Mosello, R., B. Petriccione and A. Marchetto (Guest Editors)
Long-term ecological research in Italian forest ecosystems
J. Limnol., 61 (Suppl. 1): 55-61, 2002

Tree ring growth by core sampling at the CONECOFOR Permanent Monitoring Plots. The deciduous oak (*Quercus cerris* L.) type

Maria Chiara MANETTI

Istituto Sperimentale per la Selvicoltura, Viale S. Margherita 80, I 52100 Arezzo, Italy
e-mail: issar@ats.it

ABSTRACT

*Radial growth analysis evaluates the ability of trees to grow under different site and environmental conditions, thus contributing to bio-ecological studies aimed at increasing understanding of forest stand evolution. Tree ring growth is analysed in five Permanent Monitoring Plots (PMPs) dominated by Turkey oak (*Quercus cerris *L.). Common structural features of these PMPs are their origin (coppice forest) and their current physiognomy as stored coppice and transitory crop. A dendroecological approach was used to analyse past radial stem growth, the influence of silvicultural background and stand age, as well as to compare the growth rhythm of stands in different site-indexes and environmental conditions. Tree coring was carried out at the time of the first inventory (winter 1996/97) by sampling 8 to 11 dominant and co-dominant trees representative of the upper storey in the buffer area of each PMP. The basic stem and crown growth variables were measured for each tree sampled and two cores collected at 1.30 m. Annual ring width was determined by the Tree Ring Measurement System SMIL3 and the data were elaborated by the ANAFUS software. Site mean curves and growth trend per social class in each stand were defined both by visual comparison and statistical analysis among individual tree series. The main results were as follows: i) social differentiation becomes established earlier with better site indexes and higher tree densities; ii) sensitivity to external disturbances is higher and more defined in the dominant class than in the co-dominant tree layer; iii) competition cycles are clearly discernible and related to both stand density and site-index in young stands under natural evolution (stored coppices); iv) when silvicultural interventions were performed in the past is quite visible readable in the stands under conversion into high forest (transitory crops); v) the mean series per site are statistically related and common periods characterized by a similar growth trend have been recognized.*

Key words: forest monitoring, tree ring growth, Quercus cerris *L.*

1. INTRODUCTION

Turkey oak coppices are one of the most representative and problematic forest typologies in Italy, due to the impact for centuries of intense human activity which has modified stand structures and conditioned their specific composition. At present, the spread of different silvicultural types - managed coppices, abandoned coppices, coppices converted into high forest – as well as the different types of ownership and the low quality of the wood produced, is creating problems for the environmental and economic development of these woodlands. The high sensitivity to environmental stress which characterises this species (Corona 1989), and the current lack of a well-defined silviculture, play an important role in its growth dynamics.

Time series analysis may be regarded as a tool both for defining the individual growth stage and for estimating the growth response at stand level according to variations in ecological, climatic and cultivation factors. In fact, annual tree ring growth provides an exact record of all the exogenous and endogenous disturbance factors acting on the forest ecosystem, both in the long and short term (Fritts 1976; Schweingruber 1988). These factors may act independently as limiting factors, generally in extreme sites, or more often interact with one another, determining a growth trend in which the limiting factor is a complex of ecological or anthropic factors.

The evaluation of the relationships between ring-width, climate and disturbances (Nola 1991; Brandini *et al*. 1994; Zarnovican & Laberge 1994; Cherubini *et al*. 1996; Meyer & Braker 2001), the study of growth dynamics within and among social classes (Fabbio 1992; van den Brakel & Visser 1996; Cherubini *et al*. 1998), and the incremental response of stands after silvicultural practices (Badeau *et al*. 1995) are therefore all specific items that can be extremely useful both in planning sound management and in evaluating stand functionality status (Amorini *et al*. 1996; Motta *et al*. 1999).

In the framework of the CONECOFOR programme (Allavena *et al*. 1999), the tree ring growth of five Permanent Monitoring Plots (PMPs) characterised by a Turkey oak (*Quercus cerris* L.) coppice was analysed using a dendroecological approach in order to compare the tree growth ability of the species under different site conditions and in different silvicultural contexts (stored coppices and transitory crops).

Only the aged Turkey oak coppice stands under natural evolution (stored coppices) or under conversion into high forest (transitory crops) have been considered in this first contribution. This study aims:

Paper prepared within the CONECOFOR programme, by the contract with the Ministry for Agriculture and Forestry Policy – National Forest Service, Italy. CONECOFOR is part of the Pan-European Level II Intensive Monitoring of Forest Ecosystem and is co-sponsored by the European Commission.

Tab. 1. Site characteristics of the examined coppice stands. * In ( ) stand age.

PMPs	UMB1	BAS1	SIC1	LAZ1	MAR1
Province	Perugia	Potenza	Palermo	Viterbo	Macerata
Altitude (m a.s.l.)	725	1125	940	690	775
Aspect	N-NE	S-W	N-NE	W-NW	S
Slope gradient	25°	5°	20	5°	35°
Annual rainfall (mm)	1250	750	800	1000	1250
Mean annual temperature (°C)	11	13	13	12	10
Management system	Transitory crop	Transitory crop	Transitory crop	Stored coppice	Stored coppice
Ring number *	50 (75)	50 (65)	45 (50)	35 (35)	25 (35)
Top height (m)	30.0	19.7	16.8	15.8	19.3
Stem number (n ha^{-1})	739	917	855	1629	4233
Basal area (m^2 ha^{-1})	34.9	41.1	25.2	24.0	35.9

i) to describe past radial stem growth according to social classes, silvicultural management and stand age;
ii) to compare the growth rhythm of stands located in different sites;
iii) to evaluate the impact of possible disturbance factors occurring in the examined tree populations.

2. MATERIAL AND METHODS

The growth series examined are from five PMPs, located in Central and Southern Italy and managed in the past under the coppice system (Fabbio & Amorini 2000). The main site and stand characteristics are reported in table 1. The stands have different ages and have been differently managed. The two youngest stands, aged 25 and 35 years, are stored coppices, whilst the three oldest stands (45 to 50 years) are transitory crops produced by an irregular thinning regime. Thinnings are difficult to date, as we have little reliable information on the silvicultural practices applied in the past.

Eight to eleven sample trees, representative of dominant and codominant classes, were selected in the upper storey of each plot. Dbh, height, crown area and crown length were measured for each tree. Two perpendicular cores at 1.30 m were collected per tree. The annual ring width was measured using the Tree Ring Measurement System SMIL3 (accuracy 0.01 mm) and the data were elaborated with the ANAFUS software (ISS Arezzo).

Visual comparison and statistical analysis (correlation coefficient and cross-dating) of all the individual chronologies were used to verify the homogeneity and reliability of the samples collected in each site, to define the growth trend per social class and to establish the site mean chronology. To evaluate the ability of the species to grow under different site conditions and management systems, the main dendrochronological parameters such as average ring width, standard deviation, autocorrelation coefficient and sensitivity were calculated both for the individual and regional series.

In the second step of the data analysis, the mean site curves were compared to see if the same growth pattern characterised the species in the different sites tested. The correlation coefficient, the t-value and the coincidence coefficient were calculated comparing the series originating in similarly managed and aged stands (Schweingruber 1988).

The last step of the data analysis was to try and pinpoint when the silvicultural practices had been performed in the transitory crops. For this purpose, the current basal area increment (b.a.i.) was used because it shows up clearly discernible ring width differences and reveals more clearly the occurrence of biological and anthropic phenomena like competition cycles or the impact of thinning practices. Generally, the growth increase produced by thinning is sudden and persistent (Devall *et al*. 1991), while the increase is slow after the resolution of a competition cycle. In the time series examined, the thinnings were dated first by defining the competition cycles (by running mean analysis) and then by considering both the sudden increment increase and the current values of tree density and basal area compared with stand age.

3. RESULTS AND DISCUSSION

3.1. Sample trees

Table 2 summarises the main characteristics of the trees sampled in each study-site. Given that the selected trees were representative of the upper storey, their growth trends give a good description of the growth of the stands examined.

The better site index of the PMPs UMB1 and MAR1 is expressed not only by dominant height values (Fig. 1), but also by crown dimensions (Tab. 2). Crown area is related in particular to age, site index and stand structure, and is a reliable indicator of the ability of a tree to grow and occupy the available growing space.

In the transitory crops, crown area mean values provide a good characterisation of the different sites, decreasing regularly according to site index variation. If

Tab. 2. Main forest measurements and crown parameters surveyed in the sampled trees. Between brackets: standard error.

PMPs	Sampled trees n	DBH cm	Tree H. m	Crown area m^2	Crown length m
UMB1	9	28.8 (1.9)	26.5 (1.1)	29.34 (7.3)	12.0 (1.2)
BAS1	8	25.0 (2.0)	18.5 (0.3)	24.49 (4.5)	8.2 (1.0)
SIC1	9	21.8 (1.1)	16.8 (0.8)	14.3 (3.7)	6.8 (0.6)
LAZ1	11	11.8 (0.6)	13.7 (0.6)	6.16 (1.0)	4.8 (0.5)
MAR1	9	19.5(2.0)	18.2 (0.7)	18.50 (4.0)	5.8(0.9)

the dominant and codominant components are considered separately (Fig. 2), the three PMPs show different crown structures: UMB1 has high values in both storeys, whilst in SIC1 and BAS1 the dominant trees have similar values, but there are marked differences in the codominant class.

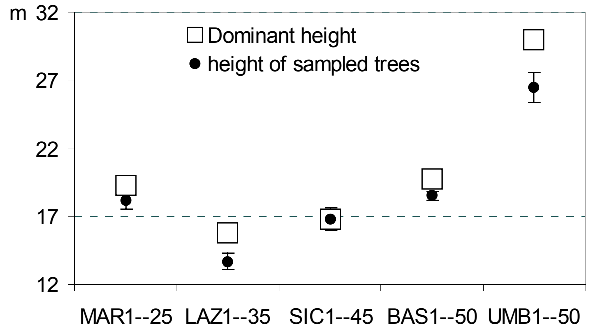

Fig. 1. Dominant height referred to the PMPs and mean height of the sampled trees (± standard error)

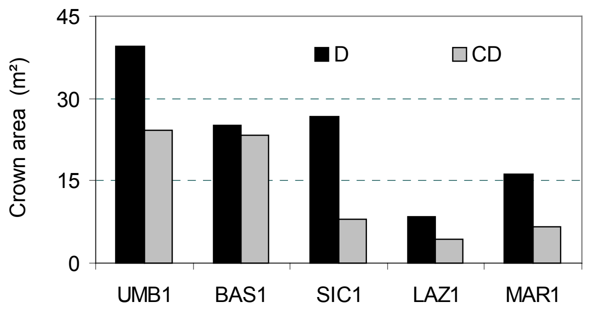

Fig. 2. Mean crown area in dominant (D) and codominant (CD) trees.

Of the stored coppices, all the recorded values in LAZ1, i.e. low site index and basal area, as well as small crown area and reduced tree density, point to an unfavourable functional status and a limited specific fitting to site characteristics due to the intensive periodical harvesting of standing crop under the coppice system. In fact, repeated harvesting selected the species which were most resistant to coppicing (Turkey oak), independently of its fitting to site.

3.2. Tree ring growth

The graphic course and the analysis of growth trends per social class (Fig. 3) reveal the biological behaviour of the species. Its demands for light in addition to its agamic origin give rise to early social differentiation and repeated short competition cycles. The different trends, however, highlight different environmental and anthropic conditions and thus the effects on growth performance per social class.

The growth recorded at the two stored coppice stands shows a juvenile phase; social differentiation is much earlier in MAR1, due both to higher tree density and a site index which enhanced the inter-tree competition level. In the transitory crops, the curves of dominant and codominant trees also show early differentiation but, as is the case in the stored coppices, the site index is the main discriminant in these areas too and therefore the differentiation period is longer in SIC1.

In both management systems, the two social classes also show different responses to external disturbances. The dominant class records better the occurrence of all the positive or negative factors, the difference between the two classes being widened by abrupt positive growth changes and narrowed by negative events.

Despite the differences in the growth trend, the correlation coefficients between the two social classes are high ($r = 0.87$ to 0.93), because both classes characterise the dominant component of the examined stands. The average chronologies for each PMP were so defined (Fig. 4), and the main descriptive statistics of the curves are reported in table 3.

The average chronologies examined describe similar behaviour in each silvicultural type. In the transitory crops, fast, irregular growth characterises the first 15-20 year period after coppicing; in contrast, the subsequent period features a steadier, more continuous growth decrease. This trend is also evident in the stored coppices, even though the best site index of MAR1 restricts abrupt changes in the growth rhythm and limits both the length and frequency of competition cycles.

In all the sites examined, the mean ring widths are comparable in spite of the age differences between the two silvicultural types. In the stored coppices, given their relatively young age, the expected growth values should be higher, even though the good functional status of MAR1 is confirmed by slightly broader ring widths.

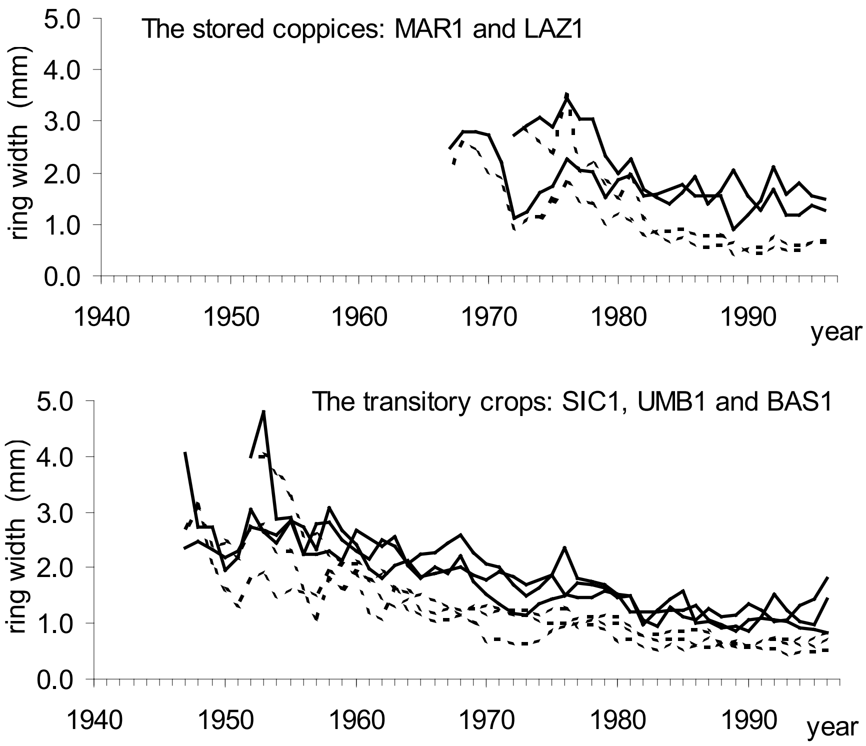

Fig. 3. Tree ring width in the dominant (continuous line) and in codominant (broken line) social classes.

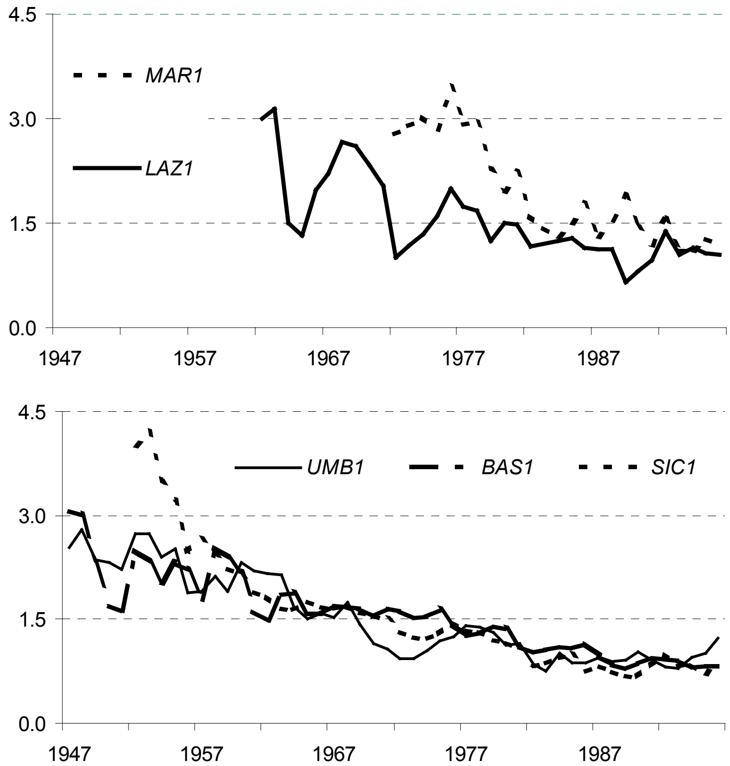

Fig. 4. Tree ring width in the five mean site curves.

Tab. 3. Main statistics of the five average chronologies (radius increment in mm).

PMPs	Period	Mean	s.d.	Autocorrelation	mean sensitivity	cross dating
UMB1	1947-1996	1.53	0.63	0.914 – 0.827 – 0.759	0.170	0.63
BAS1	1947-1996	1.58	0.58	0.806 – 0.615 – 0.569	0.181	0.58
SIC1	1952-1996	1.57	0.86	0.875 – 0.724 – 0.609	0.190	0.49
LAZ1	1962-1996	1.54	0.62	0.675 – 0.321 – 0.221	0.241	0.78
MAR1	1962-1996	1.94	0.73	0.839 – 0.739 – 0.623	0.198	0.80

Tab. 4. Correlation among the mean site curves: correlation coefficient, *t* value and coincidence coefficient.

PMPs	correlation coefficient			*t* values			coincidence coefficient		
	BAS1	SIC1	MAR1	BAS1	SIC1	MAR1	BAS1	SIC1	MAR1
UMB1	0.73	0.82		11.26	14.20		60%	64%	
BAS1		0.76			11.53			52%	
LAZ1			0.41			4.03			54%

To get a better understanding of the growth dynamics of the tested stands as a function of age, the time series were divided into 10 to 15 year periods. The transitory crops are thus made up of four periods (15, 10, 10, 15 years) and the stored coppices are characterised by two (MAR1 15, 10 years) and three periods (LAZ1 15, 10, 10 years). In the first lifespan (15 years), all sites record a fairly good growth rate (average from 2.24 to 2.88 mm); the next period (10 years) is then characterised by a sudden, marked decrease in growth (1.48 to 1.67), and this state of affairs continues in the following periods. The highest differences were recorded in the juvenile phase in MAR1 and SIC1, where the density of the shoots probably started a process of strong competition whose resolution determined a clear reduction in growth rhythm.

All the analysed dendroecological parameters show similar behaviour in the various series, and results are comparable with other studies carried out on *Q. cerris* in different regions: high autocorrelation coefficients which remain constant even in the second and third order, and satisfactory values of mean sensitivity (Martinelli *et al.* 1994; Romagnoli & Codipietro 1996; Romagnoli & Barnabei 1997). In this frame of reference, the only plot showing different behaviour is LAZ1, where poor regularity in growth trend is confirmed by the low and abruptly decreasing autocorrelation coefficients, and high susceptibility to external disturbances by the high value of mean sensitivity. Moreover, the sensitivity analysis, calculated for ten year periods, shows the consistent reduction of the parameter in this PMP - from 0.280 to 0.156 - while in the other sites the values are more or less constant or increasing.

Finally, the time series of each silvicultural type were compared (Tab. 4) to see whether the growth trend of the same species grown under different site conditions could be conditioned by environmental and anthropic factors.

In the transitory crops, all the statistics considered pointed to a similar, harmonious pattern, and common periods characterised by a similar growth trend were recognised by means of the pointer years analysis (Schweingruber *et al.* 1990; Meyer 1999). Negative years (1954, 1982, 1988) and positive years (1975, 1990) were detected in all site mean series.

In the stored coppices, because of the short time series it was not possible to distinguish the share of growth due to age increase from that of site index variation; the correlation between the two series was therefore not very high and only the minimum of 1982 was recognised.

3.3. Basal area

For the transitory crops analysed, there is no information about when and how silvicultural practices were applied in changing the management system from coppice to high forest. It was attempted to date thinnings using the b.a.i. analysis (Fig. 5). The growth trends are different, mainly because of their different backgrounds (origin and intensity of stresses).

The UMB1 pattern is characterised by frequent, major peaks due to the high site index enhancing tree competition level. In this area, four competition cycles are discernible: an early one (1947-1957) in which competition was centred inside the stools, with the following ones (1957-1972; 1972-1983; the last in progress) contributing to a definition of the present stand structure. In this area a single thinning, probably datable to the early seventies, can be identified from the current basal area value and tree density; after this, b.a.i. shows a sudden, lasting increase.

In BAS1 the growth course rose until 1967, since when it has remained more or less steady. This trend, along with the high basal area value and current tree density, indicates that thinning occurred in the juvenile phase, probably in 1962.

In SIC1, b.a.i. analysis and stand parameters were used to define three periods when there was interaction between natural selection and anthropic action: the first period ending in 1973, the second one in 1990 and the third one still in progress. In this area two thinnings are discernible; the first can be dated to the early seventies because of the sharp increase after the negative peak of 1973, culminating in 1976 and subsequently slowing down until 1990. The second thinning is recent (current low basal area value) and datable to about 1990 (sudden increment increase).

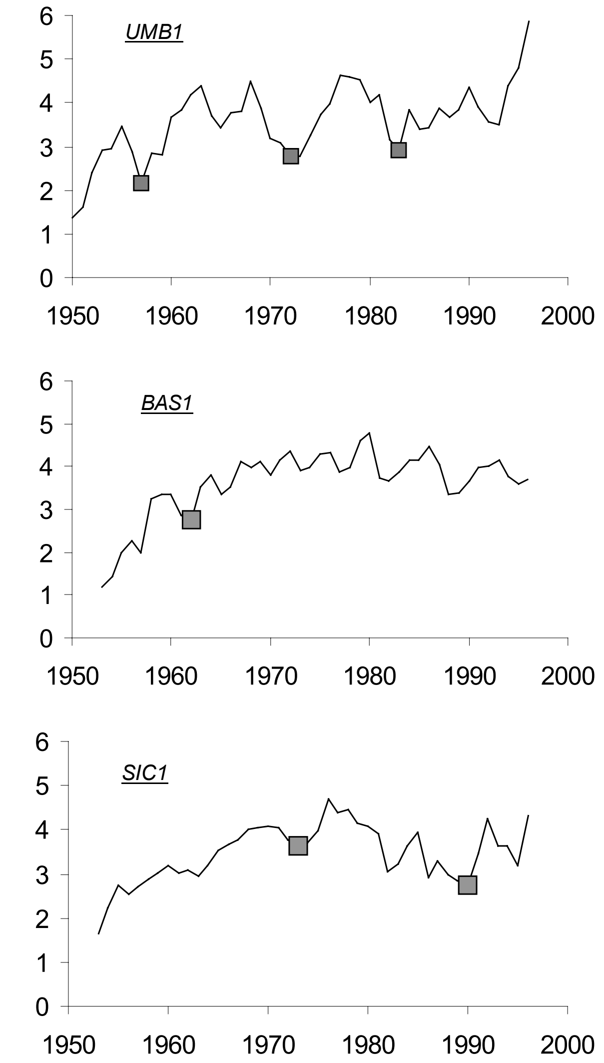

Fig. 5. Basal area increment growth trend in the three transitory crops.

4. CONCLUSIONS

Growth analysis was used to survey the past growth of differently aged and managed stands, to highlight the existing relationships between dominant and codominant trees, and to characterise the trend typical of the species. In addition, the occurrence of thinning was identified, filling the information gap regarding the stand management of transitory crops.

A few common tendencies were highlighted in all the examined stands, both in mean site chronologies and growth trend per social class, even though some growth discriminants (age, site index and silvicultural management) were identified. The juvenile phase is always characterised by high growth values and by a shortwave trend; growth then decreases slowly over time following a more regular pattern. Site index conditions the length and frequency of competition cycles, social arrangement, and recovery after external disturbances. Lastly, silvicultural practices interact with environmental and biological factors by modelling stand structure and reducing competition level, thus determining abrupt, continuous releases in the growth trend.

The stored coppices showing a natural growth pattern (no thinnings performed since coppicing), are relatively young, and site index emerged as the main discriminant between the two PMPs concerned. The unfavourable functional status of LAZ1 compared with MAR1 is mainly due to a lower site index, which conditioned both tree and canopy characteristics, as well as the growth trend. The dendroecological behaviour of LAZ1 - late social differentiation, lower competition level, irregular growth trend – made this PMP more susceptible to external disturbances.

In the transitory crops, the radial growth rhythm is comparable and similar in all the three PMPs and pointer years were found in the mean site curves. The main differences were revealed by b.a.i. analysis. Site index variation and when or whether thinnings were performed explain the different growth trends, which are quite similar at SIC1 and BAS1 while showing sudden, continuous peaks even in the juvenile phase at UMB1.

The influence of climate on growth was not considered in this study, even though an analysis of annual rainfall and annual mean temperature reveals marked differences among Southern and Central PMPs. Climate certainly affects the site index and therefore tree growth, and plays an important role in stand development in the Mediterranean and sub-Mediterranean area, where summer drought is a major limiting factor.

ACKNOWLEDGMENTS

The author thanks Marco Conedera for his helpful comments and text revision. Special thanks to M. G. Di Lorenzo for core reading and preliminary data elaboration.

REFERENCES

Allavena, S., R. Isopi, B. Petriccione & E. Pompei. 1999. *Programma Nazionale Integrato per il Controllo degli Ecosistemi Forestali*. Ministero per le Politiche Agricole, Roma: 167 p.

Amorini, E., M. Biocca, M.C. Manetti & E. Motta. 1996. A dendroecological study in a declining oak coppice stand. *Ann. Sci. For.*, 53: 731-742.

Badeau, V., J.L. Dupouey, M. Becker & J.F. Picard. 1995. Long-term growth trends of *Fagus sylvatica* L. in northeastern France. A comparison between high and low density stands. *Acta Ecologica*, 16(5): 571-583.

Brandini, P., M.G. Cantiani, N. Martinelli, O. Pignatelli & G. Tabacchi. 1994. Climate-radial growth relationships in spruce. Preparing a model in the Valle di Fiemme (Trentino, Italy). *ISAFA Comunicazioni di ricerca*, 94/2: 37-52.

Cherubini, P., P. Piussi & F.H. Schweingruber. 1996. Spatiotemporal growth dynamics and disturbances in a subalpine spruce forest in the Alps: a dendroecological reconstruction. *Can. J. For. Res.*, 26: 991-1001.

Cherubini, P., M. Dobbertin & J.L. Innes. 1998. Potential sampling bias in long-term forest growth trends reconstructed from tree ring: a case study from the Italian Alps. *Forest Ecology and Management*, 109: 103-118.

Corona, E. 1989. Significato dendrocronologico delle querce. *Monti e Boschi*, 1: 6-8.

Devall, M.S., J.M. Grender & J. Koretz. 1991. Dendroecological analysis of a longleaf pine *Pinus palustris* forest in Mississippi. Vegetatio, 93: 1-8.

Fabbio, G. & E. Amorini. 2000. Tree growth surveys and increment assessment. Contribution to the integrated evaluation of ecosystem's status. *Annali Istituto Sperimentale per la Selvicoltura*, 30: 81-89.

Fabbio, G. 1992. Dinamica della popolazione arborea in un ceduo di cerro in invecchiamento. *Annali Istituto Sperimentale per la Selvicoltura*, XXIII: 41-72.

Fritts, H.C. 1976. *Tree Rings and Climate*. Academic Press, London: 567 pp.

Martinelli, N., O. Pignatelli & M. Romagnoli. 1994. Primo contributo allo studio dendroclimatologico del cerro (*Quercus cerris* L.) in Sicilia. *Dendrochronologia*, 12: 61-76.

Meyer, F.D. 1999. Pointer years analysis in dendroecology: a comparison of methods. *Dendrochronologia*, 16-17: 193-203.

Meyer, F.D. & O.U. Braker. 2001. Climate response in dominant and suppressed spruce trees, *Picea abies* (L) Karst., on a subalpine and lower montane site in Switzerland. *Ecoscience*, 8 (1): 105-114.

Motta, R., P. Nola & P. Piussi. 1999. Structure and stand development in a mixed Norway spruce (*Picea abies* (L.) Karst.), larch (*Larix decidua* Mill.) and stone pine (*Pinus cembra* L.) stand in Paneveggio (Trento, Italy). *Dendrochronologia*, 16-17: 57-73.

Nola, P. 1991. Primo approccio alla dendroclimatologia della quercia (*Quercus robur* L. e *Quercus petraea* (Mattuschka) Liebl.) in pianura Padana (Italia settentrionale). *Dendrochronologia*, 9: 71-94.

Romagnoli, M. & G. Codipietro. 1996. Pointer years and growth in Turkey oak (*Quercus cerris* L.) in Latium (central Italy). A dendroclimatic approach. *Ann. Sci. For.*, 53: 671-684.

Romagnoli, M. & M. Barnabei. 1997. Analisi dendrocronologica preliminare nella Tenuta presidenziale di Castelporziano (Roma). *Linea Ecologica EM*, 4: 50-59.

Schweingruber, F.H. 1988. *Tree rings. Basics and applications in dendrochronology*. Reidel, Dortrecht: 276 pp.

Schweingruber, F.H., D. Eckstein, F. Serre-Bachet & O.U. Braker. 1990. Identification, presentation and interpretation of event years and pointer years in dendrochronology. *Dendrochronologia*, 8: 9-38.

Schweingruber, F.H. 1993. *Trees and wood in dendrochronology*. Springer-Verlag, Berlin: 402 pp.

van den Brakel, J.A. & H. Visser. 1996. The influence of environmental conditions on tree-ring series of Norway spruce for different canopy and vitality classes. *Forest Science*, 42(2): 206-218.

Zarnovican, R. & C. Laberge. 1994. *Survey of the effects of forest drainage operations: Climate and volume increment of black spruce and tamarack at Saint-Anaclet*. Information Report LAU-X 108E, Natural Resources Canada, Canadian Forest Service – Quebec Region: 24 pp.