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	*$N\text{-}NO_3$ deposition*	1998-2005	10	Seasonal Kendall test	1	1	8
	$N\text{-}NH_4$ 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)

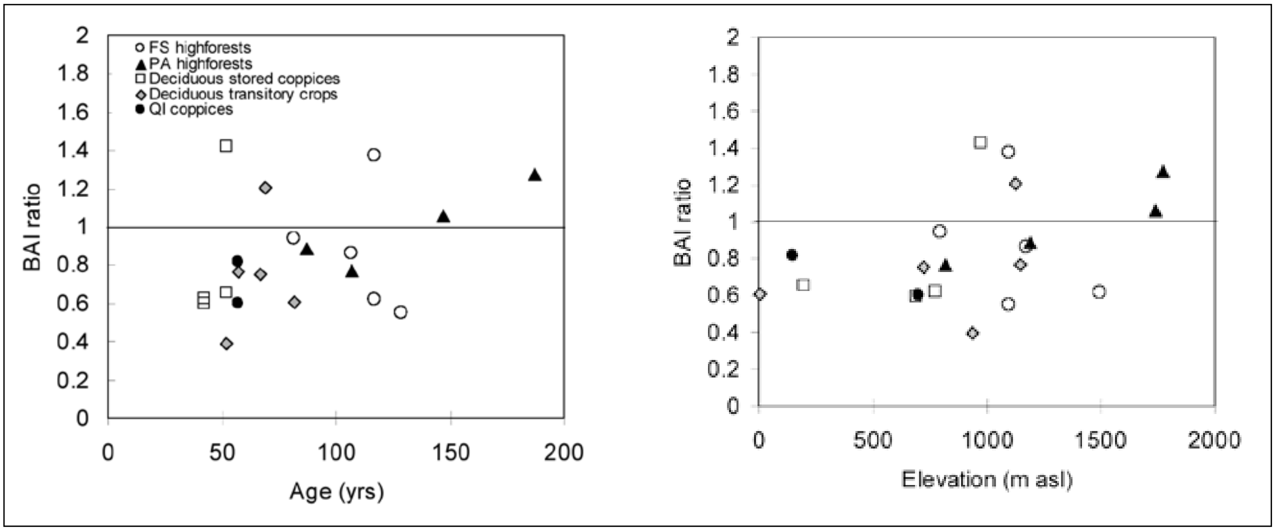

Figure 1 - Ratio between BAI 2000-04 and BAI 1997-99 in the dominant layer (original data in % of 1997 BA) plotted against age (left) and elevation (right). FS: *Fagus sylvatica*; PA: *Picea abies*; QI: *Quercus ilex*. Deciduous stored coppices and transitory crops included plots with different main 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.

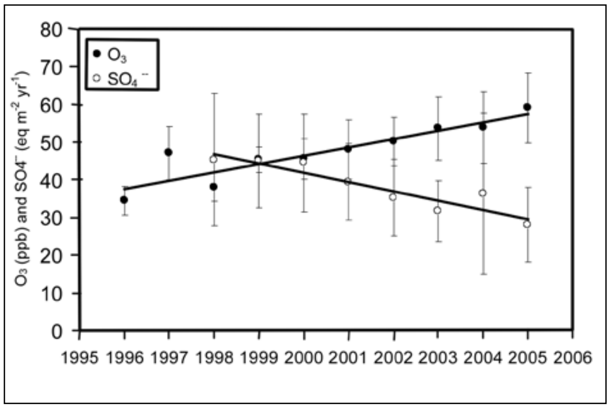

Figure 2 - Time trend of Ozone concentration and non-marine sulphate deposition over the period 1996-2005. Error bars indicate the standard deviation between plots.
Tendenza temporale delle concentrazioni di Ozono e della deposizione di solfati non marini nel periodo 1996-2005. Le barre di errore indicano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