

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

Filippo Bussotti^{1*}, Marco Calderisi², Enrico Cenni¹, Alberto Cozzi¹, Davide Bettini¹, Marco Ferretti²

Accepted 5 October 2007

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 la 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.*

F.D.C. 572.1:572.2:524.634

Introduction

Crown conditions are currently evaluated in international monitoring programmes, aimed at assessing the conditions of individual trees and forests, both in North America (MC LAUGHLIN 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-

¹ Dipartimento di Biologia Vegetale, Università di Firenze. Piazzale delle Cascine 28, 50144 Firenze (Italy).

² Current address: TerraData environmetrics, Siena (Italy).

* Corresponding author: filippo.bussotti@unifi.it

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	<i>Fagus sylvatica</i> L.	30	100%
02BAS1	1996	<i>Quercus cerris</i> L.	31	94%
03CAL1	1996	<i>Fagus sylvatica</i> L.	32	100%
04CAM1	1996	<i>Fagus sylvatica</i> L.	30	100%
05EMI1	1996	<i>Quercus petraea</i> (Matt.) Liebl.	30	70%
06EMI2	1996	<i>Fagus sylvatica</i> L.	30	97%
07FRI1	1996	<i>Carpinus betulus</i> L.	32	72%
08FRI2	1996	<i>Picea abies</i> Karst.	30	100%
09LAZ1	1996	<i>Quercus cerris</i> L.	33	100%
10LOM1	1996	<i>Picea abies</i> Karst.	30	60%
11MAR1	1996	<i>Quercus cerris</i> L.	31	87%
12PIE1	1996	<i>Fagus sylvatica</i> L.	30	87%
13PUG1	1996	<i>Fagus sylvatica</i> L.	32	94%
14SAR1	1996	<i>Quercus ilex</i> L.	30	100%
15SIC1	1996	<i>Quercus cerris</i> L.	30	100%
16TOS1	1996	<i>Quercus ilex</i> L.	30	100%
17TRE1	1996	<i>Picea abies</i> Karst.	31	100%
18UMB1	1996	<i>Quercus cerris</i> L.	32	94%
19VAL1	1996	<i>Picea abies</i> Karst.	31	100%
20VEN1	1996	<i>Fagus sylvatica</i> L.	31	100%
23LOM2	1999	<i>Picea abies</i> Karst.	22	100%
24LOM3	1999	<i>Fagus sylvatica</i> L.	28	100%
25TOS2	1999	<i>Quercus ilex</i> L.	28	100%
26TOS3	1999	<i>Fagus sylvatica</i> L.	28	100%
27BOL1	2000	<i>Picea abies</i> 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 $\pm 10\%$ 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 $[y = b_0 + b_1x]$, where: x = year; y = (i) annual mean values and/or (ii) annual percentage of trees exceeding the 25% transparency threshold; b_0 and b_1 = 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

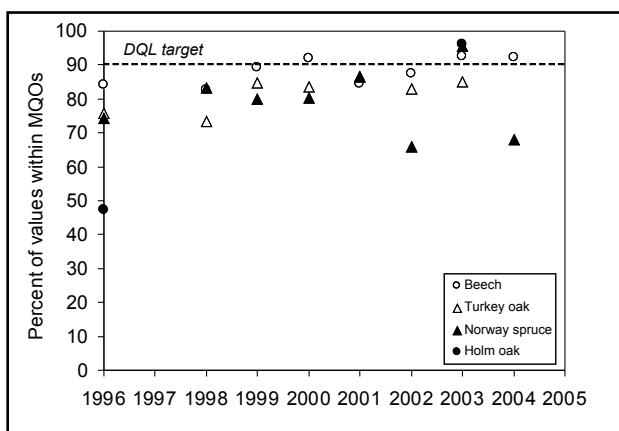


Figure 1 – Quality of crown transparency data over the period 1996-2004 for the main tree species. MQOs: Measurement Quality Objectives ($\pm 10\%$ of reference value); DQL: Data Quality Limit.

Qualità dei dati della trasparenza della chioma nel periodo 1996-2004, per le specie principali. MQOs: obiettivi di qualità delle misure ($\pm 10\%$ 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
<i>Fagus sylvatica</i>									
01ABR1									
03CAL1									
04CAM1									
06EMI2									
12PIE1									
13PUG1									
20VEN1									
24LOM3									
26TOS3									
<i>Deciduous oaks</i>									
02BAS1									
05EMI1 sp41									
05EMI1 sp48									
09LAZ1									
11MAR1									
15SIC1									
18UMB1									
<i>Quercus ilex</i>									
14SAR1									
16TOS1									
25TOS2									
<i>Picea abies</i>									
08FRI2									
10LOM1									
17TRE1									
19VAL1									
23LOM2									
27BOL1									
<i>Carpinus betulus</i>									
07FRI1									

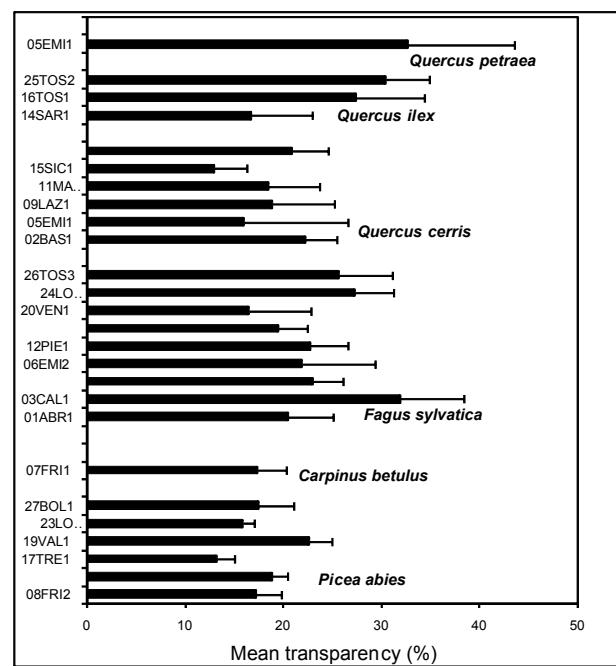


Figure 2 – Mean crown transparency (1996-2004 period) for the various plots. The main tree species is reported for each group of plots. Error bars represent the standard deviation.

Trasparenza media della chioma (1996-2004) nelle diverse aree. La specie principale 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.

	n	A. Crown transparency		B. Trees with transp. $>25\%$	
		slope	p	slope	p
<i>Fagus sylvatica</i>					
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				
<i>Deciduous oaks</i>					
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
<i>Quercus ilex</i>					
14SAR1	10			-	<0.05
16TOS1	10	-	<0.01	-	<0.01
25TOS2	7	-	<0.1	-	<0.01
<i>Picea abies</i>					
08FRI2	10				
10LOM1	10			+	<0.01
17TRE1	10				
19VAL1	10				
23LOM2	7				
27BOL1	6	-	<0.1		
<i>Carpinus betulus</i>					
07FRI1	10	+	<0.01		

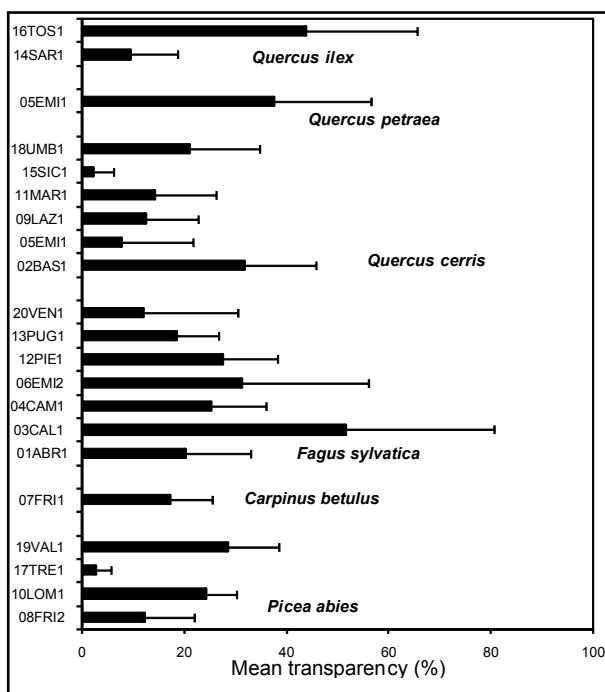


Figure 3 – Mean frequency of trees with crown transparency >25% (1996-2004 period) for the various plots. The main tree species is reported for each group of plots. Error bars represent the standard deviation.

Frequenza media degli alberi con trasparenza della chioma >25% (1996-2004) nelle diverse aree. La specie principale 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; EICHORN *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; MATYS-SEK 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 KLAPE *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.

Acknowledgements

This paper was prepared within the contract between the Ministry for Agriculture and Forestry Policy - National Forest Service (co-ordinator of the CONECOFOR Program, National Focal Centre - Italy)

and the Department of Plant Biology, University of Florence, Italy. We are grateful to all the surveyors for their valuable work in the field.

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