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.

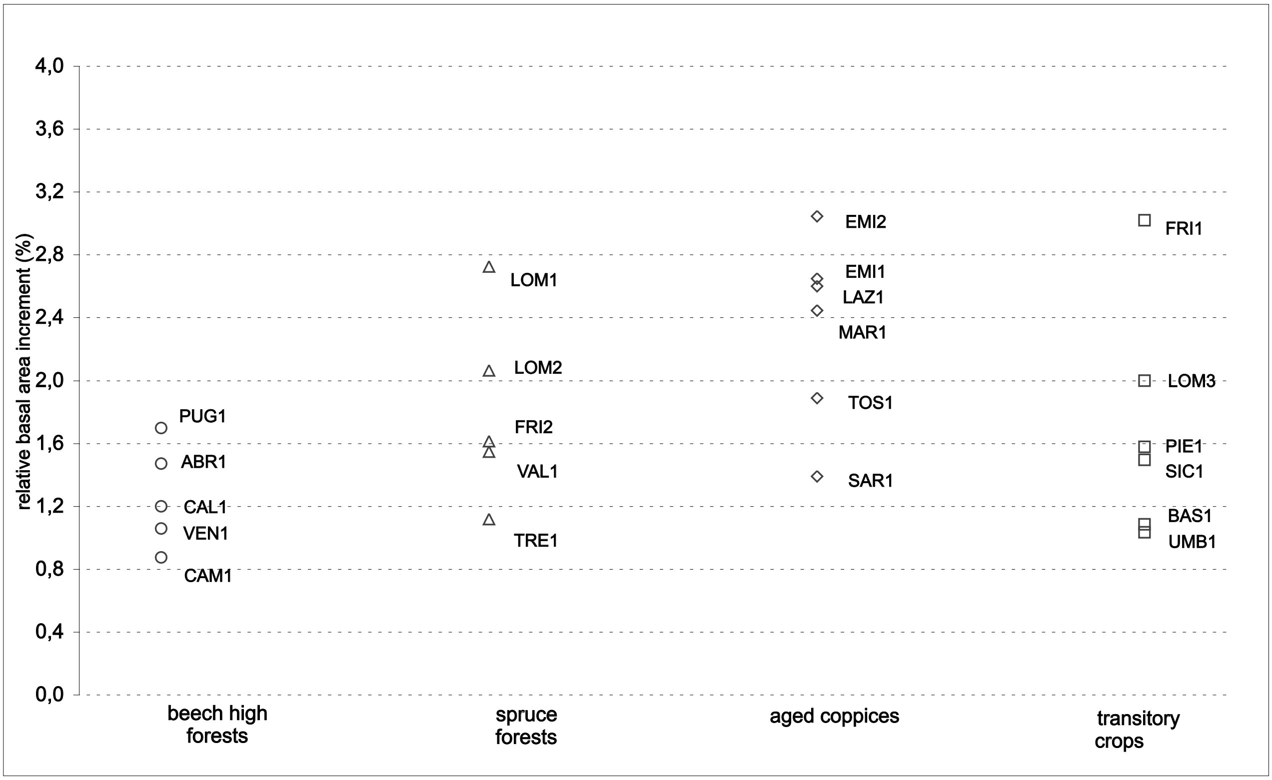

Figure 1 - Annual b.a.i. 1997-04 (% of b.a. 1997) per plot and forest type.
Incremento annuale di area basimetrica nel periodo 1997-2004 in % dell'area basimetrica al 1997 per area e tipologia.

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

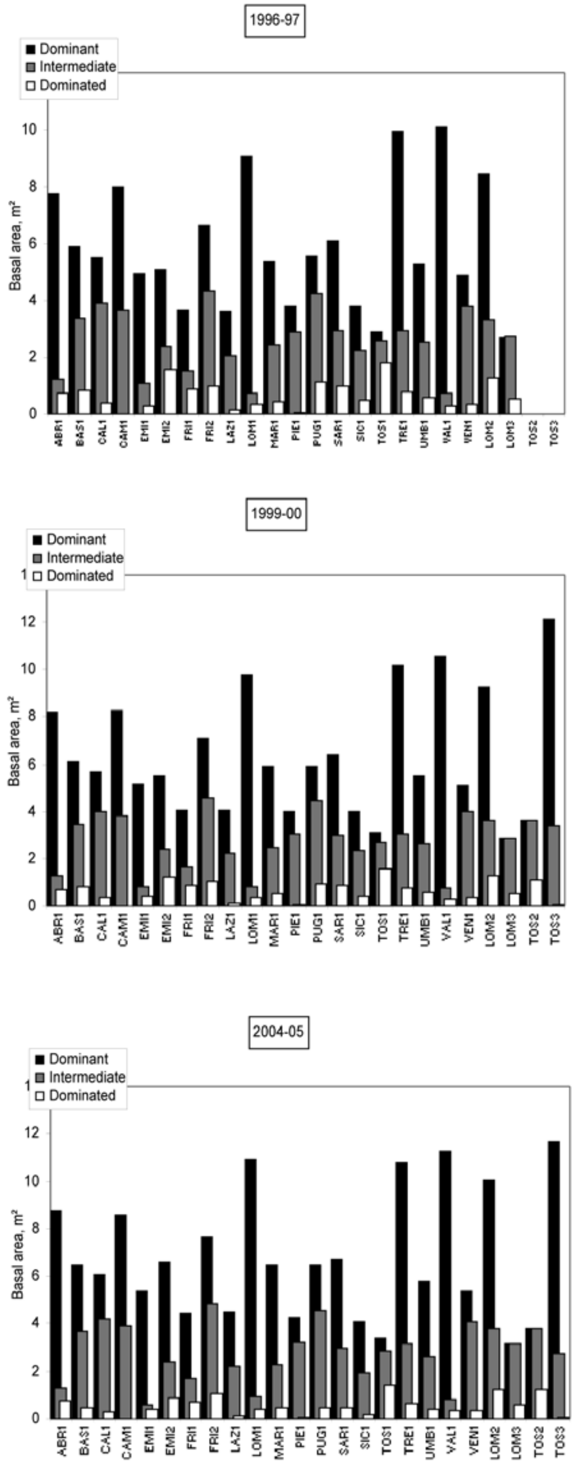

Figure 2 - B. a. allocation per plot and layer at each survey.
Distribuzione dell'area basimetrica per area e strato ai successivi inventari.

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.

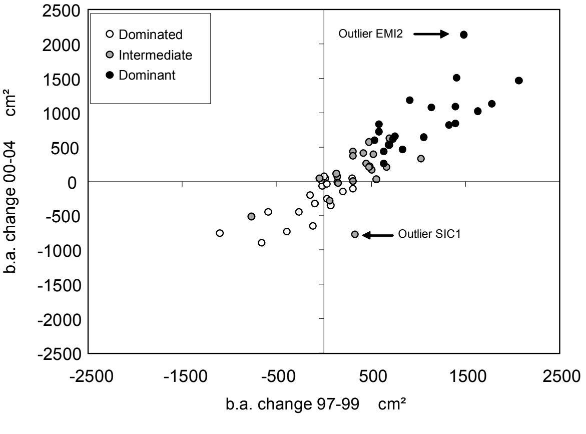

Figure 3 - Annual b.a. change 2000-04 vs. 1997-99. Two outliers are identified.
Variazione annuale in area basimetrica nel periodo 2000-04 rispetto al periodo 1997-99. Le frecce indicano i due outlier del modello autocorrelativo.

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

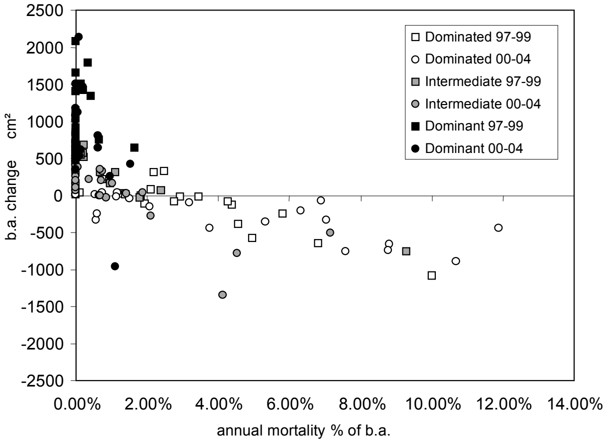

Figure 4 - Annual b.a. change plotted vs. annual mortality (b.a. %).
Variazione annuale di area basimetrica in funzione della mortalità annuale espressa in % di area basimetrica.

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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