the possibility to perform *PMP*-based statistical test of between-years significant differences (the surveys of 1995 and 1997 were under responsibility of another institution). To test for difference at the *PMP* level, we used the unpaired *t-test* with a two tailed significance level; considering that the two surveys have been carried out in a relatively short period, a significance limit of $P < 0.05$ was selected for between-years difference.

At the species level, beech was sampled in 7 *PMPs* for all three years, Norway spruce in 3 *PMPs* in 1995, 4 in 1997 and 5 in 1999, while the genus *Quercus* was sampled in 9 *PMPs* in 1995, 7 in 1997 and 8 in 1999. Turkey oak represented 5, 5 and 3 of the *PMPs*, respectively in 1995, 1997 and 1999, while, in the same years, Holm oak was sampled in 2, 1 and 3 cases. At this level, the between-years comparison was performed starting from the *PMP* average values, so it was possible to compare all three surveys. In this second case, it must be stressed that the number of *PMPs* of a certain species/genus was not always constant between years and, sometimes, there were slight differences in the *PMPs* sampled in the different years. The datasets were compared using one-way ANOVA and performing posthoc tests of differences only if overall P was less that 0.05. In such a case, single years were compared using the Bonferroni multiple comparison test. Furthermore, if an increasing or decreasing trend was present, we tested if that trend was significant or not.

All the described statistical test were performed using the Graphical/Statistical package GraphPad PRISM® (GraphPad Software, Inc.).

Results and Discussion

An example of the type of data produced after the sampling and analysis of foliar material is presented in Table 1, where the nutrient concentrations of the 1999 survey are reported.

The Table, highlights how the values vary among different species and, for the same species, among different plots. From the standard deviations of the concentrations, the deviation from the true mean at plot level (inter-tree variability) can be calculated as the average coefficient of variation of the available measurements. The deviation ranged from 7.1% (N, min-max: 3.6-12) to 24.1% (Ca, 5.6-44.5) for Norway spruce (4x2 *PMPs*), from 4.7% (N, 1.7-9.1) to 11.8% (P, 3.1-20.2) for deciduous oaks (5 *PMPs*), from 8.3% (N, 2.9-14.8) to 17.1% (Mg, 10.9-21.8) for holm oak (3 *PMPs*) and from 5.6% (N, 3-9.8) to 15.9% (Mg, 10.7-24.7) for beech (7 *PMPs*). Interestingly, for all species, N was the nutrient that showed the lower variability (4.7-8.3) and the overall ranking of deviations for all species was N<S=K<P<Ca<Mg. For beech, the ranking of the *PMP* average deviations for the main nutrients were N<S<K≤P<Ca<Mg, that can be compared to those found for 29 beech plots sampled in France in 1996-97 that was N<P<K<Ca<Mg (S was not reported, DUSQUENAY *et al.* 2000). Hence, apart from P that showed a larger variability than K, the deviations found in Italy in 1999 ranked similarly to the French ones. With exception of P, the percentage deviations were lower in our case, may be due to the lower number of sampled *PMPs*.

When the species (genus for oaks) average nutrient concentrations are calculated, in almost all cases the between-plot deviation from the mean is larger for all nutrients and species than the average inter-tree variability at *PMP* level (S for deciduous oaks, Mg and K for Norway spruce were the exceptions). That deviation ranged from 13.1% (deciduous oaks) to 20.7% (holm oak) for N, from 7% (dec. oaks) to 28.4% (Norway spruce) for S, from 13.2% (beech) to 30.7% (holm oak) for P, from 18.2% (deciduous oaks) to 34.9%

Table 1 - Averages and standard deviations of the concentrations of the six main nutrients analysed in 1999 for 20 PMPs in Italy. N, Nitrogen; S, Sulphur; P, Phosphorous; Ca, Calcium; Mg, Magnesium; K, Potassium. In each PMP, five trees were sampled. (0), foliar material of the current year; (1), foliar material of the previous year.
Medie e deviazioni standard delle concentrazioni dei sei nutrienti principali analizzati nel 1999 nelle 20 PMP in Italia. N. azoto; S. zolfo; P. fosforo; Ca. calcio; Mg. magnesio; K. potassio. In ogni PMP, sono stati campionati 5 alberi. (0), materiale fogliare dell'anno corrente; (1), materiale fogliare dell'anno precedente.

PMP	Species	N (mg g^{-1})	S (mg g^{-1})	P (mg g^{-1})	Ca (mg g^{-1})	Mg (mg g^{-1})	K (mg g-^{1})
01-ABR1	Beech	27.4±2.7	2.1±0.1	1.5±0.1	19.0±2.2	2.1±0.3	8.9±1.7
04-CAM1	Beech	25.5±0.9	2.0±0.1	1.6±0.2	17.9±1.2	2.4±0.3	12.7±1.0
05-EMI1	Sessile oak	29.5±2.7	1.7±0.2	0.7±0.1	8.9±0.5	2.0±0.3	4.2±0.5
06-EMI2	Beech	31.4±1.0	2.4±0.3	1.4±0.2	16.6±1.5	2.5±0.3	11.6±0.8
07-FRI1	Hornbeam	25.5±0.9	1.7±0.1	1.0±0.1	13.1±1.6	3.1±0.5	6.1±0.5
07-FRI1	Pedunculate oak	28.3±1.1	1.9±0.3	1.2±0.1	11.3±1.2	2.9±0.4	8.5±0.8
08-FRI2	Spruce	14.5±1.8	1.2±0.1	0.8±0.1	8.7±1.3	1.3±0.2	5.0±0.6
09-LAZ1	Turkey oak	31.1±0.5	1.7±0.1	1.4±0.1	10.1±0.4	2.4±0.1	10.5±1.0
10-LOM1	Spruce (0)	16.1±1.6	0.7±0.2	1.7±1.2	8.4±3.8	1.3±0.4	6.0±1.7
10-LOM1	Spruce (1)	15.6±0.8	0.7±0.1	1.8±0.2	8.1±2.8	1.3±0.3	6.1±1.1
12-PIE1	Beech	35.3±1.6	2.3±0.2	1.4±0.2	8.4±1.2	1.5±0.2	10.1±0.6
14-SAR1	Holm oak	17.8±1.3	1.5±0.0	1.0±0.1	7.0±1.0	1.4±0.3	4.3±1.0
15-SIC1	Turkey oak	25.9±1.2	1.7±0.2	1.5±0.0	12.7±0.3	2.1±0.1	11.9±0.5
16-TOS1	Holm oak	12.9±0.4	1.2±0.1	0.9±0.1	3.8±0.8	3.1±0.3	5.9±0.4
17-TRE1	Spruce (0)	16.9±1.8	1.1±0.1	1.7±0.0	5.5±1.4	1.2±0.2	6.5±0.2
17-TRE1	Spruce (1)	15.3±0.7	1.0±0.2	1.3±0.2	6.3±0.6	0.9±0.3	5.3±0.2
18-UMB1	Turkey oak	21.9±0.9	1.6±0.1	1.7±0.3	14.2±0.9	1.2±0.1	11.0±1.0
19-VAL1	Spruce	11.0±0.5	1.1±0.2	1.4±0.1	9.1±0.5	1.1±0.1	6.2±0.5
20-VEN1	Beech	23.2±1.1	1.8±0.1	1.8±0.1	12.2±1.0	2.3±0.4	7.3±0.7
23-LOM2	Spruce (0)	13.8±0.9	0.6±0.2	1.1±0.1	15.1±6.2	1.0±0.1	5.1±1.0
23-LOM2	Spruce (1)	13.6±0.5	0.8±0.2	1.2±0.1	16.2±2.9	1.0±0.1	4.9±0.9
24-LOM3	Beech	31.9±1.9	1.6±0.1	1.2±0.1	20.0±7.7	3.0±0.5	6.4±1.2
25-TOS2	Holm oak	12.5±1.8	1.2±0.1	0.5±0.1	7.9±1.3	1.6±0.4	4.5±0.8
26-TOS3	Beech	20.3±1.6	1.6±0.2	1.4±0.3	10.1±0.7	1.8±0.4	9.8±2.1

(holm oak) for Ca, from 13.5% (Norway spruce) to 44.7% (holm oak) for Mg and from 9.4% (Norway spruce) and 33.4% (dec. oaks) for K. These findings confirm the generally reported larger variability among plots with respect to that among trees of the same plots (Bauer *et al.* 1997, Dusquenay *et al.* 2000). The general ranking of the variability, above all plots and species, showed a pattern with two classes, one with sulphur and nitrogen, showing average coefficient of variation of 15.5% and 16.6%, respectively and the other four elements with c.v. higher than 20%. This pattern showed only minor differences when compared to that reported for the inter-tree variability (see above).

From the simple values of nutrient concentrations, it is not possible to define the nutrient status of a forest stand as equilibrate, deficient or luxurious, but there is the need to set some reference or threshold that can help to detect nutritional imbalances or disturbances (Linder 1995, Stefan *et al.* 1997). For this purpose, we have compared data collected in the three surveys with the thresholds fixed at European level for the ICP-Forest monitoring programme.

The percentage distribution for 1999 of *PMPs* in the various classes defined by the European thresholds is reported in Table 2.

For Norway spruce, more than 80% of the *PMPs* is in the medium class for 4 nutrients out of 6 (N, P, Mg and K). S and Ca show an opposite distribution, the first having 87.5% of the *PMPs* in the lower class, while the second shows the same percentage in the upper class. For beech, it is interesting to note that none of the *PMPs* resulted in class 1 for any of the nutrients, while for N, S, Ca and Mg more than 50% of *PMPs* are in the upper class, with peaks of 86% and 100%, respectively for Mg and Ca. The level of P was in the medium class for the majority of *PMPs*.

As reported in Material and Methods, we have calculated three percentage distribution for oaks, one for the *PMPs* with deciduous species, one for those with holm oak and a third including all areas with oaks, using always the same thresholds.

For deciduous oaks, more than 50% of the *PMPs* resulted in the upper class for N, (80%), Ca (80%) and K (60%), while the distribution was largely intermediate for P and Mg (80% in class 2). Only in one cases, for P and K, the PMPs resulted in the lower class. On the contrary, holm

Table 2 - Percentage distribution of the *PMPs* according to the thresholds fixed at European level for nutrient concentrations. Assignment of *PMPs* to a class has been done on the basis of the average values. In parenthesis, the thresholds definig each class are reported. For S, no thresholds have been defined for oaks.
Distribuzione percentuale delle PMP in base alle soglie fissate a livello europeo per le concentrazioni di nutrienti. Le singole PMP sono state assegnate ad una determinata classe in base ai valori medi dei nutrienti. In parentesi sono riportati i valori soglia che definiscono le classi. Per le querce, non sono state definite soglie per lo zolfo.

Species/year	N	Class	N	S	P	Ca	Mg	K
Norway spruce	5	1	12.5 (≤12.0)	87.5 (≤1.1)	12.5 (≤1.0)	---- (≤1.5)	---- ≤0.6)	---- (≤3.5)
		2	87.5 (17.0)	12.5 (1.8)	87.5 (2.0)	12.5 (6.0)	100 (1.5)	100 (9.0)
		3	---- (>17.0)	---- (>1.8)	---- (>2.0	87.5 (>6.0))	---- (>1.5)	---- (>9.0)
Beech	7	1	---- (≤18.0)	---- (≤1.3)	---- (≤1.0)	---- (≤4.0)	---- (≤1.0)	---- (≤5.0)
		2	28.6 (25.0)	42.9 (2.0)	85.7 (1.7)	---- (8.0)	14.3 (1.5)	57.1 (10.0)
		3	71.4 (>25.0)	57.1 (>2.0)	14.3 (>1.7)	100 (>8.0)	85.7 (>1.5)	42.9 (>10.0)
Deciduous oaks	5	1	---- (≤15.0)		20 (≤1.0)	---- (≤3.0)	---- (≤1.0)	20 (≤5.0)
		2	20 (25.0)		80 (1.8)	20 (8.0)	80 (2.5)	20 (10.0)
		3	80 (>25.0)		---- (>1.8)	80 (>8.0)	20 (>2.5)	60 (>10.0)
Holm oak	3	1	66.7 (≤15.0)		66.7 (≤1.0)	33.3 (≤3.0)	---- (≤1.0)	66.7 (≤5.0)
		2	33.3 (25.0)		33.3 (1.8)	66.7 (8.0)	66.7 (2.5)	33.3 (10.0)
		3	---- (>25.0)		---- (>1.8)	---- (>8.0)	3 3.3 (>2.5)	---- (>10.0)
Oaks, all	8	1	25 (≤15.0)		37.5 (≤1.0)	12.5 (≤3.0)	---- (≤1.0)	37.5 (≤5.0)
		2	25 (25.0)		62.5 (1.8)	37.5 (8.0)	75 (2.5)	25 (10.0)
		3	50 (>25.0)		---- (>1.8)	50 (>8.0)	25 (>2.5)	37.5 (>10.0)

oak was preferentially distributed in the lower class for N, P and K (66.7%), in the intermediate class for Ca and Mg and only in one case, a *PMP* was present in the upper class for Mg. Similar findings were reported for 1995 in Spain, where the presence of a larger number of *PMPs* in the lower threshold class was explained by the larger number of holm oak stands in the country (Stefan *et al.* 1997). Hence, as far as the distribution of *PMPs* according to thresholds is concerned, it seems reasonable to exclude holm oak from the calculation because of its different leaf life span and its evergreen habit. Nevertheless, it is possible to verify that, when the distribution is calculated for the entire genus *Quercus*, the larger number of *PMPs* in the lower class is largely determined by the *PMPs* with evergreen species.

As reported, the nutrient concentrations may be of limited value in detecting nutritional imbalances, while more precise information can be retrieved by the calculation of some ratios between the main nutrients (Linder 1995, Bauer *et al.* 1997, Dusquenay *et al.* 2000). In Table 3, the

Table 3 - Percentage distribution of the *PMPs* according to the thresholds fixed at European level for the ratios of nutrient concentrations. Assignment of *PMPs* to a class has been done on the basis of the average values. In parenthesis, the thresholds definig each class are reported. For S, no thresholds have been defined for oaks.
Distribuzione percentuale delle PMP in base alle soglie fissate a livello europeo per i rapporti fra nutrienti. Le singole PMP sono state assegnate ad una determinata classe in base ai valori medi dei rapporti. In parentesi sono riportati i valori soglia che definiscono le classi. Per le querce, non sono state definite soglie per lo zolfo.

Species/year	N	Class	N/P	N/K	N/Ca	N/Mg	K/Ca	K/Mg	Ca/Mg
Norway spruce	5	1	---- (<6.0)	---- (<1.33)	50 (<2.0)	---- (<8.0)	25 (<0.58)	---- (<2.33)	---- (<1.0)
		2	100 (17.0)	100 (4.86)	50 (11.33)	100 (28.33)	75 (6.00)	100 (15.00)	75 (11.00)
		3	---- (>17.0)	---- (>4.86)	---- (>11.33)	---- (>28.33)	---- (>6.00)	---- (>15.00)	25 (>11.00)
Beech	7	1	---- (<10.59)	---- (<1.8)	85.7 (<2.25)	42.9 (<12.0)	42.9 (<0.63)	28.6 (<3.33)	---- (<3.67)
		2	71.4 (25.00)	85.7 (5.0)	14.3 (6.25)	57.1 (25.0)	57.1 (2.50)	71.4 (10.0)	100 (8.00)
		3	28.6 (>25.00)	14.3 (>5.0)	---- (>6.25)	---- (>25.0)	---- (>2.50)	---- (>10.0)	---- (>8.00)
Deciduous oaks	5	1	---- (<8.33)	---- (<1.5)	20 (<1.88)	---- (<6.0)	20 (<0.63)	---- (<2.0)	---- (<1.2)
		2	80 (25.0)	80 (5.0)	80 (8.33)	100 (25.0)	80 (3.33)	100 (10.0)	87.5 (8.0)
		3	20 (>25.0)	20 (>5.0)	---- (>8.33)	---- (>6.0)	---- (>0.63)	---- (>10.0)	12.5 (>8.0)
Holm oak	3	1	---- (<8.33)	---- (<1.5)	33.3 (<1.88)	33.3 (<6.0)	66.7 (<0.63)	33.3 (<2.0)	---- (<1.2)
		2	100 (25.0)	100 (5.0)	66.7 (8.33)	66.7 (25.0)	33.3 (3.33)	66.7 (10.0)	100 (8.0)
		3	---- (>25.0)	---- (>5.0)	---- (>8.33)	---- (>6.0)	---- (>0.63)	---- (>10.0)	---- (>8.0)
Oaks, all	8	1	---- (<8.33)	---- (<1.5)	25 (<1.88)	12.5 (<6.0)	37.5 (<0.63)	12.5 (<2.0)	---- (<1.2)
		2	87.5 (25.0)	87.5 (5.0)	75 (8.33)	87.5 (25.0)	62.5 (3.33)	87.5 (10.0)	87.5 (8.0)
		3	12.5 (>25.0)	12.5 (>5.0)	---- (>8.33)	---- (>6.0)	---- (>0.63)	---- (>10.0)	12.5 (>8.0)

percentage distribution for 1999 of the nutrient ratios of *PMPs* in the threshold classes set at European level, is presented.

Generally, the overall distribution seems to indicate for all species an harmonious level of nutrition, with almost all ratios being preferentially distributed in class 2. For Norway spruce, only N/Ca shows 50% of the plots in the lower class, in agreement with the percentage distribution of Ca (see Table 2). Both beech and deciduous oaks, which presented a larger number of *PMPs* in the upper class for many of the single nutrients, conversely show an equilibrate nutrition, particularly for oaks, where from 80% to 100% of the *PMPs* are in class 2 for all ratios. For beech, most of the plots (85.7%) are in class 1 for the N/Ca ratio. This result, when coupled to N in the upper class in 71.4% of the plots (Tab. 2), seems to indicate that Calcium is present in excess with respect to the demand and/or the prevailing calcareous origin of the soils in the studied beech stands. As for as nutrient ratios are concerned, it is worth noting that the distribution of holm oak plots signals that also the plots of this species are characterized by an equilibrate nutrition level, even if the thresholds are those set for the whole genus *Quercus*. In fact, the most plots (66.7-100%) show ratios in class 2, only the K/Ca ratio having a larger number of plots in class 1. The harmonius nutritional status for holm oak can be due both to the classes for ratios larger than classes for nutrients and to the evergreen habit for the species. It is also possible that the sites with holm oak are really characterized by a lower level of nutrients than those with deciduous oaks. This finding should be taken into account in setting thresholds for comparison.

The analysis of 1999 data allowed to discuss the nutritional conditions of *PMPs* in that year. By comparing data from subsequent surveys, it is possible to comment on changes over time in the *PMPs*. This comparison should be based on statistical procedures and hence there is the need to come back to the original values of the five trees sampled in each *PMP*. Unfortunately, analytical PMP-based data are available only for the first (1995) and the more recent (1999) survey.

In Table 4, the significant increases (sign +) or decreases (sign -) of the nutrient concentrations between 1999 and 1995 are reported. It is worth nothing that, in many cases, significant ($P<0.05$) changes were detected (39/66, 59%), with at least one nutrient concentration changing in each *PMP*. The large majority of the significant changes highlights increasing nutrient concentrations (34/39, 87.2%). Norway spruce nutrient concentrations changed in 5 out of 12 cases (42%), but one *PMP* (FRI2) resulted to be the most stable of the dataset, while in TRE1, N, Mg, P and S increased significantly in 1999. The plots with deciduous species showed the largest changes, with beech *PMPs* having significant concentration increases in 13 cases and decreases in 2 cases over a total of 24 values (62.5%). Deciduous oaks showed the more important changes (17/24, 71%), with an increasing nutrient concentration in almost all cases (16/17). If data are analysed separately for Turkey oak, (3 PMPs) the increase in nutrient concentrations is generalized, with 83% of the concentrations being significantly higher in 1999 than in 1995.

It is not easy to clearly attribute the reported changes at the *PMP* level to precise reasons and processes and it is probable that locally based conditions may be more important than general trends in determining such changes. Climatic differences, such as cool *vs.* warm or dry *vs.* wet years may occur at some sites and not in others, driving the reported changes. Nevertheless the general trend reported in Table 4 shows an increase of nutrient concentrations and there can be an overall factor that could explain, at least partially, the observed changes.

When assessing nutrient concentrations, one important factor helping to lower the *PMP*-based variability is the time of sampling. Optimal sampling periods have been proposed for the major species by European regulation annexes. When the difference in sampling dates is large, the year to year comparability of data may be affected, making more difficult detecting significant trends among surveys. So the sampling date should be less variable for the different surveys (Croise *et al.* 1999) and included within the optimal sampling periods. In the comparison of

1999 and 1995 data, we should check if time of sampling could play a role in causing nutrient concentration changes.

In 1999, the foliar sampling was performed within the optimal periods for the different species in 18 out of 21 *PMPs* (86%), while more than half of the plots were sampled outside those periods in 1995 (12/20). In the different surveys, the number of *PMPs* sampled outside of the optimal periods kept on decreasing from 60% (1995) to 21% and 14%, respectively in 1997 and 1999. The average difference in days between years was 27 days between 1997 and 1995 (c.v. 75), 19 days between 1999 and 1997 (c.v. 63) and 48 days between 1999 and 1995 (c.v. 99). In the latter case, excluding one *PMP*, sampled 204 days later in 1999, the average difference was 37 days (c.v. 60). The number of *PMPs* in which the sampling was anticipated or delayed resulted balanced between 1999 and 1997 (9/6), while, compared to 1999, in 1995 the sampling resulted postponed in most cases (11/16, 69%). This fact, together with the large number of material collections occurred outside the optimal periods in 1995, should cast caution into the consideration of the reported significant increases between the two survey years. Indeed, seasonal trends of nutrient concentrations with higher values in spring, constant in mid summer and then decreasing until leaf senescence are reported in literature both for North American oaks and maples and European beech (REICH *et al.* 1991, MATTEUCCI 1998, WARING and SCHLESINGER 1985). Some nutrients are more actively removed from leaves during senescence, with reabsoption being particularly important for N and P (up to 60%, WARING and SCHLESINGER 1985). As these processes are more important in deciduous than in conifer tree species, it is possible that the general increase in beech and oaks in 1999 is related to some resorption processes occurred in 1995 and not in 1999. Indeed, in 1995, the survey was performed outside the optimal period and late in the season in 3 out of 4 *PMPs* with deciduous oaks, in 2 of the beech plots, while it was too early in the season (summer) for the two spruce plots. In this latter case, the significant increase in nutrient concentrations recorded in 1999 could also be linked to the fact that, for this species, the carbohydrate content can make up 40% of needle dry weight in summer that, when not corrected for, can cause artificial low nutrient concentration (LINDER 1995, BAUER *et al.* 1997).

If nutrient ratios are used, some of the reported inconsistencies may be smoothed and this seems the case also in the presented comparison (Table 5). Nevertheless, the overall results for the nutrient ratios are indicating a lower importance of the changes occurring for the single nutrients, with significant differences being present in less than 50% of the cases (37/77, 48%). Again, significant changes for more than 50% of the ratios were detected for beech (16/28, 57%) and deciduous oaks (15/28, 54%). For both genera, decreases in nutrient ratios were more

Table 4 - Differences in nutrient concentrations between the 1995 and the 1999 surveys. Significant increases are indicated with a plus sign, while a minus sign indicates a significant decrease. Only values with P<0.05 are reported.
Differenze tra le concentrazioni di nutrienti rilevate nel 1995 e nel 1999. un aumento significativo è indicato con il segno +, mentre una diminuzione con il segno - Sono riportate solo le differenze con P<0.05.

PMP	Species	N	S	P	Ca	Mg	K
08-FRI2	Spruce						-
17-TRE1	Spruce	+	+	+		+	
01-ABR1	Beech		+	+	+	-	
04-CAM1	Beech		+	+			+
06-EMI2	Beech	+		-	+		
20-VEN1	Beech		+	+	+	+	
09-LAZ1	Turkey oak	+		+	+	+	+
15-SIC1	Turkey oak	+	-	+	+	+	+
18-UMB1	Turkey oak		+	+	+	+	
05-EMI1	Sessile oak	+		+			
16-TOS1	Holm oak		+			-	

Table 5 - Differences in the ratios of nutrient concentrations between the 1995 and the 1999 surveys. Significant increases are indicated with a plus sign, while a minus sign indicates a significant decrease. Only values with P<0.05 are reported.
Differenze tra i rapporti tra le concentrazioni di nutrienti rilevati nel 1995 e nel 1999. un aumento significativo è indicato con il segno +, mentre una diminuzione con il segno -. Sono riportate solo le differenze con P<0.05.

PMP	Species	N/P	N/K	N/Ca	N/Mg	K/Ca	K/Mg	Ca/Mg
08-FRI2	Spruce		+			-		+
17-TRE1	Spruce		+			-		
01-ABR1	Beech	-	-	-	+	-		+
04-CAM1	Beech	-	-			+		
06-EMI2	Beech				+			+
20-VEN1	Beech	-		-	-	-	-	
09-LAZ1	Turkey oak	-			-		-	
15-SIC1	Turkey oak			-	-	-	-	
18-UMB1	Turkey oak	-		-	-	-	-	
05-EMI1	Sessile oak		+	+	+			
16-TOS1	Holm oak				+			

present than increases (11/16 for beech and 12/15 for oaks), up to 100% of the cases in Turkey oak.

PMPs mean data from three surveys (1995-97-99) are available and we can try to see if it is possible to identify any particular trend at the species level. These trends may be an indication for changes at a scale larger than that of *PMP*.

The species mean values of nutrient concentrations for the three surveys are presented in Table 6 and their percent changes from one year to another are presented in Table 7. It is possible to see that, for all species and nutrients, changes between 20 and 30% are frequently present between years, with some values also in the 50-60% range (Table 7). However, these changes are generally not occurring in a consistent way, showing increases or decreases for the same nutrient and within the same species. In a study on 25 beech plots, Dusquenay and colleagues (1999) performed a detailed statistical analysis and determined the number of plots required to show evidence of a 5, 10 or 20% relative variation of the mean foliar concentrations at the 95% confidence level between two sampling dates. Extrapolating the results of their study to our case, we can estimate that, basing on the number of *PMPs*, we should be able to show evidence of relative variation for deciduous species (beech, 7 *PMPs*; oaks 5-7 *PMPs*) of 5-10% for N and P and of 10-20% for the other nutrients, while, for Norway spruce, only for P the detectable variation can be 10-20%, but should be larger than 20% for all the other nutrients. When our data were analysed by one-way ANOVA, only Nitrogen for beech changed significantly along the three surveys (P<0.05). Even if the multiple comparison test did not produce significant differences between years, the increasing linear trend was significant, with r^2 of 0.25 and a slope of 2.304 (P<0.05).

The overall results reported for concentrations are confirmed when nutrient ratios are considered (Table 8). The ratios presented percent changes of a similar order of magnitude and similar inconsistencies (data not shown). In the case of nutrient ratios, two datasets showed significant overall changes, specifically for N/Mg in Norway spruce and for Ca/Mg in deciduous oaks (Table 8). In both cases, the ratios decreased from 1995 to 1997 and increased between 1997 and 1999 and the Bonferroni post-test evidenced significant differences between 1997 and 1999.

The data presented in Table 6, 7 and 8 are indicating that changes in the nutritional status of the species sampled in Italy, do not support

Table 6 - Mean values of the six main nutrients at the species level for the three surveys. The number of plots on which the mean is calculated is reported in the column with the headings "PMPs". For Norway spruce data have been calculated on current year needles. For oaks, the data of deciduous species, holm oak and the entire genus are reported. Figures reported in bold font indicate overall significant differences (P<0.05).
Valori medi dei sei principali nutrienti riportati per specie e per anno di campionamento. Il numero dei siti da i quali sono state calcolate le medie è riportato nella colonna PMPs. Per l'abete rosso i dati sono stati calcolati sugli aghi dell'anno. Per le querce, oltre al quadro di insieme, vengono presentati i dati separati tra specie decidue e sempreverdi (leccio). I numeri in grassetto indicano differenze significative (P<0.05).

Species/genus	Year	PMPs	N	S	P	Ca	Mg	K
Norway spruce	1995	3	13.05±1.02	1.27±0.49	1.10±0.26	5.57±1.05	1.12±0.30	5.93±1.14
	1997	4	11.21±1.42	0.95±0.24	1.02±0.48	7.97±2.40	1.57±0.29	6.25±3.56
	1999	5	14.45±2.28	0.93±0.27	1.35±0.37	9.35±3.50	1.19±0.11	5.75±0.65
Beech	1995	7	**23.25±2.25**	1.73±0.43	1.17±0.21	10.53±4.08	2.00±0.81	8.11±1.43
	1997	7	**24.00±1.71**	1.44±0.37	1.35±0.49	11.87±3.94	3.09±1.02	11.23±5.86
	1999	7	**27.86±5.29**	1.96±0.34	1.46±0.19	14.88±4.61	2.21±0.50	9.55±2.24
Deciduous oaks	1995	7	21.47±1.60	1.51±0.28	1.00±0.44	10.82±4.44	1.85±1.18	8.21±2.25
	1997	6	21.96±2.23	1.50±0.19	0.80±0.26	10.30±2.16	2.48±0.66	10.53±4.22
	1999	5	27.35±3.58	1.75±0.12	1.29±0.37	11.43±2.09	2.13±0.61	9.20±3.07
Holm oak	1995	2	12.21±0.11	0.97±0.07	0.77±0.09	5.12±0.18	2.60±1.59	7.12±1.71
	1997	1	13.20	1.01	0.88	5.16	4.73	4.99
	1999	3	14.40±2.99	1.32±0.13	0.82±0.25	6.24±2.18	2.08±0.93	4.89±0.84
Oaks	1995	9	19.41±4.31	1.39±0.34	0.95±0.40	9.55±4.60	2.01±1.21	7.97±2.09
	1997	7	20.71±3.89	1.43±0.25	0.81±0.24	9.57±2.77	2.80±1.04	9.73±4.39
	1999	8	22.49±7.40	1.59±0.25	1.12±0.40	9.48±3.33	2.11±0.68	7.58±3.25

Table 7 - Percentage differences between sampling years for the six main nutrients. The differences have been calculated from the mean values at the species level (Table 6). In bold are reported the values that, basing on the number of sampled plots, may be attributed to effective changes and not to simple samples variability. *For sulphur this calculation is not reported. For Norway spruce, mean values have been calculated on current year needles.
*Differenze percentuali tra campionamenti successivi per i sei principali nutrienti. La differenza è calcolata sul valore medio di specie. Sono sottolineati i valori che statisticamente, in base al numero di aree campionate, potrebbero essere attribuibili a reali cambiamenti e non a semplice variabilità del campione. *Per lo zolfo tale calcolo non è stato effettuato. Per l'abete rosso i dati sono stati calcolati sugli aghi dell'anno.*

Species/ genus	Year	N	S*	P	Ca	Mg	K
Norway spruce	1997-1995	-14.1	-25.2	-7.6	43.0	40.0	5.4
	1999-1997	**28.9**	-2.1	**33.2**	17.4	-24.0	-8.1
	1999-1995	10.8	-26.8	**-23.1**	**67.8**	6.4	-3.2
Beech	1997-1995	3.2	-16.7	**15.2**	12.7	**54.6**	**38.4**
	1999-1997	**16.1**	36.5	**8.5**	**25.4**	**-28.4**	-14.9
	1999-1995	**19.8**	13.7	**25.0**	**41.3**	10.7	**17.7**
Deciduous oaks	1997-1995	2.3	-0.7	**-20.0**	-4.8	**34.2**	**28.2**
	1999-1997	**24.5**	16.8	**61.3**	11.0	-14.1	-12.6
	1999-1995	**27.4**	15.9	**29.1**	5.7	15.3	12.1
Holm oak	1997-1995	(8.2)	(3.9)	(13.8)	(0.8)	(81.8)	(-30.0)
	1999-1997	(9.1)	(30.2)	(-7.0)	(20.9)	(-56.1)	(-2.0)
	1999-1995	18.0	35.3	5.9	21.9	-20.2	-31.4
Oaks	1997-1995	6.7	2.8	**-14.5**	0.2	**39.0**	**22.1**
	1999-1997	**8.6**	11.1	**37.2**	-0.9	**-24.7**	**-22.1**
	1999-1995	**15.9**	14.2	**17.3**	-0.7	4.7	-4.8

any particular long-term trend. In this respect, the limited number of datasets that showed significant changes prevents also any further interpretation for the species for which the changes were detected.

Significant changes of five main nutrients and of 6 out of 8 nutrient ratios (all increasing except Mg/Ca) were reported to occur in 25 beech plots in France, surveyed in 1969-71 and 1996-97 (Dusquenay *et al.* 2000). The lack of significant changes in our case could be largely due to the limited time frame over which our three surveys were carried out. Over a 5 years period, it is likely that local factors are causing changes, thereby obscuring possible long-term trends. Indeed, in our study, when *PMPs* data of nutrients and nutrient ratios of species were compared by one way ANOVA over the same year, the results showed that in nearly all cases, the *PMPs* were overall significantly different, often with $P<0.01$ or $P<0.001$. The few exceptions were K, Mg, N/Mg and K/Mg for the spruce plots, S and P for deciduous oaks and K/Mg for holm oaks plots. The same findings were reported for the French study, where the analysis was performed in six plots over five consecutive years (1993-1997),

Table 8 - Mean values of the six main nutrients at the species level for the three surveys. The number of plots on which the mean is calculated is reported in the column with the headings "PMPs". For Norway spruce data have been calculated on current year needles. For oaks, the data of deciduous species, holm oak and the entire genus are reported. Figures reported in bold font indicate overall significant differences (P<0.05).
Valori medi dei sei principali nutrienti riportati per specie e per anno di campionamento. Il numero dei siti da i quali sono state calcolate le medie è riportato nella colonna PMPs. Per l'abete rosso i dati sono stati calcolati sugli aghi dell'anno. Per le querce, oltre al quadro di insieme, vengono presentati i dati separati tra specie decidue e sempreverdi (leccio). I numeri in grassetto indicano differenze significative (P<0.05).

Species/genus	Year	PMPs	N/P	N/K	N/Ca	N/Mg	K/Ca	K/Mg	Ca/Mg
Norway spruce	1995	3	12.86±3.89	2.26±0.28	2.45±0.02	**12.35±3.57**	1.11±0.15	5.66±2.00	5.19±1.40
	1997	4	12.70±5.23	2.13±0.89	1.54±0.61	**7.34±1.65***	0.90±0.74	4.17±2.67	5.04±1.04
	1999	5	11.46±3.82	2.59±0.46	1.90±0.91	**12.49±1.86***	0.76±0.33	4.93±0.59	8.59±3.95
Beech	1995	7	20.61±3.31	2.98±0.48	2.63±1.34	13.97±5.90	0.89±0.38	4.75±1.69	5.58±1.80
	1997	7	21.04±11.22	2.98±2.20	2.22±0.75	8.42±2.39	0.98±0.46	3.54±1.27	3.90±0.75
	1999	7	19.75±5.54	3.11±1.03	2.10±0.98	13.58±5.02	0.72±0.30	4.75±1.68	6.76±1.30
Deciduous oaks	1995	7	25.51±10.48	2.91±0.91	2.35±0.99	17.18±10.44	0.87±0.37	6.85±4.58	**8.40±6.28**
	1997	6	29.54±8.21	2.29±0.63	2.19±0.38	9.38±2.66	1.02±0.30	4.20±0.89	**4.35±1.36***
	1999	5	23.90±10.91	3.53±2.07	2.51±0.73	13.56±2.91	0.80±0.22	4.80±2.64	**6.03±3.15***
Holm oak	1995	2	16.24±1.64	1.80±0.46	2.49±0.07	5.83±3.58	1.43±0.31	3.66±2.94	2.50±1.64
	1997	1	15.00	2.65	2.56	2.79	0.97	1.05	1.09
	1999	3	18.43±4.22	3.12±1.07	2.58±0.99	8.25±4.39	0.94±0.60	2.66±0.69	3.77±2.22
Oaks	1995	9	23.45±9.97	2.67±0.94	2.38±0.86	14.66±10.41	1.00±0.42	6.14±4.33	7.09±6.05
	1997	7	27.46±9.29	2.34±0.59	2.24±0.37	8.43±3.48	1.01±0.28	3.75±1.44	3.89±1.75
	1999	8	21.85±9.01	3.38±1.68	2.53±0.76	11.57±4.23	0.85±0.37	4.00±2.31	5.18±2.91

and plots resulted to affect significantly the observed changes for all concentrations and ratios of nutrients at $P<0.001$, with year of sampling being much less important (Dusquenay *et al.* 2000).

In our study, the interannual coefficient of variation is, generally smaller or, at best, of the same order of magnitude of the inter-*PMP* variability.

Conclusions

Nutrient concentrations and their ratios are good indicators of the nutritional status of the Permanent Monitoring Plots surveyed within the ICP-Forest CON.ECO.FOR. monitoring programme.

In 1999, the percentage distribution of Italian *PMPs* within the classes defined according to the European thresholds is signalling a generally equilibrate situation of the nutritional status (Table 2 and 3).

However, the detection of significant changes and their interpretation is generally difficult based on the available short-term data sets.

As we have seen, within the same year (1999), the between-plot variability of nutrients is larger that the inter-tree variability, confirming that plot conditions are important in determining the nutritional status on a single year basis. On a time frame of 5 years (1995-1999), the plot variability is still more important than the inter-year variability, limiting the possibility to assess significant changes. Indeed, in the investigated time frame, factors like climate or atmospheric deposition of pollutants are likely to present minor changes or to be more or less constant at regional and national scales.

Some of the differences that were found between the surveys 1995 and 1999 were probably linked to the fact that the sampling of leaf material was not always performed in the otpimal periods, particularly in 1995. It is therefore important that for future surveys, the optimal sampling periods are respected, in order to limit the importance of random, unwanted factors in causing the variability of the nutritional status of *PMPs*.

In all cases that we presented, holm oak behaved differently from the other oak species. With regard to this peculiarity, that is also mentioned in European reports (EC-UN/ECE, Stefan *et al.* 1997), it is important that specific thresholds for this species are proposed, also by discussing the matter with the countries where holm oak is as important as in Italy (Spain, Greece).

References

Allavena S., Isopi R., Petriccione B., Pompei R., 1999 - *Programma Nazionale Integrato per il controllo degli ecosistemi forestali*. Ministero delle Politiche Agricole, Roma, Italia, 220 p.

Bauer G., Schulze E.-D., Mund M. 1997 - *Nutrient contents and concentrations in relation to growth of* Picea abies *and* Fagus sylvatica *along a European transect*. Tree Physiology 17: 777-786.

Bauer G.A., Persson H., Persson T., Mund M., Hein M., Kummetz E., Matteucci G., Van Oene H., Scarascia Mugnozza G., Schulze E.-D. 2000 - *Linking plant nutrition and ecosystem processes*. In "Carbon and Nitrogen Cycling in European forest Ecosystems". Ecological Studies 142 Schulze E.-D. ed. Springer Verlag, Heidelberg, 500 p.: 63-98.

Bonneau M. 1988 - *Le diagnostic foliaire*. In: "Diagnostics en Forêt" n° Sp. Revue Forestiere Francaise XL, 159 p.: 19-28.

Croise L., Cluzeau C., Ulrich E., Lanier M., Gomez A. 1999 - *RENECOFOR – Interprétation des analyses foliaires réalisées dans le 102 peuplements du réseau de 1993 a 1997 et premières évaluations interdisciplinaires*. Office National des Foréts, Départment Recherche et Développement, ISBN 2–84207–189-1, 413 pp.

Dusquenay A., Dupouey J.L., Clement A., Ulrich E., Le Taon F. 2000 - *Spatial and temporal variability of foliar mineral concentration in beech (*Fagus sylvatica*) stands in northeastern France*. Tree Physiology 20: 13-22.

EC-UN/ECE, Stefan K., Fürst A., Hacker R., Bartels U. 1997 - *Forest foliar condition in Europe – Results of large-scale foliar chemistry surveys (survey 1995 and data from the previous years)*. EC-UN/ECE, Austria Federal Forest Reseach Centre, 207 pp.

Evans J.R. 1989 - Photosynthesis and nitrogen relationships in leaves of C3 plants. Oecologia 78: 9-19.

Evans J.R., Seeman J.R. 1989 - *The allocation of protein nitrogen in the photosynthetic apparatus: costs, consequences and control*. In: "Photosynthesis". Briggs W.R. ed. Alan R. Liss Inc. New York, p. 183-205.

Field C.B., Mooney H.A. 1986 - *The photosynthesis-nitrogen relationship in wild plants.* In: "On the economy of plant form and function". Givnish T.J. ed. Cambridge University Press, Cambridge, United Kingdom, p. 25-55.

Hikosaka K., Terashima I. 1995 - *A model of the acclimation of photosynthesis in the leaves of C3 plants to sun and shade with respect to nitrogen use.* Plant, Cell and Environment 18: 605-618.

Linder S. 1995 - *Foliar analysis for detecting and correcting nutriwnt imbalances in Norway spruce.* Ecological Bullettin 44: 178-190.

Marschner H. 1986 - *Mineral Nutrition of Higher Plants.* Academic Press, Harcourt Brace Jovanovich, Publishers, London-San Diego, 510 p.

Matteucci G. 1998 - *Bilancio del carbonio in una faggeta dell'Italia Centro-Meridionale: determinanti ecofisiologici, integrazione a livello di copertura e simulazione dell'impatto dei cambiamenti ambientali.* PhD Thesis, University of Padova, Italy, pp. 300.

Reich P.B., Walters M.B., Ellsworth D.S. 1991 - *Leaf age and season influence the relationship between leaf nitrogen, leaf mass per area and photosynthesis in maple and oak trees.* Plant, Cell and Environment 14: 251-259.

Reich P.B., Kloeppel B.D., Ellsworth D.S., Walters M.B. 1995 - *Different photosynthesis-nitrogen relations in deciduous hardwood and evergreen coniferous tree species.* Oecologia 104: 24-30.

Waring R.H., Schlesinger W.H. 1985 - *Nutrient uptake and internal plant distribution: the intrasystem cycle.* In: "Forest Ecosystems. Concepts and Management". Waring R.H., Schlesinger W.H. edit., Academic Press Inc., San Diego, California, 340 p.: 157-180.

Atmospheric deposition and streamflow chemistry at the Permanent Monitoring Plots of the CONECOFOR programme§

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Abstract - Five indexes were proposed to describe the chemistry of atmospheric deposition in the CON.ECO.FOR. permanent plots: the deposition of total nitrogen and of acidifying compounds, both estimated in the open field and in the plot, and the nitrogen saturation stage obtained from the seasonal pattern of runoff nitrate concentration. For each site, their values in 1988 and 1999 are reported, and discussed in relation to the higher amount of precipitation experienced in 1999.

Key words: *atmospheric deposition, forest stands, throughfall, stemflow, streamflow.*

Riassunto – Chimica delle deposizioni e delle acque di ruscellamento nelle aree permanenti del programma CONECOFOR. Vengono proposti cinque indici numerici adatti a descrivere sinteticamente la composizione chimica delle deposizioni atmosferiche nelle aree permanenti CON.ECO.FOR.: si tratta dei flussi di azoto e di ioni acidificanti, entrambi stimati separatamente a cielo aperto e all'interno dell'area permanente, e di un indice di saturazione di azoto calcolato a partire dalla distribuzione stagionale delle concentrazioni di nitrati nelle acque di ruscellamento. I valori degli indici sono stati calcolati per il 1998 e per il 1999, e discussi anche in funzione della maggiore quantità di precipitazioni registrata nel 1999.

Parole chiave: *deposizioni atmosferiche, foreste.*

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The chemistry of atmospheric deposition is considered an important factor potentially affecting the growth and health of forest stands. High levels of atmospheric deposition fluxes may influence the chemistry of soil solution and the nutritional status of forests.

The major aims of this study are then to quantify the atmospheric input of sulphur, nitrogen (as nitrate and ammonium), base cations, acidity and alkalinity, and to evaluate the interaction of forest canopy with the ionic fluxes from the atmosphere to forest soil.

Atmospheric deposition is the sum of wet deposition, where particles and gases are carried through precipitation, and dry deposition, where they deposit directly onto surfaces, such as forest canopy. Wet deposition can be measured using wet-only samplers, or derived from bulk deposition, which also includes a fraction of dry deposition and a certain amount of dust originated locally from the soil or transported from farther sources.

Information on the quality of atmospheric deposition in remote areas in Italy is relatively scarce (Mosello and Marchetto 1996), and it was decided to extend the monitor activity to 15 permanent CON.ECO.FOR. sites. The methods of sampling, sample treatment and analysis are in strict agreement to those used in Europe with minor adaptations, and are reported elsewhere (Mosello *et al.* 1998). It is however important to note that sampling was performed weekly.

Five different samplings of atmospheric deposition were considered

1. Bulk samples collected in the open field, using 2 or 3 continuously exposed collectors, comprising a 2-litre graduated polyethylene bottle, with a funnel of 19.5 cm diameter, a filter to prevent leaves or insects from entering the container and a guard ring to prevent birds from perching on the funnel. Snow samples were collected by using either polyethylene plastic sacks or cylinders. Open field samples represent the deposition fluxes reaching the plot, as they are

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experienced by forest canopy;

2. Wet-only samples collected in the open field, using automatic collectors which are open during rain or snow. Sampling is performed in 4 stations, to quantify the effect of local dust in open field bulk sampling;
3. Throughfall samples, collected by means of 9 or 16 collectors similar to those used in the open field, distributed regularly in the permanent plot. Throughfall and stemflow samples together represent the so-called "in the plot" deposition, *i.e.* the result of the interaction of total (wet and dry) deposition with forest canopy, and the input to the soil system;
4. Stemflow samples, obtained from 3-7 trees, representative of different age classes, diameters and heights. Following EEC regulation n° 926/93, stemflow analysis is mandatory for beech trees, only. However it was found that this fraction is relatively important also for the different species of Quercus.
5. Runoff water was analysed at four stations in small permanent streams draining areas very close to the permanent observation plot, with uniform characteristics, and similar to those of the plot. Comparing runoff and deposition chemistry gives more insight in ion cycling in the forest stands, with particular attention to nitrogen compounds.

Methods

Sampling protocol directly affects the information gathered from the study of the chemistry of atmospheric deposition at the CON.ECO.FOR. sites.

Weekly samples, for example, can not be used to obtain information on the maximum ionic concentration or the minimum pH, as smaller events, which usually carry higher amounts of ions and of acidity, can be diluted by other precipitation occurred during the same week.

Furthermore the use of bulk samplers prevents a correct quantification of the flux of base cations, because of the interference of dust produced locally and collected by the funnels.

As the most relevant effect of the pollution of atmospheric deposition are acidification and nitrogen enrichment, we propose to describe atmospheric deposition chemistry in each plot by means of the total fluxes of acidifying compounds and of nitrogen compounds. The indexes are calculated both for open field deposition, acting directly on forest canopy, and for in-the-plot deposition, representing the input to forest soil. A further index, based on runoff analysis, was also used for evaluating nitrogen dynamics in the plot.

The total flux of acidifying compounds is the sum of the deposition of ammonium, nitrate and sulphate. Acidity produced by each mole of ammonium ion was assumed as 1.5 moles, averaging the values of 1, which is valid in case of uptake from vegetation, and 2, which is valid in case of oxidation to nitrate (REUSS and JOHNSON 1987, VAN BREEMEN *et al.* 1984). Sulphate was corrected for the contribution of sea spray. Nevertheless it must be considered that a further fraction of sulphate may be due to minerals transported from North Africa (CARRATALÀ *et al.* 1996, GUERZONI and CHESTER 1996, LOYE-PILOT and MARTIN 1996), which can reach the whole Italian territory.

The deposition of acidifying compounds, DEP(acid), was calculated in open field (*OF*) and in the plot (*IP*), as the sum of throughfall (*TF*) and stemflow (*SF*):

$$(1)\ DEP_{OF}\ (acid) = 2 \cdot DEP_{OF}\ (SO_4{}^*) + DEP_{OF}\ (NO_3) + 1.5 \cdot DEP_{OF}\ (NH_4)$$

$$(2)\ DEP_{IP}\ (acid) = 2 \cdot DEP_{TF}\ (SO_4{}^*) + 2 \cdot DEP_{SF}\ (SO_4{}^*) + DEP_{TF}\ (NO_3) + DEP_{SF}(NO_3) + 1.5 \cdot DEP_{TF}(NH_4) + 1.5 \cdot DEP_{SF}\ (NH_4)$$

where units are mmol $m^{-2}\ y^{-1}$, and the asterisk denotes corrections for sea-salt contribution.

It must be emphasised that these values do not express an actual or potential acidity, as most of the anions are buffered by the high concentrations of calcium and other base cations. However, these indexes can consistently track temporal trend in the acidifying potential of atmospheric deposition, assuming that they would not be used for comparisons among stations. They avoid the difficulties connected with the estimation of base cation fluxes, namely the episodic deposition of Saharan dust (LOYE-PILOT *et al.* 1986) and the effect of local dust on bulk samples. For example, in the case of station LAZ1, in 1999 base cation flux measured through bulk samplers was about twice that measured through wet only samples.

Nitrogen deposition was also considered in the open field and in the plot. For open-field deposition, total nitrogen (TN) concentration was measured in most sites, and nitrogen flux was then directly available. In site TOS1, where total nitrogen was not measured, nitrogen deposition in the open field was estimated as:

$$(3)\ DEP_{OF}\ (N) = DEP_{OF}\ (NO_3^-) + DEP_{OF}\ (NH_4^+)$$

where units are mmol m^{-2} y^{-1}.

In throughfall and stemflow samples, where the organic nitrogen compound are an important part of the total nitrogen flux, the following equation was used:

$$(4)\ DEP_{IF}\ (N) = DEP_{TF}\ (TN) + DEP_{SF}\ (TN)$$

where units are mmol m^{-2} y^{-1}.

Nitrogen loads may be compared with the nitrate and total nitrogen concentrations in the stream waters. To synthesise the concentrations and the seasonal variations of nitrate we used the STODDARD and TRAAEN criteria (Table 1), as applied to watercourses with frequent samplings (TRAAEN and STODDARD 1995). The criteria give a quantification of the level of nitrogen saturation of the watershed; the higher is the stage of saturation, the lower is the possibility of soil and vegetation to metabolise and immobilise the amount of nitrogen deposited from atmosphere.

Results

The values obtained for the five indexes in 1998 and 1999 are listed in Table 2, together with the amount of precipitation measured in the open field samplers. Nitrogen saturation index was not available in 1999, as runoff analysis was not carried out in any station.

In-the-plot nitrogen deposition was not calculated for site TOS1, where total nitrogen was not measured, and stations FRI1 and ABR1 were not considered in 1998 and 1999, respectively, as they were not run for the whole year.

Apart two cases (MAR1 and TOS1), the values of all indices in 1998 are lower than in 1999, because of the higher amount of precipitation experienced in the latter year. In fact, in most

Table 1 - The nitrogen saturation model for stream with frequent samples (TRAAEN and STODDARD 1995).
Stadi di saturazione di azoto degli ecosistemi forestali rilevati attraverso analisi frequenti di un corso d'acqua, secondo TRAAEN e STODDARD (1995)

STAGE	CRITERION	MEANING
0	More than one sample in the growing season with $[NO_3] < 3$ µM and no sample with $[NO_3] > 10$ µM	Nitrogen cycle dominated by forest and microbial uptake
0/1	One sample in the growing season with $[NO_3] < 3$ µM and no sample with $[NO_3] > 10$ µM or more than one sample in the growing season with $[NO_3] < 3$ µM and one sample with $[NO_3]$ between 10 and 20 µM	Intermediate between stage 0 and stage 1
1	More than one sample in the growing season with $[NO_3] < 3$ µM and one sample with $[NO_3] > 20$ µM	Watershed proceeds toward saturation: nitrate concentration frequently exceeds typical values
1/2	One or more samples in the growing season with $[NO_3]$ between 3 and 5 µM	Intermediate between stage 1 and stage 2
2	More than one sample in the growing season with $[NO_3]$ between 5 and 50 µM	Nitrogen cycle dominated by loss through leaching and denitrification
2/3	One or more samples in the growing season with $[NO_3] < 50$ µM and one or more with $[NO_3] > 50$ µM	Intermediate between stage 2 and stage 3
3	All samples in the growing season with $[NO_3] > 50$ µM	Amplification of stage 2: deposition, mineralization and nitrification contribute nitrate to leaching water

Table 2 - Precipitation amount (open field, mm), deposition of acidifying ions and of total nitrogen (mmol m^{-2} y^{-1}), and nitrogen saturation stage in the CON.ECO.FOR. plots in 1998 and 1999
Quantità di precipitazione a cielo aperto (mm), deposizione areale annua (mmol m^{-2} a^{-1}) di ioni coinvolti nei processi di acidificazione e di azoto, e stadi di saturazione in azoto, per le aree permanenti CON.ECO.FOR. nel 1998 e 1999.

Site	Precipitation amount (mm)		DEP_{OF} (acid)		DEP_{IF} (acid)		DEP_{OF} (N)		DEP_{IF} (N)		N saturation stage
	1988	1999	1998	1999	1998	1999	1998	1999	1998	1999	1998
01 ABR1	591	-	63	-	121	-	43	-	149	-	-
03 CAL1	1257	1848	93	164	142	159	55	96	86	86	-
04 CAM1	850	1428	71	136	130	154	48	89	92	116	-
05 EMI1	567	929	119	166	227	357	84	101	170	234	-
06 EMI2	845	1433	90	164	105	194	56	88	78	124	2
07 FRI1	-	961	-	142	-	165	-	86	-	115	
08 FRI2	1335	1489	98	104	110	198	65	62	84	128	1
09 LAZ1	906	1077	90	114	113	127	58	73	83	97	1
10 LOM1	1593	2157	136	180	126	152	72	151	117	114	-
11 MAR1	1038	1166	170	123	104	115	106	87	85	90	-
12 PIE1	1252	1995	170	281	176	312	112	172	124	207	3
15 SIC1	582	544	70	118	105	134	56	54	71	96	-
16 TOS1	717	1006	132	131	198	209	-	-	-	-	-
17 TRE1	1048	1135	81	125	53	63	55	101	47	55	-
20 VEN1	1203	1530	143	174	199	177	94	111	136	123	-

stations ion concentration in deposition was very close in 1998 and in 1999, and the increase in the amount of deposition was reflected as an increase in ionic fluxes. This pattern is consistent with the remote location of the sampling sites, where the extraction of particles and gases from the atmosphere by rain and snow (wash out) represent a minor part of total deposition.

Nitrogen saturation stage was calculated in 1998 for stations EMI2, FRI2, LAZ1 and PIE1. Sites FRI2 and LAZ1 resulted in stage 1, EMI2 in stage 2, and PIE1 in stage 3. These values confirm that all the areas are undergoing an overload of nitrogen, very marked in the case of EMI2 and PIE1, where vegetation and soil microflora are no more able to regulate the nitrogen flux. These conclusions are further supported from the relevant content of organic nitrogen in the two streams, where nitrate level is relatively low.

References

CARRATALÀ A., BELLOT J., GOMEZ A., MILLAN M., 1996 - *African dust influence on rainwater on the Eastern coast of Spain*. In: "The impact of desert dust across the Mediterranean". Kluwer, Dordrecht: 389 p.: 323-332.

GUERZONI S., CHESTER R. (Eds), 1996 - *The impact of desert dust across the Mediterranean*. Kluwer, Dordrecht, 389 p.

LOYE-PILOT M.D., MARTIN J.M., MORELLI J., 1986 - *Influence of Saharan dust on the rain acidity and atmospheric input to Mediterranean*. Nature 321: 427-428.

LOYE-PILOT M.D., MARTIN J.M., 1996 - *Saharan dust input to the Western Mediterranean: an eleven year record in Corsica*. In: " The impact of desert dust across the Mediterranean". Kluwer, Dordrecht: 389 p.: 191-200.

MOSELLO R., MACHETTO A., 1996 - *Chemistry of atmospheric wet deposition in Italy: results from a five-year study*. Ambio, 25: 21-25.

MOSELLO R., BOGGERO A., MARCHETTO A., TARTARI G.A., 1998 - *National integrated programme for the control of forest ecosystems (CON. ECO. FOR.). Study of atmospheric deposition chemistry*. C.N.R. Istituto Italiano di Idrobiologia, Verbania Pallanza, Technical Report, 40 p.

REUSS J.O., JOHNSON D.W., 1987 – *Acid deposition and the acidification of soils and waters*. Ecological studies 59, Springer, New York, 119 p.

TRAAEN T.S., STODDARD J.L., 1995 - *An assessment of nitrogen leaching from watersheds in ICP on waters. Convention on Long-range Transboundary Air Pollution. International Cooperative Programme on assessment and monitoring of acidification of rivers and lakes*. Prepared by the Programme Centre, Norwegian Institute for Water research. NIVA-report, 3201, 39 p.

VAN BREEMEN N., DRISCOLL C.T., MULDER J., 1984 – *Acidic deposition and internal proton sources in acidification of soils and waters*. Nature, 307: 599-604.

Ozone measurements by passive samplers at Italian forest sites[§]

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Abstract – During the late spring and summer months of the period 1996 – 1999 ozone passive samplers were exposed to ambient air at 20 permanent investigation plots of the Italian Programme for Forest Ecosystems Control (CON.ECO.FOR.). Mean ozone concentrations over the monitoring periods display values between 30 – 65ppb and weekly maxima above 80ppb. The concentrations over the monitoring periods vary substantially from year to year due to the influence of climatic conditions. The highest mean ozone levels are observed generally at monitoring sites in Central and Southern Italy. Results of the study emphasise the presence of possible risks to forest species at the sites considered due to ozone pollution.

Key words: *ozone, passive samplers, monitoring.*

Riassunto – Misure di ozono mediante campionatori passivi presso siti forestali italiani. Nei mesi tardo – primaverili ed estivi degli anni 1996 – 1999 sono stati esposti campionatori passivi per la misura dell'ozono presso 20 aree di indagine permanenti del Programma Nazionale per il Controllo degli Ecosistemi Forestali (CON.ECO.FOR.). I valori di concentrazione media nei periodi di misura sono compresi tra 30 e 65 ppb mentre i valori massimi su base settimanale superano 80 ppb. I valori di concentrazione media su tutto il periodo di indagine variano sensibilmente di anno in anno in relazione alle condizioni climatiche. Gli anni in cui la presenza di questo inquinante è risultata più consistente sono il 1997 e 1999. I valori medi più elevati nei periodi di osservazione sono stati registrati generalmente presso i siti di monitoraggio dell'Italia Centrale e Meridionale. I risultati evidenziano la presenza nei siti considerati di possibili rischi per le specie forestali in relazione all'inquinamento da ozono.

Parole chiave: *ozono, campionatori passivi, monitoraggio.*

F.D.C. 425:524.634: (450.5/.7)

Because of its high level of phytotoxicity, tropospheric ozone (O_3) is considered as one of the most critical pollutants in Europe. O_3 is formed in the troposphere through reactions between nitrogen oxides and hydrocarbons that are dependent on light. Ozone precursors are emitted to the air from traffic, industrial processes and power production. The formation and occurence of ozone in the troposphere is described in detail in Crutzen (1995) and PORG (I997). Current levels of O_3 can be obtained from stationary measurements as from modelling approaches (*e.g.* EMEP). At European level ground measurements are limited in several regions and especially in Southern Europe to the most populated and industrialised areas. Models, on the other hand, consider emission of precursors, transformations and loads of airborne pollutants as they move about over wide areas but the spatial resolution limits the use of these data for local investigations. EMEP data show that threshold concentrations for the protection of forests are exceeded in large parts of Europe (Hettenligh *et al.* 1997). The assessment of environmental risks related to O_3 effects on vegetation is currently based on the critical level concept, the concentration of gaseous pollutants above which direct adverse effects on receptors, such as plants, ecosystems and materials may occur according to present knowledge (Bull 1991, Skarby 1993). Critical level for O_3 is expressed as AOT40, the cumulative exposure over 40 ppb ($AOT40_c$ for agriculture crops is 3000 ppb·h and $AOT40_f$ for forests 10000 ppb·h) considering either the concentrations during daylight hours (10 a.m. – 5 p.m.) or the ozone concentrations recorded when the radiation is greater than 50 W/m^2. $AOT40_c$ refers to ozone concentration data recorded from May to July, $AOT40_f$ to data collected from April to September. Other indexes regarding short-time peak concentrations or averages over the vegetation period or the whole year are considered by national legislation, EU directives or other international guidelines. In Italy O_3 has to be considered the most important air pollutant in rural and forest areas during the growing season due to the presence of fa-

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vourable conditions to its formation. Model outputs show that O_3 levels in Italy may lead to exceedences of concentrations up to 4 times the proposed thresholds in the Northern Apennines and in the South (Hettenligh *et al.* 1997). In spite of this, information about O_3 concentrations is substantially limited to urban areas and data from remote areas, especially in the South, are scarce and fragmentary.

In order to begin to define a picture of air pollutant concentration in remote areas passive samplers have been used in several studies (Monn *et al.* 1990, Kirchner *et al.* 1994, Hangartner 1996) as they are easy to handle and transport, and need no power supply There are, however, limitations in the use of the data obtained from passive samplers. Because the passive sampler provides an integrated measurement over time, usually one-week, no information is obtained regarding short-time concentration peaks or the diurnal patterns at the monitoring locations. Passive (diffusive) samplers may be regarded as devices capable of taking samples of gas from the atmosphere at a rate controlled by physical processes such as diffusion through a static air layer without involving active movement of air through the sampler (Harper and Purnell 1987, Brown and Wright 1994).

In the framework of the National Programme for Forest Ecosystem Control (CON.ECO.FOR.) financed by the European Union and the Italian forest authorities (Allavena *et al.* 1999) O_3 data were collected using passive samplers at short distance from 20 forest plots. This paper reports results of the O_3 monitoring activity carried out from 1996 to 1999.

Materials and methods

Passive samplers were exposed at 20 forest plots of the CON.ECO.FOR. network during late spring and summer months, from 1996 to 1999. The approach adopted is based on tube type diffusive samplers and on the reaction between indigo ($C_{16}H_{10}N_2O_2$), the well known dyestuff, with ozone. The tubes (PVC) are 570 mm long and have a diameter of 70 mm. Indigo impregnated paper filters are placed in the tubes and kept in position (450 mm from mouth) by a rod. Indigo reacts with ozone to isatin which can be determined spectrophotometrically. A detailed description of the exposition device is given in Werner (1992). The preparation of the indigo papers can be briefly described as follows: filter papers (Macherey MN 8276, ∅ 60 mm, centre hole 16 mm) are fixed individually in a container avoiding mutual contact and washed in ethanol and afterwards in des. water. Once dried they are fixed in a rotating device and placed in an indigo solution. The solution is prepared from indigo powder (Fluka 56980) which is preliminarily washed with ethanol and with des. water. A suspension of indigo (8 g/l) is shortly exposed in a container at 20°C to an ultrasound treatment until a full homogeneity is reached. The papers are placed in the suspension and rotated for 8 min at 20°C. Afterwards, filter papers are dried in an air tight container for 24 h above 1 kg silica gel. The dried papers undergo a new treatment with ethanol and are finally dried again. At last they are placed in air closed polythene bags and are sent for exposition.

Once exposed indigo papers are again closed in polythene bags and taken to the laboratory. The exposed indigo papers are placed in air tight polystirol containers filled with 10 ml ethanol and agitated for 15 min. Spectra of the ethanol solution are taken by a double beam UV-VIS spectrometer (Perkin Elmer Lambda 2 with 1 nm resolution) at 200-700 nm. Typically, the isatin peak can be observed at 408 nm but it may be shifted towards shorter wavelengths due to matrix effects. Spectral data were analysed and corrected by specific software routines. The resulting extinction values read at the isatin peaks may be converted in O_3 ppbv by a calibration curve developed from an active analyser.

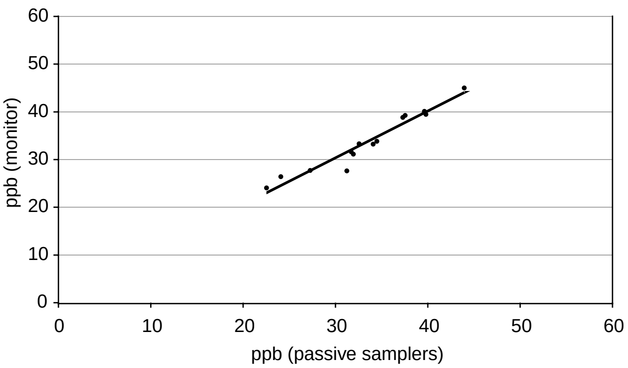
At the permanent investigation plots the monitoring devices were placed in areas with free air circulation and at least 20 m from major physical obstacles (trees, houses, *etc*) and from disturbance sources (roads, cultivated fields, *etc.*). Maximum distance of O_3 measurement sites from the permanent plots was 0.5 km. A detailed description of the permanent investigation plots is reported elsewhere in this volume.

In 1996 five replications were exposed in parallel, in 1997 three, while in the last two years one passive sampler only was exposed at each site. Samplers were changed weekly. Correlation of indigo papers with continuous measurements was checked by simple regression procedure to fit a linear model (Statgraphics Plus, Manugistics Inc., 1998) at a monitoring station of the Environmental Protection Agency of Valle d'Aosta at short distance from the plot VAL 1.

Results and discussion

Data from passive samplers have shown to be significantly correlated with O_3 concentration from continuous measurements in 1996 (r = 0.97, p<0.001, more than 94% of variance explained by a linear model). The correlation is closer than what found in previous projects (Hangartner *et al.* 1996) and may be due on one hand to improvements in indigo paper preparation and on the other hand to the favourable conditions for the use of these samplers in rather dry countries (Werner 2000 *personal communication*). The same comparison performed on data collected in 1999 (no replicate exposition) shows a lower correlation coefficient (r = 0.86, p<0.001, 74% of variance explained by a linear model). Linear regression plots are reported in Figure 1. In 1996 pooled standard deviation (Taylor 1990) of O_3 concentration data at VAL 1 was 0.758 while data among all monitored plots were lower than 1.5 (when 5 replications were exposed), and lower than 5.5 in 19 out of 20 plots in 1997 (3 replications).

The monitoring periods and the weekly maximum concentrations are reported in Table 1, while mean O_3 concentration values over the



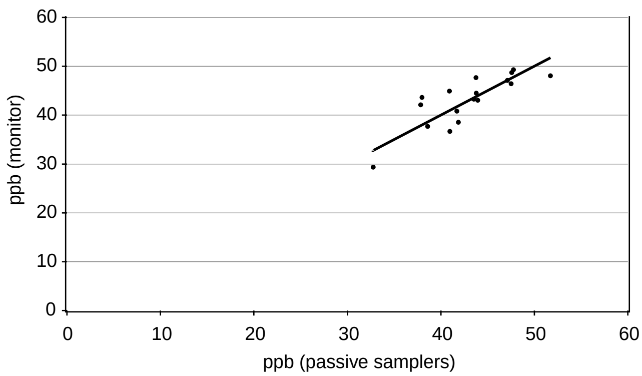


Figure 1 - Comparison of parallel measurements of ozone concentration taken by passive samplers and an automatic monitor in 1996 (left) and 1999 (right).
Confronto di misure di concentrazione di ozono condotte in parallelo mediante campionatori passivi e un analizzatore automatico negli anni 1996 (a sinistra) e 1999 (a destra).

Table 1 - Maximum weekly ozone concentrations (in ppb) recorded by passive samplers at the permanent forest plots (1996 – 1999).
Concentrazioni massime settimanali di ozono (in ppb) rilevate mediante campionatori passivi presso le aree di indagine permanenti(1996 – 1999).

Period	Year	ABR1 ppb	BAS1 ppb	CAL1 ppb	CAM1 ppb	EMI1 ppb	EMI2 ppb	FRI1 ppb	FRI2 ppb	LAZ1 ppb	LOM1 ppb
15/6 - 30/9	1996	48.5	41.7	40.8	49.6	41.5	42.8	40.2	44.2	44.6	-
17/6 - 1/10	1997	49.6	65.7	52.1	83.6	57.0	65.7	42.5	62.9	56.7	49.8
16/6 - 29/9	1998	54.2	42.7	37.2	44.6	46.7	66.0	47.8	43.3	50.0	40.6
4/5 - 28/9	1999	60.0	48.2	48.6	70.7	48.7	57.5	48.9	55.6	51.8	44.5

Period	Year	MAR1 ppb	PIE1 ppb	PUG1 ppb	SAR1 ppb	SIC1 ppb	TOS1 ppb	TRE1 ppb	UMB1 ppb	VAL1 ppb	VEN1 ppb
15/6 - 30/9	1996	46.8	44.6	45.3	43.9	52.9	40.2	43.8	44.0	43.9	42.2
17/6 - 1/10	1997	63.6	49.4	73.0	50.3	87.0	48.1	58.2	55.8	52.8	46.0
16/6 - 29/9	1998	45.3	37.4	57.1	39.5	66.7	43.5	48.1	38.3	62.1	51.7
4/5 - 28/9	1999	64.3	56.2	60.4	58.6	71.7	55.0	56.7	56.9	67.5	50.6

monitoring periods are shown in Figure 2. The highest mean and weekly maximum concentration values were recorded in 1997 and 1999 at forest plots located in Central and Southern Italy confirming indications from modelling approaches reported by Hettenlingh *et al.* (*op. cit.*). The lowest O_3 concentrations values were found in 1996, an year characterised in Italy by an unusually perturbed summer weather.

Figure 3 reports weekly O_3 concentrations recorded by passive samplers during the summer period at 4 forest plots. Patterns among different years may vary substantially due to the influence of climatic conditions and thus a five-year average is recommended for integrated assessment purposes (UBA 1996). The average

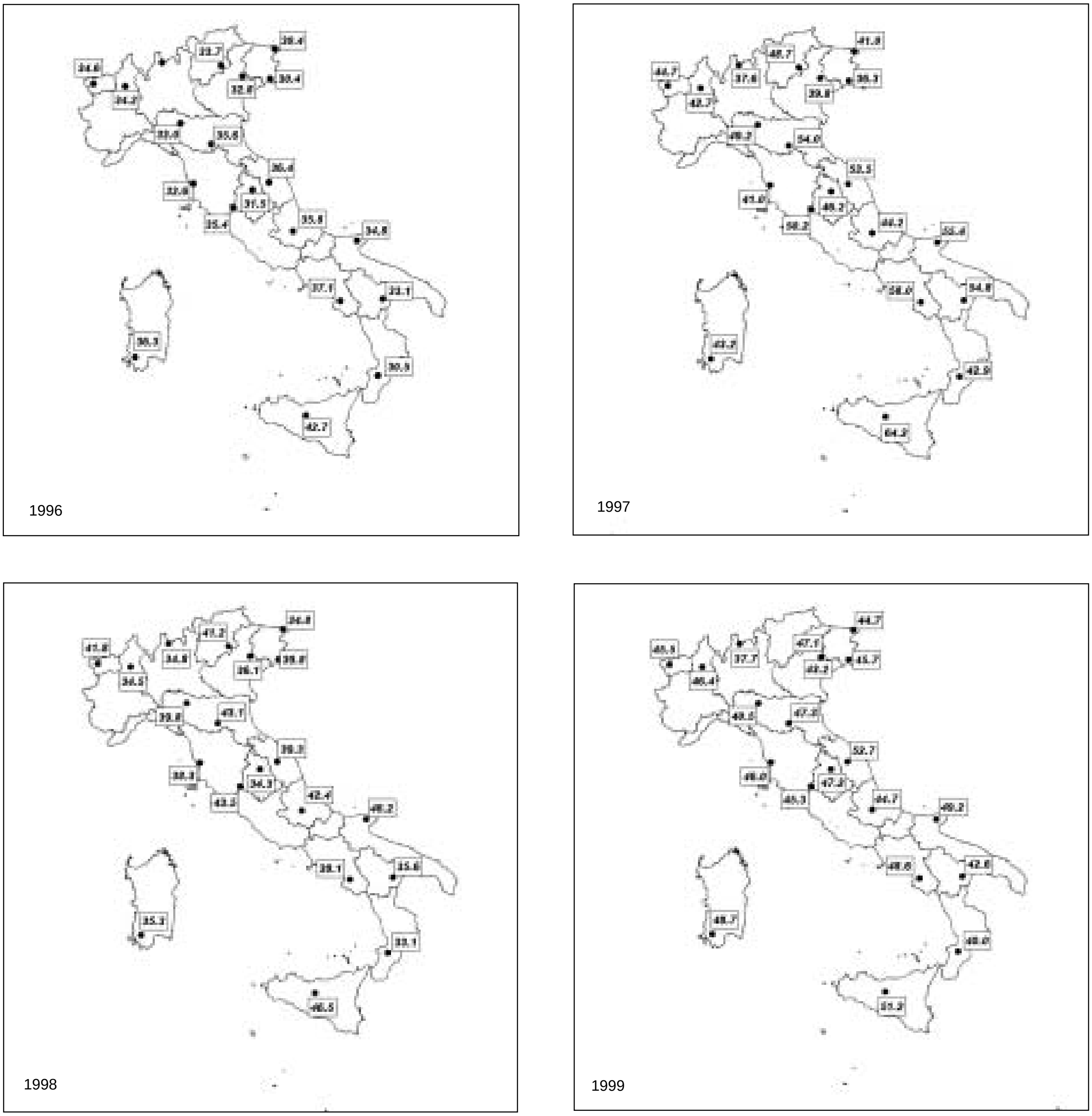


Figure 2 - Mean ozone concentrations (in ppb) recorded by passive samplers in the period 1996 - 1999 at the permanent forest plots.
Concentrazioni medie di ozono (in ppb) rilevate con campionatori passivi nel periodo 1996 - 1999 presso le aree di indagine permanenti.

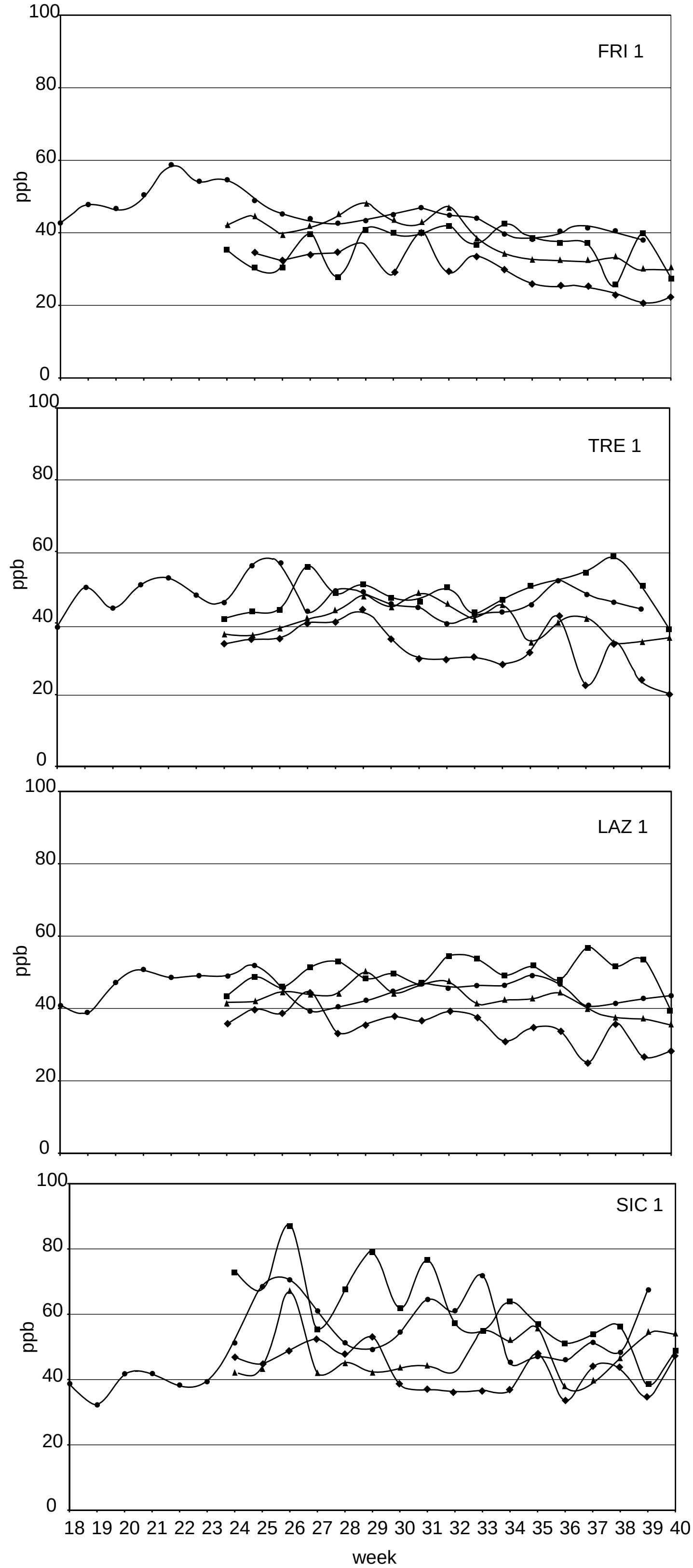


Figure 3 - Ozone weekly mean concentrations at 4 permanent forest plots in 1996 (♦), 1997 (■), 1998 (▲) and 1999 (●).
Concentrazioni medie settimanali presso 4 aree di indagine permanenti nel corso degli anni 1996 (♦), 1997 (■), 1998 (▲) and 1999 (●).

concentrations recorded at the Alpine plots were close to those recorded in previous measurements (BUWAL 1994; ROCCHETTI 1999, WERNER *et al.* 1999).

Data recorded at the forest plot SIC 1 are generally among the highest measured in this study and this is reasonably due to the position of the plot placed downwind of major emission sources of precursors (BISTACCHI *et al.* 1996).

Correlation analysis was performed on concentration data collected at the forest plots located in Northern Italy in order to highlight relationships between data sets collected in the same geographical region (Po Valley). Results of the analysis performed on data from 1997 are shown in Table 2. Data highlight statistically significant relationships among different sites which are placed in some cases at distances up to several hundred kilometres. Comparable figures were observed in the other three years (data not shown).

The presence of relationships between the reported sites, with the exception of FRI 1 which is characterised by a weekly mean NO_2 concentration during the warm season up to 30-40 $\mu g/m^3$) indicates that the climatic factor (high pressure conditions in spring and summer) may be reasonably considered the driving factor which induces the formation of ozone via photochemical processes subsequently transported also to remote areas.

Similar patterns were recorded in other studies based on bioindicator plants carried out at several sites in Northern Italy (MIGNANEGO *et al.* 1992).

The highest correlation value is recorded between the sites of EMI 1 and EMI 2 separated by 60 km. The distance between monitoring sites, however, appears not to be the main factor explaining correlated ozone trends.

The availability of air quality data from continuous measurements allows some more detailed considerations about O_3 presence at the VAL 1 plot. In Table 3 summary data about O_3 concentrations from 1996 to 1999 during the vegetative period (April - September) are

Table 2 - Correlation analysis of mean weekly concentrations measured in 1997 at the permanent forest plots located in Northern Italy.
Analisi di correlazione delle concentrazioni medie settimanali di ozono rilevate nel 1997 presso le aree di indagine dell'Italia settentrionale.

VAL 1	PIE 1	LOM 1	TRE 1	VEN 1	FRI 2	FRI 1	EMI 1	EMI 2	
1	0.436	0.708	0.508*	0.131	0.595	0.589	0.550	0.609	VAL 1
	1	0.860*	0.890*	0.746	0.380	0.470	0.890	0.900**	PIE 1
		1	0.866*	0.821*	0.604	0.426	0.926**	0.941***	LOM 1
			1	0.560*	0.718	0.571	0.890*	0.870*	TRE 1
				1	0.844*	0.803	0.890**	0.889*	VEN 1
					1	0.520	0.695	0.622	FRI 2
						1	0.592	0.629	FRI 1
							1	0.988***	EMI 1
								1	EMI 2

*(P<0.05), **(P<0.01), ***(P<0.001)

reported. Missing values, generally referring to short periods, were calculated by either interpolation (short periods) or considering meteorological parameters influencing ozone levels. AOT40 was calculated on concentration data recorded from 10 a.m. to 5 p.m.. The same index is reported also for two years as sum of O_3 hourly records when global radiation exceeds 50 W/m^2. The two approaches, commonly used to assess ozone doses, underscore relevant differences. As for mean ozone concentration data also AOT40$_f$ data vary from year to year depending from the meteorological conditions during the spring and summer months. AOT40$_f$ was exceeded in 1998 and 1999. The threshold value for the protection of vegetation indicated by the EU Council Directive 92/72 - 65µg/m^3 as 24 h-mean (1ppb O_3 = 1.96µg/m^3 at 20°C and at sea level) was exceeded at VAL 1 plot in all four years with a maximum in 1999 and in 1998. The threshold of 200 µg/m^3 as hourly mean was exceeded only in 1998.

Although no direct relationship can be drawn from mean concentration to dose data it has to be underlined that weekly mean values recorded by passive samplers at several plots are substantially higher than the corresponding data from the VAL 1 plot.

Conclusions

The measurement of O_3 concentration in forest areas of Mediterranean countries is considered a recognised need for the next years. The measurements carried out at 20 plots of the Italian network CON.ECO.FOR. over 4 years using passive samplers highlight relevant weekly mean concentrations (up to 87 ppb) at several sites, especially in Central and Southern Italy. Passive samplers have shown to be sufficiently precise and simple to use and may contribute to define a first picture of ozone pollution at remote sites.

The availability of air chemistry data for the forest plot VAL 1 allowed to highlight exceedences of AOT40$_f$ and of other thresholds for the protection of vegetation. The presence of risks for forest species from ozone pollution should lead to further investigations.

Table 3 - Indexes of ozone concentration at the permanent forest plot VAL 1. AOT40 is calculated on ozone hourly means (h 10 - 17). (1) AOT40 is calculated from ozone concentration data when global radiation is greater that 50 W/m^2.
Indici di concentrazione di ozono presso l'area VAL 1. AOT 40 è calcolata sui dati di ozono medi orari (h 10 - 17). (1) AOT40 è calcolata sulle misure di concentrazione di ozono delle ore in cui la radiazione globale è maggiore 50 W/m^2

Year	Mean ppb	AOT40 ppb*h	Mean daily maxima ppb	Hours with mean concentration >100 ppb n. hours	Days with mean concentration > 32.5 ppb n. days	Ozone valid data %
1996	32.3	3.464	55.6	0	79	85.5
1997	31.7	3.692	42.7	0	91	97.4
1998	46	17.603 (27.757[1])	55.4	20	166	99.9
1999	45.7	13.730 (19.359[1])	53.6	0	168	92.0

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References

ALLAVENA S., ISOPI R., PETRICCIONE B., POMPEI E. (eds) 1999 - *Programma Nazionale Integrato per il Controllo degli Ecosistemi Forestali*, Ministero per le Politiche Agricole, Roma, 167 p.

BISTACCHI S., BOCCHIOLA G., BRASASCA G., COMI W., FOSSA W., MARCACCI P., MARZORATI A., MORSELLI M.G., PELLEGRINI U., 1996. - *Caratterizzazione meteorologica dell'area della città di Palermo*. Relazione ENEL-CRAM 19960106, 35 p.

BROWN R. H., WRIGHT M.D., 1994. - *Diffusive sampling using tube-type samplers.* Analyst 119: 75-77.

BULL, K.R., 1991. - *The critical load/level concept approach to gaseous pollutant emission control.* Environ. Pollut. 69: 105-123.

BUWAL, 1994. - *NABEL - Luftbelastung 1994*. Bundesamt fur Umwelt, Wald und Landschaft. Schriftenreihe Umwelt n. 244, 93 p.

CRUTZEN P.J., 1995. - *Ozone in the troposphere.* In: H.B. Singh (Ed.): Composition Chemistry, and Climate in the Atmosphere. Van Nostrand Reinol Publ. New York, pp. 349-393.

HANGARTNER M., 1996. - *Diffusive sampling as an alternative approach for developing countries.* Paper presented at the World Congress on Air Pollution in Developing Countries, Costa Rica, 1996.

HANGARTNER M., KIRCHNER M.,, WERNER H., 1996. - *Evaluation of passive methods for measuring ozone in the Eurpean Alps.* Analyst 121: 1269-1272.

HARPER M., PURNELL C.J., 1987. - *Diffusive sampling – A Review.* Am. Ind. Hyg. Assoc. J. 48(3): 214-218.

HETTENLIGH J.-P., POSCH M., DE SMET P.A.M., 1997. - *Analysis of European Maps.* In: POSCH M., HETTENLIGH J.-P., DE SMET P.A.M., DOWNING R.J. (eds). - *Calculation and Mapping of Critical Threshold in Europe. Status Report 1997.* National Istitute of Public Health and the Environment, Rep. 259101007, Bilthoven, Netherlands, 163 p.: 3-18.

KIRGHER M., KAMMERLOHR R., KOHMANNS B., REDISKE G., SCHODL M., WELZL G., 1994. - *Erfassung der Immissionsbelastung im Alpenraum mit Passivsammlern*. Bayerisches Staatsministerium fur Landesentwicklung und Umweltfragen. Materialien 116, 169 p.

MIGNANEGO L., BIONDI F., SCHENONE G., 1992. - *Ozone Biomonitoring in Northern Italy*. Environ. Mon. Assess. 21: 141-159.

MONN C., FIEBIGER A., WANNER H-U., 1990. - *Measurements of ozone and nitrogen dioxide at different altitudes at Eggbergen (Swiss Alps) with passive sampling devices and continuous monitors.* Environ. Technol. 11: 867-876.

PORG, 1997. - *Ozone in the United Kingdom.* - Department of the Environment. Fourth Report, HMSO, London, 234 p.

ROCCHETTI F., 1999. - *Caratterizzazione meteorologica e della qualità dell'aria del sito Alpe Albero (Monte Mottarone).* Relazione ENEL/AMB RF-99-0032, 122 p.

SKARBY L., 1993. - *Critical levels for ozone to protect forest trees.* In: FUHRER J., ACHERMANN B. (eds). *Critical levels for ozone* a UN ECE workshop report. Swiss Federal Station for Agricultural Chemistry and Environmental Hygiene, Liebefeld-Bern, Switzerland, 328 p.: 74-87.

STATGRAPHICS PLUS, 1998. - Manugistics Inc., Rockville, Maryland, USA.

TAYLOR J.K., 1990. - *Statistical Techniques for Data Analysis.* Lewis Publ. Inc., Chelsea, 200 p.

WERNER H., 1992. - *Das Indigopapier. Sensitives Element zum Aufbau von Passivsammlern zur Messung von Ozonimmissionen.* Forstl. Forschungsberichte, Munchen. Schriftenreihe der forstwissenschatlichen Fakultat der Universitat Munchen und der Bayer. Forstlichen Versuchs- und Forschungsanstalt n. 122, 145 p.

WERNER H., KIRCHNER M., WELZL G., HANGARTNER M., 1999. - *Ozone measurements along vertical transects in the Alps.* Environ. Sci & Pollut. Res. 6(2): 83-87.

UBA, 1996. - *Manual on Methodologies and Criteria for Mapping Critical Levels/Loads and geographical areas where they are exceeded.* UN/ECE Convention LRTAP, Federal Environmental Agency , Texte 71/96, Berlin, 96 p.

Calculation of meteorological stress indices for Italian forest ecosystems[§]

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Abstract - Environmental stress is a daily fact of life that plants must be able to cope with to survive. Much of the wide variation in plant morphology, physiology and developmental biology is a reflection of nature's capacity to adapt to climatic changes. Temperature and water give rise to two of the major abiotic stress factors, and they are the principal factors that characterise both the climate and plants distribution. The tolerance of plants to temperature extremes is not static. The ability to adjust in response to a change in temperature is common in plants, and includes both higher and lower values relative by to the optimum temperature. Besides, the availability of liquid water depends not only on the amount of water present, but also on temperature. In this work temperature and water stresses for 14 stations (Open Field and In the Plot) in 9 areas have been analysed through some simple indices. Temperature stresses are based on threshold values related to the photosynthesis trend; water stress is based on Thornthwaite model.

Keywords: *temperature stress, drought stress.*

Riassunto – Calcolo di indici meteorologici di stress in ecosistemi forestali italiani. Per sopravvivere le piante devono affrontare quotidianamente gli stress derivanti da avverse condizioni ambientali. La maggior parte delle modificazioni nella morfologia, fisiologia e sviluppo riflette la capacità delle piante di adattarsi ai cambiamenti climatici. I principali fattori di stress abiotici dipendono dalla temperatura e dalla disponibilità di acqua; questi ultimi infatti caratterizzano il clima e la distribuzione delle piante. La tolleranza delle piante agli estremi di temperatura non è statica: spesso gli alberi devono acclimatarsi ai repentini sbalzi termici (alti e bassi) rispetto alla temperatura ottimale. Inoltre la temperatura influenza anche la disponibilità idrica. In questo lavoro sono stati analizzati gli stress termici ed idrici relativi a 14 centraline (in ampia radura e all'interno della vegetazione) di 9 aree permanenti attraverso alcuni semplici indici, i primi basati su valori di soglia legati all'attività fotosintetica, i secondi basati sul modello di Thornthwaite.

Parole chiave: *stress termici, siccità.*

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It is generally accepted that changes in the forest conditions are not related to one single factor, but rather to a mixture of causes, which can alter life cycle of trees. These causes include the particular climatic and geomorphological conditions of the examined areas and the availability of soil resources. Indeed plants adjust their structure to meteorological changes when unfavourable events (such as high or low temperatures, drought, storms, snow, frost, *etc.*) occur. However, in many cases that is not enough, so that trees loose their foliage or show discoloration of needles and leaves resulting in a decreased vitality of the forest trees.

Plants growing in natural environments may encounter various stresses, such as high radiation stress, water stress, high and low temperature stresses, during part of their growth and development. The term stress is defined as an environmental change that inhibit the normal functioning of the cycle systems. Plant species or varieties differ in their optimal environments and their susceptibility to a particular stress. Stress may also have a greater damaging effect during specific phases of the plants life cycle. In order to predict the impact of stress on plants, information on 1) the temporal variation in stress, 2) the plant's potential to acclimatise to stress, 3) the interaction between different stresses and the plant responses, is needed. The environment is seldom optimal for plant growth.

The action of physiological stresses on plants has been the subject of numerous studies. Plants are able to survive and grow even under unfavourable environmental conditions. Each species has its own optimal temperature, and its lower and higher temperature limits. When exposed to changing temperatures, various structural modifications are known to take place at molecular level. Such modifications include changes in the rate of metabolic reactions as well as modifications of subcellular structures.

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Table 1 - Geographical characteristics for 14 stations in 9 areas.
Caratteristiche geografiche di 14 centraline in 9 aree.

Station	Latitude N	Longitude E	Altitude m	Exposure	Slope %
01-ABR1 OF	41° 50' 51''	13° 35' 23''	1560	O	10
01-ABR1 IP	41° 50' 51''	13° 35' 23''	1500	S	0
05-EMI1 OF	44° 43' 05''	10° 12' 13''	200	-	0
05-EMI1 IP	44° 43' 06''	10° 12' 13''	200	S	3
06-EMI2 OF	44° 07' 03''	11° 07' 00''	860	SO	0
06-EMI2 IP	44° 06' 24''	11° 07' 00''	975	O	45
08-FRI2 OF	46° 29' 28''	13° 35' 36''	850	N	0
08-FRI2 IP	46° 29' 28''	13° 35' 36''	820	N	-
09-LAZ1 OF	42° 49' 39''	11° 53' 51''	675	S	20
09-LAZ1 IP	42° 49' 50''	11° 54' 10''	690	NO	1
10-LOM1 OF	46° 14' 14''	09° 33' 16''	1188	E/NE	10
16-TOS1 OF	43° 30' 34''	10° 26' 19''	150	NE	16
17-TRE1 IP	46° 21' 37''	11° 29' 42''	1775	NE	25
19-VAL1 OF	45° 43' 50''	06° 55' 37''	1660	S	10

Table 2 - Measured parameters.
Parametri misurati.

Area	Measured parameters							
	AT	ST	RH	PR	SR	WS	WD	SD
01-ABR1 OF	x	x	x	x	x	x	x	x
01-ABR1 IP	x	x	x	x				x
05-EMI1 OF	x	x	x	x	x	x	x	x
05-EMI1 IP	x	x	x	x				x
06-EMI2 OF	x	x	x	x	x	x	x	x
06-EMI2 IP	x	x	x	x				x
08-FRI2 OF	x	x	x	x	x	x	x	x
08-FRI2 IP	x	x	x	x				x
09-LAZ1 OF	x	x	x	x	x	x	x	x
09-LAZ1 IP	x	x	x	x				x
10-LOM1 OF	x		x	x	x	x	x	
16-TOS1 OF	x		x	x	x	x		
17-TRE1 IP	x		x	x	x			
19-VAL1 OF	x	x	x	x	x	x	x	

AT= air temperature, ST= soil temperature, RH= relative humidity, PR= precipitation, SR= solar radiation, WS= wind speed, WD= wind direction, SD= snow depth

Water is among the most limiting factors for plant productivity and growth rates are proportional to water availability. Because of its essential role in plant metabolism, at both cellular and whole-plant level, any decrease in water availability has an immediate effect on plant growth, and processes ranging from photosynthesis to solute transport and accumulation are seriously affected. Plants are generally subject to shortage in water availability varying from hours to days. Water lost by transpiration causes temporary water deficits even in plants growing in wet places, so that most plants suffer at least regular and daily water shortages. However, plants have evolved physiological responses as well as ecological strategies to cope with water shortages by either stress avoidance or stress tolerance. These responses allow them to survive and even to maintain some growth under very harsh circumstances.

The aim of this work is to describe the characterisation of meteorological stresses of the trees over the past 5 years. In particular, temperature and drought stresses have been analysed through some simple indices.

Materials and Methods

We have considered climatic data related to 9 areas. Table 1 shows geographical characteristics of the areas. Due to problems with data consistency and quality or missing data, stress indices could not be calculated for some of these areas. These problems will probably be overcome in the near future, so that all the data provided by 22 stations of 14 areas in Italy will be analysed. Some areas have two stations, one *In the Plot* (*IP*, under the canopy) and one *Open Field* (*OF*), in close proximity (generally at no more than 2 km) from the monitoring plot. The *OF* stations are in accordance to the World Meteorological Organisation Standards (W.M.O. 1969).

As some of the stations are not standard, Table 2 shows how many parameters have been submitted for each plot.

Temperature stress indices

Climate effects on vegetation can be evaluated using four indices related to temperature stress (KLAP *et al.* 1997, CALLEART *et al.* 1997):

1. *Winter index* I_W: is the sum of daily mean temperatures below 0 °C in the period from 1st of October to the 1st of April (degree days below 0 °C).
2. *Late Frost index* I_{LF}: is the lowest minimum temperature (below 0 °C) in a period starting 15 days before the beginning of the growing season and ending at June 30.
   This index was calculated according to UE Report (EC-UN/ECE 1997).
   Instead of air temperature, it would be better to refer to tissue temperature, which is higher than air temperature; so the absolute values of Late Frost index will be lower. Unfortunately tissue temperature is not measured.
3. *Heat index* I_H: is the sum of the differences between daily maximum temperatures in

Table 3 - Start of the growing and dormant season per tree species for 9 areas, estimated by phenological observation.
Inizio della stagione di crescita e di dormienza per le specie arboree in 9 aree, stimate mediante osservazioni fenologiche.

Area	Starting date growing season	Starting date dormant season	Tree specie
01-ABR1	April 20	October 10	*Fagus sylvatica*
05-EMI1	April 1	November 1	*Quercus petraea*
06-EMI2	April 20	October 10	*Fagus sylvatica*
08-FRI2	April 16	October 16	*Picea abies*
09-LAZ1	April 1	October 1	*Quercus cerris*
10-LOM1	April 16	October 1	*Picea abies*
16-TOS1	April 16	October 16	*Quercus ilex*
17-TRE1	June 10	October 1	*Picea abies*
19-VAL1	May 1	October 16	*Picea abies*

the growing season and a threshold value of 35 °C (degree days above 35 °C).

4. *Summer index* I_S: is the sum of the differences between daily mean temperatures during the growing season and a threshold value of 5 °C (degree days above 5 °C).

The thresholds of 5 °C and 35 °C are related to the photosynthesis trend; however these values are rather arbitrary, since no information on such values was found in literature. The dates of start and end of the growing season, used to calculate these indices, depend on geography and tree species living in the areas.

We estimated the start of the growing and dormant season per tree species for the areas using phenological observations (Table 3) and not the table of UE Report for climatic areas (EC-UN/ECE 1997).

Drought stress indices

With respect to the drought stress, the relative transpiration, calculated as the ratio between the actual transpiration and the potential transpiration (ETR/ETP), may be a suitable stress factor. Unfortunately, we do not measure the actual transpiration and we can estimate potential evapotranspiration only with an empirical relationship that requires less data input with respect to the deterministic formula of Penman-Montheith. This empirical formula is the well-known Thornthwaite equation (Thornthwaite 1948):

$$EPT_m = 16 \cdot (10 \cdot T_m / I)^a F$$

where I = annual heat index

$$I = \sum_m (T_m/5)^{1.514}$$

with T_m = mean monthly temperature (°C)

$$a = 675 \cdot 10^{-9} \cdot I^3 - 771 \cdot 10^{-7} \cdot I^2 + 1792 \cdot 10^{-5} \cdot I + 0.49239$$

and F = Thornthwaite correction factor depending on month and latitude.

The use of the difference between precipitation and potential evapotranspiration can be proposed as a simple indicator of drought stress, but not as a measure of water balance of the forest. As problems of drought stress are most likely to appear over summertime, the (P-ETP) index on a monthly basis can be applied. If the precipitation is lower than the potential evapotranspiration, it can be assumed that transpiration will be reduced, as not all the amount of needed water is available to the plants.

This analytical index is too rough; so we adopted the index RE_T (relative evapotranspiration):

$$RE_T = 100 \cdot \sum_m ETR_m / \sum_m ETP_m$$

where ETR_m = actual monthly evapotranspiration. ETR_m has been defined by the following approximation:

$$ETR_m = \begin{cases} ETP_m & \text{if} \quad ETP_m < P_m \\ P_m & \text{if} \quad ETP_m > P_m \end{cases}$$

This index is a simple indicator of drought stress, although, in this way, soil water reserve is not considered. It represents the maximum limit of possible water deficit.

Results and Discussion

Temperature stress indices

The variation in temperature indices, calculated for 9 areas in the considered 5 years pe-

Table 4 - Temperature stress indices for 14 stations on 9 areas.
Indici di stress termici per 14 centraline in 9 aree permanenti.

Station	Year	I_W	I_{LF}	I_S	I_H
01-ABR1 OF	1998	-	-5,4	1247	0,0
	1999	-303,3	-	1240	0,0
01-ABR1 IP	1998	-147,1	-	1171	0,0
	1999	-200,5	-	1196	0,0
05-EMI1 OF	1998	-	-2,2	2728	0,0
	1999	-27,3	0,0	2743	0,0
05-EMI1 IP	1998	-	-2,1	2670	0,0
	1999	-27,3	-1,4	2664	0,0
06-EMI2 OF	1999	-116,7	-0,1	1790	0,0
06-EMI2 IP	1999	-94,5	0,0	1723	0,0
08-FRI2 OF	1999	-329,2	-2,1	1482	0,0
08-FRI2 IP	1999	-373,9	-2,3	1394	0,0
09-LAZ1 OF	1998	-3,6	-3,5	2266	11,9
	1999	-47,7	-2,5	2229	0,0
09-LAZ1 IP	1998	-5,0	-3,9	2096	0,0
	1999	-51,7	-2,6	2101	0,0
10-LOM1 OF	1997	-	-4,4	1340	0,0
	1998	-148,0	-	-	-
	1999	-260,3	-2,1	1424	0,0
16-TOS1 OF	1996	0,0	0,0	3252	0,0
	1997	-14,0	-0,3	2373	0,0
	1998	-	-	-	-
	1999	-3,4	0,0	2589	0,0
17-TRE1 IP	1999	-719,0	-1,9	548	0,0
19-VAL1 OF	1995	-	-3,6	933	0,0
	1996	-431,5	-2,0	953	0,0
	1997	-296,6	-7,2	1081	0,0
	1998	-258,1	-5,1	1067	0,0
	1999	-407,6	-7,1	1052	0,0

I_W= Winter index, I_{LF}= Late Frost index, I_S= Summer index, I_H= Heat index

riod, is given in Table 4. The indices referred to *Open Field* data concern stresses suffered by canopy, whereas *In the Plot* data are referred to ground vegetation, the two microclimates being different.

Winter index is an indication of severeness of the winter. Low temperatures can cause damage in cases of severe or lasting winter frost through freezing or dehydration of needles and buds by which they can be damaged or die off. In general the winter of 1999 is stronger than the winter of the years before. During the observation period at VAL1 the winter 1996 and at TOS1 the winter 1997 have been colder than the winter 1999. We believe that this index on its own is not sufficient to study the effects of winter severeness, but we have to join information about the number of days during which mean temperatures were below 0 °C, duration and strength of the phenomenon.

For example, during 1999, the distribution of temperatures below 0 °C was as follows:

- Temperatures between 0 and –13.6 °C for 85 days at ABR1 *OF* and for 78 days *IP*;
- Temperatures between 0 and –3.3 °C for 19 days at EMI1 *OF* and *IP*;
- Temperatures between 0 and –6.9 °C for 39 days at EMI2 *OF* and for 35 days *IP*;
- Temperatures between 0 and –10.6 °C for 91 days at FRI2 *OF* and for 107 days *IP*;
- Temperatures between 0 and –6.7 °C for 21 days at LAZ1 *OF* and *IP*;
- Temperatures between 0 and –9.6 °C for 84 days at LOM1 *(OF);*
- Temperatures between 0 and –1.6 °C for 3 days at TOS1 *(OF);*
- Temperatures between 0 and –16.2 °C for 125 days at TRE1 *(IP);*
- Temperatures between 0 and –13.2 °C for 95 days at VAL1 *(OF)*.

The results show that in some areas, especially in Northern Italy, temperature was below 0 °C for a long time. This phenomenon could have damaged trees, but we can only theorise this because we have no information about checks *in situ*.

Late frost index is an indication of severeness of late frost in spring, that can cause serious damage to trees when growth has just started and the buds and young shoots are very sensitive to frost, which reduces growth and affects unfavourably tree architecture. The values range from 0 °C to –7.2 °C of VAL1 in 1997. We believe that the observed minimum temperatures did not damage trees; phenological studies should indicate if plants tolerate these changes of temperature.

Heat index is an indication of the possible occurrence of damage by high temperatures. A heat shock is induced when a plant is exposed near to its higher temperature limit for growth. Of course, even a relatively weak temperature variation can alter the normal cellular biochemical processes. However, an increase of 10-15 °C above normal growth temperature will cause a deep modification of growth without being necessarily lethal. Heat stress results in a progressive decline of photosynthetic activity in terms of electron transport and CO_2 fixation. In general, the photosynthetic activity remains stable up to 30 °C but rapidly decreases above this temperature to reach a complete inhibition at about 40 °C (Berry *et al.* 1980). For all years and areas taken into account in the present analysis, summer temperatures have been below 35 °C, except LAZ1 *OF* in 1998. Although in this area the magnitude and duration of heat stress exceeded fixed threshold, we can only suppose that cells have been damaged.

Summer index is an indication of the quality of growing season, and affects the photosynthetic activity and the possibility of the trees to produce reserve assimilates for purposes of defence and growth at the beginning of the next season. The values varied from 548 °C of TRE1 *IP* in 1999 to 3252 °C of TOS1 *OF* in 1996. Summer 1998 and 1999 are very similar at all sites, but there are great differences among areas. 1995 and 1996 summers were colder at VAL1, whereas 1996 was much warmer at TOS1

Table 5 - Drought stress indices, calculated on whole year, for 13 stations in 8 areas.
Indici di stress idrico, calcolati per l'intero anno, per 13 centraline in 8 aree.

Station	Year	P mm	ETP mm	ETR mm	P- ETP mm	RE_T %
01-ABR1 OF	1998	744,6	501,7	274,8	242,9	55
	1999	846,6	518,3	298,6	328,3	58
01-ABR1 IP	1998	835,9	497,9	248,7	338,0	50
	1999	801,0	510,0	313,3	291,0	61
05-EMI1 OF	1998	613,0	736,2	362,9	-123,2	49
	1999	917,6	746,5	449,2	171,1	60
05-EMI1 IP	1998	548,2	729,9	353,0	-181,7	48
	1999	730,8	720,6	382,1	10,2	53
06-EMI2 OF	1999	1262,4	616,5	418,6	646,4	68
06-EMI2 IP	1999	1360,6	615,7	421,8	744,9	68
08-FRI2 OF	1999	1370,8	553,7	553,7	817,1	100
08-FRI2 IP	1999	1178,8	543,0	509,3	635,8	94
09-LAZ1 OF	1998	888,8	688,4	396,5	200,4	58
	1999	1023,6	677,9	417,5	345,7	62
09-LAZ1 IP	1998	786,0	664,8	388,0	121,2	58
	1999	747,0	664,5	361,3	82,5	54
16-TOS1 OF	1996	1087,0	720,5	420,3	366,5	58
	1997	615,0	748,4	407,9	-133,4	55
	1998	647,0	759,9	339,4	-112,9	45
	1999	943,5	757,4	421,4	186,1	56
17-TRE1 IP	1999	626,8	436,4	420,6	190,4	96
19-VAL1 OF	1995	1023,2	488,4	314,8	534,8	64
	1996	707,2	476,8	328,2	230,4	69
	1997	699,0	509,1	350,1	189,9	69
	1998	649,2	500,5	343,4	148,7	69
	1999	924,8	485,4	437,6	439,4	90

P= precipitation, ETP= potential monthly evapotranspiration,
ETR= actual monthly evapotranspiration, P- ETP= difference between P and ETP,
RE_T= relative evapotranspiration.

Drought stress indices

Table 5 shows drought stress indices, calculated on whole year, for 8 areas (precipitation data of LOM1 are not reliable) over the last monitoring years. The values of the (P-ETP) index are always positive, except EMI1 in 1998 and TOS1 in 1997 and in 1998. These results confirm our previous considerations about the roughness of this index. Its analysis on a reduced basis (*e.g.* monthly) may improve its sensitivity but we could not express it with a single value.

The second index about relative evapotranspiration is fairly accurate to differentiate areas among them and years in the same area. Table 5 shows that the highest values occurred in 1999. The risk is therefore practically absent, especially for Alpine areas which present values higher than 90 %. Higher risks were present for TOS1 and EMI1 in 1998, with values lower than 50 %.

Table 6 shows drought stress indices, calculated on growing season, for 8 areas over the last years of monitoring. The values of the (P-ETP) index are always negative, except TRE1 e FRI2 in all years and VAL1 in 1995 and in 1999. These values confirm that Italian pluviometrical trend is characterised by deficit in precipitations during growing season.

The relative evapotranspiration values are lower than values on Table 5 for all areas, especially for TOS1 and LAZ1. Only Alpine areas and EMI2 present values above 60 %. Higher risks were presented for TOS1 with values between 32 % in 1998 and 49% in 1996.

Conclusions

The quality of the calculated temperature stress indices depends mainly on threshold values (0 °C for winter index, 5 °C for summer index, 35 °C for heat index). All relationships between these threshold values and tree properties are quite known. For instance, no difference was made between tree species.

Table 6 - Drought stress indices, calculated on growing season, for 13 stations in 8 areas.
Indici di stress idrico, calcolati per la stagione di crescita, per 13 centraline in 8 aree.

Station	Year	P mm	ETP mm	ETR mm	P- ETP mm	RE_T %
01-ABR1 OF	1998	386,4	490,9	224,1	-64,6	50
	1999	271,4	457,1	237,4	-185,7	52
01-ABR1 IP	1998	349,9	448,3	199,1	-98,4	44
	1999	284,0	447,8	251,1	-163,8	56
05-EMI1 OF	1998	466,8	672,5	305,5	-205,7	45
	1999	582,0	689,0	391,7	-107,0	57
05-EMI1 IP	1998	420,4	660,6	293,6	-240,2	44
	1999	448,8	660,1	329,3	-211,3	50
06-EMI2 OF	1999	369,2	525,4	328,2	-156,0	62
06-EMI2 IP	1999	362,8	511,9	317,9	-149,0	62
08-FRI2 OF	1999	929,8	500,0	500,0	429,8	100
08-FRI2 IP	1999	749,2	490,3	456,6	258,9	93
09-LAZ1 OF	1998	372,8	569,5	277,6	-196,7	49
	1999	393,4	561,1	269,3	-208,6	54
09-LAZ1 IP	1998	337,6	546,2	300,7	-167,7	49
	1999	281,8	546,3	243,1	-264,5	44
16-TOS1 OF	1996	492,0	570,0	278,1	-78,0	49
	1997	273,0	586,9	256,3	-313,9	44
	1998	249,5	614,6	194,1	-365,1	32
	1999	350,0	609,3	273,3	-259,3	45
17-TRE1 IP	1999	438,0	359,9	344,1	78,1	96
19-VAL1 OF	1995	418,6	396,4	241,7	22,2	61
	1996	260,4	398,0	256,9	-137,6	65
	1997	374,2	410,9	281,8	-36,7	69
	1998	320,8	426,0	268,8	-105,2	63
	1999	543,2	424,1	376,4	119,1	89

P= precipitation, ETP= potential monthly evapotranspiration,
ET_R= actual monthly evapotranspiration, P- ETP= difference between P and ETP,
RE_T= relative evapotranspiration.

The quality of the calculated drought stress indices depends on the quality of chosen indicators, the results from the calculations have a considerable uncertainty. The advantage of the RE_T index is that it can be computed without any modelling of soil water balances; the disadvantage is that it does not take into account water storage in soil or capillarity.

The quality of the calculated drought stress indices depends also on the estimate of potential evapotranspiration. Thornthwaite formula generally undervalues this parameter, but this is the only internationally acknowledged formula based on climatological parameters usually measured (as air temperature). We could not use other formulas (such as Penman-Montheith, probably more careful), because these require climatological parameters not measured or not internationally accepted formulas. Anyway the approximations would be considerable, because it is impossible to carry out soil water balances.

Theoretically it would be better to determine risk of drought stress using calculations based on the only period of growing season, rather than yearly calculations. However, for both cases, threshold values of risk would be estimated through checks *in situ* about possible damage suffered by plants, but these checks actually are not available.

References

BERRY J., BJORKMANN O., 1980 - *Photosynthetic response and adaptation to temperature in higher plant.* Ann. Rev. Plant Physiol. (31): 491-543.

CALLEART G., VAN RANST E., SCHEIRLINCK H., LUST N., 1997 - *Klimatologische vereisten en risicobepaling voor klimaatsextremen van de voornaamste Europese boomsorten (in dutch).* Universditeit Gent en Ministerie van de Vlaamse gemeenschap, 129 p.

EC-UN/ECE, 1997 - *Ten Years of Monitoring Forest Condition in Europe - Technical Background Report.* Brussels, Geneva, 227 p.

KLAP J. M., DE VRIES W., ERISMAN J. W., VAN LEEUWEEN E. P., 1997 - *Relationship between forest condition and natural and anthropogenic stress factors on the European scale; pilot study.* Wageningen, the Netherlands, DLO Winand Staring Centre for Integrated Land, Soil and Water Research, Report 150.

THORNTHWAITE, C.W., 1948 - *An approach toward a rational classification of climate.* Geographical Review 38(1): 55-94.

W.M.O., 1969. *Guide to meteorological instrument and observing practices.* No. 8 TP. 3.

Definition of risk, status and changes in the Permanent Monitoring Plots in Italy – A preliminary attempt§

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Abstract - The data collected at the Permanent Monitoring Plots (PMPs) of the CONECOFOR program were subjected to a first evaluation which can be considered as a preliminary attempt at providing a concrete example of the Integrated and Combined (I&C) evaluation system. In this context, the potential for co-occurrence of sensitive soil conditions and high deposition of acidifying compounds and nitrogen was examined. Similarly, ozone levels and indices of drought stress were considered. Tree condition, ground vegetation and ozone data collected at beech PMPs were jointly examined to show how the Status and Change (S&C) analysis could work. Results show that there is the potential for exceedance of critical loads for nutrient nitrogen in most of the examined forest ecosystems. Ozone values were rather high as mean weekly values; however, there is evidence that the uptake of ozone may be affected by different meteorological conditions in different years. The status and changes of 5 beech plots were found to fluctuate around a mean, with two PMPs (namely ABR1 and EMI2) being "far" from the mean distance in 1999.

Key words: *atmospheric deposition, ozone, risk analysis, status and changes.*

Riassunto – Definizione di rischio, stato e cambiamenti nelle aree permanenti di monitoraggio in Italia – un esempio. I dati raccolti sulle aree permanenti del programma CONECOFOR sono stati oggetto di una prima valutazione da considerare come dimostrazione pratica di come il sistema di valutazione integrata e combinata (I&C) può funzionare. Con queste premesse, è stata valutata la potenziale associazione tra condizioni di sensibilità del suolo ed elevati input azotati ed acidificanti. Similmente, sono stati considerati l'evenienza di elevati livelli di ozono e di indici di siccità. Lo stato degli alberi, la vegetazione erbacea ed i livelli di ozono sono stati usati per mostrare un esempio di funzionamento dell'analisi di stato e cambiamenti. I risultati evidenziano un potenziale superamento dei limiti di carico critico per l'azoto nutriente per molti degli ecosistemi esaminati. I livelli di ozono sono risultati alti come valori medi settimanali; tuttavia ci sono evidenze che l'assorbimento di ozono può essere influenzato dall'evenienza di differenti condizioni meteorologiche ai diversi anni. Lo stato ed i cambiamenti in 5 aree a prevalenza di faggio si sono dimostrati fluttuanti attorno ad una media, con tuttavia 2 aree permanenti (ABR1 ed EMI2) "lontane" dallo stato medio nel 1999.

Parole chiave: *deposizioni atmosferiche, ozono, analisi di rischio, stato e cambiamenti.*

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Forest ecosystems are subjected to a variety of biotic and abiotic stressors which may affect different ecosystem compartments at different times and with different intensity. Effects can concern individual species (as in the case of some diseases – Manion and Lachance 1992; Skelly and Innes 1994), as well as more complex processes like the biogeochemistry of the whole ecosystem (as in the case of long-term deposition of pollutants – Rasmussen *et al.* 1992). Effects need to be identified in terms of the chance or probability that they might occur; they also need to be described in terms of their connection with the stressor of concern, quantified and monitored for their spatial and temporal allocation. All these steps are fundamental when a feedback (*e.g.* air pollution abatement strategies) on the causes is the ultimate goal of the monitoring. The three analyses suggested within the Integrated and Combined (I&C) evaluation system aim to address the above needs (Ferretti *et al.* this volume). In this paper we will try to show how the I&C system could work providing some examples related to Risk Analysis (RA) and Status and Change (S&C) analysis. The Nature of Change (NoC) analysis cannot even be attempted as it needs a much longer time series than the one currently available. Up to date, the availability of the data is a major problem also for the other RA and S&C analyses. Therefore, it goes beyond the scope of this paper to investigate exhaustively all the possible major stressors of the forest ecosystems monitored by the CONECOFOR program or to provide a robust estimation of status and changes. As reported several times in the methodological section of this volume, the data available to date do not allow any in-depth analysis. Rather, here we want to report some first results obtained by combining data from different investigations to show the potential effects of a few stressor categories among those measured at the Italian Permanent Monitoring Plots (*PMPs*). In addition, there will be some first attempts to demonstrate the value of the S&C analysis.

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Methods

Risk analysis

Acidic and nitrogen inputs

As discussed by Ferretti *et al.* (this volume), given the available data, only indirect, soil-mediated effects of acidic and nitrogen deposition can be evaluated. Acidic and nitrogen deposition can lead to various consequences that are not fully understood yet (Rennenberg and Gessler 1999; Emmet 1999): changes in soil chemistry, onset of soil acidification and eutrophication with potential effects on N retention up to nitrate leaching through the soil water may occur (*e.g.* Emmet 1999). Changed soil condition may affect soil biota, the ground vegetation composition, the nutritional balance of the trees and the water quality (*e.g.* Bredemeier *et al.* 1995; Thimonier *et al.* 1992 and 1994; Gundersen and Lutz 2000). Imbalanced tree nutrition may ultimately result in symptoms at foliage/crown level, increased sensitivity to pests and diseases and changes in growth and yield (*e.g.* Schulze 1989; Flückiger and Braun 1999). However, this chain of effects is likely to occur when acidifying and/or nitrogen compounds deposition is coupled with the condition of ecosystem sensitivity. On the other hand, ecosystem sensitivity is mainly determined by its soil condition, ground vegetation and forest composition, which are obviously inter-related. To identify soil sensitivity to acidification, Van Mechelen and co-workers (EC-UN/ECE, Van Mechelen *et al.* 1997) suggested a model based on the buffering potential of the soil, its actual acidification status and hydraulic conductivity. Unfortunately, data needed to such a model are not available for Italy yet. For this reason, different indices were considered. According to Rieck (1999), changes in soil chemistry can be expected when soil pH is between 3.1 and 5. Similarly, Rieck (1999) considers soil with a C/N ratio between 17 and 38 to be sensitive to changes associated to nitrogen inputs. Gundersen (1999) and Gundersen *et al.* (1998) suggested a combination of indices like the N input, the foliar content of N, the proportion of N leached and the forest floor C/N ratio to separate N-saturated from N-limited forests (Table 1). In particular, "forest floor C/N ratios may be used to asses the risk for nitrate leaching" (Gundersen and Lutz 2000). The value of this kind of threshold should be not overestimated. Every ecosystem is unique and its responsiveness to a given soil pH or C/N ratio can be modified by a number of factors. For example, the Critical Load (CL) approach uses different input data to calculate the CL values for acidity and nutrient N for a given ecosystem (Posch *et al.* 1999). At the end, to obtain a first idea as to the sensitivity and the actual exposure situation of the *PMPs*, different indicators are used: the pH of the mineral layers, the C/N ratio and the values of CLmax(S), CLmin(N) and CLmax(N) estimated for Italy (De Smet *et al* 1999; Buffoni com. pers.). The foliar content of N and the N/P ratio (EC-UN/ECE, Stefan *et al.* 1997; Matteucci *et al.* this volume) and the Stoddard index (see Stoddard 1994, Stoddard and Traaen 1995, Traaen and Stoddard 1995; Mosello and Marchetto this volume) are used to identify potential effects of the exposure of the concerned *PMPs* to deposition loads. Finally, the CLs for acidification and nutrient nitrogen estimated for the 1x1 km cells where the *PMPs* are located are used in comparison to data about deposition to identify and/or confirm situations where exceedance is likely to occur. Details about CLs calculations are given in the Italian National Focal Center Report (Posch *et al.* 1999, p. 106).

Table 1 - Typical values for N indices in coniferous forest ecosystems at different status of N saturation (after Gundersen and Lutz 2000).
Valori tipici di alcuni indici relativi all'azoto in ecosistemi forestali a conifere in diversi lievlli di saturazione da azoto (after Gundersen and Lutz 2000).

Nitrogen status	N-saturated	Intermediate	N-limited
Input (kg/ha per year)	40-100	15-40	0-15
Needle (%)	1.7-2.5	1.4-1.7	<1.4
Proportion of input leached	30-100	0-60	<10
C/N ratio (gC/gN)	<25	25-30	>30

Ozone

Exposure to ozone may cause different effects on forest ecosystems, ranging from visible injury to foliage, to hidden biochemical and ultrastructural damage and growth reduction (*e.g.* Kärenlampi and Skärbi 1996; Skelly *et al.* 1999; Matyssek and Innes 1999). Ozone is usually absorbed by foliage through stomata, therefore stomatal conductance is an important feature to be considered. Stomatal conductance depends on a variety of factors, the most important being atmospheric humidity and soil water content. Thus, high ozone concentration does not automatically lead to high ozone uptake; a number of modifying factor must be taken into account. Ozone data available for the *PMPs* include weekly mean values (nightime+daylight hours), seasonal average values, and maximum seasonal weekly values (Buffoni and Tita this volume). AOT40 cannot be calculated properly at the moment, while alternative approaches to derive dose-response functions seem promising (Grünhage *et al.* 2001). At the moment, data on modifying factors include only Relative Evapotranspiration (RE) and the difference between precipitation and evapotranspiration (P-EPT) as an indicator of potential drought stress on 8 *PMPs* (Amoriello and Costantini this volume).

Status and changes

Data analysis

To show how the method works, data obtained from crown condition, ground vegetation and ozone for the years 1996, 1998 and 1999 in beech *PMPs* were used. These are the only data collected yearly, thus allowing a sufficient ratio of cases:variables. Data from 1997 were not considered as ground vegetation assessments were not carried out that year. Crown condition data include crown transparency, crown form, extent of foliage discoloration. They were converted into one synthetic index as described by Bussotti *et al.* (this volume). Ground vegetation data include Fisher's alpha, calculated as described by Campetella and Canullo (this volume). Ozone data include seasonal weekly averages (Buffoni and Tita this volume). All these data are reported in Table 2. Data were processed as described by Ferretti *et al.* (this volume).

Presentation of PMP status

For the purposes of this paper, the *PMPs* status is graphically presented using different diagrams. To show the results obtained with the data described above (crown condition, ground vegetation and ozone), two types of diagrams were used:

(i) a three dimensional graph were cases which are "far" from the overall mean status are represented;

(ii) a two dimensional graph showing the trend of the status over the years considered.

A status which is "far" from the mean is defined analytically using the distribution of the values of the Mahalanobis distance and setting a threshold, here defined by the average distance

Table 2 - Indices used for the example of S&C analysis. The cumulated index of crown condition is the sum of the amount of crown transparency and discoloration and the type of crown form (see Bussotti *et al.*, this volume, for details); information about Fisher alpha are provided by Canullo *et al.* (this volume); ozone data were provided by Buffoni and Tita, (this volume).
Indice usati per l'esempio di analisi S&C, L'indice cumulato dello stato delle chiome è la somma dell'ammontare di trasparenza e discolorazione più la forma della chioma (dettagli sono disponibili in Bussotti et al,, *in questo volume); informazioni sull'alfa di Fisher sono fornite da Canullo* et al. *(in questo volume); i dati sulle concentrazioni di ozono sono forniti da Buffoni e Tita (in questo volume).*

Cases n	Year	PMP code	Variables Crown Condition Cumulated index	Ground Vegetation Fisher alpha	Ozone Summer mean, ppb
1	1996	ABR1	0,31	2,96	36,4
2	1996	CAL1	0,47	3,79	30,5
3	1996	CAM1	0,46	3,85	37,1
4	1996	EMI2	0,25	3,53	35,6
5	1996	VEN1	0,13	3,18	32,8
6	1998	ABR1	0,31	2,43	39,3
7	1998	CAL1	0,43	3,69	33,1
8	1998	CAM1	0,4	4,12	38,1
9	1998	EMI2	0,26	4,03	43,1
10	1998	VEN1	0,19	3,79	36,1
11	1999	ABR1	0,25	2,22	52,7
12	1999	CAL1	0,38	4,03	40
13	1999	CAM1	0,28	3,58	48,6
14	1999	EMI2	0,34	5,82	47,3
15	1999	VEN1	0,29	2,52	43,2

plus 1.5 times its standard deviation: all *PMPs* falling within this limit are considerd to be “close” to the mean condition, while the others are classified as “far” from the mean, and thus “anomalous”. Note that – in the context of the S&C analysis - the term “anomalous” is not used as a value judgement (*e.g.* “unhealthy”) but only to identify those situation that deviate markedly from the mean distance. This is because high distance from the mean can be generated not only from negative situation but also from particularly good condition.

In the first graph, the “normal” status is given by an ellipsoid defined by all the points that fall within the average Mahalanobis distance plus 1.5 times the standard deviation. “Anomalous” cases (*i.e. PMPs*) are outside the ellipsoid.

In the second graph, the distance between the status of a given *PMP* (given by the Mahalanobis distance of any given *PMP* from the average distance) is plotted *vs.* the time, thus allowing the identification of the *PMPs* and the years where “anomalous” situation occurred.

A third type of graph is needed when more then three indices will be used for the S&C analysis. Actually, a possible problem with the S&C analysis may be connected with the difficulty we have in imagining a space with more than three dimensions. To allow a visual perception that may help in identifying differences between different sites in the same year, or between different years at the same site, radar diagrams were used. Each arm of the diagram represents an index of ecosystem status, and indices referring to biological, chemical and physical (meteo) status are located in different parts of the diagram. To provide an example, a much more detailed data matrix was used to create examples of the diagrams (Table 3). These data were collected in, averaged over, or referred to the period 1995-1998 with the sole aim of providing a visual illustration of the differences we will compute mathematically as soon as a sufficient number of data will become available. Using these data, examples of diagrams were built-up for each *PMP* of beech, Turkey oak, and spruce. In the heading, the *PMP* code, the evaluation level (EL) and the period to which the data refer are re-

Table 3 - Indices used for the example of a diagram representing *PMP* status.
Indici usati per l’esempio di rappresentazione grafica dello stato delle varie aree permanenti.

Index	Code	Reporting units	Reporting range
Biological status			
Crown transparency	Trp	%	0-50
Discoloration, amount	CdF	%	0-50
Discoloration, type	CdF-T	5 classes	0-5
Leaf malformations	MF	%	0-50
Crown form	Str	5 classes	0-0.5
Leaf Area Index	LAI	$m^2 \cdot m^{-2}$	0-10
Basal area per hectar	G	m^2	0-100
Dominant height	HD	m	0-50
Number of species	Species	number	0-100
Fisher Alpha	Alpha	index	0-10
Dry weight 100 leaves/1000 needles	Mass(f)	g	0-50
Chemical status			
Foliar Nitrogen	N(f)	$mg \cdot g^{-1}$	0-50
Foliar Sulfur	S(f)	$mg \cdot g^{-1}$	0-5
N/P ratio	N/P(f)	number	0-100
N/Ca ratio	N/Ca(f)	number	0-10
N/Mg ratio	N/Mg(f)	number	0-50
N/K ratio	N/K(f)	number	0-10
pH mineral soil	PH(s)	Unit pH	0-12
Exchangeable Basic Cations	BCE(s)	$Cmol \cdot kg^{-1}$	0-25
Exchangeable Acid Cations	ACE(s)	$Cmol \cdot kg^{-1}$	0-10
C/N in mineral soil	C/N	numero	0-50
Acidic deposition in throughfall	H(d)	$meq \cdot m^{-2} \cdot y^{-1}$	0-300
Nitrogen deposition in throughfall	N(d)	$meq \cdot m^{-2} \cdot y^{-1}$	0-300
Ozone weekly concentration	O_3	$\mu g \cdot m^{-3}$	0-250
Physical status (meteo)			
[Winter index]	IW	°C	0-500
[Late Frost index]	ILF	°C	0-500
Heat index	IH	°C	0-50
Summer index	IS	°C	0-5000

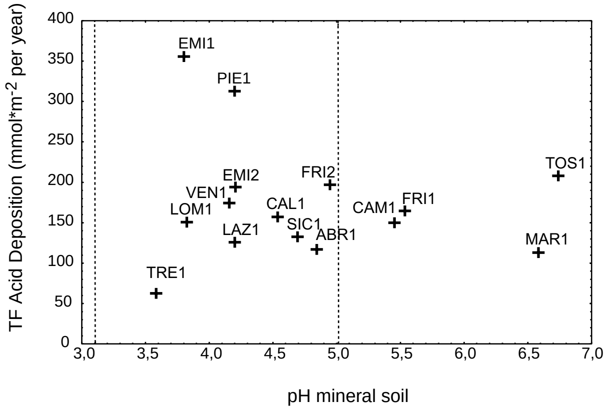


Figure 1 - Soil pH (mineral soil) and deposition of acidifying compounds in the throughfall in 1999 (Mosello and Marchetto this volume). Dotted lines identify the range of pH values believed to be sensitive to changes induced by acidic deposition (Riek 1999). The codes of individual *PMPs* are reported in the graph.
Associazione tra valori di pH negli orizzonti minerali del suolo e deposizioni di acidificanti sottochioma (TF, in basso) 1999 (Mosello and Marchetto in questo volume). Le linee verticali delimitano il campo di pH in cui i suoli sono ritenuti suscettibili ai cambiamenti indotti da deposizioni di acidi (Riek 1999).

ported. See Ferretti (this volume) for details about evaluation levels. Obviously, only similar ELs are fully comparable: however, since the ELs are cumulative and since the diagrams are designed consistently with the ELs, individual portions of the diagrams can always be compared.

Results

Risk analysis

Acidic and nitrogen inputs

The median pH levels of the mineral soil horizons (Alianiello *et al.* this volume) were plotted against the throughfall deposition rates of acidifying compounds in 1999 (Mosello and Marchetto this volume) (Fig. 1). Low soil pH coupled with relatively high deposition rates occurs in some plots (namely EMI1, PIE1); low soil pH with moderate acidic deposition occurs in several *PMPs* (LOM1, LAZ1, CAL 1, ABR1, EMI2, SIC1, FRI2, VEN1); other PMPs (TRE1, FRI1, CAM1, MAR1, TOS1) display either low deposition or high soil pH or both. The situation of beech *PMPs* (PIE1, VEN1, EMI2, ABR1, CAM1, CAL1) is of particular interest since they seem to be located on a deposition and/or soil pH gradient.

As an example, in Fig. 2 sulphur and nitrogen throughfall deposition for 1999 is plotted on a diagram showing the relevant critical load function based on the 5th, the 50th and the 95th CL values estimated for Italy (Posch *et al.* 1999). Although the critical load function is site specific, Fig. 2 suggests that deposition rates never exceed the 95th and 50th percentile critical load function, i.e. the function that identified protective values for the less sensitive ecosystems. However, the 5th percentile CL function is frequently exceeded by 1999 deposition loads (Fig. 3), thus suggesting that the most sensitive ecosystems may experience deposition rates exceeding their carrying capacity. Interestingly, *PMPs* PIE1 and EMI1 appear potentially impacted and TRE1 potentially unimpacted in both Figs. 1 and 3. However, the actual sensitivity of these *PMPs* (which differ in many characteristics) must be known in detail before making any kind of statement with certainty. For example, Table 4 reports estimated CL values for acidity for the 1x1 km cell within which the *PMPs* are located and the deposition rates actually measured at the

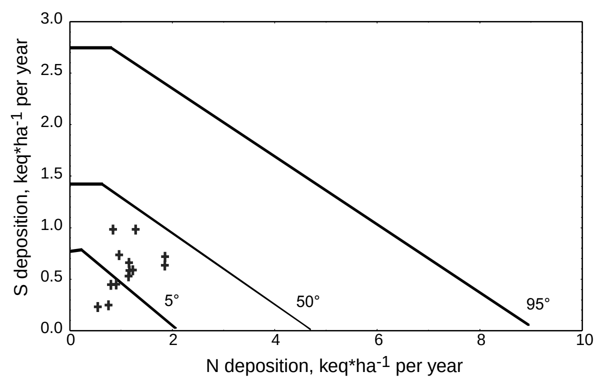


Figure 2 - Critical load functions for S and acidifying N at 5th, 50th, and 95th percentile for Italy (de Smet and Posch 1999) in 1999 (Mosello and Marchetto this volume). The 5th percentile can be considered as the load above which effects are likely to occur in the most sensitive ecosy-stems; on the other hand, the 95th percentile is the threshold above which the less sensitive ecosystems can be affected. Deposition rates at individual *PMPs* are reported.
Funzione di carico critico per l'acidificazione ai livelli del 5°, 50° e 95° percentile (de Smet and Posch 1999) e deposizioni sottochioma nel 1999 (Mosello and Marchetto in questo volume). A titolo di esempio il 5° percentile indica il livello di possibile deposizione oltre al quale sono possibili effetti sugli ecosistemi più sensibili; il 95° percentile indica il livello oltre al quale sono da attendersi effetti sugli ecosistemi più resistenti.
Sono riportati i tassi di deposizione alle singole aree permanenti.

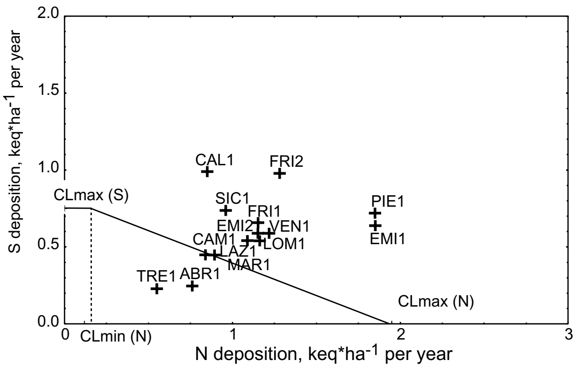


Figure 3 - Critical load functions for S and acidifying N at 5th percentile for Italy (de Smet and Posch 1999) in 1999 (Mosello and Marchetto this volume). The 5th percentile can be considered as the load above which effects are likely to occur in the most sensitive ecosystems. Deposition rates at individual *PMPs* with their codes are reported.
Funzione di carico critico per l'acidificazione ai livelli del 5° percentile (de Smet and Posch 1999) e deposizioni sottochioma nel 1999 (Mosello and Marchetto in questo volume). Il 5° percentile indica il livello di possibile deposizione oltre al quale sono possibili effetti sugli ecosistemi più sensibili. Sono riportati i tassi di deposizione nelle varie aree permanenti identificate dal loro codice.

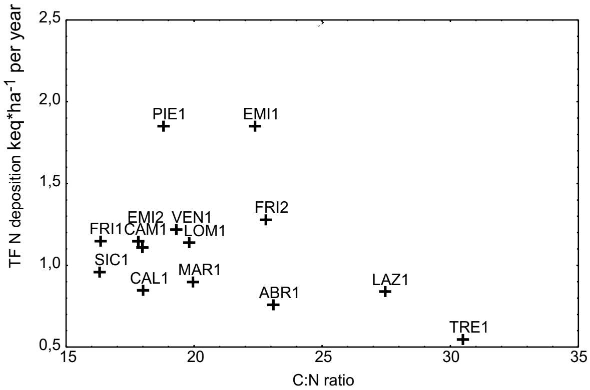


Figure 4 - Forest floor C/N and deposition of nitrogen in the throughfall in 1999 (Mosello and Marchetto this volume). The codes of individual *PMPs* are reported in the graph.
Associazione tra valori di C/N negli orizzonti organici e deposizioni di azoto sottochioma (TF).

PMPs. Apparently, PIE1 is confirmed to receive exceeding acififying compounds, while the situation is more doubtful for EMI1, where sensitivity to acidification seems to be much less. On the other hand, acidic deposition seems to exceed CL at TRE1, thus suggesting a potential impact even at low deposition rates. Thus, future work in this direction is needed to build up site-specific critical load functions.

Fig. 4 reports the throughfall deposition of N plotted against the C/N ratio in in the forest floor. The C/N ration is frequently below 25, a threshold which is considered typical for N-saturated coniferous forest ecosystem (Table 1). Within the considered *PMP*, FRI2, LOM1 and TRE1 are located in Norway spruce forests. In Fig. 5 the critical load functions (5th, 50th and 95th percentile) are reported together with the deposition rates for each individual *PMP*. From both Figs. 4 and 5 it seems that a risk due to excessive N deposition may occur for many *PMPs*.

Table 4 - Critical loads for acidity and nitrogen estimated for the 1x1 km grid cells where the *PMPs* are located (after: de Smet and Posch 1999; Buffoni, pers. com.), actual deposition rates at the *PMPs* (1999) and potential exceedance. Data are reported in eq•ha^{-1} per year.
Carichi critici per acidità ed azoto stimati per le celle chilometriche dove sono localizzate le aree permanenti (da de Smet e Posch 1999; Buffoni, com. pers.), tassi di deposizione effettivi (1999) e potenziali eccedenze. I dati sono in eq•ha^{-1} per anno.

	Critical Loads		Deposition		Exceedance	
PMP	**Acidity**	**nutrient N**	**Acidity**	**N**	**Acidity**	**N**
ABR1	>2000	578	1210(*)	760	Unlikely	182
BAS1	1388	928	Not Measured	Not Measured	Unknown	Unknown
CAL1	>2000	883	1590	850	Unlikely	?
CAM1	>2000	815	1540	1110	Unlikely	295
EMI1	>2000	600	3570	2205	?	1605
EMI2	>2000	750	1940	1150	?	400
FRI1	>2000	723	1650	1150	Unlikely	427
FRI2	>2000	883	1980	1280	?	397
LAZ1	>2000	621	1270	840	Unlikely	219
LOM1	1575	404	1520	1140	?	736
MAR1	>2000	734	1150	900	Unlikely	166
PIE1	1929	922	3120	1850	1191	928
PUG1	>2000	876	Not Measured	Not Measured	Unknown	Unknown
SAR1	>2000	499	Not Measured	Not Measured	Unknown	Unknown
SIC1	>2000	130	1340	960	Unlikely	830
TOS1	>2000	622	2090	840(**)	?	218
TRE1	505	791	630	550	125	Unlikely
UMB1	>2000	906	Not Measured	Not Measured	Unknown	Unknown
VAL1	>2000	407	Not Measured	Not Measured	Unknown	Unknown
VEN1	>2000	975	1770	1220	Unlikely	245

(*) 1998 data; (**)only N-NH_3 and N-NH_4 considered

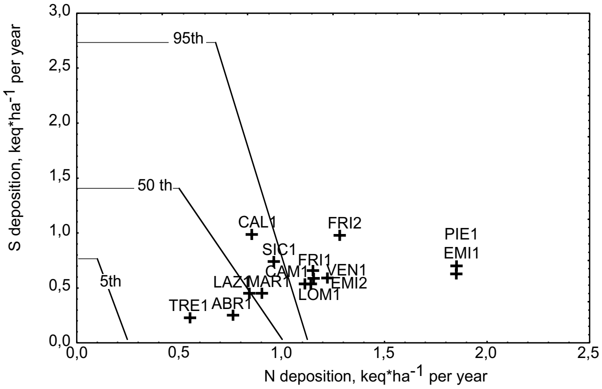


Figure 5 - Critical load functions for nutrient N for Italy (DE SMET and POSCH 1999) and throughfall deposition in 1999 (MOSELLO and MARCHETTO this volume). The 5th percentile can be considered as the load above which effects are likely to occur in the most sensitive ecosystems. On the other hand, the 95th percentile is the threshold above which the less sensitive ecosystems can be affected. Deposition rates at individual *PMPs* are reported.
Funzione di carico critico per l'azoto nutriente ai livelli del 5°, 50° e 95° percentile (DE SMET and POSCH 1999) e deposizioni sottochioma nel 1999 (MOSELLO and MARCHETTO in questo volume). A titolo di esempio il 5° percentile indica il livello di possibile deposizione oltre al quale sono possibili effetti sugli ecosistemi più sensibili; il 95° percentile indica il livello oltre al quale sono da attendersi effetti sugli ecosistemi più resistenti. Sono riportati i tassi di deposizione alle singole aree permanenti.

This is confirmed by Table 4, where it is obvious that estimated CLs are well exceeded at most of the considered *PMPs*. As an example, Fig. 6 reports the mean N concentration (1995-1999 period) in beech leaves at the various *PMPs* with beech as the main species plotted against the estimated exceedance of nutrient N. While the various *PMPs* differs for many characteristics (*e.g.* FABBIO and AMORINI this volume; CAMPETELLA and CANULLO this volume), there is an apparent good relationship between N exceedance and foliar N (R^2: 0.85). The example of PIE1 is interesting. This PMP was found (i) to receive considerable N deposition, (ii) to have a high N foliar concentration (3.5% in 1999, MATTEUCCI *et al.* this volume), (iii) high N/P foliar ratio and (iv) a Stoddard index showing N saturation with potential for nitrate leaching (MOSELLO and MARCHETTO this volume).

Ozone

Mean weekly ozone concentration at the various *PMPs* fluctuated year by year, with 1997 and 1999 displaying the highest values (BUFFONI and TITA this volume). In 1999, mean values were

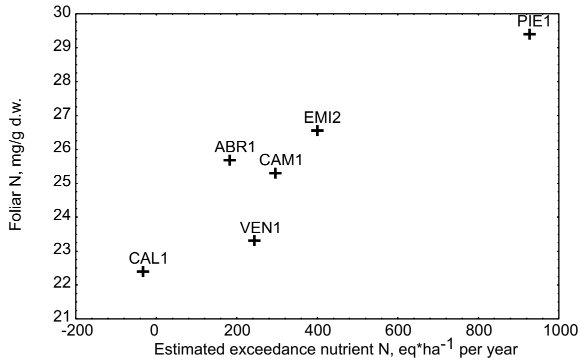


Figure 6 - Estimated exceedance of nutrient N at the beech *PMPs* plotted against the mean (1995-1999) foliar N concentration in beech leaves at the same *PMP*.
Eccedenza stimata per l'azoto nutriente per le aree permanenti a prevalenza di faggio in relazione alla concentrazione media (1995-1999) di azoto nelle foglie di faggio delle stesse aree.

always above 40 ppb, suggesting that potentially high ozone doses will be available for the plants. However, in the same years the meteorological conditions changed as well (AMORIELLO and COSTANTINI this volume), thus potentially influencing the uptake of ozone. Fig. 7 reports the situation for two plots (TOS1, VAL1) where the data series started in 1996, with the P-EPT values used as an indicator for drought stress, which may influence ozone uptake. The P-EPT index does not account for soil moisture, so it has a number of limitations for this purpose. Yet, it could give an idea as to how the potential for ozone uptake

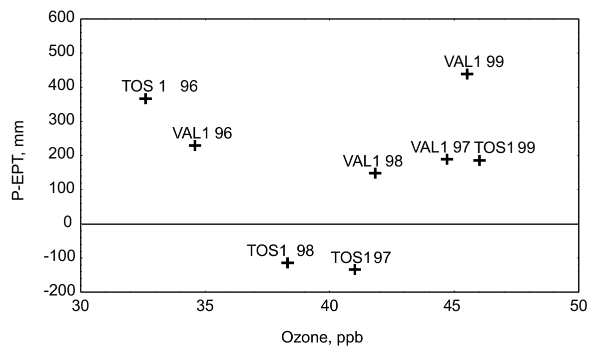


Figure 7 - Mean weekly ozone concentrations for the summer periods 1996-1999 at TOS1 and VAL1 plotted against the P-EPT values (BUFFONI and TITA this volume, and AMORIELLO and COSTANTINI this volume).
Concentrazioni medie settimanali di ozono nel perido estivo 1996-1999 presso le aree permanenti TOS1 e VAL1 rappresentati in relazione ai valori di P-EPT (vedi BUFFONI and TITA in questo volume, e AMORIELLO e COSTANTINI in questo volume.

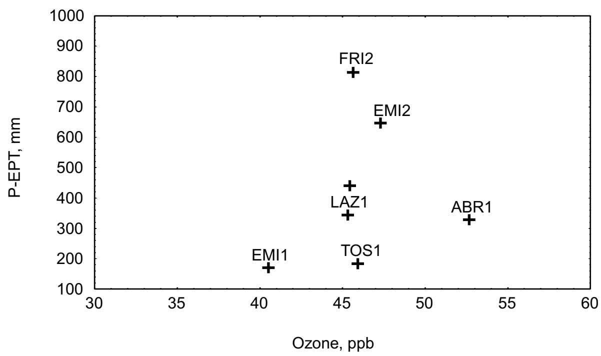


Figure 8 - Mean weekly ozone concentrations in 1999 at various *PMPs* equipped for meteo measurements in Italy plotted against the P-EPT values (see Buffoni and Tita this volume and Amoriello and Costantini this volume).
Concentrazioni medie settimanali di ozono nel 1999 presso varie aree permanenti dotate di centralina meteo rappresentati in relazione ai valori di P-EPT (vedi Buffoni e Tita in questo volume, e Amoriello e Costantini in questo volume).

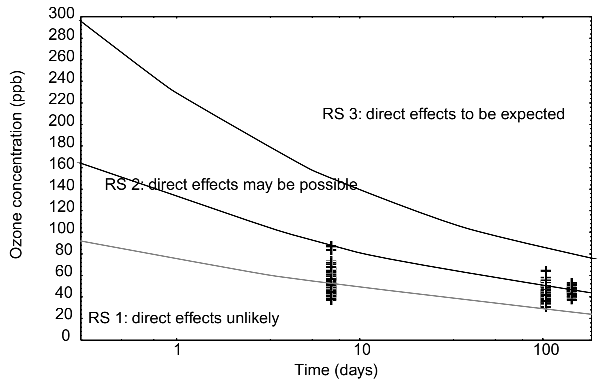


Figure 9 - Ozone concentration at individual *PMPs* for each individual year (1996, 1997, 1998 and 1999) plotted against different times of exposure: 7-days (maximum weekly average), 103 days (measurement period in 1996, 1997 and 1998) and 144 days (measurement period in 1999). The three different Risk Scenarios (RS) according to Grünhage *et al.* (2001) are reported.
Concentrazioni di ozono presso le singole aree permanenti per ciascun anno (1996, 1997, 1998, 1999) in relazione a differenti tempi di esposizione: 7 giorni (massime settimanali), 103 giorni (periodo di misurazione nel 1996, 1997 e 1998) e 144 giorni (periodo di misurazione nel 1999). Sono riportati i tre differenti scenari di rischio (RS) definiti da Grünhage et al. *(2001).*

may be influenced. As shown in Fig. 7, 1996 and 1999 were the years with the highest P-EPT values for both TOS1 and VAL1. However, 1996 and 1999 differ markedly for ozone levels, suggesting that the uptake of ozone was potentially high in 1999. On the other hand, comparatively higher levels of ozone occurring in 1997 and 1998 have potentially resulted in lower ozone uptake as compared to 1996, because of unfavourable conditions. Fig. 8 reports the situation for 1999 at all the *PMPs* with both meteo and ozone measurements. Note that, for similar levels of ozone concentration, the P-EPT values vary between *PMPs*, suggesting that potentially different ozone fluxes may be occurring. Ozone sensitivity is also dependent on species and age, with highly competitive species with a high growth rate being more sensitive (*e.g.* Mills *et al.* 2000). It is expected that ozone uptake is higher in younger trees because of their higher rates of gas exchange. Within the *PMPs* of the CONECOFOR program there is a huge variability in age. For example, the mean age of the dominant storey in beech *PMPs* varies from 40 to 110 years and this is another factor to be taken into account.

Fig. 9 reports the average maximum weekly and the seasonal averages of ozone concentration over the period 1996-1998 plotted into a diagram showing the three risk scenarions according to Grünhage *et al.* (2001). Because the concentrations at the CONECOFOR plots are not measured at the canopy layer (as required by the model by Grünhage *et al.* 2001), an overstimation of risk is likely in Fig. 9. However, the meaning of Fig. 9 is just to show a possible approach for the time when the Risk Analysis will be attempted in depht, with the full consideration of modifying factors.

Status and changes

The status and changes of 5 beech *PMPs* in relation to crown, ground vegetation and ozone are reported in Figs. 10 and 11. Fig. 10 reports the ellipsoid (average Mahalanobis distance plus 1.5 time the standard deviation) and the condition which are "far" from the mean distance. The same data are reported in Fig. 11. As it is obvious, in 1999 both ABR1 and EMI2 fall outside the limit, while in 1996 VEN1 falls very close to the 1 StDev limit. However, the reasons behind these facts are probably different for the two *PMPs* (Table 5). At ABR1, 1999 was the year with the highest ozone concentration (52.7 ppb) as compared to the previous years and the other *PMPs* (Table 2). In 1999, such high concentration was coupled with low value of Fisher alpha. Indeed, Fisher alpha was always low for ABR1 (Table 2). High ozone concentration was re-

Table 5 - Outcomes of the S&C analysis. Position, potentially critical indices and related possible causes for deviations from the mean status are reported casewise.
Risultati dell'analisi S&C. Posizione, indici potenzialmente critici e possibili cause della deviazione dalla media sono riportate per ciascun caso.

Case n	Year	PMP code	Position	Critical Index	Possible causes
1	1996	ABR1	within 1 StDev	-	
2	1996	CAL1	within 1 StDev	-	
3	1996	CAM1	within 1 StDev	-	
4	1996	EMI2	within 1 StDev	-	
5	1996	VEN1	within 1.5 StDev	crown	particulary good crown condition
6	1998	ABR1	within 1 StDev	-	
7	1998	CAL1	within 1 StDev	-	
8	1998	CAM1	within 1 StDev	-	
9	1998	EMI2	within 1 StDev	-	
10	1998	VEN1	within 1 StDev	-	
11	1999	ABR1	exceed 1.5 StDev	ozone, Fisher alpha	increased ozone concentration, low specific individual diversity
12	1999	CAL1	within 1 StDev	-	
13	1999	CAM1	within 1 StDev	-	
14	1999	EMI2	exceed 1.5 StDev	ozone, Fisher alpha	increased ozone concentration, high specific individual diversity
15	1999	VEN1	within 1 StDev	-	

corded also at EMI2 and CAM1 at the same year. However, besides ozone, EMI2 deviates markedly from the overall situation mainly because high values of Fisher alpha (Table 2). Campetella and Canullo (com. pers.) reports this high value to be due to an increase of the overall diversity of species coupled with a simultaneous strong decrease of the number of individuals, which is nearly halved for both herbaceous and woody plants.

The interpretation of the above data is not easy at the present time. The indices that caused deviation from the mean condition (ozone levels, ground vegetation diversity) seems to be particularly subjected to short-term fluctuations. In this perspective, the observed deviations can be interpreted more in the sense of short-term "pulses" then as signals of actual trend. However, much longer time series is needed.

Figs. 12-14 report the radar diagrams showing the status of the *PMPs* with beech (Fig. 12), Turkey oak (Fig. 13) and Norway spruce (Fig. 14) over the period 1995-1998. The value of this diagrams is just to help and give concrete evidence to the "shape" that the status of different *PMPs* could have.

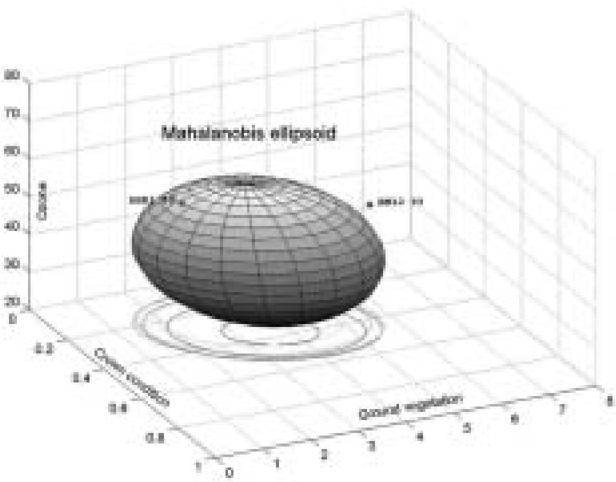


Figure 10 - 3D representation of the ellipsoid defining the status "close" to the mean and the cases which are "far", identified by the dots ouside the ellipsoid.
Rappresentazione tridimensionale dell'ellissoide che definisce lo stato "vicino" alla media e dei casi "lontani", identificati dai punti esterni all'ellissoide.

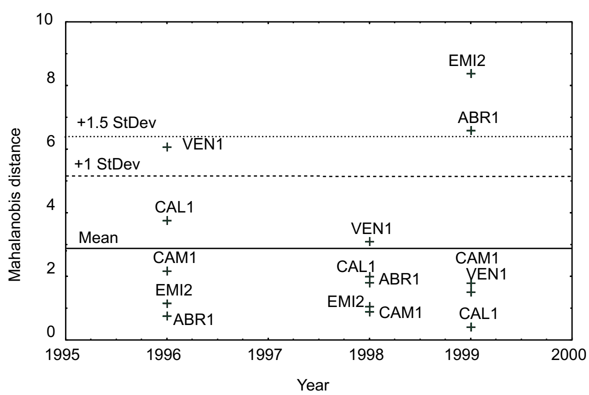
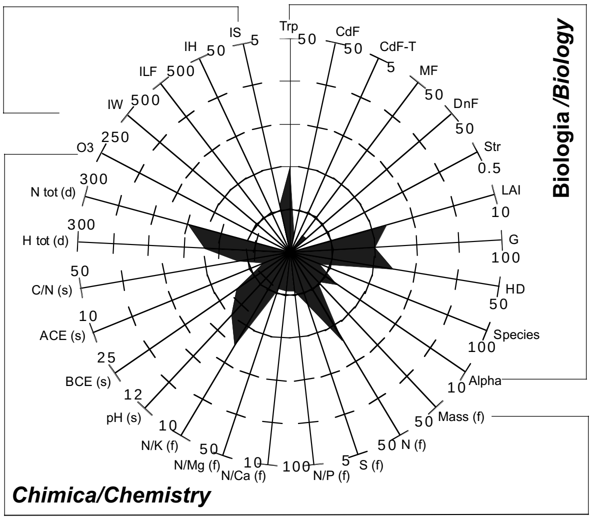


Figure 11- Time trend of the values of the Mahalanobis distance for the beech *PMPs*. Mean distance and different limits (mean plus 1 time the StDev and mean plus 1.5 times the StDev) are reported.
Andamento temporale dei valori di distanza di Mahalano bis per le aree di saggio a prevalenza di faggio. Sono riportati la distanza media e vari limiti (la media più 1 volta la deviazione standard e la media più 1.5 volte la deviazione standard).

Valutazione I&C / *I&C evaluation*

APM / *PMP*:	ABR1
Livello di analisi / *Evaluation level:*	3
Anno di interesse / *Year of concern*:	1995-1998

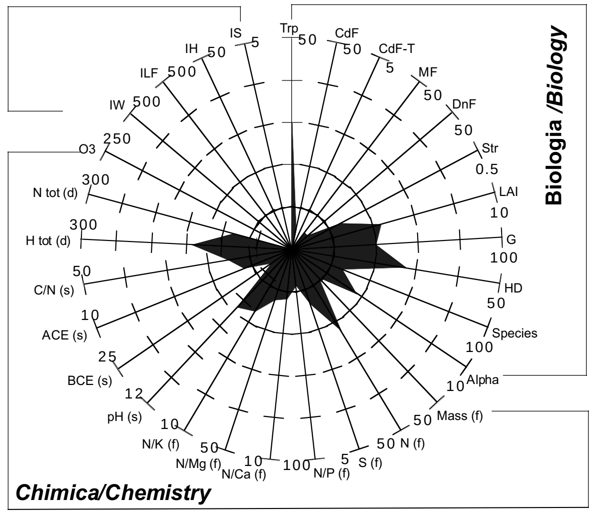
1. Stato / Status



Valutazione I&C / *I&C evaluation*

APM / *PMP*:	CAL1
Livello di analisi / *Evaluation level:*	2
Anno di interesse / *Year of concern*:	1995-1998

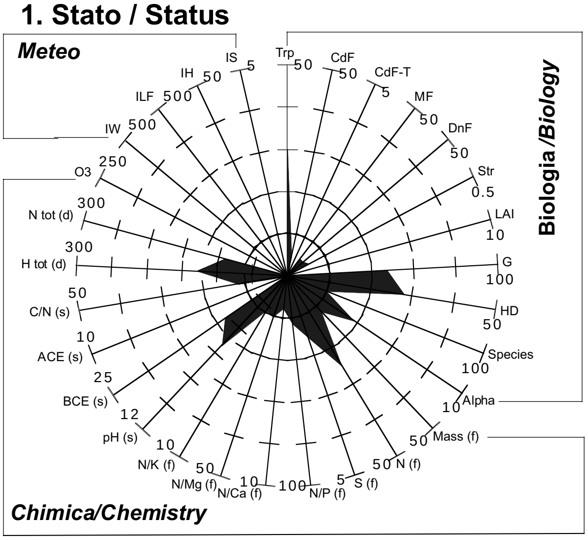
1. Stato / Status



Valutazione I&C / *I&C evaluation*

APM / *PMP*:	CAM1
Livello di analisi / *Evaluation level:*	2
Anno di interesse / *Year of concern*:	1995-1998

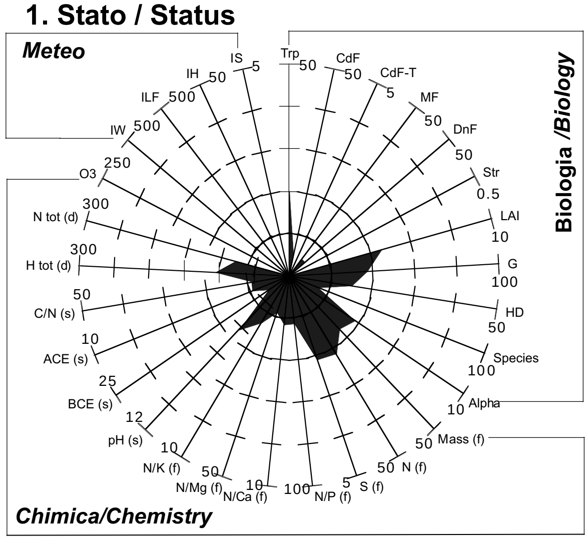
1. Stato / Status



Valutazione I&C / *I&C evaluation*

APM / *PMP*:	EMI2
Livello di analisi / *Evaluation level:*	2
Anno di interesse / *Year of concern*:	1995-1998

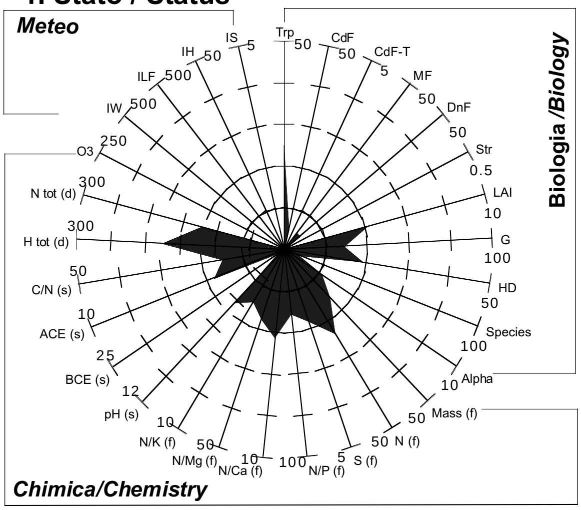
1. Stato / Status



Valutazione I&C / *I&C evaluation*

APM / *PMP*: PIE1
Livello di analisi / *Evaluation level:* 2
Anno di interesse / *Year of concern*: 1995-1998

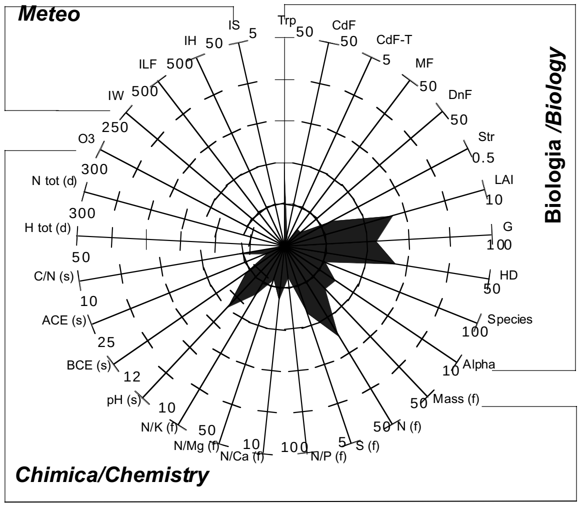
1. Stato / Status



Valutazione I&C / *I&C evaluation*

APM / *PMP*: PUG1
Livello di analisi / *Evaluation level:* 1
Anno di interesse / *Year of concern*: 1995-1998

1. Stato / Status



Valutazione I&C / *I&C evaluation*

APM / *PMP*: VEN1
Livello di analisi / *Evaluation level:* 2
Anno di interesse / *Year of concern*: 1995-1998

1. Stato / Status

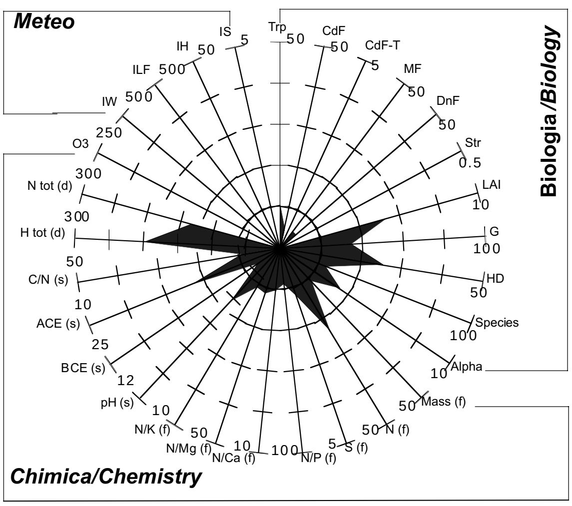
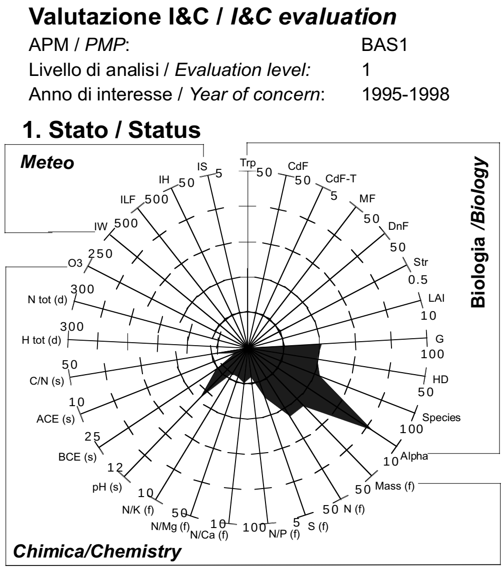


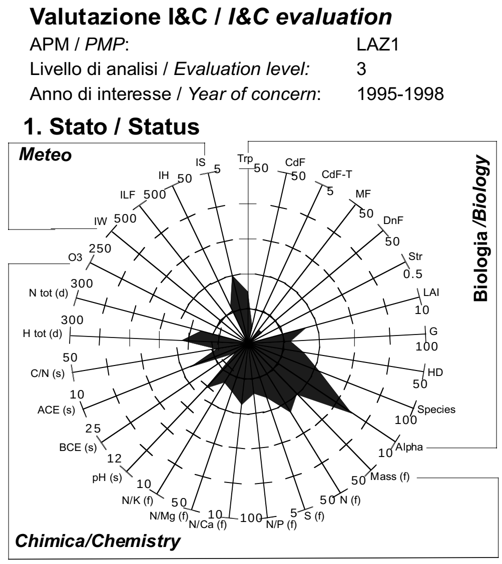
Figure 12 - Example of graphic presentation of the status of the various *PMPs* with beech as main tree species.
Esempio di rappresentazione di stato per le APM a faggio.

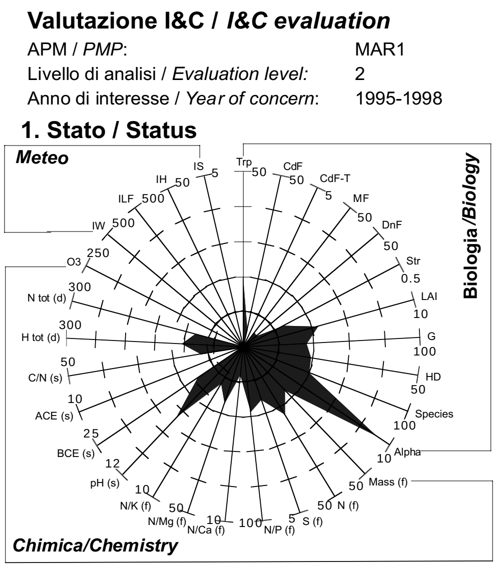
Conclusions

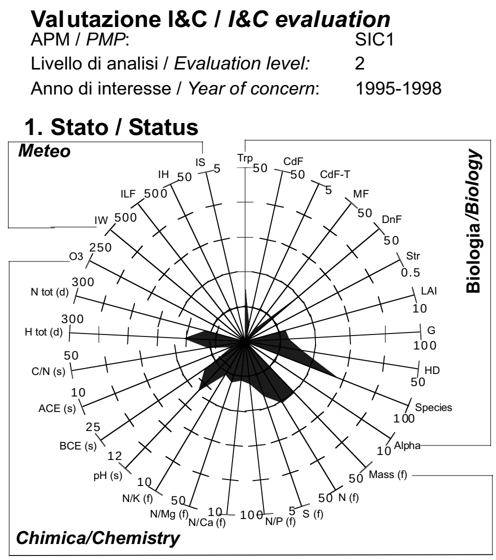
A first comparison between deposition of acidifying S and N and soil pH and Critical Load functions estimated for ecosystems with different degrees of sensitivity in Italy, reveals that depositions of acidifying S and N are still within protective values for the less sensitive ecosystems. On the other hand, Critical Loads for the most sensitive ecosystems are potentially exceeded. Concerning the role of N, Critical Loads for nutrient N seem to be potentially exceeded at many of the *PMPs*. Evidence of potential N-saturation was reported for PIE1 among others. However, there are many uncertainties with this approach, the most important being that Critical Loads are a site specific parameter, and the CL function needs to be calculated for each *PMP*. The available data should allow this, and – together with the completion of the deposition database – they will also allow a proper and full examination of the actual risk in each *PMP*.

Ozone measurements reveal fairly high weekly averages, which in some cases exceed 70 ppb. However actual ozone uptake is influenced by a number of modifying factors that the present database does not allow us to explore fully. When a potentially influencing factor was considered, the data revealed a wide variation









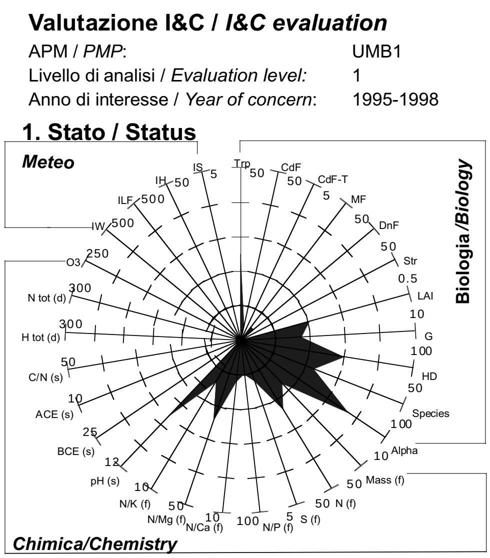


Figure 13 - Example of graphic presentation of the status of the various *PMPs* with Turkey oak as main tree species.
Esempio di rappresentazione di stato per le APM a cerro.

between *PMPs,* which may experience similar ozone levels but display very different P-EPT values. The reverse is also true. Thus, effects of ozone cannot be inferred by the simple evaluation of ozone levels. With the year 2000, five years of ozone data are now available and efforts should be devoted to exploring in depth the actual and potential effects of ozone on monitored forest ecosystems.

The example of S&C analysis was carried out essentially to show possible outcomes of this method. For this example, annual data collected

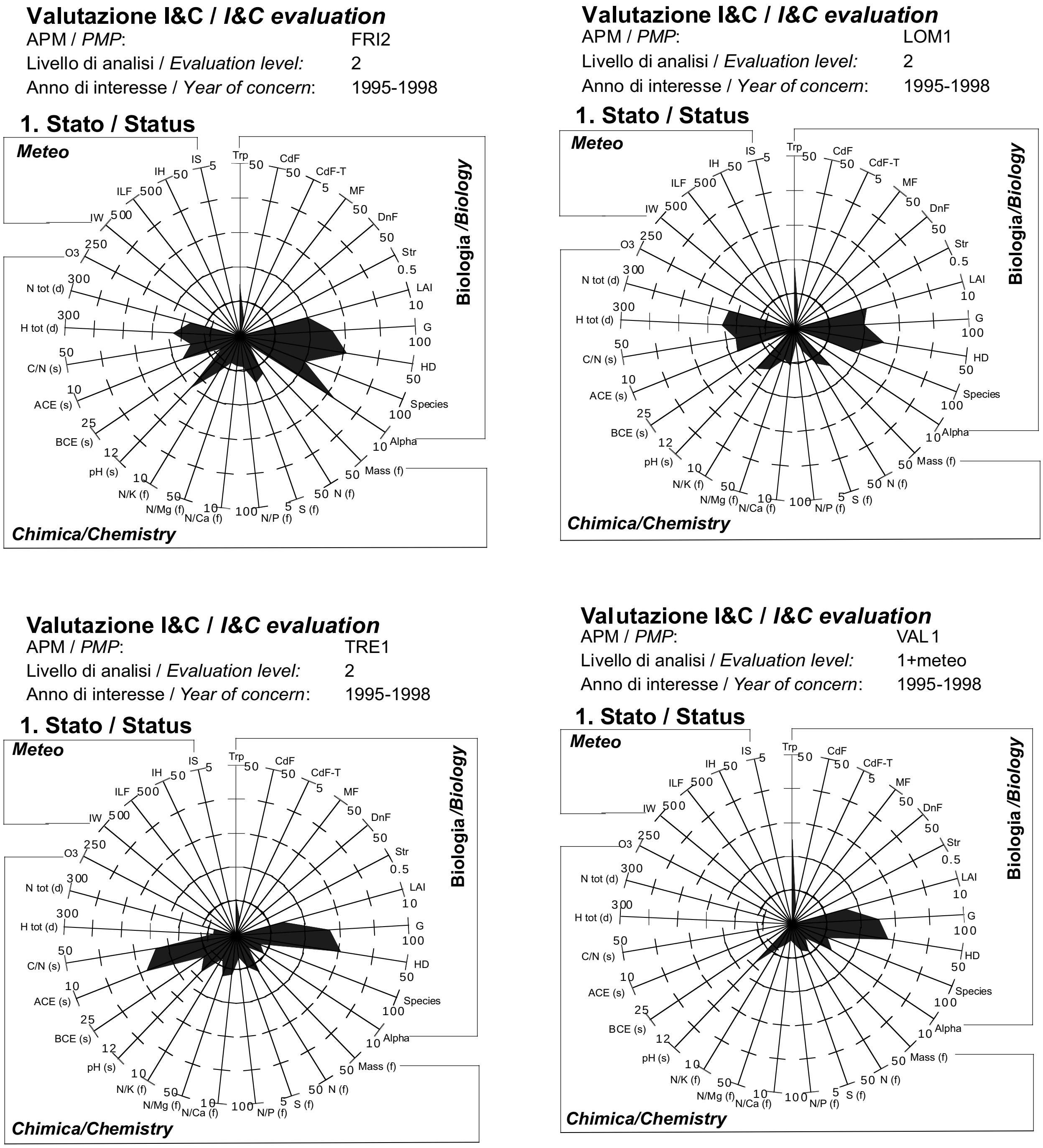


Figure 14 - Example of graphic presentation of the status of the various *PMPs* with Norway spruce as main tree species.
Esempio di rappresentazione di stato per le APM a picea.

by the investigations on crown condition, ground vegetation and ozone were used. Conditions which are “far” from the mean were identified formally at the analitycal stage for two *PMPs* (namely, ABR1 and EMI2). These deviations occurred both in 1999, but were due to different causes: mostly changes in ozone levels (ABR1) and changes in ground vegetation (EMI2). While the S&C analysis has not the aim to provide explanation of deviating trajectories, such an analysis can provide formal evidence about when and where “anomalous” situations occurr.

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References

Alianiello F., Biondi A., Ferrari C., Mecella G. 2000 - *Forest Soil Conditions at the Permanent Monitoring Plots In Italy*. In: Ferretti M. (ed.), "Integrated and Combined (I&C) evaluation of intensive monitoring of forest ecosystems in Italy – Concepts, Methods and First Results", Annali dell'Istituto Sperimentale per la Selvicoltura, Special Issue, anno 1999, 30: 99-104.

Amoriello T., Costantini A. 2000 - *Calculation of meteorological stress indices for italian forest ecosystems*. In: Ferretti M. (ed.), "Integrated and Combined (I&C) evaluation of intensive monitoring of forest ecosystems in Italy – Concepts, Methods and First Results", Annali dell'Istituto Sperimentale per la Selvicoltura, Special Issue, anno 1999, 3: 129-134.

Bredemeier M., Blank K., Lamersdorf N., Wiedey G. A. 1995 – *Response of soil water chemistry to experimental "clean rain" in the NITREX roof experiment at Solling, Germany*. Forest Ecology and Management, 71: 31-44.

Buffoni A., Tita M. 2000 - *Ozone measurements by passive samplers at Italian forest sites*. In: Ferretti M. (ed.), "Integrated and Combined (I&C) evaluation of intensive monitoring of forest ecosystems in Italy – Concepts, Methods and First Results", Annali dell'Istituto Sperimentale per la Selvicoltura, Special Issue, anno 1999, 30: 121-127.

Bussotti F., Ferretti M., Giordano P., Mazzali C. 2000 - *A synthetic index to estimate tree condition in the Permanent Monitoring Plots of the CONECOFOR program*. In: Ferretti M. (ed.), "Integrated and Combined (I&C) evaluation of intensive monitoring of forest ecosystems in Italy – Concepts, Methods and First Results", Annali dell'Istituto Sperimentale per la Selvicoltura, Special Issue, anno 1999, 30: 67-72.

Campetella G., Canullo R. 2000 - *Plant biodiversity as an indicator of the biological status in forest ecosystems: community and population level indices*. In: Ferretti M. (ed.), "Integrated and Combined (I&C) evaluation of intensive monitoring of forest ecosystems in Italy – Concepts, Methods and First Results", Annali dell'Istituto Sperimentale per la Selvicoltura, Special Issue, anno 1999, 30: 73-79.

De Smet P. A. M., Posch M. 1999 - *Summary of National Data*. In: Posch M., De Smet P.A.M., Hettelingh J.-P., Downing R. J., 1999 "Calculation and mapping of critical thresholds in Europe". RIVM Report No. 259101009: 13-27.

EC-UN/ECE, Stefan K., Fürst A., Hacker R., Bartels U., 1997 - *Forest foliar condition in Europe. Results of large scale foliar surveys (survey 1995 aand data from previous year)*. EC, UN/ECE, Austrian Federal Research Centre, 207 pp.

EC-UN/ECE, Vanmechelen L., Groenemans R., Van Rast E. 1997 - *Forest soil condition in Europe. Technical Report*. Ministry of Flemish Community, EC, UN/ECE, Austrian Federal Research Centre, 257 pp.

Emmet B. A. 1999 – *The impact of nitrogen on forest soils and feedbacks on tree growth*. Water Air and Soil Pollution, 116: 65-74.

Fabbio G., Amorini E. 2000 - *Tree growth survey and increment assessment*. In: Ferretti M. (ed.), "Integrated and Combined (I&C) evaluation of intensive monitoring of forest ecosystems in Italy – Concepts, Methods and First Results", Annali dell'Istituto Sperimentale per la Selvicoltura, Special Issue, anno 1999, 30: 81-89.

Flückiger W., Braun S. 1999 – *Nitrogen and its effects on growth, nutrient status and parasite attacks in beech and Norway spruce*. Water Air and Soil Pollution, 116: 99-110.

Ferretti M., Giordano P., Mazzali C. 2000 - *Methods of analysis of the I&C evaluation system*. In: Ferretti M. (ed.), "Integrated and Combined (I&C) evaluation of intensive monitoring of forest ecosystems in Italy – Concepts, Methods and First Results", Annali dell'Istituto Sperimentale per la Selvicoltura, Special Issue, anno 1999, 30: 33-42.

Grünhage L., Krause G.H.M., Köllner B., Bender J., Weigel H-J., Jäger H.-J., Guderian R. 2001 – *A new flux-oriented concept to derive critical levels for ozone to protect vegetation*. Environmental Pollution, 111: 355-362.

Gundersen P., Lutz M. 2000. *The role of nitrogen in forest ecosystems*. In: EC and UN/ECE (2000), Forest condition in Europe, 2000 Executive Report. UN/ECE and EC Geneva and Brussels:

Gundersen P. 1999. *Nitrogen status and impact of nitrogen input in forests – indicators and their possible use in critical load assessment*. In: Nielsen K. E., Critical Loads Copenaghen – Abstracts, 21-25 November 1999, Copenaghen, Denmark: 37-39.

Gundersen P., Callesen I., De Vries W. 1998. *Nitrate leaching in forest ecosystems is controlled by forest floor C/N ratio*. Environmental Pollution, 102: 403-407.

Kärenlampi L., Skärbi L. 1996 - *Critical levels for Ozone in Europe. Testing and finalizing the concepts*. UN-ECE Workshop report, published by the University of Kuopio, Dept. Ecology and Environmental Science, 363 pp.

Manion P. D., Lachance D. (Eds.) 1992. F*orest Decline Concepts*, APS Press, St. Paul, Minnesota.

Matyssek R., Innes J.L. 1999 – *Ozone – a risk factor for trees and forests in Europe?* Water Air and Soil Pollution, 116: 199-226.

Matteucci G., Magnani E., Riguzzi F., Scarascia - Mugnozza G. 2000 - *Possible indicators for the status and changes of Permanent Monitoring Plots derived from leaves and needles analysis.* In: Ferretti M. (ed.), "Integrated and Combined (I&C) evaluation of intensive monitoring of forest ecosystems in Italy – Concepts, Methods and First Results", Annali dell'Istituto Sperimentale per la Selvicoltura, Special Issue, anno 1999, 30: 105-116.

Mills G., Hayes F., Buse A., Reynolds B. 2000 - *Air pollution and vegetation.* UN/ECE ICP Vegetation, Annual Report 1999/2000. Centre for Ecology and Hydrology: 48 ps.

Mosello R., Marchetto A. 2000. *Atmospheric Deposition and Streamflow Chemistry at the Permanent Monitoring Plots of the CONECOFOR programme* In: Ferretti M. (ed.), "Integrated and Combined (I&C) evaluation of intensive monitoring of forest ecosystems in Italy – Concepts, Methods and First Results", Annali dell'Istituto Sperimentale per la Selvicoltura, Special Issue, anno 1999, 30: 117-120.

Posch M., Desmet P.A.M., Hettelingh J.-P., Downing R. J. 1999 - *Calculation and mapping of critical thresholds in Europe.* RIVM Report No. 259101009: 165 ps.

Rasmussen L., Brydges T., Mathy P. (Eds.) 1992 - *Experimental manipulations of biota and biogeochemical cycling in ecosystems. Approaches – Methodologies-Findings.* Ecosystems Research Report no. 4, Commission of the European Communities: 348 ps.

Rennenberg H., Gessler A. 1999 – *Consequences of N deposition to forest ecosystems – Recent results and future research needs.* Water Air and Soil Pollution, 116: 47-64.

Rijek 1999. *Stratifizierung der BZE-Stichprobe hunsichtlich der Dynamik bodenchemischer Eigenschaften.* Fachhoschule Eberswalde, Internal report: 45 ps.

Skelly J. M., Innes J. L. 1994. *Waldsterben in the forests of Central Europe and Eastern North America: fantasy or reality?* Plant Disease, 1021-1031.

Skelly J. M., Innes J.L., Savage J.E., Snyder K.R., Vanbderheyden D.J.,. Zhang J.W., Sanz M. J. 1999 - *Observation and confirmation of foliar ozone symptoms of native plant species Switzerland and south Spain.* Water Air Soil Pollution, 116: 227-234.

Schulze E.-D. 1989. *Air pollution and forest decline in spruce (Picea abies) forest.* Science 244: 776-783.

Stoddard J.L. 1994 - *Long-term changes in watershed retention of nitrogen. Its causes and aquatic consequences.* in: Environmental Chemistry of Lakes and reservoirs. ACS Advances in Chemistry Series No. 237. American Chemical Society.

Stoddard J.L., Traaen T. S. 1995 - *The stages of nitrogen saturation: classification of catchments included in the "ICP on Waters".* In: Hornung, M., M.A. Sutton and R.B. Wilson. "Mapping and modelling of critical loads for nitrogen: a workshop report". Proceedings of the Grange-Over-Sands Workshop, 24-26 October1994. UK Department of Environment and Institute of terrestrial Ecology (Merlewood research Station).

Thimonier A., Dupouey J.L., Timbal J. 1992. *Floristic changes in the herb-layer vegetation of a deciduous forest in the Lorrain Plain under the influence of atmospheric deposition.* Forest Ecology and Management, 55: 149-167.

Thimonier A., Dupouey J.L., Bost F., Becker M. 1994. *Simultaneous eutrophication and acidification of a forest ecosystem in North-East France.* New Phytol., 126: 533-539.

Traaen T.S., Stoddard J.L. 1995 - *An assessment of nitrogen leaching from watersheds.* In: ICP Waters. NIVA Report, Oslo, 39 pp.

The Integrated and Combined (I&C) evaluation system – Achievements, problems and perspectives[§]

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Abstract – Achievements, problems and future work of the Integrated and Combined (I&C) evaluation system are outlined. Achievements include (i) improved cooperation within the scientists involved in the programme and between the scientists and the program managers, (ii) knowledge about the overall quality and precision of monitoring data, (iii) the development of indices and (iv) first evidence that nitrogen deposition and ozone may actually act as stressor. Some problems were identified with the design of the program, to the priority given to some measurements and their location, all of them placing limitations to data analysis. Future activity will include update of data and methods, periodical reviews and full data evaluations. A complete risk analysis is foreseen for the year 2004-2005, while the status and changes analysis and nature of change analysis are scheduled for the years 2006-2010. An important challenge that should be faced within 2005 is the identification of an error model that take into account all the investigations.

Key words: *I&C evaluation system, achievements, problems, future work.*

Riassunto – Il sistema di valutazione Integrata e Combinata (I&C) - Risultati, problemi e prospettive. Si discutono i risultati, i problemi e le prospettive future del sistema di valutazione I&C. Tra i risultati si annoverano una migliore cooperazione tra ricercatori e tra ricercatori e direzione del progetto, conoscenza della complessiva qualità e precisione dei dati, lo sviluppo di una serie di indici sintetici e prime evidenze di una possibile eccedenza dei carichi critici dell'azoto nutriente e dell'ozono come agenti di stress. Sono stati evidenziati problemi con il design del programma, con la priorità data ad alcune misurazioni e con la loro localizzazione, tutti aspetti che pongono limiti all'analisi dei dati. Le prospettive di lavoro futuro includono un aggiornamento dei dati del sistema I&C e dei suoi metodi, revisioni periodiche e completamento della valutazione dei dati. L'analisi di rischio dovrebbe essere completata entro il 2004-2005, mente l'analisi di stato e cambiamenti e della natura dei cambiamenti è prevista per gli anni 2006-2010. Un aspetto importante che dovrà essere sviluppato entro il 2005 è la creazione di un modello di errore che tenga conto di tutte le varie indagini.

Parole chiave: *sistema di valutazione I&C, risultati, problemi, lavoro futuro.*

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The intensive monitoring of forest ecosystems in Italy (CONECOFOR) has started at national level in 1995 with the soil and leaves/needle survey (Allavena *et al.* 1999). To date, the program has grown considerably in terms of data collection, internal and external cooperation. A number of scientists from many istitutions are now involved in the program and this provides the basis for exchange of ideas and common achievements. One of the first recognition of the assorted group of experts was the need to start as soon as possible with the development of concepts and methods to face an important challenge: the integrated evaluation of the intensive monitoring data. First discussion on this topic has started in summer 1998, and a first proposal was prepared, discussed and accepted by autumn 1998 (Gruppo degli Esperti CONECOFOR, 1998). A Task Force for the Integrated and Combined (I&C) evaluation was set up (Ferretti *et al.* 2000). The year 1999 was devoted to develop concepts and methods, to start the indicators and indices development and the preparation of the data. Three meetings were held (Florence, April; Rome, July; December) with interim reports discussed (Ferretti *et al.* 1999 a, b, c). In the year 2000 new data were submitted and processed and this report has been prepared. The whole process was useful to identify actual or potential problems, evaluate

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achievements and suggest perspectives: these issues will be reviewed in the following sections.

Achievements

Cooperation

It seems to be a general feeling that common works has provided an important chance for improving the mutual understanding of the value of the activities undertaken within the CONECOFOR program. For example, scientists leading individual investigation were made aware about the constraints existing to keep the program adequately funded, and program managers probably now know much better the reasons behind some technical issues oftenly raised by scientists. Within the scientists, the importance and the meaning of some measurements of common interests are now probably much more clear. Cooperation needs mutual understanding and this an important step for a comprehensive program as the CONECOFOR is.

Characteristics of the data

The I&C system has given some attention to data quality and precision. At least for some investigations, now we know the level of reproducibility of the data and their internal consistency. In addition, the precision of the estimates of the mean at the level of individual Permanent Monitoring Plots (*PMPs*) and for many investigation is known.

Development of indices

An important part of the I&C process was devoted to discuss the value, the pros and the cons of indices of ecosystem status. Specific Investigations (SIs) teams provided concepts and data for the indices relevant to their own field, and indices were preliminary tested in the first run of the system. Indices were identified and calculated for most of the investigations: this has resulted in a series of thoughts that will continue and will probably influence also the collection of data in the field.

Development of methods

When data analysis is concerned, there is difference between a program based on a relatively limited number of plots (as the CONECOFOR one) and a program based on hundreds of plots (as the Pan-European programme). The most important problem for CONECOFOR is the fact that the ratio between variables and cases does not allow analysis based on the horizontal dimension (data from different plots at the same year). In addition, there is some common problem with the methods to select and locate the monitoring plots (preferential sampling, no explicit model adopted) and this is a strong limit to the inferential process.

A further problem is that methods like regression analysis does not provide any quantitative measure of the changes occurring at individual *PMPs*. This and other consideration has forced us to explore different methods to analyse the data generated by the CONECOFOR program. For this reasons, explicit hypothesis and work lines were suggested, discussed and partially implemented. The result is that CONECOFOR has now a clear strategy for the integrated and combined evaluation of the data. Explicit questions were placed which needs clear answers.

Evidence of potential problems related to air pollution

Within the limits of the available data, the first attempt to identify potential risks for the *PMPs* provide evidence that atmospheric input can locally act as stress factor. While deposition of acidifying compounds is almost always below the estimated critical load for acidity, deposition of nitrogen almost always exceeds the critical load estimated for nutrient nitrogen. Obviously, there are different sources of uncertainty that need to be solved. For example, available critical loads are estimated for a 1x1 km grid based on available maps and information, and not calculated for individual *PMP*; deposition data refers just to a couple of years, while at least five years of data are necessary. Yet, it is an important indication for future steps to recognize that the I&C working hypothesis is somewhat substantiated by facts.

Ozone measurements at the *PMPs* oftenly exceed 40 ppb as summer averages (night plus daylight hours). Although such measurements do not allow any statement about the actual doses available and the actual uptake of ozone, they let us to suggest that peak values can be high and the same probably occur for AOT40. However, the first analysis provides evidence that higher ozone levels may occur in situation with potential water stress. In this case, the importance of the meteorological measurements is clear. Recent attempts to develop a dose-response curve have been considered in the form of an example. Although there is the risk for overestimating risk scenarios, the data suggest that ozone can be a potential risk for some of the monitoring plots.

Evidence of fluctuation of ecosystem status

Ecosystems are complex and their dynamics is likewise difficult to be traced. Within the limits of the available data, year-by-year fluctuations of response and stressors are obvious. In some cases, deviations from the "normal" dynamics have been identified and this seems to support the value of the adopted method. However, further implementation is needed.

Problems

Effect-oriented design of the monitoring program

When the concepts and the data aggregation were discussed (*e.g.* Ferretti this volume), the points were oftenly made that many problems related to the I&C comes from the design of the monitoring program. Amongst others, the allocation of monitoring plots over a wide array of ecological situation (for example: different prevailing tree species) has been proven to be a strong limitation for data analysis. Thus, the problems related to the design of the program needs to be considered once again. It is not the non-probabilistic nature of the site selection that is questioned here: given the type of the program it would be very difficult to have a probabilistic selection of monitoring sites. Rather, one should think whether – at national level - is useful to spread monitoring sites over a wide range of forests, with very different species composition, stand structure, history, age and site condition. The answer is obviously related to some other previous questions, like: what are the objectives of the program? How data should be analysed? If the objective of the program is to track individual sites through time, then it could be of value to have monitoring sites installed within different forest ecosystems, and one could accept to have a very fragmented set of sites. However, it needs also the recognition and the acceptance that integrated multivariate data analysis will be possible only after several (probably dozens) years.

The situation is different when the objective of the monitoring program is the assessment of air pollution (or other stressors) on forests (*e.g.* Köhl *et al.* 1994). In this case, the approach should be different and the more homogeneous the sites are, the higher is the chance to obtain robust results. Although with some limits, homogeneous monitoring sites can be arranged as replicates of an experiment along *e.g.* pollution gradients or soil sensitivity and so on. In this case, the advantage for data processing is clear. On the other hand, one must decide to sacrifice information on different ecosystem to a more defined target for one or two ecosystem types.

For the above reasons, it is clear that both the approaches can be valid – in general terms. However it is also clear that spreading sites in many different ecosystems can cause constraints in data analysis unless long or very long time series will be available. This situation has been somewhat acknowledged at European level (*e.g.* EC-UN/ECE 1998 and 1999) and becomes striking at national level as it was obvious when designing the I&C system.

Measurement priority

The whole European program is based upon the concept of increasing intensity of monitoring level. Within Level II, there is a set of core measurements to be carried out on all the monitoring plots (crown condition, soil chemistry, foliar chemistry, growth, ground vegetation), which should be supplemented by other measurements (deposition chemistry, meteorology and soil water chemistry) at a limited number of plots. It implicitely admits that the core measurements are more important then the others. Although it is easily understood that the cost is probably the most important reason for which the above ranking was done, yet one could questions its validity. The best example is meteorological measurement: this is a true basic information (a real core measurement) for many – if not all – investigations carried out at the monitoring plots. Yet, the meteorological measurements are limited to a reduced number of sites. For example, within the I&C evaluation, the paucity of meteo sites have been stressed also because meteo data are important to evaluate the effects of ozone. One could argue that meteo data can be available from many sources: however, temperature, precipitation and wind are subjected to such a strong spatial variation and – under complex terrain condition – data collected few kilometers apart may be not relevant to the target monitoring sites. This is particularly important for countries like Italy where mountains, hills and associated valley systems are easily the most frequent condition.

Location of measurements

When there are limitations to certain measurements like meteorology and they cannot be undertaken at each plot, the decision of which plot should be considerd is important. Should they be of the same main species (*e.g. PMPs* with beech) or should be they chosen regardless their composition? It is a decision similar to the location of monitoring plots in different ecosystems and has strong impact on the data analysis since it conditions the case:variable ratio for certain analyses.

Intermittent monitoring

The data series available up to date for the various investigation show a number of gaps: sometime an investigation or a particular index is missing at one year on all or part of the plots. This can be due to a variety of reasons (*e.g.* malfunctioning of meteo devices, problems in sampling deposition at certain sites, unsuited condition to estimate some crown indices,…). Intermittent monitoring is a problem for certain I&C analysis that needs consistent data series (*e.g.* meteo). Although it is always possible that technical problems cause loss of data, efforts should be placed in ensuring the continuous and consistent monitoring through time at a given site.

Perspectives

Updating of the I&C data set

A continuous update of the I&C data set is needed as soon as new data are collected, validated and processed. The I&C data set is not the collation of the dataset of specific investigations: rather, it is based on data that have been already processed and with which sinthetic indices are calculated. At the same time, the data about quality control will be update in order to keep track of the major source of uncertainty related to the data quality.

A process that is thought to be continuous and intimately connected to the update of the I&C data set is the review of the sinthetic indices. As the research progress and new findings will be available, more suited indices will be probably found. Thus, it may be necessary to back-calculate the new indices also for the previous data.

Updating the methods of the I&C evaluation system

While the I&C system has identifyed some methods to carry out the analyses needed, these methods are thought to be neither unique nor unchangeable. Rather, attention will be paid to review and possibly improve in *e.g.* statistical methods and approaches.

Review of the I&C evaluation system

Together with the methods, also the entire I&C system is thought to be periodically reviewed. Obviously, the review of the system cannot be done at each year: in this case there will be an impasse. The year 2005 could be seen as an appropriate deadline for reviewing the results provided by the I&C system.

Review of the monitoring program

The results and the analyses carried out within the I&C system may be of help also to have a feedback on the ability of the whole monitoring program to get its objectives. For example, the I&C evaluation may provide information about the value of certain measurement at certain sites or about the value of certain indices against others. These information may help the whole program to be more in line with its objectives.

Error model

Every investigation carried out at the *PMP* provides data which are affected by errors that originates from different sources, from the sampling tactic at the plot level, to observer errors, malpractice in sampling, contamination of samples and so on (Wagner 1995, Köhl *et al.* 2000). These errors can be either random or systematic, serious or negligeable but there is a clear need to try and quantify such error as much as possible. This is because there is the clear risk of error propagation into the various models we will adopt to analyse the data. Thus, a model to calculate an error budget should find a priority between the future activity of the I&C evaluation system.

The I&C evaluations in the period 2001-2005

In the period 2001-2005 the collection of data will make it possible to carry out a robust Risk Analysis (RA) for ozone, atmospheric deposition and meteorological stress. These analysis will be the major concern of the I&C for the next five years. Desirably, ozone would be the concern of the years 2001-2002, deposition of the years 2002-2003, and meteo of the years 2003-2004.

At the same time, some first attempt to carry out Status and Changes (S&C) and Nature of Change (NoC) will be possible, especially for *PMPs* with beech (*e.g.* the most frequent *PMPs* in Italy). These attempts could desirably take place in the year 2005.

The I&C evaluations in the period 2006-2010

In the period 2006-2010 it will be possible to have a comprehensive S&C and NoC analysis and to update and review the RA. Desiderably, the years 2006-2007 will be devoted to the S&C analysis, the years 2007-2008 to the NoC and the years 2008-2010 to review and update the RA.

Conclusions

First results obtained within the I&C evaluation system provide evidence of potential exceedance of nutrient nitrogen for the monitored forest ecosystems and of high ozone concentration. These are two of the issues planned to be covered in the next years, when the data availability will allow full evaluation of the risk at the monitoring plots. The I&C will desirably complete its first phase by the year 2005, when an internal review might probably take place. A second phase aimed to identify Status and Changes, Nature of Changes and up-date Risk Analysis is foreseen for the period 2005-2010.

Besides its technical value, the I&C evaluation system provides the chance for closer cooperation between scientists and program managers involved in the CONECOFOR monitoring program. This chance is actually used to identify problems in the monitoring set-up (both at national and international level), develop common position for negotiations during the meetings of the EC and UN/ECE forest monitoring program and to review and update data, findings and evaluation system according to the objective of the program.

References

Allavena S., Isopi R., Petriccione B., Pompei R., 1999 - *Programma Nazionale Integrato per il controllo degli ecosistemi forestali*. Ministero delle Politiche Agricole, Roma, Italia, 220 p.

EC-UN/ECE, 1998 - De Vries W, Reinds G. J., Deelstra H.D., Klap J. M., Vel E. M. – *Intensive Monitoring of Forest Ecosystems in Europe*, 2000 Technical Report. EC, UN/ECE 1998, Brussels, Geneva. 193 ps.

EC-UN/ECE, 1999 - De Vries W, Reinds G. J., Deelstra H.D., Klap J. M., Vel E. M. – *Intensive Monitoring of Forest Ecosystems in Europe*, 2000 Technical Report. EC, UN/ECE 1999, Brussels, Geneva. 173 ps.

Ferretti M., 2000 - *Concepts of the integrated and combined evaluation (I&C) evaluation system designed for the intensive monitoring of forest ecosystems in Italy*. In: Ferretti M. (ed.), “Integrated and Combined (I&C) evaluation of intensive monitoring of forest ecosystems in Italy – Concepts, Methods and First Results” Annali dell’Istituto Sperimentale per la Selvicoltura, Special Issue, anno 1999, 30: 7-16.

Ferretti M., Giordano P., Mazzali C., Nibbi R.,1999a - *Valutazione integrata e combinata (I&C) dei dati raccolti nelle aree permanenti di monitoraggio (APM) intensivo degli ecosistemi forestali in Italia*. Rapporto Fase 1. Università di Firenze, Dipartimento di Biologia Vegetale, Laboratorio di Botanica Forestale ed Applicata, Aprile 1999: 19 ps + Annexes 1-7.10.

Ferretti M., Giordano P., Mazzali C., Nibbi R., 1999b - *Valutazione integrata e combinata (I&C) dei dati raccolti nelle aree permanenti di monitoraggio (APM) intensivo degli ecosistemi forestali in Italia.* Rapporto Fase 2. Università di Firenze, Dipartimento di Biologia Vegetale, Laboratorio di Botanica Forestale ed Applicata, Luglio 1999: 30 ps.

Ferretti M., Giordano P., Mazzali C., Nibbi R., 1999c - *Valutazione integrata e combinata (I&C) dei dati raccolti nelle aree permanenti di monitoraggio (APM) intensivo degli ecosistemi forestali in Italia.* Rapporto Fase 3. Università di Firenze, Dipartimento di Biologia Vegetale, Laboratorio di Botanica Forestale ed Applicata, Aprile 1999: 27 ps.

Ferretti M., Bussotti F., Giordano P., Mazzali C., Nibbi R., 2000 - *Program CONECOFOR* – Integrated and Combined (I&C) Evaluation of Risk, Status and Changes of Forest Ecosystems. In: *SISEF,* Atti, 2: 435-440.

Gruppo di Esperti CONECOFOR-I&C, 1998 - *Valutazione integrata e combinata (I&C) dei dati raccolti nelle aree permanenti di monitoraggio (APM) intensivo degli ecosistemi forestali in Italia. Rapporto 0.* Internal report adoped at the meeting in Rome, 24 November 1998.

Köhl M., Scott C. T., Zingg A., 1994 - *Permanent monitoring plots: potential and limitations,* In: Innes, J. L. (Ed), Assessment of increment in permanent sample plots established to determine the effects of air pollution on forests, Proceed. of the Sopron workshop, August 28 to September 1, 1993, Sopron, Hungary, WSL/FNP: 17-24.

Köhl M., Traub B., Päivinen R., 2000 - *Harmonization and standardization in multi-national environmental statistics – mission impossible?* Environmental Monitoring and Assessment, 63: 361-380.

Wagner G., 1995 - *Basic approaches and methods for quality assurance and quality control in sample collection and storage for environmental monitoring.* The Science of Total Environment, 176: 63-71.

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