

The Integrated and Combined (I&C) evaluation system to detect status and trends of the CONECOFOR Permanent Monitoring Plots

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ABSTRACT

CONECOFOR is the Italian program for the intensive monitoring of forest ecosystems sponsored by the Ministry for Agricultural and Forest Policy and the European Commission. It is based upon a series of investigations carried out on 20 (27 from 1999) plots located throughout Italy. The investigations collect data on various ecosystem compartments (soil, ground vegetation, trees, atmosphere) and processes (atmospheric inputs, tree nutrition and growth). A major benefit of intensive monitoring programs is the opportunity they provide to organize integrated studies aimed at understanding the driving forces acting at the ecosystem level. In Italy, the Integrated and Combined (I&C) evaluation system within the CONECOFOR program involves 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. The I&C project involves scientists from many institutions; major emphasis is placed on the evaluation of data quality and precision. These are regarded as the basic steps in the whole project and a likely source of information about the suitability of the current sample sizes for providing a proper estimation of the parameters under consideration. The paper will provide information on the conceptual and methodological background of the I&C project

Key words: ecosystem monitoring, status, change, ozone, nitrogen

1. INTRODUCTION

Well-designed and properly implemented long-term monitoring programs are important in so far as they provide baseline data on natural resources, highlight changes, and permit the creation of a basis for long-term ecological research which is crucial to an understanding of the causes of changes (Bricker & Ruggiero 1998; Innes 1998; Spellerberg 1994). For this reason, the intensive and integrated monitoring of forest ecosystems currently being implemented in Europe (Kleemola & Forsius 2000; EC-UN/ECE 1998; Skjelvåle & Ulstein 1998), and similar programs carried out in North America (e.g. Vaughan *et al.* 2001), offer major opportunities for field ecologists. However, the understanding of how forest ecosystems function, and of their response to environmental factors, is a complex matter that needs robust design for site selection and data collection, long-term, good quality data on carefully selected indicators and appropriate data analysis and evaluation systems (Elzinga *et al.* 2001; Legendre & Legendre 1998). In these respects, while great care is generally devoted to identifying which measurements should be performed at the monitoring sites (a sort of "shopping list"), and which methods of measurement, much less attention is paid to design issues and data evaluation. For example, within the intensive monitoring of forest ecosystems in Europe established under the auspices of the Convention on Long-Range Transboundary Air Pollution (CLRTAP) and with the support of the European Union,

Expert Panels and working groups provide expertise for every investigation to be carried out. Unfortunately, despite their considerable importance (in strategic terms much greater than the individual investigations), no comparable effort has been devoted to design features and evaluation systems, which have not been subjected to the review of any Expert group. This is unfortunate for many reasons: (i) unclear design can lead to inconsistent criteria for site selection; (ii) inconsistency in site selection criteria may hamper the data evaluation; and (iii) suggested evaluation systems may either not cover the issues of concern or be inadequate to provide results at the level of individual countries, i.e. failing to provide policy relevant, robust information to decision makers (Ferretti 2000b). These are the reasons for which in 1998 the National Focal Centre (NFC) of Italy took the decision to develop a formal evaluation system to process and evaluate the data generated by the Italian intensive forest ecosystem monitoring program (whose Italian acronym is CONECOFOR) (Gruppo di Esperti CONECOFOR-I&C, 1998). The first step was to establish a Task Force (TF) for the integrated and combined (I&C) evaluation of intensive monitoring data which includes the team leaders of the various investigations carried out at the Permanent Monitoring Plots (PMPs) of the program. In this paper I will present an overview of concepts, definitions, methods and first outcomes of the I&C evaluation system. The system is termed Integrated and Combined (I&C) because it is an attempt (i) to integrate data on different indicators, col-

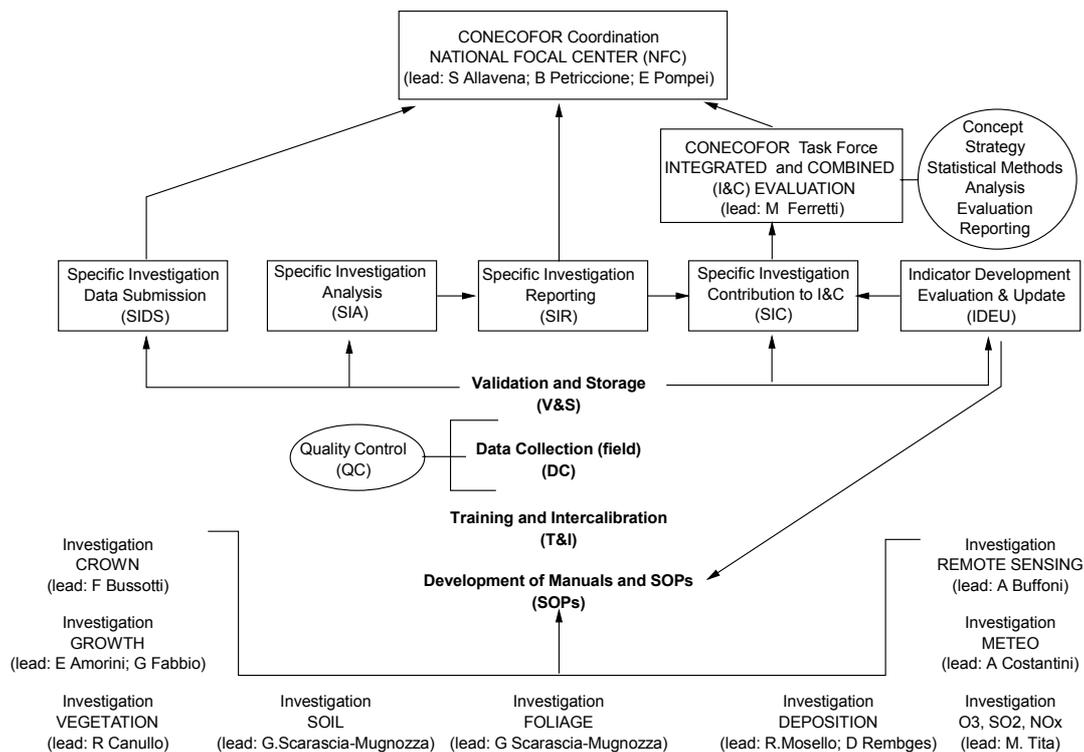


Fig. 1. The operational structure of the CONECOFOR program and the position of the I&C evaluation system.

lected according to different sampling regimes and to different metrics; and (ii) to combine different evaluation perspectives in a cohesive and consistent evaluation system. Detailed information has been published elsewhere (e.g. Ferretti *et al.* 2000b; Ferretti 2000a) and this paper will make extensive reference to the previous ones.

2. DEFINITION AND METHODS

2.1. Structure and position of I&C within the CONECOFOR program

A general scheme is provided in figure 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, training and intercalibration, data collection, quality control, validation and storage of data, data submission, analysis, and reporting. 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 can have a clear feedback on the standard operating procedures (SOPs). IDEU also plays an important role in the attempt to reduce the number of variables that can be used in the statistical analysis, thus improving the ratio between variables and cases.

2.2. The I&C evaluation system

A full use of monitoring data needs different approaches. In this context, three kinds of analysis were

identified to set up the I&C evaluation system (Fig. 2): (i) risk analysis (RA), (ii) ecosystem status and changes analysis (S&C), and (iii) nature of change analysis (NoC). Additional analyses will be explored in the future, with meta-analysis being of particular interest (e.g. Adams *et al.* 1997).

Risk analysis (RA) was 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.* 2000b), i.e. to identify whether the actual or potential exposure to pollutants can be actually or potentially dangerous to the forest ecosystem concerned. The RA suggested within the I&C has similarities with the Risk Assessment widely adopted and debated in the U.S. (Suter II 1990; Hunsaker *et al.* 1990; Power & 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

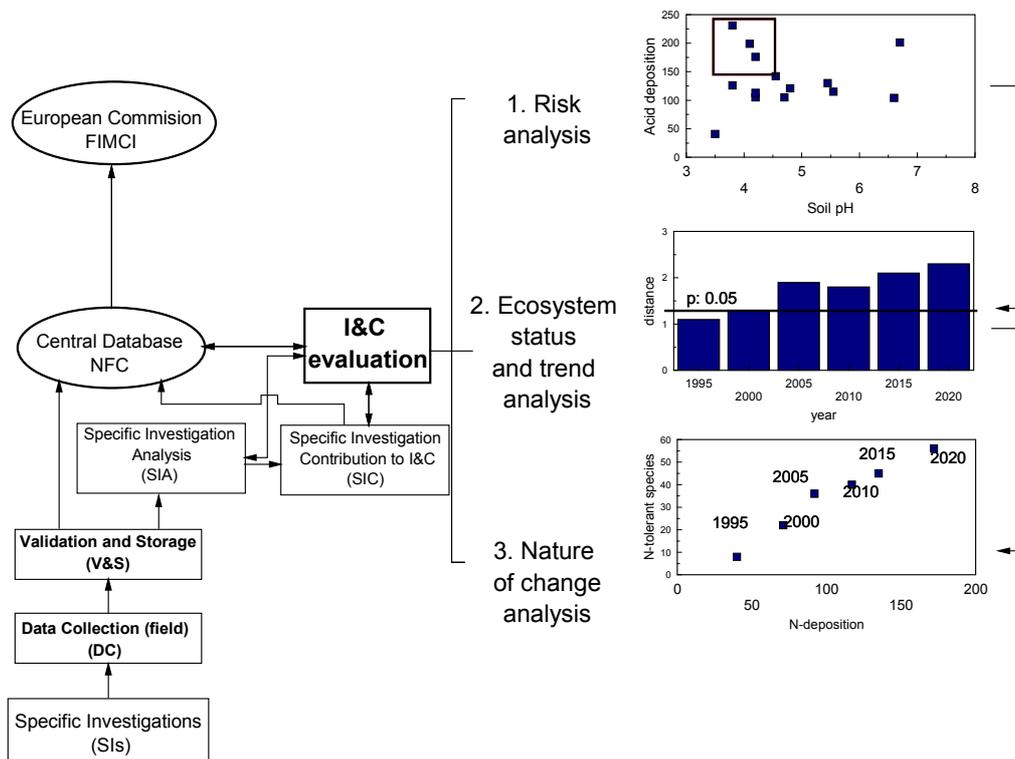


Fig. 2. The three analyses incorporated in the I&C evaluation. See text for further explanations.

Tab. 1. Stressor, type of effect, expected actions (examples), exposure and response indicators adopted for Risk Analysis.

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

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.* 2000b). For each of them, both acute and chronic effects are considered (Tab. 1). 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 & Freer-Smith 1995). Table 1 provides an overview of the stressors, examples of their expected actions, indicators of exposure to the given stressors and indicators of response.

The aim of the 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 an 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.* 2000b), or in relation to a defined target condition or management objective (e.g. Lundquist & 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

Tab. 2. Time series needed to explore relationship between deposition (assumed as stressor) and various response entities. (a): in many plots, deposition data starts in 1998, while soil- and growth survey are always in 1995 and 1996, respectively.

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

Tab. 3. Beech 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.

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

Lundquist & Beatty 1999; Johnson 1988) and then for forests (Lundquist & 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 & 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) 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 $X=(X_1, X_2, \dots, X_n)$ 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, \dots, X_n are used to identify the ecosystem status Y_1, Y_2, \dots, Y_k at any given year t_1, t_2, \dots, t_k and the distance between the status identified by the mean vector μ and each relevant year Y_1, Y_2, \dots, 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.* (2000c).

While RA and S&C are aimed at identifying risks and quantifying changes, the Nature of Change analysis (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 (exceedance of) N 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, with an evolution towards multiple regression. There are many exposure/predictors and response indicators/variables, and the choice of which to use will be made 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. This analysis will be used to integrate the data from individual PMPs through time, and it will take time to collect a sufficient number of cases to allow proper correlation (Tabs 2, 3).

All the above analyses can be performed independently, although it is easy to recognize connections between them: 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).

2.3. Indicators and indices

The number of indicators and indices adopted at a given PMP defines the intensity level of monitoring. 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, the 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

Tab. 4. Number of variables (number of mandatory indicators) according to the intensity level of monitoring. (a): considered defoliation, discoloration only; (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.

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

Tab. 5. 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. In brackets: number of plots inclusive of those selected/incorporated in 1999 and/or not operational yet.

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

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, and solar radiation as an index of the physical condition. The various papers in this issue of the journal can easily provide an idea as to the indicators and indices adopted by the monitoring program. 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).

2.4. Variables and cases

The whole I&C system is strongly limited by the unfavourable ratio between variables (many) and cases (few) (Ferretti 2000c) (Tabs 4, 5). A value of 4-5 is considered the minimum acceptable ratio between cases and variables in multivariate statistics. It is therefore important to define variables and cases explicitly. Within the framework of the I&C evaluation system a "variable" is a quantitative expression (either measured or calculated) of the index describing the status of a given indicator at a given PMP. 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 (Calabria 1) 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 depend-

ence 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. The latter especially will be considered when attempting to select the indices to be used as response-predictors in the model.

2.5. 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.* 2000b). Details on each of these issues are given by Ferretti & Nibbi (2000). In addition, the timing and the spatial allocation of the various investigations cause problems for data aggregation (Ferretti 2000c). 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.* 2000b). 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 have been 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 of ELs are given by Ferretti (2000c).

The "time window" is defined taking into account 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 over a given time window, and this is particularly relevant for the S&C. Details on time windows are given by Ferretti (2000c).

2.6. 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 of them. 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 (Tab. 3). As is obvious from table 3, 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 are not adequately considered.

2.6. 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 some time (Ferretti 2000c), but this does not mean that results will be not available for dozens of years. This is because the nature of the I&C 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 for the CONECOFOR PMPs (year 2000). Proper assessment of risks due to deposition will be addressed after five years of deposition data have been 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 priorities.

3. FIRST RESULTS

Some first results obtained by combining data from different investigations are reported below to show the potential effects of a few stressor categories among those measured at the Italian PMPs and to demonstrate the value of the S&C analysis.

3.1. Acidic and nitrogen deposition

Low soil pH (Alianiello *et al.* 2000) coupled with relatively high deposition rates (Mosello & Marchetto 2000) occurs in some plots (namely EMI1, PIE1) (Fig. 3). As an example, in figure 4 sulphur and nitrogen throughfall deposition for 1999 is plotted on a diagram showing the relevant critical load (CL) function based on the 5th, the 50th and the 95th CL values estimated for Italy (Posch *et al.* 1999). Figure 4 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. On the other hand, the 5th percentile CL function is frequently exceeded by 1999 deposition loads, thus suggesting that the most sensitive ecosystems may experience deposition rates exceeding their carrying capacity. However, the actual sensitivity of the PMPs (which differ in many characteristics) must be known in detail before any kind of statement can be made with certainty. For example, table 6 reports estimated CL values for acidity for the 1×1 km cell within which the PMPs are located and the deposition rates actually measured at the PMPs (Posch *et al.* 1999; Buffoni, pers. com.). Apparently, PIE1 is confirmed as receiving exceeding acidifying 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.

In figure 5 the critical load functions for nutrient N (5th, 50th and 95th percentile) are reported together with the deposition rates for each individual PMP. Both table 6 and figure 5 suggest that many PMPs may be at risk due to excessive N deposition. As an example, figure 6 reports the mean N concentration (1995-1999 period, Matteucci *et al.* 2000) 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 differ in many characteristics (e.g. Fabbio & Amorini 2000; Campetella & Canullo 2000), there is an apparently good relationship between N exceedance and foliar N (R^2 : 0.85).

3.2. Ozone

Ozone has been repeatedly reported as a dangerous air pollutant for plants (e.g. Fuhrer *et al.* 1997; Grünhage *et al.* 2001) and symptoms attributable to ozone have been reported on spontaneous vegetation in Italy (e.g., Gravano *et al.* 1999; Cozzi *et al.* 2000). Mean weekly ozone concentration at the various PMPs fluctuated year by year, with 1997 and 1999 displaying the highest values (Buffoni & Tita 2000). Potentially, there could be some risk due to ozone exposure (Fig. 7). For example, in 1999 mean weekly seasonal values were always above 40 ppb, suggesting that potentially high ozone doses will be available for the plants.

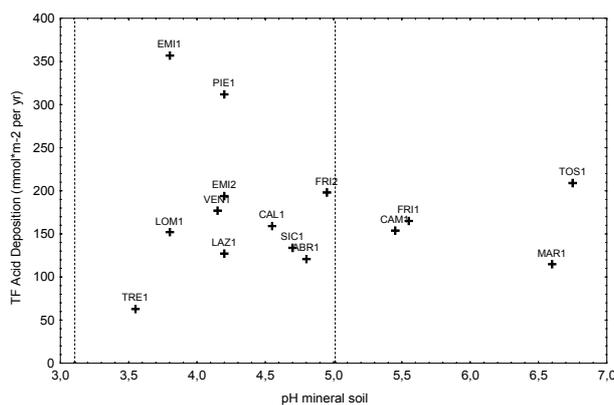


Fig. 3. Soil pH (mineral soil) and deposition of acidifying compounds in the throughfall in 1999 (Mosello & Marchetto 2000). Dotted lines identify the range of pH values believed to be sensitive to changes induced by acidic deposition (Riek 1999). The codes of individual PMPs are reported in the graph.

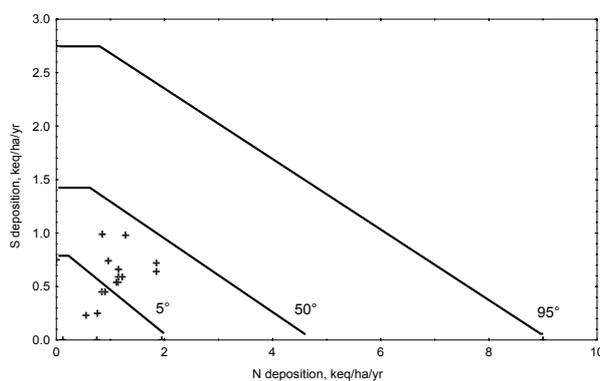


Fig. 4. Critical load functions for S and acidifying N at 5th, 50th, and 95th percentile for Italy (De Smet & Posch 1999) in 1999 (Mosello & Marchetto 2000). The 5th percentile can be considered as the load above which effects are likely to occur in the most sensitive ecosystems; on the other hand, the 95th percentile is the threshold above which the less sensitive ecosystems can be affected. Deposition rates at individual PMPs are reported.

Tab. 6. Critical loads for acidity and nitrogen estimated for the 1x1 km grid cells where the PMPs are located (after: de Smet & Posch 1999; Buffoni, pers. com.), actual deposition rates at the PMPs (1999) and potential exceedance. Data are reported in $\text{meq m}^{-2} \text{y}^{-1}$. (*) 1998 data; (**): only N-NH₃ and N-NH₄ considered.

PMP	Critical Loads		Deposition		Exceedance	
	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

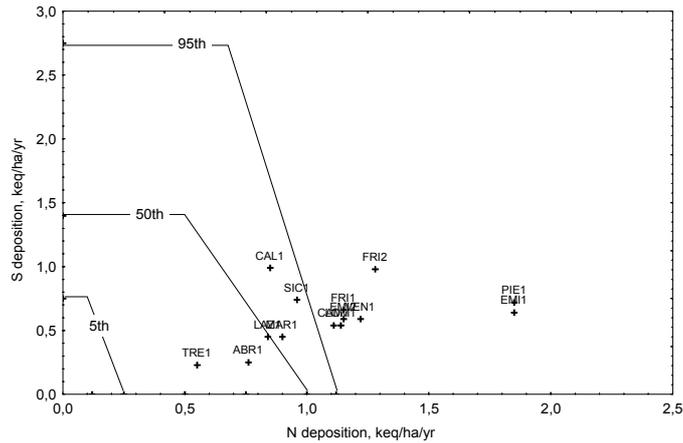


Fig. 5. Critical load functions for nutrient N for Italy (De Smet & Posch 1999) and throughfall deposition in 1999 (Mosello & Marchetto 2000). The 5th percentile can be considered as the load above which effects are likely to occur in the most sensitive ecosystems. On the other hand, the 95th percentile is the threshold above which the less sensitive ecosystems can be affected. Deposition rates at individual PMPs are reported.

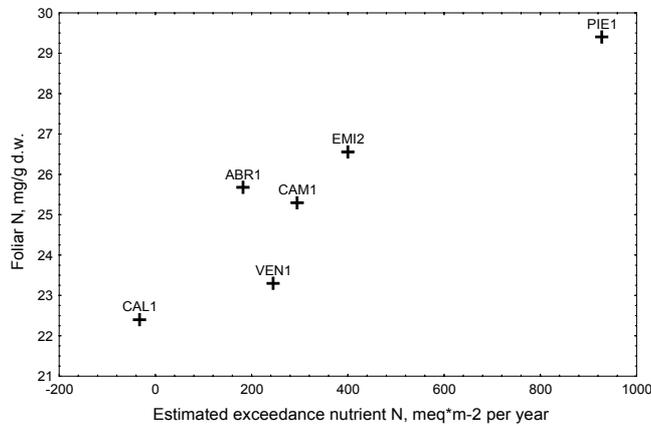


Fig. 6. Estimated exceedance of nutrient N at the beech PMPs plotted against the mean (1995-1999) foliar N concentration in beech leaves at the same PMP.

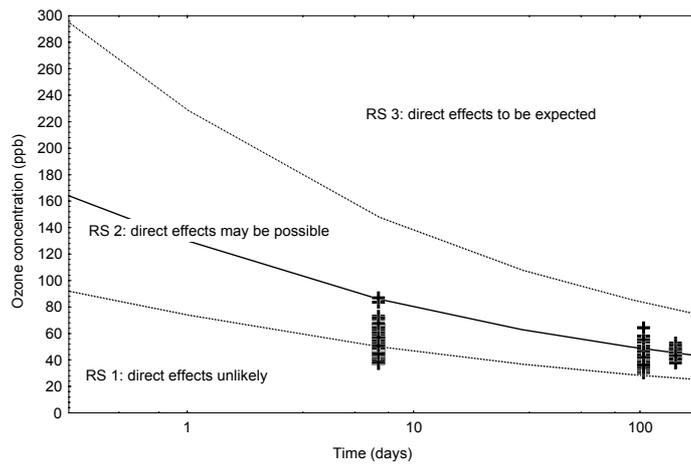


Fig. 7. Ozone concentration at individual PMPs for each individual year (1996, 1997, 1998 and 1999) plotted against different times of exposure: 7-days (maximum weekly average), 103 days (measurement period in 1996, 1997 and 1998) and 144 days (measurement period in 1999). The three different Risk Scenarios (RS) according to Grünhage *et al.* (2001) are reported.

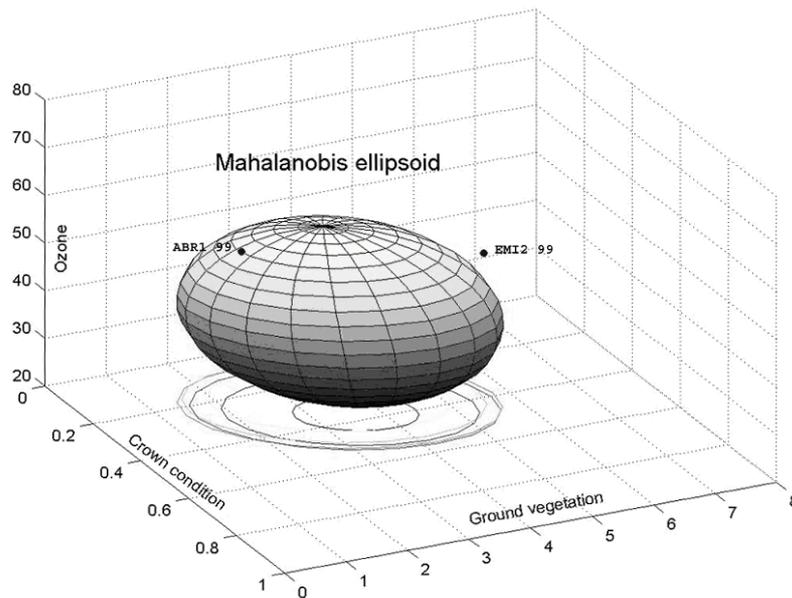


Fig. 8. 3D representation of the ellipsoid defining the status "close" to the mean and the cases which are "far", identified by the dots outside the ellipsoid.

However, the uptake of ozone by plants is controlled by many factors, with water stress being particularly important. For example, for similar levels of ozone concentration, the P-EPT (precipitation minus evapotranspiration) drought stress index varies between PMPs, suggesting that potentially different ozone fluxes may be occurring (Ferretti *et al.* 2000d). The P-EPT index does not account for soil moisture, so it has a number of limitations as an indicator of water stress (Amoriello & Costantini 2000), yet it could give an idea as to how the potential for ozone uptake may be influenced. 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). Ozone uptake depends also on tree age and within the PMPs of the CONECOFOR program there is a considerable 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.

3.3. Status and Changes

The status and changes of 5 beech PMPs in relation to crown, ground vegetation and ozone are illustrated in figures 8 and 9. Figure 8 shows the ellipsoid (average Mahalanobis distance plus 1.5 times the standard deviation) and the condition, which are "far" from the mean distance. The same data are reported in the time dimension in figure 9. In 1999 both ABR1 and EMI2 fall outside the limit. However, the reasons behind these facts are probably different for the two PMPs (Ferretti *et al.* 2000d). At ABR1, 1999 was the year with the highest ozone concentration (52.7 ppb) compared to the previous years and the other PMPs (Buffoni & Tita 2000). In

1999, this high concentration was coupled with a low value of Fisher alpha (Campetella & Canullo 2000). High ozone concentration was recorded also at EMI2 and CAM1 in the same year. However, apart from its ozone concentration, EMI2 deviates markedly from the overall situation mainly because of the high values of Fisher alpha (Tab. 2). Campetella & Canullo (pers. com.) suggests that this high value is due to an increase in the overall species diversity coupled with a simultaneous strong decrease in the number of individuals, which is nearly halved for both herbaceous and woody plants.

It is not easy to interpret the above data at the present time. The indices that caused deviation from the mean condition (ozone levels, ground vegetation diversity) seem to be particularly subject to short-term fluctuations. In this perspective, the observed deviations can be interpreted more in the sense of short-term "pulses" than as signals of an actual trend.

4 CONCLUSIONS

A summary of the achievements, problems and prospects emerging from the first phases of the I&C analysis is provided by Ferretti *et al.* (2000a). Achievements include cooperation between scientists and program managers, improved knowledge about actual and potential data quality and precision, the value, the pros and the cons of indicator/indices of ecosystem status, formulation of explicit hypotheses and lines of research, identification of potential problems related to atmospheric input (mainly N deposition and ozone) and evidence of fluctuation of ecosystem status and its deviation from the "common" dynamics.

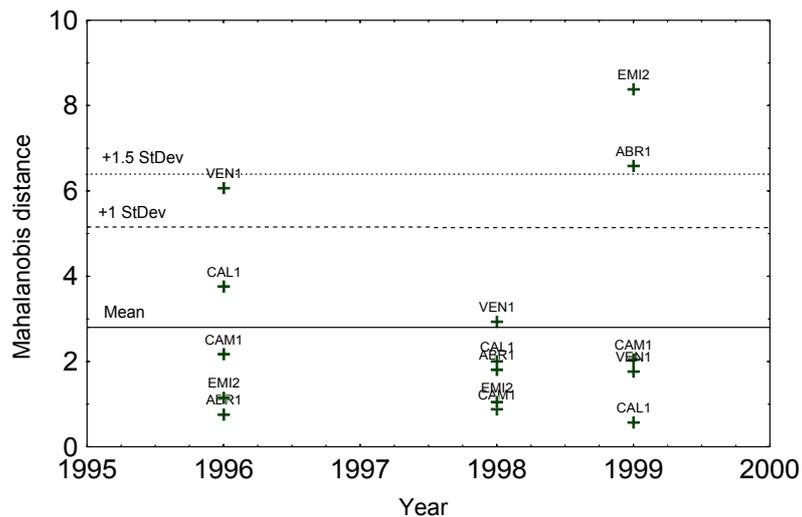


Fig. 9. Time trend of the values of the Mahalanobis distance for the beech PMPs. Mean distance and different limits (mean plus 1 time the s.d. and mean plus 1.5 times the s.d.) are reported.

Apart from the achievements, various problems can be identified with the I&C evaluation system, particularly problems with the original design of the network, in terms of site selection, measurement priority and allocation, and intermittent monitoring.

The future prospects of the I&C include two different activities: on one hand there will be a continuous update of the I&C data set, a review of the synthetic indices, a review of the entire I&C system and its contribution to the overall program review, and the construction of an error model. On the other hand, the I&C Task Force (2001) recently agreed on the nature of the next reports to be produced. Forthcoming reports (2002-2005) will be thematic and will deal with robust Risk Analysis (RA) for ozone, atmospheric deposition and meteorological stress. Vascular plant diversity and carbon stocks will be targeted over the same period. In the medium term (2006-2010) it will be possible to have a comprehensive S&C and NoC analysis and to update and review the RA.

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