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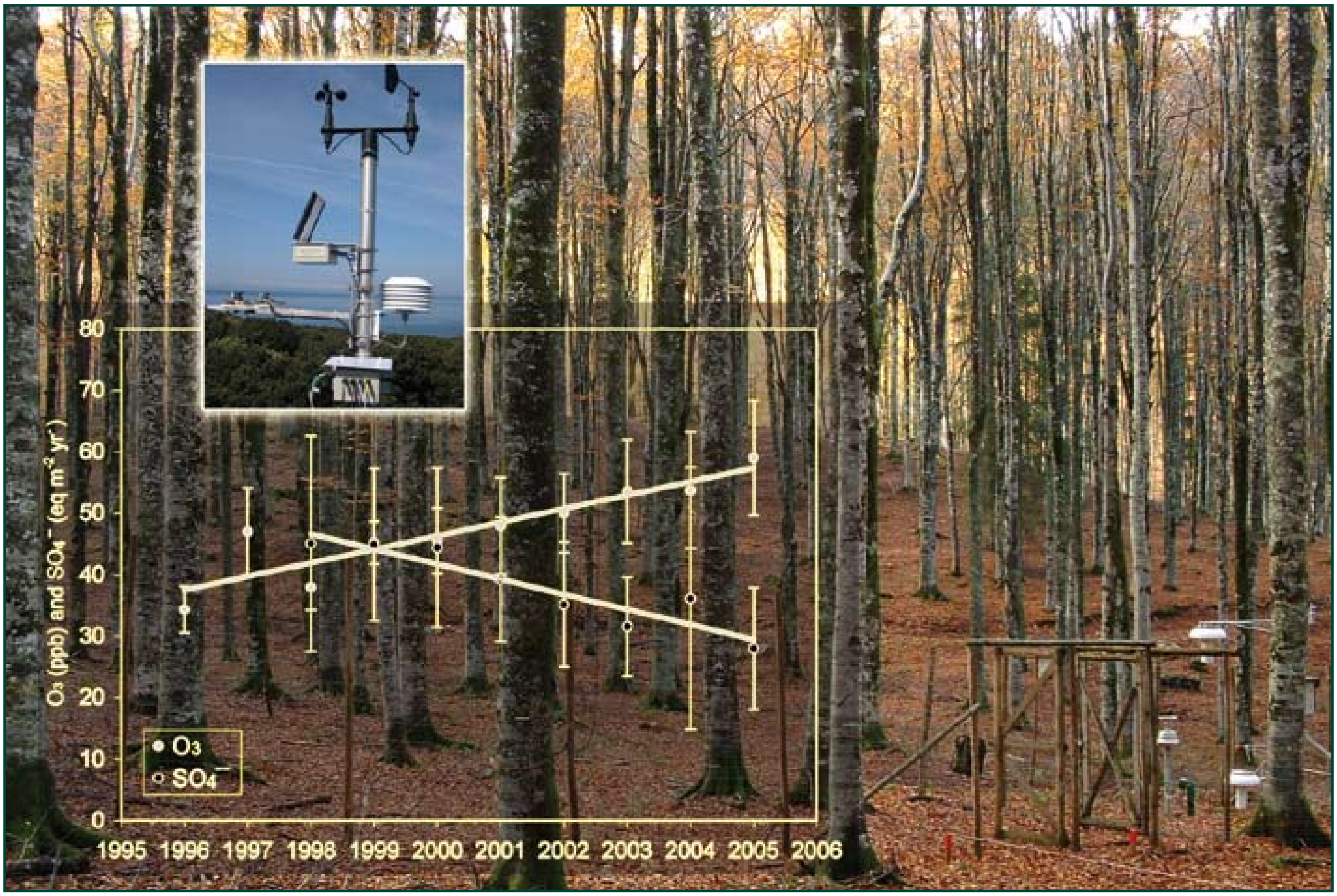

Status and changes 1995 - 2005

Arezzo Volume 34 2005 - 2006

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A N N A L I
C.R.A. - CENTRO DI RICERCA PER LA SELVICOLTURA

Special Issue on

ECOLOGICAL CONDITION OF SELECTED FOREST ECOSYSTEMS IN ITALY

Status and changes 1995 - 2005

Report 4 of the Task Force on Integrated and Combined (I&C) Evaluation of the CONECOFOR programme

F.D.C. 57: 524. 634: (450)

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 Union (EU) under the Regulation no. 2152/2003 " Forest Focus" and co-operate with the UN/ECE ICP-Forests and the UN/ECE ICP-Integrated Monitoring of Ecosystems. CONECOFOR is managed by Corpo Forestale dello Stato, Divisione 6ª, CONECOFOR Board, acting also as National Focal Center (NFC) of Italy within the EU and UN/ECE programmes.

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Contents

The CONECOFOR programme from 1995 to 2005

Bruno Petriccione[1]

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Abstract – Climate change, ozone effects on forests as well as the loss of biodiversity are nowadays the top priorities of environmental monitoring programmes in Europe. The first set of twenty Level II PMPs (Permanent Monitoring Plots) of the CONECOFOR programme was installed in 1995. At the moment, the intensive monitoring network includes 31 PMPs. All the plots were framed into the UN/ECE ICP-Forests; since 1998, 10 plots were also included into the UN/ECE ICP-IM as bio-monitoring sites. With the entering into force of EC Regulation Forest Focus, these new priorities found an EU legal basis for co-funding the related pilot projects, developed at trans-national level in the field of forest biodiversity monitoring: *ForestBIOTA* and *BioSoil.* In the frame of the EEA programme SEBI2010, a specific qualitative forest indicator has been developed by the Italian Forest Service. The Forest Status Indicator is based on sub-indicators identified and implemented at pan-European and National level, such as tree condition, forest structure, deadwood, plant species composition and naturalness, mostly available at European level and collected according to harmonized methods. In 2004, the Italian Forest Service (CONECOFOR Board) joined the Network of Excellence *ALTER-Net.* The participation to ALTER-Net gave the opportunity to Italy to become official member of the International Long Term Ecological Research Network (ILTER) in 2006: four LTER-Italy sites include forest environments and 10 research stations (plots) belong to CONECOFOR Level II network. At international level, CONECOFOR is the leader in *FutDiv* proposal (Future Forest Biodiversity Monitoring in Europe) and an associated beneficiary in the *FutMon* proposal (Further Development and Implementation of an EU-level Forest Monitoring System), already submitted under the EC Regulation LIFE+.

Key words: *forest management, CONECOFOR, biodiversity.*

Riassunto – Il programma CONECOFOR dal 1995 al 2005. Gli effetti dei cambiamenti climatici e dell'ozono troposferico, così come la perdita di biodiversità, sono divenute oggi le priorità assolute di tutti i programmi paneuropei di monitoraggio ambientale. Le prime venti aree di monitoraggio permanente di Livello II del Programma CONECOFOR sono state installate nel 1995. Oggi, la rete di monitoraggio intensivo comprende 31 aree. Tutte fanno parte della Rete UN/ECE-ICP Forests; a partire dal 1998, 10 aree sono state anche incluse nella Rete UN/ECE ICP-IM come siti di monitoraggio biologico. Con l'entrata in vigore del Regolamento (EC) Forest Focus, queste nuove priorità hanno finalmente trovato una base giuridica per il co-finanziamento dei relativi progetti pilota, sviluppati a livello trans-nazionale nel campo del monitoraggio della biodiversità forestale: *ForestBIOTA* e *BioSoil*. Nel quadro del programma dell'EEA SEBI2010, il Corpo Forestale dello Stato ha sviluppato uno specifico indicatore qualitativo. Il *Forest Status Indicator* è basato su sub-indicatori identificati ed applicati a livello pan-europeo e nazionale, come condizione delle chiome, struttura forestale, legno morto, composizione di specie vegetali e naturalità, generalmente disponibili a livello europeo e raccolti secondo metodi armonizzati. Nel 2004, il Corpo Forestale dello Stato (Ufficio CONECOFOR) ha contribuito alla costituzione del Network di Eccellenza *ALTER-Net*. La partecipazione ad ALTER-Net ha dato all'Italia la possibilità di diventare ufficialmente membro della Rete di Ricerche Ecologiche a Lungo Termine ILTER nel 2006: quattro siti LTER-Italia comprendono ambienti forestali e 10 stazioni di ricerca fanno parte della Rete CONECOFOR di Livello II. A livello internazionale, CONECOFOR è leader del progetto *FutDiv* (Futuro Monitoraggio della Biodiversità Forestale in Europa) e partecipa al progetto *FutMon* (Ulteriore Sviluppo ed Applicazione di un Sistema di Monitoraggio delle Foreste a livello di Unione Europea), già presentati nell'ambito del Regolamento (EC) LIFE+.

Parole chiave: *monitoraggio delle foreste, CONECOFOR, biodiversità.*

F.D.C. 524. 634: 180: (450)

Introduction

To better understand the current situation, it is important to recall the origin of the programme CONECOFOR (acronym from the Italian CONtrollo ECOsistemi FORestali, Forest Ecosystem Monitoring). CONECOFOR is the intensive monitoring programme of forest ecosystems in Italy: it was launched in 1995 and is managed from the very beginning by the Corpo Forestale dello Stato, CONECOFOR Board, acting also as Italian National Focal Center (NFC) within the EU and UN/ECE programmes. In fact, CONECOFOR is the Italian technical and scientific tool for the implementation of several EU and UN/ECE programmes: the EU policy for monitoring and protecting the European forest from the atmospheric pollution (EU Regulation n°. 1091/94 and n°. 2152/2003 Forest Focus, co-funding the Programme); the UN/ECE Convention on Long Range

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Trans-boundary Air Pollution (CLRTAP), ratified by Italy in 1982; and the Resolutions of the Ministerial Conferences on the protection of forests in Europe.

It is worth noting that the EU and the UN/ECE Programmes were launched as a response to the major concern generated by the air pollution effects on biota, including forest ecosystems. Today the overall picture has changed a lot: not only the concern about the effects of air pollutants on forests has been decreasing, but also the legal framework has changed and the knowledge gained originated a revision of the environmental priorities. Climate change, ozone effects on forests as well as the loss of biodiversity are nowadays the top priorities of environmental monitoring programmes in Europe and elsewhere. While CONECOFOR was considering these themes for from the very beginning, over the past ten years several changes have occurred in the structure of the programme.

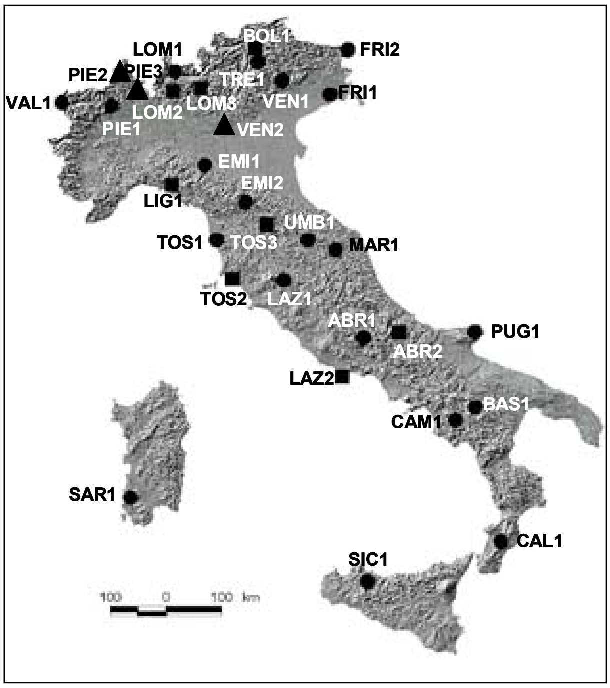


Figure 1 - The location of the Permanent Monitoring Plots of the CONECOFOR programme. Circles: PMPs operational within the programme since 1995; squares: PMPs that have joined the programme in 1999-2000; triangles: PMPs incorporated in 2002-2003.
Localizzazione delle aree permanenti di monitoraggio del programma CONECOFOR. I cerchi indicano le aree permanenti operative fino dal 1995; i quadrati indicano le aree incorporate nel 1999-2000; i triangoli quelle inserite nel 2002-2003.

Development and changes in the network structure

Permanent Monitoring Plots

The first twenty Level II Permanent Monitoring Plots of the CONECOFOR programme were installed in 1995 (Figure 1). A few of these plots were already existing, as they were installed on a regional basis during the 1980s and early 1990s, when only a national early-warning systematic network (the so-called Level I network) was operative. Between 1999 and 2003, the network's geographical and ecological coverage was improved, with the inclusion of eleven new plots in Northern and central Italy, including also forest types like holm oak and flood-plain forests, and high elevation spruce and larch forests. At the moment, the intensive monitoring network includes 31 Level II plots (Figure 1; Table 1). All the Level II plots were framed into the UN/ECE ICP-Forests (International Co-operative Programme for monitoring the effects of atmospheric pollution on Forests); starting from 1998, 10 plots were also included as bio-monitoring sites into the UN/ECE ICP-IM (International Co-operative Programme for Integrated Monitoring of the effects of atmospheric pollution on ecosystems).

Investigations

Figure 2 reports the progress of the "traditional" investigations on the original 20 plots installed in 1995. A clear increase in the number of investigations and plot coverage is obvious over the period 1995-2005. It is worth noting that most analyses presented in this report were based on the investigations and on the number of plots reported in Figure 2. On the other hand, Table 2 reports the investigations carried out at all the plots. In the future, new surveys belonging to the top priority areas (biodiversity and climate change) will be implemented at the selected core sites (see below), on larger areas like catchments, taking into account new scales of investigation and the relationship among different *ecocoenotopes* (landscape approach).

Expertise and CONECOFOR staff

Alongside with the changes in the investigations, the experts in charge for the "traditional" surveys have been complemented in the time by new experts in the field of biodiversity, climate change and landscape ecology.

Table 1 – Permanent Monitoring Plots (PMPs) of the CONECOFOR programme over the period 1995-2005. Asterisks indicate the PMPs incorporated in the ICP-IM. In brackets: cases of PMPs installed outside the CONECOFOR programme and subsequently incorporated in the programme. The report will concentrate mainly on the first 20 PMPs, *e.g.* those operational since 1995.
Aree permanenti del programma CONECOFOR nel periodo 1995-2005. Gli asterischi indicano le aree permanenti incorporate in ICP-IM. Tra parentesi: i casi di aree installate indipendentemente da CONECOFOR e successivamente incorporate nel programma. Il rapporto si concentrerà principalmente sulle prime 20 aree, cioè quella attive dal 1995.

PMP no.	Code	Lat	Long	Elevation (m a.s.l.)	Main tree species	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
1	*ABR1	415051	133523	1500	*Fagus sylvatica*	+	+	+	+	+	+	+	+	+	+	+
2	BAS1	403638	155225	1125	*Quercus cerris*	+	+	+	+	+	+	+	+	+	+	+
3	*CAL1	382538	161047	1100	*Fagus sylvatica*	+	+	+	+	+	+	+	+	+	+	+
4	CAM1	402558	152610	1175	*Fagus sylvatica*	+	+	+	+	+	+	+	+	+	+	+
5	*EMI1	444306	101213	200	*Quercus petraea*	+	+	+	+	+	+	+	+	+	+	+
6	*EMI2	440631	110700	975	*Fagus sylvatica*	+	+	+	+	+	+	+	+	+	+	+
7	FRI1	454734	130715	6	*Q.robur/Carpinus betulus*	+	+	+	+	+	+	+	+	+	+	+
8	FRI2	462928	133536	820	*Picea abies*	+	+	+	+	+	+	+	+	+	+	+
9	*LAZ1	424950	130010	690	*Quercus cerris*	+	+	+	+	+	+	+	+	+	+	+
10	*LOM1	461416	93316	1190	*Picea abies*	+	+	+	+	+	+	+	+	+	+	+
11	*MAR1	431738	130424	775	*Quercus cerris*	+	+	+	+	+	+	+	+	+	+	+
12	PIE1	454055	80402	1150	*Fagus sylvatica*	+	+	+	+	+	+	+	+	+	+	+
13	PUG1	414910	155900	800	*Fagus sylvatica*	+	+	+	+	+	+	+	+	+	+	+
14	SAR1	392056	83408	700	*Quercus ilex*	+	+	+	+	+	+	+	+	+	+	+
15	SIC1	375432	132415	940	*Quercus cerris*	+	+	+	+	+	+	+	+	+	+	+
16	*TOS1	433034	102619	150	*Quercus ilex*	+	+	+	+	+	+	+	+	+	+	+
17	*TRE1	462137	112942	1775	*Picea abies*	+	+	+	+	+	+	+	+	+	+	+
18	UMB1	432757	122757	725	*Quercus cerris*	+	+	+	+	+	+	+	+	+	+	+
19	*VAL1	454326	65555	1740	*Picea abies*	+	+	+	+	+	+	+	+	+	+	+
20	VEN1	460326	120156	1100	*Fagus sylvatica*	+	+	+	+	+	+	+	+	+	+	+
21	ABR2	415409	142100	980	*Q. cerris/C. betulus/Abies alba*								+	+	+	+
22	LAZ2	415051	133523	190	*Quercus ilex*								+	+	+	+
23	LOM2	455726	100753	1150	*Picea abies*		(+)	(+)	(+)	+	+	+	+	+	+	+
24	LOM3	455441	93017	1250	*Fagus sylvatica*					+	+	+	+	+	+	+
25	TOS2	425212	104634	30	*Quercus ilex*	(+)	(+)	(+)	(+)	+	+	+	+	+	+	+
26	TOS3	434418	113422	1170	*Fagus sylvatica*	(+)	(+)	(+)	(+)	+	+	+	+	+	+	+
27	*BOL1	463516	112604	1740	*Picea abies*	(+)	(+)	(+)	(+)	(+)	+	+	+	+	+	+
28	LIG1	442410	92730	1290	*Fagus sylvatica*							(+)	+	+	+	+
29	PIE2	453129	84234	135	*Quercus robur, Carpinus betulus*											+
30	PIE3	461958	81650	1860	*Larix decidua*											+
31	VEN2	451203	104408	60	*Quercus robur, Carpinus betulus*											+

In the early 2000s, the central coordination team CONECOFOR has been enforced with new staff members, from the forestry and ecology sectors. Nowadays, the team is able to directly manage project preparation and implementation in many field of long-term forest and ecosystem monitoring.

Staff members and experts have meetings two- to three times per year within the frame of the Task Force for the Integrated and Combined Evaluation of the CONECOFOR data.

Products

The huge amount of data collected in the first 10 years of CONECOFOR activity has been the basis for publishing several scientific reports, elaborated through a joint collaboration among all researchers participating to the CONECOFOR activities, under the Task Force for the Integrated and Combined Evaluation CONECOFOR.

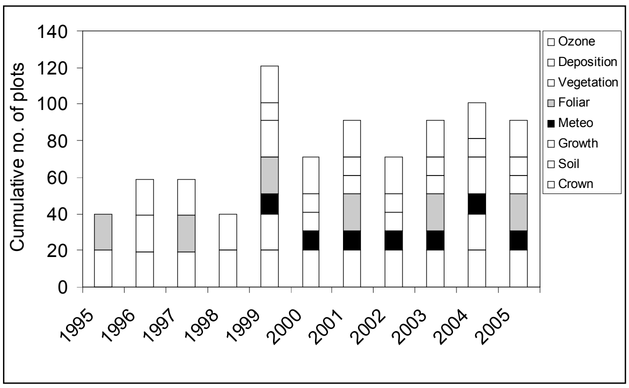


Figure 2 - The cumulative number of plots (sum of the plots operational for each investigation) over the period 1995-2005.
Numero cumulato di aree (somma delle aree attive per ogni indagine) nel periodo 1995-2005.

A synthetic report describes the scientific activities in place in the CONECOFOR Level II network (Mosello *et al.* 2002), whereas three reports are based on the Integrated & Combined evaluation of data (Ferretti

Table 2 – Investigation categories carried out at the PMPs of the CONECOFOR programme. In brackets: cases of investigations formerly undertaken outside the CONECOFOR programme. Note: individual investigations may have covered only part of the 1996-2005 period. Details about the nature of the various investigations are provided by Petriccione and Pompei (2002), Ferretti (2000) and Ferretti *et al.* (2003, 2006)
Categorie di indagini condotte presso le aree permanenti del programma CONECOFOR. Tra parentesi: indagini iniziate prima dell'incorporazione nella rete CONECOFOR. Nota: alcune indagini possono non avere coperto l'intero periodo 1995-2005. I dettagli sulla natura delle varie indagini sono riportati da Petriccione e Pompei (2002), Ferretti (2000) e Ferretti et al. *(2003, 2006).*

PMP no.	Code	Site data	Tree cond.	Soil chem.	Foliage chem.	Forest structure tree growth	LAI	Litterfall	Ground vegetation	Deposition chem.	Ozone meas.	Meteo meas.	Remote sensing	Lichens	Deadwood	Insects	Naturalness	Landscape
1	ABR1	+	+	+ (1)	+	+	+	+	+	+	+	+	+				+	
2	BAS1	+	+	+	+	+		+	+		+		+					
3	CAL1	+	+	+	+	+	+	+	+	+	+	+	+		+	+		
4	CAM1	+	+	+	+	+		+	+	+	+		+					
5	EMI1	+	+	+	+	+	+	+	+	+	+ (3)	+	+	+				
6	EMI2	+	+	+	+	+	+	+	+	+ (2)	+	+	+					
7	FRI1	+	+	+	+	+	+	+	+	+	+ (3)		+					
8	FRI2	+	+	+	+	+	+	+	+	+ (2)	+	+	+	+			+	
9	LAZ1	+	+	+ (1)	+	+	+	+	+	+ (2)	+	+	+					
10	LOM1	+	+	+	+	+	+	+	+	+	+	+	+	+			+	
11	MAR1	+	+	+	+	+	+	+	+	+	+		+					
12	PIE1	+	+	+	+	+	+	+	+	+ (2)	+	+	+					
13	PUG1	+	+	+	+	+	+	+	+		+ (3)		+					
14	SAR1	+	+	+	+	+	+	+	+		+ (3)		+		+	+		
15	SIC1	+	+	+	+	+	+	+	+	+	+		+		+	+		
16	TOS1	+	+	+	+	+	+	+	+	+	+ (3)	+	+	+			+	
17	TRE1	+	+	+	+	+	+	+	+	+	+	+	+	+			+	+
18	UMB1	+	+	+	+	+	+		+		+		+					
19	VAL1	+	+	+	+	+	+	+	+		+ (3)	+	+					
20	VEN1	+	+	+	+	+	+	+	+	+	+	+	+	+				
21	ABR2	+	+			+			+		+				+	+	+	
22	LAZ2	+	+			+			+		+						+	
23	LOM2	+	+	(+)	+	+			+	+	+							
24	LOM3	+	+		+	+			+	+	+	+						
25	TOS2	+	+	(+)	+	+	+	+	+	+	+	+		+			+	
26	TOS3	+	+	(+)	+	+	+	+	+	+	+							
27	BOL1	+	+	(+)	+	(+)	(+)	(+)	+	+	+	+					+	+
28	LIG1	+	+	(+)	(+)				+	+	+	+						
29	PIE2	+	+						+		+							
30	PIE3	+	+						+	+	+							
31	VEN2	+	+						+		+							

(1) plus soil solution chemistry
(2) plus streamflow chemistry
(3) plus SO_2

2000, Ferretti *et al.* 2003, 2006)

As concerns the biodiversity issues, a specific report prepared by the Italian Forest Service (CONECOFOR Board) has been published by the European Environment Agency (Forest Status Indicator, Petriccione *et al.* 2007).

Changes in concerns and legal framework

The effects of atmospheric pollution, and particularly of atmospheric deposition, on forests was of major concern at the beginning of programme. This reflected the situation at European level. A first element of change was that in Italy ozone was incorporated in the monitoring activity since the very beginning in 1996. It makes now possible to analyse the trend of ozone concentrations over a 10 years period and the CONECOFOR has already produced a national thematic report on ozone (Ferretti *et al.* 2003), as well as reports about international projects (Ferretti *et al.* 2004; Bussotti and Ferretti 2007).

The diversity of vascular species and of the forest structure were incorporated in the monitoring since 1996. However, biodiversity activity has increased since 2003, with the start of new surveys on invertebrates, lichens, deadwood and naturalness and the consideration of the landscape perspective. During this test-phase (Petriccione 2004), a high value for nature conservation was discovered: community interest or priority habitats and species occur on 8 out of 12 plots, according to the Habitat Directive (EEC) n. 92/43. This activity has allowed a report to be published by 2006 (Ferretti *et al.* 2006).

In the early 2000s, priorities of CONECOFOR activities were re-oriented towards national and international projects and initiatives with the final aim to establish a pan-European network for biodiversity monitoring. These initiatives aim at the assessment of progress towards the target of halting (or reducing) the loss of biodiversity by 2010, as requested by the UN Convention on Biological Diversity, the UN Framework Convention on Climate Change (both ratified by Italy in 1994) and the EU policy instruments for their implementation, like the EU Commission Communication COM(2006)216 (European Commission 2006) and the EEA SEBI2010 process (Streamlining European Biodiversity Indicators by 2010, EEA 2006). With entering into force of EC Regulation no. 2152/2003 Forest Focus, these new priorities found an EU legal basis for co-funding the related pilot projects, developed at trans-national level in the field of forest biodiversity monitoring: (i) *ForestBIOTA*, a joint project carried out in 2004-2005 by 12 European Countries, based on 107 EU/ICP Forests Level II permanent plots, collecting data on four main biodiversity indicators in a standardized way (BFH 2004) and (ii) *BioSoil*, a joint project undertaken in 2006-2007 by 21 European Countries, based on ca. 4000 EU/ICP Forests Level I systematically placed plots, collecting data on three main biodiversity indicators in a standardised way (JRC 2006).

Very recently, in the frame of the EEA programme SEBI2010, a specific forest qualitative indicator, taking into account status and trends of key characteristics of forest ecosystems, has been developed by the Italian Forest Service (Forest Status Indicator, FSI, PETRICCIONE 2007; PETRICCIONE *et al.* 2007). FSI is based on sub-indicators identified and implemented at pan-European and national level, such as tree condition, forest structure, deadwood, plant species composition and naturalness, mostly available at European level and collected according to harmonized methods (EU pilot projects *ForestBIOTA* and *BioSoil*, EU Forest Focus & UN/ECE ICP Forests and ICP IM, National Forest Inventories). Changes in time and "distance" from a defined target or other reference values can be easily recognized by the change in shape of the applied "radar" diagrams (Figure 3).

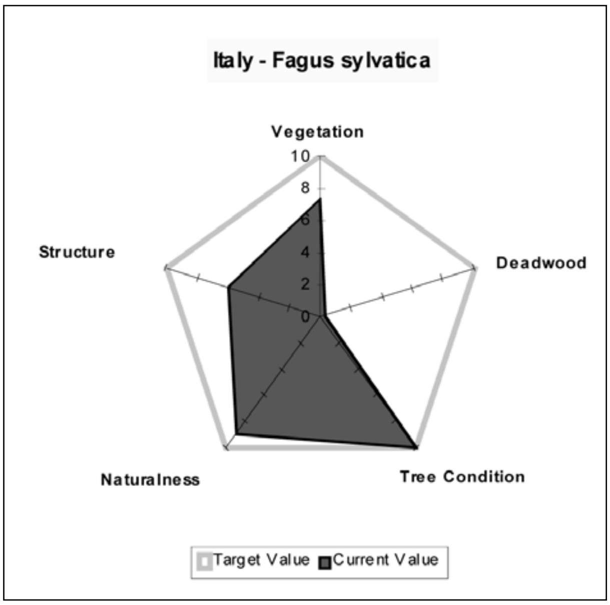
Perspectives

Extending co-operation and shifting from monitoring to research

In 2004 the Italian Forest Service (CONECOFOR Board) joined the *ALTER-Net* Network of Excellence (A Long-Term international research Network on ecosystems, for action and awareness on biodiversity, ALTER-Net 2007), a large EU co-funded consortium of 24 research bodies from 17 EU Member States. ALTER-Net aims to (i) develop an integrated a pan-European Long-Term Ecological Research Network; (ii) develop appropriate research following harmonized methods in the field of biodiversity and climate change and (iii) develop methodological tools for improving public awareness and European policies as concerns biodiversity protection.

The participation to ALTER-Net gave to Italy the opportunity to become official member of the International Long Term Ecological Research Network (ILTER) in 2006. A long lasting both scientific and organizational process, starting in the 1990s at national level, brought Italy to get to that important objective. Through communication issues, selection criteria and activities, several researchers and scientists coming from public Agencies, Universities and research Institutions were involved in order to spread information about the initiative and search for suitable research sites to be included in the Network. A managing structure for the Network was created: the National Forest Service (CONECOFOR Board) was involved in the LTER-Italy Network start up since the very beginning as well and is even now in charge for the national overall co-ordination. During 2005, through several internal meetings, the national Steering Committee of the Network started to analyse the proposed sites and the ongoing research activities within them. In 2006 a rank list of Italian sites was produced. Among those, suitable sites were finally selected with the scientific revision of external experts: at the moment, LTER-Italy consists of an integrated group of 17 sites

Figure 3 – Examples of polar diagram based on same sub-indicators of Forest Status Indicator (from PETRICCIONE *et al.* 2007).
Esempio di diagramma polare basato sugli stessi sotto-indicatori del Forest Status Indicator (da PETRICCIONE et al. *2007).*



developing long-term ecological research. Admitted sites represent all main ecosystem types (forest, freshwater, marine, alpine, *etc.*). Sites are linked each other by ecological and bio-geographical similar traits and may include more than one research station. Four sites include forest environments ("Forests of the Alps", "Forests of the Apennines", "Mediterranean forests" and "Lowland forest"): 10 research stations (plots) belong to the CONECOFOR Level II network (BREDEMEIER *et al.* 2007; CORPO FORESTALE DELLO STATO 2007a).

Integration among monitoring networks

Alongside the development of the Level II network (see above), two major processes took place. Firstly, 240 Level I sampling "points" have been transformed into "plots" (2500 m^2), through the recent implementation of the pilot project *BioSoil*. Secondly, there is an ongoing process of integration between Level I and the National Forest Inventory (NFI), the latter being based on a probabilistic sampling design. A trend towards an integration among the three networks (Level I, Level II, NFI) is being developed. In this framework, a re-organization of the Level II network will be implemented, selecting 11 very intensive "integrated monitoring core sites" (with even more intensive and additional surveys at larger scale), 11 "Level III sites" (with all "traditional" surveys implemented) and 9 "regular" Level II plots.

Seeking for new funding routes

The specific EU co-funding legal tools in the field of forest monitoring were not extended over the end of 2006, the deadline of the last dedicated EC Regulation no. 2152/2003 Forest Focus. CONECOFOR is now going to apply to the new EC Regulation no. 614/2007 concerning the Financial Instrument for the Environment LIFE+. The CONECOFOR board decided to participate in some proposals: two at International level, one national. At the international level, CONECOFOR is leader in the *FutDiv* proposal (Future Forest Biodiversity Monitoring in Europe) and an associated beneficiary in the *FutMon* proposal (Further Development and Implementation of an EU-level Forest Monitoring System). At national level, CONECOFOR is associated beneficiary in the FORCLIMATE proposal (Atmospheric Drivers and Forest Response to Climate along Nitrogen and Ozone Gradients - Reliability of Model Predictions).

In particular, the FutDiv proposal has been submitted with the aim to include a harmonized system for long-term biodiversity monitoring and to provide prompt responses to the requirements of the EU policies for the implementation of the UN Convention on Biological Diversity. Italy will be the leading Country of 14 Member States, including National Forest Inventories (NFIs), Level I and Level II networks, IM and LTER sites all over Europe (CORPO FORESTALE DELLO STATO 2007b).

This report

On the basis of the data collected over the period 1995-2005, this report aims to investigate if, and at what extent, changes that invariably occur in our forests ecosystems are somewhat directional. The various papers will cover the analysis of data derived from the biological components of the ecosystems (tree condition, growth and mortality; species richness and diversity), the chemical characteristics (deposition chemistry, soil solution chemistry, tropospheric ozone), and the meteorological measurements. Further information will cover the changes at landscape level. An integrated evaluation will be developed, attempting to summarize the actual results of changes in individual attributes. In the final chapter, a synthesis will be provided.

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Status and trend of tree growth and mortality rate at the CONECOFOR plots, 1997-2004

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Abstract – The circumference of trees in the CONECOFOR permanent monitoring plots (PMPs) were measured by three surveys carried out in 1997, 2000 and 2005. Plots were arranged into forest types according to tree species, management system and stand structure: beech (*Fagus sylvatica* L.) and spruce (*Picea abies* K.) high forests, aged coppice forests and transitory crops (deciduous, evergreen oaks and beech). Diameter distribution, basal area, basal area increment, tree mortality rate and in-growth were calculated per layer (dominant, intermediate, dominated) within each PMP, to point out relative contributions and changes. A range in relative annual growth was detected both within and between types over the monitored period, but an obvious reduction of annual increment was found in two/thirds of plots over 2000-04 as compared to 1997-99. Current mortality, mostly allocated into the dominated and intermediate layers, can be explained as "regular" due to overstocking and high inter-tree competition in almost all of the observed case-studies. Opposite patterns were found to occur as for stand growth vs. mortality rate between coppice forests and the other types owing to the different dynamics of tree competition in progress. Drought 2003 is the likely large-scale factor determining the reduced annual growth course over the second period.

Key words: *forest monitoring, basal area, growth rate, growth trend, tree mortality.*

Riassunto – Stato e andamento dell'accrescimento arboreo e della mortalità nel periodo 1997-2004 nelle aree CONECOFOR. Sono esaminati l'accrescimento ed il suo andamento attraverso i due intervalli 1997-99 e 2000-04 definiti dagli inventari 1997, 2000 e 2005. L'insieme delle aree è stato ordinato per tipi forestali in funzione di specie componenti, forma di governo e struttura del soprassuolo in fustaie di faggio (*Fagus sylvatica* L.) e abete rosso (*Picea abies* K.), cedui invecchiati ed in avviamento di querce caducifoglie, sempreverdi e di faggio. I dati di accrescimento sono stati calcolati per area e stratificati nei piani (dominante, intermedio, dominato) corrispondenti ai differenti ambienti di crescita nella struttura del bosco. Obiettivo dell'analisi è identificare i cambiamenti nella distribuzione diametrica, nell'incremento annuale e allocazione dell'area basimetrica, nell'incidenza e collocazione della mortalità a ciascun inventario, per area e piano. I dati evidenziano sia la variabilità nei tipi e fra i tipi monitorati, che la riduzione di accrescimento medio su due terzi delle aree nel periodo 2000-04 rispetto al periodo precedente 1997-99. La mortalità corrente, prevalentemente localizzata nei piani dominato ed intermedio, può essere attribuita alle elevate densità e quindi alla competizione interindividuale nella quasi totalità dei casi esaminati. Andamenti opposti sono stati determinati nel rapporto accrescimento-mortalità tra il ceduo e le altre tipologie per il diverso modello di competizione realizzato. Il periodo secco registrato nell'anno 2003 è il probabile fattore di larga scala determinante la riduzione dell'accrescimento medio nell'intervallo 2000-04.

Parole chiave: *monitoraggio delle foreste, area basimetrica, livello di accrescimento, andamento dell'accrescimento, mortalità.*

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Introduction

Tree growth refers to an increase in size that can be measured in length, diameter or weight. "Increment" is the increase in size of an element within a defined time interval (Bertalanffy 1951 in Prodan 1968). These definitions of growth and increment can be applied also to tree populations (Prodan *op. cit.*). Tree growth processes can be ranked by order of importance in foliage growth, root growth, bud growth, storage tissue growth, stem growth, growth of defence compounds and reproductive growth (Waring 1987 in Dobbertin 2005). Growth and growth allocation are individual (tree) attributes and result after the interaction between the biological, chemical and physical compartments of the ecosystem. They include age, genotype, adaptive ability, available growing space, site conditions, as well as the action of biotic, abiotic and anthropogenic disturbances and management. Radial stem growth is sensitive to

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factors acting in the short as well as in the long-term. Within a population (a hierarchical set of interacting organisms), inter-individual competition (Barclay and Layton 1990; Spiecker 1995) and climate (Le Goff and Ottorini 1993) may become the prevailing constraints originating either a reduced growth and/or a "regular" mortality (*sensu* Oliver and Larson 1990), at least on a part of tree population and on a year-to-year basis. Impacts of environmental factors on tree growth are known to change gradually across altitudinal, latitudinal and longitudinal gradients (Mäkinen *et al.* 2002) and therefore the synergism between driving forces depends also on locally limiting factors. For instance, the increase of average air temperature and the contemporary occurrence of severe droughts may become a heavy stressor to tree growth in low elevation sites in Southern Europe, while the reverse can be true for high elevation sites and/or Northern countries. For these reasons, measured increment at subsequent times on the same Permanent Monitoring Plot (PMP) provides the record of growth rates and is essential in forest monitoring to allow to a proper evaluation of the condition of forests through time (Dobbertin *et al.* 2000).

An unexpected (in relation to the foreseen forests decline in the early 1980s), positive shift in growth rates was detected at individual tree and stand level across central Europe and Southern boreal zone in the last 50 years (Spiecker *et al.* 1996). The consensus of the extensive literature is that the environmental forcing agents most likely to cause increased forest growth rates were: CO_2 and N fertilisation, changes in temperature or rainfall (Mcguire *et al.* 1995; Thornley and Cannell 1996; Briffa *et al.* 1998 in Hunter and Schuck 2002; De Vries *et al.* 2006; Magnani *et al.* 2007). Higher current growth rates have been reported for a few target European tree species by Lorentz *et al.* (2004). Nitrogen deposition appeared to be the main cause of the observed growth increase (EFI 2002 in Dobbertin *op. cit.*).

An exhaustive analysis of factors involved in the increased forest growth in Europe is given in Hunter and Schuck (*op. cit.*); the authors emphasise the less intensive exploitation of forest resources, namely wood harvesting, forest floor use (*i.e.* litter raking, livestock grazing …) occurred over the last decades throughout Europe. The action of a more limited pressure on forests and the resulting recovery of improved management conditions may have contributed to the monitored increase in tree growth rates, besides the mentioned emerging factors. This background is particularly relevant to the Mediterranean region, where a much longer and severe extensive exploitation of forests has been historically undertaken. Here, the suspension of harvesting at regular rotations into a share of coppice forest and the reduction of silvicultural practices (thinnings and regeneration cuttings) into high forest, has been even more drastic than in other countries. This generalized condition, already in progress since a few decades, shows anyway controversial effects as for forest growth rate.

The paper investigates tree growth at 20 PMPs in Italy (see Petriccione, this volume) over 1997-2004. During this time, three measurements were carried out over the dormant season in 1996-97, 1999-00 and 2004-05. The paper aims at answering the following questions:

(i) which are the growth rates over the observed time-window?
(ii is there any significant difference between dbh distributions at the three inventories?
(iii) how much is the basal area allocated in the different tree layers (dominant, intermediate, dominated) at each inventory?
(iv) is there any change in the annual basal area increment from the first to the second growth period?
(v) which are the mortality rates and where is tree mortality allocated at each measurement time?

Materials and methods

Dataset

The database is made up of 24 PMPs: 20 established since 1997, 2 entered officially the network in 2000 but formerly framed within a regional monitoring programme, 2 measured since 2000 onwards. Site and stand characteristics have been reported in previous papers (Fabbio and Amorini 2000 and 2002; Alianello *et al.* 2003).

The main discriminants between the PMPs were the management system, structure, tree species, stand age (see Chapter 1) (Table 1): seven plots were aged coppice forests, six plots were transitory crops, *i.e.* coppice stands undergoing conversion into high forest by periodical thinnings; eleven plots were high forests. Stand age in the dominant storey varied from 45 to 85 yrs (coppice forests and transitory crops) and from

Table 1 - Descriptive statistics of dbh distribution (cm) at the various PMPs, survey 2004-05.
Statistiche descrittive della distribuzione diametrica (cm) all'inventario 2004-05.

PMP	main tree species	forest type	age	dbh 2004, percentiles 25	50	75	CV	Skewness
ABR1	*Fagus sylvatica*	*High forest*	*120*	8.4	20.1	32.0	59.5	0.300
BAS1	*Quercus cerris*	*Transitory crop*	*70*	15.2	24.2	34.2	47.5	0.338
CAL1	*Fagus sylvatica*	*High forest*	*120*	28.0	39.2	54.3	44.5	-0.254
CAM1	*Fagus sylvatica*	*High forest*	*110*	41.7	51.1	58.7	28.8	-0.305
EMI1	*Quercus spp.*	*Stored coppice*	*55*	3.8	4.9	14.6	91.5	1.575
EMI2	*Fagus sylvatica*	*Stored coppice*	*55*	5.7	9.2	15.0	55.8	0.742
FRI1	*Mixed broadleaves*	*Transitory crop*	*55*	10.3	16.9	22.6	52.3	0.305
FRI2	*Picea abies*	*High forest*	*110*	30.7	37.2	42.2	29.2	-0.675
LAZ1	*Quercus cerris*	*Stored coppice*	*45*	11.9	14.0	17.0	30.0	1.119
LOM1	*Picea abies*	*High forest*	*90*	7.8	13.1	26.8	78.9	1.305
MAR1	*Quercus cerris*	*Stored coppice*	*45*	4.1	6.4	13.5	70.6	1.267
PIE1	*Fagus sylvatica*	*Transitory crop*	*70*	11.7	15.4	20.2	45.6	1.299
PUG1	*Fagus sylvatica*	*High forest*	*85*	11.6	22.3	33.9	59.6	0.477
SAR1	*Quercus ilex*	*Stored coppice*	*60*	10.1	15.6	22.2	57.6	1.562
SIC1	*Quercus cerris*	*Transitory crop*	*60*	18.5	20.4	22.6	19.0	0.321
TOS1	*Quercus ilex*	*Stored coppice*	*60*	5.6	9.2	14.0	74.6	2.316
TRE1	*Picea abies*	*High forest*	*200*	34.4	43.9	51.9	37.7	-0.720
UMB1	*Quercus cerris*	*Transitory crop*	*85*	18.5	25.2	30.0	39.5	-0.449
VAL1	*Picea abies*	*High forest*	*150*	18.5	28.5	37.2	43.7	0.12
VEN1	*Fagus sylvatica*	*High forest*	*130*	28.3	35.8	42.6	26.3	0.370
LOM2	*Picea abies*	*High forest*	*75*	19.3	26.2	33.9	39.7	0.502
LOM3	*Fagus sylvatica*	*Transitory crop*	*55*	15.3	18.8	22.4	35.5	1.954
TOS2	*Quercus ilex*	*Stored coppice*	*65*	6.4	8.8	13.1	58.9	2.855
TOS3	*Fagus sylvatica*	*High forest*	*155*	33.0	38.2	46.8	32.5	-0.122

75 to 200 yrs (high forests). As far as the structure of standing crops and current growing stocks are concerned, the prevailing attitude to environmental conservation resulted into a frequent reduction of harvesting and thinning practice. This situation originated quite often fully stocked stands. With respect to high forests, the former application of silviculture has been more regular in the Alps and less continuative across the Apennine range, depending on the background and locally tailored management rules.

Most of stands are even-aged and only a few alpine PMPs show irregular, to two-storied or typically uneven-aged structures. Detailed information on both structural and tree composition diversity is provided in Fabbio, Manetti and Bertini (2006).

Selection of indicators

The selected growth indicators were: dbh calculated after circumference measurement; basal area (b.a.); basal area increment (b.a.i); tree mortality and in-growth over the minimum threshold of 5 (high forests) and 3 cm (coppice forests). Their variation over time was computed in terms of annual (mean periodical) change.

The computation of tree mortality and in-growth at each inventory allowed to determine their occurrence, level, distribution across dbh range and to account for their contribution on stand growth. The original classification of each tree according to the social rank (Kraft) made possible the stratification of measurements into three well-discernible (dominant, intermediate, dominated) vertical strata. This resulted into information on the contribution of each layer to stand performance. Aim of this arrangement was to achieve also a "reference growth rate" attributable to the upper stratum, less influenced by inter-individual competition. Current growth rates, vertical stand structure and inner growth environments can be therefore related (Fabbio and Amorini 2000; Seidling 2005).

Data quality

A two-stage data control was implemented for tree circumference measurements: a routine cross-check allowed to verify individual data consistency between subsequent surveys and to repeat not consistent measurements. Randomly sorted sub-plots (10x10m) where re-measured at each PMP by a different field crew and equipment to verify measurement reproducibility and instrumental accuracy. A second test was performed at data processing to highlight incidental recording or storage errors. Measurement errors detected at previous inventories were corrected on the basis of the annual increment calculated for the same plot and tree rank.

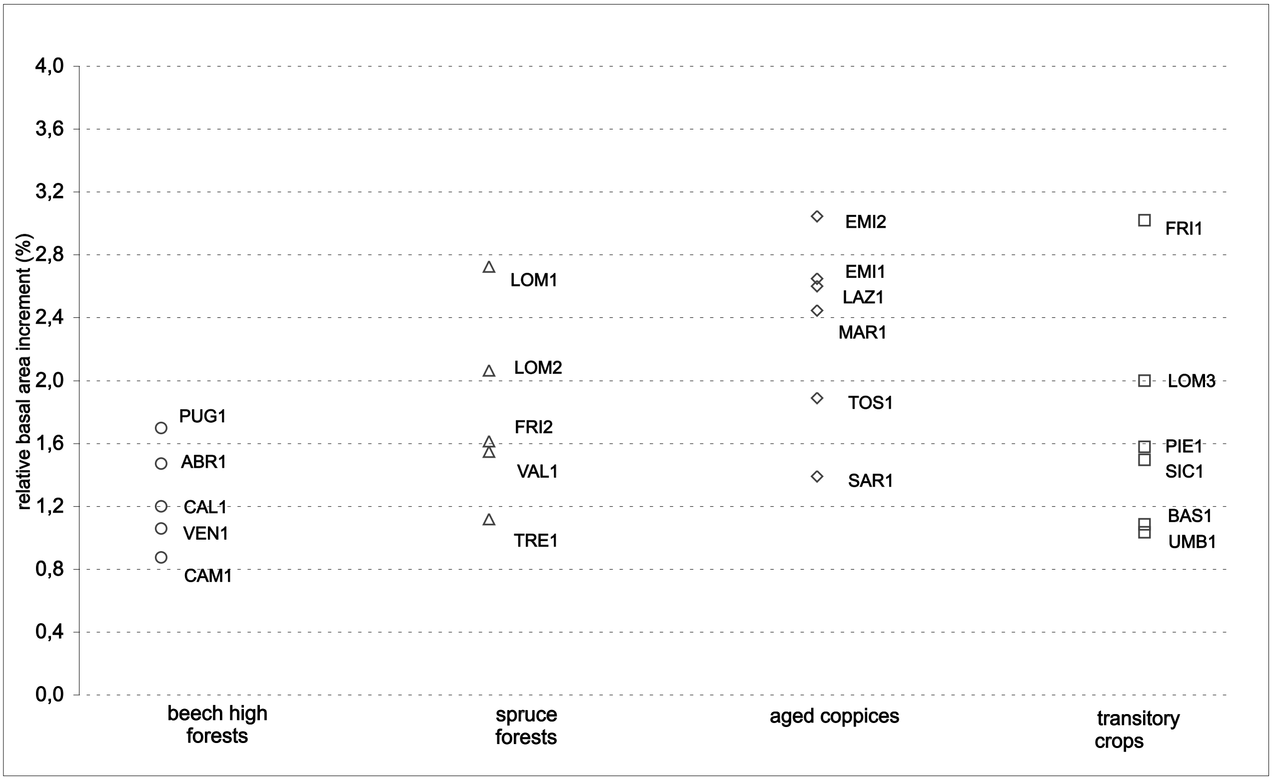

Figure 1 - Annual b.a.i. 1997-04 (% of b.a. 1997) per plot and forest type.
Incremento annuale di area basimetrica nel periodo 1997-2004 in % dell'area basimetrica al 1997 per area e tipologia.

Growth rate calculation

Because of the widespread occurrence of tree mortality and/or in-growth among plots, a difference was made between inventoried (*gross*) and actual (*net*) growth. Inventoried growth was computed as the difference between b.a. at subsequent inventories including the contribution of trees dead in between (null in terms of current growth and negative in terms of periodical increment), plus the positive contribution of trees overcoming the minimum dbh threshold in the time interval. In this calculation, these trees entered as new individuals with their own b.a. (not in terms of b.a.i. over the surveyed period). Actual growth was calculated vice versa as the increment of trees alive and present at both inventories (dead trees excluded) plus the increment of new entries. The size of deviation actual vs. inventoried growth was zero when neither mortality nor in-growth occurred and positive where mortality (as usual) was higher than in-growth. Both calculations were applied in the analysis.

Statistical analysis

The non-parametric Kolmogorov-Smirnoff test was used to compare dbh distributions at each inventory. The descriptive statistics (quartiles, coefficient of variation and skewness) allowed to assess stand structure in terms of tree size. Correlation between b.a. at different layers and over each inventory was tested. Annual b.a.i. per layer 2000-04 was plotted against b.a.i. 1997-99 to test the associate variation.

Results and discussion

Growth rate over the period 1997-2004

Actual growth expressed as annual b.a.i. 1997-04 in percent of b.a. in 1997 (opening of monitoring period) is reported for each forest type and PMP in Figure 1. Plots' installation into mass vegetation areas and inside homogeneous forest covers (10 to 100 hectares) resulted into site conditions consistent with species auto-ecology, in a range of site-classes and dominant ages within and between types. The following results were outlined:

(i) Beech high forests: limited b.a.i. variation (0.9-1.7%) within similar site-classes. Differences can be explained by the variable tree density due to the irregular thinning regime;

(ii) Spruce forests: wider growth range (1.1-2.7%) mostly attributable to the varying standing crop ages and structures as well (even, to uneven-aged, to irregular);

(iii) Coppice forests: quite similar high growth rates (2.5-3.1%) into beech and deciduous oaks plots. A much lower b.a.i. (1.4-1.9%) has been recorded into Mediterranean evergreen oak plots. The lower growth rate is a regular attribute of evergreen oak stands as compared to deciduous oaks and beech. Both the high tree densities and the heavy mortality rates within coppice forests do not affect stand growth in the age span observed (after Amorini, Fabbio and Cantiani 2006; Fabbio and Amorini 2006).

(iv) Transitory crops: low to medium growth range (1.0-2.0%) excepted FRI1, plot located on alluvial soil provided with a permanent ground water content. The current, quite dense stocking in these stands (aged likewise the previous type but showing the physiognomy of young, one-storied high forests), is the very likely driver of the reduced growth observed within.

Dbh distribution

Descriptive dbh statistics at inventory 2004-05 are reported in Table 1. Coefficient of variation (dbh_{cv}) is higher in: (i) aged coppice forests, *i.e.* the comparatively younger stands showing the lowest median dbh but size-differentiated and storied tree populations; (ii) uneven-aged high forests (*e.g.* LOM1); (iii) beech high forests where an advance regeneration (*i.e.* a much younger and small-sized tree population) has been established under the main crop layer (*e.g.* ABR1 and PUG1).

The more homogeneous and less storied is the standing crop, the lower is dbh_{cv} as in the even-aged, regularly managed high forests. Skewness is positive in most plots due to overstocking and negative in a few high forests where large canopy trees are prevailing (*e.g.* a few beech and spruce plots).

The analysis of dbh distribution per plot showed no significant differences (Kolmogorov-Smirnoff, P>0.05) over the inventories.

Basal area allocation

The arrangement of b.a. per plot and layer at the three inventories is shown in Figure 2. No correlation was found (data not shown) between b.a. at different

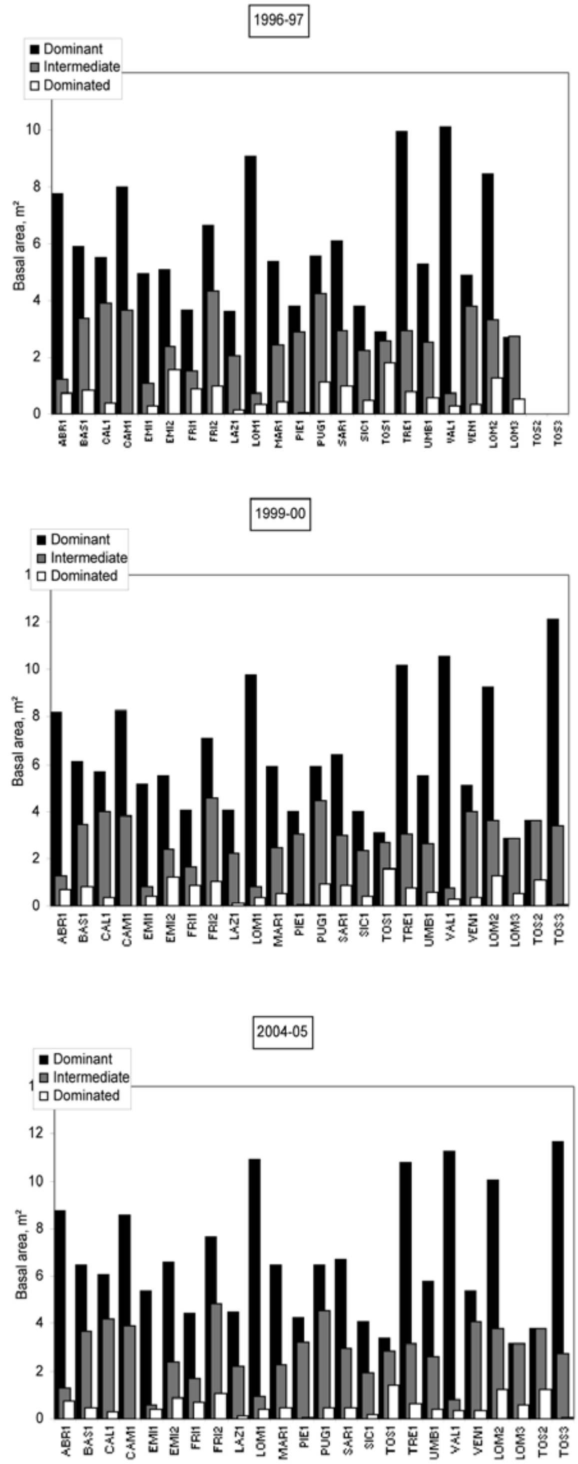

Figure 2 - B. a. allocation per plot and layer at each survey.
Distribuzione dell'area basimetrica per area e strato ai successivi inventari.

layers, whereas the expected high autocorrelation per layer was confirmed over the subsequent assessments: *i.e.* plots with comparatively high b.a. in a given layer tend to keep a high value through time, and plots with comparatively low b.a. tend to keep low values.

Layering is driven by stand structure (even, to uneven-aged, to irregular), tree density and specific autoecology into mixed forests. The typically uneven-aged (LOM1) or irregular (VAL1) forests maintain about 90% of total b.a. in the dominant layer; the allocation drops to 73% in TRE1 (two-aged) and to 55-65% into the other even-aged spruce forests (FRI2 and LOM2). Beech forests show a wider b.a. range in the upper layer (55-80%) because of the specific ability to fill up canopy gaps throughout the stand lifespan. CAL1 and VEN1, *i.e.* the plots undergoing the shelterwood system and a regular thinning practice up to thirty years ago, show quite similar values (54-58 %). As for aged coppice forests and transitory crops, b.a. allocation in the dominant layer varies from a minimum of 40-43% in TOS1 and TOS2 (holm oak dominated forest with many subsidiary broadleaves) to 85% in EMI1 (two-storied deciduous oaks forest). The range is between 56-70% into the remaining plots.

B.a. in the intermediate layer reaches about 40% in several beech plots (CAL1, PIE1, PUG1, VEN1, LOM3) and again in two aged evergreen oak forests (TOS1 and TOS2), where a substantial contribution is given by the other broadleaves.

The observed trend is to consolidate b.a. in the upper, dominant layer and maintain or reduce its allocation in the intermediate and/or lower strata.

Basal area increment 1997-99 vs. 2000-04

The synthesis of actual annual b.a.i. change over the two periods is reported in Table 2. A generalized b.a.i. decrease was detected on 12 out of 22 PMPs in 2000-04. Opposite variations per layer or a positive trend in all layers (SIC1 and TOS1) were reported in the other plots. Given its significance on the overall plot growth, a closer examination was made on the dominant layer. Here, b.a.i. reduction was higher than 20% in 8 plots, namely ABR1, FRI1, FRI2, LAZ1, MAR1, PIE1, UMB1, VEN1, all these plots being located in Northern and central Italy. An intermediate decrease (10-20%) was detected in CAM1, EMI1 and LOM2 (central and Northern Apennines and Western Alps, respectively) and a low decrease (1-10%) in LOM1, VAL1 (Western Alps) and PUG1 (Southern Italy). A substantial increase was detected in BAS1, CAL1 (Southern Italy), EMI2 (Northern Apennines) and TRE1 (Eastern Alps). A slight increase in SIC1 (Sicily), TOS1 (central Italy), LOM3 (Western Alps).

Table 2 - Synthesis of annual b.a.i. change between 1997-99 and 2000-04. No change (±1%): =; slight increase/decrease (>1→10%): +/-; medium increase/decrease (>10→20%): ++/--; high increase/decrease (>20%): +++/---.
Sintesi della variazione dell'incremento annuale di area basimetrica tra il 1997-99 e il 2000-04. Nessun cambiamento (±1%): =; leggero cambiamento (>1→10%): +/-; cambiamento medio (>10→20%): ++/--; cambiamento forte (>20%): +++/---.

plot	dominated	tree layer intermediate	dominant
ABR1	---	---	---
BAS1	-	+++	+++
CAL1	---	-	+++
CAM1	---	---	--
EMI1	---	---	--
EMI2	--	+++	+++
FRI1	---	---	---
FRI2	---	-	---
LAZ1	---	---	---
LOM1	---	--	-
MAR1	---	---	---
PIE1	++	---	---
PUG1	---	---	-
SAR1	---	---	=
SIC1	+++	+	+
TOS1	++	++	+
TRE1	+++	---	+++
UMB1	---	---	---
VAL1	+	---	-
VEN1	---	---	---
LOM2	---	---	--
LOM3	--	++	+

The short time-window and its further partitioning into a three and five yrs assessments does not allow any hypothesis for the forthcoming period, at now. Single events affecting annual growth were reported for a few plots (*e.g.* a complete defoliation occurred in LAZ1 by *Lymantria dispar* in 2002, Canullo *et al.*, this volume); a more lasting change of site conditions for EMI1 (subsequent dry years which affected the drought-sensitive sessile oak) and again many withering trees, tree tips and top branches dried up under water stress conditions in LAZ1. The only factor able to produce a large-scale disturbance was the severe drought associated to high air temperature recorded in summer 2003 (Amoriello and Costantini, this volume). Its evidence on b.a.i. should be more detectable at low elevation and in central and Northern Italy, where the deviation from mean seasonal condition was higher than in the Southern peninsula and major islands. A lasting effect to the subsequent years is likely to have occurred for the species with a pre-determined early growth (oak sp. and beech). It is worth noting that the highest measured growth reduction (upper layer) involved 8 plots all located in Northern and central peninsula: in seven of these, the dominant tree species were deciduous oaks and beech. Tree coring undertaken at the purpose in 2005-06 on canopy trees (deciduous oaks and beech) in EMI1, VEN2, LAZ1, TOS3 (Bertini and Amoriello 2006, unpublished), was anyway not conclusive in this regard. No response to the 2003 drought for European and sessile oak was reported by Fischer and Dobbertin (2006). The diffuse growth reduction both in the intermediate and lower layer is vice versa expected because of the stocked condition prevailing on a large share of the PMPs.

There is a high autocorrelative component in the inventoried basal area increment ($R^2 = 0.78$; $P<0.0001$), namely plots with a high b.a.i. over 1997-99 tend to keep this rate also over 2000-04, whatever the layer considered (Figure 3). The high autocorrelation allows some prediction about the expected b.a.i. and, by comparison with the measured data, to identify outliers, *e.g.* cases where growth was lower or higher than expected. Two outliers were identified, namely SIC1 (low growth in the intermediate layer) and EMI2 (high growth in the dominant layer). The former case (SIC1) is explained by tree mortality (4.9%) due to stem breakage or uprooting (see next paragraph) between 2000 and 2005 (Table 3). The latter case (EMI2), is reasonably due to growth dynamics of ageing coppice forests made up of a series of well-discernible decadal or sub-decadal competition cycles (Amorini and Fabbio 1986 and 1989). Such a dynamics produces consecutive growth peaks and drops in between; the observed outlier may be therefore the expression of the phase in progress.

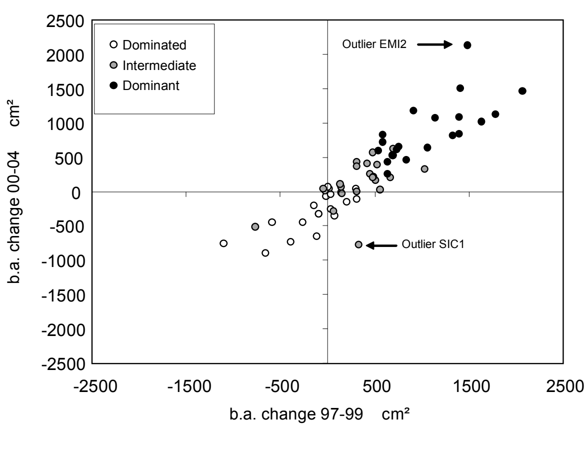

Figure 3 - Annual b.a. change 2000-04 vs. 1997-99. Two outliers are identified.
Variazione annuale in area basimetrica nel periodo 2000-04 rispetto al periodo 1997-99. Le frecce indicano i due outlier del modello autocorrelativo.

Table 3 - Annual mortality rates (n° of trees) per layer in each monitored period.
Mortalità annuale per strato (in % del n° di alberi) nei due periodi esaminati.

	mortality 97-99			mortality 00-04		
PMP	**dominated**	**intermediate**	**dominant**	**dominated**	**intermediate**	**dominant**
ABR1	2.46	0.00	0.00	0.67	0.00	0.00
BAS1	4.30	0.00	0.00	9.88	0.00	0.00
CAL1	3.57	0.00	0.00	11.20	0.00	0.00
CAM1	0.00	0.00	0.00	0.00	0.00	0.00
EMI1	2.17	5.60	2.13	1.25	4.75	2.15
EMI2	6.77	2.63	0.28	8.15	2.93	0.25
FRI1	4.07	0.46	0.41	6.27	1.39	0.50
FRI2	0.00	0.00	0.00	1.60	0.00	0.00
LAZ1	2.67	0.17	0.00	7.83	2.34	0.00
LOM1	2.01	0.48	0.00	1.03	1.47	0.73
MAR1	2.30	3.02	0.31	3.03	2.41	0.09
PIE1	5.13	0.18	0.00	0.00	0.11	0.00
PUG1	10.26	0.69	0.00	6.60	1.19	0.00
SAR1	6.86	0.74	0.00	8.31	1.49	0.89
SIC1	6.17	0.00	0.00	10.91	4.94	0.74
TOS1	4.51	1.86	1.39	3.88	1.65	0.40
TRE1	1.52	0.00	0.00	2.86	0.74	0.00
UMB1	2.78	0.00	0.00	5.45	0.63	0.00
VAL1	1.11	0.00	0.31	0.00	0.00	0.00
VEN1	0.00	0.00	0.00	0.00	0.00	0.63
LOM2	2.16	0.00	0.00	4.53	0.74	0.24
LOM3	2.50	0.00	0.00	1.08	0.00	0.00

Tree mortality rate

Annual mortality rate was found to follow the expected trend (Table 3); mortality drops from the dominated to the dominant layer except in EMI1, where the likely influence of drought has occurred. The prevailing condition of relatively high tree densities and multi-storied stands caused high competition-driven mortality in the lower and intermediate strata. This explains why top rates are recorded in the fully stocked aged coppice forests, in the dense transitory crops, and in beech high forests where a natural but temporary advance regeneration has been established. The self-thinning hypothesis seems therefore to apply to most cases.

Mortality is drastically reduced in the upper layer and present in 6 and 10 out of 22 plots in 1997-99 and 2000-04, respectively. Its rate is < 1% (TOS1 (1997-99) and EMI1 (1997-04) excepted). Its source is different between high forests - occasional extreme events as wind storms uprooting a few canopy trees - and coppice forests - a poor resistance at stem insertion

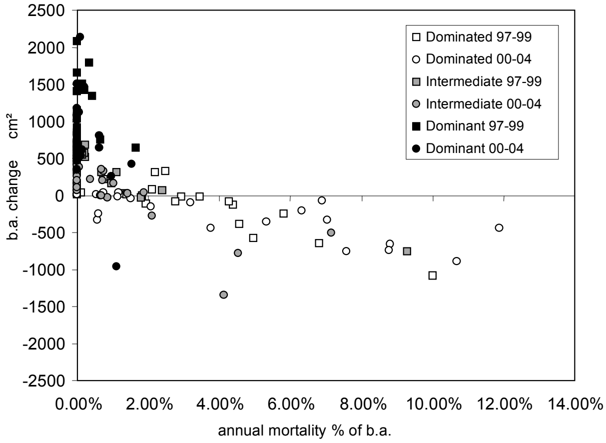

Figure 4 - Annual b.a. change plotted vs. annual mortality (b.a. %).
Variazione annuale di area basimetrica in funzione della mortalità annuale espressa in % di area basimetrica.

originating stem breakage or uprooting following a mechanical stress. This usually occurs when two or more dominant stems are growing on the same stool, thus leading to asymmetric crown expansion.

Basal area increment vs. tree mortality rate

Inventoried b.a. change is affected by mortality occurring in between, this leading up to negative b.a.i. calculations (Figure 4). Each layer and measurement period are reported in the graph. There is evidence of the substantial b.a. decrease at increasing mortality rates and that the observed mortality is a typical attribute of the dominated and intermediate layers.

Conclusions

The annual b.a.i. recorded over 1997-04 at 22 PMPs ranged between 0.9 and 3.1% of the early basal area (1997). Although current growth rates can be explained by several contributing factors, two points deserve consideration:

- (i) Opposite patterns were detected as for the actual and expected growth *vs.* mortality rates between types. Overall, the growth performance was better into fully stocked coppice forests and under high self-thinning rates. On the other hand, lower growth rates were recorded into transitory crops and high forests against a less heavy mortality. This may be explained by the competition pattern acting in the clustered tree distribution ruling coppice forests. It originates the early tree-size differentiation, promotes the further growth of dominant trees and is able to buffer the high mortality rates in the storied structure. The less pronounced competition acting in the more homogeneous structures prevailing into the other stand types, works vice versa as a radial growth constraint, following the suspension of intermediate removals.
- (ii) The considerable reduction of annual b.a.i. in the dominant layer measured in several plots in 2000-04, was obvious especially at low elevation and in the area subject to drought in 2003. At these plots, the species were the drought-sensitive oaks and beech, and this supports the climate-disturbance hypothesis. Further ad-hoc studies are anyway necessary at the investigated sites; in this connection, a test-phase of early and late annual growth assessment by tree coring, and of intra-annual radial growth recording by girth bands, is in progress in 2008. The same actions are aimed to be developed according to a common protocol in the frame of LIFE+ programme from 2009 onwards.

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Status and change of tree crown condition at the CONECOFOR plots, 1996 - 2005

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Abstract – Between 1996 and 2005 crown condition at Italian Level II plots was assessed annually within the CONECOFOR programme. Three different assessment forms and manuals were adopted over this period of time (the first in 1996-97, the second between 1998 and 2004, the last starting in 2005); as a result, many of the parameters investigated and the data collected are neither homogeneous nor comparable over time. Since, however, neither the definition nor the assessment criteria for transparency changed, this parameter was chosen to represent crown condition variations over time. (In this survey, transparency is used as a proxy for defoliation.) Yearly field surveys were always preceded by an inter-calibration course, and were followed up by Quality Control surveys done by one or more Reference Teams. After 10 years, the results suggest that statistically significant variations in transparency, from one year to the next, are only scattered and display no recognizable trend. Overall, there were 15 variations, of which 7 were positive (i.e. increase in transparency), and 8 negative (i.e. decrease in transparency). The majority of variations is concentrated in the 1997-98 period. Significant defoliation trends were identified in 11 out of the 27 considered plots. In 4 cases these trends were positive (increased transparency).

Key words: *Crown conditions, defoliation, Quality Assurance, temporal trends, transparency.*

Riassunto – Stato e cambiamento della condizione delle chiome nelle aree CONECOFOR nel periodo 1996-2005. Fra il 1996 ed il 2005 è stata effettuata annualmente la valutazione delle condizioni delle chiome nelle aree di Livello II in Italia, nell'ambito del programma CONECOFOR. Nel corso di questo periodo sono state adottate tre differenti schede e manuali (il primo nel 1996-97, il secondo dal 1998 al 2004, l'ultimo a partire dal 2005), di conseguenza molti dei parametri considerati soffrono di una certa disomogeneità e non sono comparabili nel tempo. Per questo motivo, per rappresentare le variazioni delle condizioni delle chiome nel tempo è stata scelta le trasparenza (usata nella presente indagine come *proxy* per la defogliazione), per la quale la definizione ed il criterio di valutazione è rimasta invariata nel tempo. Le indagini annuali di campo sono sempre state precedute da un corso di intercalibrazione, e sono state accompagnate da controlli di qualità da parte di uno o più *Reference Team*. I risultati di questi 10 anni indicano che le variazioni di trasparenza significative da un anno all'altro sono sparse e non seguono un andamento riconoscibile. Complessivamente ci sono state 15 variazioni, di cui 7 di segno positivo (incremento della trasparenza) e 8 di segno negativo (diminuzione della trasparenza). La maggior parte delle variazioni è concentrata nel periodo 1997-98. Trend significativi della defogliazione media sono stati individuati in 11 aree sulle 27 considerate. In 4 casi si tratta di trend positivi (incremento della trasparenza). Di particolare rilievo il caso di EMI1, in cui *Quercus petraea* pare aver risentito della siccità dell'estate 2003.

Parole chiave: *Condizioni delle chiome, defogliazione, Quality Assurance, tendenze temporali, trasparenza.*

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Introduction

Crown conditions are currently evaluated in international monitoring programmes, aimed at assessing the conditions of individual trees and forests, both in North America (Mclaughlin and Percy 1999; Zarnoch *et al.* 2004) and in Europe (De Vries *et al.* 2000; Müller-Edzards *et al.* 1997). The European programme started in the early '80s with an extensive network (Level I) where only the parameters of defoliation (or transparency) and discoloration were assessed to describe overall crown conditions. Then, a more intensive network of plots was established (Level II), and the assessment of crown condition came to include a number of additional parameters (UN-ECE 1998). Recently, a new methodology was adopted both for Level I and Level II networks and a number of different indices are now taken into consideration to describe crown condition and specific symptoms related to abiotic and biotic damage agents (UN-

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ECE 2005). Defoliation (or transparency) is the only parameter that has always been assessed over the years on both networks. It is evaluated according to a proportional scale, thus allowing comparison of the data from different plots and years, and analysis of spatial distribution and trends of the time series using statistical tools (Bussotti *et al.* 2003; Seidling and Mues 2005). More recently, crown condition - in terms of changes in defoliation over a 5-year time window - was selected as one of the indicators under criterion 2, Forest health, within the Ministerial Conference of Protection of Forests in Europe (MCPFE 2002).

In Italy, the assessment of tree condition has been carried out since 1987 on Level I plots. When the Level II programme started, crown condition assessment on Level II Permanent Monitoring Plots (PMPs) began in 1996 and, from the outset, included a specific Quality Assurance (QA) plan (Ferretti *et al.* 1999) both for Level I and Level II networks.

The aim of this paper is to identify whether significant changes have occurred in the Level II plots over the 1996-2005 period in terms of annual differences and overall trend, and to investigate possible similarities between plots.

Material and Methods

Data set

In a previous paper (Bussotti *et al.* 2000), we suggested a way to combine several assessed indices, in order to gain a synthetic expression of the overall condition of the crowns. However, it was not possible to use a similar index across the whole ten-year period because of the heterogeneity of the changes in the assessment criteria during the same period 1996-2005. In 1996 and 1997, when no common guidelines for crown assessment in Level II plots existed, a Manual originally elaborated for regional surveys was adopted (Cenni *et al.* 1995). In 1998 new manuals (Bussotti *et al.* 1998a, b) acknowledged the new UN-ECE guidelines (UN-ECE 1998), both for Level I and Level II plots. Finally, the current manual was adopted in 2005 (Bussotti *et al.* 2005a), incorporating the latest UN-ECE changes (UN-ECE 2005). This Manual is primarily focussed on the assessment of "damaging" causes and symptoms, with special attention to biotic parasites (insects and fungi). For this reason, forest pathologists and entomologists have been involved in all phases of the monitoring process.

Over ten years and three different manuals, the definition and the scoring system for many of the considered parameters has changed. The only one which has remained constant over time, allowing statistical analysis, is "Transparency" (assumed as proxy for defoliation), assessed on "photoguide" basis (photographic reference allows a better temporal analysis than the so-called "reference tree" method, see Redfern and Boswell 2004). Transparency, or defoliation, is also the most used index to compare tree conditions across countries and time (Müller-Edzards *et al.* 1997). Transparency is evaluated according to a proportional scale, with 5% intervals (0= not transparent tree; 5; 10; 15 ... 100 = dead tree).

The composition of the sample, too, has changed over time; and the Permanent Monitoring Plots (PMPs) increased from 20 at the beginning of the survey (1996), to 24 in 1999, 25 in 2000 and 30 at present. For the purposes of this investigation, all PMPs operational since 1996, 1999 and 2000 were considered. For these plots, only the main tree species was investigated. Table 1 reports plots and the relevant composition. Representative tree species are beech (*Fagus sylvatica* L., 9 plots), Turkey oak (*Quercus cerris* L., 6 plots), Norway spruce (*Picea abies* Karst., 6 plots), holm oak (*Quercus ilex* L., 3 plots), common

Table 1 – Plots considered (PMP = Permanent Monitoring Plot) and relevant composition.
Aree oggetto dell'indagine e loro composizione.

PMP	First assessment	Main Tree Species (MTS)	No. Trees	% of MTS
01ABR1	1996	*Fagus sylvatica* L.	30	100%
02BAS1	1996	*Quercus cerris* L.	31	94%
03CAL1	1996	*Fagus sylvatica* L.	32	100%
04CAM1	1996	*Fagus sylvatica* L.	30	100%
05EMI1	1996	*Quercus petraea* (Matt.) Liebl.	30	70%
06EMI2	1996	*Fagus sylvatica* L.	30	97%
07FRI1	1996	*Carpinus betulus* L.	32	72%
08FRI2	1996	*Picea abies* Karst.	30	100%
09LAZ1	1996	*Quercus cerris* L.	33	100%
10LOM1	1996	*Picea abies* Karst.	30	60%
11MAR1	1996	*Quercus cerris* L.	31	87%
12PIE1	1996	*Fagus sylvatica* L.	30	87%
13PUG1	1996	*Fagus sylvatica* L.	32	94%
14SAR1	1996	*Quercus ilex* L.	30	100%
15SIC1	1996	*Quercus cerris* L.	30	100%
16TOS1	1996	*Quercus ilex* L.	30	100%
17TRE1	1996	*Picea abies* Karst.	31	100%
18UMB1	1996	*Quercus cerris* L.	32	94%
19VAL1	1996	*Picea abies* Karst.	31	100%
20VEN1	1996	*Fagus sylvatica* L.	31	100%
23LOM2	1999	*Picea abies* Karst.	22	100%
24LOM3	1999	*Fagus sylvatica* L.	28	100%
25TOS2	1999	*Quercus ilex* L.	28	100%
26TOS3	1999	*Fagus sylvatica* L.	28	100%
27BOL1	2000	*Picea abies* Karst.	23	100%

hornbeam (*Carpinus betulus* L., 1 plot) and sessile oak (*Quercus petraea* (Matt.) Liebl., 1 mixed stand with *Quercus cerris*). The general features of the survey were already presented by Bussotti *et al.* (2002).

Quality Assurance (QA) procedures

The mission of the QA program is to ensure that the quality of data and statistical products were documented and of sufficient quality to satisfy the requirements of data users, policy makers, and the public. The aim of the QA team is to provide continuous improvement of monitoring and assessment activities by identifying, controlling, and documenting errors and variations that are detrimental to the quality of the results provided by crown condition assessments. The procedures adopted in Italy (Ferretti *et al.* 1999) include:

(i) the use of Standard Operative Procedures (SOPs), consisting of photoguides (Müller and Stierlin 1990; Ferretti (Ed.) 1994) and field manuals, updated yearly according to the instructions of the Expert Panel on Crown Conditions and past field experience;

(ii) the establishment of Measurement Quality Objectives (MQOs) expressed by Data Quality Limits (DQLs) for each tree condition index. For transparency, 90% of observations are required to have a value included in a ±10% range in relation to the standard score;

(iii) a yearly National Training and Intercalibration Course (NT&IC) to provide surveyors with standard guidelines and to obtain the highest possible homogeneity and harmonisation in the evaluation. Currently, the NT&IC course is organized in two different sessions: for Alpine regions, and for the Apennines and Mediterranean regions. Each surveyor must evaluate a number of trees that have been pre-evaluated by the Reference Team (RT). RT is made up of well-trained people, and their assessment is assumed as standard score. The differences between the standard and the scores of each field crew express the degree of reproducibility of the assessment;

(iv) field checks (FC), performed yearly by the RT on a number of plots previously assessed by the field crews, to test the reproducibility of the field data. During the 1996-2005 period each PMP was visited by the RT between 2 and 4 times;

(v) control of the completeness, consistency and plausibility of the data before they are finally recorded in the archives.

Sampling design

Trees were selected starting from the one closest to the centre of the plot and proceeding in a spiral pattern, until a total of 30 trees were selected, representing the main tree species (MTS). In some cases *(e.g.* EMI1) more than one tree species was selected. In some plots there were less than 30 trees per plot. The sampling procedure adopted in agreement with the ICP-Forests guidelines (UN-ECE, 1998; 2005), allows for an objective selection of trees, but not for a statistical design. This implies that, in statistical terms, data cannot be considered representative of the plot (or any population of trees), but only of the trees selected.

Statistical methods

Crown transparency data have a skewed distribution that in general is significantly different from normal. The skewness changes plot by plot and – within the plot – year by year. Thus, no single normalisation procedure can be adopted. For this reason, during the first stage, we used Friedmann non parametric statistical tests for testing differences between years with repeated measurements. Correlations were analysed by the coefficient of Spearman.

For time trend detection, estimates were based on linear first order model [y = b0+b1x], where: x = year; y = (i) annual mean values and/or (ii) annual percentage of trees exceeding the 25% transparency threshold; b0 and b1 = regression coefficients.

The 25% transparency threshold was chosen according to the usual reporting methods (see ICP-forests reports, *www.ICP-forests.org*) and the MCPFE criteria (MPCFE 2002). However, even officially adopted within Europe, it remains an arbitrary threshold and doesn't distinguish species-specific characteristics (Bussotti *et al.* 2001).

Results

Quality of crown transparency data

In general, the frequency of data within the MQOs has increased over the period 1996-2004. For beech, achievements of MQO was always between 82 and 92%, with DQLs formally achieved in the years 2000, 2003, 2004. For Turkey oak, the frequency of data

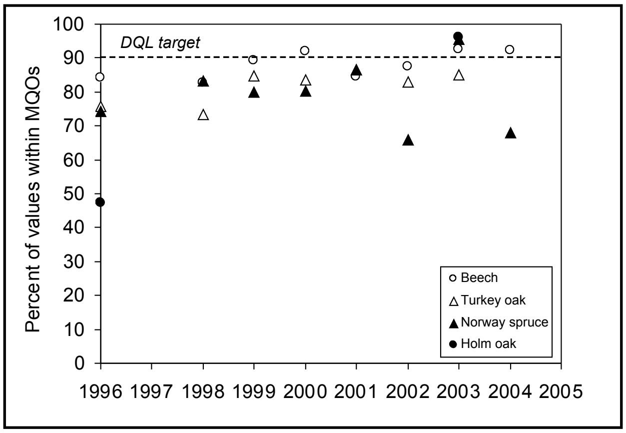

Figure 1 – Quality of crown transparency data over the period 1996-2004 for the main tree species. MQOs: Measurement Quality Objectives (±10% of reference value); DQL: Data Quality Limit.
Qualità dei dati della trasparenza della chioma nel periodo 1996-2004, per le specie principali. MQOs: obiettivi di qualità delle misure (±10% rispetto al valore di riferimento); DQL: Limiti di qualità dei dati.

Table 2 – Occurrence of significant (p<0.05) annual changes in mean crown transparency: + indicates a significant increase; - indicates a significant decrease. In 05EMI1: sp. 41 = *Quercus cerris*; sp. 48 = *Quercus petraea.*
Eventi di cambiamenti significativi (p<0.05), fra anni successivi, nella trasparenza media della chioma: + = aumento significativo della trasparenza; - = diminuzione significativa. In 05EMI1: sp. 41 = Quercus cerris*; sp. 48 =* Quercus petraea.

	96-97	97-98	98-99	99-00	00-01	01-02	02-03	03-04	04-05
Fagus sylvatica									
01ABR1								-	
03CAL1		+							
04CAM1									
06EMI2									-
12PIE1		+							
13PUG1									
20VEN1		+	+	-					
24LOM3									-
26TOS3							+		
Deciduous oaks									
02BAS1									
05EMI1 sp41									
05EMI1 sp48									
09LAZ1									
11MAR1				+					
15SIC1		-							
18UMB1									
Quercus ilex									
14SAR1									
16TOS1									
25TOS2									
Picea abies									
08FRI2									
10LOM1									
17TRE1									
19VAL1								-	
23LOM2									
27BOL1						-			
Carpinus betulus									
07FRI1									

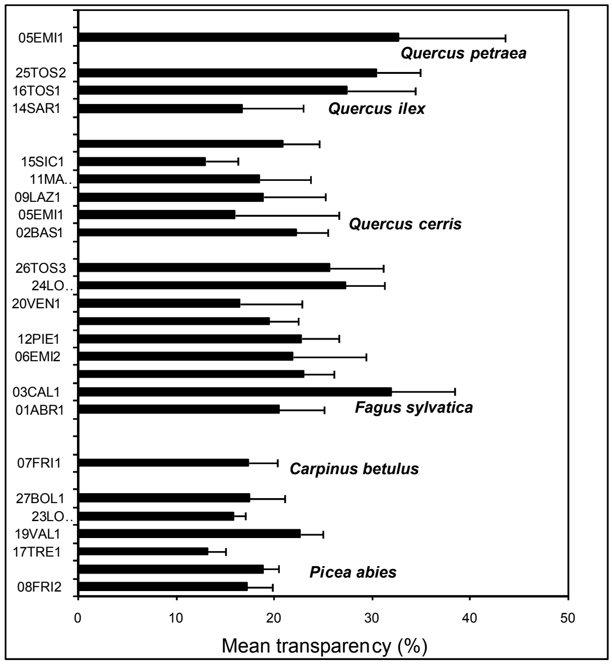

Figure 2 – Mean crown transparency (1996-2004 period) for the various plots. The main tree species is reported for each group of plots. Error bars represent the standard deviation.
Trasparenza media della chioma (1996-2004) nelle diverse aree. La specie principali è riferita per ciascun gruppo di aree. Le barre d'errore indicano la deviazione standard.

within MQOs increased from 75 to 85% over the 1996-2003 period. However, DQLs were not formally achieved. Assessment of Norway spruce was within MQOs from 68 to 95% of cases (Figure 1).

Annual changes

Mean crown transparency for each plot, for the 1996-2005 period, is reported in Figure 2. Plots with relatively highest transparency were VAL1 (Norway spruce), CAL1 (beech), BAS1 (Turkey oak), EMI1 (sessile oak) and TOS1 (holm oak). Table 2 reports the occurrence of significant annual changes. Significant annual changes occurred in 15 plots (7 significant increases and 8 significant decreases). The year 1998 is the one with the highest frequency of significant changes with respect to the previous year. Accordingly, Table 3 identifies significant correlations between 1996 and 1997, on the one hand, and 1998 and the subsequent years up to 2005, on the other. It is obvious that 1996 and 1997 stand apart from the other years until 2004.

Medium term trends

Medium term (1996-2005) trends were evaluated in relation to the mean crown transparency and to the

Table 3 – Year by year correlations of tree transparency in the whole sample. The Spearman coefficient correlation is indicated in the table. In bold are evidenced the correlations significant with p<0.05.
Correlazioni anno per anno della trasparenza della chioma nell'insieme del campione. In tabella è indicato il coefficiente di correlazione di Spearman. In grassetto sono evidenziate le correlazioni significative con p<0.05.

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
1996	1									
1997	**0.907**	1								
1998	**0.670**	**0.683**	1							
1999	**0.435**	**0.446**	**0.863**	1						
2000	**0.558**	**0.590**	**0.795**	**0.619**	1					
2001	**0.606**	**0.596**	**0.734**	**0.541**	**0.856**	1				
2002	0.332	0.261	**0.588**	**0.552**	**0.518**	0.676	1			
2003	0.276	0.379	**0.670**	**0.614**	**0.619**	0.726	0.801	1		
2004	0.137	0.292	**0.529**	**0.466**	**0.526**	0.524	0.667	0.775	1	
2005	0.220	0.213	0.332	0.287	0.255	0.082	0.139	0.168	**0.516**	1

frequency of trees with defoliation >25%. The latter is particularly important as an indicator of sustainable forest management. PMPs that have shown significant medium term changes in crown transparency are reported in Table 4A. Significant increase of defoliation was recorded for EMI1 (both the considered species), FRI1 and PIE1; significant decrease was observed for the plots CAM1, MAR1, TOS1, TOS2, LOM3, BOL1 and UMB1.

Comparison with expectations

International initiatives use the 25% defoliation values as a threshold to identify poor forest health (*e.g.* UN/ECE ICP-Forests). Accordingly, the MCPFE process identifies the changes in the frequency of trees with defoliation >25% as indicators of sustainable forest management. In Italy, defoliation is assessed by a proxy indicator: crown transparency. Figure 3 reports the mean frequency of trees with transparency >25%. Table 4B reports the plots with significant changes in the frequency of trees with transparency >25%. Significant increase has occurred for 4 plots (EMI1 both species, LAZ1, LOM1, PIE1), while a significant decrease has occurred on 7 plots (CAM1, LOM3, UMB1, MAR1, TOS1, TOS2 SAR1).

Discussion and Conclusions

An important finding of the survey was the high degree of reproducibility of the observations carried out by the various field crews (82 – 92% respect to the reference teams). This degree of reproducibility is of the same order of that found in Switzerland in various surveys (min. 76%, max 90%, see Dobbertin *et al.* 1997). On the other hand, the reproducibility of 90% is usually reached in the Level I surveys in Italy (Bussotti *et al.* 2001).

The overall conditions of the crowns depend on the basic ecological features of the sites where the trees

Table 4 – Medium term (1996-2005) significant pattern of changes in crown transparency (A) and in trees with transparency >25% (B). N = Number of years. Slope: + = significant increase of transparency; - = significant decrease.
Andamenti significativi, fra il 1996 e il 2005, della trasparenza della chioma (A) e degli alberi con trasparenza superiore al 25% (B). N = Numero di anni. Pendenza (slope): + = aumento significativo della trasparenza; - = diminuzione significativa.

		A. Crown transparency		B. Trees with transp. >25%	
	n	slope	p	slope	p
Fagus sylvatica					
01ABR1	10				
03CAL1	10				
04CAM1	10	-	<0.01	-	<0.05
06EMI2	10				
12PIE1	10	+	<0.05	+	<0.05
13PUG1	10				
20VEN1	10				
24LOM3	7	-	<0.1	-	<0.05
26TOS3	7				
Deciduous oaks					
02BAS1	10				
05EMI1 sp41	10	+	<0.05	+	<0.05
05EMI1 sp48	10	+	<0.05	+	<0.01
09LAZ1	10			+	<0.05
10MAR1	10	-	<0.05	-	<0.01
15SIC1	10				
18UMB1	10	-	<0.01	-	<0.05
Quercus ilex					
14SAR1	10			-	<0.05
16TOS1	10	-	<0.01	-	<0.01
25TOS2	7	-	<0.1	-	<0.01
Picea abies					
08FRI2	10				
10LOM1	10			+	<0.01
17TRE1	10				
19VAL1	10				
23LOM2	7				
27BOL1	6	-	<0.1		
Carpinus betulus					
07FRI1	10	+	<0.01		

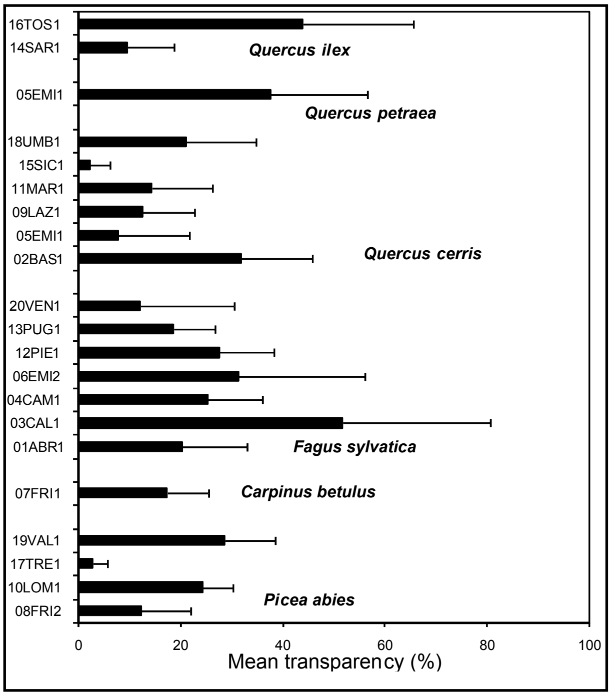

Figure 3 – Mean frequency of trees with crown transparency >25% (1996-2004 period) for the various plots. The main tree species is reported for each group of plots. Error bars represent the standard deviation.
Frequenza media degli alberi con trasparenza della chioma >25% (1996-2004) nelle diverse aree. La specie principali è riferita per ciascun gruppo di aree. Le barre d'errore rappresentano la deviazione standard.

grow (altitude, climate, bedrock, soil features …), the stand characteristics (tree age, crown spacing, species assemblage ….) and the species-specific ecosystem relationships (insects, fruit bearing …) (AAMLID *et al.* 2000; Eichhorn *et al.* 2005; SEIDLING 2004; BUSSOTTI *et al.* 2005b). Crown transparency can be considered an index of the acclimation status of the tree with its environment. For example, at dry sites crowns are usually thinner to reduce the transpiration from leaf surfaces. Nevertheless, defoliation (or transparency) at a given site may vary year by year, as a consequence of pest attacks and/or abiotic events, whereas permanent environmental changes can drive the crown conditions to a new and different "steady" equilibrium point. The constant assessment of defoliation at the PMPs allows us to register the consequences of occasional "damaging" events (*year by year variations*), and/or the "acclimation" effort toward changed ecological conditions (*constant trends*).

The experiences carried out in Europe within the forest monitoring programmes have revealed that drought is the most important environmental factor affecting changes in the defoliation status of trees (POUTTU and DOBBERTIN 2000; SOLBERG 2004; SEIDLING *in press*) even if, according to DOBBERTIN (2005), drought doesn't exert its effects in the year when it occurs, but rather in the following years. The effects of environmental pollution have also been considered contributing factors to the worsening of crown conditions. In the past years, several studies on the role of acidic depositions and soil acidifications in tree defoliation have been carried out in several countries (see MÜLLER-EDZARDS *et al.* 1997). More recently, the majority of efforts were devoted to establishing the effects of ozone, as the most widespread phytotoxic factor impacting on forests (SKÄRBI *et al.* 1998; MATYSSEK and INNES 1999).

Correlations between predictive variables (site features, environmental parameters) and crown condition (defoliation and discoloration) were investigated by multivariate statistical analysis and multiple correlations; and the possible influence of ozone on European forests as a whole was reported by KLAP *et al.* (2000). The main findings concern *Quercus ilex* and *Fagus sylvatica* (significant correlation between AOT60 and defoliation). In the holm oak the correlation was only slightly significant, while in the beech it was more marked. FERRETTI *et al.* (2007) have identified ozone as one of the variables that significantly explains defoliation in *Fagus sylvatica* in observation areas in South-Western Europe, but the variance explained by this factor is very limited (it only accounts for 4-8% of the total). ZIERL (2002) applied to Swiss forests an ideological model that simulates stomatal conductance, and therefore ozone absorption; he was thus able to confirm the hypothesis that ozone is a factor contributing to defoliation (yet the Author stresses the presence of a vast range of factors that alter ozone response and questions the real effectiveness of using defoliation as a response parameter).

The aim of this paper is not to identify the environmental forces and/or the biotic factors which determine the trends and/or fluctuations in crown condition status at the Level II PMPs belonging to the CONECOFOR programme in Italy. That will be the purpose of further, more comprehensive studies. We merely want to determine whether something is happening in these PMPs, *i.e.* if signals of changes (and, if possible, in which direction) are recognisable in these Italian forests.

The most relevant changes occurred in the year '98, at the time of the first change of manual, and when new assessment concepts were introduced. It is noticeable that the first two years (1996-1997) show a different behaviour as compared to the following years. Year-by-year changes appear to be scattered, and no common behaviour by year and by species has been highlighted. The effects of severe drought and extreme temperatures in 2003 are evident only in *Quercus petraea* at EMI 1, where defoliation increased from 27% (in 2002) to 49% (in 2003) and to 55% (in 2004). These changes, nevertheless, were not statistically significant because of the large variation among individual trees.

The medium-term trends are site-specific. In three cases defoliation increased; in other 7 cases, defoliation decreased. Probably the causes are related to site-specific ecological conditions and events (meteorological events; pest attacks ...), in relation to the species-specific physiological features. The new guideline for biotic and abiotic damage agents assessment will enable us to analyse damaging events.

As conclusions, some considerations can be proposed:

1. At least in the first years, the results may have been influenced by the training level of the field crews. A continuous QA programme is an indispensable condition to have reliable data over space and time.
2. No general trends can be recognised in the Italian Level II PMPs, considering either the whole sample (20 plots) or sub-samples homogeneous for species composition or geographic localisation. This supports some preliminary results coming from the Italian level I network (Bussotti *et al.* 2001). This behaviour may be connected to the large variability of the ecological conditions in the forest sites, which differ in climate, orography, species assemblage and biodiversity, stand characteristics *etc.* The variation of site-specific relationships is the result of a complicate ecological mosaic, inducing very different response patterns.

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Status and changes of ground vegetation at the CONECOFOR plots, 1999 - 2005

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Abstract – The vegetation dataset (1999-2005) of the CONECOFOR network is analyzed in the paper, to produce a present-day status and evaluation of changes in a sub-set of Permanent Monitoring Plots (PMPs). Descriptors such as mean number of species (community and population scale), diversity indices and species turnover were selected. Each PMP was investigated to evaluate: (i) type and direction of variations; (ii) significant changes of species indicator values. At the community level, significant variations in richness occurred in sites affected by recent anthropic or natural disturbances. In few PMPs directional changes can be observed; in most of cases a typical fluctuation pattern (more or less regular) was detected. The use of *a priori* reference standard (RS) supported the interpretation of changes. At finer scale (population level), annual richness variations are frequent but of minor importance. Higher values of species turnover occurred in communities under intense dynamic processes, interested by disturbance or influenced by neighboring communities. The abundance of *nitrophilous* species was consistent in beech forests, while the contribution of *acidophilous* species was not important. Moreover, our results suggest that: (a) the data collected at the community level seem more sensitive to describe important changes at the forest stand level; (b) a strong relationship is present between plant diversity and the forest dynamical state. The inherent non-linear dynamics of forest regeneration processes emphasizes the needs of long-term datasets for detecting the plant diversity responses to environmental changes.

Key words: *forest monitoring, long term studies, species diversity, Reference Standard, species richness, species turnover, species indicator values.*

Riassunto – Stato e cambiamenti della vegetazione nelle aree CONECOFOR nel periodo 1999 - 2005. In questo contributo viene analizzato il set di dati sulla vegetazione (1999-2005) della rete CONECOFOR per valutare lo stato ed i cambiamenti in alcuni Plot di Monitoraggio Permanenti (PMP). A tale scopo si sono selezionati descrittori quali il numero medio di specie (sia a scala di comunità che di popolazione) indici di diversità e di turnover di specie. Ciascun PMP è stato analizzato per valutare (i) tipologia e tendenza delle variazioni e (ii) cambiamenti significativi dei valori indicatori delle specie. A livello di comunità, significative variazioni in ricchezza si sono rilevate in siti influenzati da recenti disturbi. In pochi PMP sono apprezzabili cambiamenti direzionali, mentre, nella maggior parte dei casi, si sono verificati dei modelli di fluttuazione (più o meno regolari). L'utilizzo di uno Standard di Riferimento (RS) definito *a priori*, ha supportato la valutazione dei cambiamenti. A scala fine (livello di popolazione), le variazioni annuali della ricchezza specifica sono frequenti, ma di minor importanza. I più alti valori di turnover delle specie si sono registrati in comunità guidate da intensi processi dinamici, interessate da disturbi o da altre comunità confinanti. L'abbondanza delle specie *nitrofile* era consistente nelle foreste di faggio, mentre il contributo delle *acidofile* non ha mostrato particolari evidenze. Inoltre, i nostri risultati suggeriscono: (a) i dati raccolti a livello di comunità sembrano più sensibili a descrivere importanti cambiamenti a livello di stand forestale; (b) una forte relazione tra diversità di piante e stato dinamico della foresta. La dinamica non lineare del processo di rigenerazione enfatizza la necessità di dataset a lungo termine per poter determinare la risposta della diversità di piante ai cambiamenti ambientali.

Parole chiave: *monitoraggio foreste, studi a lungo termine, diversità specifica, Standard di Riferimento, ricchezza specifica, turnover di specie, valore indicatore delle specie.*

F.D.C. 187: 524.634: (450)

Abbreviations: PMP = Permanent Monitoring Plot; SU = Sampling Unit; QA = Quality Assessment; QC = Quality Control; RS = Reference Standard; T = species turnover; S = Sørensen's index Dissimilarity; N = Nitrophilous species; A = Acidophilous species;

Introduction

People, politicians and resource managers call for a basic understanding of potential human effects on forests health (Anderson *et al.* 2000; Spellemberg 2005). Anthropic activity may influence a variety of ecological attributes including the presence of species, populations, and communities as well as

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the occurrence, rate, or scale of processes (Angermeier and Karr 1994; Campetella *et al.* 2004). Understanding the implications of anthropogenic disturbances on an ecological system is complicated by variability in ecological response. Identification of indicators which capture key ecological responses to human actions provides a useful tool for improving understanding of ecological effects and for monitoring and management (Dale *et al.* 2002). Among the variables describing the forests condition, a huge amount of literature demonstrated that ground vegetation is strictly related to several ecological aspects (Ellemberg 1992; Wilson *et al.* 2003; Pignatti 2005; Gray and Azuma 2005; Lenière and Houle 2006; Kreyer and Zerbe 2006) and sensitive to the atmospheric pollution (Brunet *et al.* 1996; Grandin 2004; Tamis *et al.* 2005, Canullo *et al.* 2006). In facts, plant population can be used as indicators for soil acidity and nutrient availability, important factors leading to changes of site conditions (Ellemberg 1992; Seidling 2005). The availability of regional "biological floras" offers detailed datasets of species indicator values, which can be used for the interpretation of local data (Borhidi 1993; Bohling *et al.* 2002; Pignatti 2005). Ground floor vegetation also plays a key role in determining plant biodiversity of temperate forest (Seidling 2005), and it represents an excellent indicator of human impacts and natural processes (Zas and Alonso 2002; Holeska 2003; Hanley 2005; Zanne and Chapman 2005; Canullo and Campetella 2006b; González-Rivas 2006).

The Italian intensive forest ecosystem monitoring network (CONECOFOR) consists now of 31 permanent plots and is part of the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) (de Vries *et al.* 2003). After 10 years (1996 – 2006) of vegetation assessments, the consistency of temporal information leads, at least in a subset of PMPs (11 of them, each of 0.25 ha, Table 1), to produce a present-day status and changes evaluation respect to the starting point (t_0), with a corroborated ecological meaning, as foreseen in a previous contribution (Canullo *et al.* 2006). The primary aim of this report is to define the status of the PMPs from the point of view of plant diversity components. Secondly, the investigation on possible significant changes was performed by using the vegetation data sets. Particular attention was devoted to: (i) type and direction of variations *(i.e.* directional, cyclic, irregular variations), (ii) significant changes of species indicator values (acidophilous and nitrophilous species). To face with the above mentioned questions we selected some descriptors, such as mean number of species per sampling unit (SU), diversity indices of common use (Campetella and Canullo 2000; Canullo *et al.* 2006), frequency and mean cover of species sharing certain ecological indications (*sensu* Ellemberg 1992). Since species composition and species diversity responses are not always related, species turn-over indices as well as diversity *per se* were considered (Roberts and Gilliam 1995).

Each kind of ecosystem can be characterized by strict relationships between temporal scale and processes, with a huge range distribution (Falinski 1986). In case of forest ecosystem, 10 years still represent a narrow window to detect important dynamics aspects (*i.e.* time series analysis). However, considering the consistency of our data set, we guess that a robust reference standard (RS) might be detected as basic

Table 1 – General information on the CONECOFOR PMPs presenting the larger series of diachronic observations (1999-2005). The last column includes the total number of species recorded in all surveys (vascular plants, bryophytes and lichens included) at both the community and population level.
Informazioni generali sui PMP della rete CONECOFOR dove si posseggono le più ampie serie di dati diacronici (1999-2005). L'ultima colonna include il numero complessivo di specie raccolte in tutti i rilevamenti effettuati (piante vascolari, briofite e licheni inclusi) sia a livello di popolazione che di comunità.

N	Site name	Italian Region	Latitude	Longitude	m a.s.l.	Forest type	cumulative species number
1	ABR1 - Selvapiana	Abruzzo	+415051	+133523	1500	beech	50
3	CAL1 - Piano Limina	Calabria	+382538	+161047	1100	beech	76
4	CAM1 - Serra Nuda	Campania	+402558	+152610	1175	beech	91
5	EMI1 - Carrega	Emilia	+444306	+101213	200	sessile-oak	81
7	FRI1 - Bosco Boscat	Friuli-Venezia-Giulia	+454958	+131004	6	hornbeam-oak	85
9	LAZ1 - Monte Rufeno	Lazio	+424950	+115410	690	turkey-oak	145
10	LOM1 - Val Masino	Lombardia	+461416	+093316	1190	spruce (and fir)	111
11	MAR1 - Roti	Marche	+431738	+130424	775	turkey-oak	92
16	TOS1 - Colognole	Toscana	+433034	+102119	150	holm-oak	59
19	VAL1 - La Thuile	Valle d'Aosta	+454326	+065555	1740	spruce	140
20	VEN1 - Pian di Cansiglio	Veneto	+460326	+120156	1100	beech	70

aspect of monitoring activity (*i.e.* mean values related to first years of observation). Significant departures from standard reference may indicate important change (Hellawell 1991). Vegetation is also a complex spatial phenomenon, and its scale dependence (pattern and processes) is generally accepted, just as the mosaic nature of plant communities is well recognized at different hierarchical levels (Juhász-Nagy 1985; Podani *et al.* 1993; Bartha *et al.* 1998; Canullo and Campetella 2006a). As our databank contains the vegetation records from two approaches at different scale (population level on the understorey, community level on whole plot, Campetella and Canullo 2000), we analyzed their relative output, in order to verify if and how the same dynamical status can appear with different "indicators" variations at the investigated scales.

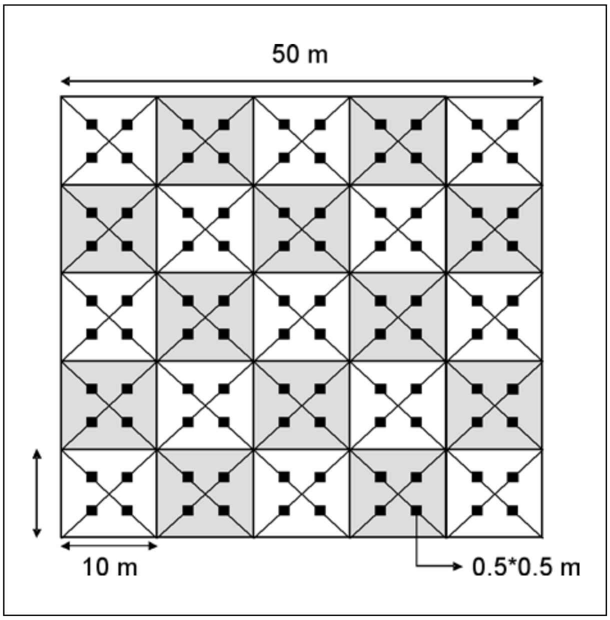


Figure 1 – Sampling design adopted for vegetation assessments within the PMPs of the italian network (CONECOFOR). Twelve 10*10m sampling units were selected for monitoring at the community level (shaded ones). One-hundred 0.5*0.5 m quadrates were identified for the monitoring at the population level (black squares along diagonals) (based on Canullo *et al.* 1999a).
*Disegno di campionamento adottato per le stime della vegetazione nei PMP della rete italiana (CONECOFOR). 12 unità di campionamento 10x10m sono state selezionate per il monitoraggio a livello di comunità (unità ombreggiate). Cento quadrati 0.5*0.5m sono stati utilizzati per il monitoraggio a livello di popolazione (quadrati neri lungo le diagonali) (basato su Canullo* et al. *1999a).*

Methods

Data collection

In the present paper, for reasons related to data quality and sampling procedures (Canullo *et al.* 2006), the evaluation of species composition focused on vascular plants and considered the data set originating from the surveys carried out from 1999 to 2005 (Table 1). According to the ICP-Forests Manual on Ground Vegetation Assessment (Dupouey 1998; Aamlid *et al.* 2002), the sampling design is related to the internal area of each PMP and it considers two different approaches (Figure 1):

- large scale, previously called "community level";
- fine scale, or "population level".

At the community level, twelve 10x10 m sampling units (SU) out of the 25 possible within each 50x50 m fenced PMP were systematically selected in a chessboard pattern to minimize spatial correlation (further details: Canullo *et al.* 1999, 2001, 2006; Campetella and Canullo 2000). The specific cover for the tree, shrub, herb and moss layers was recorded by visual cover estimates, according to the phytosociological method, assigning each species to correspondent classes (Braun-Blanquet 1951), further transformed in percent median values according to Van Der Maarel (1979). At the population level, a systematic grid of one-hundred 50x50 cm quadrates was selected within the fenced PMP (Figure 1). Species-specific cover estimates, density of rooting functional individuals, and frequency of mechanical and parasitic damages were recorded in the understory (up to the height of 1.3 m). In this paper, only data obtained from the summer surveys of both the approaches were used to estimate indices and descriptors. In all the initial 20 PMPs of the network (now increased to 31) the vegetation assessment began in 1996. After the validation of both the field methodology and Quality Assessment of data (QA), with the exception of SIC1, all the 19 PMPs were visited during 1999 in order to have the initial standard description of plant diversity at the various plots. On the other hand, data covering the 1999-2005 period were available only for 11 PMPs and were used to explore our hypotheses. At the population level the data of 2003 and 2004 are incomplete or missing.

Quality Assurance (QA)

In order to improve the consistency and data sets comparability, a Quality Control (QC) programme has been applied, with clearly defined quality objectives.

A Quality Assurance programme was implemented, including:

1. Field manual adoption (CANULLO *et al.* 1999) to assure harmonization.
2. Definition of Measurement Quality Objectives and Data Qualities for each parameter.
3. Annual team-training course, consisting in harmonization and field intercalibration of all the teams composed of two members including a control team; repeated observations on the same plot were also performed.
4. The control team carries out field controls on randomly chosen PMPs and a related fraction of SU; this control is used to observe the concordance between values recorded by the control team and the survey teams. Departure from expected values can be used to define the agreement with Quality Objectives thresholds (in case, refusal will be considered).
5. The data acquisition is successive to further validation executed by data-base procedures, in order to ascertain the consistency and plausibility of the data. After the taxonomical validation according to PIGNATTI's Italian flora (1982), the database performs some checks, verifying the correspondence with a set of thresholds previously defined by the system supervisor. Further inspections of data integrity for observations on both community and population levels are also performed. Finally, the automatic association between the Italian flora archive and the coded archive of *Flora Europaea* is performed (derived from the PANDORA taxonomic database system of the Royal Botanic Garden, Edinburgh; ICP-Forests-BHF 2007).

For more details on Data Quality programme, see also CANULLO *et al.* (2002).

Data analysis

Vascular plant species richness was expressed as the total number of vascular species identified in the SUs, the mean number of species $*100\ m^{-2}$ and the mean number of species $*2500\ cm^{-2}$ (± confidence interval at $p=0.05$). To appreciate the species turnover (*i.e.* differences in species composition) along the diachronic estimations, two descriptors of species variation were considered for data collected on 10∗10 m SUs.

The species turnover score was assessed for each SU as follows

$$\mathbf{T} = (S_{t0} + S_{t1}) - (2 \times C)$$

where S_{t0} is the number of species recorded in a reference year and S_{t1} the number of species collected in the next year, C represents the shared species number.

The Sørensen's index of dissimilarity (1-Sørensen) is frequently considered as a *beta* diversity estimator. It gives a measure of heterogeneity in plant species composition between sites or - as in our case - diachronic rélevées (MAGURRAN 2003). It was assessed for each SU as follows

$$\mathbf{S} = 1 - [(2 \times C)/(S_{t0} + S_{t1})]$$

where the symbols have the above mentioned meaning. The index ranges from 0 to 1, the latter indicating the maximum dissimilarity.

At the community level, richness-abundance relations were assessed using the Shannon index. This non-parametric estimator can be considered a good indicator of the heterogeneity level (PEET 1974), incorporating both Evenness and species richness.

The index was calculated by the following formula:

$$H' = -\Sigma\, pi \log_2 (pi)$$

where pi is the relative abundance of the species i. As suggested by the results of the previous report, only the mean cover of species was used as abundance parameter in this paper, as it gives a more realistic representation of the textural contribution of the species (CANULLO *et al.* 2006). The pi parameter is estimated using ci/C in which ci is the average relative cover of the species i in all layers of the 12 SUs, and C is the summation of the average relative cover of all species. To analyze the cover distribution level among species, the Shannon Evenness was also calculated as follows:

$$E = H'/H'_{max}$$

where H'_{max} represents the maximum H' at the given species richness ($H'_{max} = \log_2 S$, where S is the total number of species).

The population level data are very suitable for the application of the diversity index based on Fisher's logarithmic series (FISHER *et al.* 1943). This is one of the most widely used indices which have a relative stability respect to the variation of the sampled area size, has a good discriminate power, and can be calculated quite easily (Magurran 2003):

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

where α (specific-individual diversity) is obtained as follows:

$$\alpha = N(1-x)/x$$

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, or ramets of modular organisms (Harper 1977) collected in the complete sample (100 SU). In our case only the species rooting inside the SU were considered.

As the 10∗10 m SUs approach collected an higher number of species, highly related to the total richness (Ferretti *et al.* 2006), all the vascular species from summer surveys (1999-2005) within the sampling system, were assigned to widely accepted "ecological" groups (Sage *et al.* 2005; Fischer *et al.* 2002). Ellenberg's indicator values for the Italian flora (Pignatti 2005) were modified to summarize few indicators of different environmental conditions (soil pH, nitrogen and nutrient contents). The time variation of mean cover and frequency of *nitrophilous* and *acidophilous* plants species belonging to the upper fourth of the index range were considered as an additional overall ecosystem evaluation.

The repeated measurements on the same SUs (at both the scales) at more than two time-points leads to inherent autocorrelation. Therefore, in order to appreciate possible significant differences in species richness over time, the Repeated Measures ANOVA (RMA) test has been applied in each PMP, considering the variation of mean species number recorded on the 10∗10m SUs (Within-Subjects Effects test); possible linear trend over time was also tested (Within-Subjects Contrasts test). In the PMPs where the Within-Subjects Effects test gives significant variation in richness ($p<0.05$), the Bonferroni test was applied in order to compare all possible pairwises of temporal data. Significant differences of species turnover estimators (T and S) and abundance of *nitrophilous* and *acidophilous* species over time were also assessed by RMA procedure.

The distribution of species richness at the population level (SUs 50∗50cm) wasn't normal, thus the Friedman's non parametric test was used to assess significant differences over time. The linear regression for both Shannon and Fisher indices values vs. time were also calculated, by estimating the angular coefficient and its significant level by ANOVA.

Moreover, a baseline standard was established for each estimator (diversity indices not included). Considering the monitoring period length and data storage quantity, we *a priori* considered the first 4 years of data collection as surveillance period and its related mean value as monitoring reference (Reference Standard – RS), defined by the confidence intervals at 99%. Yearly mean values departing from such interval can be interpreted as important variations. Such possible changes are expected to have a more robust ecological meaning respect to that obtained by the traditional statistic tests. Data representing ecological values are inherently susceptible of unpredictable errors (*i.e.* interpretation), and then the confidence interval was calculated at 99.9%.

Nomenclature of species follows *Flora Europaea* (Tutin *et al.* 1964 -1980).

Results

Community level

Species richness

The annual changes in mean number of species ∗100 m^{-2} over the period 1999-2005 are shown in Table 2. As in the previous report, the Variation Coefficient on each PMP resulted almost stable (lower than 25%) within the observation period, indicating a good stationarity and (assuming 15% of tolerable error) the number of SUs was always adequate. Annual mean species variations are frequent and can be due to natural cycles of vegetation structure and/or recovery from previous disturbances (natural or man induced by forest management). With the only exception of CAL1, LOM1 and VAL1, the RMA test revealed significant changes in species richness over the period (Between-subjects effect). A significant linear positive trend was reported for CAM1, FRI1 and VEN1, while LAZ1 presents negative tendency (Table 2: Between-subjects contrast test). The Bonferroni *post-hoc* test

Table 2 – Annual changes in species richness. Total number of vascular species listed in the sampled area and mean number of species*100 m^{-2} (and its confidence interval) in each PMP (CONECOFOR data sets range 1999-2005). Significant differences among the diachronic observations (Within-subjects effects) and significant linear trend (Within-subjects contrasts) based on Repeated Measures Anova test are in bold. A reference standard (mean values of the first four years of observation, delimited by confidence interval at 99%) was also reported. Underlined values state significant departures from RS.
*Cambiamenti annuali nella ricchezza specifica. Numero totale di specie vascolari rinvenute nell'area campionata e numero medio di specie*100 m^{-2} (e suo intervallo di confidenza) in ogni PMP (CONECOFOR dataset 1999-2005). Le differenze significative tra osservazioni diacroniche (Within-subjects effects) ed i trend lineari significativi (Within-subjects contrasts) sono evidenziati in grassetto (Repeated Measures Anova). Viene inoltre riportato un riferimento standard (RS, valore medio dei primi quattro anni di osservazione, delimitati dall'intervallo di confidenza al 99%). I valori sottolineati certificano variazioni significative dal RS.*

Plot	Indicator	Years							Repeated Measures Anova		Reference
		1999	2000	2001	2002	2003	2004	2005	Between-subj effect (p)	Between-subj contrasts (p)	Standard
	total number of species	23	24	22	22	19	21	21			
01ABR1	n sp * 100 m^{-2}	8.92	9.58	9.67	9.67	8.67	9.08	<u>8.33</u>	**0.044**	0.152	**9.46 (± 0.85)**
	confidence interval (±)	1.26	1,30	1.35	1.35	1.23	1.28	1.69			
	total number of species	34	31	35	34	31	32	37			
03CAL1	n sp * 100 m^{-2}	17.41	17.66	17.25	16.16	16.75	17.50	16.83	0.352	0.425	**17.15 (± 1.07)**
	confidence interval (±)	1.98	2.03	1.65	1.45	1.50	1.86	2.41			
	total number of species	31	26	28	35	33	39	29			
04CAM1	n sp * 100 m^{-2}	14.83	<u>12.50</u>	14.33	14.75	<u>16.75</u>	<u>19.50</u>	14.41	**0.000**	**0.002**	**14.10 (± 0.99)**
	confidence interval (±)	1.92	1.26	1.37	1.13	1.13	1.64	1.06			
	total number of species	28	37	41	39	27	31	27			
05EMI1	n sp * 100 m^{-2}	<u>11.41</u>	12.58	13.83	<u>14.75</u>	<u>11.41</u>	<u>11.33</u>	12.41	**0.000**	0.578	**13.23 (± 0.89)**
	confidence interval (±)	1.00	1.42	1.00	1.22	1.09	1.47	1.26			
	total number of species	53	53	55	53	57	61	63			
07FRI1	n sp * 100 m^{-2}	<u>24.25</u>	25.33	26.33	<u>27.91</u>	<u>28.41</u>	<u>30.33</u>	<u>30</u>	**0.000**	**0.000**	**25.96 (± 1.36)**
	confidence interval (±)	2.31	1.97	1.88	1.95	1.62	1.76	1.34			
	total number of species	55	55	57	52	50	49	54			
09LAZ1	n sp * 100 m^{-2}	23.50	22.00	23.25	<u>20.08</u>	<u>20.00</u>	20.91	21.33	**0.000**	**0.011**	**22.23 (± 1.75)**
	confidence interval (±)	3.14	2.53	2.47	2.30	2.43	2.29	2.12			
	total number of species	53	56	55	58	62	56	57			
10LOM1	n sp * 100 m^{-2}	29.09	28.54	29.54	28.54	29.18	28.45	27.90	0.654	0.423	**28.93 (± 2.00)**
	confidence interval (±)	2.94	3.36	2.77	2.91	2.20	2.44	2.86			
	total number of species	64	64	61	60	60	60	62			
11MAR1	n sp * 100 m^{-2}	<u>31.08</u>	29.08	28.58	<u>27.16</u>	<u>27.08</u>	27.75	30.25	**0.001**	0.207	**28.98 (± 1.67)**
	confidence interval (±)	1.98	2.62	2.75	2.52	2.01	2.25	2.91			
	total number of species	37	34	33	35	33	35	36			
16TOS1	n sp * 100 m^{-2}	16.33	15.25	14.66	16.41	<u>14.16</u>	15.50	15.75	**0.010**	0.534	**15.67 (± 1.13)**
	confidence interval (±)	1.74	1.54	1.62	1.92	1.68	1.37	1.75			
	total number of species	34	35	37	34	32	34	33			
19VAL1	n sp * 100 m^{-2}	13.83	13.91	13.50	13.33	13.75	13.25	13.24	0.739	0.300	**13.67 (± 0.82)**
	confidence interval (±)	1.40	1.22	1.26	1.19	1.56	1.32	1.40			
	total number of species	26	33	33	34	36	38	35			
20VEN1	n sp * 100 m^{-2}	<u>12.16</u>	15.41	15.83	<u>16.08</u>	15.58	<u>17.08</u>	16.25	**0.000**	**0.001**	**14.92 (± 1.14)**
	confidence interval (±)	1.01	1.03	1.94	1.80	1.70	1.79	2.20			

considered all pairwise comparisons in the richness data, detecting in which surveys significant variation appears (Figure 2).

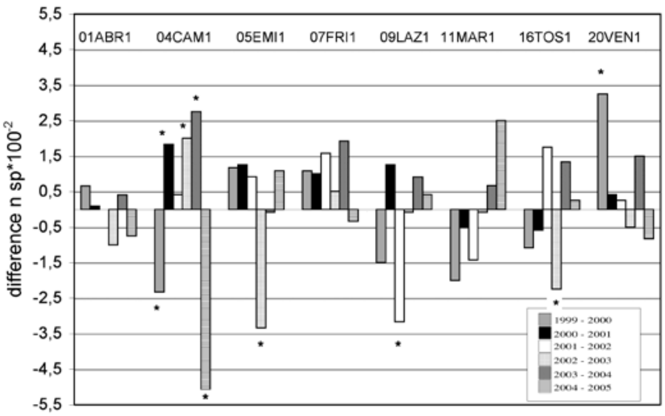


Figure 2 – Changes in mean number of species*100m^{-2} occurred in each couples of consecutive years. Here are considered only the PMPs that reported significant variation (Between-subjects effect test) in the considered period (1999-2005). When appropriate, the results of Bonferroni test have been reported (p<0.05, star indicates significant variations).
*Variazioni nel numero medio di specie*100m^{-2} in ciascuna coppia di anni consecutivi. Vengono considerati solo i PMP che hanno riportato variazioni significative (Between-subjects effect test) nel periodo considerato (1999-2005). I risultati del test Bonferroni sono stati riportati (p<0.05, gli asterischi indicano variazioni significative).*

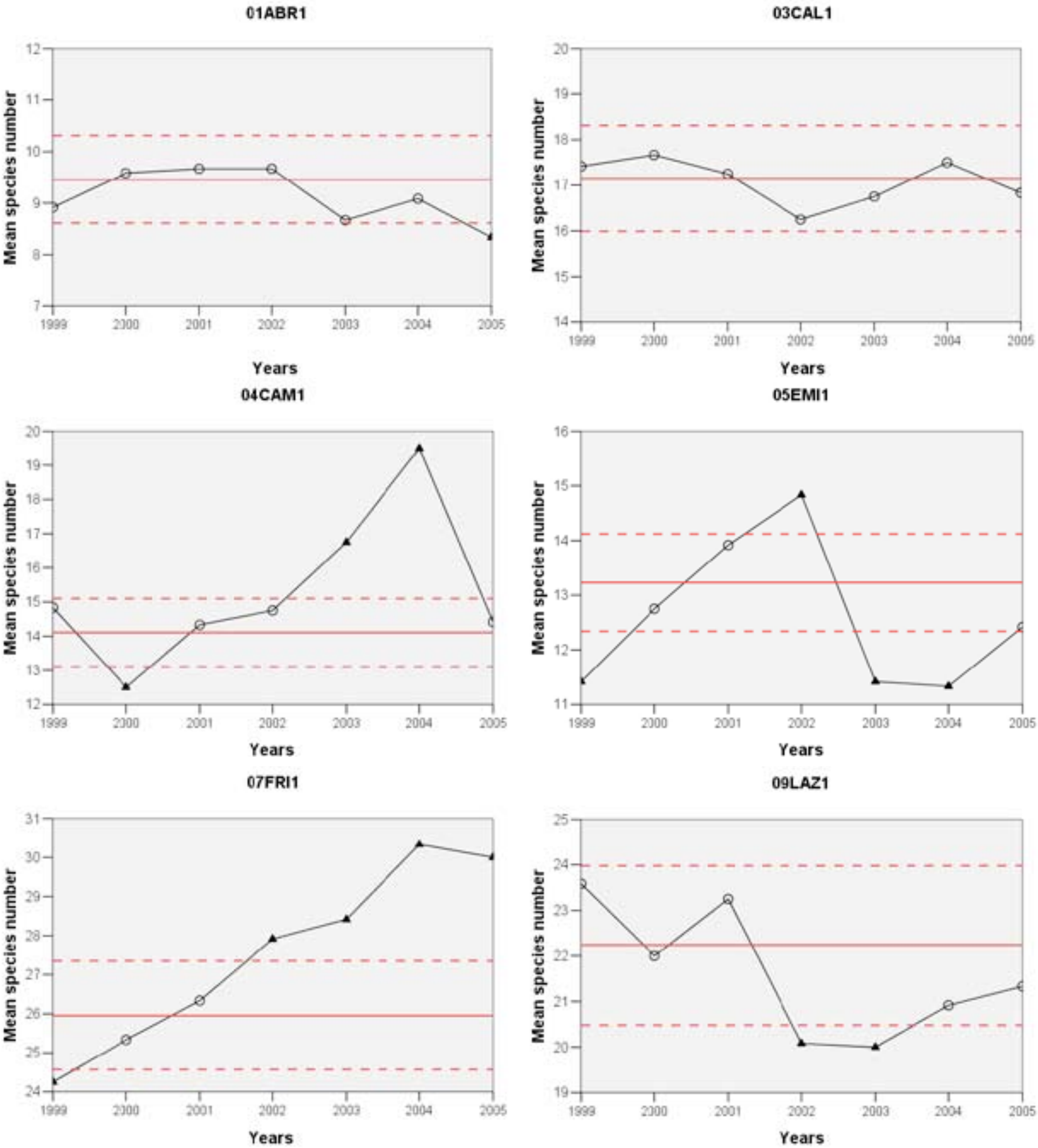
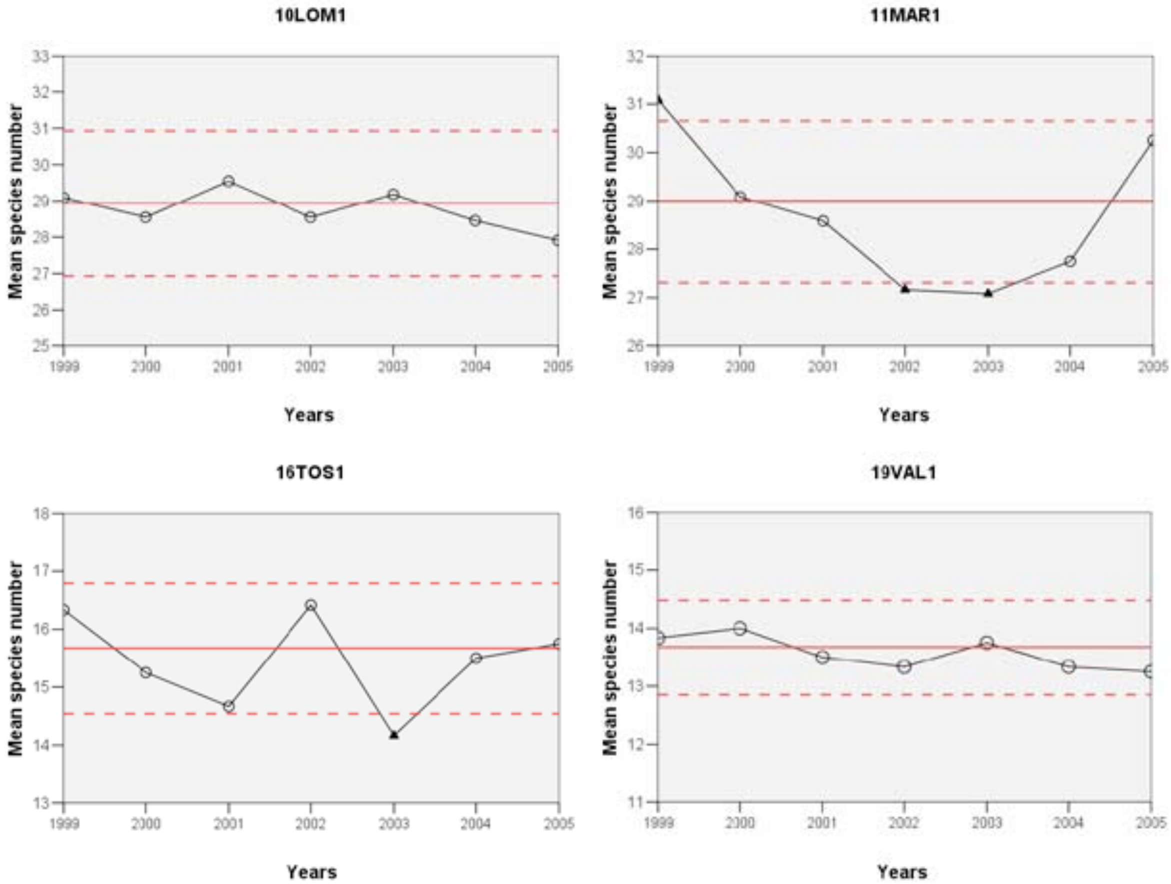
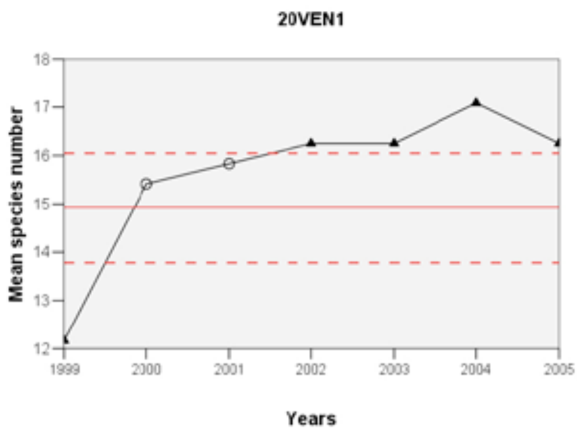


Figure 3 – Control graphs on 11 PMPs of the CONECOFOR network. Variation of species mean number *100 m^{-2} in the considered period is compared to the reference standard (RS). The straight line represents the mean value of the first 4 years while dotted lines indicate the upper and lower values of confidence interval (p<0.01). Dark triangles represent significant departure from RS. (Continue next page).
*Grafici di controllo su 11 PMP della rete CONECOFOR. Le variazioni del numero medio di specie*100 m^{-2} nel periodo considerato viene comparato con lo standard di riferimento (RS). La linea continua rappresenta il valore medio dei primi 4 anni mentre le linee tratteggiate indicano i limiti dell'intervallo di confidenza (p<0.01). I triangoli neri rappresentano variazioni significative rispetto ad RS. (Continua alla pagina seguente).*

In Figure 3, control graphs reported significant departures of richness values from reference standard (RS). CAL1, LOM1 and VAL1 PMPs didn't show significant variations respect to the standard reference, indicating an evident richness stability in the considered period. All of them are located in high forest communities, with a stabilized tree structure, which have been neither affected by known disturbances nor influenced by neighbouring open communities. ABR1 presents the narrowest RS confidence interval. As it is high forest too, it depicts a similar situation to the previous areas: the variation in richness was very low

figure 3 (continued)





in the first years with a significant reduction of species number at the last term.

Shannon index

Shannon index and its relative Evenness were based on the specific mean cover contribution by SU (Table 3); in the previous report they performed a good discriminant ability respect to the same obtained by using frequency data (not considered in this paper). In fact, the cover estimation by relative classes, even though is not a precise measure of the species abundance (Magurran 2003), gives a more realistic representation of the species textural contribution, related to the resource use and the real investment of the species in the community.

PMPs with higher diversity values (Shannon index > 3.0 bits) can be found on the PMPs FRI1, LOM1, MAR1, and TOS1; an intermediate group (<3 and >2 bits) include CAL1, EMI1 and VAL1 forest stands, while ABR1, CAM1, LAZ1, and VEN1 share the lowest values (<2 bits).

The values of Evenness range from 0.10 to 0.76 (Table 3). The PMPs where such index reach the higher values are MAR1 (0.57), FRI1 (0.63), LOM1 (0.63) and TOS1 (0.76), which are forests submitted to anthropic disturbance and with a good proportion of woody species and internal heterogeneity.

The communities where the Evenness resulted

Table 3 – Shannon index and the relative Evenness values for vascular species at the community level in the PMPs of the CONECOFOR network. The indices values vs. time linear regression were accomplished. Significant directional changes occurred in 07FRI1, LOM1 and VEN1 PMPs. Bold figure indicate significant values (p<0.05).
Risultati dell'indice di Shannon e del relativo Evenness per le specie vascolari a livello di comunità nei PMP della rete CONECOFOR. Sono riportati anche i valori della regressione lineare degli indici rispetto al tempo. Variazioni direzionali significative si registrano nei PMP FRI1, LOM1 e VEN1. I valori in grassetto indicano cambiamenti significativi (p<0.05).

	years							linear regression vs. time		
PMPs	1999	2000	2001	2002	2003	2004	2005	R^2	b	p
01ABR1										
H'	0.810	0.574	0.805	0.805	0.717	0.677	0.369	0.331	-0.043	0.177
E	0.179	0.125	0.181	0.181	0.169	0.154	0.084	0.508	-0.009	0.245
03CAL1										
H'	2.362	1.570	2.018	1.792	2.029	2.005	2.385	0.064	0.034	0.586
E	0.464	0.316	0.393	0.352	0.409	0.401	0.380	0.114	-0.002	0.808
04CAM1										
H'	1.500	1.262	1.322	1.176	1.438	1.723	1.574	0.513	0.045	0.239
E	0.302	0.268	0.275	0.229	0.285	0.326	0.324	0.428	0.007	0.338
05EMI1										
H'	2.443	2.405	2.588	2.469	2.243	2.404	2.490	0.152	-0.071	0.746
E	0.508	0.461	0.483	0.467	0.471	0.485	0.523	0.267	0.003	0.562
07FRI1										
H'	3.263	3.276	3.329	3.510	3.544	3.719	3.633	0.944	0.079	**0.001**
E	0.569	0.571	0.575	0.612	0.607	0.627	0.607	0.842	0.009	**0.018**
09LAZ1										
H'	1.453	1.599	1.462	3.295	2.038	1.727	2.114	0.336	0.100	0.461
E	0.251	0.276	0.250	0.578	0.361	0.307	0.367	0.347	0.018	0.446
10LOM1										
H'	3.502	3.551	3.580	3.618	3.675	3.645	3.673	0.941	0.028	**0.002**
E	0.611	0.611	0.619	0.617	0.617	0.627	0.629	0.932	0.003	**0.002**
11MAR1										
H'	3.328	3.143	3.081	3.335	3.022	3.359	3.046	0.248	-0.171	0.592
E	0.555	0.524	0.520	0.565	0.512	0.568	0.511	0.156	-0.021	0.793
16TOS1										
H'	3.209	3.120	2.848	3.155	3.834	3.301	3.178	0.323	0.045	0.480
E	0.616	0.613	0.565	0.615	0.760	0.643	0.614	0.314	0.009	0.492
19VAL1										
H'	2.550	2.011	2.120	2.199	1.984	2.047	2.395	0.193	-0.019	0.678
E	0.501	0.392	0.407	0.432	0.396	0.402	0.474	0.120	-0.002	0.798
20VEN1										
H'	0.695	0.912	0.960	1.194	1.342	1.520	1.513	0.983	0.145	**0.000**
E	0.147	0.180	0.190	0.234	0.259	0.289	0.295	0.989	0.026	**0.000**

very low are high forests dominated by beech (0.10 - 0.20), where the abundance models characterizing the forest ecosystem is very uneven for vascular species. Both the indices result sometimes independent to the number of species collected in the whole sample (Table 2): the linear regressions between the Shannon index vs. total number of species shows very low R^2 values (often <10%).

The annual variations of the indices over the course of the 1999-2005 surveys were of different size. The directional changes for the cover Shannon index and relative Evenness (Table 3) were highly significant in only three cases (FRI1, LOM1, VEN1). These changes point out an increase in diversity, guided almost exclusively by richness improvements.

Species turn-over

Indices related to species turnover are reported in Table 4. This can add relevant information about the mechanisms related to the complex vegetation dynamics processes. In most of the PMPs the β-diversity level has resulted rather low and levelled, as demonstrated by the mean values of Sorensen dissimilarity. In fact, such index ranges from 0.000 (ABR1, 2002) to 0.299 (CAM1, 2005) and in CAL1, FRI1, LOM1 and TOS1 it is always < 0.200, thus all the sets are relatively similar. By the species turn-over index (T) we can appreciate the number of species involved in the compositional variation (*i.e.* new entry species + disappeared species). Such index show (Table 5) a larger variation among the PMPs (0-12.25; ABR1, 2002 and MAR1, 2003 respectively). As expected, such index can be unrelated to Sørensen index, where the latter is a sort of standardization by the amount of species involved.

The annual changes of the indices over the course of the 1999-2005 surveys were of different magnitude.

Table 4 – Mean values in number of species turn-over (T) and Sørensen's index Dissimilarity (S) occurred in each couples of consecutive years at 100 m² scale in the CONECOFOR network. PMPs that reported significant variation (Between-subjects effect and contrast tests, p<0.05) in the considered period (1999-2005) are reported in bold.
Valori medi del turn-over delle specie (T) e l'indice di Dissimilarità di Sørensen (S) che si sono verificati in ciascuna coppia di anni alla scala di 100 m² della rete CONECOFOR. In grassetto sono riportati i PMP che hanno evidenziato variazioni significative (Between-subjects effect e contrast test, p<0.05) nel periodo considerato (1999-2000).

Plot	Indicator	year 1999/2000	2000/2001	2001/2002	2002/2003	2003/2004	2004/2005	Repeated Measures Anova Between-subjects effect (p)	Between-subjects contrasts (p)
01ABR1	**Sorensen Dissimilarity**	0.172	0.266	0.000	0.186	0.180	0.178	**0.000**	0.830
	St. Dev.	0.118	0.117	0.000	0.095	0.102	0.105		
	Species number Turn-over	3.166	5.083	0.000	3.500	3.25	3.083	**0.000**	0.510
	St. Dev.	2.208	2.274	0.000	2.237	1.864	2.065		
03CAL1	**Sorensen Dissimilarity**	0.129	0.159	0.150	0.074	0.096	0.149	**0.009**	0.399
	St. Dev.	0.058	0.061	0.063	0.048	0.032	0.095		
	Species number Turn-over	4.583	5.583	5.083	2.416	3.416	4.833	**0.006**	0.213
	St. Dev.	2.274	2.353	2.503	1.505	1.505	2.855		
04CAM1	**Sorensen Dissimilarity**	0.184	0.137	0.197	0.175	0.242	0.299	**0.000**	**0.000**
	St. Dev.	0.064	0.062	0.068	0.072	0.084	0.075		
	Species number Turn-over	5.000	3.666	5.750	5.500	8.750	10.083	**0.000**	**0.000**
	St. Dev.	1.858	1.723	2.005	2.276	3.048	2.466		
05EMI1	**Sorensen Dissimilarity**	0.204	0.234	0.200	0.190	0.218	0.169	0.353	0.177
	St. Dev.	0.064	0.094	0.100	0.083	0.065	0.070		
	Species number Turn-over	4.833	6.250	5.750	5.000	5.083	4.083	0.177	0.113
	St. Dev.	1.466	2.701	2.927	2.412	2.274	2.020		
07FRI1	**Sorensen Dissimilarity**	0.104	0.119	0.101	0.084	0.105	0.108	0.317	0.703
	St. Dev.	0.037	0.054	0.034	0.041	0.040	0.030		
	Species number Turn-over	5.250	6.166	5.583	4.750	6.166	6.500	0.193	0.353
	St. Dev.	2.005	2.918	2.234	2.261	2.329	1.783		
09LAZ1	**Sorensen Dissimilarity**	0.138	0.157	0.217	0.222	0.173	0.201	**0.002**	**0.021**
	St. Dev.	0.047	0.041	0.066	0.067	0.065	0.057		
	Species number Turn-over	6.166	7.083	9.500	8.916	7.250	8.583	**0.005**	**0.059**
	St. Dev.	2.208	2.234	3.397	2.843	3.306	3.146		
10LOM1	**Sorensen Dissimilarity**	0.149	0.112	0.173	0.097	0.117	0.128	**0.003**	0.106
	St. Dev.	0.046	0.038	0.061	0.047	0.051	0.055		
	Species number Turn-over	8.727	6.636	10.272	5.363	6.727	7.272	**0.001**	0.076
	St. Dev.	3.379	2.500	4.606	2.1105	3.0361	3.165		
11MAR1	**Sorensen Dissimilarity**	0.176	0.127	0.196	0.228	0.183	0.151	0.081	0.839
	St. Dev.	0.052	0.043	0.067	0.120	0.105	0.052		
	Species number Turn-over	10.416	7.333	10.750	12,250	10.000	8.833	0.081	0.832
	St. Dev.	2.843	2.774	3.018	6.383	5.608	3.459		
16TOS1	**Sorensen Dissimilarity**	0.141	0.142	0.103	0.140	0.134	0.086	0.065	0.054
	St. Dev.	0.059	0.070	0.054	0.058	0.072	0.038		
	Species number Turn-over	4.416	4.250	3.083	4.250	4.000	2.750	0.080	0.052
	St. Dev.	1.928	2.340	1.621	1.815	2.044	1.422		
19VAL1	**Sorensen Dissimilarity**	0.105	0.117	0.070	0.065	0.061	0.109	**0.011**	0.349
	St. Dev.	0.074	0.054	0.054	0.043	0.066	0.040		
	Species number Turn-over	2.916	3.250	2.000	1.833	1.833	2.916	**0.022**	0.355
	St. Dev.	1.928	1.602	1.651	1.337	2.081	1.164		
20VEN1	**Sorensen Dissimilarity**	0.204	0.093	0.080	0.074	0.075	0.063	**0.000**	**0.00**0
	St. Dev.	0.065	0.040	0.035	0.053	0.050	0.040		
	Species number Turn-over	5.583	2.916	2.583	2.333	2.333	2.000	**0.000**	**0.000**
	St. Dev.	1.676	1.443	1.240	1.723	1.302	1.348		

In the ABR1, CAL1, CAM1, LAZ1, LOM1, VAL1 and VEN1 PMPs both the indices showed significant changes over the period (RMA, p<0.05); significant directional changes appear in only three cases (Table 4): data from CAM1 and VEN1 show an increase of species variation, while in VEN1 a downward tendency occurred.

Indicator values

The abundance and variation in contribution of *nitrophilous* (N) and *acidophilous* (A) plants species were assessed using their mean cover and mean number in the SUs. The number of N-species was higher respect to the acidophilous ones in most of the PMPs; only in LAZ1, LOM1 and VAL1 was the opposite; such difference is strengthened by the relative cover. The results of RMA test and the significant changes respect to the appropriate RS are reported in Table 5. Only TOS1 and LOM1 PMPs did not show significant changes. In ABR1, the cover of N-species reaches significant departure from RS in 2005 and it seems particularly due to variation in cover of *Fagus sylvatica*, while the significant changes of A-species is of relative importance (only two species involved). CAL1 shows a significative minimum of N-species cover at the last record, due to *Fagus sylvatica* and *Rubus hirtus*, while higher species frequencies are to be found. In CAM1 the same change, but to a lesser extent, can be observed; here the transitory entrance of *Galium parisiense* caused a significant variation in cover of A-species in 2003, above the RS upper limit. In spite of the N-species contingent remain almost stable over the period, FRI1 undergoes significant changes in their frequency during 2003-2005, together

Table 5 – Nitrophilous (N) and acidophilous (A) species abundance considering their mean number *100 m^{-2} and mean relative cover (± SD) in each PMP of the CONECOFOR network. Significant differences among the diachronic observations (Within-subjects effects) and significant linear tendecy (Within-subjects contrasts) based on Repeated Measures Anova test (RMA) are in bold. A reference standard (RS: mean values of the first four years of observation, delimited by confidence interval at 99.9%) was also reported and significant departures were underlined.
*Importanza delle specie nitrofile (N) e acidofile (A) considerando il loro numero medio *100 m^{-2} e la loro copertura media (± SD) in ciascun PMP della rete CONECOFOR. Le variazioni significative tra osservazioni diacroniche (Within-subjects effects) e tendenze lineari significative (Within-subjects contrasts) basate sul test Repeated Measure Anova (RMA) sono in grassetto. E' inoltre riportato un riferimento standard (RS: valori medi dei primi quattro anni di osservazione, delimitati dall'intervallo di confidenza al 99.9%) ed i valori che vi si discostano significativamente.*

PMPs	Indicator sp	1999		2000		2001		2002		2003		2004		2005		RMA between-subject p			
		mean	± sd	mean	± sd	mean	± sd	mean	± sd	mean	± sd	mean	± sd	mean	± sd	effect	contrasts	RS	±c.i.
01ABR1	**N** n*100m^{-2}	3.50	0.80	3.42	0.67	4.25	0.87	4.25	0.87	3.67	0.65	3.67	0.78	3.08	0.67	**0.000**	0.356	**3.86**	4.61_3.10
	N % cover	89.88	9.30	93.43	6.34	90.62	8.06	90.62	8.06	91.32	8.64	91.50	8.77	97.39	2.09	**0.001**	**0.026**	**91.14**	93.37_88.56
	A n*100m^{-2}	0.75	0.62	0.75	0.62	0.92	0.79	0.92	0.79	0.50	0.67	0.25	0.45	0.08	0.29	**0.000**	**0.001**	**0.83**	0.99_0.68
	A % cover	0.61	0.83	0.30	0.32	0.44	0.83	0.44	0.83	0.19	0.29	0.11	0.20	0.05	0.16	0.055	**0.013**	**0.45**	0.66_0.24
03CAL1	**N** n*100m^{-2}	3.50	1.17	3.42	1.31	3.42	1.16	3.33	0.98	3.33	1.07	3.67	1.44	3.83	1.53	0.433	0.186	**3.42**	3.53_3.30
	N % cover	61.84	5.31	77.97	7.47	73.36	6.21	73.10	7.74	70.62	8.06	72.33	8.32	57.71	9.33	**0.000**	**0.015**	**71.57**	82.85_60.28
	A n*100m^{-2}	0.75	0.62	0.58	0.51	0.50	0.52	0.42	0.51	0.50	0.52	0.58	0.51	0.67	0.49	0.085	0.674	**0.56**	0.80_0.33
	A % cover	0.51	0.70	0.15	0.22	0.21	0.22	0.06	0.15	0.16	0.20	0.19	0.20	0.17	0.15	**0.004**	0.116	**0.23**	0.55_-0.08
04CAM1	**N** n*100m^{-2}	3.33	1.30	2.08	0.67	2.83	0.94	3.25	0.87	3.33	0.78	4.67	0.78	3.17	0.83	**0.000**	**0.018**	**2.88**	3.81_1.94
	N % cover	74.03	9.01	78.16	10.31	77.55	10.01	78.12	10.00	73.36	8.52	76.52	10.35	69.65	7.96	**0.005**	**0.043**	**76.96**	80.22_73.71
	A n*100m^{-2}	1.08	0.29	1.00	0.00	1.00	0.00	1.08	0.29	1.75	0.45	1.83	0.39	1.00	0.00	**0.000**	**0.001**	**1.04**	1.12_0.96
	A % cover	1.78	1.08	1.69	1.13	3.28	3.83	1.46	1.28	4.59	5.16	3.05	2.56	2.54	2.76	**0.025**	0.061	**2.05**	3.42_0.68
05EMI1	**N** n*100m^{-2}	0.42	0.51	0.58	0.67	1.08	1.08	1.25	0.62	1.00	0.95	0.92	0.79	0.75	0.75	**0.011**	0.167	**0.83**	1.49_0.18
	N % cover	0.00	0.00	0.20	0.35	0.83	1.33	0.85	1.21	0.75	1.07	0.83	1.55	2.25	4.39	**0.016**	0.109	**0.47**	1.18_-0.25
	A n*100m^{-2}	1.17	0.39	1.50	0.80	1.50	0.67	1.58	0.67	1.08	0.51	1.00	0.60	1.00	0.60	**0.005**	0.063	**1.44**	1.74_1.13
	A % cover	0.03	0.08	0.63	0.33	0.76	0.49	0.57	0.46	0.21	0.28	0.30	0.32	0.13	0.25	**0.000**	0.056	**0.50**	1.02_-0.03
07FRI1	**N** n*100m^{-2}	3.50	1.45	3.75	1.22	3.75	1.29	4.08	1.38	4.17	1.03	4.58	1.38	4.67	1.23	**0.026**	**0.024**	**3.77**	4.16_3.38
	N % cover	10.23	7.25	11.09	7.47	13.55	9.68	14.48	9.88	15.68	12.59	15.31	10.26	13.21	8.94	**0.007**	**0.037**	**12.34**	15.64_9.04
	A n*100m^{-2}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	-	-	-
	A % cover	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	-	-	-
09LAZ1	**N** n*100m^{-2}	1.25	0.75	1.08	0.79	1.08	0.90	1.17	0.94	0.75	0.62	1.17	1.03	1.08	0.79	0.251	0.470	**1.15**	1.28_1.01
	N % cover	3.25	6.84	3.18	6.67	1.96	3.11	7.29	9.70	4.13	5.32	2.82	6.61	4.39	8.42	**0.002**	0.183	**3.92**	7.74_0.10
	A n*100m^{-2}	4.00	1.13	3.58	0.79	3.92	0.67	3.83	0.39	3.67	0.89	4.17	0.72	3.83	1.03	0.506	0.749	**3.83**	4.13_3.54
	A % cover	1.93	0.79	3.21	1.88	1.94	1.13	8.35	4.19	5.14	2.77	4.85	3.85	7.28	5.56	**0.000**	**0.002**	**3.86**	8.89_-1.17
10LOM1	**N** n*100m^{-2}	5.55	1.75	5.55	1.51	5.64	1.50	5.82	2.14	6.09	2.02	5.55	2.21	5.91	1.81	0.797	0.572	**5.64**	5.85_5.42
	N % cover	28.20	15.04	24.77	11.94	22.06	13.12	26.13	13.84	22.71	16.22	20.64	16.23	24.34	16.55	0.134	0.288	**25.29**	29.53_21.06
	A n*100m^{-2}	3.27	1.10	3.82	1.17	4.27	1.56	3.73	1.49	3.55	1.04	3.73	1.27	3.45	1.04	0.194	0.809	**3.77**	4.45_3.10
	A % cover	5.96	6.48	4.68	3.57	8.60	7.26	5.42	8.69	5.91	8.84	6.14	8.72	6.36	8.60	0.414	0.891	**6.16**	8.98_3.35
11MAR1	**N** n*100m^{-2}	5.08	1.51	4.33	1.23	4.92	1.08	4.75	1.36	4.92	1.00	5.00	1.28	4.83	0.72	0.312	0.680	**4.77**	5.30_4.24
	N % cover	14.00	10.22	16.65	12.56	17.36	12.70	20.53	17.17	18.36	14.80	18.11	15.07	14.62	15.28	0.614	0.469	**17.13**	21.55_12.72
	A n*100m^{-2}	0.58	0.90	0.50	0.80	0.42	0.67	0.25	0.45	0.42	1.00	0.33	0.89	0.58	0.90	0.418	0.608	**0.44**	0.67_0.20
	A % cover	0.17	0.26	0.19	0.31	0.17	0.27	0.09	0.16	0.00	0.01	0.03	0.10	0.11	0.21	**0.013**	**0.048**	**0.15**	0.23_0.08
16TOS1	**N** n*100m^{-2}	1.00	0.00	1.00	0.43	1.08	0.29	1.00	0.43	1.08	0.29	1.17	0.39	0.83	0.39	0.318	0.732	**1.02**	1.09_0.95
	N % cover	6.72	10.97	6.34	9.34	4.53	6.44	4.86	5.94	5.85	9.34	6.32	12.39	4.60	8.69	0.901	0.147	**5.61**	7.39_3.84
	A n*100m^{-2}	0.67	0.65	0.67	0.65	0.75	0.62	0.75	0.62	0.67	0.49	0.58	0.51	0.50	0.52	0.238	0.231	**0.71**	0.79_0.63
	A % cover	0.34	0.53	0.23	0.22	0.39	0.56	0.19	0.18	0.44	0.65	0.44	0.69	0.06	0.11	0.166	0.446	**0.29**	0.44_0.14
19VAL1	**N** n*100m^{-2}	2.67	0.89	2.00	0.60	2.33	0.78	2.25	0.62	2.42	0.67	2.25	0.75	2.00	0.60	**0.006**	0.079	**2.31**	2.77_1.86
	N % cover	2.52	1.40	4.47	4.67	3.04	1.33	3.96	2.30	4.05	2.49	3.66	2.08	5.14	3.95	0.199	0.135	**3.50**	4.94_2.05
	A n*100m^{-2}	4.83	1.40	5.08	1.56	4.83	1.40	4.92	1.56	5.33	1.50	5.08	1.31	5.42	1.83	0.064	0.050	**4.92**	5.11_4.72
	A % cover	30.17	17.04	26.39	17.75	25.22	16.39	16.16	12.54	14.33	8.29	17.87	10.63	22.83	14.77	**0.002**	0.058	**24.49**	34.26_14.72
20VEN1	**N** n*100m^{-2}	5.92	1.24	6.92	0.90	7.17	1.47	7.08	1.00	7.25	1.14	7.67	1.23	7.50	1.31	**0.000**	**0.001**	**6.77**	7.72_5.82
	N % cover	95.53	1.47	92.69	3.70	92.27	3.98	90.51	5.05	94.56	1.55	95.41	1.07	95.88	1.11	**0.000**	**0.027**	**92.75**	96.17_89.33
	A n*100m^{-2}	0.00	0.00	0.92	0.29	1.17	0.39	0.92	0.29	1.00	0.60	1.25	0.45	1.00	0.74	**0.000**	**0.002**	**0.75**	1.60_-0.10
	A % cover	0.00	0.00	0.46	0.15	0.59	0.20	0.44	0.14	0.42	0.25	0.77	0.62	0.36	0.26	**0.000**	**0.007**	**0.37**	0.79_0.23

with a significant peak (5%) in mean cover in 2003. The PMP LAZ1 reaches the significative maximum cover of both the species groups at 2002, but their number remain stable, except for a lower value of the N-species in 2003. The stand in LOM1 experienced a rise in nitrophilous species frequency in 2003 and 2005 with significant departure respect to RS. Moreover, VAL1 revealed a significant minimum in A-species cover in 2003, while in VEN1 the frequency of N-species continuously varies in the observed period (however, in both cases, within the RS confidence interval).

In some cases a linear tendency is revealed by Between-subjects contrast test. Namely, an upward tendency of N-species frequency appeared in CAM1, EMI1, FRI1 and VEN1 while the cover increases in ABR1 and FRI1 PMPs. Only in CAM1 and LAZ1 A-species are rising up, while in most of the other PMPs they show a slight but significant reduction.

Population level

Species richness

The annual changes in mean number of species $*2500\ cm^{-2}$ over the period 1999-2005 (2003 and 2004 data are missing) is reported in the Table 6. As expected, the total number of species collected by the sample was always lower respect to the recorded sample at 100 m^2 scale (community level). Such difference ranges from 50% in ABR1 to 17% in LOM1. ABR1, CAM1 and EMI1 resulted the PMPs with lower richness ($< 2 * m^{-2}$), while FRI1 and LOM presented the higher values.

The annual changes in mean number of species $*2500\ cm^{-2}$ over the period 1999-2003, 2005 can be observed in the Table 6. The Variation Coefficient in each PMP resulted almost stable (lower than 20%) within the observation period, indicating a good stationarity and (assuming 15% of tolerable error) the number of SUs (100) was always adequate. In the considered period, the non-parametric Friedman's test revealed significant changes in species richness in all the PMPs except in LAZ1 and VAL1, in which also significant departures from RS didn't occur (as well as ABR1 and EMI1). Annual mean species variations are frequent but of relative importance. Significant increases occurred in CAM1, FRI1, MAR1 and VEN1 and, on the opposite, reduction in richness are located in LOM1 and TOS1 PMPs.

Table 6 - Total number of vascular species listed in the sampled area (100 SU) and mean number of species*2500 cm^{-2} (with relative confidence interval) in each PMP of the CONECOFOR network (data sets range 1999-2003, 2005). Significant differences among the diachronic observations based on non-parametric Friedman's test are reported in bold (p<0.05). Underlined values state significant departures from Standard Reference (mean values of the first four years of observation, delimited by its confidence interval at 99%).
*Numero totale di specie vascolari raccolte nell'area campionata (100 SU) e numero medio di specie*2500 cm^{-2} (con relativo intervallo di confidenza) in ogni PMP della rete CONECOFOR (dataset 1999-2003, 2005). La comparazione tra le osservazioni diacroniche è stata effettuata tramite il test non parametrico di Friedman e i risultati significativi (p<0.05) sono riportati in neretto. I valori sottolineati indicano invece differenze significative rispetto al Reference Standard (valori medi dei primi 4 anni di osservazione delimitati dai rispettivi intervalli di confidenza al 99%).*

PMPs	descriptor	1999		2000		year 2001		2002		2005		Friedman Asympt. p	RS	± c.i.
01ABR1	total n of species	13		11		12		13		11				
	n sp * 0.25 m^{-2} ± *c.i.*	1.05	*0.31*	0.87	*0.28*	1.04	*0.30*	1.21	*0.34*	0.82	*0.29*	**0.000**	**1.04**	1.22_0.86
03CAL1	total n of species	28		26		25		26		24				
	n sp * 0.25 m^{-2} ± *c.i.*	5.24	*0.49*	4.84	*0.40*	5.16	*0.49*	5.09	*0.46*	5.27	*0.49*	**0.048**	**5.08**	5.31_4.86
04CAM1	total n of species	21		16		22		22		21				
	n sp * 0.25 m^{-2} ± *c.i.*	1.71	*0.30*	1.35	*0.27*	1.65	*0.33*	1.45	*0.28*	1.99	*0.31*	**0.000**	**1.54**	1.76_1.32
05EMI1	total n of species	11		16		18		15		18				
	n sp * 0.25 m^{-2} ± *c.i.*	1.73	*0.31*	1.62	*0.33*	1.81	*0.33*	1.90	*0.32*	1.64	*0.34*	**0.005**	**1.77**	1.92_1.61
07FRI1	total n of species	32		34		35		37		42				
	n sp * 0.25 m^{-2} ± *c.i.*	5.46	*0.52*	5.46	*0.58*	5.45	*0.60*	5.67	*0.55*	6.55	*0.56*	**0.000**	**5.51**	5.65_5.37
09LAZ1	total n of species	43		42		39		35		38				
	n sp * 0.25 m^{-2} ± *c.i.*	4.93	*0.47*	4.83	*0.48*	4.83	*0.46*	4.77	*0.51*	4.79	*0.53*	0.653	**4.84**	4.93_4.75
10LOM1	total n of species	44		43		42		46		40				
	n sp * 0.25 m^{-2} ± *c.i.*	5.65	*0.75*	5.61	*0.76*	5.95	*0.79*	4.95	*0.70*	4.98	*0.70*	**0.000**	**5.54**	6.08_5.00
11MAR1	total n of species	40		43		37		37		40				
	n sp * 0.25 m^{-2} ± *c.i.*	2.98	*0.41*	2.45	*0.39*	2.42	*0.42*	2.90	*0.41*	3.20	*0.48*	**0.000**	**2.69**	3.07_2.31
16TOS1	total n of species	22		25		24		23		18				
	n sp * 0.25 m^{-2} ± *c.i.*	4.00	*0.36*	3.94	*0.34*	4.26	*0.37*	4.22	*0.37*	3.57	*0.33*	**0.000**	**4.11**	4.48_3.90
19VAL1	total n of species	25		21		23		23		23				
	n sp * 0.25 m^{-2} ± *c.i.*	3.34	*0.53*	3.24	*0.49*	3.37	*0.47*	3.33	*0.44*	3.22	*0.48*	0.458	**3.32**	3.43_3.21
20VEN1	total n of species	15		22		20		22		25				
	n sp * 0.25 m^{-2} ± *c.i.*	2.42	*0.27*	3.16	*0.36*	3.02	*0.30*	2.99	*0.28*	3.90	*0.31*	**0.000**	**2.90**	3.32_2.48

Table 7 – Fisher's α diversity index over the period 1999-2005. Total number of functional individuals and total number of species collected in the complete sampling (100SU) are also reported. The α values vs. time linear regression was accomplished. p<0.05, bold indicates significant values.
Indice di diversità Fisher α nel periodo 1999-2005. Numero complessivo di individui funzionali e numero totale di specie raccolte nell'intero campione (100SU). Sono riportati i risultati della regressione lineare dei valori di α rispetto al tempo (p<0.05)con in grassetto i valori significativi.

				year				α vs time linear regr.	
PMPs	**Indicators**	**1999**	**2000**	**2001**	**2002**	**2005**	**R^2**	**b**	**p**
	total n of species	13	11	12	13	11			
01ABR1	n funct. individuals	170	114	425	503	692			
	Fisher α index	**3.28**	**3.00**	**2.30**	2.44	**1.86**	0.859	-0.228	**0.024**
	total n of species	27	24	24	25	23			
03CAL1	n funct. individuals	3854	2943	3597	3221	3992			
	Fisher α index	**3.92**	**3.57**	**3.45**	3.69	3.23	0.668	-0.092	0.091
	total n of species	19	14	19	19	16			
04CAM1	n funct. individuals	1248	1201	1675	1611	2389			
	Fisher α index	**3.18**	**2.22**	**3.00**	3.02	2.30	0.200	-0.087	0.450
	total n of species	11	12	15	13	15			
05EMI1	n funct. individuals	389	356	461	465	337			
	Fisher α index	**2.11**	**2.40**	**2.97**	2.48	3.22	0.701	0.164	0.077
	total n of species	30	30	32	33	38			
07FRI1	n funct. individuals	1667	1381	1401	1667	1910			
	Fisher α index	**5.20**	**5.41**	**5.83**	5.83	**6.72**	0.976	0.250	**0.002**
	total n of species	41	39	37	33	36			
09LAZ1	n funct. individuals	1822	2079	2160	1808	1428			
	Fisher α index	**7.45**	**6.81**	**6.34**	5.73	6.71	0.163	-0.111	0.500
	total n of species	42	43	40	45	37			
10LOM1	n funct. individuals	1532	1539	1566	1665	1761			
	Fisher α index	**7.98**	**8.21**	**7.48**	8.52	6.62	0.471	-0.221	0.201
	total n of species	38	38	33	32	36			
11MAR1	n funct. individuals	615	495	387	528	600			
	Fisher α index	**8.95**	**9.59**	**8.63**	7.50	8.41	0.258	-0.169	0.383
	total n of species	20	24	22	21	14			
16TOS1	n funct. individuals	306	294	341	322	252			
	Fisher α index	**4.79**	**6.18**	**5.25**	5.03	3.20	0.599	-0.364	0.124
	total n of species	23	20	22	22	21			
19VAL1	n funct. individuals	**7607**	**5655**	**5331**	**3358**	**4014**			
	Fisher α index	**2.92**	**2.60**	**2.93**	3.16	2.90	0.079	0.024	0.647
	total n of species	14	21	17	18	17			
20VEN1	n funct. individuals	960	1289	1218	1354	4659			
	Fisher α index	**2.32**	**3.56**	**2.80**	2.93	2.22	0.151	-0.091	0.518

Diversity index

The herb layer vegetation diversity at population level was estimated using Fisher's α (Campetella and Canullo 2000), as reported in Table 7, where also the factors included in the index (*i.e.* total number of individuals - here intended as functional individuals - and total number of rooting species) are shown.

The extreme variability of the individuals number (particularly in ABR1, CAL1, LAZ1, VAL1 and VEN1 PMPs) can be explained by the different incidence of the woody species renewal, the count of functional units that reflects the morphological-evolutive characteristics of the herbaceous species (Canullo and Falinska 2003) and by the effect of local disturbance. On the contrary, some PMPs show a good stability of individuals density (EMI1, FRI1, LOM1, MAR1, TOS1). Variability and stability of individuals may influence the index in different way: VAL1 show a very high variability in individuals (even 2000 in only one year) but an almost stable index, and in MAR1 a certain stability in individuals number is translated in a high variation of index. This is due to the effect of the species number, that in such index have a stronger influence than individuals.

The higher mean values of *alpha* index are located in MAR1 (8.62) and LOM1 (7.76); intermediate values (< 7 and > 4) can be found in FRI1, LAZ1 and TOS1, while the lower mean values (< 4) characterize ABR1, CAL1, CAM1, EMI1, VAL1 and VEN1.

Discussion

The ground vegetation features and the patterns of changes detected by various diversity indices, were discussed at different resolutions (community and population level).

Community level

As to the previous report (Canullo *et al.* 2006), ABR1 (due to the species reduction recorded in

2005) resulted new among the ones showing significant variations. In CAM1 (high forest stand aged 100 yrs, large-sized stems with low-density) the beech tree population didn't show important structural changes. Consequently, the significant variations in richness can be due to both the ephemeral species penetration from the neighboring ecosystems (as *Myosotis arvensis*, *Geranium lucidum*, *Galium parisiense*) and the influence of seasonal shifting of some geophytes (*Anemone apennina*, *Allium ursinum*, *Ornithogalum umbellatum* and *Symphytum tuberosum;* Bierzychudek 1982). Irregular significant changes of richness occurred in the period; in 2005 a drastic reduction occurred, mostly due to the absence of geophytes species (Table 2, Figure 2).

In 2002-2003 the forest stand in EMI1 experienced a heavy mortality rate in the tree layer (6.4% to 10.8%) mainly hitting *Quercus petraea* dominant individuals, probably connected to the 2003 water stress condition (Amoriello and Costantini this volume; Fabbio *et al.* this volume): a significant reduction in richness of the understory vegetation could be linked to above mentioned factors. A slow recovery process seems to be started again, producing a positive balance in the years 2004-2005.

In the Turkey-oak stand of LAZ1, after three years of slight fluctuations in richness, the significant species depletion occurred in the 2002 is directly linked to the complete defoliation of the tree species due to *Lymantria dispar*, which partially continued in 2003. As a resilience signal after this particular event, the two last years produced a positive balance in this area with consequent cover recovery.

The PMP TOS1 undergoes a significant decrement of species in 2003, possibly due to the heat wave (Amoriello and Costantini this volume); VEN1 showed a drastic increase in 2000, explainable by its recovery from a tremendous hailstorm in 1998 (with recorded frequency of mechanical damages at the population level up to 100%). After this episode the richness increased slightly, with a tendency to be more stable: probably the ecosystem reached the complete recovery after 6 years.

FRI1 and MAR1 PMPs are located in two aged coppices where the traditional management ceased. In MAR1, the downward significant tendency up to 2003 has been diverted on his course: an increasing in richness can be inspected, especially in 2005. FRI1 maintain directional and significant changes with upward tendency for all the considered period, confirming the previous trend (Canullo *et al.* 2006). However, in both cases, the time lag in which is possible to appreciate important changes is larger than two years. According to Amorini and Fabbio (1989) and Campetella *et al.* (2004), our results can be interpreted as the outcome of the natural non-linear regeneration processes, influenced by the alternation of trees (shoots) mortality and growing phases. We assume that such changes in structure may affect the total richness by imposing the same indirect model of temporal variation. Probably we are observing two different phases of the same general resilience-type process, so that in FRI1 the species decrement recorded in 2005 can introduce a new future downward tendency. Consequently, the present trends do not enable us to make a linear forecast.

At all the other PMPs where a significant linear trend can be detected (CAM1, LAZ1 and VEN1, Table 2; Canullo *et al.* 2006), we invite the readers to be careful when considering this interpretation: i) the linear disposition of data seems dependent on stochastic disturbances; ii) as we still consider a short time window, what seems to be a tendency could be recognized as a little step of a more complex dynamics in a larger time range.

The variations were also tested against a Reference Standard represented by a range of values as determined by the first four surveys. As literature-based information on long time series for comparable descriptors and ecosystems are missing, the RS limits cannot represent the normal or expected variation. The arbitrary interval used was assumed for all PMPs just as a range to be used for the present dataset as a "starting point" derived from the real surveys. For some sites it can further result inappropriate, especially for systems whose dynamics lasts longer than the investigated period, showing different time series with different properties. Therefore the time series achievement is a strategic objective, also enabling to apply some analyses which can reveal adequate time intervals (Percival *et al.* 2004);

Among beech high forests, CAM1 and VEN1 show significant changes respect to RS, the former with irregular variations (2000, 2003, 2004), the latter with a strong increase in richness, stabilized after the recovering from the hailstorm. EMI1 shows significant changes (decrease alternate to increase in richness) probably due to tree mortality events (Fabbio *et al.* this volume). FRI1, LAZ1, MAR1 and TOS1 represent communities under regeneration, originated by previous disturbances (coppice management). All of them show significant changes respect to RS, which assume a directional increase in FRI1 and non-linear changes for the others (*i.e.* due to natural disturbances as gypsy moth attack or 2003 heat wave).

Higher values of Shannon index (> 3.0 bits) can be found on PMPs characterized also by the higher species equidistribution and the larger species number (FRI1, LOM1, MAR1: Table 3); only TOS1 shows the highest woody species ratio with a large occurrence of shrubs, leading to the absolute maximum Evenness scores. All these communities present a high level of structural heterogeneity caused by recent anthropic or natural disturbances. According to several contributions (Levin and Paine 1974; Beatty 1984; Peterson and Pickett 1990; Tilman and Pacala 1993), our results can be interpreted by the light of the strict interactions between disturbance (natural events and previous management) and patchiness (*i.e.* heterogeneity, niche differentiation, as suggested by the presence of several woody species in all layers), corroborating the theory in which species diversity is often greatest at intermediate levels of disturbance intensity or frequency in forest communities (Connell 1978; Petraitis *et al.* 1989; Stone and Wolfe 1996).

Intermediate values appear on forest stands with a lower number of species but an intermediate level of Evenness (CAL1, EMI1 and VAL1) and a good proportion of woody species (EMI1: number of woody species/total number of species > 0.5).

Beech dominated communities (ABR1, CAM1 and VEN1) with simple high forest tree structure (only the tree layer is well developed) belong to the last group (<2 bits) in which the total species number and the proportion of woody species are poor. LAZ1 is included in this group, but the 2002 event must be underlined: the *Lymantria dispar* attack reduced the woody species cover and the related total number of species but, at the same time, improved so much the Evenness in cover to raise up the Shannon index at 3.295 (1.3 up to the mean value of the period).

The directional changes in FRI1, LOM1, VEN1 (cover Shannon index and relative Evenness: Table 3) point out an increase in diversity, guided almost exclusively by richness improvements. Notwithstanding the tendency reported in the previous report is confirmed (Canullo *et al.* 2006), it is difficult to consider these results as a "real trend" in plant species diversity; in fact, the time considered is still too short if related to the type of processes which occur in forest ecosystems.

Considering species turnover data, VAL1 represents the area of higher taxonomic stability (T < 3.2); the higher level of species exchanges (9.5-12.25) is related to forest stands under intense dynamic processes (*i.e.* the regeneration of old coppice forests: MAR1), affected by disturbance (*i.e.* the *Lymantria attack*: LAZ1) or in connection with other different plant communities (LOM1 and CAM1).

Concerning the annual changes, it is interesting to note that the indices remain stable in the communities characterized by intense dynamical processes (*i.e.* MAR1, FRI1). In these cases, the in-out process is always balanced over time so that the local species pool is virtually stable (thus S can be considered constant). This recall the so-called "carousel model" which can play a role in maintaining the community diversity at a given time-rate (Van Der Maarel and Sykes 1993). The above mentioned sites cannot be considered stable by all the diversity indicators at the observed period, but the shape of variations (Figure 3) suggests a sort of fluctuation possibly synchronized with the time-rotation of coppice management.

Sporadic significative changes (respect to RS limits) on both nitrophilous and acidophilous abundance indicators appear at all PMPs; minimum values can be related to the 2003 drought season (Amoriello and Costantini this volume). The prevailing role of A-species in LOM1 and VAL1 is linked to the lowest pH values in organic and superficial soil layers (Alianello *et al.* 2002; Matteucci com. pers.), and not influenced by the atmospheric deposition (Mosello *et al.* 2005).

An increase in the number or frequency of nitrophilous species in deciduous and mixed woodlands in western, north-western and central Europe has been pointed out by different authors (Wilmanns *et al.* 1986; Tyler 1987; Thimonier *et al.* 1994; Brunet *et al.* 1997). Data reported by Ferretti *et al.* (2006) show that for some beech forest sites of the Italian network, the soil N content was higher in PMPs located in southern Italy and, on the other side, the exceedance of N critical level raised up in PMPs located in northern Italy, with the lowest N content in the soil. The increase in cover and/or frequency of nitrophilous species in some northern PMPs (EMI1, VEN1) and their relative reduction in two southern beech communities

(CAL1 and CAM1) might be influenced by the above mentioned N pattern.

A-species tendencies are always of neglectable amount both as frequency and cover values, in most cases with a significant reduction. Decline and extinction of acidophilous species were also observed in deciduous, coniferous and mixed woods growing on less fertile soils (FANGMEIER *et al.* 1994; WALTHER; 1997; VAN TOL *et al.* 1998).

Population level

The richness values at the population level show annual changes that seem to reflect only in some cases the variation occurred at the community level (CAM1, LAZ1, LOM1, MAR1, VEN1); this can be due to ecological mechanisms acting in the whole system (species penetration from other communities or reaction to disturbances).

The RS percentage ratio related to the mean number of specie in the SUs at both the scales (RS population/RS community) can be interpreted as a sort of heterogeneity index of plant species distribution, to define an additional structural state of the PMPs. It always shows very low values, always below 30% which indicate an intense patchy distribution of plants in the understory vegetation, one of the well-known features of forest ecosystems (WATT 1964; LIU and HYTTEBORN 1991; GLENN-LEWIN and VAN DER MAAREL 1992; CAMPETELLA *et al.* 2004; KOTLIAR and WIENS 1991; BOBIEC 1998). A minor level of patchiness can be inferred in CAL1, TOS1 and VAL1 (respectively 29.63%, 26.19%, 24.28%), while the highest level of aggregation occurred in MAR1 (9%). In the latter, a spatial pattern analysis of herb layer vegetation confirmed a high level of patchiness and species aggregation also at a finer scale (CAMPETELLA *et al.* 1999).

Aspects related to scale and structure of vegetation must be taken into account in the monitoring activity, because they can heavily influence the results and the relative deductions (PODANI 2006). In fact, the scale dependence of vegetation pattern and processes is generally accepted, just as the mosaic nature of plant communities is well recognized at different hierarchical levels (PODANI *et al.* 1993; CANULLO and CAMPETELLA 2006a).

In most cases, significant departures from RS where located in a single observation. Probably, the sampling system at the population level can capture only the composition and dynamics of the singles patches, microcommunities (which seems more stables over time), but cannot reveal the result of interaction among patches, aspect that focus much better the main features of the ecosystem, its dynamic and relative reaction to disturbance.

Although some differences, the results of Fisher's α index reflect the same picture described at larger scale. In fact, the medium-high values of diversity are located in communities affected by recent anthropic or natural disturbances.

Related structural studies carried on in MAR1 suggest that although individuals (ramets) of herb layer species are aggregated, their patches show a high level of species compositional diversity and are spatially independent from each other (CAMPETELLA *et al.* 1999). The older stands, represented by stabilized tree layer structure (mature high forest, in most cases dominated by beech, as CAM1 and CAL1) probably reflect an inner habitat homogenization; especially in the herb layer (*i.e.* litter composition, shadow distribution, *etc.*). These aspects can reduce the level of niche differentiation, with the consequent reduced variability in species composition among patches, as reflected by low diversity values. The disturbance occurred in VEN1 (hailstorm) directly influenced the herb layer and didn't modify the tree structure, maintaining unaltered the inner environmental conditions. In this case, the dramatic increase of functional individuals reflects the rate of recovery from mechanical damages in the first years.

Directional changes of Fisher's α index were significant in only two PMPs: ABR1 with a downward tendency opposite to FRI1. The abundance repartition in terms of ramets per species indicates a higher equitability in the latter PMP.

Conclusions

The forest vegetation data collected in a subset of PMPs (CONECOFOR Italian network) over the period 1999-2005, were analyzed to produce a present-day status and evaluation of changes, inferred by statistical tests or departures from *a priori* reference standard (RS).

All the descriptors contributed to generate a main picture of the forest sites (PMPs) in terms of structure (considering the supply of different layers), vascular species composition, effects of disturbance and dynamical mechanisms. The analysis of selected descriptors raised up relevant changes in vegetation.

At the community level, significant variations in richness are more frequent in sites with high structural heterogeneity caused by recent anthropic or natural disturbances. In few PMPs directional changes can be appreciated (CAM1, FRI1, LAZ1 and VEN1) but in most cases the variations assumed a typical fluctuation pattern (more or less regular), with different cycle length. The use of a reference standard (RS) supported the interpretation of changes, even if the *a priori* time lag selection may generate a term of comparison from extremely heterogeneous data (*i.e.* recovering processes include a heavy variability year by year or last longer than our surveillance period).

At population level annual mean species variations are frequent but of minor importance. Probably, the finer scale sampling system is not able to detect structural complexity derived by the interaction among patches, which can reveal the ecosystem features, its dynamics and the relative reaction to disturbances.

Considering the monitoring activity, the results at the community level seem more sensitive to describe important changes at the level of forest stand: variations in richness, diversity, species turnover and species composition are strictly linked both to the nature of forests community and the observed disturbances. The population level results lead to the assessment of fine scale variability and to investigate the role of species assemblages in diversity maintenance (Herben *et al.* 1993; Van Der Maarel and Sykes 1993; Czárán 1998). Moreover, other accurate data collected at that scale (*i.e.* number of individuals or ramets, their cover, damages entity) could be used to obtain appropriate descriptors, as abundance and variation of functional groups, woody species renewal, population dynamics of key species, *etc.*

In most of the PMPs the Sorensen's dissimilarity index has resulted rather low and leveled, while the species turn-over index has shown a larger variation among the forests. Higher values occurred in communities under intense dynamical processes, affected by disturbance or influenced by neighboring plant communities with a different species composition (CAM1, LAZ1, LOM1, MAR1).

The abundance of *nitrophilous* species was particularly consistent in beech forests; the increase in the PMP VEN1 and the relative reduction in two southern beech communities (CAL1 and CAM1), corroborates the relation patterns with N soil content previously described (Ferretti *et al.* 2006). The contribution of *acidophilous* species at the extreme values of the indicator's range, didn't show particular evidences.

The relationship between plant diversity and the forest dynamical state seems relevant: at both the sampling scales, the higher values of diversity indices occurred in communities with a high level of structural heterogeneity caused by recent anthropic or natural disturbances. Our results pointed out the interaction between disturbance and patchiness, corroborating the theory of maximum species diversity at intermediate levels of disturbance intensity or frequency in forest communities.

All the studied stands are characterized by significant changes in richness which can be influenced by the 2003 drought season: in both the EMI1 sessile oak and TOS1 holm oak stands a particular co-occurrence with the minimum values in coverage and species richness seems evident.

As a general remark, the inherent non-linear dynamics of forest regeneration processes emphasizes the needs of long-term datasets for detecting the plant diversity responses to environmental changes.

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Ecological transformations in the forest landscape unit at one alpine spruce (*Picea abies* K.) CONECOFOR plot, 1998-2004

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Abstract – The landscape unit (LU) of the Lavazé Pass (Trentino-AltoAdige) is mainly formed (75.3%) by a forest cover dominated by *Picea abies*. In the period 1998-2004 the LU changed the composition of its forest cover because of the increasing of the ski rides (+2.9%) and the naturally destroyed patches (+3.1%). These quite small transformations did not change the geo-botanical structure of the LU, while carried altered ecological consequences. The diagnostic index of the LU, based on a set of 10 landscape ecological parameters, diminished in only 6 years from 0.75 to 0.60. Consequently, in absence of re-balancing interventions, the landscape characters of the LU are changing from semi-natural to managed ones, thus affecting the selected plot too.

Key words: *landscape ecology, forest transformation, diagnostic evaluation.*

Riassunto – Trasformazioni ecologiche nell'unità di paesaggio di un'area CONECOFOR alpina di abete rosso nel periodo 1998-2004. L'unità di paesaggio (LU) del Passo Lavazè (Trentino-AltoAdige) è formata principalmente (73%) da foreste di *Picea abies*. Nel periodo 1998-2004 la LU ha cambiato la composizione della sua copertura forestale a causa dell'aumento delle piste da sci (+2.9%) e degli appezzamenti distrutti da cause naturali (+3.1%). Queste piccole trasformazioni non hanno cambiato la struttura geobotanica della LU, mentre hanno portato consequenze ecologiche. L'indice diagnostico della LU, basato su 10 parametri ecologici del paesaggio, è diminuito in soli 6 anni da 0.75 a 0.60. Conseguentemente, in assenza di interventi di riequilibrio, i caratteri paesaggistici della LU stanno cambiando da seminaturali a gestiti e ciò potrà influenzare lo stato dell'area di monitoraggio.

Parole chiave: *ecologia del paesaggio, trasformazioni forestali, valutazione diagnostica.*

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Introduction

Observing that vegetation - a biological system (Pignatti *et al.* 2002) - is the basilar component of the landscape - the upper biological organisation system (Forman 1995; Meffe & Carroll 1997; Ingegnoli, 1993, 2002) - the study of forest patches outside their landscape units (LU) fails its synecological significance. Therefore, the Italian CONECOFOR programme inserted a pilot study of a LU based on the permanent plot contest of TRE1 at the Lavazé Pass (Trentino-Alto Adige). It is possible to demonstrate that studying a LU, we can solve crucial problems, as:

a) how to use the ecological characters of all the different types of vegetation existing within a LU to arrive to a diagnostic evaluation of the ecological state of the studied forest and of its landscape;
b) how to integrate the other ecological parameters of the LU, like HH (human habitat) or SH/SH* (carring capacity) with vegetational ones (Ingegnoli 1993, 2002) to verify the human disturbance on a forest system;
c) how to weight the contribution of a forest tessera to the metastability of the LU;
d) how to compare the data of the forest patch with those of other vegetation elements in the same landscape unit.

Moreover, problems like these are linked with the study of the dynamic of a landscape unit, the period of time depending on the history of the system.

The case study of the Lavazè Pass LU (1800 m a.s.l, in the Dolomite Alps) focused on the landscape dynamic along a short period (1998-2004) and on the reconstruction of the landscape structure since 1935-40. The main objective of this study is to reach a diagnostic evaluation of the ecological state of the forest landscape after the transformations of this recent period. The small landscape unit of the Pass measures 172.6 ha and it is formed by four ecotopes (Figure 1): (1) the Lavazé Pass highland prairie veg-

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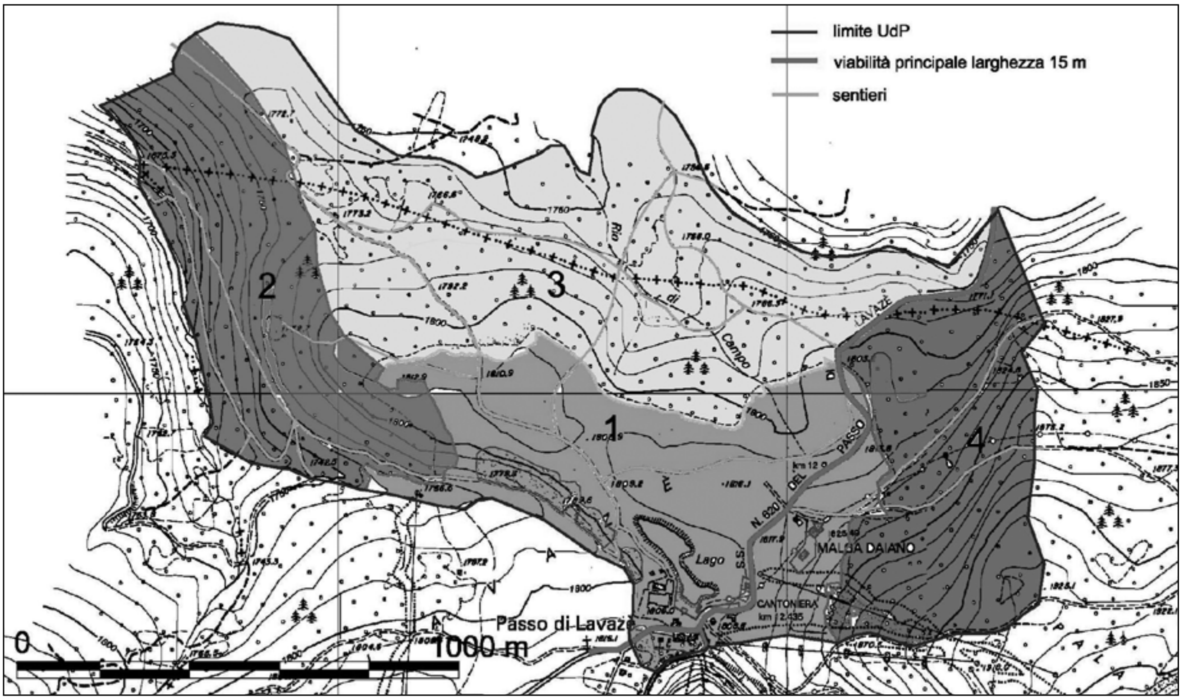

Figure 1 - The Lavazé Pass landscape unit (LU) 1800 m a.s.l. in the Alpine region of Trentino-AltoAdige, Italy. Forest cover 75.3%. We can see the 4 ecotopes composing the LU: only the ecotope 1 is mainly formed by prairie and shrubs.
L'unità di paesaggio (LU) del Passo di Lavazé, 1800 m s.l.m. nella regione alpina del Trentino-AltoAdige, Italia. Le foreste coprono 75.3%. Osserviamo 4 ecotopi: solo l'ecotopo 1 è formato da praterie e arbusti.

etation (25.9%), (2) the West slope forest (19.7%), (3) the North belt forest with bogs (36.6%) and (4) the East slope forest (17.8%). The forest is dominated by *Picea abies* with some presence of *Pinus cembra* in the classical syntaxonomic association of *Homogino-Piceetum*, Zukrigl 1973.

Methods

The study followed the Landscape Ecological discipline (Naveh & Lieberman 1984; Forman & Godron 1986; Finke 1986) in the form proposed by Ingegnoli (1993, 2002) and Ingegnoli and Giglio (2005) as "biological integrated". This school of landscape ecology is based on the recognition that the complex adaptive system of the landscape is a proper level of biological organisation, so much more than a simple set of spatial characters. Therefore, this school tried to focus the landscape ecological elements and processes, proposing new concepts (*e.g.* ecocoenotope, ecotissue), new functions (*e.g.* biological and territorial aspects of vegetation-BTC-) and new studying methods (*e.g.* LABISV landscape survey and evaluation of vegetation), *etc.* Let us briefly present some of them:

(i) The biological territorial capacity of vegetation or BTC (Ingegnoli 1991, 2002), is a synthetic function, referred to the vegetation of an ***ecocoenotope,*** *i.e.* the ecological system, composed of the community (biotic view), the ecosystem (functional view) and the microchore (*sensu* Zonneveld 1995). It expresses the flux of energy a vegetation system must dissipate during a year to maintain its degree of organization and metastability. It is based on: (1) the concept of resistance stability (Odum 1971); (2) the principal types of ecosystems of the ecosphere (Whittaker 1975); (3) their metabolic data (biomass, gross primary production, respiration, R/PG, R/B) (Duvigneaud 1977; Piussi 1994; Pignatti 1995). Two coefficients are present within this function:

$a_i = (R/GP)_i / (R/GP)_{max}$ $\qquad$ $b_i = (dS/S)_{min}/(dS/S)_i$

- where: R is the respiration, GP is the gross production, dS/S is equal to R/B and is the maintenance/structure ratio (or a thermodynamic order function; Odum 1971, 1983) and i are the principal ecosystems of the ecosphere.

The factor a_i measures the degree of the relative metabolic capacity of the principal ecosystems; b_i measures the degree of the relative antithermic (*i.e.*

order) maintenance of the principal ecosystems. We know that the degree of homeostatic capacity of an ecocoenotope is proportional to its respiration (Odum 1971, 1983). So through the a_i and b_i coefficients, even related in the simplest way, we can have a measure which is a function of this capacity:

$$BTC_i = (a_i + b_i)\, R_i \; w \qquad (Mcal/m^2/y)$$

(ii) The Human habitat (HH) and the ecotissue concept. The areas where human populations live and work permanently, limiting the self-regulation capability of natural systems form the human habitat. The HH is differentiated from the natural habitat (NH), but their sum is >1 , because of the concept of ecotissue. The *ecotissue* is the complex multidimensional structure of a landscape where a main spatial mosaic of tesserae (generally formed by the vegetation coenosis) is hierarchically integrated with the set of correlated mosaics and information of different temporal and spatial scales.

(iii) The landscape biological integrated survey of vegetation or LaBISV is the method proposed to study the vegetation in a landscape (Ingegnoli 2002; Ingegnoli e Giglio 2005; Ingegnoli 2005). It is able to integrate three different criteria (a biotic one, an environmental one and a configurational one) with different temporal and spatial scales. It helps in the definition of the so called "*normal state*" for each specific type of tessera (the term tessera can be used to individuate -in practice- an ecocoenotope).

It uses a *parametric standard form* (a proper one for each type of vegetation) for the analysis and evaluation of a vegetated tessera. The standard form (or schedule) (Figure 2) has been designed to check the

Example of the LABISV methodology synthetized in the present standard form

BOREAL FOREST T. TESSERA CHARACTERS (Ts)	1	5	14	25	score
T1 – Vegetation height (m)	< 9	9.1-18	18.1-29	**> 29.1**	Canopy
T2 – Cover of the canopy (%)	< 30	> 90	**31-60**	61-90	Ts surface
T3 – Structural differentiation	low	medium	**good**	high	Age, space groups, etc.
T4- Interior/edge (%)	none	< 30	**31-89**	> 90	(% Ts)
T5 - Management	simple coppice	coppice	wood	**natural forest**	Or similar
T6 – Permanence (years)	< 80	81-160	**161-240**	> 240	Old trees
F. VEGETATIONAL BIOMASS(ABOVE GROUND)					
F1- Dead plant biomass	near 0	> 10	**1-5**	5-10	% of living biomass
F2- Litter depth	near 0	< 1.5	**1.6-3.5**	> 3.5	cm
F3 – Biomass volume (m^3/ha)	< 200	201-500	**501-950**	> 950	pB = **696** m^3/ha
E. ECOCENOTOPE PARAMETERS					
E1- Dominant species (n°)	> 3	3	2	**1**	As pB volume
E2- Species richness	< 15	16-30	31-40	**> 40**	n° sp./Tessera
E3- Key species presence (%)	< 5	6-40	41-80	**> 80**	Phytosociological
E4- Allochthonous species (%)	> 10	10-4	< 4	**0**	From other ecoregions
E5- Infesting plants %	near all	> 25	< 25	**0**	Coverage on Ts
E6- Threatened plants	evident	suspect	risk	**0**	Even acid rain damage
E7- Biological forms (n°)	< 3	4-5	**6-7**	> 7	Cfr. Box 1987, mod.
E8- Vertical stratification	2	3	**4**	> 4	traditional
E9- Renew capacity	none	intense	**sporadic**	normal	Dominant species
E10- Dynamic state	degradation	recreation	**regeneration**	fluctuation	Cfr. Ingegnoli 2002
U. LANDSCAPE UNIT (LU) PARAMETERS					
U1- Similar veg. contiguity	0	< 25	**26-75**	> 76	% of perimeter
U2- Source or sink	sink	neutral	**Partial**	source	Species & resources
U3- Functional role in LU	reduced	minor	**evident**	important	Context & typology
U4- Disturbances incorporation	insufficient	scarce	normal	**high**	Local disturbances
U5- Geophisical instabilities	evident	partial	**risk**	none	On the phisiotope
U6- Permeant fauna interest	low	medium	**good**	attraction	Key species
U7- Tranformation modalities of the Ts	strong distubances	gradual changes	temporal instabilities	**fluctuation**	Today + tendency
U8- Landscape pathology interference	serious	near chronicle	**easy to incorporate**	none	From landscape
U9- Permanance of analogous vegetation (years)	< 100	100-300	300-1200	**> 1200**	Historical presence
RESULTS OF THE SURVEY					
Total score Y (= h+j+k+w)	h = 0	j = 0	k = 17	w = 11	Y = 513
Quality of the Ts	Q = Y / 700				**Q = 73,3** [%]
Estimation of the BTC	BTC (b) = 0,01339 (y-28) + 0,12 (pB / 70)				**BTC = 7,69** [Mcal/m^2/a]

Figure 2 - Example of the LaBISV methodology of survey synthesized in the present standard form. Forest permanent CONECOFOR plot TRE1 (Lavazè Pass, Alps) *Piceion abietis*, 1.800 m. Survey: August 2004 by Ingegnoli and Giglio. Also the equation of estimation of the BTC derives from the model of Ingegnoli (2002).
Esempio della metodologia LaBISV dell'indagine riassunta nella scheda standard. Area permanente CONECOFOR TRE1 (Passo Lavazè, Alpi) Piceion abietis, 1.800 m. slm. Rilevamento: Agosto 2004 (Ingegnoli e Giglio). Anche l'equazione per la stima della BTC deriva dal modello di Ingegnoli (2002).

Table 1 - Measure of the landscape elements forming the main mosaic of the LU of Lavazè Pass in 1998 and 2004.
Misura degli elementi di paesaggio che formano il mosaico principale al Passo Lavazè nel 1998 e nel 2004.

Landscape element	1998 Area (ha)	1998 LU%	2004 Area (ha)	2004 LU%
Forests	117.26	67.9	109.95	63.7
Destroyed patches or clearcuts	0,5	0.3	5.94	3.4
Ski rides	1	0.6	6	3.5
Paths	4	2.3	2	1.2
Bogs	3.66	2.1	3.66	2.1
Grass patches	3.5	2.0	2.37	1.4
Forest areas	***129.92***	***75.3***	***129.92***	***75.3***
Prairie	27.56	16.0	26.08	15.1
Shrub patches	4.5	2.6	4.5	2.6
Ski rides	2	1.2	2.9	1.7
Paths	2	1.2	2.1	1.2
Lake	1.75	1.0	1.75	1.0
Prairie areas	***37.81***	***21.9***	***37.35***	***21.6***
Built tesserae	2.9	1.7	3.31	1.9
Roads and parkings	2	1.2	2.05	1.2
Built areas	***4.9***	***2.8***	***5.36***	***3.1***
Landscape unit, 1998	**172.63**	**100.0**	**172.63**	**100.0**

organisation level and to estimate the metastability of a tessera considering both general ecological and landscape ecological characters:

- T = landscape element characters (*e.g.* tessera, corridor);
- F = plant biomass (quantity and characters) above ground;
- E = ecocoenotope parameters (*i.e.* integration of community, ecosystem and microchore characters);
- U = relation among the elements and their landscape parameters.

The evaluation classes are four, the weights per class depending on an evaluation model, one for each of the main types of vegetation ecosystem (INGEGNOLI 2002).

The method let us evaluate the quality of vegetation per parametric set of data: proper equations, calibrated per vegetation type, combine the quality of the surveyed tessera vegetation and its plant biomass to estimate the BTC of the tessera itself, thus the degree of metastability of vegetation can be estimated. Results may be represented through ecograms.

Results

The first analysis concerned the measure of the landscape elements (*i.e.* types of tesserae) of the LU in 1998 and 2004 and their comparison, all based on the technical cartography (CTR) of the Province of Trento and on a program of field observations (Table 1).

The increase of both human and natural disturbances, mainly due to patches destroyed by hurricane and new ski rides, changed the forest areas, which lost about 8 ha in only 6 years. This amount (6.8% of the LU), to which we can add the small increase of built areas (0.3%), appeared to be without consequences to the Province authorities. But in the same time the tourist pressure increased, and in 2004 the total inhabitants of the LU can be estimated in 270 people (year equivalents). So, the ecological state of this LU have to be checked up more deeply.

The vegetation survey of the LU was made following the mentioned LaBISV method, choosing 13 samples based on the most significant tesserae, representing about 1/3 of their total number but all their characters, as we can see in Table 2 and 3. The forested samples presented an average BTC of 7.17 Mcal/m^2/year, corresponding to about 76% of the for-

Table 2 - Forest tesserae in the Lavazè Pass in 2004 measured through the LaBISV method.
Tessere forestali misurate al Passo Lavazè nel 2004 mediante il metodo LaBISV.

Tesserae (Ts) A. Forest Ts	sur. ha	Q.T %	Q.F %	Q.E %	Q.U %	BTC Mcal/m^2/yr	BTC/BTC$_s$ %	H m	vFM m^3/ha
Z, Ts (containing Tre1)	4.01	70.7	56	95.6	80.4	**8.50**	**90.0**	2.5	739
A, Est, q 1880 m	2.25	50	58.7	64.8	58.7	**6.19**	**65.0**	24.8	606
B, Est, q, 1800 m	4.25	50	32	74.4	71.6	**6.15**	**65.0**	26.1	320
C, Nord-Est, q 1780 m	4.40	64.7	56	73.6	67.6	**7.48**	**79.1**	25.7	872
D, Ovest di Z, q 1790m	4.18	56	56	74.4	71.6	**7.04**	**74.4**	25.6	629
E, Nord, q 1770 m	4.41	56	56	70.8	62.7	**6.93**	**73.3**	25.8	793
F, Ovest, q 1800 m	4.31	78	70.7	82.4	85.3	**9.09**	**96.1**	32	1086
G, Sud, q 1790 m	2.83	57.3	56	78.8	57.8	**6.94**	**73.4**	26.7	713
H, Sud-Ovest, q 1750 m	3.73	57.3	44	78.8	67.6	**6.65**	**70.3**	20.7	443
L, Ovest di D, q 1800 m	2.74	44	44	66.4	52.9	**5.67**	**59.9**	26.6	525
Tot. forest Ts	***37.11***	***59.4***	***53***	***76.6***	***68.9***	***7.17***	***75.8***	***26.5***	***686***

BTC_s = 0,85 BTC_F where: BTC_s= maturity threshold, BTC_F= flex of the development curve (from the model). (INGEGNOLI 2002).
QT= quality of the tessera parameters, QF= quality of the phytomass parameters, QE= quality of the ecocoenotope parameters, QU= quality of the LU parameters.
H= mean heigh of the canopy, FM= Phytomass, (using the relascope).

Table 3 - Other types of vegetation in the Lavazé Pass.
Altri tipi di vegetazione al Passo Lavazè

Tesserae (Ts) B. Other vegetation Ts	sur. ha	Q.T %	Q.F %	Q.E %	Q.U %	BTC Mcal/m²/yr	BTC/BTC_s %	H m	vFM Kg/m²
a- shrubs (*Juniperus*)	1.2	45.5	36.9	78.6	69.8	1.44	65.1	0.7	1.9
b- grass (*Nardus*)	1.6	21.9	12.5	52.8	51.4	0.58	47.5	0.4	0.8
c- alpine bog	1.5	62	51	94	72.9	1.22	85.6	0.2-1	1.5
Tot. Ts	**4.30**					**1.04**			

QT= quality of the tessera parameters, QF= quality of the phytomass parameters,
QE= quality of the ecocoenotope parameters, QU= quality of the LU parameters.

est maturity threshold. Some tesserae have not been managed by man since more than a century.

Following the old maps and the indication from local Forest Administration (asserting a constant and low management of the forest) it was possible to quantify an outline of the land use of the Lavazé Pass Unit since 1935-40. Then, always applying the methods of Ingegnoli (2002) partially reported in the previous paragraph, some of the most important ecological parameters, ranked forward, have been measured or estimated as we can see in Table 4. In figures 3 we show the increasing fragmentation due to the new ski rides in only few years (1998-2004): in this LU the ratio interior/edge changed in the forest from 3.42 in 1998 to 1.82 in 2004.

As shown in Table 4, the most evident changes in this LU mainly appeared in the last period (1998-2004), therefore it needs a diagnostic evaluation, based on the comparison with normal state parameters (Table 5).

The first question for a diagnostic evaluation is the specification of the landscape type useful to express a proper rank of normal values. In this case we have to refer to a semi-natural forest alpine landscape, as confirmed by the BTC/HH ratio in 1998 (5.05/0.214=23.6). The normal values (NV) of main parameters of that landscape (*i.e.* sub-natural forested Alpine landscape) are synthesized as follows:

a) BTC (Mcal/m^2/a), the Biological territorial capacity of vegetation (NV deduced from the HH/BTC model Ingegnoli & Giglio 2005): 5.57-6.15 Mcal/m^2/year;
b) HH (%), the Human habitat (NV deduced from the HH/BTC model Ingegnoli & Giglio 2005): 20-22;
c) ψ = H (3+D), the Structural landscape diversity (NV deduced from ψ model Ingegnoli & Giglio 2005): 5.5-5.7;
d) LM = τ *BTC, the general landscape metastability (NV deduced from HH/LM model Ingegnoli 2002): 29-31;
e) C/F (%), the Core-area/Forest surface (%) ratio (NV deduced from field observations and ecological considerations): 80-90;
f) Allochthonous plants (%), the Presence of exotic plant species (NV deduced from field observations and ecological considerations): 0-1;
g) Forest area (%), the forested surface of a landscape unit (NV deduced from field observations and ecological considerations): 65-80;
h) Agriculture area (%), the agriculture surface of a landscape unit (NV deduced from field observations and ecological considerations): 10-20;
i) σ = SH/SH*, the HH carrying capacity index (Ingegnoli 2002) (NV not less than values proper of an agricultural landscape): 3-10;
j) HCE = (BTC/HH)* σ. It represents the HH capacity evaluation. Deduced from the HH/BTC model, it helps in landscape classifying (NV from HCE model Ingegnoli 2006): 65-700;
k) Diagnostic index. It considers the gaps (%) from NV on the entire set of ecological parameters. Evaluations: 0.85-1 = normal; 0.6-0.85 = alteration; 0.35-0.6 = syndrome; 0.15-0.35 = serious syndrome; < 0.15 extinction.

Table 4 - Results of the main landscape ecological analysis on the landscape unit of Lavazé Pass.
Risultati della principale analisi ecologica dell'unità di paesaggio del Passo Lavazè.

Ecological parameters	1935-40	1998	2004
BTC (Mcal/m²/year)	5.18*	5.05	4.76
Human habitat, HH (%)	20.6*	21.4	26.7
HH/NH	0.259*	0.272	0.364
ψ = H (3+D)	4.63	4.99	5.29
LM = τ *BTC	24.27*	24.16	23.09
Interior/edge ratio	4.14	3.42	1.82
Core-area/Forest surface (%)	80.54	77.39	64.55

HH is the human habitat, NH is the natural habitat, ψ is the structural landscape diversity, LM is the general landscape metastability (from Ingegnoli 2002).
ψ = structural landscape diversity;
* estimated values

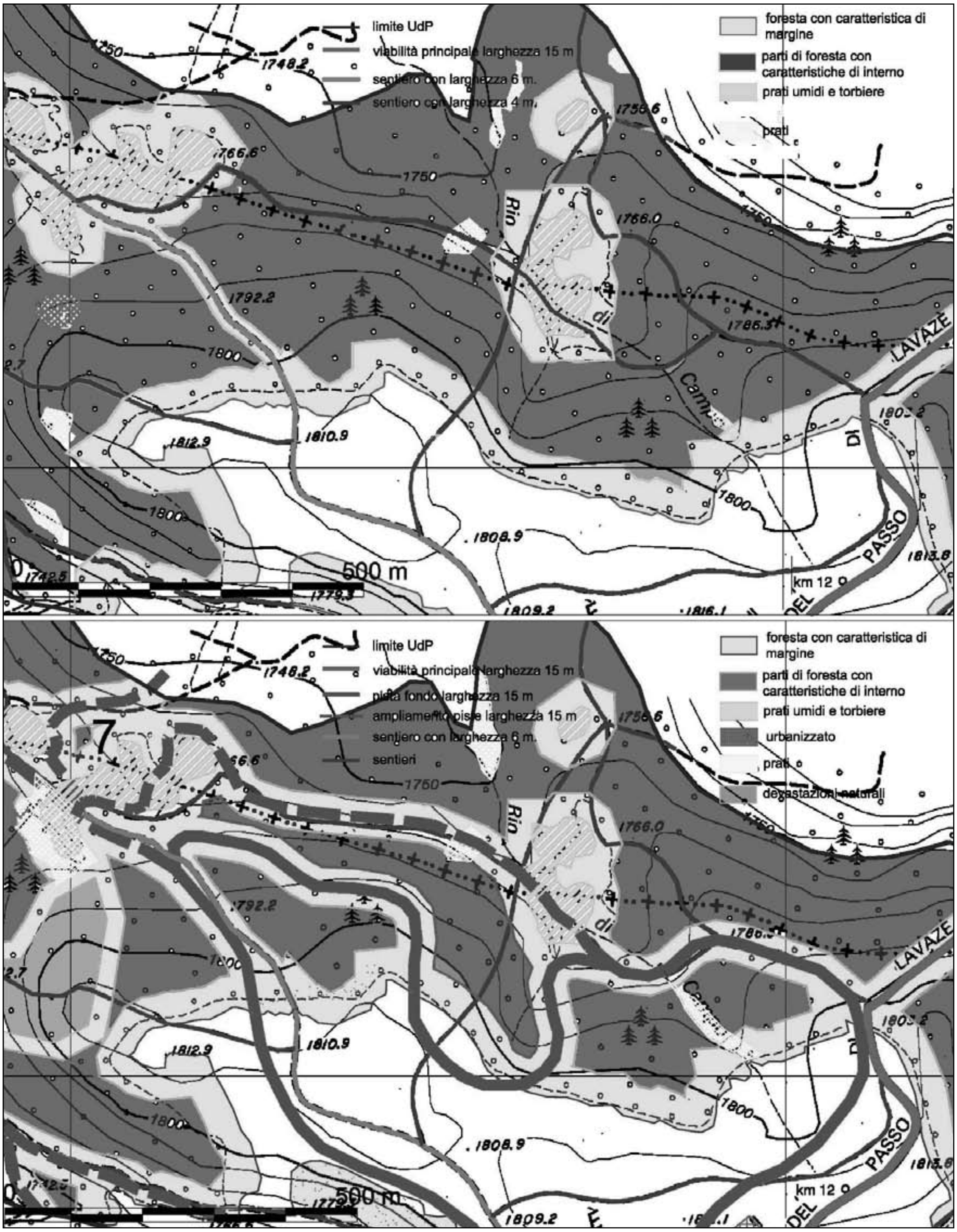

Figure 3 - Top: analysis of the fragmentation of the forest in 1998. The ratio "Core-area/For. surface" is related to forest patches and resulted 77.39 %. Therefore the inner/edge ratio was 3.42. Bottom: analysis of the fragmentation of the forest in 2004. The ratio "Core-area/For. surface" is related to forest patches and resulted 64.55 %. Therefore the inner/edge ratio decreased from 3.42 to 1.82.
Sopra: analisi della frammentazione della foresta nel 1998. Il rapporto "core-area/superficie forestale" è relazionato alle tessere forestali ed è risultato di 77.39%. Per questo il rapporto interno/bordo è risultato di 3.42. Sotto: analisi della frammentazione nel 2004. Il rapporto "core-area/superficie forestale" è relazionato alle tessere forestali ed è risultato di 64.55%. Per questo il rapporto interno/bordo è diminuito da 3.42 a 1.82.

Table 5 - Diagnostic evaluation of the ecological state of the Landscape Unit (Lavazé Pass) (Ingegnoli 2002).
Valutazione diagnostica dello stato ecologico dell'unità di paesaggio (Passo Lavazè) (Ingegnoli 2002).

Main parameters	Normal values*	1935	Gaps %	1998	Gaps %	2004	Gaps %
BTC (Mcal/m²/y)	**5.57-6.15**	5.18	**- 7**	5.05	**-9.3**	4.76	**-14.5**
HH (%)	**20-22**	20.6	**ok**	21.4	**ok**	26.7	**21.4**
ψ = H (3+D)	**5.5-5.7**	4.63	**-15.8**	4.99	**-9.3**	5.29	**-3.8**
LM = τ *BTC	**29-31**	24.27	**-16.3**	24.16	**-16.7**	23.09	**-17.6**
C/F (%)	**80-90**	80.54	**ok**	77.39	**-3.3**	64.55	**-19.3**
Allochthonous pl. (%)	**0-1**	0	**ok**	0	**ok**	0.1	**ok**
Forest area (%)	**65-80**	68.9	**ok**	67.9	**ok**	63.7	**- 2.0**
Agriculture area (%)	**10-20**	18.7	**ok**	16	**ok**	15.1	**ok**
σ = HS/HS*	**3-10**	2.9	**-3.3**	1	**-66.7**	0.92	**-69.3**
HCE = (BTC/HU)* σ	**65-700**	72.9	**ok**	23.6	**-63.7**	16.4	**-74.8**
Diagnostic index	***0.85-1***	*0.90*	***ok***	*0.75*	***-11.8***	*0.60*	***-40***

Distance (%) Evaluation Scores: 0-10 =2; 10-30 = 1; 30-60 = 0.5; > 60 = 0.
Diagnostic index: 0.85-1 = normal; 0.6-0.85 = alteration; 0.35-0.6 = syndrome; 0.15-0.35 = serious syndrome; < 0.15 extinction.
(*)Normal values: according to a sub-natural forest Landscape.

The evaluation scores depend on the concepts of tolerance and alteration of an ecological vegetation system, deduced from field observations. Ingegnoli (2006) proposed the following thresholds, based on the gaps between the NV and the measured ones: [0-10] = 2; [10-30] = 1; [30-60] = 0,5; [> 60] = 0. Therefore, a diagnostic evaluation using 10 parameters, as in this case study, should summarise a total score of 10x2 = 20. Applying this method (Tab. 5) the results (diagnostic index) were 18/20 = 0,90 in the period 1935-40, 15/20 = 0.75 in 1998, but only 12/20 = 0.60 in 2004.

The diagnostic evaluation of a landscape unit in an European (and Alpine) region is based on the five classes associated with the diagnostic index as exposed in the note of table 5, following the most significant physio-pathological phases, which implies consequent ecological health state and interventions per class, as ranked here:

I. (0.85-1.00) Normal. Homeostatic plateau, quite good health, only prevention;
II. (0.60-0.85) Alteration. Compensation needed, instable health, some therapies;
III. (0.35-0.60) Disorder. Some physiological damages, dysfunction, intervention needed;
IV. (0.15-0.35) High disorder. Harmful effects, high dysfunctions, difficult intervention;
V. (< 0.15) Extinction. Irreversible damages, degenerative transformations.

In this case study the Lavazé Pass LU results at the limit between alteration and pathology.

It is possible to confirm the previous diagnosis applying the correlation expressed in the HH/BTC model (Ingegnoli & Giglio 2005) in the case study of the Lavazé Pass (Figure 4). This figure shows the thresholds differentiating the landscape typologies (*i.e.* natural forested landscape, semi-natural forested landscape, managed forested -or forest-agricultural- landscape, agricultural landscape, rural-suburban landscape *etc.*). Five intervals of these are plotted in Figure 4. The last transformation period (1998-2004) of the LU is shown to pass from the second to the third interval, corresponding to a degradation of the traditional semi-natural type of landscape.

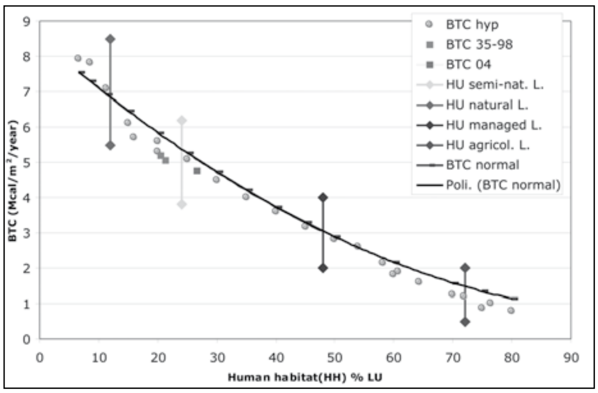

Figure 4 - The polynomial curve of the BTC/HH model is in accordance with the hypothesis of possible transformations of our case study (grey sq). We can see the movement of the LU system from 1935-98 to 2004 passing through the threshold between two landscape (L) types. These forested L. types are separated by vertical segments: 1st belt: natural L.; 2nd belt: semi-natural L.; 3rd belt managed (or forest/agricultural) L.; 4th belt: agricultural L.; 5th belt: suburban L.
La curva polinomiale del modello BTC/HH è in accordo con l'ipotesi di possibili trasformazioni del nostro caso di studio (riquadri grigi). Possiamo vedere la LU dal 1935-1998 al 2004 passare attraverso la soglia di due tipi di paesaggio (L). Questi tipi di paesaggi forestali sono separati da segmenti verticali: 1° fascia: L naturale; 2° fascia: L seminaturale; 3° fascia: L gestito (o forestale/agricolo); 4° fascia: L agricolo; 5° fascia: L suburbano.

Conclusion

This case study demonstrates that if we want to evaluate the ecological state of a forest and the transformation in a forested landscape unit, we must follow a landscape ecological method. Through a method like the one proposed by Ingegnoli we have seen that apparently small changes in few years may bring to near pathologic consequences in a forest system. Other more traditional methods, mainly referred to permanent plots, are not able to reach similar results. For instance, phytosociologic characters are not really altered in a forest like this. We hope to apply the landscape ecological theory and its proper methodologies (*e.g.* the LaBISV) to other forested landscape units, in different climatic areas, at least in Italy.

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Status and trend of atmospheric deposition chemistry at the CONECOFOR plots, 1998-2005

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Abstract – Ion deposition in the open field and under the canopy was monitored in 13 CONECOFOR plots during 1998-2005. In spite of the remote location of most plots, atmospheric deposition carries considerable amounts of anthropogenic ions (sulphate, nitrate and ammonium). Deposition acidity is buffered by the deposition of base cations, partially due to the long-range transport of Saharan dust. In the study period, sulphate deposition and deposition acidity significantly decreased, because of the decrease in sulphur dioxide emissions in Europe, while nitrate and ammonia deposition did not show a clear temporal pattern.

Key words: *Deposition chemistry, forest sites, acidity, sulphate, nitrogen, time trends.*

Riassunto – Stato e tendenze della chimica delle deposizioni atmosferiche nelle aree CONECOFOR nel periodo 1998-2005. Questo lavoro descrive la deposizione di ioni di origine antropica in 13 aree permanenti della rete. Benché i siti CONECOFOR siano stazioni remote in ambito forestale, la deposizione di solfati, nitrati e ammonio è elevata, ma la loro distribuzione spaziale è differente: nel caso dei solfati, le deposizioni sono minori nelle stazioni di alta quota, mentre la deposizione di ammonio è elevata nella Pianura Padana e quella dei nitrati è relativamente costante in tutto il Paese. La deposizione di ioni alcalini, in parte di origine sahariana, porta ad una notevole riduzione dell'acidità delle deposizioni su tutto il territorio.
Nel periodo di studio si osserva in molte stazioni una diminuzione della deposizione di solfati e di conseguenza dell'acidità delle deposizioni, nonostante una tendenza alla diminuzione della deposizione di ioni alcalini.

Parole chiave: *Chimica delle deposizioni, siti forestali, acidità, solfati, azoto, tendenze temporali.*

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Introduction

Nutrient cycling and soil acidity are important factors influencing forest distribution, growth and health. During the 1980s the pollutant loads from atmospheric deposition were identified as agents which could destabilise forest ecosystems. Studies focused in particular on the effects of the acidity of atmospheric deposition on the functionality of foliar surfaces, the ion exchange between deposition and foliar surfaces, the alteration of ion ratios in the soil, and the load of nutrients, especially nitrogen, reaching the soil.

Trace gases and particulates present in the atmosphere may be deposited through gravity or interception by the receiving surface. The former mechanism is more important for particles deposited directly ("dry deposition") than for those deposited in drops of water ("wet deposition"). However, a portion of wet deposition, referred to as "occult deposition", occurs through interception, for instance, in the case of fog, hoarfrost or dew (Hicks *et al.* 2000).

The quantity of compounds deposited through gravity does not depend on the receiving surface, and may be estimated with a good degree of precision using both continuously open samplers (*bulk samplers*), which however are also affected by locally generated dust, and automatic samplers which open during precipitation *(wet samplers*). In contrast, deposition by interception depends largely on the nature of the receiving surface, so that direct measurement is more complex. In a forest ecosystem, total deposition may be estimated by analyzing deposition collected in the open field, under the crowns (throughfall), and along the trunks of the trees (stemflow). It should be remembered that the chemical composition of atmospheric deposition is changed through contact

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with the crowns and trunks of the trees. To detect the interaction between atmospheric deposition and the tree canopy, the chemical composition of open field bulk deposition is compared to the quality of throughfall water.

Some ions have prevalently natural origin: sodium and chloride, and a component of sulphate, mainly derive from marine aerosol, and their concentrations depend essentially on the distance of the plot from the sea; calcium, magnesium and potassium, on the other hand, are largely terrigenous in origin. Other ions derive mainly from the washout of atmospheric pollutants such as ammonium, an ion produced by the ammonia emitted in agricultural and stock-raising activities, and nitrate and sulphate, ions produced by industrial, domestic and vehicle fuel combustion.

Atmospheric deposition may be acidic as a consequence of atmospheric pollution: nitrogen and sulphur oxides emitted into the atmosphere during fossil fuel combustion are transformed in the atmosphere into nitric and sulphuric acid, respectively. Nitrogen and sulphur emission increased during the twentieth century because of industrial development and traffic increase. From the 1980s, the protocols agreed under the framework of the 1979 Geneva Convention on Long-range Transboundary Air Pollution (UN ECE 1996) led to a substantial decrease in the emission of sulphur and nitrogen oxides into the atmosphere (Figure 1). Ammonium ion deriving from ammonia emitted by agriculture and stock raising is also present in atmospheric deposition, and can produce further acidity directly in the soil during the process of bacterial oxidation (Schuurkes 1986). In most of Italy, the acidity transported annually by atmospheric deposition to forest soils is partially or totally neutralised by episodic deposition of alkalinity deriving from the long-range transport of Saharan dust.

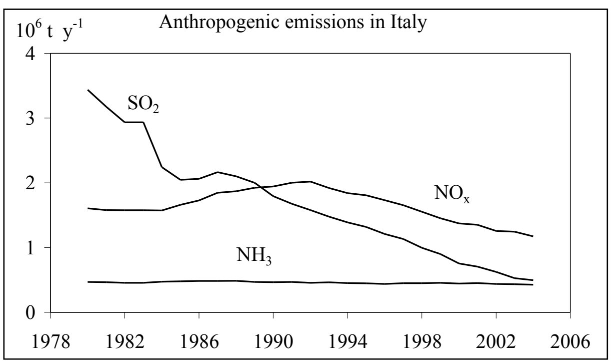


Figure 1 – Trends in emissions in the atmosphere of SO_x, NO_x, NH_3 in Italy (source http://www.emep.int).
Evoluzione temporale delle emissioni di ammoniaca (NH_3) e degli ossidi di zolfo (SO_x) e di azoto (NO_x) in Italia (dati tratti dal sito http://www.emep.int).

Within the CONECOFOR programme, acidity, main ions and nutrient nitrogen inputs from the atmosphere at a maximum of 20 monitoring plots in Italy are analysed.

In this paper we evaluate trends in the amount of precipitation and the concentration of some selected ions in atmospheric deposition reaching the thirteen stations for which analyses were carried out continuously from 1998 to 2005.

This evaluation is designed to detect trends in:

(a) mineral acidity (H^+) of atmospheric deposition and in the input of anthropogenic compounds related to atmospheric pollution, namely sulphate ($SO_4^=$), nitrate (NO_3^-) and ammonium (NH_4^+), in response to emission control enforced by recent legislation;

(b) the amount of precipitation, sea salt contribution (Na^+, Cl^-) and in the basic cation (Ca+Mg) deposition which can buffer the acid input, in response to changes in global and regional atmospheric circulation;

(c) in the canopy response to long-term pollution and its changes, through the analysis of throughfall and runoff water compared to open field deposition.

Methods

Sampling

Open field (OF) depositions were sampled weekly using continuously exposed collectors, comprising a 2-litre graduated polyethylene bottle, with a funnel of 14.5 or 19.5 cm diameter, depending on the mean amount of precipitation to the plot. Three open field collectors were placed in each area, the samples pooled together and an aliquot sent to the laboratory. Snow sampling was carried out in winter 1998 using polyethylene plastic bags placed in PVC tubes, one meter high, with a diameter of 25 cm. Since 1999 the snow samplers have been replaced with a cylindrical PVC container (diameter = 20 cm, height = 80 cm). The snow sample was then melted in a warm room, the volume measured using a graduated cylinder, and the sample bottled for mailing to the laboratory.

For throughfall (TF) sampling, sixteen rain collectors or eight snow collectors similar to those used for the OF were distributed at regular intervals in the plot.

In the same way as for the OF, the samples were pooled together and an aliquot sent to the laboratory.

This paper considers thirteen of the twenty plots: BOL1, CAL1, CAM1, EMI1, EMI2, FRI2, LAZ1, LOM1, PIE1, PIE2, PIE3, TOS1 and TRE1. Bulk open field and throughfall data for the period 1998-2005 were used in the data analysis, with the exception of PIE2 and PIE3, where wet only data were available. The remaining plots were not considered because of gaps in the sampling period, or because they are no longer active in the programme, or because samplings started later than 1998.

Plots PIE2 and PIE3 entered the CONECOFOR programme only in 2003, but wet-only data for the period 1998-2005 are available because of other ongoing research projects. These results were compared with those of the bulk open field of the other permanent plots.

Analysis

The analyses were performed on filtered samples (0.45 µm), except for measurements of pH and conductivity, for which unfiltered samples were used. Major ions (sodium, potassium, magnesium, calcium, sulphate, chloride and nitrate) were analysed by ion chromatography (IC), ammonium and phosphate by spectrophotometry, alkalinity (samples with pH >5.0) by automated Gran titration and total nitrogen by persulphate wet digestion followed by UV spectrophotometric quantification of nitrate. Analyses were performed by the following laboratories: Joint Research Center (Ispra, VA) and CNR-ISE (since 2001) for CAL1, CAM1, EMI1, FRI1, LAZ1 and TRE1; Università di Siena and CNR-ISE (since 2005) for TOS1; CNR Istituto di Ricerca sulle Acque (Brugherio, MI) for LOM1; Agenzia Provinciale per la Protezione dell'Ambiente (Laives, BZ) for BOL1; and CNR-ISE for PIE2 and PIE3.

As sulphate ion derives from both natural (marine) and anthropogenic sources, non-marine sulphate (SO_4*) was calculated on the basis of the $SO_4^{=}/Cl^-$ ratio in sea water (OECD 1979).

Quality control

An analytical quality control programme was set up, involving evaluation of the analytical methods used in the five laboratories taking part in the study, comparison of internal quality controls applied in the laboratories, and the organisation of systematic intercalibration exercises (*e.g.* Mosello *et al.* 1999, 2002b).

Data validation followed the criteria of ion balance and comparison of measured and calculated conductivities (Ulrich and Mosello 2000). Furthermore, comparisons between measured conductivities and sum of cations and anions were performed on the values of each station and each sample type. Deviations from linearity of different sets of values were examined in the light of the completeness of the analyses and considering all the possible causes of errors.

Data pooling

Monthly deposition data were obtained from the sum of the product of weekly concentration by the weekly amount of precipitation. Samples falling between two months were assigned to both, according to the number of sampling days belonging to each month. Monthly pH values were obtained from the volume weighted average concentration of hydrogen ion.

Sampling error

A detailed computation of sampling error for all plots is not available. TF sampling error can be estimated from a study carried out in 1997 on a plot similar to the CONECOFOR plots, located at Ispra (VA), between sites PIE1 and PIE2 (Leyendecker, unpublished), and from a second study carried out in 2006 at site EMI1. In both cases, all sixteen samples were individually analysed on a weekly basis for 15 and 9 weeks, respectively, following the CONECOFOR protocol. The average of the sampling error in the study period was below 10% for all ion concentrations, apart from H^+, and K^+ (both sites), NH_4^+ and NO_3^- (Ispra, only) and Mg^{++} (EMI1, only) for which it ranged between 11 and 19%. This figure represents an upper limit for monthly samples, which integrate 1 to 4 weekly samples.

Statistical analysis

Temporal trends in precipitation chemistry were tested with the Seasonal Kendall Test (SKT) (Hirsch *et al.* 1982) applied to monthly data. SKT has been identified as a suitable method for analysis of water quality data (Loftis and Taylor 1989), and is applied in a number of monitoring programmes, including ICP Waters and ICP Integrated Monitoring (Stoddard *et al.* 1999; Forsius *et al.* 2001). SKT is a refinement of the Mann-Kendall Test, a non-parametric method of trend analysis which is robust with regard to non-normality, missing or censored data (Evans *et al.* 2001). SKT is also robust with respect to seasonality in time series, whereby data are first grouped into either monthly or quarterly mean values (Hirsch *et al.* 1982).

All data pairs within a time series (x_j, x_k, where $j > k$) are assigned a function sgn($x_j - x_k$) with values of +1, 0 or –1 depending on the sign of $x_j - x_k$. These are then summed to give the Mann-Kendall statistic S:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \text{sgn}(x_j - x_k) \quad (1)$$

where n is the number of data values. The value of S, together with calculated variance, Var(S), are used to derive a test statistic z, which is positive if the trend is upward and negative if the trend is downward. The magnitude of z is used to estimate trend significance. S and Var(S) are calculated within each seasonal block and summed for all seasons to give full dataset statistics S´ and Var(S´), which are then used to compute z. The estimate of Var(S´) was obtained using a modified procedure presented by HIRSCH and SLACK (1984), which provides a more robust significance test with respect to serial correlation.

Trend magnitudes and slopes were calculated for the monthly deposition of the main ions (H^+, NH_4^+, Ca^{++}+ Mg^{++}, Na^+, Cl^-, $SO_4^=$, NO_3^-) in both bulk and throughfall samples. Significance thresholds of $p < 0.001$, $p < 0.01$, and $p < 0.05$ were applied to trend tests. Trend slopes were calculated according to Sen (1968) as the median of between-year differences in values within each seasonal block.

Results

Quality control and data comparability in time and space

This paper considers only those stations which were run for the whole study period (1998-2005), at least ten months per year. Analytical quality control allowed error detection and repetition of suspect analyses, leading to less than 2% of the analyses showing a difference between measured and calculated conductivity higher than 30%, while for 89% of the analyses the difference was smaller than 15%, which is the target value proposed within the ICP-Forest programme for diluted samples (Ulrich and Mosello 2000).

Data comparability in space and time was assured by uniform sample collection and handling and by the intercomparison exercises for laboratory methods. Apart from the case of TOS1, all the measurements in each plot were made during the seven years of data collection using the same analytical methods.

Present status

The yearly deposition for 2005 of some selected ions, and the amount of precipitation for the thirteen plots, are presented in Table 1, together with the yearly pH obtained form the volume weighted average of hydrogen ion deposition. The amounts of precipitation measured in the bulk open field collectors range between 739 and 2158 mm y^{-1}. The highest value was recorded at CAL1 in the Southern Apennines, the lowest at PIE2, in the Po Plain. Apart from CAL1, all the plots show pH values equal or higher than 5, with a maximum of 5.6 at EMI1 and TRE1: in the past, lower values were recorded for most of the plots. The mean annual fluxes of NH_4^+ and NO_3^- show wide spatial variation, the former ranging from 19 meq m^{-2} y^{-1} (CAM1) to 57 meq m^{-2} y^{-1} (EMI1) and the latter from 20 meq m^{-2} y^{-1} (TRE1 and BOL1) to 57 meq m^{-2} y^{-1} (PIE1). High depositions of SO_4^* (71 meq m^{-2} y^{-1}) were measured at

Table 1 - Annual precipitation (mm) and atmospheric deposition fluxes of some selected ions at the CONECOFOR sites in 2005. SO_4^*: non-marine sulphate.
Precipitazioni annue (in mm) e flussi di deposizione di alcuni ioni nelle stazioni CONECOFOR per il 2005. SO_4^*: solfati corretti per la frazione di origine marina.

2005 *open field*	mm	pH	NH_4^+ meq m^{-2} y^{-1}	NO_3^- meq m^{-2} y^{-1}	SO_4^* meq m^{-2} y^{-1}	Ca + Mg meq m^{-2} y^{-1}
BOL1	818	5.5	24	20	13	19
CAL1	2158	4.9	31	40	71	113
CAM1	974	5.2	19	23	28	50
EMI1	935	5.6	57	39	26	33
EMI2	1701	5.2	31	36	33	54
FRI2	1484	5.3	22	24	22	29
LAZ1	1258	5.3	23	27	29	65
LOM1	898	5.3	23	25	18	21
PIE1	1246	5.0	63	57	39	29
PIE2	739	5.4	54	42	31	31
PIE3	907	5.1	27	27	17	20
TOS1	968	5.0	21	28	31	73
TRE1	973	5.6	25	20	13	20
throughfall						
BOL1	604	5.5	11	22	10	36
CAL1	1744	5.3	26	40	102	211
CAM1	776	5.5	16	38	34	99
EMI1	781	5.8	81	63	37	76
EMI2	1246	5.4	31	52	34	85
FRI2	1150	5.8	21	41	29	114
LAZ1	1034	5.4	14	37	31	99
LOM1	744	5.7	23	38	18	45
PIE1	1057	4.9	56	60	35	36
TOS1	735	5.5	14	35	50	157
TRE1	702	5.4	14	18	10	27

Table 2 – Results of the SKT applied to monthly deposition values of the period 1998-2005. Level of significance: p< 0.001 (***), p< 0.01 (**), p <0.05 (*); b: trend slope, meq m^{-2} y^{-2}. SO4*: non-marine sulphate. §: wet only samples.
Risultati del test stagionale di Kendall effettuato sui valori di deposizione mensile per il periodo 1998-2005. Livelli di significatività: < 0.001 (***), p< 0.01 (**), p <0.05 (*); b: pendenza, meq m^{-2} y^{-2}, §: campioni di deposizione umida (wet only).

Open field	mm		H+		NH_4^+		NO_3^-		SO_4^*		Ca+Mg	
	b	p	b	p	b	p	b	p	b	P	b	p
BOL1	-1.8	*	-0.03	**	-0.05	*	-0.04		-1.2	**	-0.06	
CAL1	5.0		0.08	**	0.15	***	0.19	**	-1.3	*	0.06	
CAM1	1.0		0.01		-0.02		-0.14		-3.2	**	-0.92	***
EMI1	2.1		0.00		0.14		0.08		-3.7	***	-0.11	
EMI2	6.3		0.01		0.17	*	-0.14		-3.7	***	-0.29	
FRI2	0.3		-0.03		0.02		0.06		-1.9	**	-0.01	
LAZ1	1.4		0.00		0.04		0.01		-2.4	***	-0.09	
LOM1	-9.5	***	-0.13	***	-0.09	*	-0.17	**	-1.8	***	-0.30	**
PIE1	0.2		-0.11	**	0.10		0.05		-1.7	*	-0.07	
PIE2§	-4.4		-0.09	***	-0.14		-0.23		-2.8	**	-0.06	
PIE3§	-9.5	**	-0.25	***	-0.08	**	-0.20	***	-1.5	***	-0.08	*
TOS1	-1.1		-0.03	**	-0.23	***	0.02		-4.9	***	-0.27	
TRE1	-2.4		0.01	*	-0.03		-0.01		-2.5	***	-0.57	***
Throughfall												
BOL1	-2.0	*	-0.03	***	-0.04	**	-0.07		-3.3	***	0.06	
CAL1	4.6		0.00		0.11	**	0.13	*	-3.0	*	0.31	
CAM1	-3.0		0.01		-0.21	***	-0.14		-2.9		-0.86	*
EMI1	2.0		0.00		0.12		0.16		-5.6	**	-0.11	
EMI2	4.5		-0.00		-0.01		0.01		-5.0	***	-0.03	
FRI2	4.3		-0.10	***	0.03		0.06	*	-3.4	**	0.46	*
LAZ1	0.0		0.00		-0.01		0.04		-2.7	**	-0.04	
LOM1	-7.5		-0.03	***	-0.06	**	-0.09	*	-2.9	***	-0.31	*
PIE1	2.5		-0.03	*	0.02		-0.01		-2.0		-0.15	*
TOS1	-1.4		-0.01	**	-0.23	**	0.19		-7.9	*	-0.89	
TRE1	-2.6	*	0.00		0.00		0.01		-2.6	***	0.33	***

CAL1, while for the other plots the range was from 13 meq m^{-2} y^{-1} (BOL1, TRE1) to 39 (PIE1) meq m^{-2} y^{-1}.

For base cations (Ca, Mg), the sum is reported, ranging from 19 meq m^{-2} y^{-1} at BOL1 to 113 meq m^{-2} y^{-1} at CAL1, with a strong latitudinal gradient. Most of these cations derive from the long range transport of Saharan dust, which is obviously more important at the southernmost sites. Calcium is in general the main cation, followed by sodium, magnesium and potassium. Higher values of magnesium and sodium deposition are registered in the plots closer to the sea, due to the contribution of sea spray. For throughfall chemistry, the fluxes in all the plots are higher than the respective bulk values, with the exception in some cases of ammonium, indicating a possible foliar uptake.

Detected trends

The results of the trend analysis performed on the monthly data of the 13 plots are shown in Table 2. A highly significant negative trend was found for SO_4^* for most of the plots in the case of open field data; the trend slope is negative for all the stations and ranges (in units of meq m^{-2} yr^{-1}) between -4.9 at TOS1 and -1.2 at BOL1. Significant negative trends were also found for H^+ for a lower number of stations, the trend slope varying between -0.25 at PIE3 and 0.08 at CAL1. A significant negative trend was also detected for the sum of Ca and Mg at CAM1, LOM1 and TRE1.

Some stations showed significant trends in precipitation amount. As shown in Figure 2 and 3, detected trends are superimposed on a strong interannual variability, but in the case of sulphate the decrease is clear: its mean decrease from 1998-99 to 2004-05 accounts for 25% and 15% of the 1998-99 sulphate deposition for open field and throughfall samples, respectively. In the case of hydrogen ion, the decrease amounts to 11% and 20%, respectively.

No pattern of significant trends was detected for Na, Cl, K and Mg, either in the open field or in the throughfall samples.

Discussion

In spite of the remote location of many CONECOFOR sites, atmospheric deposition carries high amounts of anthropogenic ions. Apart from some high mountain sites (BOL1, LOM2, PIE3, TRE1, FRI2), bulk sulphate deposition shows values higher than 8 kg S ha^{-1} y^{-1} (25 meq m^{-2} y^{-1}). Ammonia deposition is concentrated in the Po Plain (PIE1, PIE2, EMI1), where it reaches 8-9 kg N ha^{-1} y^{-1} (53-63 mmol m^{-2} y^{-1}), while nitrate deposition is more widespread throughout the country at levels generally ranging between 3 and 6 kg N ha^{-1} y^{-1} (20-42 mmol m^{-2} y^{-1}). These different patterns are related both to the different emission sources and pollutant spread. Ammonia and sulphate are mainly emitted from point sources respectively in agriculture and industry, while nitrate is mainly emitted by diffuse sources, like traffic. On the other hand, ammonia deposition is more related to local sources, while sulphate and nitrate can be transported over long distances. The highest deposition values are found at CAL1 and can be related to the high precipitation amount recorded at this site. Base cation deposition, mainly due to the long-range transport of Saharan dust, is significant at all stations, with a strong latitudinal gradient, allowing the buffering of acid deposition, so that the mean annual acidity is very low at all sites. However, base cation deposition is episodic, and in all sites most of the samples were more acidic.

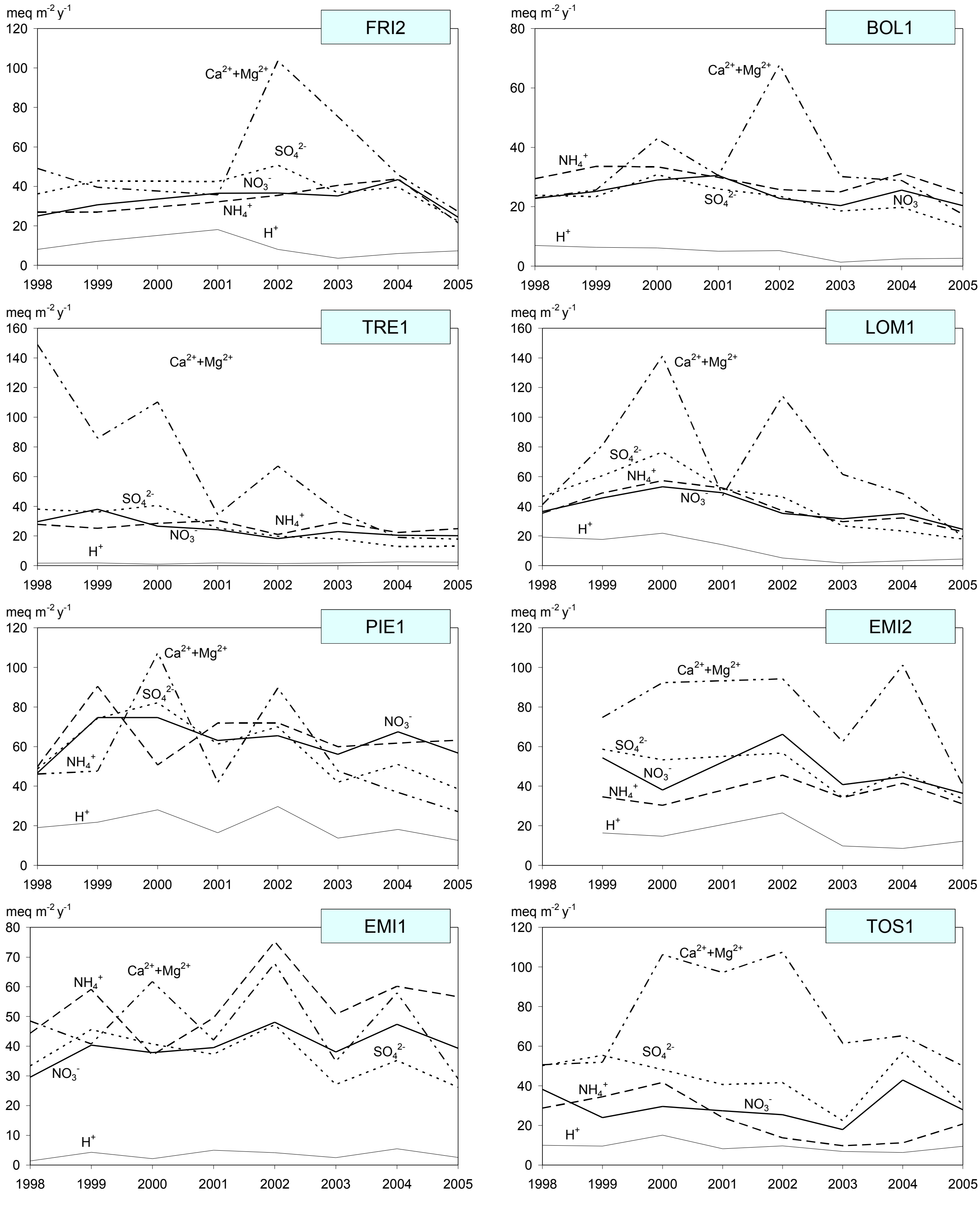
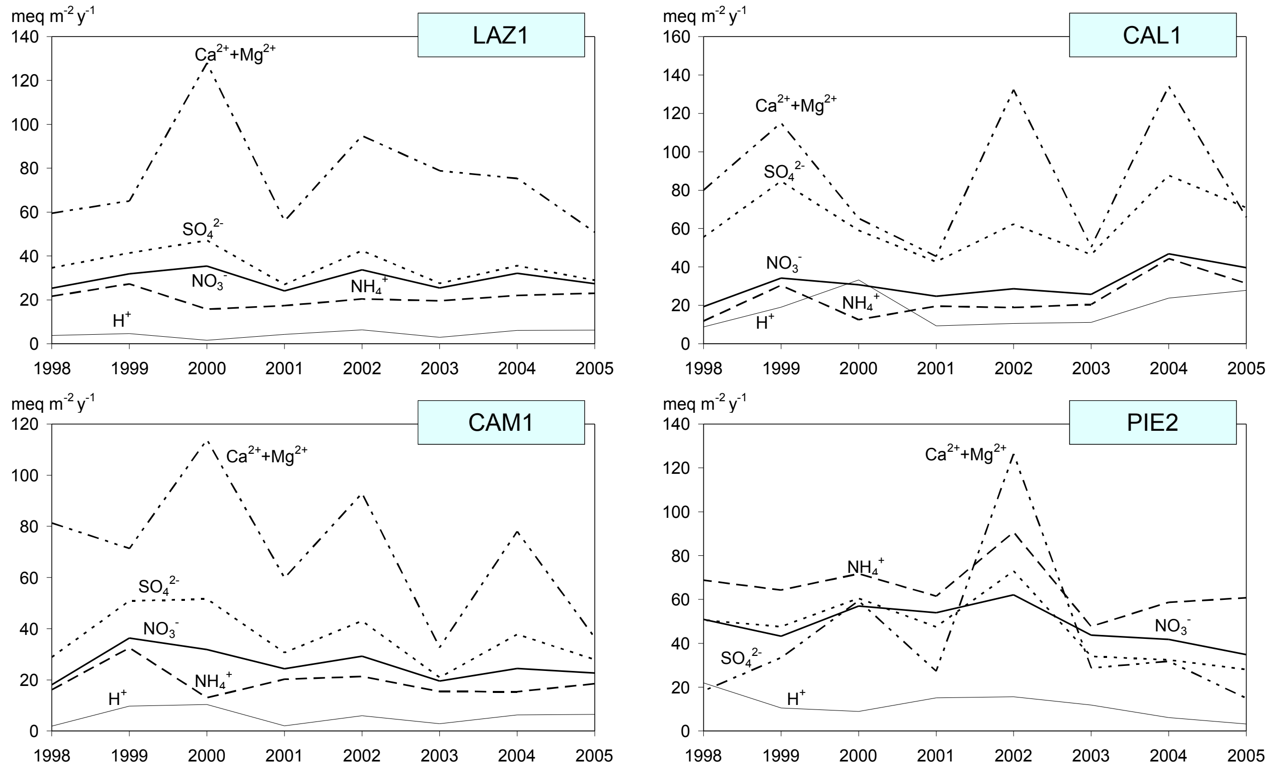


Figure 2 – Open field annual deposition of some selected ions, corrected for sea-salt contribution (in meq m^{-2} y^{-1}).
Deposizione media annua a cielo aperto di alcuni ioni, corretta per il contributo marino (in meq m^{-2} y^{-1}).



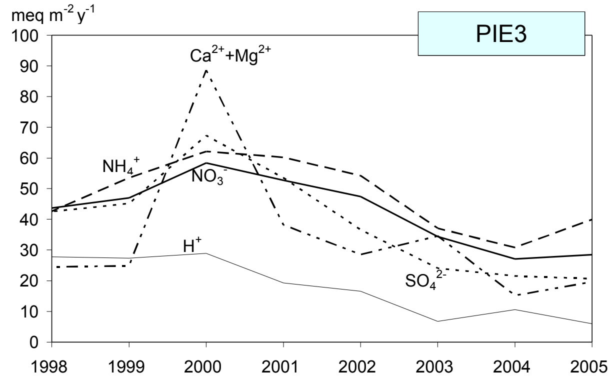


figure 2 (continued)

The interaction with the canopy leads to an increase in sulphate, nitrate and base cations, showing the significant contribution of dry deposition at these sites. In contrast, ammonia is partly retained in the canopy.

Variations in the deposition of sulphate, nitrate and ammonium can be compared to the trends in the emissions of SO_x, NO_x and NH_4 as evaluated by the EMEP (Figure 1). The declining trends of sulphate and acidity in deposition are in agreement with the decreased emissions of SO_x, while the less marked decline in the emissions of NO_x has not yet had an effect on nitrate deposition. Altogether these variations determined a significant increase of pH at 6 out of 13 sites, in spite of the negative trend of base cation deposition.

The variations observed in the CONECOFOR plots are in agreement with the results obtained in other studies in Italy (Rogora *et al.* 2004) and in Europe (Stoddard *et al.* 1999, Skjelkvåle *et al.* 2005).

Conclusions

Atmospheric deposition carries high amounts of sulphate, nitrate and ammonium to all CONECOFOR permanent plots. The lowest values of deposition are in Alpine plots, which however are the most sensitive and fragile from the ecological point of view, while ammonium and sulphate deposition is higher in the Po Plain. On an annual basis the deposition of acidity is low, because of the buffering effect of alkalinity and base cations, enhanced by frequent episodic events of long range transport of calcareous dust from North Africa. Furthermore, this study demonstrated the decreasing trends of both sulphate and acidity, closely related to the decrease in emissions of SO_x into the atmosphere in Italy. On the other hand the deposition of nitrate and ammonium remains high, showing trends only in a small number of plots, furthermore not

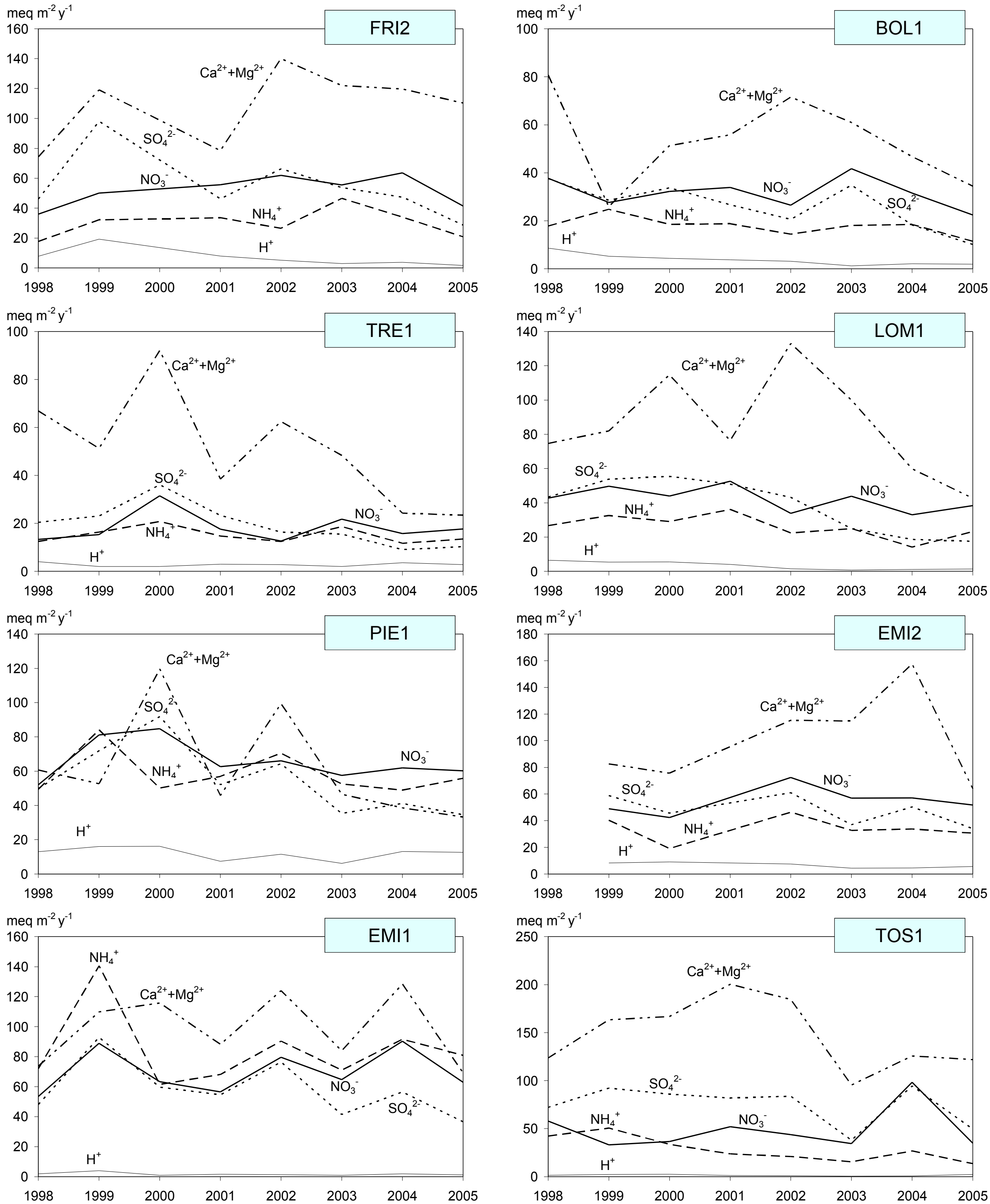
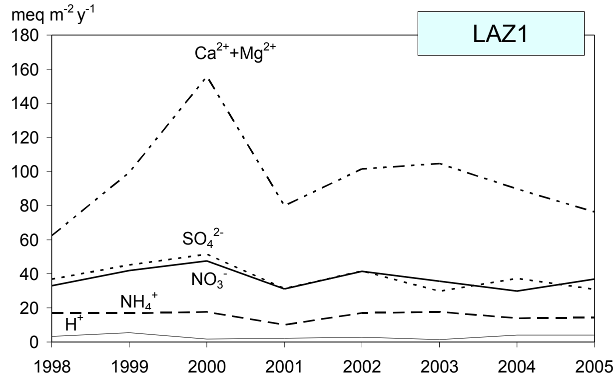
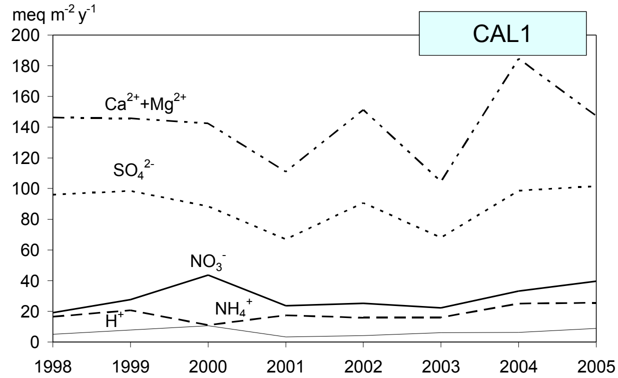


Figure 3 – Throughfall annual deposition of some selected ions, corrected for sea-salt contribution (in meq m^{-2} y^{-1}).
Deposizione media annua sotto chioma di alcuni ioni, corretta per il contributo marino (in meq m^{-2} y^{-1}).





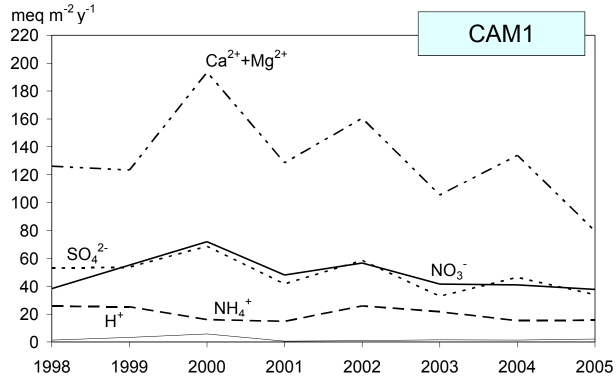


figure 3 (continued)

of the same sign. This is partly in agreement with the pattern of emissions, which is constant for ammonium and only slightly decreasing for nitrate.

Other studies performed in the context of the CONECOFOR project demonstrate the wide exceedance of the actual nutrient N load over the critical load in most of the plots, with nitrate leaching in the surface waters (Mosello *et al.* 2002a; Rogora *et al.* 2003). This confirms that, in the case of Italy, nitrogen deposition remains an important environmental issue. For this reason, significant efforts are still needed to reduce ammonia and nitrogen oxides in the atmosphere, a field on which research and monitoring should be focused in the next few years.

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Soil solution chemistry at one mountain beech (*Fagus sylvatica* L.) CONECOFOR plot, 1999 to 2005

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Abstract – Soil solution monitoring aims to understand various temporal scales of soil processes. The first eight years of observation in ABR1 Level II site have brought significant elements of understanding about the shorter temporal scales. It is suggested that certain solutes, regularly produced by forest floor microbial processes, are transferred to the highly mobile portion of the soil solution by a non linear process, producing irregular pulses and creating a strong high frequency component. Seasonal processes remain nonetheless detectable after simple and rough filtering. A multi-year trend of diminished nitrate mineralization and increased pH of forest floor solutions is possible. It is estimated that much more accurate analysis will be possible in a relatively short time span of further monitoring.

Key words: *beech forest, soil solution, trends.*

Riassunto – Chimica della soluzione del suolo in un'area CONECOFOR montana di faggio nel periodo 1999-2005. Tra gli scopi del monitoraggio delle soluzioni circolanti del suolo c'è la comprensione delle diverse scale temporali dei processi. I primi otto anni di osservazione nel sito Livello II ABR1 hanno portato significativi elementi di comprensione rispetto alle scale temporali più brevi. Le osservazioni suggeriscono che certi soluti, regolarmente prodotti da processi microbici negli orizzonti organici, siano trasferiti alle soluzioni del suolo per mezzo di un processo non lineare, che produce pulsazioni irregolari e determina una forte componente ad alta frequenza nello spettro temporale. Ciò nonostante, gli andamenti stagionali restano individuabili con l'applicazione di un filtraggio molto semplice. I dati suggeriscono la possibilità di tendenze poliennali verso la diminuzione del flusso di nitrati e l'aumento del pH nelle soluzioni all'interfaccia organico-minerale. Si ritiene che un notevole miglioramento della possibilità di analisi dei dati sarà possibile dopo una ulteriore fase di monitoraggio di durata relativamente breve.

Parole chiave: *faggio, soluzione del suolo, tendenze temporali.*

F.D.C. 114.28: 524.634: 176.1 Fagus sylvatica

Introduction

The main value of continuous monitoring of soil solution composition rests in the ability to observe different scales of temporal trends in soil genesis, physiological, and chemical processes. However, such ability comes neither cheaply nor easily; multiple methodological obstacles are disseminated along the road and some measure of strength and patience is required of the researcher. Among the main methodological problems, we start from the need that a purposely designed solution sampler is properly placed. As purposely designed at it may be, the sampler is bound to disturb local soil environment. Gravity samplers, normally used below the forest floor, may alter rates of organic matter deposition and decomposition; tension samplers, normally used within the mineral soil, can produce preferential water flow paths, and always include an intrinsic ambiguity between free-flowing and weakly retained water. The proportions of these water fractions will vary with time, according to complex physical forcings. Spatial variability, especially when considering dynamic soil fluids over short time frames, may be up to extreme. Temporal variability, for how sought after it is, may be troublesome to handle. Temporal variability of soil solution composition realizes itself across a very wide span of scales, and it is often difficult to discriminate between the different components. The typically irregular, and low, sampling frequencies definitely

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don't help. The main starting point to start disentangling these issues is to examine seasonal trends. This because we do have plenty of "physical" (as opposed to statistical) knowledge about the forces driving seasonal variations; this should help us to understand apparent trends, even when data amount is not up to rigorous statistical standards. Seasonal variations may eventually be strongly covariant with other "noise" sources, such as soil water content and rate of water flux through soil. This is partly a double-edged sword, as effects may show up in a bundled form and be difficult to separate, but again solid physical bases about processes and factors promise help.

This paper reports the exploratory analyses of soil solution chemistry for ABR1 site, with the goal to start building an understanding of seasonal trends and related sampling issues. The aim is to assess minimum requirements concerning time span and data density for the development of effective algorithms for separating the components of the time spectrum of soil solution composition, to allow isolation of meaningful multi-year trends.

Methods

Soil solution sampling in ABR1 station started in 1999 (Cecchini *et al.* 2002), with additional support from previous research. Presently, data are available until 2005, giving a temporal baseline over which an exploratory evaluation is possible. On the other hand, it must be kept in mind that the sample base amounts to only 74 samples; just to set the scales, this number of samples is equivalent to about 2 years of deposition sampling, and insufficient to apply suitable advanced statistical analysis as found in Spangenberg and Bredemeier (1999) or Stein and Sterk (1999). Gravity samplers in ABR1 were renewed in fall 2004, as part of the normal procedure required by "ageing" of such samplers; this adds to the complexity of the task. The set of solution samplers is the one prescribed by ICP manuals, and routine ICP quality control procedures are performed on the results; this includes regular participation to solution chemistry ring tests, organized by both ICP and by NIVA. General site and soil characteristics are described in Cecchini *et al.* (2002). Data obtained by previous researches are also examined, as relevant to the issue of sampler "ageing" effects.

Results

For initial data exploration, a summary analysis of overall parameter variability and dynamics was applied, comparing of the different sampler sets. From such rapid assessment it was evident how forest floor samplers produce the data set which are of most interest for time series analysis.

Various concomitant factors make this happen. In bio-physical terms, forest floor reacts to environmental variations faster than any other soil compartment, reflecting in the high dynamics of all solution parameters. Previous, single event-based, analyses (Cecchini *et al.* 2002) showed how solutions from forest floor samplers often register analyte concentrations one or two orders of magnitude higher with respect to all other soil solution samplers, notwithstanding the fact that they see the largest water flow. This suggests that, for the time scales accessible here, forest floor processes are capacious enough to "swamp" other processes, and that behaviour of lower horizons may be, at this stage, approximated as a response to forest floor inputs.

In data processing terms, forest floor phenomena are likely to show the most tractable problems of time delay between driving (precipitation, climatic, phenological) factors and response. The possibility to assume small and constant time delays should be quite useful in establishing general trends of seasonal behaviour, to be used as a reference to evaluate time delay issues in lower horizons. In statistical terms, forest floor provides the most uniformly distributed sampling time intervals and the highest data density in time, both factors of great help in time series analysis.

Examination of data from individual sampling times tends to support the interpretations put forward in Cecchini *et al.* (2002). The driving variables of soil solution equilibrium still appear to be the supply of nitrate anion, produced within the forest floor by litter decomposition, and the balancing availability of basic cations, of partly external origin. These interactions bear heavily on such fundamental soil solution properties as pH and EC.

According to this process-oriented analysis, a small set of parameters were selected for detailed statistical analysis. These include pH, EC, Nitrate and Sulphate; this last analyte was selected as a shorthand indicator of total external dust supply (Cecchini *et al.* 2002).

As a first step, parameters were plotted versus time (Figure 1). Even if a few irregularities spoil visual evidence, seasonal trends look rather clear. Nitrate con-

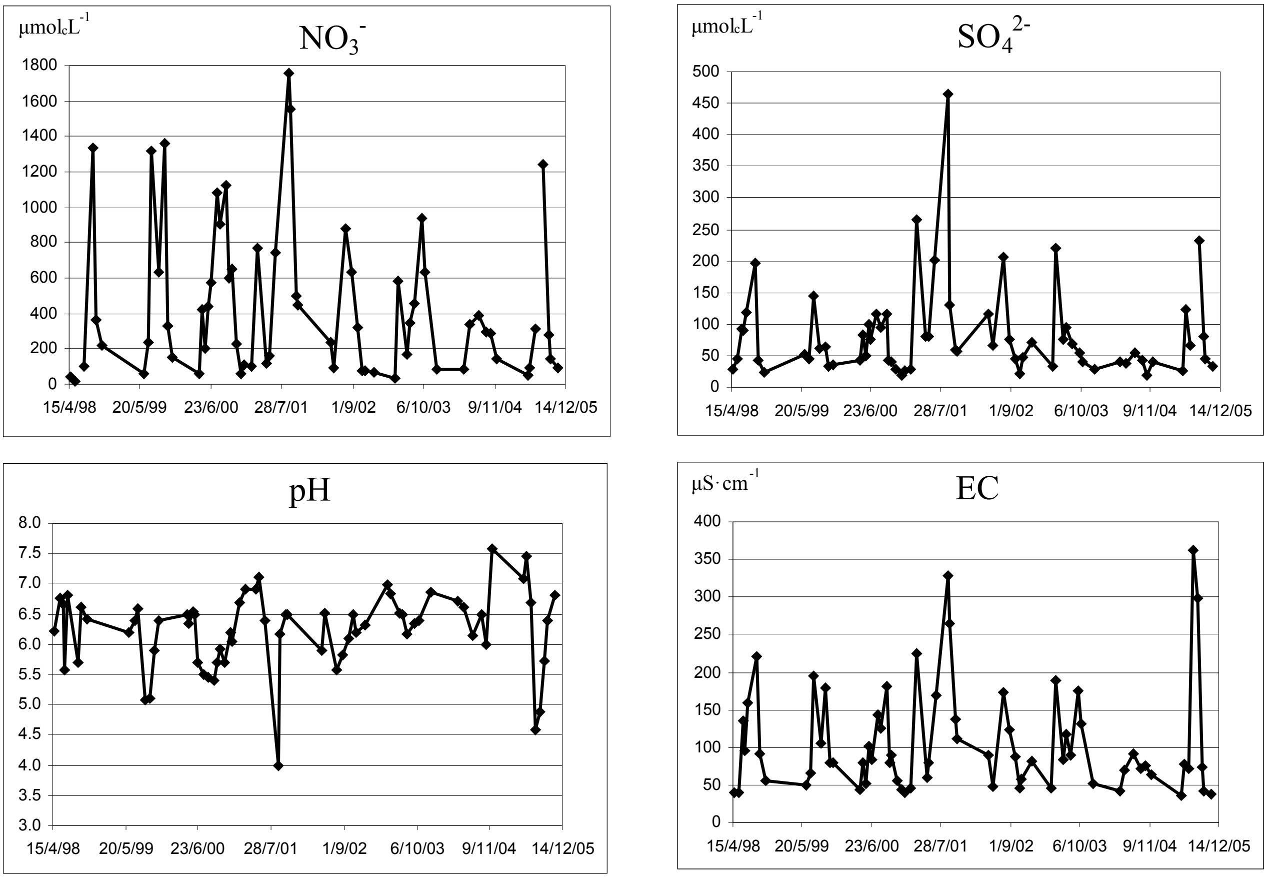


Figure 1 - Time series of selected soil solution parameters.
Serie temporali di parametri selezionati delle soluzioni del suolo.

centration peaks in summer months; in some cases, a well defined "fork" aspect is visible, with an early summer peak, a decrease and then a second peak, in late summer or, sometimes, in early fall.

EC follows nitrate values very closely. Sulphate follows the same general trend, but not as closely; in particular, the summer "fork" is not evident; pH appears less regular, but a closer look, and consideration of measurement uncertainties, suggests an essentially stable value, broken by sudden, short-term, drops, typically in summer.

If these seasonal trends are clear, use of simple, strictly chronological, detrending tools is barred by small irregularities in actual dates, so that "early summer" varies from late June to late July, "late summer" from mid-August to early October, and so on. Logically, it is the actual climatic sequence for each individual year that determines the exact position of peaks and valleys. A climatically-based detrending tool is expected within the next few years, when a somewhat larger base of data will become available.

The large measure of agreement between these parameters, as summarized in Figure 2, prompted a regression analysis for the main parameter pairs. Such analysis evidenced how both nitrate and sulphate are significantly correlated with EC, while pH definitely is not (Figure 3).

This suggests EC as a potential scale for detrending of both nitrate and sulphate values. Such suggestion has a physical base; in summer conditions, reduced water flux may obviously be responsible for increased concentrations of analytes. However, such a concept model would imply the assumption that nitrate flux from solid phase to solution is essentially constant, what is definitely unlikely. As rate of litter decomposition should vary greatly, on a seasonal basis, under

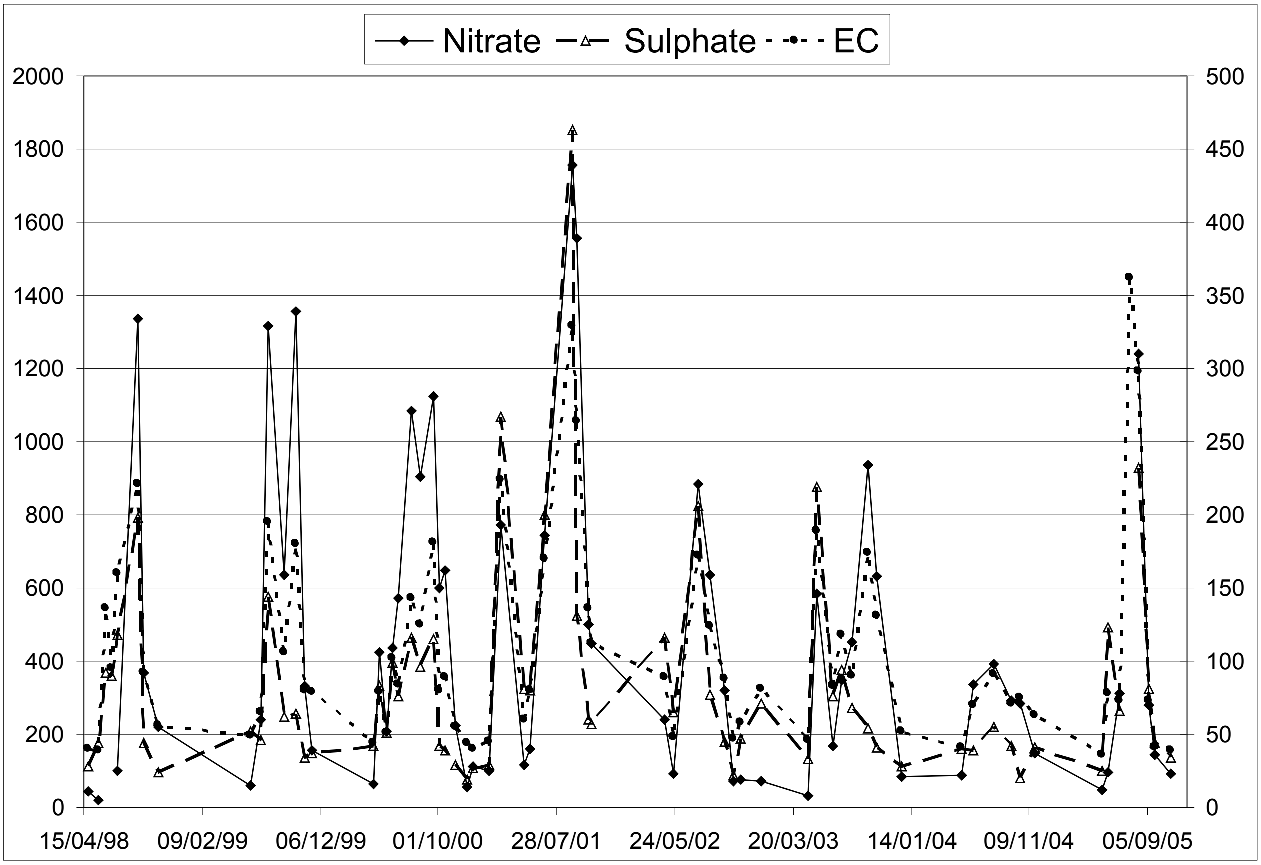


Figure 2 - Joint time series of Nitrate, Sulphate *in* $\mu mol_c L^{-1}$ *(left axis)* and EC *in* $\mu S \cdot cm^{-1}$ *(right axis).*
Serie temporali di Nitrato, Solfato e Conducibilità Elettrica (EC); Nitrato e Solfato in $\mu mol_c L^{-1}$ *(scala a sinistra); EC in* $\mu S \cdot cm^{-1}$ *(scala a destra).*

the influence of temperature and moisture, summer peaks are clearly enhanced by faster mineralization under warmer temperature. However, mineralization rate should undergo a slow change, and cannot explain the strong high-frequency component that is evident in most raw analyte time series. To produce this kind of temporal variation, it is more or less necessary to call into play some specific process of forest floor solution mobilization, depending on water flow.

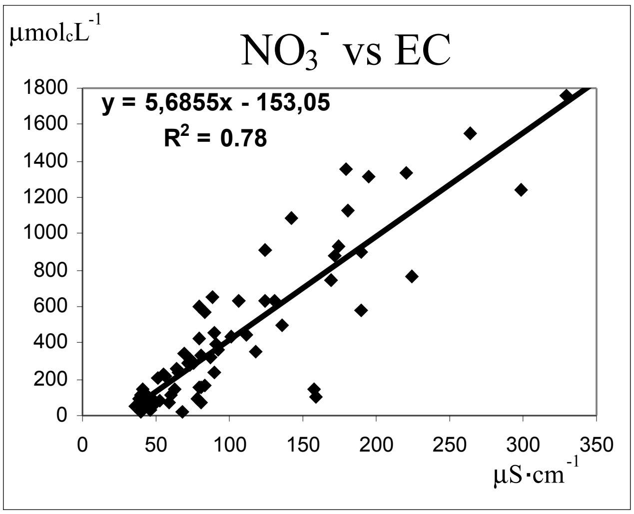
A second set of interactions to be considered concerns the secondary effects of high nitrate concentrations on other solution parameters. Total ion strength of soil solutions is upper bound by the availability of conjugate bases (Ugolini and Sletten 1991). Nitrate is the most important conjugate base in these solutions, then its concentration could be a major factor in controlling release of cations. The causal relation between nitrate and EC should then work both ways, and detrending according to EC is too severe.

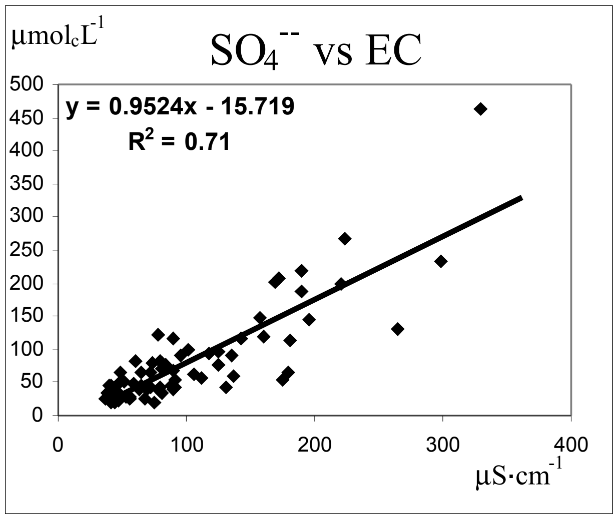
From this initial evaluation of the complexity of the interactions involved, we conclude that more complex and truly efficient detrending algorithms need to be developed, based on broader bases of data and that, for the time being, it is sensible to interpret together a "raw" time series of nitrate and sulphate concentrations and a "detrended" one, obtained by calculating the difference between measured concentrations and those estimated by the regression equation on EC. Compared, raw and detrended, time series for nitrate and sulphate are shown in Figure 4.

It appears very clearly that detrending by EC does not completely suppress seasonal trends; this is a good result, implying that the method is not physically absurd. We can infer, from this results, that the seasonal trends evident in "raw" data, and consistent with process knowledge, are also strong enough to survive an excessively severe detrending treatment. They can then be considered as a safe base for further understanding.

A divergence of possible interpretations yet arises concerning prospective long-term trends. Raw data suggest a multi-year trend of nitrate decrease that, however, could well be a sampling artefact. The presence of very high peaks in both 1999-2001 and 2005 would suggest that high nitrate release can be a reaction to the disturbance caused by inserting the samplers. The early peak would have been followed by progressive normalization in 2002-2003 and the return to high nitrate output been caused by the new samplers. When looking at the detrended data, however, we observe that the values in both 1997-1998 and 2005 could be not so different from 2002-2004, true nitrate peaks being those of 1999-2001. Further argument for a physical long-term trend comes from the observation that, while the first "disturbance peak" would have showed up with a significant delay after installation, the 2005 one would have been quite immediate, suggesting that the same physical processes are not at work in the two cases. Decreasing nitrate release from the forest floor could then be a robust long-term trend, following a 1999-2001 peak. Linked to this could be another apparent trend, a slow rising pH of the forest floor solution (fig. 1). These ambiguities will anyway be resolved in the next few years of observations. These should also build up a long enough pH time series, as the present one is too small with respect to the skewed and high-kurtosis distribution of the values, limiting usable statistical techniques.

Comparison of detrended data shows that covariance between nitrate and sulphate is only broad and does not hold at this level of detail; this is a further support for the hypothesis that a major sulphate input is not from organic matter mineralization, but rather from atmospheric pollution and/or dust, as previously supposed (Cecchini *et al.* 2002).





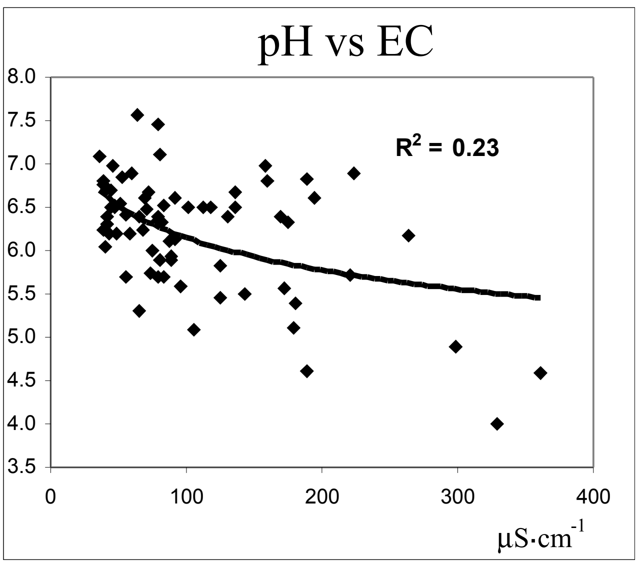


Figure 3 - Regressions of Nitrate, Sulphate and pH on EC.
Regressioni di Nitrato, Solfato e pH sulla EC.

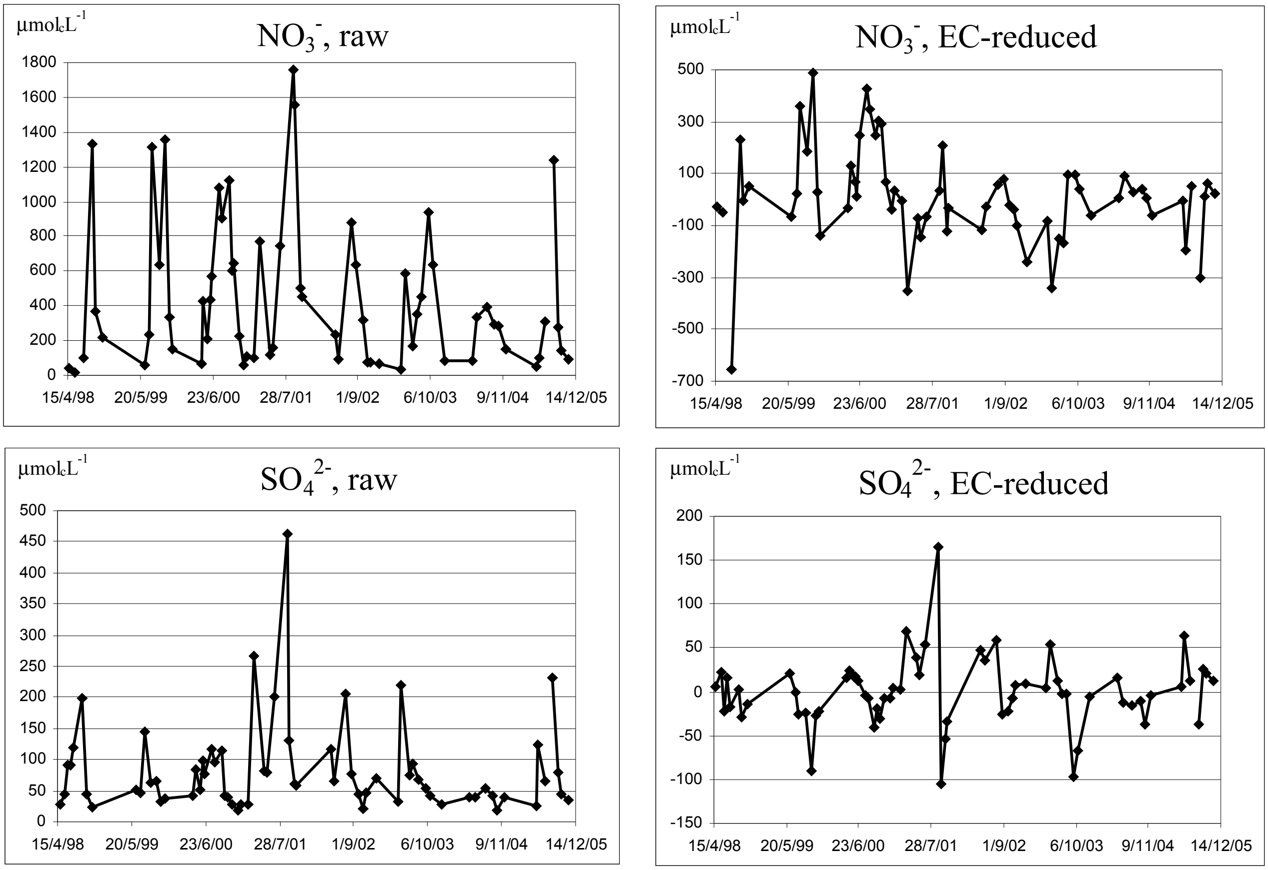


Figure 4 - Comparison of unprocessed and EC-reduced time series.
Confronto tra serie temporali grezze e ridotte in base a EC.

Conclusions

Soil solution monitoring requires a long-term effort to build up a base of data large enough to overcome many serious limitations to statistical analysis. Nevertheless, the first eight years of monitoring in ABR1 station are revealing various significant knowledge. The basic elements of the interplay between processes that produce the most important solutes and those that otherwise control their movement are beginning to be revealed. The need of further data is clearly defined, and likely to be met within a few years.

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Status and changes in key meteorological variables at the CONECOFOR plots, 1996 - 2005

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Abstract – In this paper, variability of precipitation, temperatures and temperature stress indexes of permanent monitoring plots (PMPs) of Italian CONECOFOR network are analyzed. The study is carried out in 16 Open Field areas over the period 1996-2005. For four areas among these (BOL1, EMI1, VAL1, VEN1) longer time series are considered. An eventual trend in time series is analysed using the Mann-Kendall test, applied to annual and seasonal values, and using the additive stochastic model to separate the seasonal variation, despite the limited number of available data. Both methods do not show clear temperature or precipitation trends on long-term period. Changes in annual climatic parameters for different areas may be related to fluctuations on short-term period.

Key words: *trends, precipitation, temperature, time series.*

Riassunto – Stato e cambiamenti in variabili meteorologiche chiave nel periodo 1996-2005. Questo studio analizza le variazioni di alcuni parametri meteorologici (temperature, precipitazioni e indici di stress termico) per 16 aree permanenti della rete CONECOFOR per il periodo 1996-2005. Per 4 di queste aree (BOL1, EMI1, VAL1, VEN1) sono stati utilizzati dati antecedenti al periodo indicato. Nonostante la limitatezza dei dati disponibili, l'analisi del trend è stata effettuata tramite il test di Mann-Kendall, applicato a valori annuali e stagionali, sia mediante l'uso di un modello stocastico additivo che isoli le variazioni dovute alla stagionalità. Entrambi i metodi non mostrano trend su lungo periodo per le temperature o le precipitazioni. Cambiamenti in alcuni parametri climatici possono essere legati a fluttuazioni di breve periodo.

Parole chiave: *tendenze, precipitazioni, temperature, serie temporali.*

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Introduction

The monitoring of the climate attained a great importance and a public attention in discussions of a possible global warming in the last years. The available observational data indicate the existence of persistent trends in earth climate characteristics during the last century. The planet surface is about 0.6 °C warmer with respect to the beginning of the 20th century and the continental precipitation are 5 to 10 % higher (http://www.met-office.gov.uk/research/hadley-centre). Analysis of surface temperature recorded at meteorological stations shows unprecedented rate of temperature change during the past 25 years (Hansen *et al.* 1999; Folland 2001). The global warming in the European and in the Mediterranean area is stronger over the regions of Central and Eastern Europe and Asia Minor during the winter, and over the regions of Southern Europe and Northern Africa during the summer. The largest increase of annual mean surface precipitation decreases over Southern Europe and the Mediterranean area, whereas it shows a slight tendency to increase during summer (Buermann *et al.* 2003).

The present work focuses on analyzing the behaviour of the thermal variables (maximum, minimum and mean temperatures), the temperature stress indexes (winter index, summer index, late frost index, heat index), the precipitation and precipitation index in the growth season, at monthly or yearly scale for the period 1996-2005.

There are many questions of interest, particularly in connection with climate change, including whether there are any regularities in temperature fluctuations, whether there is evidence of a consistent rise in temperature going beyond natural fluctuations, or an evidence of seasonality in precipitation and a decline in it, whether extreme events occur, *etc.*

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In attempt to investigate this issue, classical statistical analysis and time series analysis such as autocorrelation and additive stochastic model based on monthly monitored data for precipitation and temperatures were used.

Methods

Data collection

In this study, meteorological data collected on 16 permanent monitoring plot (PMPs) are used during the period 1996-2005 (Table 1, Figure 1). We considered only data from Open Field stations, situated in proximity (generally no more than 2 km away) from the monitoring plot. The Open Field stations are in accordance to the World Meteorological Organisation Standards (WMO 1969).

The measured parameters considered in this work are: air temperature at 2 m (AT), the minimum air temperature (AT_{min}), the maximum air temperature (AT_{max}), precipitation at 1.5 m (PR). We also considered some calculated parameters: winter index (WI), number of days with temperatures below 0 °C (N_WI), summer index (SI), heat index (HI), late frost index (LFI), number of days with precipitation (N_PR), precipitation index during the growing season (GPRI). WI, SI, HI, LFI indexes are related to the temperature stress (Klap *et al.* 1997; Calleart *et al.* 1997; Amoriello and Costantini 2000); we used the periods reported in Table 2 to calculate these indexes.

To carry out a time series analysis with a larger number of years, we considered also data from another dataset of EMI1, coming from a meteorological station placed near the CONECOFOR plot. The excellent overlapping between the common data (1998-2001) of the two stations justified the use of this other dataset to supply lacking data before 1998.

Table 1 - Sampling period and completeness of data for the 16 PMPs.
Periodo di campionamento e completezza dei dati considerati per le 16 aree permanenti.

PMP	Sampling period	Completeness (%)
ABR1	1998-2005	92
CAL1	2000-2005	97
EMI1	1998-2005	100
EMI2	1999-2005	97
FRI2	1999-2005	98
LAZ1	1998-2005	98
LOM1	2004-2005	99
PIE1	2000-2005	100
TOS1	1996-2001	88
TRE1	2000-2005	97
VAL1	1994-2005	95
VEN1	1993-2005	98
LOM2	2002-2005	98
LOM3	2002-2005	85
TOS2	2001-2005	96
BOL1	1990-2005	94

Figure 1 - PMPs equipped with meteorological stations.
Aree permanenti dotate di centraline meteorologiche.

Quality of the data

At first, data availability was defined at each individual plot and sampling year. If possible, the lacking data, due to instrumentation malfunctioning or damages, had to be recovered through the same parameter at different heights, for instance, or through cross controls between all parameters, or through data from the station located in the plot, if present. Logical, climatological and temporal controls gave assurance of estimates goodness.

The completeness of time series, defined as the ratio between the actual and the expected number of records, was carried out for each plot (Ferretti *et al.* 1999). Low numbers indicate incomplete datasets. Only plots with more than 80 % of data have been considered.

Data had to be homogeneous for each plot. A time series is defined homogeneous if its variations are due only to climate or meteorological weather modifica-

Table 2 - Start of the growing and dormant season of tree species for the 16 areas, estimated by phenological observation.
Inizio della stagione di crescita e di dormienza delle specie arboree nelle 16 aree, stimate mediante osservazioni fenologiche.

PMP	Start of the growing season	Dormant season	Tree specie
ABR1		October 10	*Fagus sylvatica*
CAL1	March 16	October 16	*Fagus sylvatica*
EMI1	April 1	November 1	*Quercus petraea*
EMI2	April 20	October 10	*Fagus sylvatica*
FRI2	April 16	October 16	*Picea abies*
LAZ1	April 1	October 10	*Quercus cerris*
LOM1	April 16	October 1	*Picea abies*
PIE1	April 16	October 10	*Fagus sylvatica*
TOS1	April 16	October 16	*Quercus ilex*
TRE1	June 10	September 30	*Picea abies*
VAL1	May 1	October 16	*Picea abies*
VEN1	April 16	October 10	*Fagus sylvatica*
LOM2	April 16	October 1	*Picea abies*
LOM3	April 20	October 10	*Fagus sylvatica*
TOS2	April 1	October 10	*Quercus ilex*
BOL1	May 1	October 10	*Picea abies*

tions. Data have been rejected, if the consistency was not guaranteed, to the aim of reducing systematic errors during data analysis.

Statistical analysis

The non-parametric Mann-Kendall tests (Mann 1945; Kendall 1975) was used to detect whether a temporal trend exists in annual data (ATmax, ATmin, WI, N_WI, SI, LFI). This test is widely used in environmental science, because it is simple, robust and can cope with missing values and a restricted number of annual values. It has the following important advantages: missing data are allowed, no assumption of normality is required (the data do not need to conform to any particular distribution); it is resistant to outliers; it admits censored data (as only ranks are used).

The Mann-Kendall statistic for a time series (Z_k, k=1,2,...,n) of data is defined as

$$T = \sum_{j<i} \mathrm{sgn}(Z_i - Z_j) \quad [1]$$

where

$$\mathrm{sgn}(x) = \begin{cases} 1 & x > 0 \\ 0 \quad \text{if} & x = 0 \\ -1 & x < 0 \end{cases} \quad [2]$$

If no ties between the observations are present and no trend is present in the time series, the test statistic is asymptotically normal distributed with

$$E(T)=0 \quad \text{and} \quad Var(T)=n(n-1)(2n+5)/18 \quad [3]$$

Temporal trends in monthly data (AT, PR, N_PR, GPRI) are detected with the seasonal Mann-Kendall test, where each data set is adjusted for seasonality (Hirsch *et al.* 1982). This test has all the advantages of the Mann-Kendall test, offering higher power because it removes short-term variability caused by seasonality that would otherwise appear as background noise in a Mann-Kendall test for the whole time series. It is computed by first separating the data into ω subseries, every series representing a season

$$T_j = \sum_{k<l} \mathrm{sgn}(Z_{lj} - Z_{kj}) \quad [4]$$

where j=1,…, ω. T_j is the Mann-Kendall statistics for season j, which is summed over all seasons to obtain the seasonal statistics

$$S = \sum_{j=1}^{\omega} T_j \quad [5]$$

Significance threshold of $p<0.05$ is applied to trend tests.

The number of annual values can be less than 10. If it happens, the absolute value of T is compared directly to the theoretical distribution of T derived by Mann and Kendall (Gilbert 1987).

The temporal dependence structure of a univariate time series can be examined statistically through the autocorrelation function ACF (Box *et al.* 1994). The simple autocorrelation analyses quantifies the linear dependency of successive values over a time period. The definition of the correlogram C(k), which outlines the memory of the system, and the slope of the autocorrelation function r(k) are expressed as

$$r(k) = \frac{C(k)}{C(0)} \quad [6]$$

$$C(k) = \frac{1}{n} \sum_{t=1}^{n-k} (x_t - \overline{X})(x_{t+k} - \overline{X}) \quad [7]$$

where k is the time lag, n is the length of the time series, x is a single event, $\overline{X}$ is the mean of the events and m is the cutting point. The cutting point is usually determined based on the interval of the analysis. The ACF ranges from -1 to +1, with positive values indicating that a high value would tend to be followed by another high value at lag k. A 95 % confidence interval, around the zero r(k), can be determined using the method of Quenouille (1947), and is dependent upon both the number of data points in the time series, and the absolute value of the autocorrelation coefficient.

If the time series shows a strong interdependency and a long memory effect, the ACF decreases gently and shows a non-zero value over a long time lag. It could mean that a trend is present. If the time series is uncorrelated, the ACF decreases very quickly and reaches a zero value in a short time. If the time series is cyclic, the ACF is also cyclic and has the same cycle length.

The temporal dependence structure of a time series can help understanding if it displays a regular pattern of fluctuations repeated from year to year. This periodic pattern, called seasonality, is very often observed in most climatic elements. The natures of seasonal variations are analyzed in an additive model for temperatures and precipitation. The general model for structure decomposition method is:

$$Y_t = T_t + S_t + \varepsilon_t \qquad [8]$$

where T_t is the trend term, S_t the seasonal term and ε_t the random term. Once seasonal changes are separated from another time series components, it will be clear if a trend occurs.

Results and discussion

Quality of the data

Table 1 shows the sampling period and data completeness for each plot. Altogether almost 10% of the data were recovered for all plots. In particular, precipitation was recovered between cross controls with the amount of precipitation from atmospheric deposition survey.

Completeness of acquired data ranges between 85% (LOM3) and 100 % (EMI1, PIE1). Data from LOM1 for the period 1997-2003 and from TRE1 for the period 1998-1999 were rejected because of not completeness (< 80%) and not homogeneity or malfunctioning of the meteorological station and following replacement.

Climatological characteristics

During the observed period, three events happened in a more or less marked way throughout Italy:

- Cool and rainy summer 2002: in all PMPs the seasonal mean temperatures were lower than the means of the surveyed period, until – 8% at TRE1, whereas the precipitations were higher with a range between + 7% at FRI2 and + 160% at TOS2.
- Very hot and dry summer 2003: in all PMPs the summer mean temperatures were higher, with a range between +7% at CAL1 and + 24% at VAL1 and BOL1, whereas the precipitations were lower with a range between -8% at TRE1 and -62% at BOL1.
- Very cold winter 2004-2005: in all PMPs the winter mean temperatures were lower, with a range between -2% at PIE1 and -72% at EMI2.

Table 3 and Figure 4 show the high interannual and spatial variability for almost all PMPs, and give an idea of the above mentioned events.

Figure 2 shows the mean temperatures plotted against altitude. As expected, the altitude is the most important factor of temperature variation, but not the only one. In fact, FRI2 and EMI2 are at the same altitude but FRI2 has lower values because of its exposure. The mean temperatures range between 4.1°C of BOL1 and 16.0°C of TOS2. The maximum temperature was recorded at EMI1 during 2003 (38.1°C), while the minimum temperature was -27.5°C at VEN1 in 2005.

No dependence from altitude was registered for the precipitation (Figure 3). CAL1, PIE1 and VEN1 showed the highest amount of mean rainfall with 1859, 1846 and 1840 mm, respectively. TOS2 reached

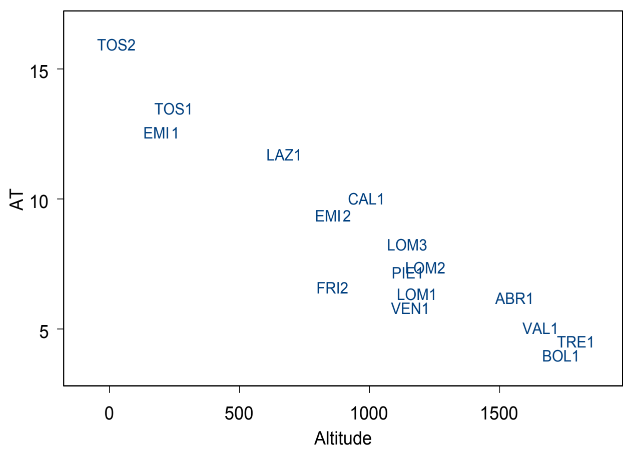

Figure 2 Air temperature against altitude for the 16 PMPs.
Temperatura dell'aria in funzione dell'altitudine per le 16 aree permanenti.

Table 3 - Simple statistics (mean, minimum, maximum and standard deviation) for the variables considered (air temperature AT, maximum air temperature ATmax, minimum air temperature ATmin, winter index WI, number of days with temperatures below 0 °C N_WI, summer index SI, heat index HI, late frost index LFI, precipitation PR, number of days with precipitation N_PR, precipitation index during the growing season GPRI) for all the PMPs.
Statistiche di base (media, minimo, massimo e deviazione standard) per le variabili oggetto di studio per tutte le aree permanenti.

PMP		AT (°C)	ATmax (°C)	ATmin (°C)	WI (°C)	N_WI	SI (°C)	HI (°C)	LFI (°C)	PR (mm)	N_PR	GPRI (mm)
ABR1	mean	6.3	26.6	-13.0	-248	73	1248			878	101	341
	min	5.2	23.1	-15.4	-393	52	1085	0.0	-12.4	728	88	233
	max	6.8	28.5	-10.4	-125	85	1544	0.0	-1.5	1145	124	533
	s. dev	0.5	1.7	1.8	91	15	141			145	11	110
CAL1	mean	10.1	31.7	-7.5	-29	19	1898			1859	123	780
	min	9.2	30.5	-8.9	-46	3	1797	0.0	-7.3	1541	99	404
	max	10.5	33.6	-4.2	-2	36	2039	0.0	-2.0	2449	140	1079
	s. dev	0.5	1.1	1.7	16	12	103			351	18	243
EMI1	mean	12.6	34.7	-6.2	-22	16	2802			843	79	531
	min	11.4	33.5	-9.1	-30	9	2592	0.0	-2.2	613	68	330
	max	13.4	38.1	-4.8	-13	20	3083	18.4	0.0	1028	90	684
	s. dev	0.6	1.5	1.3	7	4	141			156	8	115
EMI2	mean	9.4	31.9	-12.7	-112	39	1745			1448	104	494
	min	8.5	28.3	-15.9	-155	18	1078	0.0	-8.7	1022	87	302
	max	9.9	34.0	-10.5	-48	53	2091	0.0	-0.1	1879	120	795
	s. dev	0.5	1.9	2.3	33	11	317			356	12	167
FRI2	mean	6.7	30.8	-15.8	-339	85	1504			1704	115	1020
	min	6.0	29.0	-19.7	-437	50	1408	0.0	-10.9	1371	99	924
	max	7.3	33.1	-14.1	-194	106	1703	0.0	-2.1	2041	139	1183
	s. dev	0.5	1.3	2.0	73	18	101			249	14	82
LAZ1	mean	11.8	35.0	-7.8	-26	15	2287			970	89	437
	min	11.2	32.1	-10.1	-48	5	2130	0.0	-6.2	820	78	324
	max	12.4	37.5	-5.2	-4	21	2565	11.9	0.0	1181	103	551
	s. dev	0.4	2.0	1.6	16	7	129			141	11	79
LOM1	mean	6.4	29.0	-13.2	-270	88	1362			1126	101	628
	min	6.3	28.5	-14.8	-322	84	1305	0.0	-2.8	987	91	596
	max	6.5	29.5	-11.5	-218	91	1420	0.0	-2.3	1264	110	659
	s. dev	0.1	0.7	2.3	73	5	81			196	13	45
PIE1	mean	7.2	25.7	-11.3	-169	55	1383			1846	107	1147
	min	6.5	23.7	-14.4	-255	41	1264	0.0	-8.0	1229	93	610
	max	7.8	28.2	-9.1	-90	72	1697	0.0	-1.8	3025	124	1857
	s. dev	0.5	1.9	1.9	67	13	160			754	12	488
TOS1	mean	13.6	34.3	-3.8	-4	2	2523			853	73	348
	min	12.7	31.7	-6.0	-14	0	2355	0.0	-0.6	615	38	269
	max	14.0	35.8	-0.3	0	4	2590	1.2	0.0	1177	104	466
	s. dev	0.4	1.6	2.1	5	2	89			249	23	73
TRE1	mean	4.6	27.9	-17.0	-367	93	811			1027	103	411
	min	3.7	22.2	-20.4	-502	78	597	0.0	-4.2	827	80	302
	max	5.4	30.7	-11.7	-278	114	1020	0.0	0.0	1297	127	579
	s. dev	0.6	3.2	2.9	91	13	157			199	18	112
VAL1	mean	5.1	26.3	-15.4	-337	89	1070			816	97	470
	min	4.1	24.3	-18.7	-440	69	977	0.0	-7.2	526	69	298
	max	5.7	28.6	-12.4	-218	113	1384	0.0	-1.5	1075	125	674
	s. dev	0.5	1.5	1.9	74	13	112			195	17	129
VEN1	mean	5.9	26.6	-20.0	-368	87	1292			1840	112	1045
	min	4.9	24.1	-27.5	-573	57	1139	0.0	-14.2	1291	71	705
	max	6.8	30.4	-13.3	-207	110	1535	0.0	-0.7	2795	133	1442
	s. dev	0.6	1.5	3.3	109	17	102			356	16	257
LOM2	mean	7.4	29.3	-11.0	-152	53	1465			1216	122	704
	min	6.9	28.1	-14.9	-202	39	1329	0.0	-7.9	1135	108	502
	max	8.1	31.9	-8.8	-117	62	1744	0.0	-0.3	1368	138	821
	s. dev	0.6	1.8	2.8	45	13	189			131	15	139
LOM3	mean	8.3	29.2	-9.9	-124	44	1653			1356	99	660
	min	7.4	27.8	-13.5	-189	32	1534	0.0	-8.7	1173	90	448
	max	9.2	30.8	-7.9	-67	53	1903	0.0	-0.5	1690	118	778
	s. dev	0.7	1.2	2.6	50	11	170			290	16	184
TOS2	mean	16.0	32.9	-1.4	0	0	2854			651	65	262
	min	15.1	31.3	-2.4	-1	0	2579	0.0	-0.8	496	55	159
	max	16.9	35.9	-0.4	0	1	3264	2.3	0.0	871	79	453
	s. dev	0.7	1.8	0.7	0	1	263			140	10	128
BOL1	mean	4.1	21.8	-15.2	-396	96	871			899	90	478
	min	2.6	19.8	-18.2	-526	83	783	0.0	-7.2	529	64	266
	max	4.9	24.6	-12.3	-310	110	1153	0.0	-0.9	1116	112	663
	s. dev	0.7	1.6	2.1	87	10	127			168	16	123

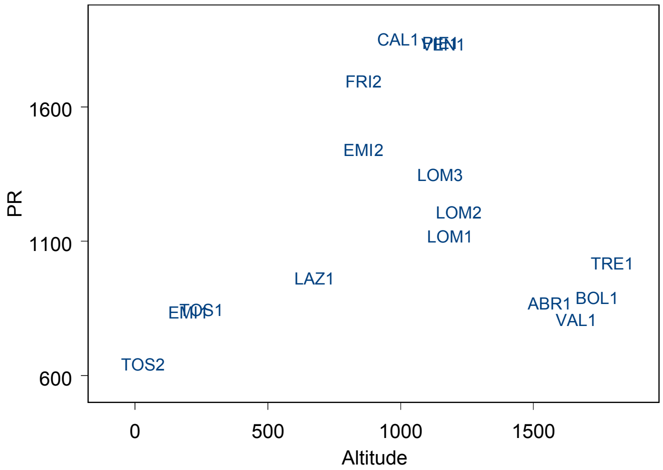

Figure 3 - Precipitation against altitude for the16 PMPs.
Precipitazioni in funzione dell'altitudine per le 16 aree permanenti.

the minimum value of 651 mm. The box plot of PR (Figure 4) showed a high interannual variability inside the same plot. The 2004 was the rainiest year while the 2003 the driest one.

The number of rainy days is rather constant at all PMPs and follows the trend of precipitation. The extreme events (PR > 100 mm/day) were recordered as follows:

- 1 in 2003 at ABR1;
- 2 in 1999 1 in 2000, 1 in 2001, 2 in 2003, 1 in 2004 at CAL1;
- 1 in 2000, 1 in 2003 at EMI2;
- 2 in 2000, 1 in 2002, 2 in 2003, 1 in 2004 at FRI2;
- 6 in 2000, 8 in 2002, 1 in 2003, 1 in 2004 at PIE1;
- 2 in 2000 at VAL1;
- 2 in 1996, 2 in 1997, 2 in 1998, 2 in 1999, 4 in 2000, 1 in 2001, 5 in 2002, 3 in 2004 at VEN1;
- 1 in 2003, 1 in 2004 at LOM3.

The spatial variation in temperature stress indexes, calculated for 16 plots, is given in Table 3 and is well represented through the box plots in Figure 4.

Winter index WI is an indication of severeness of

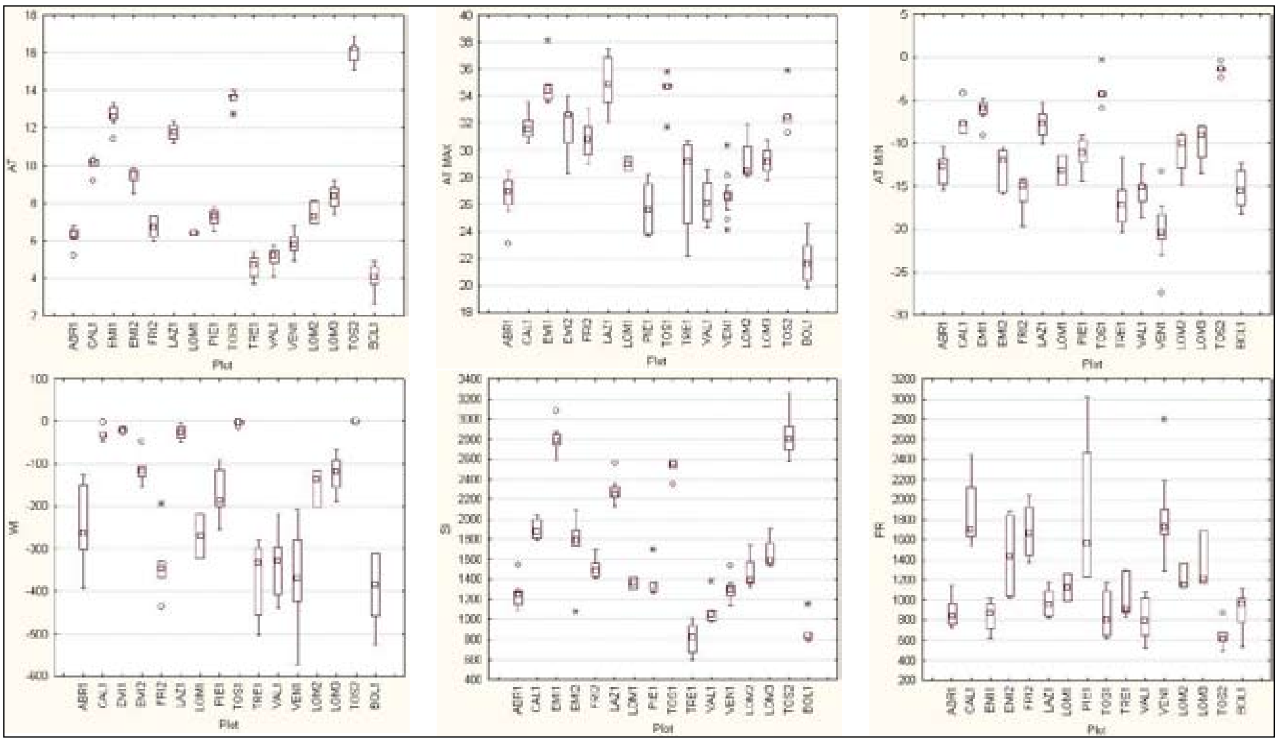

Figure 4 - Box plots of a few surveyed variables (air temperature AT, maximum air temperature AT_{max}, minimum air temperature AT_{min}, winter index WI, summer index SI, precipitation PR).
Box plot di alcuni parametri oggetto di studio.

the winter. The mean values range between -396°C at BOL1 and 0°C at TOS1. Low temperatures, below 0°C, were recordered in all plots of Northern Italy, especially at BOL1, TRE1 e VEN1. The mean number of days with temperatures below 0°C (N_WI) was very high: it exceeded 50% of dormant season days in many Alpine areas. The minimum value was detected at VEN1 with -573°C in winter 1999-2000. Generally the plots located at a low altitude, like TOS1, TOS2 and EMI1, did not suffer winter freezing nor tree damages.

Late frost index LFI is an indication of frost severeness in spring, when growth has just started. The values range from 0°C to -14.2°C at VEN1. In spite of the rather low minimum temperatures reached, no phenological evidence indicated a non tolerance of the trees to this stress.

Summer index SI is an indication of the quality of the growing season. The mean values varied from 811°C at TRE1 to 2854°C at TOS2. The minimum value was 597°C at TRE1 in 1997 and the maximum value was 3264°C at TOS2 in 2003.

Heat index HI is an indication of the possible occurrence of damage by high temperatures. Only TOS1, TOS2, EMI1 and LAZ1 plots reached values above 35°C. In particular, the maximum value of HI (18.4°C) was reached at EMI1 in summer 2003, in confirmation of an exceptionally hot summer.

Variability and trends analysis

To determine whether there is a linear trend in annual data sequences from 16 areas, the Mann-Kendall test at 5 % significance level was applied to AT_{max}, AT_{min}, WI, N_WI, SI, LFI, GPRI datasets without gaps.

The results are given in Table 4. No trends were found for almost all parameters and plots, with some exceptions. A positive significant trend was found for AT_{max} at BOL1 and TOS1, with a correspondent positive trend for SI at TOS1, and a negative trend for AT_{min} at VEN1. PIE1 exhibited a significant negative trend for WI and a positive trend for N_WI; it means that a decrease in the sum of temperatures below 0°C and an increase in the number of days reaching these temperatures occurred. Besides, a negative trend of GPRI was found at TRE1: the annual amount of precipitation was constant but the rainfall during the growing season decreased.

Trends in monthly data of AT, PR and N_PR were tested through the seasonal Mann-Kendall test at 5% significance level. CAL1 showed a negative trend for AT and a positive trend for PR and N_PR.

At last, the number of rainy days of FRI2 significantly decreased.

The autocorrelation functions of monthly temperatures (Figure 5) for the 4 plots having a sufficient number of data to compute this analysis (BOL1 1990-2005, EMI1 1977-2005, VAL1 1995-2005, VEN1 1993-2005) showed a sinusoidal pattern implying, as expected, that a high short-term autocorrelation was present due to a seasonal factor.

The autocorrelation function of monthly precipitation (Figure 6) showed the same sinusoidal behaviour of temperatures, even if strongly marked for BOL1 in

Table 4 - Results of the Mann-Kendall test for 10 parameters (ns: trend not significant; ↑ and ↓ downward and upward trends, respectively, at 95% confidence level).
Risultati del test di Mann-Kendall per 10 parametri (ns: trend non significativo; ↑ and ↓ trend positivo e negativo, rispettivamente, a 95% livello di confidenza).

PMP	AT	AT_{max}	AT_{min}	WI	N_WI	SI	LFI	PR	N_PR	GPRI
ABR1	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
CAL1	*↓	ns	ns	ns	ns	ns	ns	* ↑	*↑	ns
EMI1 (98-05)	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
EMI1 (77-05)	ns	-	-	-	-	-	-	ns	ns	-
EMI2	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
FRI2	ns	ns	ns	ns	ns	ns	ns	ns	*↓	ns
LAZ1	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
LOM1	-	-	-	-	-	-	-	-	-	-
PIE1	ns	ns	ns	*↓	* ↑	ns	ns	ns	ns	ns
TOS1	* ↑	* ↑	ns	ns	ns	* ↑	ns	ns	ns	ns
TRE1	ns	ns	ns	ns	ns	ns	ns	ns	ns	* ↓
VAL1	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
VEN1	ns	ns	* ↓	ns	ns	ns	ns	ns	ns	ns
LOM2	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
LOM3	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
TOS2	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
BOL1 (99-05)	ns	* ↑	ns	ns	ns	ns	ns	ns	ns	ns
BOL1 (90-05)	ns	-	-	-	-	-	-	ns	-	-

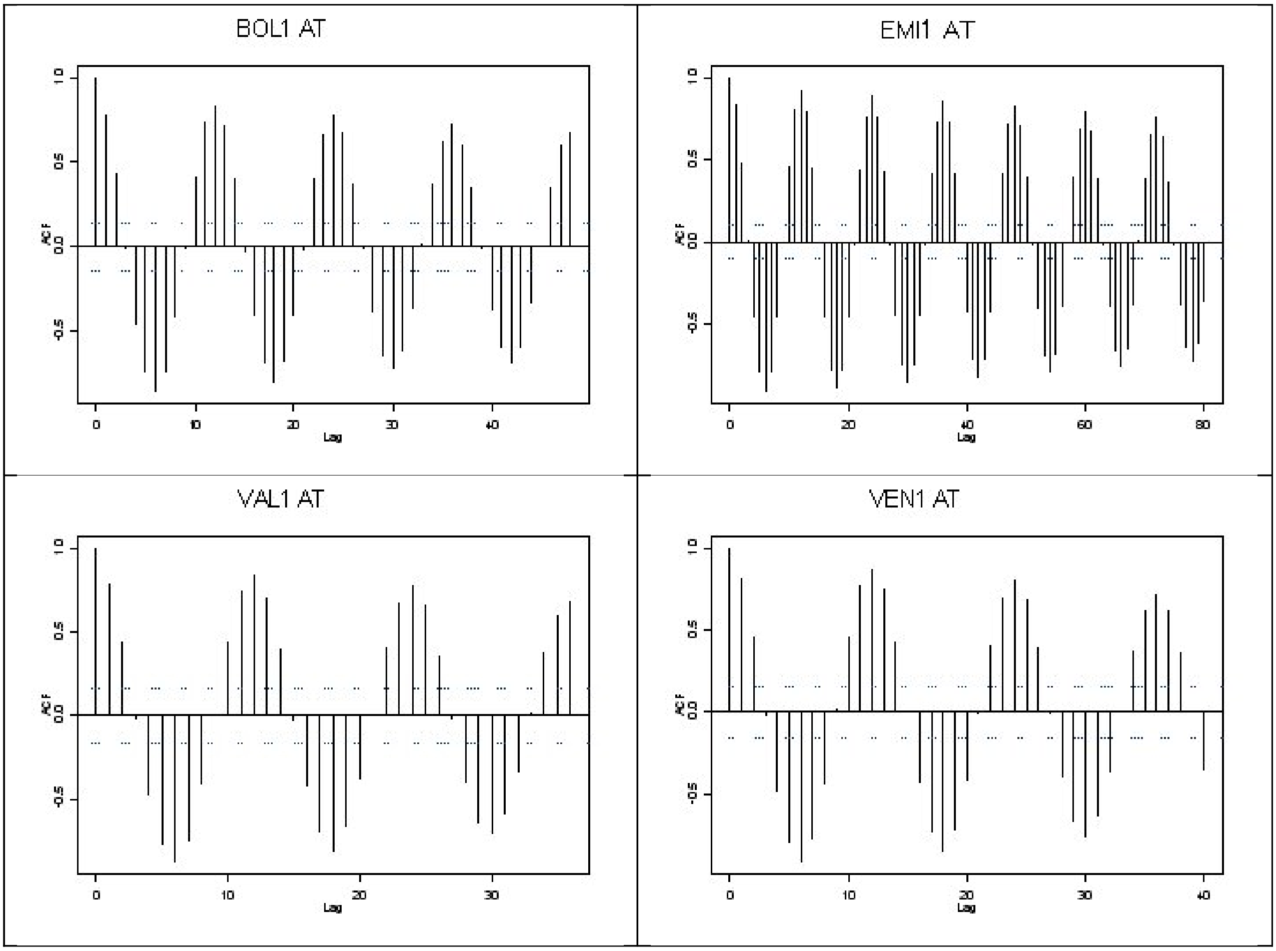

Figure 5 - Air temperature autocorrelation function.
Funzione di autocorrelazione della temperatura dell'aria.

comparison with EMI1 and VEN1. The ACF of VAL quickly reached a null value (clearly a white noise) and it means no seasonal component.

For these data sequences, the cyclic seasonal component was removed to isolate the trend term. The seasonalized and smoothed trends of temperatures and precipitation for the 4 plots are given in Figure 7 and 8, respectively. Although the eye tends to impute negative trends to precipitation of BOL1 and VAL1, no linear trends are present. The outliers play an important role on trend and they could introduce a bias due to the too small datasets. For instance, the positive trend to temperatures of EMI1 was caused by the exceptionally hot summer 1993. This analysis confirms the result obtained with the Mann-Kendall test.

Conclusions

Although ten years of data are not sufficient to point out any possible climatic trends in Italy, the analysis was useful to a first evaluation of the high interannual and spatial variability at almost all PMPs. This evaluation integrates the results from the other CONECOFOR surveys.

The Mann-Kendall test was used to investigate trends in temperature, precipitation and temperature stress indexes, both annually and monthly. A significant increase was observed in precipitation and in the number of rainy days only for CAL1, with a correspondent decreasing in temperature. A temperature increase happened for TOS1, due especially to the increase of summer temperature (SI) and linked to an increase of maximum temperature. A decrease of winter temperature was measured only at PIE1, as showed by WI and N_WI; it is interesting that this phenomenon is not joined to a corresponding decrease of mean temperature, which on the contrary showed an increase, even if not significant. All these trends could be influenced by the reduced number of available data and short- term fluctuations. On a longer period, no trends in temperatures or precipitation were found for EMI1 (1977-2005) and BOL1 (1990-2005).

Time series analysis for EMI1, BOL1, VAL1, and VEN1 also provided the same results of the Mann-Kendall test. From the autocorrelation, temperatures and, to a lesser extent, precipitation showed a strong dependence from seasonal periodicity. The deseasonalised time series showed no trends in temperatures or precipitation for the 4 PMPs with long datasets.

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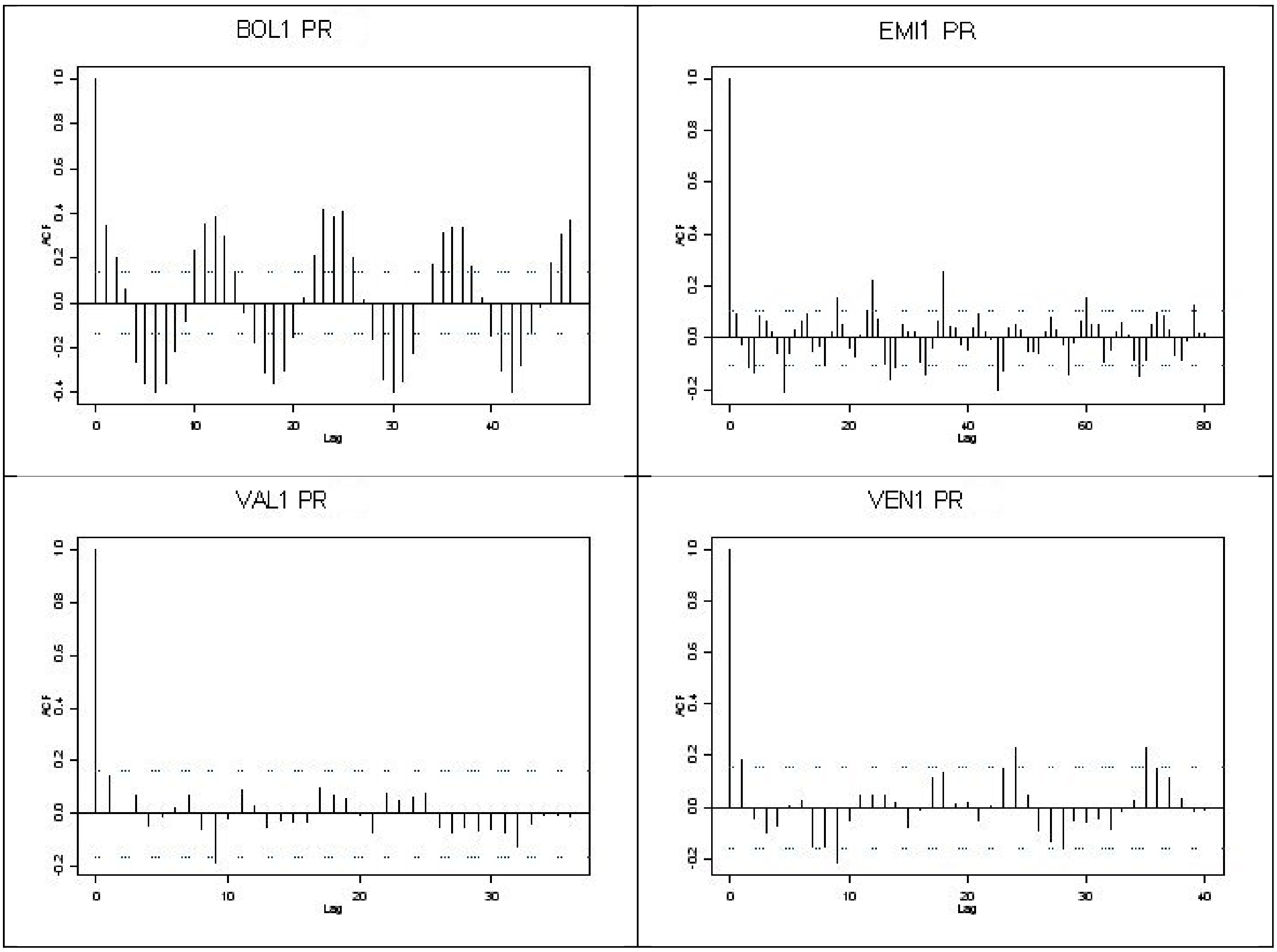

Figure 6 - Precipitation autocorrelation function.
Funzione di autocorrelazione delle precipitazioni.

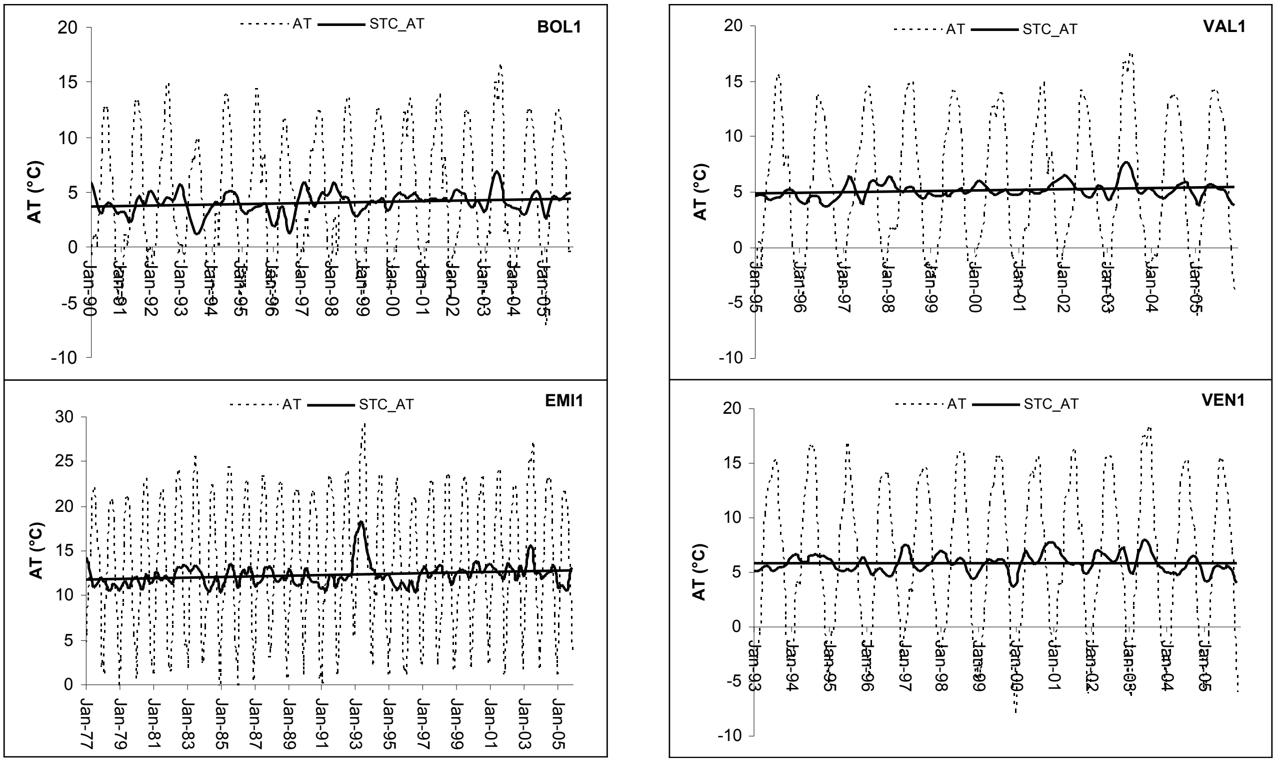

Figure 7 - Monthly mean air temperature AT (dotted line), deseasonalised and smoothed monthly mean air temperature STC_AT (undotted line) and trend at 4 PMPs.
Temperatura media mensile dell'aria AT (linea tratteggiata), temperatura mensile media dell'aria destagionalizzata e lisciata STC_AT (linea continua) e trend per 4 aree permanenti.

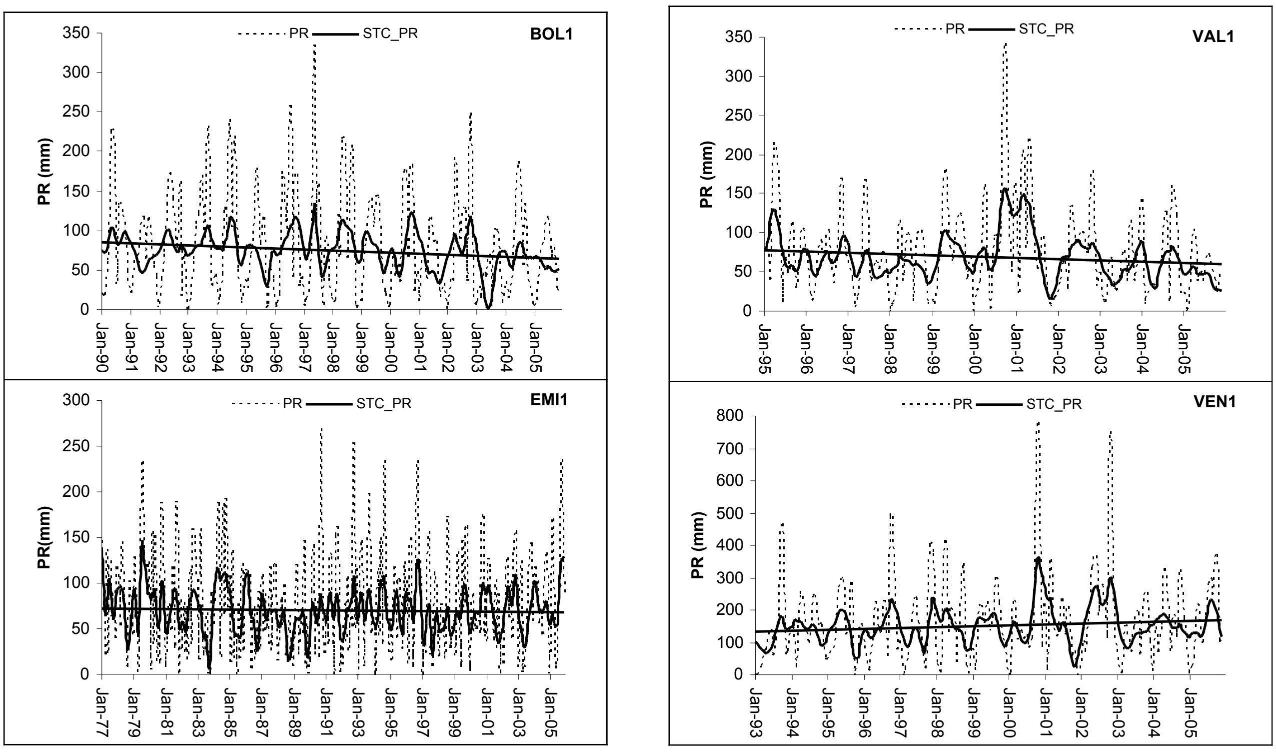

Figure 8 - Monthly precipitation PR (dotted line), deseasonalised and smoothed monthly precipitation STC_PR (undotted line) and trend at 4 PMPs.
Precipitazioni mensili PR (linea tratteggiata), precipitazioni destagionalizzate STC_PR (linea continua) e trend per 4 aree permanenti.

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Status and trend of ground-level ozone at the CONECOFOR plots, 1996 - 2005

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Abstract – Ozone measurements are performed since 1996 at the Permanent Monitoring Plots (PMPs) of the National Integrated Programme for Forest Ecosystem Monitoring (CONECOFOR). Weekly ozone concentrations are determined by passive samplers during spring and summer months, over a time period of 10 yrs. We analyzed data collected over a time period of ten years. Ozone shows potentially phytotoxic concentrations especially at the plots located in the central and Southern regions. Although monitoring periods at the different plots are not homogeneous, statistically significant differences between yearly concentrations of subsequent years were observed, highlighting a considerable temporal variability of ozone pollution levels. Trend analysis performed on ten years data series points out an increase of ozone concentrations over the considered time period at seven plots, all located in central and Southern Italy. The same analysis performed on data collected during the vegetative period (April - September) at the different PMPs from 2001 to 2005 shows significant positive trends at 5 plots, three of them located in the Alpine region, and 2 in Southern Italy.

Key words: *Ozone, passive sampler, long-term monitoring, temporal trends.*

Riassunto – Stato e tendenza dell'ozono troposferico nelle aree CONECOFOR nel periodo 1996 - 2005. Dal 1996 vengono effettuate misurazioni di ozono presso le aree permanenti del programma nazionale integrato di monitoraggio delle foreste (CONECOFOR). Le concentrazioni medie settimanali sono misurate mediante dosimetri passivi durante i mesi primaverili ed estivi. L'ozono mostra concentrazioni potenzialmente fitotossiche, specialmente nelle aree del centro e sud Italia. Sebbene i periodi di misura siano diversi tra le aree, ci sono differenze statisticamente significative tra i diversi anni che evidenziano notevoli variazioni temporali. Le tendenze temporali su 10 anni hanno mostrato un aumento delle concentrazioni medie da Giugno a Settembre in sette aree al centro e sud Italia. Nel periodo 2000-2005, un'aumento significativo è stato evidenziato in cinque aree, di cui tre localizzate nella Regione alpina e due nel sud Italia.

Parole chiave: *ozono, campionatori passivi, monitoraggio a lungo termine, tendenze temporali.*

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Introduction

Ozone (O_3) in the lower troposphere forms through a photochemical reaction between different compounds generally divided into two groups, namely nitrogen oxides (NO_x=NO+NO_2), mostly emitted by human activities, and volatile organic components (VOC) of human and biogenic origin. High O_3 concentrations during the vegetative period can cause negative impacts on vegetation, resulting in yield losses in agriculture and damage to forest species (Fuhrer *et al.* 1997).

Tropospheric O_3 was first measured in ambient air in the second half of the XIX[th] century. At Moncalieri, Italy, O_3 levels were measured on a daily basis by the Schönbein technique (a colorimetric method) for twenty years showing an average concentration of 10 ppb (Anfossi *et al.* 1991). Similar studies were carried out in Paris, France, from 1876 to 1910 with comparable results (Volz and Kley 1988). Between 1899 and 1900 measurements were performed in Zagreb (Croatia) during day and night time and in this area higher mean concentrations (30 ppb) than in France are reported by Lisac and Grubisic (1991). Measurements at high elevation (Pic du Midi, France, 3000 m a.s.l.) showed, at the end of the last century, mean concentrations of about 10 ppb (Marenco *et al.* 1994). Although there are some uncertainties about the Schönbein technique and on possible interferences (Pavelin *et al.* 1999), the reported figures highlight a relevant increase of O_3 concentrations in the past century. Analysis of historical O_3 records indicated

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that tropospheric O_3 levels, in both hemispheres, have increased by a factor of 3-4 during that time (Sandroni *et al.* 1992; Sandroni and Anfossi 1994).

More recently tropospheric O_3 was found to increase in the northern hemisphere. Mean O_3 concentrations raised, for example, by a factor of two between the end of the 50's and 1990 at the Swiss site Arosa (Staehelin *et al.* 1998). Although reliable surface O_3 measurements are available since the late 1980's at a number of sites, studies on O_3 trends are complex due to large inter-annual variations in O_3 levels related to the influence of meteorological conditions, making it difficult to identify significant trends (Jonson *et al.* 2005).

Roemer (2001) reports that the average O_3 concentrations in Finland over the period 1989 – 2001 are stable or slightly increasing. In UK gradual increase in background O_3 values are reported, even if the pollutant's precursors emissions (NO_x and VOC) have been reduced successfully over the past 10 years (Monks *et al.* 2003). Also Coyle *et al.* (2000) showed an overall picture of an increasing background concentration in the UK and decreasing concentrations during photochemical episodes, although only a few of the considered sites had statistically significant temporal trends. According to the UK National Expert Group on Transboundary Air Pollution (NEGTAP, 2001), there is an evidence that the mean ground-level concentration over the UK is increasing and is expected to continue over the coming decades, despite the peak concentrations decreased by about 30% since the 1980's. Some rural Belgium and German EMEP sites showed a concentrations increase over the period 1990-2002, whereas measurements at the same network sites in the Netherlands displayed opposite trends (Derwent 2006). Results from more than 300 German O_3 sites between 1990 and 2000 including urban locations, showed a pronounced downward trend of the higher percentiles while upward trend was indicated for low and medium percentiles (Beilke and Wallasch 2000). Sicard *et al.* (2006) investigated O_3 background concentrations in France from 1995 to 2003, reporting increasing trends for annual, winter and autumn concentrations. Other overviews of reported trends are given in Derwent *et al.* (2003) and TOR-2 (2003).

Since the late 1980's the emissions of O_3 precursors, NO_x, CO and VOC, were substantially reduced in most parts of Europe (Vestreng *et al.* 2004) as a result of international agreements (*e.g.* CLRTAP Convention) and of a stricter EU legislation about national measures. The emission reduction resulted in a corresponding decrease of the O_3 precursor species concentrations (Derwent *et al.* 2003). The expected effects are that O3 levels in the summer months would consequently reduced and O_3 thresholds, for the human health and environment protection, would be less frequently violated. At many monitoring sites, however, O_3 ambient concentrations increased during all seasons, but particularly in winter and spring. At mountain tops (1000–3000 m) in Europe this pollutant levels continuously raised since the first measurements were made in 1870 and are still increasing (Marenco *et al.* 1994; Jonson *et al.* 2005; Scheel *et al.* 2002). A comprehensive evaluation of long-term measurements over Europe is provided by the European Environmental Agency (Beck *et al.* 1998).

Scarce information is available for South European countries. Actually, trend analysis of O_3 measurements are mainly restricted to Northern and Western parts of Europe where routine measurement of O_3 first started, yielding time series long enough for this kind of analysis. In Italy a limited number of background and rural monitoring stations are available, few of them in Central and Southern regions. Additional information is provided for forest areas by the Italian Intensive Forest Monitoring Programme (CONECOFOR) co-ordinated by the Italian National Forest Service (Petriccione and Pompei 2002).

The CONECOFOR Programme covers at the moment (2006) 31 Permanent Monitoring Plots (PMP) located at forest sites. At each plot O_3 concentrations are measured from April to September by passive samplers. These devices are particular suited for measurements at remote sites as they can be easily handled, transported and are not dependent from electric supply. The low time resolution of data, however, greatly limits their use to analyse O_3 trends.

Data recording began in 1996 and 5 to 10 years data series are available for most of the plots. This paper gives a general description of the research activities carried out in this time period to assess O_3 concentration levels, and reports the calculated trend of O_3 concentrations over the same period.

Materials and methods

Measurement devices

Weekly O_3 concentrations were measured at the

Permanent Monitoring Plots (PMPs) of the Italian intensive forest monitoring programme (CONECOFOR) by means of passive (diffusion) samplers. From 1996 to 2000 passive samplers, developed by the Institute for Bioclimatology and Environmental Research of the University of Munich, were used to measure O_3 concentrations (Method 1). The sampling founds on the principle of gas molecules passive diffusion to an absorbing medium, in this case indigo blue dye. Cellulose filters coated with indigo blue were placed in 70 cm tubes which represent the diffusion path. The indigo molecule contains 1 carbon double bond (C = C) that reacts with O_3 and results in nearly colourless reaction products. The determinations were done by spectrophotometry, at 250 and 600 nm. A detailed description of these samplers and the related analytical procedure are reported in Werner (1991 and 1992), and Werner *et al.* (1999).

Since 2001 passive samplers were provided by the Swiss company Passam AG (Method 2). As recommended, the exposition period was set to 7 days. The tubes were protected from sunlight, rain and wind disturbances by an opaque cylindrical shelter. The passive samplers consist of 4.9 cm long calibrated tubes with an inside diameter of 0.9 cm, inside which air diffuses by molecular diffusion. The chemical compound, which reacts with O_3 is 1,2-di (4-pyridyl) ethylene (DPE) solution, deposited in the sampler on a fibreglass filter supported by a grid. The other end is left open to permit air diffusion. Addition of MBTH reactant produces a coloured complex, which is measured in a spectrophotometer at 442 nm. The reaction is specific to O_3, although interferences due to the presence of other oxidants may occur. The diffusion coefficient for O_3 is unknown and the reaction of O_3 with DPE is not stoichiometric. The samplers were therefore calibrated by the manufacturer on the basis of long term parallel measurements with co-located O_3 automatic analyser.

The two methods were subjected to parallel measurements in previous studies (Hangartner *et al.* 1996; Werner *et al.* 1999). The samplers adopted since 2001 were tested for precision and accuracy (Bernard *et al.* 1999). Recent tests (Gerboles *et al.* 2006) have shown that these samplers (Method 2) are in good agreement with the reference methods of the European Directive (EEC, 2002) and fulfil the 30% accuracy requirement for O_3 monitoring. Accuracy was checked also during this study by comparing passive samplers measurements with co-located O_3 continuous analyser (Buffoni and Tita 2003). Regression analysis and two samples comparison tests were applied to the different datasets. Results of additional parallel measurements carried out at the EMEP monitoring stations located at the JRC (Ispra Italy) in 2004 and 2005 show a good agreement but display a rather constant overestimate (Table 1), although within the mentioned accuracy requirements.

Table 1 - Results of the regression analysis performed on passive sampler data and a co-located continuous analyser (JRC, Ispra).
Risultati dell'analisi di regressione svolta sui dati del campionatore passivo e di un analizzatore automatico situati nel medesimo sito (JRC, Ispra).

	n	R^2	Slope	Intercept (ppb)
2004	24	0.74	0.85	8.44
2005	25	0.75	0.92	10.18

Measurement periods and location

O_3 measurements started as an experimental activity which covered only a part the vegetative period (June-September) until 2000. Since 2001 O_3 monitoring became a more regular activity, parallel to the mandatory studies requested by the EU Regulation 1091/94. Thus, from 2001 to 2005 sampling activity has a duration of 26 weeks, from the beginning of April until the end of September, each year.

The geographical location of PMPs and a detailed description of their characteristics are given in Allavena *et al.* (2000). O_3 measurements were first performed at 20 PMPs (1996 - 2000). Following the establishment of new PMPs the number of O_3 measurement sites grew consequently to 31 in 2005 (Table 2). O_3 measurements were performed generally close to the forest plots at 2-3 m from the ground and within a maximum distance of 1.5 km from PMPs. A number of requirements, fulfilled by most of the PMPs, were set for O_3 measurements (Buffoni and Tita 2003). Air pollutant measurements have to be carried out at sites with free circulating air and without relevant obstacles which may influence ambient air characteristics. Measurement devices are generally placed in clearings near the forest plots (PMPs). A location close to the PMPs is preferred to perform investigations about ecosystem-atmosphere interactions but this is not always possible, especially for wide and closed forest stands without suitable clearings. Dif-

Table 2 - Periods covered by O3 measurements at the CONECOFORPMPs over the years 1996 – 2005.
Periodi coperti dalle misurazioni di O3 alle PMP di CONECOFOR dal 1996 al 2005.

Year	n. of PMPs	Begin	End	Weeks n.
1996	19	15/6	1/10	15
1997	20	17/6	7/10	16
1998	20	16/6	6/10	16
1999	20	18/5	5/10	20
2000	21	4/5	3/10	22
2001	25	3/4	2/10	26
2002	25	9/4	1/10	26
2003	26	1/4	30/9	26
2004	26	30/3	5/10	26
2005	31	5/4	4/10	26

ferences in exposition and elevation (positive and negative) between O_3 monitoring sites and the related PMPs are generally small. At few sites measurements are carried out above the tree canopies (LAZ2, TOS2, SIC1; TOS1 since 2005)

Morever, long-term studies should be performed at the same site avoiding changes in location or measurement height during the monitoring period. Unfortunately, for different reasons, some monitoring sites initially located close to the CONECOFOR plots have been moved during the 10 years considered. The main displacement took place at the PMP ABR1, where O_3 measurements were initially carried out close to the plot. Since 2001 instruments were moved to another more open and elevated location. In addition, the new measurement site presents stronger winds which may overpass the indicated threshold to avoid disturbances to the passive diffusion process, on which the O_3 measurements are based. Consequently, the two 5-year periods (1996-2000 and 2001-2005) are considered separately and the corresponding measurement sites are indicated as ABR1a and ABR1b. At the PMP CAL1 and CAM1 measurement sites moved from a non ideal position for O_3 monitoring to a new one. Finally, the samplers exposed at the PMP TOS1, previously placed at ground level at short distance from the plot, were lifted in 2005 above the canopies by means of an aluminium tower. At present, the effects of the mentioned changes cannot be fully evaluated.

Data quality

Several measures were taken to provide high quality data. Passive samplers were monthly sent to the local operators to keep the time period between the preparation and the analysis to a minimum. As O_3 diffusion tubes (Method 2) are known to degrade over time they were kept refrigerated before and after exposure and care was taken during transport from and to the laboratory (blanks were used to check the possible transport influence). Manuals with detailed instructions were provided to local operators.

While the 7-days exposition period, set in 1996, was maintained over time, the number of replications varied from 5 (1996) to 1 (1998-2000). Since 2001 two samplers were exposed in parallel every week according to the suggestions of UN-ECE/ICP Forests regarding monitoring of air quality (UN-ECE 2000).

Statistical methods

Comparison between years

As the majority of the annual data series present a non-normal distribution, they were log (base 10) transformed. The distance from the normal distribution of the transformed data were analysed, year by year and plot by plot, by means of the skewness and kurtosis tests. According to data distribution, the parametric *T* test (WELCH 1947) or the non-parametric *U* test (MANN and WHITNEY 1947) have been adopted.

The arithmetic means (x) and the variance (σ^2) have been calculated for each year and plot, to determine if the differences between subsequent years, for each PMP, are significantly different from 0. As the pooled variances for the different data groups are different, the *T* test, a variant of the *t* test, was applied:

$$T = \frac{\left|\bar{x}_1 - \bar{x}_2\right|}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}} \qquad \text{[eq. 1]}$$

where n_n are the data available for each year and plot. This ratio does not follow the t distribution, but can be approximated to it, by means of freedom degrees calculation.

For non-normal distribution of data, significance of the differences between means has been verified by the *U* test. All the observations were arranged into a single ranked series and the number of precedences were summed. U_{x_n} is the smallest number of precedences:

$$U = \sum_{x=n}^{x=1} U_{x_1}, U_{x_2} \ldots U_{x_n} \qquad \text{[eq. 2]}$$

U was than transformed to *Z*, because of high repetitions number:

$$Z = \frac{U - \frac{n_1 \cdot n_2}{2}}{\sqrt{\frac{n_1 \cdot n_2 \cdot (n_1 + n_2 + 1)}{12}}} \quad \text{[eq. 3]}$$

Z can be thus compared with the tabulated values of the normal distribution, to verify the difference significance.

Trend analysis

Considering the prevailing non-normal distribution of the data, two statistical analyses were performed: the first, the Mann-Kendall test, analyses the presence of a monotonic increasing or decreasing trend, the second, the non-parametric Sen's method (Sen 1968), estimates the magnitude of the trend. The two approaches are proposed within the procedure "MAKESENS" (Salmi *et al.* 2002), which has been developed by the Finnish Meteorological Institute within an EMEP project (the European Environmental Monitoring Programme of the United Nations), to easily detect and estimate the temporal trends in air pollution time series. The model has been implemented using the O_3 annual median levels (in ppb) measured at the PMPs with a data capture greater than 75%, with a minimum of four yearly medians. The Mann-Kendall test is suitable for time series which may be assumed to be monotonic; the Sen's method deals with the estimate of the slope of the observed trend (Gilbert 1987).

The Mann-Kendall test is applicable to time series which fit the linear model:

$$x_1 = f(t) + \varepsilon_1 \quad \text{[eq. 4]}$$

where $f(t)$ is a continuous monotonic increasing or decreasing function of time. This test is based on two statistics, the so called S and the normal approximation (Z statistics).

The Mann-Kendall statistic S is calculated according to:

$$S = \sum_{k-1}^{n-1} \sum_{j=k+1}^{n} \operatorname{sgn}(x_i - x_k) \quad \text{[eq. 5]}$$

where x_j and x_k are the annual values in years j and k, with $j > k$.

If the data available are nine or less, the absolute value of S is compared directly to the theoretical distribution of S, derived from Mann and Kendall (Gilbert 1987), using the two-tailed test for two significance levels (0.05 and 0.01). If the absolute value of S equals or exceeds the tabulated value at certain probability, means that the presence of a monotonic upward or downward trend, according to the S sign, is respectively probable or very probable.

The variance of S is computed as follows:

$$VAR(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p-1}^{q} t_p(t_p - 1)(2t_p + 5)\right]$$

Where q is the number of tied groups and t_p is the number of data values in the p^{th} group. The tested significance levels α are 0.05 and 0.01.

If the data available are equal ten or more the value of the normal approximation Z is used, to assess the presence of a statistically significant trend. However, if there are several tied values (*i.e.* equal values) in the time series, it may reduce the validity of the normal approximation when the number of data values is close to 10.

The values of S and VAR(S) are exploited to calculate Z:

$$Z = \begin{cases} \frac{S-1}{\sqrt{VAR(S)}} \ldots if \ldots S > 0 \\ 0 \ldots\ldots\ldots\ldots\ldots if \ldots S = 0 \\ \frac{S+1}{\sqrt{VAR(S)}} \ldots if \ldots S < 0 \end{cases} \quad \text{[eq. 7]}$$

A positive (negative) value of Z indicates an upward (downward) trend. To test for either an upward or downward monotone trend (*i.e.* a two-tailed test) at α level of significance, the Z value is compared with tabulate values obtained from the standard normal cumulative distribution tables. The tested significance levels α, as for S, are 0.05 and 0.01.

To assess the true slope of an existing tendency (as change per year) the Sen's non-parametric method could be used. This method can be utilized when the trend can be assumed as linear. This means that $f(t)$ in equation 4 equate to:

$$f(t) = Qt + B \quad \text{[eq. 8]}$$

where Q is the slope and B is the intercept. A 100 (1-α) two-sides confidence interval about the slope estimate is obtained by non-parametric technique based on the normal distribution. The method is valid for n as small as 10 unless there are many ties. The procedure in MAKESENS computes the confidence interval at two different confidence levels (0.01 and 0.05), resulting in two different confidence intervals. To get the slope estimate Q in equation 8 the slopes of all data pairs were first computed:

$$Q_i = \frac{x_i - x_k}{j - k} \qquad \text{[eq. 9]}$$

The Sen's estimator of the slope is the median of the n values of Q_i. To obtain an estimate of the intercept B in equation 8 the n values of differences $x_i - Q_{ti}$ are calculated. The median of these values gives the estimate of B (Sirois 1998). The estimates for the lines constant B at 99 and 95% confidence intervals are calculated by a similar procedure of the slope one.

Results and discussion

More than 10,000 measurements were carried out from 1996 to 2005. Descriptive parameters of the data collected are given in Table 3 (1996-2000) and Table 4 (2001-2005). Data capture is generally high. For plots with data capture lower than 75%, measurements of

Plot	1996 D.c. %	1996 Median ppb	1996 C.V. %	1996 Max ppb	1996 Min ppb	1997 D.c. %	1997 Median ppb	1997 C.V. %	1997 Max ppb	1997 Min ppb	1998 D.c. %	1998 Median ppb	1998 C.V. %	1998 Max ppb	1998 Min ppb
ABR1a	100	35.6	22	48.5	22.6	100	43.9	7	49.7	40.0	100	41.8	11	54.3	34.5
BAS1	94	34.1	16	41.7	21.5	75	53.6	13	65.8	42.8	81	35.8	15	42.7	21.8
CAL1	94	27.7	22	40.9	20.4	100	43.6	11	52.1	35.8	100	33.0	15	44.1	27.4
CAM1	94	38.1	25	49.7	12.5	38	55.5	25	83.6	46.4	81	36.9	9	44.6	33.8
EMI1	100	33.6	20	41.6	18.1	100	48.7	15	57.0	30.8	100	39.6	14	46.8	27.3
EMI2	100	36.3	17	42.9	19.8	81	55.1	25	92.2	34.8	94	40.7	31	66.1	0.0
FRI1	94	29.4	18	40.3	17.6	100	37.9	14	42.6	25.8	100	39.0	16	47.8	30.0
FRI2	88	28.8	28	44.3	12.0	100	39.4	16	62.9	37.2	13	33.4	1	33.7	33.1
LAZ1	100	35.7	13	44.6	25.2	100	50.5	7	56.7	43.4	100	43.2	8	50.0	37.1
LOM1						100	36.7	16	49.8	27.1	100	34.5	10	40.7	27.7
MAR1	82	38.2	17	46.8	25.2	100	53.5	11	63.6	42.9	100	39.4	10	45.3	32.0
PIE1	94	34.4	17	44.7	20.1	100	44.4	11	49.4	33.2	69	34.6	5	37.4	31.2
PUG1	94	36.2	26	45.4	14.9	94	56.4	14	73.1	43.0	100	45.6	13	57.2	36.1
SIC1	100	43.6	15	52.4	33.2	100	59.6	20	87.1	38.7	100	43.8	18	66.7	37.6
SAR1	94	36.9	14	43.9	25.3	100	42.9	10	50.4	36.0	100	36.2	11	39.5	27.2
TOS1	100	32.6	14	40.2	23.5	100	40.5	12	48.2	31.4	100	37.5	10	43.5	29.2
TRE1	100	34.1	18	43.8	20.1	100	49.1	10	58.2	41.3	100	41.2	11	48.2	34.5
UMB1	100	32.2	17	44.1	21.4	100	45.0	13	55.8	39.2	100	34.0	7	38.3	27.1
VAL1	100	33.6	15	44.0	24.3	100	42.6	18	59.6	35.6	100	39.6	19	62.2	32.2
VEN1	94	32.9	12	42.3	25.6	100	39.1	9	46.0	31.0	94	34.4	16	51.7	30.4
LIG1															

Plot	1999 D.c. %	1999 Median ppb	1999 C.V. %	1999 Max ppb	1999 Min ppb	2000 D.c. %	2000 Median ppb	2000 C.V. %	2000 Max ppb	2000 Min ppb
ABR1a	91	43.4	13.18	60.0	35.0	91	44.7	14	59.2	37.5
BAS1	95	42.6	6.64	48.2	37.7	95	53.1	17	73.8	39.0
CAL1	100	40.5	10.61	48.6	27.1	100	45.7	8	54.6	38.0
CAM1	100	47.5	12.93	70.8	41.8	100	47.7	20	69.3	34.2
EMI1	95	41.2	12.17	48.7	29.3	95	47.9	17	64.0	35.7
EMI2	77	46.1	12.36	57.5	39.1	95	42.8	12	51.1	34.0
FRI1	100	44.4	12.21	58.7	38.0	100	40.5	11	48.7	31.3
FRI2	100	43.7	11.24	55.6	38.4	100	40.6	12	51.2	32.5
LAZ1	100	46.1	8.31	51.9	38.9	91	44.5	15	62.4	31.9
LOM1	100	37.4	9.09	44.5	32.0	100	38.0	12	44.3	26.6
MAR1	100	51.9	9.80	64.4	43.0	100	50.9	9	57.4	40.2
PIE1	100	47.9	12.43	56.2	37.3	95	42.9	12	50.6	30.4
PUG1	100	47.4	10.32	60.5	42.8	100	48.5	13	59.7	37.9
SIC1	100	50.1	23.11	71.7	32.3	100	61.2	28	89.4	27.1
SAR1	100	47.3	9.44	58.6	42.8	100	46.4	15	68.5	35.2
TOS1	100	46.0	9.96	55.0	36.3	100	43.3	13	53.1	31.9
TRE1	100	45.7	10.36	56.8	38.5	100	43.7	13	51.7	23.6
UMB1	100	47.4	10.39	57.0	36.9	95	43.5	11	55.8	37.7
VAL1	91	43.7	18.47	67.6	38.0	91	40.5	9	47.2	33.6
VEN1	100	42.7	10.34	52.0	36.5	100	43.3	4	47.1	39.8
LIG1						95	53.4	13	68.6	44.2

Table 3 - Data capture (D.c.), median monthly concentrations (median) over the monitoring period, coefficient of variation (C.V.), maximum and minimum monthly concentrations (Max, Min) at the CONECOFOR PMPs data over the years 1996–2000.
Completezza dati (D.c.), mediana mensile delle concentrazioni (median) nel periodo di monitoraggio, coefficiente di variazione (C.V.), concentrazioni massime e minime (Max, Min) nelle aree CONECOFOR dal 1996 al 2000.

the corresponding year were excluded from further statistical analysis.

Median concentrations, weekly maximum and minimum recorded over the monitoring periods, vary substantially from year to year. The lowest weekly medians were recorded in 1996, the maxima, depending from the plot, between 2003 and 2005.

As measurement locations are located in a wide range of latitudes and elevations, PMPs display different climatic conditions and meteorological trend

	2001					2002					2003				
Plot	D.c. %	Median ppb	C.V. %	Max ppb	Min ppb	D.c. %	Median ppb	C.V. %	Max ppb	Min ppb	D.c. %	Median ppb	C.V. %	Max ppb	Min ppb
ABR1b	96	70.0	20	96.9	45.4	85	68.2	15	89.0	47.3	77	81.6	16	94.4	46.1
BAS1	88	56.8	26	105.6	35.4	88	60.7	16	76.6	40.0	96	57.8	17	77.6	41.2
CAL1	100	51.7	13	67.7	40.6	96	53.2	15	67.8	39.5	100	58.5	16	68.4	33.3
CAM1	100	61.8	13	80.8	48.6	96	60.8	12	72.9	42.5	92	66.9	15	91.7	56.2
EMI1	96	46.7	14	62.3	36.0	88	46.8	11	56.4	31.9	100	44.5	32	84.3	27.3
EMI2	35	37.0	20	47.8	29.1	92	50.8	12	61.0	35.0	100	54.7	16	73.2	40.4
FRI1	96	39.6	18	49.5	27.0	96	39.4	17	55.5	26.5	100	41.0	19	54.5	27.7
FRI2	92	41.4	14	52.0	26.5	92	45.8	15	55.8	34.3	100	45.6	24	82.5	28.1
LAZ1	96	50.7	12	66.1	35.4	96	55.6	12	72.3	46.1	96	49.6	24	65.9	19.5
LOM1	100	37.2	20	49.5	16.9	96	40.1	19	50.6	26.9	100	40.4	20	59.1	29.8
MAR1	96	51.4	15	68.9	37.4	96	52.6	11	61.2	40.1	96	54.5	22	83.5	34.0
PIE1	100	51.3	14	61.7	35.5	92	52.2	13	69.2	43.2	100	68.8	13	84.0	53.5
PUG1	96	51.1	10	60.1	38.7	85	51.4	8	57.3	41.9	100	50.2	18	68.9	31.4
SIC1	92	60.2	30	86.9	18.8	96	52.9	20	77.2	32.9					
SAR1	100	56.7	20	87.7	41.1	100	53.2	12	66.7	40.3	88	54.8	19	76.7	26.4
TOS1	96	38.1	19	54.5	25.0	100	37.6	16	54.7	30.2	92	47.3	14	69.2	36.1
TRE1	96	50.5	24	94.2	32.5	92	55.0	14	69.0	43.6	96	61.9	14	77.0	42.8
UMB1	96	45.5	13	61.5	25.6	96	49.4	9	58.7	42.0	100	53.7	16	69.3	37.0
VAL1	96	45.6	13	56.0	30.2	100	47.8	21	71.7	29.5	73	64.5	14	81.4	47.7
VEN1	96	38.1	20	52.6	19.5	96	45.7	12	54.8	30.8	92	50.1	21	89.0	32.9
LIG1	100	43.0	18	56.7	27.8	100	46.1	16	58.2	30.3					
ABR2											65	49.3	18	62.5	36.6
LOM2	100	54.8	28	85.5	36.0	100	46.1	18	68.6	32.3	100	50.3	21	74.7	31.0
LOM3	100	52.0	27	92.8	40.3	96	69.7	16	88.0	36.9	100	74.8	18	100.6	50.6
TOS2	100	49.7	23	83.9	38.4	92	52.0	12	60.4	39.9	100	46.6	26	68.1	25.5
TOS3	96	48.0	18	64.9	30.5	77	52.8	10	61.9	43.6	100	58.6	16	72.4	37.8
BOL1	88	50.0	15	63.3	32.2	100	60.0	14	77.9	44.2	88	66.1	15	80.0	48.2
LIG1	100	43.0	18	56.7	27.8	100	46.1	16	58.2	30.3					

	2004					2005				
Plot	D.c. %	Median ppb	C.V. %	Max ppb	Min ppb	D.c. %	Median Ppb	C.V. %	Max ppb	Min ppb
ABR1b	96	82.5	11	95.0	62.8	92	97.3	35	141.5	69.3
BAS1	96	61.0	9	71.7	48.6	96	66.3	23	81.1	47.0
CAL1	85	60.1	11	79.0	52.2	62	60.6	39	70.7	33.8
CAM1	93	79.9	21	122.7	51.4	92	87.7	35	127.5	49.1
EMI1	89	46.0	13	59.4	38.3	96	50.5	26	63.4	34.7
EMI2	100	57.3	11	68.0	46.3	96	58.2	34	69.2	29.5
FRI1	85	40.4	18	53.8	28.9	100	46.8	45	60.3	22.9
FRI2	96	45.1	15	52.0	28.0	100	46.2	51	70.2	19.3
LAZ1	100	54.3	13	72.7	40.5	85	61.6	33	83.5	40.4
LOM1	96	42.4	20	60.1	20.0	100	49.3	40	64.7	27.0
MAR1	96	57.1	10	68.2	46.9	100	61.5	28	76.9	36.2
PIE1	93	60.5	14	78.1	45.7	100	62.7	34	86.5	46.0
PUG1	96	53.3	12	65.5	37.6	100	59.1	22	68.9	37.2
SIC1										
SAR1	93	53.8	15	71.8	35.9	88	59.8	34	86.2	44.7
TOS1	85	46.0	14	55.9	32.8	100	56.5	25	73.2	39.9
TRE1	96	63.1	16	86.4	42.2	100	63.9	40	91.6	42.2
UMB1	100	53.1	10	68.0	45.0	100	57.0	23	70.6	44.1
VAL1	74	49.7	15	71.8	38.7	77	62.0	45	90.1	21.0
VEN1	78	45.3	18	56.3	26.3	100	52.4	42	73.2	24.0
LIG1						92	69.0	25	78.9	48.6
ABR2	96	53.7	13	75.0	42.6	100	60.0	30	73.8	38.1
LOM2	93	47.9	23	66.0	28.9	92	51.7	50	76.5	14.9
LOM3	100	77.7	44	125.7	48.4					
TOS2	67	60.0	8	69.9	52.3	92	72.5	26	89.6	50.1
TOS3	93	60.8	11	75.7	48.1	100	61.3	18	72.7	48.2
BOL1	85	56.0	16	75.0	42.8	81	61.5	48	104.3	39.6
LIG1						92	69.0	25	78.9	48.6
PIE2	59	32.7	16	38.2	17.9	100	56.6	36	68.3	33.1
PIE3	70	52.5	17	62.8	31.5	77	44.3	70	72.2	16.7
LAZ2						77	70.0	26	87.7	57.8
VEN2						96	39.6	35	50.2	23.2

Table 4 - Data capture (D.c.), median monthly concentrations (median) over the morning period, coefficient of variation (C.V.), maximum and minimum monthly concentrations (Max, Min) at the CONECOFOR PMPs over the years 2001 – 2005.
Completezza dati (D.c.), mediana mensile delle concentrazioni (median) nel periodo di monitoraggio, coefficiente di variazione (C.V.), concentrazioni massime e minime (Max, Min) nelle aree CONECOFOR dal 2000 al 2005.

Table 5 - Differences (expressed as percentages: [ppb year (x) – ppb year (x+1)]/ ppb year (x)) between means of the monitoring periods of consecutive years. Significance level *: $p<0.05$, **: $p < 0.001$.
*Differenze (espresse come percentuali: [ppb year (x) – ppb year (x+1)]/ ppb year (x)) tra le medie di periodi di monitoraggio di anni consecutivi. Significatività: *: p<0.05, **: p < 0.001.*

Plot	97'-96'	98'-97'	99'-98'	00'-99'	01'-00'	02'-01'	03'-02'	04'-03'	05'-04'
ABR1a	30 **	-6	8						
ABR1b						-16 *	7	17 *	22 **
BAS1	71 **	-36**	22 **	29 **	14	-16 *	1	15 **	3
CAL 1	46 **	-24**	20 **	17 **	15 **	-10 *	9	15 *	
CAM1			28 **	3	25 **	-8 *	15 *	38 **	-12 *
EMI1	52 **	-19**	2	32 **	-6	-6	-13 *	15 *	2
EMI2	61 **	-24**	8 *	-6			9	3	-7
FRI1	23 **	5	14 *	-11 **	4	-9	4	6	4
FRI2	42 **			-9	-1	8	-4	0	0
LAZ1	45 **	-15**	4	-1	17 **	8	-29 **	38 **	2
LOM1		-7	11 *	-1	-10	9	12	-1	6
MAR 1	49 **	-27 **	36 **	-7	7	-5	-4	24 **	-2
PIE1	30 **			-3	19 *	1	37 **	-23 **	14 *
PUG1	64 **	-17 **	6	3	8	-8 **	-5	9 *	6
SAR1	20 **	-20 **	37 **	-3	24 *	-12	0	1	-4
SIC 1	45 **	-24 **	21 **	7	-11	1			
TOS1	26 **	-6	23 **	-11 *	-7	-8	35 **	-7	17 *
TRE1	51 **	-17 **	15 **	-7	23 *	1	13	2	1
UMB1	47 **	-27 **	41 **	-7	2	9 *	2	0	10
VAL1	33 **	-9	14 *	-14 *	5	11			
VEN1	20 **	-9 *	18 **	-3	-14	16 *	16 *	-19 *	9
ABR2									7
LOM2						-26 **	21 *	-6	-6
LOM3						9	10	8	1
TOS2						-6	-15 *		
TOS3						1	3	17 *	-5
BOL1						22 **	16 *	-17 **	7
PIE2									
PIE3									
LIG1					-17 **	-1			
LAZ2									
VEN2									

for each years. Meteorological conditions greatly influence O_3 concentrations, especially during the warm season (Amoriello *et al.* 2003). In this respect, variations in climatic conditions can exert sufficiently large impact on O_3 concentrations to mask any trends, that could be traced to variations in precursor emissions. The meteorological adjustment of tropospheric O_3 can be achieved by statistical modelling of the association between ozone concentrations and meteorological variables, capable to detect disguised O_3 trends by meteorological variations (Vingarzan and Taylor 2003). The O_3 concentrations, measured during these sampling campaigns, were not meteorologically adjusted as they should reflect the actual level of the pollutant that may impact on the vegetation health, growth and dynamics.

To investigate the amplitude and significance of year-to-year variations and O_3 trend over time, differences between consecutive years were determined and statistically tested. Due to the differences in duration of the monitoring periods between years, the time interval from 15/06 to 30/09 was analysed.

Results of the tests performed are given in Table 5. Comparing data of the first two years of measurements (1996-1997) a relevant increase can be observed. The differences reported for all the PMPs are highly significant indicating a sudden and relevant increase of O_3 pollution. This is due to the 1996 character which can be considered as an O_3-poor year over Italy as over large parts of Europe (EEA 2006). Actually, the O_3 levels of this year are the lowest recorded during considered 10-years period.

The comparisons of the subsequent pairs of years show a decreasing number of significant and highly significant differences. The yearly mean concentrations in 1997 and in 1999 were generally higher than in 1998. This figure is confirmed by the O_3 records collected by the EEA (2006).

From 2000 to 2005 the concentrations generally increase over years and, in general, the significance level of differences decreases. Since 2001 differences between consequent years, expressed as percentages, relevantly decreased from 24% to 6%. In particular, the last comparison (2004-2005) shows highly significant or significant differences only at the PMPs ABR1a, CAM1, PIE1 and TOS1. As mentioned before, it should be noticed that measurements were performed at the PMP TOS1 above the canopies in 2005 while in the previous years the measurement site was located in a near clearing, at the ground level. As observed in other studies O_3 concentrations at ground level may display substantially lower O_3 levels compared to measurements performed above the canopies (Gerosa *et al.* 2001).

O_3 monthly median concentration data are reported in Figure 1. The data reported highlight the frequent occurrence of high temporal and spatial variability. In general, this high variability can be attributed, to a relevant extent, to the inter-annual meteorological variations.

The expected "bell-shaped" O_3 seasonal trend can be recognized at several sites when the sampling period extends from April to September (*e.g*, LOM2, BOL1, PIE1); at a number of locations, however, the seasonal profile may be substantially different. Actually, monthly maxima are recorded in some years in April (ABR1b and EMI2 in 2003) or even in September (EMI2 in 1997 and 2004, MAR1 and UMB1 in 2003, SIC1

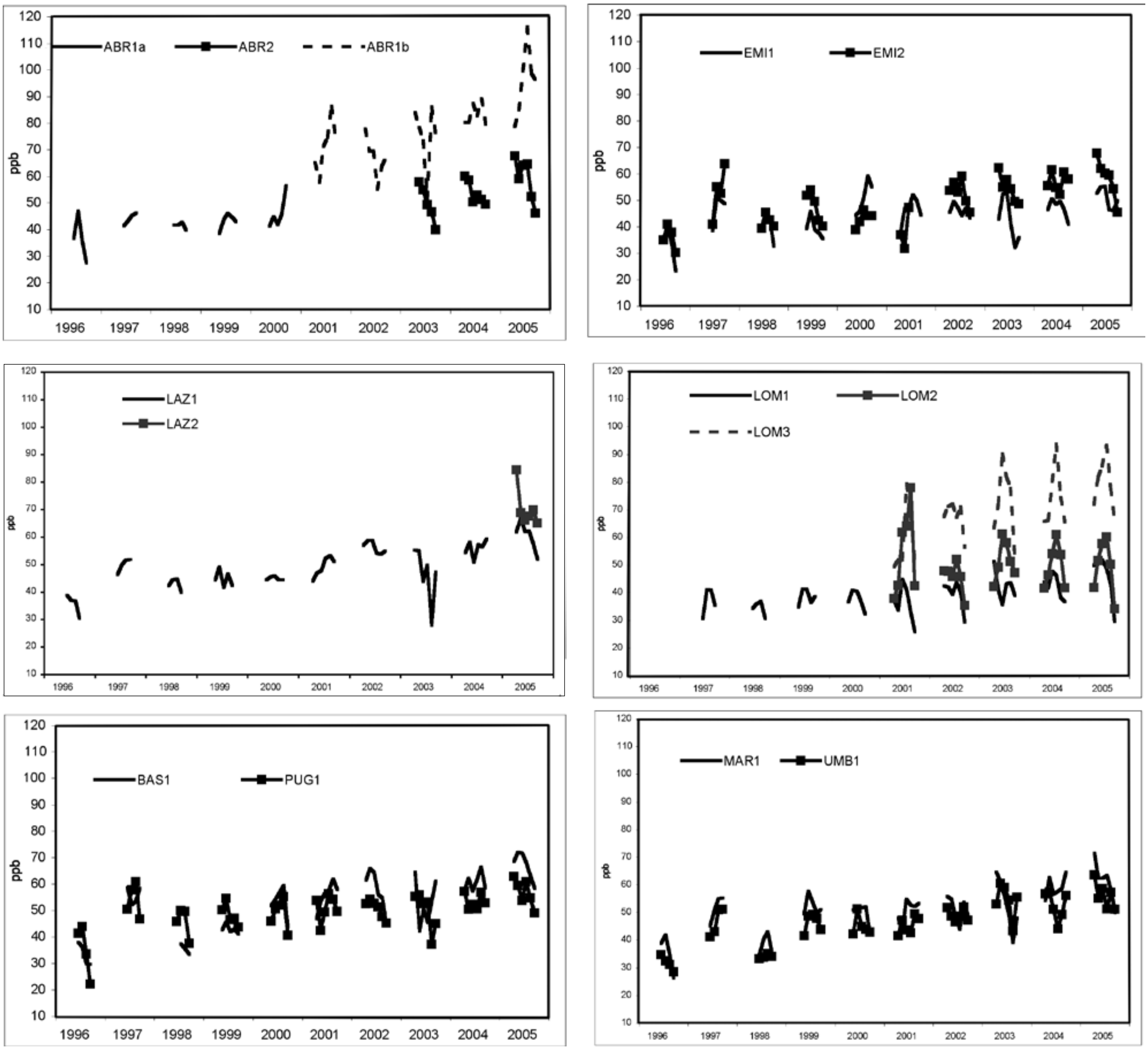
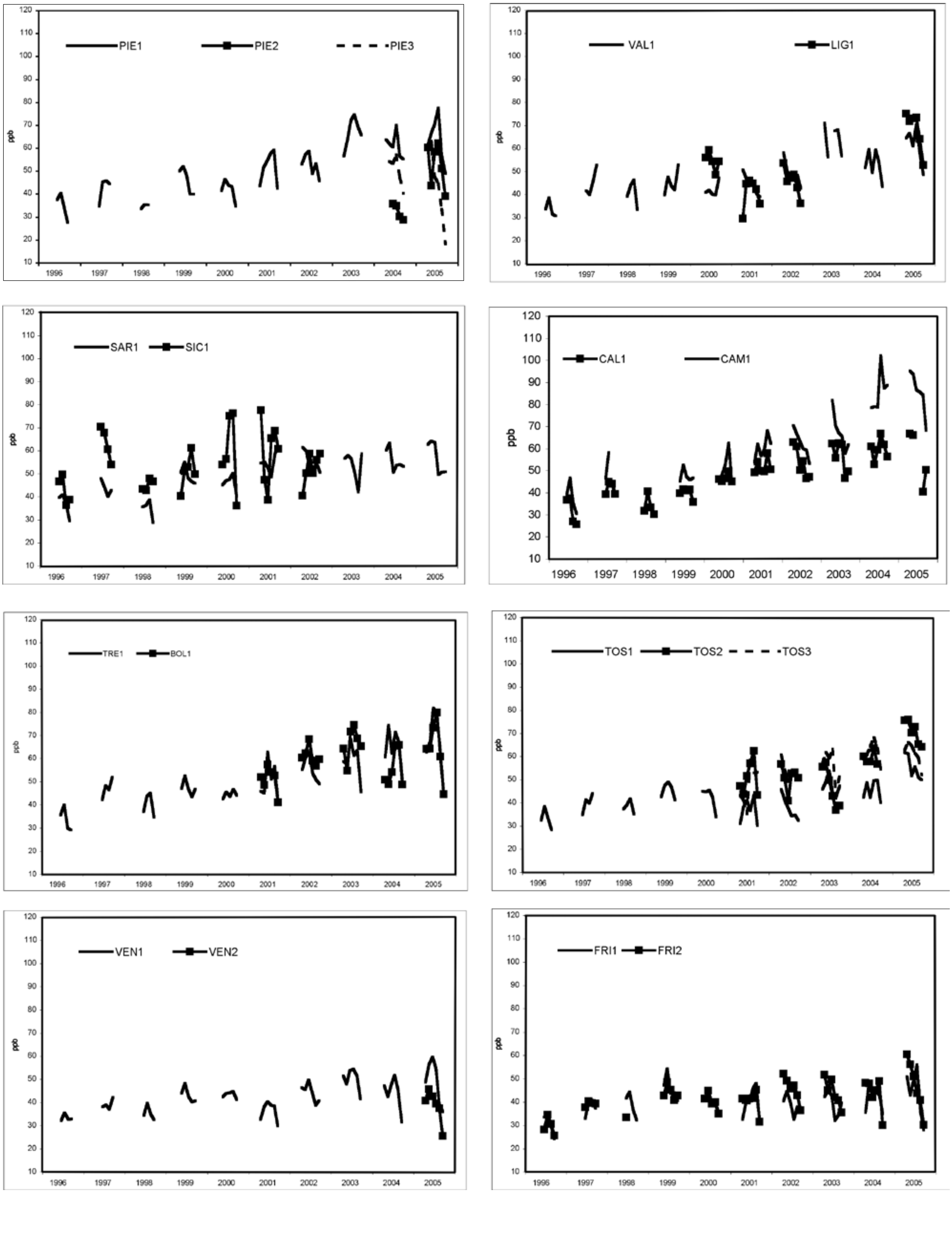


Figure 1 - Monthly median concentrations recorded at the PMPs of the CONECOFORnetwork from 1996 to 2005.
Concentrazioni mediane mensili alle aree delle rete CONECOFOR dal 1996 al 2005.

in 2002). Similar temporal concentrations tendencies are reported, as example, from the Carpathian area by Kellerova and Janik (2006). Monthly mean concentration data display the maximum value at ABR1b in July 2005 and the lowest in June 1997 at ABR1a. The sites ABR1a and ABR1b refer, as reported previously, to the same PMP ABR1. The relevant difference between the two 5-year periods can be reasonably attributed to the above mentioned location change, occurred in 2001, when instruments were moved to another probably more exposed site.

Moreover, the PMPs LOM1 and LOM3, both located in Lombardy, Northern Italy, display very different figures although the site are separated by approximately 35 km. The first is placed in a small valley protected by air mass transport from the densely populated and industrialized Po plain, the second, on the other hand, faces this area. Median concentration levels are very different but data distribution over time is similar. Both in North and South Italy parallel temporal trends between different locations can be observed, probably showing the broad climatic influence on O_3 levels. In these cases the differences in O_3 concentrations medians could be attributed to the microclimatic scenarios and local transport phenomena. In some sampling locations situated in Central Italy (Toscana, Marche

figure 1 (continued)



and Umbria) both tendencies and medians O_3 values are analogous.

Trend analysis performed on seasonal data is based on the evaluation of the possible approximation to the linearity. Data were not corrected for the different lengths of the monitoring periods. Referring to the collected O_3 data and their temporal distribution, an increasing trend can be hypothesized for several plots. Data from PMPs located in Southern Italy (ABR1b, PUG1, CAL1 and CAM1) display a rather clear upward tendency, while plots situated in Central Italy (EMI1, EMI2, TOS1, MAR1, UMB1 and LAZ1) show a positive but less evident trend. The PMPs in the Alpine region show generally a slight increasing tendency, with the exception of LOM3, PIE1 and TRE1 (Figure 2).

The results obtained from trend analysis are reported in Table 6. The first analysis was performed on 1996-2005 annual medians, computed on non-modified data derived from measurements carried out from middle of June to the end of September. A large part of the PMPs show positive slopes which means an increasing trend of the considered pollutant in the examined areas. In particular, 12 PMPs out of 27, display a significant or highly significant monotonic and upward trend. Their slopes (Q) exhibit higher values in case of substantial increments of O_3. This can be observed, for example, at the PMPs CAL1 and CAM1, both located in Southern Italy. The lowest values among the significant trends are shown at PMPs of the Alpine regions, as LOM1 and VEN1.

For 11 PMPs ten annual (seasonal) medians are available, consequently the slope and intercept significance has been tested. Results, given in Table 6, show that 7 PMPs present slopes significantly different from 0, therefore data fit a linear model.

Finally the analysis has been conducted on annual (seasonal) medians from 2001 and 2005, calculated on data collected during the complete vegetative period

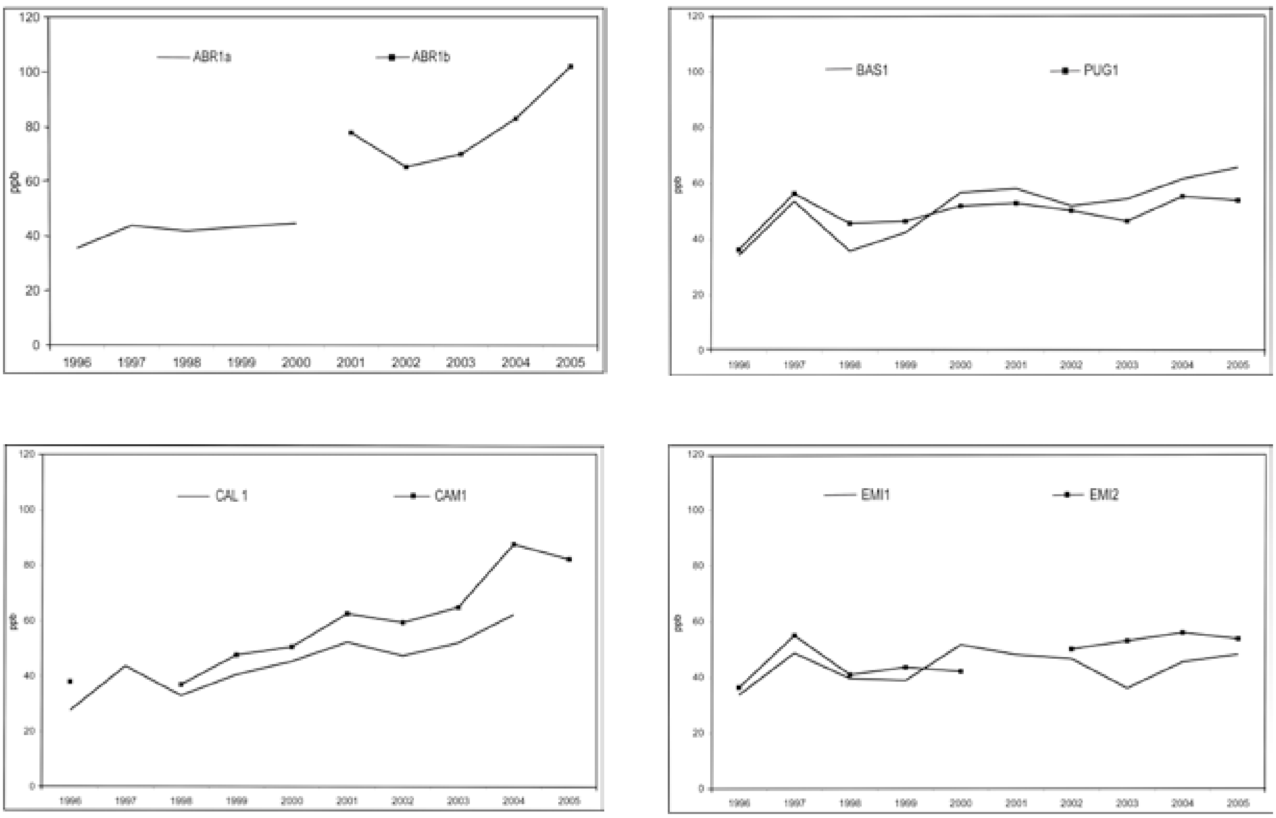
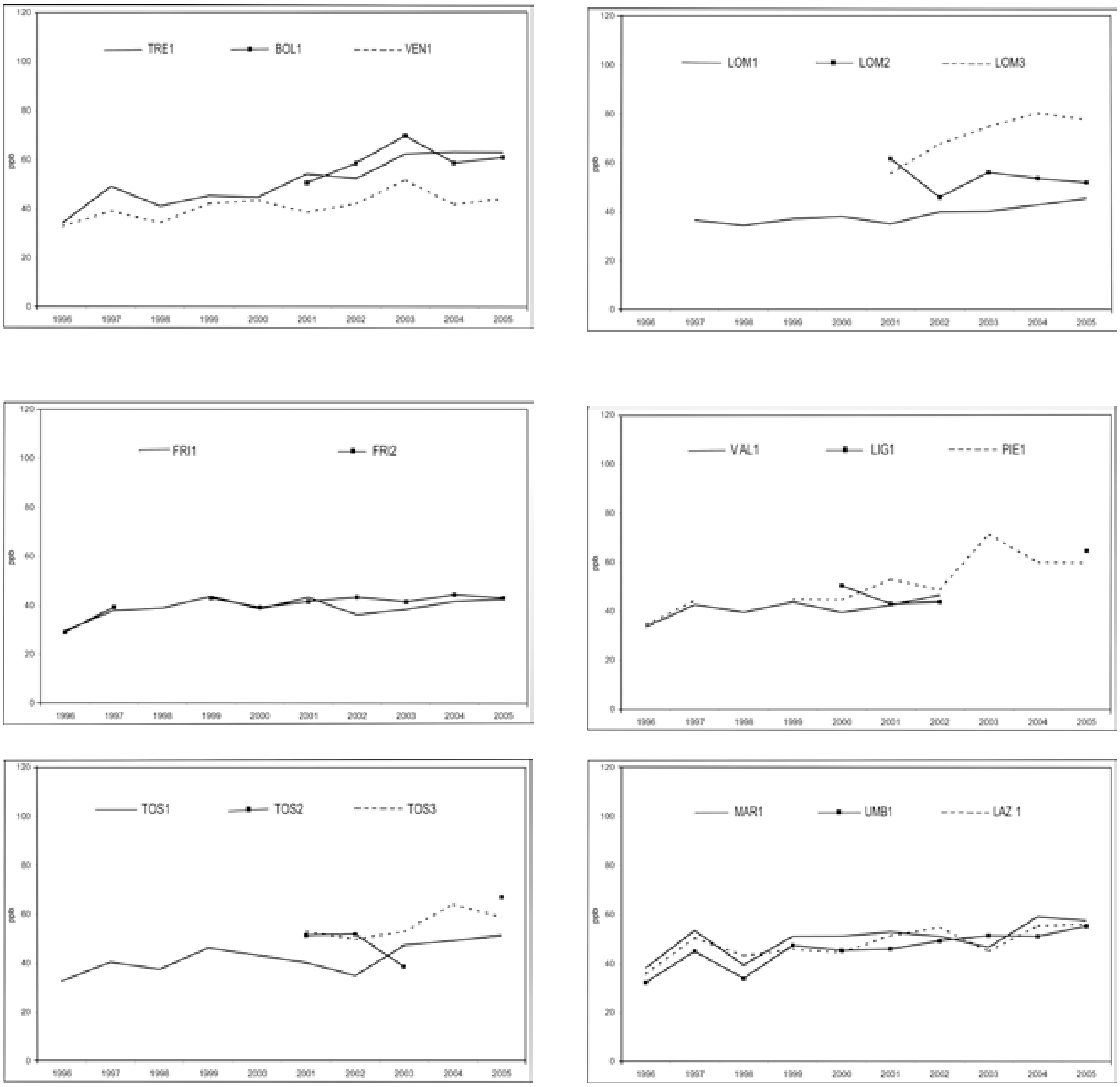
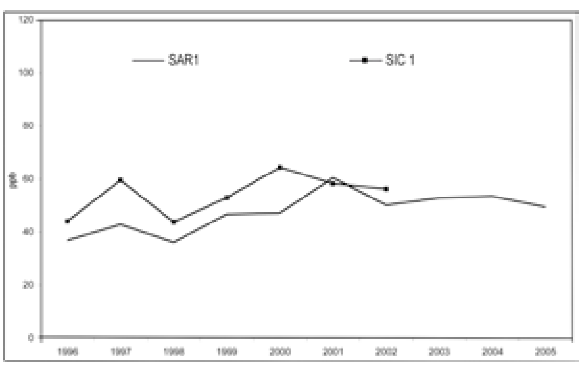


Figure 2 - Median seasonal concentrations over the measurement periods recorded at the PMPs of the CONECOFORnetwork from 1996 to 2005. Monitoring periods are of different length; measurement start and end of each year are reported in Table 1.
Concentrazioni mediane stagionali per I vari anni alle aree della rete CONECOFOR dal 1996 al 2005. I periodi sono di diversa lunghezza; inizio e fine delle misurazioni sono riprotati per ciascun anno in Tabella 1.

figure 2 (continued)





(April - September), (Table 7). The significance of the linearity has only a geometric meaning because of the small number of data. Only 5 PMPs out of 23 with at least 4 yearly medians display a significant monotonic upward trend, highlighting that the concentrations recorded in April and May can noticeably influence the tendency of this pollutant, reducing the monotonic character of the trend. In cases of non significance, the data are randomly ordered in the considered period.

The influence of individual years, both with high or

Table 6 - Results of the S and Z tests performed on data series with more than 4 and 10 annual (seasonal) data, respectively. Significance level *: p<0.05, **: p < 0.001.
*Risultati dei test S e Z effettuati su serie di dati con più di 4 e 10 annualità, rispettivamente. Significatività: *: p<0.05, **: p < 0.001.*

PMP	First year	Last Year	n.	Test S	Test Z	Slope	Intercept
ABR1a	1996	2000	5	8			
ABR1b	2001	2005	5	6			
BAS1	1996	2005	10		2.68**	3.03*	
CAL1	1996	2005	9	28**			
CAM1	1996	2005	9	30**			
EMI1	1996	2005	10		0.36		
EMI2	1996	2005	9	20*			
FRI1	1996	2005	10		1.07		
FRI2	1996	2005	9	18			
LAZ1	1996	2005	10		2.50*	1.83*	23.47*
LOM1	1997	2005	9	28**			
MAR1	1996	2005	10		1.61		
PIE1	1996	2005	9	26**			
PUG1	1996	2005	10		1.43		
SIC1	1996	2002	7	5			
SAR1	1996	2005	10		2.33*	1.57*	26.72*
TOS1	1996	2005	10		2.15*	1.62*	21.56*
TRE1	1996	2005	10		2.86**	3.20*	
UMB1	1996	2005	10		3.22**	2.00*	19.27*
VAL1	1996	2005	8	16			
VEN1	1996	2005	10		1.97*	1.24*	22.64*
LOM2	2001	2005	5	-4			
LOM3	2001	2005	5	8			
TOS2	2001	2005	4	2			
TOS3	2001	2005	5	4			
BOL1	2001	2005	5	6			
LIG1	2000	2005	4	2			

low mean O_3 levels, occurring at the beginning or the end of time series, is important. For example, 1996 has been a O_3-poor year, as mentioned before. If the corresponding data are neglected in the trend analysis the amount of PMPs with a significant trend drops from 12 to 9 PMPs. As well similar figures could be observed, depending on the PMP considered, if O3-rich years as 2003, 2004 or 2005 are neglected.

Conclusions

With 19 PMPs displaying O_3 time series of 7 to 10 years, the CONECOFOR network represents a valuable information source regarding O_3 pollution at Italian forest sites in term of concentrations and their trends through time. The data show, for a large extent, relevant mean concentrations during spring and summer months. PMPs with the highest O_3 concentration levels are located in Central and Southern Italy although some PMPs in the Alpine region highlight similarly high values. As most of PMPs are situated at remote sites, transport phenomena play a relevant role.

The influence of the recent hot and O_3-rich years play a relevant role in determining the observed trend. As there is a strong link between increasing temperatures and tropospheric O_3, a warmer and dryer climate is very likely to lead to increased O_3 concentrations. Increasing temperature are expected to influence transport phenomena, and O_3 precursor release from plants could become more active in a warmer environment. Moreover, the study highlights the importance of long-term investigations in Italy and underlines the need to develop a O_3 permanent monitoring network in remote areas.

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Table 7 - Results of the S test performed on data series referring to the years 2001 - 2005. Significance level *: p < 0.05, **: p < 0.001.
*Risultati dei test S e Z effettuati su serie di dati con più di 4 e 10 annualità, rispettivamente Significatività: *: p<0.05, **: p < 0.001.*

PMP	First year	Last Year	Valid data	Test S	Significance	Slope	Intercept
ABR1b	2001	2005	5	8		7.01	-30.52
BAS1	2001	2005	5	8		2.12	27.18
CAL1	2001	2005	4	6		3.12	7.55
CAM1	2001	2005	5	8		7.16	-41.82
EMI1	2001	2005	5	2		0.52	39.06
EMI2	2001	2005	4	6		2.53	13.54
FRI1	2001	2005	5	6		1.16	22.50
FRI2	2001	2005	5	4		0.67	34.16
LAZ1	2001	2005	5	4		2.36	17.76
LOM1	2001	2005	5	10	*	2.49	2.35
MAR1	2001	2005	5	10	*	2.38	16.88
PIE1	2001	2005	5	6		2.97	9.69
PUG1	2001	2005	5	6		1.48	29.15
SAR1	2001	2005	5	2		0.53	46.28
TOS1	2001	2005	5	6		4.60	-26.28
TRE1	2001	2005	5	10	*	3.72	-0.76
UMB1	2001	2005	5	8		2.70	8.42
VEN1	2001	2005	5	6		2.98	-1.27
LOM2	2001	2005	5	0		-0.02	50.65
LOM3	2001	2005	5	10	*	4.14	5.69
TOS2	2001	2005	4	2		3.99	-7.00
TOS3	2001	2005	5	10	*	3.65	-1.98
BOL1	2001	2005	5	4		2.44	17.49

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Were there significant changes in the overall condition of the CONECOFOR plots over the 1995 -2005 period?

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Abstract – Since 1995 the CONECOFOR programme is collecting data on a number of attributes of forest ecosystems in 20 permanent plots in Italy. In this paper, different multivariate methods were used to detect possible changes and deviations in the overall biological and chemical-physical status of the CONECOFOR plots as compared to defined reference periods. The reference periods were set-up taking into account the data availability and were as follows: 1997-1999 for biological status; 1999-2002 for chemical-physical status. Changes of the biological conditions of the plots were identified only in a few cases over the period 2000 - 2004 and were due to low values in transparency and basal area increment of the intermediate and dominated layer. On the other hand, several changes were detected in relation to the chemical and physical status over the period 2003-2005. Some few regularities were identified: (i) change/deviations concentrated on few plots; (ii) high ozone (O_3), low sulphur deposition and low precipitation were the attributes more consistently related to changes/deviations; (iii) most deviations were due to changes in the correlation structure of the attributes; and (iv) there is no consistent timing of change/deviations among plots. These findings emphasise the need to evaluate the data at the plot level and this indicate the importance of obtaining a time series long enough to enable plot-wise integrated analysis.

Key words: *permanent plots, Italy, change, deviations, Mahalanobis, PARAFAC, Hotelling T^2, Square Prediction Error.*

Riassunto – Ci sono stati cambiamenti significativi nelle condizioni complessive delle aree CONECOFOR nel periodo 1995-2005? Ormai dal 1995 il programma CONECOFOR sta raccogliendo dati su numerosi attributi degli ecosistemi forestali presso 20 aree permanenti localizzate in tutta Italia. In questo articolo, vengono utilizzati diversi metodi multivariati per identificare possibili cambiamenti e deviazioni nel complessivo stato biologico e chimico-fisico delle aree di osservazione in relazione a definiti periodi di riferimento. I periodi di riferimento sono stati definiti in relazione alla disponibilità dei dati e sono: 1997-1999 per lo stato biologico e 1999-2002 per lo stato chimico-fisico. Solo poche aree hanno mostrato cambiamenti nello stato biologico nel periodo 2000-2004, generalmente causato da bassi valori di trasparenza e di accrescimento negli strati intermedi e dominato. Invece sono stati riscontrati numerosi casi di cambiamento/deviazione dello stato chimico-fisico per il periodo 2003-2005. Sono state identificate alcune regolarità: (i) i cambiamenti/deviazioni sono risultati concentrati su poche aree; (ii) gli attributi più frequentemente e coerentemente coinvolti sono risultati alti livelli di ozono e bassi valori di precipitazione e deposizione di zolfo; (iii) in genere, le deviazioni rilevate sono dovute a cambiamenti nella struttura delle correlazioni; (iv) non esiste una coerenza temporale nell'accadimento di cambiamenti e deviazioni. Questi risultati enfatizzano la necessità di valutare i dati a livello di area ed indicano quindi l'importanza di ottenere serie di dati sufficientemente lunghe per permettere analisi integrate per ciascuna area.

Parole chiave: *aree permanenti, Italia, cambiamento, deviazioni, Mahalanobis, PARAFAC, Hotelling T^2, Square Prediction Error.*

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Introduction

Since 1995, the intensive monitoring programme CONECOFOR is collecting data about several ecosystem's attributes on 20 permanent plots scattered throughout Italy. This offers the chance to evaluate if, and at what extent, changes have occurred in the status of these plots. There are three questions of interest when assessing changes occurring in forest ecosystems over time: (i) changes in individual attributes, (ii) changes in the "overall status" of the plot (see below), and (iii) deviation from expected changes due to "common-cause" variation. As for question (i), a number of papers in this report provided evidence of several, statistically significant, temporal changes in individual attributes measured at the CONECOFOR plots (see Amoriello and Costantini, Bussotti *et al.*, Campetella *et al.*, Cecchini *et al.*, Fabbio *et al.*,

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MANGONI and BUFFONI, MARCHETTO *et al.*, this volume). They identified different trends, according to the indicator and the plot considered. It is therefore of interest to concentrate on question (ii) and (iii), *i.e.* evaluate whether reported changes in individual attributes resulted in a change in the "overall status" of the concerned plot (FERRETTI *et al.* 2000) and if there are "deviations" from expected changes. With "overall status" we refer to the status of a given plot as measured by different attributes of its biological, chemical and physical status. Let the status **S** of a given plot **P** ($P_1, P_2, P_3,...P_n$) at time $\mathbf{t}_k$ ($t_1, t_2, t_3,...t_k$) be measured by several attributes $\mathbf{I}_m$ ($I_1, I_2, I_3,...I_m$) and denoted by $\mathbf{S}_{p, t}$. Such a status can be identified by a vector in an m-dimensional space, each dimension being one measured indicator of the ecosystem status. The status of the $\mathbf{n}_{th}$-plot $\mathbf{P}_n$ at subsequent times $\mathbf{t}_{1,2,3, ...k}$ is therefore $\mathbf{S}_{p=n,\ t=1,\ 2,\ 3,\ ....k.}$ Thus, the distance between $\mathbf{S}_{p=n;\ t=1}$ and $\mathbf{S}_{p=n;\ t=2}$ can be measured to assess whether a significant change has actually occurred. In this paper we will consider selected attributes and we will combine them into a synthetic metric to figure out whether the plot of concern is still within the set of "reference condition". As "reference condition" we define the condition identified by the attributes measured at the beginning of the monitoring period, *i.e.* the set of expected condition in case no change have occured. By this way we intend to avoid value judgement (*e.g.*, "healthy", "unhealthy", "improvement", "worsening") and refer only to the measured conditions at the time the plot was installed. "Change" from such condition will be considered in statistical terms only (FERRETTI *et al.* 2000).

However, a certain degree of change is inherent to forest ecosystem. For example, ageing is a directional process affecting stand dynamics (and therefore plots status) at every plots. For this reason, not only changes, but also deviation from expected change is of interest. Here "deviation" is defined in relation to the (expected) common pattern of variation ("variation which affects the process all the time and is essentially unavoidable within the current process"). Concepts derived from the statistical process control (SPC, *e.g.*, KOURTI and MAC GREGOR 1995) are useful in this context. The objective of SPC "is to monitor the performance of a process over time to verify that it is remaining in a 'state of statistical control'. Such a state of control is said to exist if certain process or product variables remain close to their expected values and the only source of variation is 'common-cause' variation, that is, variation which affects the process all the time and is essentially unavoidable within the current process". In our case, the "product variable" is the status of our monitoring plots and the "process variables" are the various environmental characteristics that determine such a status and that we measure through various attributes. In the terms reported above, a significant change/deviation is said to occur when defined statistical limits are exceeded.

This paper aims to assess whether "changes" and "deviations" were actually detectable from our data and - if yes - to identify what attributes are involved and when and where such a change/deviation have occurred.

Methods

Data sets

Availability of the data is driven by several factors. Firstly, the time schedule of the different investigations: from continuous data collection (*e.g.* meteo), to weekly (deposition and ozone - O_3), annual (crown, vegetation), bi-annual (foliar), 5 yrs (growth) and 10 yrs (soil). Secondly, the starting time was different: soil and foliar started in 1995, O_3, crown condition assessment and ground vegetation in 1996, growth in 1996-1997 and meteo and deposition in 1998-1999. Thirdly, not all measurement are allocated to all the plots: for example, concurrent, reliable measurements of crown condition, deposition and meteo occurred only on 8 plots. These caused several restrictions for aggregating the data (FERRETTI 2000).

For the purposes of this paper we used three different datasets (Table 1 - 2). The first one refers to biological data and was denoted by B. It includes crown transparency (CT) and basal area increment (BAI) for different tree layers (upper, intermediate, lower). These attributes are indicators of forest health and productivity. The second dataset consider chemical and physical characteristics of the ecosystem and is denoted by C. It includes meteorological indicators like annual precipitation (PR), precipitation in the growing season (PRGI) and air temperature (AT) as well as O_3 (O_3) concentrations and deposition of H+, S and N (DepoH, DepoS and DepoN, respectively). The third dataset includes the C data plus tree crown transparency and is denoted by TC. Original data can be found in this volume in the papers of BUSSOTTI *et*

Table 1 – Investigations contributing data, indicators selected, areas of concern and relevant metrics.
Indagini che hanno fornito dati, indicatori selezionati, area di interesse e metrica degli indicatori.

Investigation	Indicator selected	Areas of concern	Metrics
Crown condition	Crown transparency (CT)	Forest health	% of a reference
Growth	Basal Area Increment (BAI) of the upper (s), intermediate (m) and lower (i) layers (BAI_s, m, i)	Forest productivity, C-sequestration, health	m^2
Deposition	Throughfall of N, S and H+ (DepoN, DepoS, DepoH)	Air pollution	eq m^{-2} yr^{-1}
Meteo	Air temperature (AT), annual precipitation (PR), precipitation in the growing season (PRGI)	Climate	°C (AT); mm (PR, PRGI)
Ozone	O_3 concentration	Air pollution	ppb

Table 2 – Datasets used. See text for more information.
Dataset utilizzati. Per maggiori spiegazioni, vedi il testo.

Data set	Indicators	Plots (n) Years (n)	Reference period Training set Years (n)	Evaluation period Evaluation set
B-Biological status	Crown transparency, basal area increment of three layers (upper, intermediate, lower)	All plots (n=20)	1997-1999 (n=20)	2000-2004 (n=20)
C-Chemical-physical status	P, T, PRGI, DepoH+, DepoN, DepoS	CAL1, EMI1, EMI2, FRI2, LAZ1, PIE1, TOS1, TRE1 (n=8)	1999, 2000, 2001, 2002 (n=32)	2003, 2004, 2005 (n=24)
TC-Crown transparency+C	Crown transparency, P, T, PRGI, DepoH+, DepoN, DepoS	CAL1, EMI1, EMI2, FRI2, LAZ1, PIE1, TOS1, TRE1 (n=8)	1999, 2000, 2001, 2002 (n=32)	2003, 2004, 2005 (n=24)

al. (CT), Fabbio *et al.* (BAI), Marchetto *et al.* (DepoH, -S, -N), Mangoni and Buffoni (O_3) and Amoriello and Costantini (PR, PRGI, AT).

Missing values occurred on a very limited basis. In case, they were reconstructed according to different methods in relation to the indicator considered: PCA was used for O_3 and meteo; correlation was used for crown transparency.

For each dataset, a "training set" and an "evaluation set" were considered. The training set was identified by the data belonging to the "reference period", *e.g.* the period against which we wish to detect changes (see below). The training set was used to set-up the model. On the contrary the evaluation set is made up by those data collected subsequently and tested against model expectations.

For the B-set, the multi-annual frequency of growth measurements conditioned the aggregation of the data. Thus, the training set was built up by the data collected in the years 1997-1999 (reference period), while the evaluation set was built up by the data collected in the years 2000-2004. Crown transparency and basal area increment for different layers were averaged over these periods to obtain comparable values.

For the C-set, data were aggregated on a annual basis. The training set was built up by the data collected in the years 1999, 2000, 2001, 2002 (reference period), while the evaluation set was made up by the years 2003, 2004, 2005.

For the TC-set, data were again aggregated on a annual basis. The training and evaluation sets were built up as for the C dataset.

Assumptions and limitations

As explained in other reports and papers of the I&C series (*e.g.* Ferretti *et al.* 2000, 2003, 2006), a number of attributes averaged at plot level are used as predictor and/or response indicators. This approach requires a number of assumptions (Ferretti and Chiarucci 2003). A first assumption concerns the ability of the available data to provide reliable, unbiased estimates of population parameters (*e.g.* mean plot crown transparency) at plot level. Another important assumption concerns the consistency of data through time. Although a huge effort has been placed to ensure maximum consistency, those surveys involving visual assessment (*e.g.*, crown condition) are always subject to observer error. To carry out the analysis, we assumed that data were comparable through space and time, but we invite readers to be careful when considering this aspect.

Statistical methods

Data were checked for normality and - when necessary - transformed to achieve normal distribution according to Box-Cox (Box and Cox 1964). Since the variables were measured according to different metrics and in order to obtain equal variances, data were

$$Xstd_i = \frac{(x_i - \bar{x})}{s}$$

standardized by means of autoscaling:

where:

$Xstd_i$ is the standardized value of the varaible i,
$\overline{x_i}$ is the actually measured value of i,
x is the mean value of i between the n sites,
s is the standard deviation of x between the n sites.

Different statistical methods were used: to detect changes in the overall plot status, the Mahalanobis distance was used. To detect deviations from the common-cause variations, a set of different tools were used: Principal Component Analysis (PCA), Parallel Factor Analysis (PARAFAC), Tucker3 (3-way PCA). In order to better identify possible cause of oddness of individual observations, contribution plot were used.

Mahalanobis distance

The independent variables of a data array define a multidimensional space, in which is possible to plot “mean point”, also called centroid, that is the mean of all the independent variables. The Mahalanobis distance (Mahalanobis 1936) is the distance of a case from the centroid in the multidimensional space, defined by the correlated independent variables (if

$$d_{ab} = (\bar{x}_a - \bar{x}_b)^T \bar{S}^{-1} (\bar{x}_a - \bar{x}_b)$$

the independent variables are uncorrelated, it is the same as the simple Euclidean distance):

Thus, this measure provides an indication of whether or not an observation is an outlier with respect to the independent variable values. The covariance matrix inversion (S^{-1}) allows the compression of the distance between cases located in a space defined by correlated variables and downweights high variance variables.

Principal Component Analysis (PCA)

PCA is a technique for concentrating the information in a data set into fewer dimensions (Massart *et al.* 1997; Jackson 1991; Jolliffe 1986). This is done by creating new variables, Principal Components (PCs), that are linear combinations of the original variables and which account for maximum possible variance in the data set. Each PC is constrained to be orthogonal to all previously extracted PCs (at right angles in the multidimensional space and therefore completely uncorrelated), and as a consequence they have no overlap in information content. Each PC thus represents a different fundamental property of a system, were all the original variables that are partially or largely redundant in information content influence the same PC in the same direction. This is evident in the loadings plot, which shows correlations between the PCs and the original variables. Moreover, it is possible to view how the objects of the data set are distributed in the space of the PCs by means of the scores plot. The number of significant PCs indicates the number of fundamentally different properties exhibited by the data set.

PARAFAC and Tucker3 models

PARAFAC and Tucker3 are decomposition methods and they are both considered a generalization of PCA to higher order array (see Bro 1997; Bro *et al.* 1999; Henrion 1994; Munck *et al.* 1998; Pravdova *et al.* 2002; Smilde *et al.* 2004 for a detailed description of the properties and characteristics of these two multi-way techniques). Briefly, a 3-way array **X**, of dimension $I \times J \times K$, is decomposed into a triplets of loadings vectors. Each triplet is called Component or Factor or Latent Variable (LV). For the PARAFAC, the decomposition can be mathematically expressed by the following equation:

$$x_{ijk} = \sum_{f=1}^{F} t_{if} w^j_{if} w^k_{kf} + e_{ijk}$$

Where:

F is the number of components (not orthogonal) used in the PARAFAC model, which has to be equal for the three modes;
T $(I \times F)$ with element t_{if} is the first mode score matrix;

$\mathbf{W}^J$ $(J{\times}F)$ with element w^j_{if} and $\mathbf{W}^K$ $(K{\times}F)$ with element and w^k_{if}, are the second and the third modes weights, respectively;

e_{ijk} is a residual term containing all the unexplained variation.

The equation for the Tucker3 is as follows:

$$x_{ijk} = \sum_{p=1}^{P} \sum_{q=1}^{Q} \sum_{r=1}^{R} t_{ip} w^j_{jq} w^k_{kr} g_{pqr} + e_{ijk}$$

where:

t_{ip}, w^j_{jq}, w^k_{kr} and e_{ijk} are, as discussed in PARAFAC case, the elements of the loading matrices $\mathbf{T}$, $\mathbf{W}^J$, $\mathbf{W}^K$, and of the residual array, respectively;

P, Q and R are the number of components (orthonormal) extracted for each mode;

g_{pqr} is the element of the core matrix $\underline{\mathbf{G}}$ of order $P{\times}Q{\times}R$;

The array $\underline{\mathbf{G}}$ is called core array and represents the value by which the single component product is weighted. Therefore, the value and the sign of each core element, gives information about the entity of the interaction among the components of the different modes. The squared elements of the core matrix are proportional to the variation explained by the combination of the components corresponding to their indices, *i.e.* if g_{112} is the largest core element, special attention in interpreting the model has to be given to the interaction between component 1 of mode 1, component 1 of mode 2 and component 2 of mode 3.

One of the main advantages of the multi-way techniques lies in the improvement of the visualization and interpretation of the results. In fact, separate loading plots are displayed for each mode: one for the objects, one for variables and one for the conditions, allowing distinct analysis of each source of variability, without 'flattening' or loosing any type of information.

Statistical limits to detect "deviations"

Detection of changes: for the purposes of this paper, we calculated the Mahalanobis distance for the training set and the relevant statistics (mean and its standard deviation, S) without considering the outliers. Secondly, we calculated the distance of each point of the evaluation set from the centroid of the training set. Thirdly, we compared such a distance with the mean distance of the training set augmented by 2 times S. Points falling outside this limit were considered outliers.

Detection of deviations: statistics like Hotelling's T^2 (Hotelling 1947) and Q (also defined as SPE, square prediction error, Nomikos and Mac Gregor 1995) are used in order to establish confidence limits in a multivariate space and to detect "out-of-control" situations. They are calculated on the basis of a model from principal component analysis (PCA) or partial least squares (PLS), and give superior performance to the univariate quality control methods which monitor one variable at a time.

Hotelling's T^2 statistic measures variations in the PCs. This will only detect whether or not the variation in the variables in the plane of the first PC is greater than can be explained by common cause. If a totally new type of special event occurs which was not present in the reference data used to develop the "in-control" PCA model, then new PCs will appear and the new observation will move off the plane. Such new events can be detected by computing the squared prediction error (Q) of the residuals of a new observation. The Q index measures the projection of the sample vector on the residual subspace.

Although both Q and T^2 are used, *i.e.*, for process monitoring, it is necessary to point out that they measure different situations of the process, and their roles in process monitoring are not symmetric. The Q index measures variability that breaks the normal process correlation, which often indicates an "abnormal" situation. The T^2 index measures the distance to the origin in the principal component subspace. Since the principal component subspace typically contains normal process variations with large variance that represent signals, and the residual subspace contains mainly noise, the normal region defined by the control limit for T^2 is usually much larger than that of Q. Therefore it usually takes a much larger "deviation" to exceed the T^2 control limit. On the other hand, deviations with small to moderate magnitudes can easily exceed the Q control limit.

While a fault can cause Q and T^2 to increase, an increase in T^2 alone indicates that the change is consistent with the model, *i.e.* observation with a high T^2 show an unusual variation inside the model, while samples with a high Q value demonstrate an unusual variation outside the model. In the former case, the meaning is that, within the set of the variables considered, we observe an unusual numeric value of the resulting vector which is however consistent with the overall model used to explain the overall variation,

Table 3 – Summary data for the various attributes used. Mean values for the training and evaluation sets are reported. The training sets are 1997-1999 for the B-set and 1999-2002 for the C and TC sets. Evaluation sets are 2000-2004 and 2003-2005, respectively. See text for details.
Sintesi dei dati per gli attributi usati. Vengono riportate le medie per i set di training e di valutazione. Il set training è il 1997-1999 per il set B ed il 1999-2002 per i set C e TC. I set di valutazione sono 2000-2004 e 2003-2005 rispettivamente. Dettagli nel testo.

Data set	Indicator and time coverage	Lambda values for Box-Cox	Years	ABR1	BAS1	CAL1	CAM1	EMI1	EMI2	FRI1	FRI2	LAZ1	LOM1
B	CT 1997-2005	1	97-99	20,4	22,7	35,8	24,1	21,0	22,0	18,8	19,3	14,9	17,6
			00-04	22,5	21,2	32,8	22,8	30,5	27,1	20,2	17,0	24,3	19,2
	BAI_l 1997-2004	1	97-99	-7,8	-110,2	-134,3	6,6	306,2	-1092,6	74,7	151,9	-13,8	-54,3
			00-04	10,4	-658,3	-215,5	7,5	32,2	-759,0	-357,1	-26,5	-75,1	96,1
	BAI_m 1997-2004	1	97-99	174,3	316,5	428,3	456,0	-761,8	-36,1	511,6	666,6	567,5	256,9
			00-04	85,4	423,4	399,6	247,2	-517,3	40,6	91,1	605,0	17,5	196,5
	BAI_s 1997-2004	0	97-99	1645,0	593,9	593,7	756,5	642,0	1493,4	1335,4	1402,5	1407,1	2507,9
			00-04	1011,8	716,4	813,8	648,9	420,4	2125,8	806,9	1078,7	839,0	2227,8
C, TC	CT 1999-2005	0,5	99-02			35,8		23,8	25,7		18,7	20,8	
			03-05			27,5		39,1	21,3		14,8	22,3	
	AT 1999-2005	-	99-02			10,3		12,9	9,7		6,9	11,6	
			03-05			9,8		12,5	9,1		6,3	12,1	
	PR 1999-2005	-0,5	99-02			1545,2		891,3	1301,8		1705,3	895,8	
			03-05			2094,3		855,7	1642,7		1703,0	998,0	
	PRGI 1999-2005	-0,5	99-02			721,1		562,3	504,3		1018,3	427,8	
			03-05			790,0		510,3	481,0		1022,0	414,0	
	DepoN 1999-2005	0,5	99-02			46,3		162,2	12,2		81,9	56,0	
			03-05			53,9		153,8	6,9		87,3	49,4	
	DepoS 1999-2005	0,5	99-02			111,2		74,6	10,4		68,1	55,1	
			03-05			118,5		48,4	4,0		45,9	43,7	
	DepoH+ 1999-2005	0	99-02			6,5		1,9	1,0		10,9	3,1	
			03-05			7,1		1,3	0,4		2,9	3,2	
	O3 1999-2005	-0,5	99-02			47,8		45,6	44,2		42,9	49,2	
			03-05			59,7		47,0	56,8		45,6	55,2	

Data set	Indicator and time coverage	Lambda values for Box-Cox	Years	MAR1	PIE1	PUG1	SAR1	SIC1	TOSI2	TRE1	UMB2	VAL1	VEN1
B	CT 1997-2005	1	97-99	18,5	25,6	19,1	20,2	12,5	35,8	13,0	24,3	25,2	18,9
			00-04	18,5	24,4	20,1	14,5	12,7	22,9	14,1	19,1	22,5	17,1
	BAI_l 1997-2004	1	97-99	316,5	-16,0	-653,5	-386,6	-256,6	-619,6	39,7	-86,8	5,6	42,6
			00-04	-108,4	2,9	-895,0	-742,1	-449,9	-450,7	-260,0	-331,5	65,1	-49,0
	BAI_m 1997-2004	1	97-99	67,7	535,5	716,3	191,8	340,8	313,0	494,4	313,9	133,8	522,6
			00-04	-286,6	382,2	233,3	-18,4	-783,5	355,3	216,3	-4,4	102,1	226,5
	BAI_s 1997-2004	0	97-99	1792,1	691,6	1141,9	1064,9	645,3	745,2	916,0	699,4	1414,2	836,4
			00-04	1114,0	528,4	1070,1	636,3	252,5	605,7	1168,6	527,6	1499,1	458,5
C, TC	CT 1999-2005	0,5	99-02		24,8				25,8	14,6			
			03-05		25,5				21,3	12,9			
	AT 1999-2005	-	99-02		7,6				12,8	4,9			
			03-05		7,0				9,4	4,7			
	PR 1999-2005	-0,5	99-02		2007,7				1088,7	1189,1			
			03-05		1451,3				1245,5	896,0			
	PRGI 1999-2005	-0,5	99-02		1307,6				415,3	476,3			
			03-05		838,3				566,0	306,7			
	DepoN 1999-2005	0,5	99-02		139,1				73,6	35,4			
			03-05		112,3				74,5	33,0			
	DepoS 1999-2005	0,5	99-02		72,1				106,6	26,4			
			03-05		38,3				74,2	13,4			
	DepoH+ 1999-2005	0	99-02		12,8				1,7	2,5			
			03-05		10,6				1,2	2,8			
	O3 1999-2005	-0,5	99-02		48,6				41,2	48,7			
			03-05		64,0				49,9	63,0			

i.e. the expected correlations between the variables used. On the contrary, high Q values identify vector components that are outside the expected correlations between the variables used.

Once an observation has been detected as an outlier, it is very important to understand *why* it is an outlier. This can be done by computing the contribution of each variable to the calculated statistic (Miller *et al.* 1998; R. Leardi, personal communication). A high contribution of a variable usually indicates a "problem" with this specific variable. Computing the contribution allows to split the global Q or T^2 into the contributions given by each variable and makes the interpretation much easier. The values used are the squared residuals, but in our case value of the contribution is multiplied by the sign of the residual. To give an idea about the significance of the contributions (the actual numerical value has no "practical" meaning) a critical value for each variable is computed on the basis of the distribution of the contributions on the same variable, and corresponds to the 95th percentile of the distribution of the absolute values. By dividing each contribution by its critical value a normalized value is obtained, in which the value for each variable corresponds to how many times its contribution is greater than the critical value.

Results

Table 3 summarizes the data for each plot, variable and datasets. In the following, results are discussed in relation to each dataset.

Biological status: crown transparency and basal are increment

The Mahalanobis distance between 2000-2004 and 1997-1999 is reported for of each plot in Figure 1. Three outliers were identified: SIC1, UMB1 and VEN1. According to the original data (Table 3), these outliers seem mostly caused by reduced growth, especially at UMB1 and VEN1.

The PARAFAC identifies a three-linear model where 2 components explain 63.85% of the variance of the training set (Figure 2). The subsequent PCA analysis did not display outliers within the training set (Figure 3). When considering the evaluation set, four deviations with high Q values were obvious in comparison with the training set (Figure 3). Deviations occurred for the plots SAR1, SIC1, UMB1 and VEN1 and were due to high Q values, *i.e.* a possible change in the expected correlation structure. High Q were mostly due to low values for crown transparency and BAI in the intermediate layer (Table 4). These reflects the reduction of growth observed on these plots (particularly heavy in VEN1: -57% of annual increment in the intermediate layer as compared with the 1997-1999 value) which was accompanied by a slight decrease of transparency (Bussotti *et al.*, this volume; Fabbio *et al.*, this volume) (Table 3).

Chemical and physical status: deposition, ozone and meteorology

Figure 4 reports the Mahalanobis distance of the 2003-2005 data for each plot and year. Ten outliers were identified (Figure 6), namely the plots CAL1 (yrs 2003, 2004), EMI2 (2003, 2004), LAZ1 (2005), PIE1 (2003), TOS1 (2004), and TRE1 (all years). According

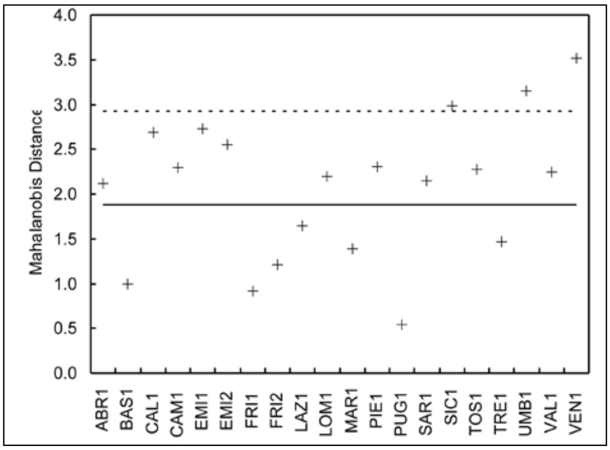

Figure 1 - Mahalanobis distance, B-set, 2000-2004. The solid line indicates le mean distance from the centroid of the 1997-1999. The dashed line indicates 2 times S.
Distanza di Mahalanobis, set B, anni 2000-2004. La linea intera indica la distanza media dal centroide 1997-1999. La linea tratteggiata indica due volte S.

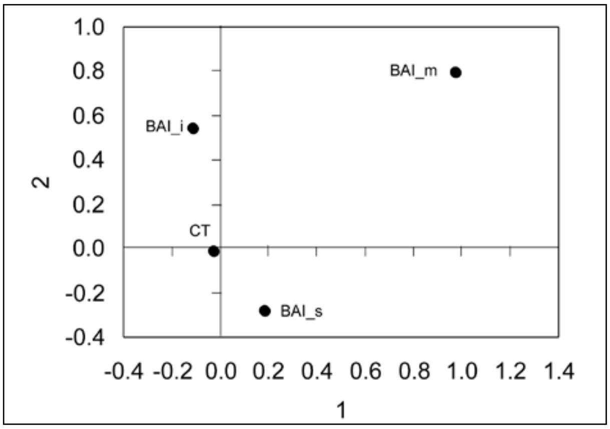

Figure 2 - B-set, 1997-1999, PARAFAC. The first two PCs explained 63.85% of the variance.
Set B, 1997-1999, PARAFAC. Le prime due PC spiegano il 63.85% della varianza.

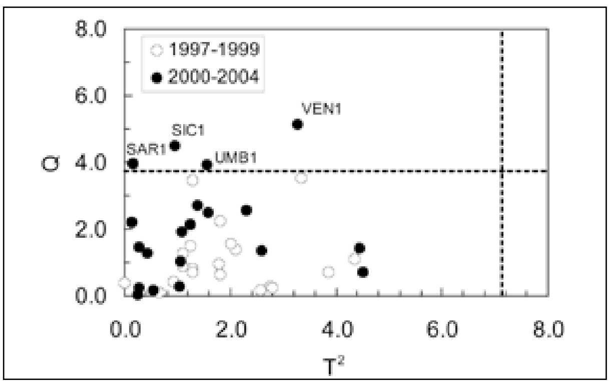

Figure 3 - Datapoints of the B-set within the T^2-Q diagram. The dashed lines indicate the critical values at p=0.05. Only datapoints having at least one diagnostic at p<0.05 are labelled with the plote code.
Dati del set B disegnati nel diagramma T^2-Q. Le linee tratteggiate indicano il livello di significatività per p=0.05. Solo i dati che mostrano almeno un criterio diagnostico eccedente il livello di significatività sono indicati con il nome dell'area.

to the original data, different factors were involved: a strong reduction (-47%) in summer precipitation occurred at CAL1 in 2003, accompanied by an increase of O_3. A similar situation occurred at EMI2, together with a reduction in sulfate, nitrate and H+ deposition at EMI2, and an increase in annual precipitation. At LAZ1, high temperature, high O_3 and reduced summer precipitation appear to be the most important factors in determining the 2005 outlier, together with a high annual precipitation value. A particularly high deposition of N appeared responsible for the outlier value at TOS1 and increased O_3 and reduced precipitation for TRE1.

A three-linear PARAFAC model where 2 components explain 82.1% of the variance was identified. These two components are reported in Figure 5. The PCA analysis identifies only one minor deviation within the training set, the plot EMI2 at year 2002, characterized by slightly high Q values (Figure 6) caused probably by a high AT (mean annual value: 9.7 °C). When considering the evaluation set (2003-2005 data), strong deviation were observed for TRE1 at years 2004 and 2005, when both T^2 and Q critical values were exceeded (Figure 6). This indicates that at this plots and in these two years something was recorded that is out of the expected correlations structure and also with anomalous numerical values. The most likely reason for T^2 exceedance was high summer O_3 and low DepoS, while low AT and PRGI contributed to high Q values (Table 5). Excedance of T^2 was observed also for PIE1 in 2003 (high O_3), while exceedance of Q were reported for EMI2 (2003, high PR), CAL1 (2003: high PR and low PRGI; 2004: high PR and DepoS and low DepoN) and TOS1 (2004: low DepoH+) (Table 5).

Table 4 – Normalized contribution for each variable in case of deviation for the B-data set. Variables that exceeded the value of 1 (in bold) have a significant contribution to the statistic considered.
Contributo normalizzato di ciascuna variabile nei casi di deviazione nel set B. Le variabili per cui viene superato il valore di 1 (in grassetto) hanno un contributo significativo alla statistica considerata.

	Normalized contribution, Q			
Indicator	**SAR1**	**SIC1**	**UMB1**	**VEN1**
CT	-0.943	**-1.383**	**-1.325**	**-1.476**
BAI_i	**-1.005**	-0.332	-0.075	-0.358
BAI_m	**-1.433**	**-1.434**	**-1.232**	**-1.533**
BAI_S*	-0.135	0.648	0.801	0.690

(*)The sign of the contribution is reversed due to the negative lambda value of the Box-Cox transformation.

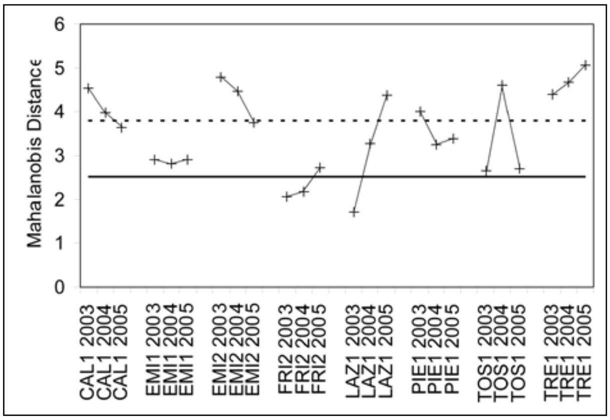

Figure 4 - Mahalanobis distance, C-set, 2003-2005. The solid line indicates le mean distance from the centroid of the 1999-2002. The dashed line indicates 2 times S.
Distanza di Mahalanobis, set C, anni 2003-2005. La linea intera indica la distanza media dal centroide 1999-2002. La linea tratteggiata indica due volte S.

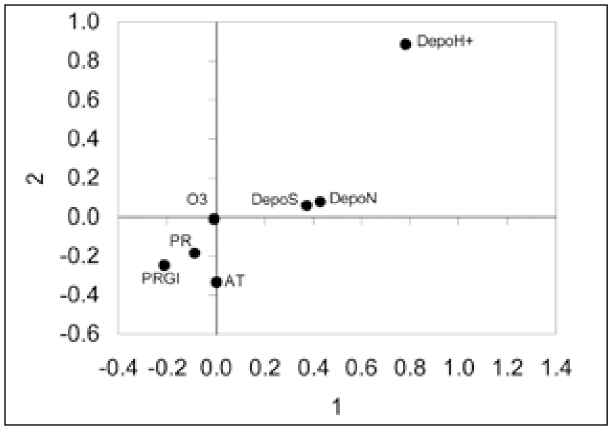

Figure 5 - C-set, 1999-2002, PARAFAC. The first two PCs explained 82.1% of the variance.
Set C, 1999-2002, PARAFAC. Le prime due PC spiegano l'82.1% della varianza.

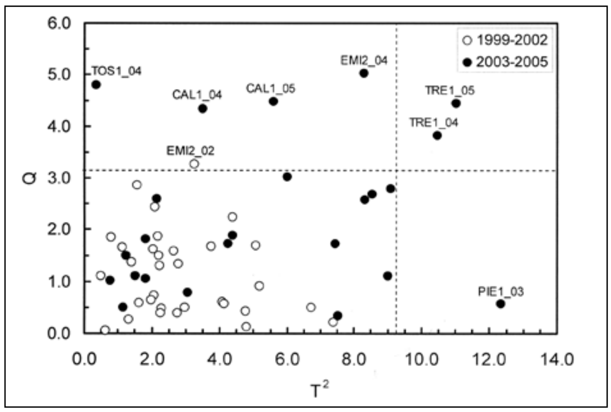

Figure 6 - Datapoints of the C-set within the T^2-Q diagram. The dashed lines indicate the critical values at p=0.05. Only datapoints having at least one diagnostic at p<0.05 are labelled with the plote code.
Dati del set C disegnati nel diagramma T^2-Q. Le linee tratteggiate indicano il livello di significatività per p=0.05. Solo i dati che mostrano almeno un criterio diagnostico eccedente il livello di significatività sono indicati con il nome dell'area.

Table 5 - Normalized contribution for each variable in case of deviation for the C-data set. Variables that exceeded the value of 1 (in bold) have a significant contribution to the statistic considered.
Contributo normalizzato di ciascuna variabile nei casi di deviazione nel set C. Le variabili per cui viene superato il valore di 1 (in grassetto) hanno un contributo significativo alla statistica considerata.

	Normalized contribution, Q						Normalized contribution, T^2		
Indicator	**CAL1_03**	**CAL1_04**	**EMI2_03**	**TOS1_04**	**TRE1_04**	**TRE1_05**	**PIE1_03**	**TRE1_04**	**TRE1_05**
DepoN	-0.881	**-1.136**	0.252	0.537	0.278	0.469	0.430	-0.732	-0.781
DepoS	0.933	**1.147**	0.112	0.569	0.156	0.304	-0.237	**-1.349**	**-1.416**
DepoH+	0.462	-0.546	-0.773	**-1.824**	0.951	0.665	0.599	-0.491	-0.472
O3*	-0.327	-0.382	-0.168	-0.183	0.053	0.025	**-2.807**	**-2.732**	**-2.789**
AT	0.289	0.607	0.432	-0.435	**-1.057**	**-1.355**	-0.312	-0.353	-0.435
PR*	**-1.000**	**-1.028**	**-1.294**	-0.725	0.621	0.586	-0.198	0.368	0.312
PRGI*	**1.129**	-0.004	0.339	-0.329	**1.144**	**1.229**	-0.623	0.370	0.333

(*)The sign of the contribution is reversed due to the negative lambda value of the Box-Cox transformation.

Crown transparency, deposition, ozone and meteorology

The TC dataset includes the C-set one plus crown transparency and covers the years from 1999 to 2005. With respect to Mahalanobis distance, 15 outliers were identified (Figure 7). They were CAL1 (all years), EMI1 (all years), EMI2 (all years), LAZ1 (2005), PIE1 (2003), TOS1 (2004), and TRE1 (all years). With the exception of EMI1 and PIE1, plots are the same identified by the previous analysis. In addition to the likely factors already identified, changes appeared due to CT (reduced at CAL1, increased at EMI1), changes in PR (all), changes in DepoN (particularly at EMI2 and PIE1), a generalized decrease of DepoS (all plots, except CAL1), a generalized increase of O_3 (all plots) (Table 3).

A three-linear model where 2 components explain 80.45% of the variance was identified by the PARAFAC. These two components are reported in Figure 8. The subsequent PCA analysis identified two datapoints displaying high Q values, the plots EMI2 at yr 2001 and TOS1 at yr 2002. High Q values seemed caused by low O_3 (both plots) and low DepoH+ at TOS1. When considering the evaluation set (2003-2005 data), several deviations were observed, with two datapoints displaying high T^2 values and nine with high Q values (Figure 9). Most deviations were concentrated on three plots: EMI2 (2003, 2004, 2005), TRE1 (2003, 2004, 2005) and PIE1 (2003, 2005).

Overall, high O_3 was reported to be a significant factor in 9 out of the 11 deviations identified. The only two cases in which O_3 was not involved were EMI1 in 2005 and TOS1 in 2004. Note, however, that these two cases were very close to the limit of the statistical significance.

In the other cases, high O_3 was always reported as a significant factor leading to deviations: it contributed

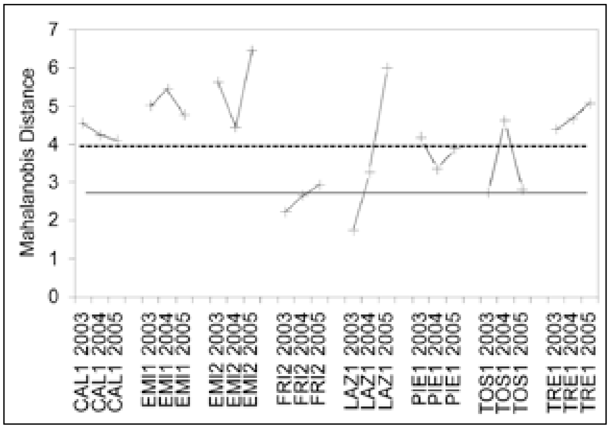

Figure 7 - Mahalanobis distance, TC-set, 2003-2005. The solid line indicates the mean distance from the centroid of the 1999-2002. The dashed line indicates 2 times S.
Distanza di Mahalanobis, set TC, anni 2003-2005. La linea intera indica la distanza media dal centroide 1999-2002. La linea tratteggiata indica due volte S

to high T^2 for EMI2 at 2003 and 2004, and to high Q values for most of the remaining plot/year combinations (Table 6).

As far as the role of the other variables is concerned, low CT had a role at EMI2 and LAZ1 in 2005, while high value was reported for EMI2 in 2003. Low DepoS contributed to high T^2 values at EMI2 and high Q values at EMI1. DepoN contribution was due to high values at EMI1 and PIE1, and low values at EMI2. Low DepoH was reported for EMI2 and TOS1, while high AT (EMI2 and LAZ1 in 2005), low PR (PIE1 2005, TRE1 2004, 2005) and low PRGI (TRE1 2004, 2005) were identified as causing changes in the correlation structure of the variables. Reduced PR and PRGI were reported for PIE1 and TRE1.

Discussion

When discussing the results, it is worthwhile to remind that the terms "change" and "deviation" do

Table 6 - Normalized contribution for each variable in case of deviation for the TC-data set. Variables that exceeded the value of 1 (in bold) have a significant contribution to the statistic considered.
Contributo normalizzato di ciascuna variabile nei casi di deviazione nel set TC. Le variabili per cui viene superato il valore di 1 (in grassetto) hanno un contributo significativo alla statistica considerata.

	T2		Q								
Indicator	**EMI2 _03**	**EMI2 _04**	**EMI1 _05**	**EMI2 _05**	**PIE1 _03**	**PIE1 _05**	**LAZ1 _05**	**TOS1 _04**	**TRE1 _03**	**TRE1 _04**	**TRE1 _05**
CT	**1.299**	0.810	0.595	**-1.617**	-0.605	-0.120	**-1.664**	-0.294	-0.634	-0.682	-0.672
DepoN	**-2.120**	**-1.998**	**1.461**	0.287	**1.526**	**1.235**	0.442	0.538	0.962	0.765	0.912
DepoS	**-1.358**	**-1.480**	**-1.076**	0.396	-0.255	-0.576	0.293	0.684	0.461	0.383	0.566
DepoH+	**-1.098**	-0.761	-0.733	-0.884	0.299	0.573	0.832	**-1.813**	0.474	**1.069**	0.783
O3*	**-1.573**	**-1.499**	-0.419	**-1.534**	**-2.343**	**-1.689**	**-2.334**	-0.445	**-2.208**	**-2.245**	**-2.382**
AT	0.187	-0.371	-0.412	**1.476**	-0.106	-0.302	**1.194**	-0.246	-0.487	-0.376	-0.595
PR*	-0.078	-0.422	0.622	-0.637	0.847	**1.314**	0.023	-0.731	0.824	**1.050**	0.987
PRGI*	0.728	0.354	-0.651	-0.634	0.556	0.169	0.710	-0.343	0.950	**1.129**	**1.202**

(*)The sign of the contribution is reversed due to the negative lambda value of the Box-Cox transformation.

not imply any positive or negative value judgement. It is the reason behind that makes a change/deviation "good" or "bad", "desirable" or "not desirable".

The evaluation of the biological status (as defined by the crown transparency and basal area increment) identified 3 plots with a significant change and 4 with significant deviations. These plots are UMB1, SIC1 and VEN1 (change and deviation), plus SAR1 (deviation only) (Figure 1, Table 3). Changes and deviation were due for the most part to the reduction in growth observed over the period 2000-2004 especially in the intermediate layer (see Fabbio *et al.*, this volume). This seems to reflect internal stand dynamics: two plots were oak dominated transitory crops (UMB1 and SIC1) and one was a stored coppice (SAR1). The fourth one (VEN1) was a 130 yrs old beech high forest. It is worth noting that, due to the timing of growth data, the evaluation was carried out on data averaged over 3 and 5 years and this may have smoothed the occurrence of change/deviations episodes over these periods.

Most instances of change/deviations were reported for the C and TC datasets (Figures, 4, 7; Table 5, 6). It is therefore interesting to search for regularities in terms of plots concerned, attributes involved, nature of deviations, and timing of the events.

Plots

Many significant changes were observed, but they were particularly frequent on 3 plots: CAL1, EMI2, and TRE1 (see Figure 4 and 7). On the other hand, deviations concentrated again on TRE1 and - to a lesser extent - on EMI2 (Table 5, 6). Although there were several other instances of significant/change deviations, these plots seemed the ones for which findings were particularly consistent.

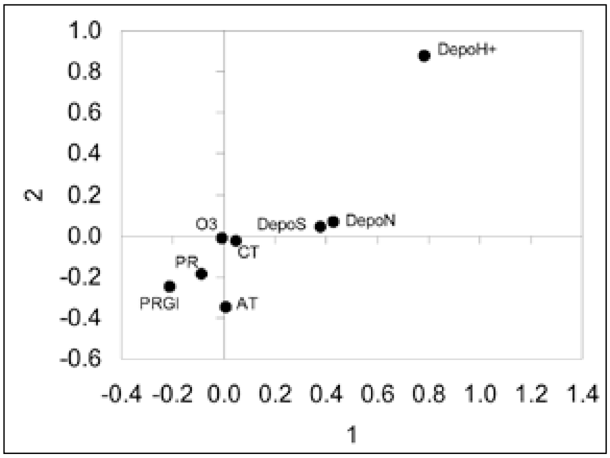

Figure 8 - TC-set, 1999-2002, PARAFAC. The first two PCs explained 80.45% of the variance.
Set TC, 1999-2002, PARAFAC. Le prime due PC spiegano l'80.45% della varianza.

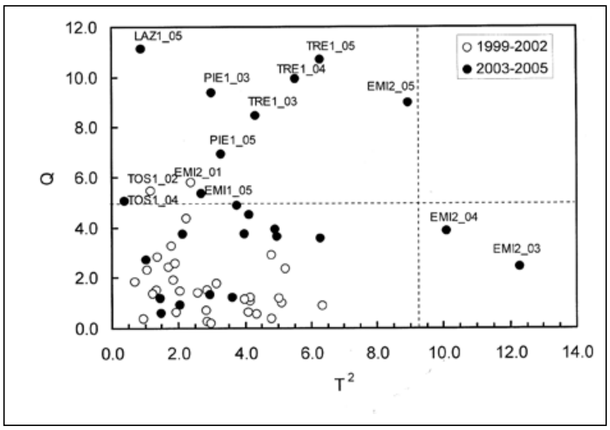

Figure 9 - Datapoints of the TC-set within the T^2-Q diagram. The dashed lines indicate the critical values at p=0.05. Only datapoints having at least one diagnostic at $p<0.05$ are labelled with the plote code.
Dati del set TC plottati nel diagramma T^2-Q. Le linee tratteggiate indicano il livello di significatività per p=0.05. Solo i dati che mostrano almeno un criterio diagnostico eccedente il livello di significatività sono indicati con il nome dell'area.

TRE1 is a 180-200 yrs-old Norway spruce plot located at 1775 m a.s.l. in Northern Italy. With respect to 1999-2002 period, the main signals apparent from the data 2003 - 2005 were:

- a reduction in PR and PRGI (-35%, see also Amoriello *et al.*, this volume), accompanied by a reduction in S deposition (-49%, see also Mosello *et al.*, this volume), that reached its minimum in 2004-2005. Reductions in AT were also reported;
- an increase in O_3 concentrations (+29%, see also Mangoni and Buffoni, this volume) and - to a lesser extent - in DepoH+ (Marchetto *et al.*, this volume).

While most of the signals were consistently identified by the T^2 and Q statistics, O_3 was by far the most clear one (Table 5, 6). Interestingly enough, despite the reduction in precipitation and an increase in O_3, an improvement of CT and an increase of annual BAI were reported for the upper canopy layer (+27%, see Table 3 and Fabbio *et al.*, this volume). In particular, over the investigated period, CT peaked in 2001 (CT=17%) and reached its minimum in 2005 (CT=12%),

EMI2 is located in a 45 yrs-old beech stored coppice at 975 m a.s.l. on the Apennines mountains in central Italy. Several changes were reported for this plot: on the average, a decrease in throughfall of S, N and H was obvious with values being reduced by 40-60%. Alongside, a significant increase in O_3 concentration (+28%) (Mangoni and Buffoni, this volume) and a net increase in annual precipitation (+26%) were reported. Over the same period, crown transparency peaked in 2003 (mean plot value: 33%), at the time with the lowest precipitation during the growing season (302 mm between April and September). Later on, a significant improvement in crown transparency was obvious, with minimum values of 7% reached in 2005 (see Bussotti *et al.*, this volume), a year characterized by relatively higher precipitation and cooler weather conditions. Note that crown transparency signals in 2003 and 2005 were recorded and identified also by the T^2 and Q statistics for this site (Table 6). Together with stand dynamics, increased precipitation can be considered likely factors leading to improved crown condition and augmented growth of the intermediate and dominant storey in this plot (+38% as compared to the 1997-1999 period) (see Table 3 and Fabbio *et al.*, this volume).

Attributes

When considering the attributes most involved in determining change/deviations, three of them showed some regularity: O_3, DepoS and PRGI. Ozone was by far the most frequent, the most consistent in direction, and with the highest scores: high O_3 values were reported for most of the investigated plots, thus contributing to significant changes/deviations from the expectations (Table 5, 6). Low values of DepoS were identified as causing high T^2 and Q values, the only exception being the site CAL1. Low values of PRGI causes high Q statistics at TRE1 and CAL1. Several other attributes were mentioned, but their role and direction were much less consistent and variable among plot and years and according to the dataset considered.

Nature

Nature of deviations reported can be discussed in relation to the T^2 and Q statistics: significant Q values were much more frequent - in terms of plot-years-attribute combinations - that significant T^2 (Table 4, 5, 6). It means that most deviation were due to events that break the expected correlation process, rather then to extreme values of the attribute. All attributes were reported to cause significant Q values. On the contrary, high T^2 values were reported for 3 plots only (EMI2, PIE1 and TRE1) and were due to 4 attributes, with DepoS, and O_3 being the most frequent. In particular, unexpected high values were always reported for O_3, and unexpected low values for DepoS.

Timing

As far as the timing of the observed change/deviations, there is no clear pattern. They were distributed on the 2003-2005 period according to the plot: some plots (*e.g.*. LAZ1, TOS1, and PIE1) showed change/deviations as single spots in different years (2005, 2004, 2003, respectively). Others, like CAL1, EMI2, TRE1 showed significant change/deviations across all the three years. All together, these findings suggest that - with very limited exceptions - there were only few common features in the detected changes and deviations. This support the need of evaluating the plots as individual case-studies, especially for cause-effect investigations.

Conclusions

Different attributes of biological, chemical and physical status of the CONECOFOR plots were considered to investigate changes in their recent condition when compared to the condition at the beginning of the monitoring programme. On the average, significant changes in the biological status, as defined by crown transparency and basal area increment, in the period 2000-2004 are limited to few plots and are driven by a slight decrease of crown transparency and a decrease of growth, especially in the dominated and intermediate layers. Most of the detected changes/deviations were detected when considering the physical and chemical attributes of the plots. Some few regularities existed and concerned the plots (most deviation concentrated on few plots), attributes (unexpected high values reported for O_3 and unexpected low values for DepoS) and nature of change/deviations (for the most part due to a change in the expected correlation structure). However, there was a considerable variation between plots, attributes involved and timing of change/deviations. When considered together with the results presented in individual papers of this volume, these findings emphasise the need to evaluate the data at the plot level and this indicate the importance of obtaining a time series long enough to enable plot-wise integrated analysis.

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Status and change of key ecosystem attributes monitored at the CONECOFOR plots, 1995 - 2005 - Achievements, problems, perspectives

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Abstract – The 1995-2005 time series obtained from the original set of 20 plots have been recently analysed in the framework of the Integrated and Combined (I&C) evaluation system of the programme. In this paper, results obtained, problems encountered and future perspectives are summarized.

Key words: *CONECOFOR, forests, Italy, monitoring.*

Riassunto – Stato e cambiamenti di attributi-chiave monitorati nelle aree CONECOFOR, 1995-2005. Risultati, problemi, prospettive. Recentemente è stata analizzata la serie di dati 1995-2005 ottenuta dalle prime 20 aree permanenti installate nell'ambito del programma CONECOFOR. L'articolo riassume i risultati principali, i problemi incontrati e le prospettive future.

Parole chiave: *CONECOFOR, foreste, Italia, monitoraggio.*

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Introduction

The CONECOFOR programme includes 31 forest permanent monitoring plots (PMPs) located throughout Italy, with the first 20 ones installed in 1995. Since then, a number of attributes related to the biological, chemical and physical compartments of the concerned forest ecosystems were measured at the PMPs (Ferretti *et al.* 2008, this volume). Routine measurements included tree condition, tree growth, forest structure, plant species diversity, foliar nutrition, deposition chemistry, ambient ozone, meteorology. On a less regular basis also soil chemistry, other gaseous air pollutants, deadwood, forest invertebrates, and landscape features were measured. Most of the 1995-2005 time series obtained from the original set of 20 plots were studied and presented in this report (see Amoriello and Costantini 2008; Bussotti *et al.* 2008; Campetella *et al.* 2008; Fabbio *et al.* 2008; Ferretti *et al.* 2008; Mangoni and Buffoni 2008; Marchetto *et al.* 2008). The report was generated after intensive discussion and by sharing concepts and methods between the various investigators and the National Focal Center. It was first launched in 2005 and subsequently implemented through a close co-operation between the various partners. Thus, the studies presented in the report offered the unique opportunity to provide information about a number of measured attributes related to important forest and environmental themes: forest health and productivity (with a clear link to C-stocks and C-sequestration), biological diversity, air pollution and climate. All of these themes are of high importance also from a political point of view, as they are relevant to international conventions and European directives: the UN/ECE Convention on Long-Range Transboundary Air Pollution, the UN Convention on Biodiversity, the Kyoto protocol, the Ministerial Conference on the Protection of Forests in Europe, the EU Air Quality Directive. After 10 years of intensive monitoring, it is therefore time to summarize the information achieved, the problems identified and future perspectives.

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Achievements

Long-term monitoring data and ecological research

The progress of the monitoring activity on the CONECOFOR plots was reported by Petriccione (2008, this volume). CONECOFOR is probably the Italian ecological monitoring programme with the widest ecological coverage and the longest data-series. Although most scientists are inclined to consider monitoring much less attractive than research, it is worth noting that the monitoring data collected by CONECOFOR programme has allowed and will allow long-term ecological research that will be impossible otherwise. Monitoring is not research, but long-term forest research is based on systematic and organized data collection, that is monitoring.

Long-term monitoring needs documented data quality

Within the CONECOFOR, a considerable effort has been made for implementing proper QA/QC procedures. As it is obvious from the various papers of this report, personnel were subject to training and labs participated to international ring tests. In most cases, internal consistency of data and the benefits arising from continuous training can be documented.

Long-term monitoring provides evidence of change

Table 1 and Table 2 summarize the observed

Table 1 - Occurrence and direction of significant trends at each plot and for the different variables considered. Variables are categorized in relation to their areas of concern. The time frame investigated is also reported.
Evenienza e direzione delle tendenze significative per area e per ciascuna variabile considerata. Le variabili sono divise in categorie secondo l'area di interesse. Viene riportato l'ambito temporale indagato.

Areas of concern	Indicator	Time frame					PLOT					
			ABR1	BAS1	CAL1	CAM1	EMI1	EMI2	FRI1	FRI2	LAZ1	LOM1
Health and productivity	*BAI*	1997-2004	-	+	+	-	-	+	-	-	-	-
	Crown transparency	1996-2005	ns	ns	ns	-	+	ns	+	ns	ns	ns
	Species richness	1999-2005	ns		ns	+	ns		+		-	ns
Diversity	*Nitrophilous species, n*	1999-2005	ns		ns	+	ns		+		ns	ns
	Acidophilous species, n	1999-2005	-		ns	+	ns		ns		ns	ns
	H$^+$ Deposition	1998-2005			+	ns	ns	ns		ns	ns	-
	SO$_4$ Deposition	1998-2005			-	-	-	-		-	-	-
Air pollution	*N-NO$_3$ deposition*	1998-2005			+	ns	ns	ns		ns	ns	-
	N-NH$_4$ deposition	1998-2005			+	ns	ns	+		ns	ns	-
	Ca+Mg deposition	1998-2005			ns	-	ns	ns		ns	ns	-
	Ozone concentration	1996-2005		+	+	+	ns	+	ns	ns	+	+
	Air Temp	1996-2005*	ns		-		ns	ns		ns	ns	
	Precipitation	1996-2005*	ns		+		ns	ns		ns	ns	
Climate	*N_Pr*	1996-2005*	ns		+		ns	ns		-	ns	
	GPRI	1996-2005*	ns		ns		ns	ns		ns	ns	

Areas of concern	Indicator	Time frame					PLOT					
			MAR1	PIE1	PUG1	SAR1	SIC1	TOS1	TRE1	UMB1	VAL1	VEN1
Health and productivity	*BAI*	1997-2004	-	-	ns	-	-	-	+	-	ns	-
	Crown transparency	1996-2005	-	+	ns	ns	ns	-	ns	-	ns	ns
	Species richness	1999-2005	ns					ns			ns	+
Diversity	*Nitrophilous species, n*	1999-2005	ns					ns			ns	
	Acidophilous species, n	1999-2005	ns					ns			ns	
	H$^+$ Deposition	1998-2005		-				-	+			
	SO$_4$ Deposition	1998-2005		-				-	-			
Air pollution	*N-NO$_3$ deposition*	1998-2005		ns				ns	ns			
	N-NH$_4$ deposition	1998-2005		ns				-	ns			
	Ca+Mg deposition	1998-2005		ns				ns	-			
	Ozone concentration	1996-2005	ns	+	ns	+	ns	+	+	+	ns	+
	Air Temp	1996-2005*		ns				+	ns		ns	ns
Climate	*Precipitation*	1996-2005*		ns				ns	ns		ns	ns
	N_Pr	1996-2005*		ns				ns	ns		ns	ns
	GPRI	1996-2005*		ns				ns	-		ns	ns

ns: not significant
+: significant increase
-: significant decrease
in case of BAI: changes >10% with respect to 1997-99 (dominant layer)
empty spaces: data not available
(*) see details in Amoriello and Costantini, 2008 (this volume)

Table 2 - Synthesis of the methods adopted and the results obtained by the various trend analyses carried out.
Sintesi dei metodi e dei risultati delle varie analisi di tendenza effettuate.

Areas of concern	Indicator	Time frame	n	Statistical method	Significant increase	Significant decrease	Not significant change
Health and productivity	*BAI**	1997-2004	20		4	14	2
	Crown transparency	1996-2005	20	Friedmann+linear model	3	4	13
	Species richness	1999-2005	11	Repeated Measures ANOVA	3	1	7
Diversity	*Nitroph. species, n*	1999-2005	11	Repeated Measures ANOVA	0	2	8
	Acidoph. species, n	1999-2005	11	Repeated Measures ANOVA	1	1	8
	H^+ deposition	1998-2005	10	Seasonal Kendall test	2	3	5
	SO_4 deposition	1998-2005	10	Seasonal Kendall test	0	10	0
Air pollution	*N-NO_3 deposition*	1998-2005	10	Seasonal Kendall test	1	1	8
	N-NH_4 deposition	1998-2005	10	Seasonal Kendall test	2	2	6
	Ca+Mg deposition	1998-2005	10	Seasonal Kendall test	0	3	7
	Ozone concentration	1996-2005	19	Mann-Kendall+Sen	12	0	7
	Air Temp	1996-2005**	11	Seasonal Kendall test	1	1	9
Climate	*Precipitation*	1996-2005**	11	Seasonal Kendall test	1	0	10
	N_Pr	1996-2005**	11	Seasonal Kendall test	1	1	9
	GPRI	1996-2005**	11	Seasonal Kendall test	0	1	10

(*) changes >10% with respect to 1997-99 (dominant layer)
(**)see details in Amoriello and Costantini, 2008 (this volume)

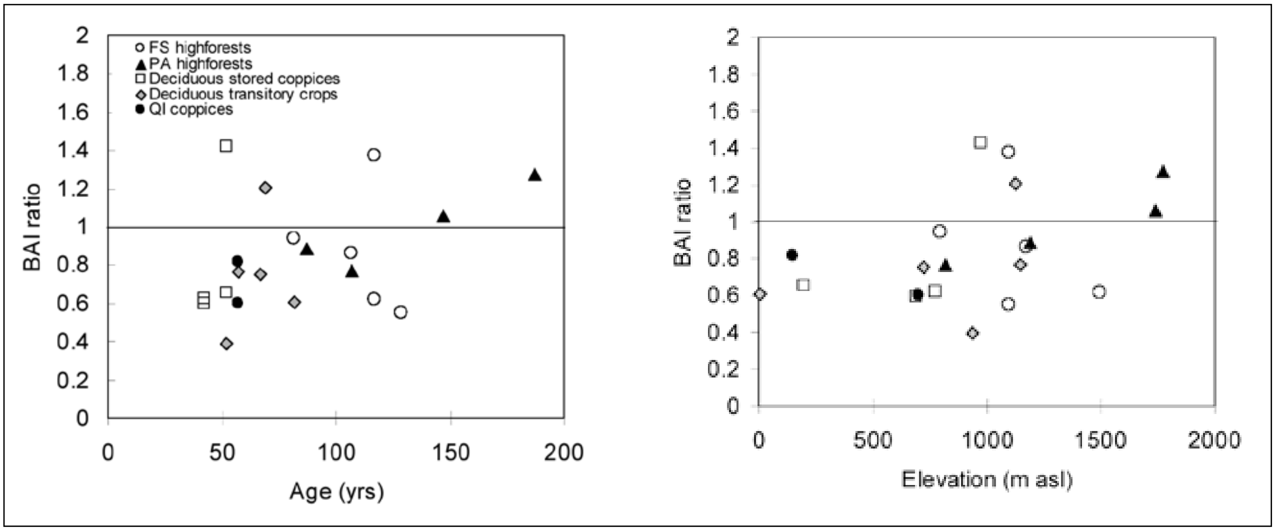

Figure 1 - Ratio between BAI 2000-04 and BAI 1997-99 in the dominant layer (original data in % of 1997 BA) plotted against age (left) and elevation (right). FS: *Fagus sylvatica*; PA: *Picea abies*; QI: *Quercus ilex*. Deciduous stored coppices and transitory crops included plots with different main tree species, with *Quercus cerris* being the most frequent one.
Rapporto tra l'incremento di area basimetrica annuale medio 2000-04 e quello 1997-99 nel piano dominante (i dati originali erano espressi come incremento % rispetto all'area basimetrica 1997) riportato in funzione dell'età (sx) e della quota (dx). FS: Fagus sylvatica*; PA:* Picea abies*; QI:* Quercus ilex. *I cedui invecchiati e in avviamento decidui comprendono aree con specie principali diverse. Il cerro è la specie rappresentata più di frequente.*

changes over the 1995-2005 period as reported by the individual papers in this volume. Although the allocation of the various investigations to the monitoring plots was not always satisfactory (*e.g.* FERRETTI *et al.*, 2000, 2003, 2006), some features emerged from the reported data.

First, a marked decrease of annual basal area increment (BAI) in the period 2000-04 as compared to 1997-99 was reported for the majority of plots (FABBIO *et al.* 2008, this volume). Reduction of growth in the dominated and intermediate layers was driven by overstocking in most of cases (FABBIO *et al.*, this volume). However, a distinct decrease of growth was obvious also in the dominant layer, and this might be less influenced by internal dynamics. Figure 1 reports the changes in BAI measured between the 1997-99 and 2000-04. Data are reported in % of the 1997 basal area. The higher BAI reductions occurred on deciduous stored coppices and on transitory crops, and at elevation < 1000 m a.s.l.. At higher elevation, growth reduction was obvious only for two beech plots (ABR1 and VEN1). As already reported, the beech transitory crop EMI2 showed a complete different pattern.

Second, a significant decrease of SO_4 deposition in throughfall was reported for all the plots (Marchetto *et al.*, this volume) (Table 2; Figure 2).

Third, a significant increase of ozone was reported for most of the plots (in the remaining there was an increase but it was not significant) (Mangoni and Buffoni, this volume) (Table 2; Figure 2).

These results were confirmed by the integrated analysis (Ferretti *et al.* 2008, this volume). They suggested that a shift in the climate pollution has been already occurred at many PMPs. These data will be explored further to figure out possible explanation for growth reduction observed on many plots.

Long-term monitoring results and implication for cause-effect studies

Available results revealed limited consistency in terms of timing of changes among attributes within a plot, and for the same attribute among plots. Crown transparency, species richness, deposition of H^+, NO_3, NH_3 and Ca+Mg, precipitation and temperatures were found to have different direction of change among the PMPs (Bussotti *et al.* 2008; Campetella *et al.* 2008; Marchetto *et al.* 2008; Amoriello and Costantini 2008; all this volume). This was also reflected by the integrated analysis (Ferretti *et al.* 2008, this volume) that showed how unexpected plot condition have few regularities in terms of timing and attributes being involved. These are clear indications that future cause-effects studies should be carried out on a plot basis.

Problems

Evidence of environmental issues of concern

Figure 2 reported SO_4 and O_3 concentrations (in open field precipitation and air) over the period 1996-2005 as averaged over the PMPs. As already reported, there is a clear change in the pollution climate, with a steady decrease of sulfate and a steady increase of ozone. While in the 1970s and 1980s sulphur was the major concern for the potential effects on forest ecosystems, our data support various other findings across the world that identify tropospheric ozone as the most important and growing pollutant to be considered as for the condition of vegetation. However, ozone effects on vegetation are not only dependent on the ozone levels in the atmosphere: a number of environmental factors may reduce or enhance the ozone uptake by vegetation and detoxification processes can also defend the plants from ozone. Future monitoring should consider these new evidence.

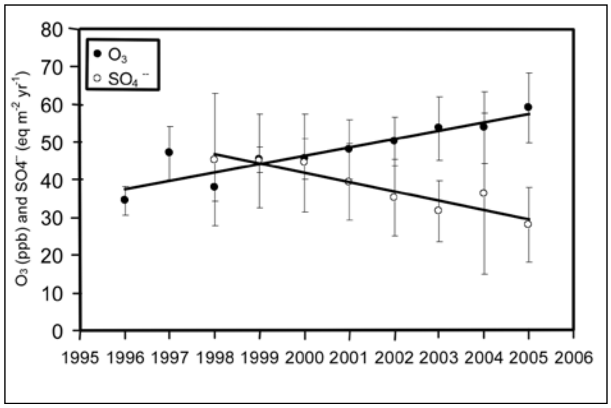

Figure 2 - Time trend of Ozone concentration and non-marine sulphate deposition over the period 1996-2005. Error bars indicate the standard deviation between plots.
Tendenza temporale delle concentrazioni di Ozono e della deposizione di solfati non marini nel periodo 1996-2005. Le barre di errore indicano la deviazione standard tra le aree.

Programme weaknesses

CONECOFOR is the only long-term multidisciplinary forest programme and its importance as a major source of data about various key attributes of ecosystem should be acknowledged. However, as reported in previous papers, it suffers some limitations. The most important are the total number of the PMPs and the way investigations were allocated to the PMPs: they cause several constrains for a complete evaluation. The combination of PMPs and investigations led to several gaps for the integrated analysis: for example data about species diversity (Canullo *et al.*, this volume) were not considered in the integrated evaluation. They were not included in the biological data set because they were available, on a consistent basis, only for a subset of sites after the year 1999. In this case, their incorporation in the analyses would have resulted in a reduction of about 50% of the total number of cases with a consequent limitation for the analysis. In addition, they were not included in the TC dataset because they do not always overlap with the sites where deposition and meteo are measured. As reported in other reports of this series, every effort should be placed in the future to avoid intermittent monitoring and to ensure the widest possible coverage of the investigations.

Inconsistencies

Inconsistency is always a major risk for long-term data. Changes in personnel, methods, reference standards, location of measurements can jeopardize monitoring results. Although most of the investigations gave considerable importance to QA/QC, some problems may have occurred. For example, in response to changes happened at international level, the manual of crown condition assessment underwent considerable changes in the years 1998 and 2003, and this caused the interruption of data series for different attributes.

Changes in personnel within the field crews may have caused problems in time consistency of those data derived from visual estimates *(e.g.* crown condition, species diversity). However, QC reported a continuous increase in the frequency of data within the accepted Data Quality Limits and this is a clear example of the benefits arising from a continuous QA/QC.

In some few cases, the location of measurements has changed. For example, this has occurred for ozone (see Mangoni and Buffoni 2008, this volume), and it has caused a loss of information at the concerned sites.

Perspectives

CONECOFOR was designed as a network for long-term forest monitoring, but its value for ecological research is now obvious. After having collected baseline data on the status of different ecosystems compartments, the programme has shown the potential for the detection of changes occurring in the various plots. In particular, the future I&C evaluation will investigate the questions related to Nitrogen deposition, an issue which has received considerable attention in relation to its possible effect on the C-sink potential of forests (*e.g.* Magnani *et al.*, 2007; De Vries *et al.*, 2006).

A more general perspective is that data series are now becoming long enough to allow plot-wise multivariate analysis. This will render the findings less subject to the noise arising by comparing different case-studies as the plots of the programme actually are.

Several changes are likely to occur in the future of the programme. On one hand, the recent formal participation in the ILTER and other international monitoring and research initiatives are important in that they allow to broaden the programme vision. In addition, the envisaged linkages with the Level I network and the National Forest Inventory will provide added value to the CONECOFOR network. On the other hand, the termination of the EU Regulations supporting the forest monitoring may cause some risks to the long-term sustainability of the programme.

Conclusions

The data collected over the 1995-2005 period at the CONECOFOR permanent plots demonstrated the potential of long-term monitoring programmes. Already after 10 yrs of monitoring it was possible to detect changes in key attributes linked to forest health, diversity and productivity. Distinct changes were detected for the pollution climate at the sites and for forest growth. Other changes appeared much more site specific and results do not allow general statements. In the near future, data analysis will be designed and implemented plot-wise and this will render the findings more robust as they will be less impacted by the inherent source of variation caused by comparing different case-studies.

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