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Original article

Stand history and its consequences for the present and future dynamic in two silver fir (*Abies alba* Mill.) stands in the high Pesio Valley (Piedmont, Italy)

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Abstract – Two silver fir (*Abies alba* Mill.) forest stands have been identified on unmanaged parts of previously managed forests in the "Alta Valle Pesio e Tanaro" Regional Park (Piedmont, Italy) in order to study their origin, past forest dynamic and disturbance history. The historical development and the successional history of these stands were investigated in two plots of 2000 m^2 by means of the following techniques: size and age structure analysis, abrupt growth changes analysis, establishment of pioneer species and of early-seral shade-intolerant species, historical data of logging. The stands investigated are relatively young; in the past 70 years some periods of heavy logging have been identified. Intense cutting has caused the establishment of an abundant regeneration of shade intolerant early-seral broadleaves species. The peak recruitment period of the broadleaves occurred around 1940 in plot 1 and around 1975 in plot 2. The current structures and composition of the forest are therefore the result of anthropogenic activity, indeed, the presence of pure silver fir stands in the past were the result of human intervention. The silver fir will share future dominance with several broadleaves species such as the beech (*Fagus sylvatica* L.) and the sycamore (*Acer pseudoplatanus* L.) although the exact successional status of these stands is unresolved.

stand history / forest dynamic / dendroecology / *Abies alba* Mill. / Alps

Résumé – L'histoire des peuplements pour outil d'aménagement forestier : les forêts de sapin blanc (*Abies alba* Mill.) dans la Haute Vallée du Pesio (CN, Italie). Deux peuplements représentatifs de sapinière de la Haute Vallée du Pesio ont été identifiés dans des zones abandonnées de forêts qui étaient fortement exploitées. Les deux peuplements ont été choisis pour étudier les effets de l'utilisation historique du territoire sur la dynamique et la composition de la forêt. En mettant en relation les analyses de croissance, le recrutement de feuillus pionnières et les données de documents historiques, nous avons reconstruit l'histoire de ces peuplements. Les deux peuplements sont relativement jeunes et ont été fortement exploités pendant le dernier siècle jusqu'à la création du Parc Naturel (1970). Le recrutement maximum a été identifié en 1940 pour le peuplement 1 et en 1975 pour le peuplement 2. L'exploitation forestière et le recrutement de feuillus ont été suivis par la fermeture du couvert. C'est seulement durant les deux ou trois dernières décennies que les deux peuplements ont pu se développer naturellement. Aujourd'hui, le sapin est en train de regagner sa place mais dans le futur, il devra vraisemblablement partager l'étage supérieur avec les feuillus mésophiles comme l'érable (*Acer pseudplatanus* L.) et le hêtre (*Fagus sylvatica* L.) même si le futur statut de ces peuplements n'est pas encore exactement établi.

histoire du peuplement / dynamique forestière / dendroécologie / *Abies alba* Mill. / Alpes

1. INTRODUCTION

The majority of forest and woodland ecosystems in Europe have been modified by man in some way, either through direct destruction of habitat or by more subtle forms of management and habitat manipulation [49, 57]. Natural disturbance regimes have been replaced by disturbances, caused by people, that are linked to economic and social development [45]. Consequently, land-use and forest-use history is a fundamental determinant in shaping vegetative composition and stand structure in forests, and this cultural legacy has important implications for the present-day structure and composition of forest ecosystems and for the present and future forest management [15, 16, 40, 58, 48].

During recent decades, European foresters have become progressively aware of the importance of past history on the structure and function of present forest communities and ecosystems [7, 9, 10, 34]. However, very little is known about the natural dynamics and disturbance history of forest stands in the European Alps for two reasons: first, because old-growth forests are rare or absent, and second, because felling is the main disturbance in cultivated forests. It is therefore

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particularly important to study the unmanaged parts of previously managed forests [41, 43]. A long history of human disturbances has resulted in severe soil erosion and nutritional leaching [24] and it is therefore not likely that the halting of logging and other types of human intervention would permit a return to pre-settlement forest vegetation and structure. It is however essential to study the dynamic of unmanaged stands in order to increase our knowledge about processes of natural regeneration and about type, frequency and intensity of the natural disturbances. Applying historical knowledge to guiding and developing management actions is a fundamental tool for a conservative and sustainable approach to managing ecosystems [5, 6, 8, 23].

A case study that fits the above description can be found in the "Alta Valle Pesio e Tanaro" Regional Park that was created mainly to protect the remaining silver fir (*Abies alba* Mill.) forests. The presence of the silver fir in the Pesio Valley is of both historic importance, due to its association with the Chartusian religious order of monks, as well as of obvious naturalistic and scenic importance. These forests were intensely exploited by man for centuries. Thus, following the creation of the Park, the first forest management goal was to restore over-exploited forests through the complete halting of all forest logging. Subsequently the growing stock of the Park's silver firs significantly increased, from approximately 170 $m^3 ha^{-1}$ in 1978 to 383 $m^3 ha^{-1}$ in the Buscaié forest and to 332 $m^3 ha^{-1}$ in the Prel forest in 1997 [18].

After the first restoration, the second step of the forest management was to begin silvicultural experiments [31] and to establish long-term research plots where all the silvicultural activities are banished in order to describe the stand history, the past and the present forest dynamic and to provide a future reference between managed and unmanaged stands.

Information for forest stand retrospective studies are available from natural and documentary archives. The natural archives are those "recorded" by earth-system processes while documentary archives are written, tabulated, mapped or photographic records. Reconstruction of environmental history are improved by complementary and comparative analyses of both natural and documentary records and it is thus necessary combining these multiple lines of evidence [33]. Studying tree-ring chronologies coupled with age structure and land use history has proven to be a particular robust approach for describing past forest stand history and past and present forest dynamic [1, 27, 42, 46, 50].

The present study deals with long term monitoring plots situated in the Buscaié (plot 1) and Prel (plot 2) forests, selected in collaboration with Park Administration.

The main objectives of the present study were to:

– quantify the composition and structure of the two stands studied;

– reconstruct their establishment and disturbance history;

– characterise forest-use history impact on present and past forest composition and dynamic;

– investigate species recruitment and generate hypotheses about the forest dynamic over the next few years.

2. MATERIALS AND METHODS

2.1. Study sites

The areas studied are located inside the "Alta Valle Pesio e Tanaro" Regional Park which covers a total area of 6673 ha, approximately 4173 of which are situated in high Pesio valley (Municipality of Chiusa Pesio). The investigated areas are in two of the Park's most important silver fir forests, the Buscaié forest (44° 21 N, 7° 66 E) with an extension of nearly 150 ha (Plot 1) and the Prel forest (44° 21 N, 7° 65 E) of approximately 90 ha (Plot 2).

These forests are important for their size, naturalistic value, historic value, and because they are both seed stands of national interest. In each forest one plot (2000 m^2) was selected. The plots were chosen on the basis of indications from the Forest Management Plan (1998–2010) and in collaboration with the Park Administration and are located in presently undisturbed by man forest areas containing large trees.

The first plot is situated at an altitude of 1250 m above-sea-level with a western exposure and a slope of 60%. The forest reference type [18] is the "eutrophic fir stand with broadleaves". The stand has a dominance of silver fir together with beech (*Fagus sylvatica* L.) and various broadleaves, including some ash (*Fraxinus excelsior* L.) and sycamore maple (*Acer pseudoplatanus* L.). The understory is characterised by the presence of *Luzula nivea* Lam., *Prenanthes purpurea* L., *Trochicanthes nodiflora* L., *Oxalis acetosella* L., *Allium ursinum* L., *Paris quadrifolia* L., *Veratrum album* L., *Euphorbia dulcis* L. and by the sporadic presence of yew (*Taxus baccata* L.).

The second plot is situated at an altitude of 1200 m above-sea-level with a north-western exposure and a slope of 70%. Here too the forest reference type is the "eutrophic fir stand with broadleaves". Among the latter, the most common are sycamore maple, hazel (*Corylus avellana* L.), mountain elm (*Ulmus montana* With.) and alpine laburnum (*Laburnum alpinum* (Mill.) Berchtlold et Presl); the most common species in the understory are *Prenanthes purpurea* L., *Trochicanthes nodiflora* Koch, *Athyrium filix-femina* L., *Geranium nodosum* L., *Paris quadrifolia* L., *Veratrum album* L. and *Polygonatum multiflorum* (L.) All.

The Park is home to various types of ungulates: chamois (*Rupicapra rupicapra* L.), roe deer (*Capreolus capreolus* L.), red deer (*Cervus elaphus* L.) and wild boar (*Sus scrofa* L.). The roe and red deer have recently been re-introduced (1970s and 1990s respectively) and the impact of the ungulates on forest regeneration, and in particular on the silver fir, at the present allows the regeneration to establish and to growth [30]. In addition, in recent years the wolf (*Canis lupus* L.) has spontaneously reappeared in Park territory as well.

The bed rock is porphyry and the soils are Typic haplorthod (plot 1) and Typic haplumbrept (plot 2). Rainfall reaches an average level of 1457 mm $year^{-1}$ at Certosa di Pesio (altitude of 860 m) with two maximum periods concentrated in the months of May and November.

2.2. Historical investigations

Historical investigations were carried out based on information from two principle sources: the Mondovì "Opera Pia Parroci" archives where all documents concerning the Chartusian monks are collected (discontinuous records from 17th century up to now), and the Chiusa Pesio "Corpo Forestale dello Stato" station archives (regularly updated between 1951–1995). Other information was collected from historical texts and documents and from interviews with people who had worked in the areas over recent decades.

2.3. Permanent plots

In 1997 two study sites were selected in relatively uniform slopes where a 20 × 100 m (2000 m^2) plot with the long side along the contour lines was marked off. In each plot the following measurements were recorded for trees with a diameter at breast height > 2.5 cm: species identification; diameter at breast height (dbh), height, and topographic coordinates within the plot. Saplings (height > 10 cm and dbh < 2.5 cm) were counted in each plot. The coordinates for the area were established by means of a Global Positioning System (GPS), the plot borders were marked permanently, and all data were analysed by means of a Geographic Information System (GIS, Arcview 3.1).

2.4. Increment cores

In order to calculate age structure and analyse growth trends, an increment core was taken upslope in each plot at a height of 50 cm from each tree with dbh > 4.0 cm (a total of 482 cores, referred to as C50). Additional cores (referred to as C130) were taken from 10 silver firs in the Buscaié forest and 10 in the Prel forest, in order to build reference chronologies for each site [36]; in this case two or three cores per tree were taken at breast height (the first one upslope and the other ones at 90–120° from the first) and only the largest, apparently healthy and dominant trees were sampled.

In the laboratory, all the cores were fixed to wooden supports and smoothed with a razor blade or by sanding until optimal surface resolution consented the measurement of annual rings. Annual growth increments were measured to the nearest 0.01 mm with a tree-ring measuring device (LINTAB) and data were recorded and stored using TSAP package [47].

Cross-dating, which ensures that the correct year is assigned to each annual ring, was initially performed on a series from the C130 cores, both by visually checking the curves and by calculating the t-values relating to the coefficient of correlation [3] and to the *gleichläufigkeit* or coefficient of agreement [51]. Then the series derived from the cores belonging to the same tree were averaged to create an individual raw chronology (IRC). Two different-site (Buscaié and Prel) raw chronologies (SRC) were obtained from the average of the IRCs.

The C50 cores were cross-dated by comparing each series with the SRC, both by visually checking the curves and by calculating t values relating to the coefficient of correlation and the *gleichläufigkeit*. The cross-dating was carried out only on the silver firs because it wasn't possible to gather the proper raw materials for constructing a site reference chronology for the other species.

The C50 cores were used to build age structure. Determining the age of a tree at an annual level of resolution is extremely difficult, uncertain and time consuming. Such information is, however, essential to the reconstruction of stand history. There are two major limitations to using increment cores in age determination: the difficulty of intercepting the pith at the coring height, and the differences in years between coring height and the total age (age at the root collar). How to estimate the number of missing rings from incomplete cores has been the object of a number of studies, and a variety of methods exist [37, 38, 56]. We adopted a graphical procedure for estimating pith location (starting from the innermost part of the core) and used a pith locator [19]; once pith location had been estimated, the length of the missing radius was also estimated. Then the number of rings on the innermost part of the core was counted for a segment as long as the estimated missing radius (EMR); this number was added to the number of rings in the core to obtain the estimated age of the tree at the coring height. Where the innermost rings showed evidence of abrupt growth change, especially of abrupt growth release [28, 52], the estimated number of missing rings was taken only from the segment of core preceding the abrupt growth change and then extended to the whole EMR using a simple proportional calculation. This method assumes that the estimated missing rings form concentric circles [32].

Estimating the number of years the trees had taken to attain the coring height (50 cm) presented two major difficulties: (i) it is almost impossible to locate the exact position of the root collar of trees exposed to snow as juveniles or which grow on microsites (stumps, dead wood and humps) where the lower stems are easily deformed under the weight of the tree [12]; (ii) furthermore, especially for species with initially slow growth, juvenile growth has very variable rates depending on microsite, competition and light conditions. A sampling conducted in the Buscaié and Prel forests on 10 harvested silver firs and on 25 broadleaves (6 beeches, 6 sycamores and 13 other broadleaves) collected near the study sites showed that the silver fir took an average of 8 years (range 4–15 years) to reach a height of 50 cm, the beech an average of 2 years and the sycamore and the other broadleaves one year. Although we are fully aware of the limitations involved, these values (8 years for the silver fir, 2 years for the beech and 1 year for the other broadleaves) were added to the number of years counted or estimated at the sampling height [31]. This procedure is based on the assumption that the harvested saplings grew at the same rate as the initial growth rate of the mature trees from which the cores were obtained [54]. In order to compensate for potential errors, age structure was built for 5-year classes [42]. To facilitate comparison between age structure data and data from logging and abrupt growth releases, the chronologies for the latter two were also constructed for 5-year classes.

2.5. Disturbance history

We identified disturbances by examining the establishment of pioneer and shade-intolerant broadleaves and by identifying sudden increases in radial growth (releases from suppression) in the C50 increment cores [17, 22, 27]. We defined the following broadleaves as pioneer and shade-intolerant early-seral species: *Fraxinus excelsior* L., *Corylus avellana* L., *Laburnum alpinum* Berchtold & J.Presl., *Ulmus montana* With., *Sorbus aucuparia* L. and *Acer platanoides* L. Releases from suppression are growth increases, occurring synchronously in neighbouring trees and showing a slow decrease in the following years due to ageing or to closure of the canopy [20, 27, 55]. We defined a release as a sudden increase in ring-width > 100% over the average of the previous 4 years. Releases are frequently caused by disturbances that open the forest canopy [4, 21, 28, 54]. In this context it should be remembered that it might take 1–2 or more years before trees show a release after the disturbance. Height growth reacts promptly to release [44], but needles live 5–6 or more years, so it takes some time before the whole tree crown is adapted to the new light conditions [11, 14].

The historical series of releases from suppression were compared to the establishment of shade-intolerant early-seral broadleaves in order to identify which disturbances provoked the clearings in the studied forest stands leading to the recruitment of trees [2] and to the logging historical series [33]. This was done in order to identify the causal factor of these disturbances and to verify which of the logging that took place in the Buscaié and Prel forests were directly related to the plots chosen for study.

3. RESULTS

3.1. Past land and forest use

The forestry history of the high Pesio valley and the land-use of the territory were strongly influenced by the arrival of the Carthusian monks in 1173. Indeed, the presence of these monks affected the entire valley, in both agricultural and landscaping terms. The Carthusian monks strongly encouraged and cultivated the silver fir as they had done in all of their monasteries throughout the Alps and Apennine mountain ranges. For many centuries the agricultural model implemented by the Carthusians was relatively simple: at low altitudes they cultivated the chesnut (*Castanea sativa* L.) mainly for its nuts, at medium altitudes they favoured the beech for use as fuelwood, and at high altitudes and in the interior of valleys they favoured and/or planted the silver fir to exploit as round timber. The forests of this valley were intensely exploited but, unlike the surrounding valleys, they were subjected to uniform management and the forests were only marginally farmed. From documents dating from 1699, it emerges that of the 3610 "giornate" (approximately 1375 hectares) administered by the Chartusians, 1620 (approximately 585 hectares) were covered with forests (excluding the chestnut groves which were considered agricultural terrain).

The peak of forest resource exploitation of the valley probably occurred between 1760 and 1854 when the "Savoia" Glass and Crystal factory in Chiusa Pesio was operating. Its closing was contemporaneous with the depletion of forest resource supplies. Historical documents show that the beech was subjected to clear cutting in average rotations of 80 years (varying between 60 and 100 years according to site index). More recently, the beech had been utilised as coppice (coppice with standards) with rotations varying between 20 and 30 years and the chestnut groves at low altitude had also become coppice following the spread of diseases that had affected European chestnut trees during the 20th century.

The silver fir, on the other hand, according to the historical documents were subjected to "selection cutting". The method of application of this treatment was however quite different from the way it is currently performed. Documents from the beginning of the 20th century (1918) refer to a "selection system" with the removal of all trees with a diameter of more than 18 cm. In all likelihood, given the frequency and intensity of the cuts, the average diameters were smaller than those presently employed. But despite the application of an exploitable diameter of 18 cm, what took place was more clearcutting with reserves (small and overtopped) or a high grading, partial harvest removing only the most valuable species or trees of desirable size and quality without regard for the condition of the residual stand, than selection cutting. The broadleaves inside the silver fir stands were treated as coppice, with shorter rotations (10–20 years), as was common in the past in the majority of silver fir forests in Piedmont [13].

Aside from the production of fuelwood from the coppice and the production of round timber from the high forest, another product which was very important in these forests until the 2nd World War was charcoal, literally the distillation of wood to its carbon content. Indeed, there are areas distributed throughout the Pesio valley forests from their lower slopes all the way up to tree-line that testify to the production of charcoal. The areas, or hearts, where the charcoal kilns were constructed were cleared and levelled. The hearts were usually 10 to 15 m in diameter. These areas are presently easy to identify due both to their morphology and to their vegetation, which is clearly different from that of surrounding areas. Charcoal production began to decline towards the end of the 19th century and was ultimately halted at the end of the 2nd World War. Charcoal was mainly produced with broadleaves but the remains of silver fir cuts (top and branches) were used too.

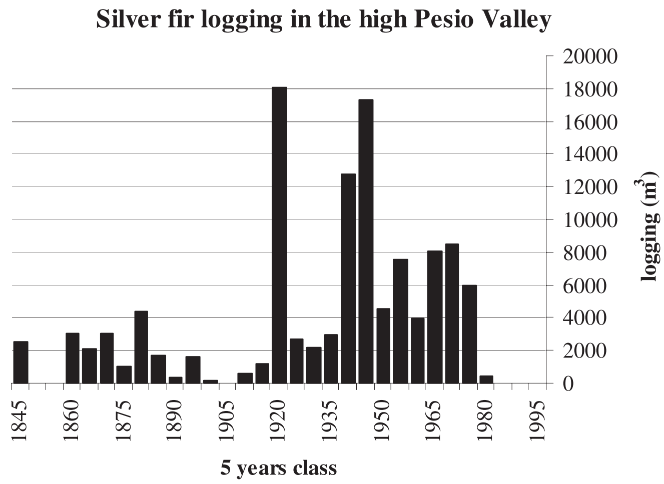

Figure 1. Documented logging in the high Pesio valley for the period 1845-1995. Data from between 1845 and 1931 are partially estimated (some forms report number of trees rather than volume) and, according to interviews carried out with local workers, all the figures are underestimated.

Forest use and exploitation continued right up to the end of the 1970's when the Park was established (Piedmont Regional Law No. 84, December 28th, 1978). During the final 150 years of exploitation, two particularly intense periods can be identified: immediately following the 1st World War and during and following the 2nd World War (Fig. 1).

3.2. Permanent plots

Inside plot 1 (Tab. I) there are more than 1200 individuals per hectare and the silver fir is the most represented species, accounting for more than 46% of individuals. The other species occurring, in order of importance, are ash, sycamore maple and beech. The silver fir represents more than 68% of the basal area. Given the high number of trees and the considerable wood biomass (356 $m^3\,ha^{-1}$), the regeneration has not been abundant (980 ha^{-1}). The silver fir represents nearly 36% of the total regeneration (dbh < 2.5 cm and height > 10 cm).

In plot 2 (Tab. II), the number of individuals per hectare (1175) is slightly lower than in plot 1. The silver fir represents only 17% of overall individuals but accounts for 60% of the basal area and more than 70% of volume (336 $m^3\,ha^{-1}$). The regeneration here is not abundant (560 ha^{-1}) and the silver fir represents 32% of the total.

The distribution of size structure (Fig. 2) has an exponential reverse J-shape progression, but in both stands there are few individuals in the upper diametric classes. In plot 1, a decrease in the frequency of the 5 cm class was observed while in the plot 2 there is a gap in the intermediate diameter classes (25–40 cm). The species are not uniformly distributed over the

Table I. Plot 1 general features (Buscaié).

Species	Trees (dbh > 2.5 cm) [n ha^{-1}]	Basal area [m^2 ha^{-1}]	Volume [m^3 ha^{-1}]	Regeneration (dbh < 2.5 cm and height > 10 cm) [n ha^{-1}]
Silver fir	565	31.3	254	315
Sycamore	135	2.7	18	15
Beech	45	1.0	4	195
Ash	395	10.0	74	135
Other broadleaves	75	0.9	6	320
Total	1215	45.9	356	980

Table II. Plot 2 general features (Prel).

Species	Trees (dbh > 2.5 cm) [n ha^{-1}]	Basal area [m^2 ha^{-1}]	Volume [m^3 ha^{-1}]	Regeneration (dbh < 2.5 cm and height > 10 cm) [n ha^{-1}]
Silver fir	205	21.0	238	160
Sycamore	400	7.6	63	25
Beech	340	4.1	31	5
Other broadleaves	230	2.3	4	310
Total	1175	35.0	336	500

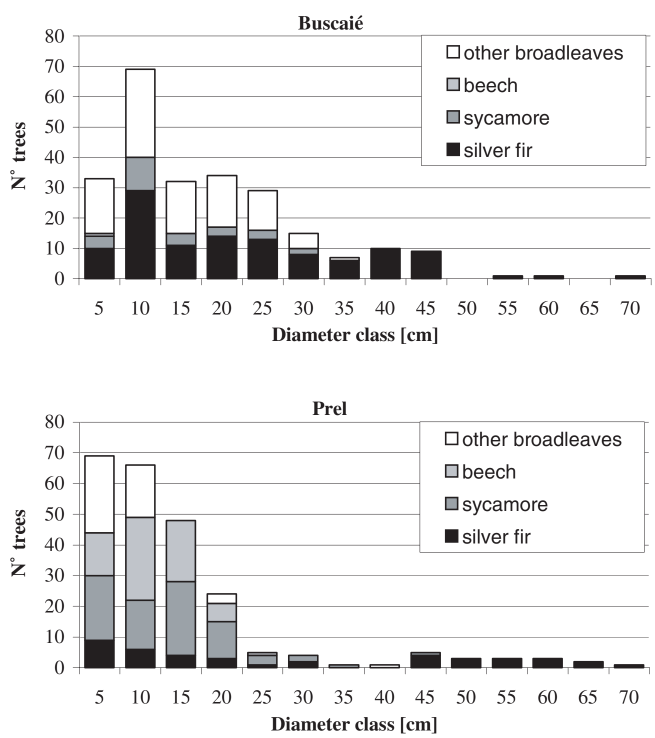

Figure 2. Size class distributions for each species in the two plots.

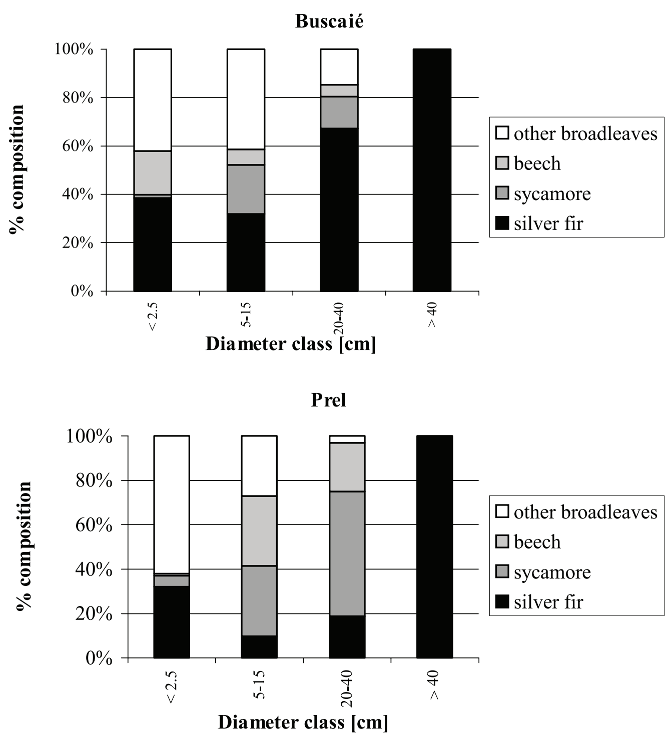

Figure 3. Percentage composition of major tree species in four size classes in the two plots.

diametric classes: in both areas the silver fir accounts for 100% of the upper diametric class individuals (Fig. 3), while it is relatively poorly represented in the classes between 5 and 40 cm (a phenomenon more pronounced in plot 2 as compared to plot 1); in both plots the number of silver firs increases notably among individuals with dbh < 2.5 cm.

3.3. Increment cores

Among the C50 series the 48% showed a visual and statistically significant synchronisation with the silver fir site chronology. The relatively low synchronisation is coherent with the low sensitivity and with the young tree age [29]. In all

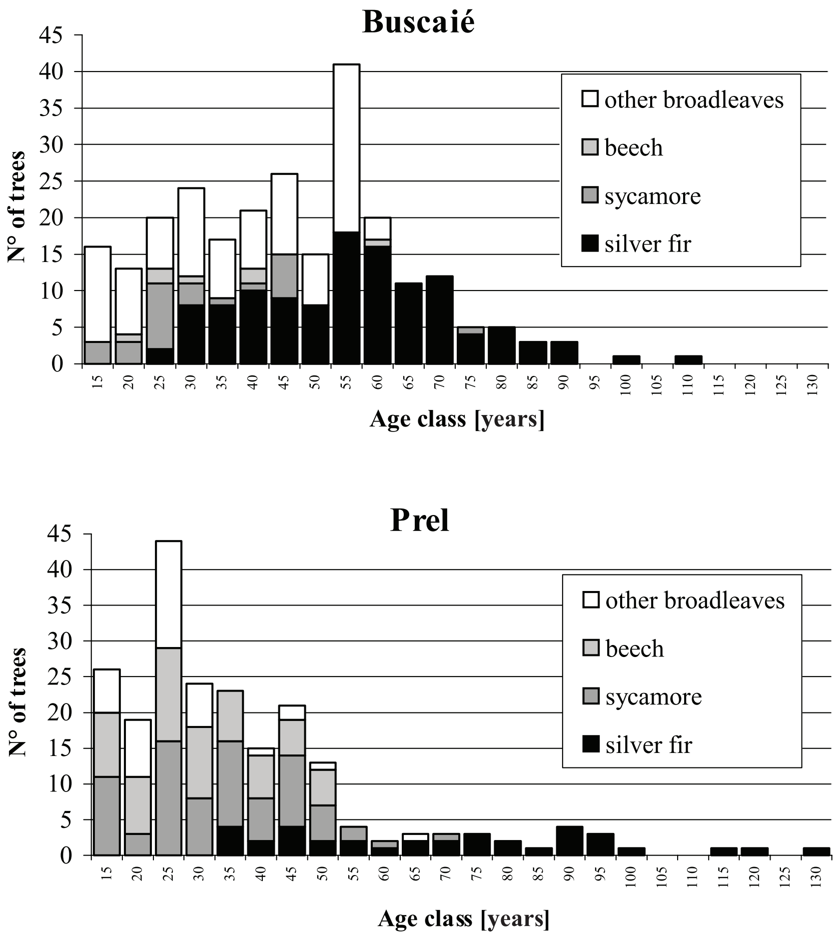

Figure 4. Age class distributions for each species in the two plots.

cases no rings were missing and no false rings were found and all the trees were used for building the age structure. The rotten cores (< 1%) were systematically discarded.

The age structure shows that both plots are relatively young (Fig. 4). The oldest tree in plot 1 is a silver fir of 108 years and the oldest tree in plot 2 is a silver fir of 132 years. The most frequent age classes are, respectively, the 55-year class in plot 1 and the 25-year class in plot 2. The individuals are not distributed regularly over age classes: the silver fir accounts for nearly all trees > 70 years, whereas the broadleaves make up the majority of younger age classes. The lack of silver firs younger than respectively 25 years and 35 years in plot 1 and plot 2 is also due to the fact that most of these trees have a diameter of < 4 cm and were therefore not recorded.

3.4. Disturbance history

Three primary criteria were used to trace the disturbance history of the forest stands investigated: the logging chronologies of the forests where the study areas were situated, the releases in radial growth that occurred in the silver fir stands, and the recruitment of pioneer and shade-intolerant early-seral broadleaves. Five periods of heavy logging were identified in the Buscaié forest (> 1000 m^3 $year^{-1}$) corresponding to the five-year intervals of 1935, 1940, 1955, 1970 and 1975 (Fig. 5). In plot 1, the periods of prominent growth releases (> 10% of the tree) took place in 1935, 1945, 1950, 1970, 1975 and 1995. Peak recruitment of broadleaves occurred in 1940. From 1940 on, broadleaf recruitment was fairly constant only to slow down rather suddenly after 1980. In the Prel forest, the major period of forest utilization was during the five-year interval of 1945 (Fig. 6); other important logging periods (> 1000 m^3 $year^{-1}$) in this area took place in the following five-year intervals: 1940, 1950, 1965 and 1970. The periods of highest growth release (> 10% of the tree) in plot 2 were in the intervals of 1945 and between 1970 and 1980. Peak recruitment of broadleaves occurred in 1975, precisely in the middle of the highest overall period of recruitment, which took place between 1970 and 1985.

4. DISCUSSION

As expected the structures of the studied plots are very different from any remaining European old-growth silver fir forests both in terms of composition and structure and in biomass [25, 26, 53].

Both plots studied are rich in fast-growing pioneers and early-seral species that have a limited vitality. The silver fir shows a relevant growth-rate (>10 m^3 ha^{-1} $year^{-1}$) due to the substantial

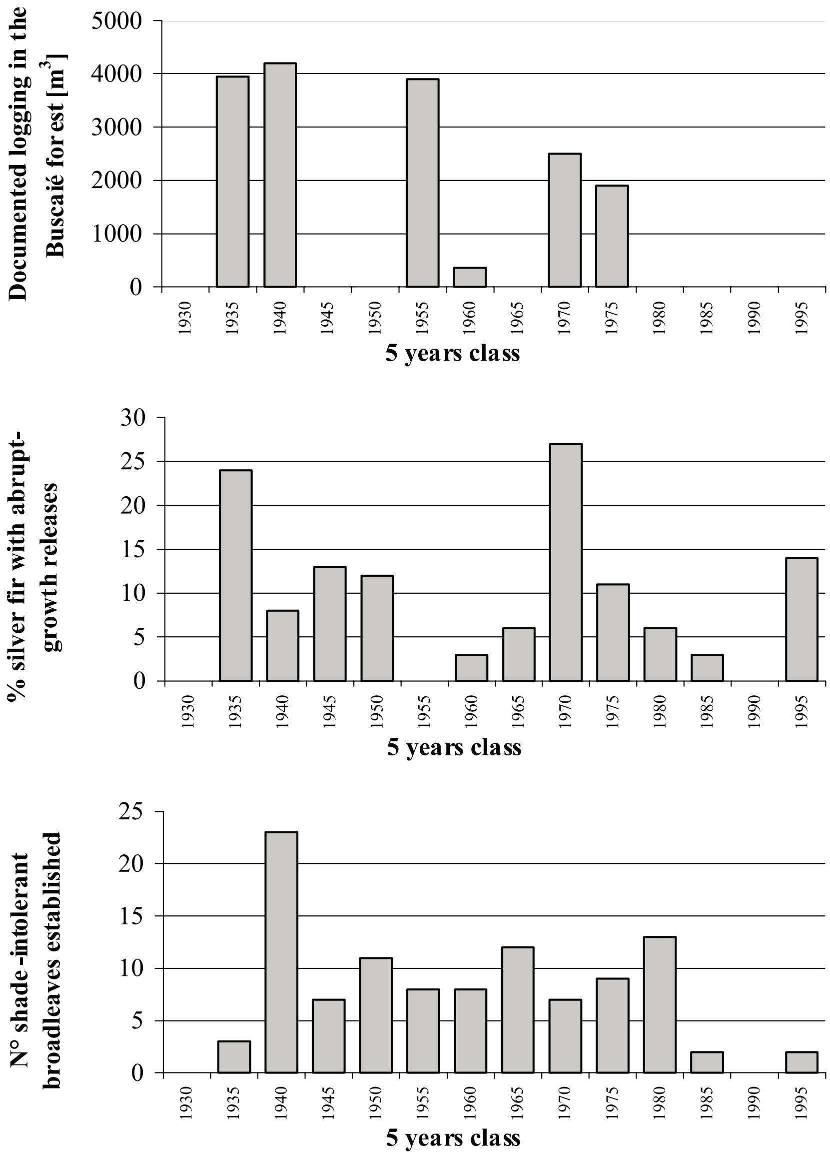

Figure 5. Documented logging in the Buscaié forest correlated to the growth releases in silver firs and to the establishment of pioneer and shade-intolerant early-seral species in plot 1. The main disturbances have been identified by growth releases and the availability of light at ground level was detected by the establishment of pioneer and shade-intolerant early-seral species. The logging chronology is helpful for suggesting the nature of the causal factors of disturbances.

rainfall and to the euthrophic site [18]; on the other hand, however, longevity is quite limited in these conditions if compared to most extreme site conditions, and, after 150 years most silver firs lose their vitality rapidly because of root decay [35].

The disturbances which occurred in the studied plots were principally caused by man. Indeed, human intervention substituted natural disturbances, eliminating mature stands and favouring regeneration. Logging of the silver fir in recent decades was fairly consistent and ceased abruptly and completely only after the establishment of the Regional Park. Historical documents are therefore indispensable for suggesting the nature of the causal factors of disturbances, though it is important to keep in mind that certain limits exist: there are no truly stand-scale descriptions of former silvicultural practices or logging since the documents in question refer only to areas of several hectares in a somewhat sketchy manner.

Consequently, to reconstruct the history of a single stand, in areas strongly affected by man, it is necessary to combine historical documents with the study of biological data banks (tree rings) and with other criteria such as pioneer and early-seral shade-intolerant recruitment. The analysis of abrupt growth changes, and of releases in particular, make it possible to document the various disturbances to which the studied plots have been subjected. When the percentage of trees that undergoes a recorded release is high (we adopted the figure of > 10% for the present study), it means that the disturbance is not a local phenomenon affecting one single tree or group, but rather that it has a certain extension.

However, this information is not sufficient to study the origin of the present-day stand; indeed there are disturbances recorded in trees where a regeneration establishment did not subsequently take place. Thinning and low-intensity cutting can provoke incremental reactions in the trees that remain after cutting, preventing adequate light from reaching the regeneration establishment. This is why it is absolutely essential to observe the dynamic of the regeneration establishment,

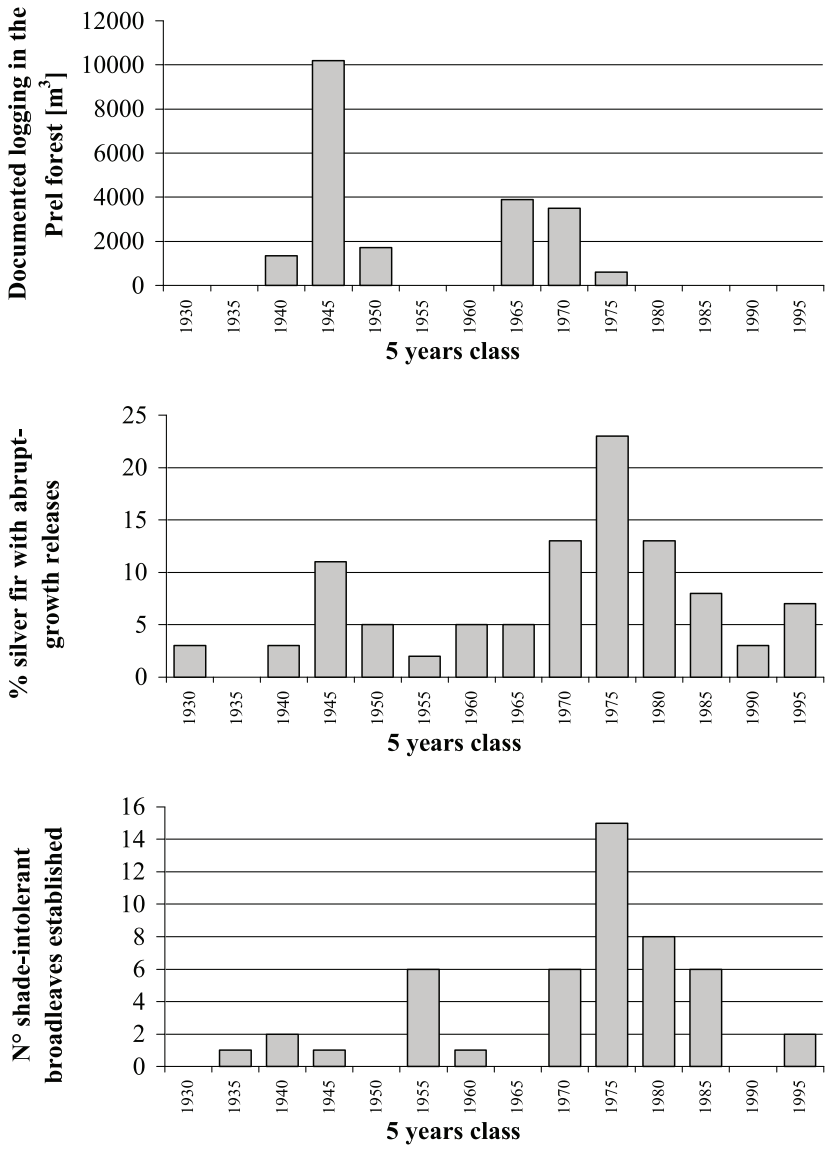

Figure 6. Documented logging in the Prel forest correlated to the growth releases in silver fir and to the establishment of pioneer and shade-intolerant early-seral species in plot 2. See other comments at Figure 5.

particularly in those species that make up the first phases of the colonization of early-seral shade-intolerant species, that can be used as reference species to indicate the presence of abundant light at ground level.

Based on a comparison of the three criteria adopted, it appears that the disturbance that gave rise to the present stand in plot 1 occurred in the five-year interval of 1935; indeed, intense logging was carried out in the Buscaié forest during that interval, and in the plot 1 more than 24% of the silver firs (probably reserves left by cutting) showed a release. In the subsequent five-year interval, a prominent recruitment of broadleaves was recorded as a consequence of clearing. After 1940, other disturbances took place (in particular during the 70s) that are corroborated by both releases and shade-intolerant broadleaf recruitment (Fig. 5). All of these disturbances were probably provoked by less intense cutting. The only exception is found in the 1995 five-year interval when the releases were provoked by windthrows.

The stand in the plot 2, on the other hand, was generated by disturbances (probably more than one logging event) that took place between 1970 and 1985. In this decade an high incidence of growth releases, and a intense establishment of shade-intolerant broadleaves was observed. Previous disturbances occurred in 1945 (whose traces probably were subsequently obscured by the logging which took place in 1975) and in 1970. In this case as well, releases were observed following wind damages in the 1995 five-year interval.

More generally speaking, the two stands, though differing in exposition and shade-intolerant broadleaf composition, seem to represent two consecutive phases of one single evolutionary process typical of eutrophic silver fir forests in the montane belt: after the clearing of a silver fir stand, a strong recruitment of shade-intolerant broadleaves takes place. During the decade of the broadleaves establishment, and in immediately subsequent decades, a reduced incidence of silver fir establishment is observed. This is partially due to poor conditions for the establishment of the species, and, in particular, to fierce competition from the shade-intolerant broadleaves in the first phases of their establishment; however, according to the "initial floristic" pattern [39], the silver fir, a late-seral species, may be present soon after the disturbance but is often overlooked because its relatively low numbers and slow initial growth.

This reduction in silver fir incidence can be observed in the age structure (Fig. 4) in the 50-year class in plot 1 and in the classes of less than 30 years in plot 2. After some years however, the silver fir, a shade-tolerant species, can gradually increase its presence in these stands, both because the vitality of the pioneer species gradually declines and previously overtopped trees can grow faster, and also because it finds again more favourable conditions for establishment. Probably, in the past, it happened that the frequent coppicing of shade-intolerant broadleaves prevented them from competing with the silver fir and from reaching the dominant, codominant and intermediate layers, thus making it possible to maintain stands which were pure or with a strong prevalence of silver fir (as verified by sixteenth- and eighteenth-century historical documents), even in the presence of frequent heavy logging. It is thus possible to hypothesise that the forest dynamic, left to its own devices in the absence of human intervention, will lead to the formation of a mixed stand with a relevant silver fir presence, with however the presence in the dominant and codominant layers of other shade-intolerant broadleaves, and in particular of beech (other late-seral species) and sycamore maple although the exact successional status of these stands is unresolved. In order to maintain this composition and a multilayered and uneven-aged structure (the suggested management objectives in the Park area that is not considered a strict forest reserve), it is necessary to avoid large gaps, where the pioneer and early-seral species can regenerate, but rather to adopt a single tree or small group selection system. At any rate the windthrows either in small- or medium-sized areas (as observed in 1995), will assure the maintenance of composition and structural variety at the landscape level.

5. CONCLUSIONS

The results of the present study confirm that in the "Alta Valle Pesio e Tanaro" Regional Park it is very difficult to distinguish natural disturbances from human disturbances, a conclusion also extendable to the European Alps in general. The presence of human activity necessitates conscientious study of the multiple sources of evidence provided by written records and biological archives. Biological data banks (tree-rings) are useful in the identification of the timing and intensity of stand-scale disturbance. Historical documents may be useful for suggesting the nature of causal factors and for checking dendroecological results, despite the fact that the information gleaned from historical documents often refers only to sections of a forest and do not therefore provide the stand-scale definition that is necessary for reconstructing the precise history of the establishment and disturbance of a single stand. Be that as it may, multiple sources of independent data do certainly help to delineate the most important features of disturbances that affected the origin and development of the stands. Given the lack of virgin and old-growth forests, it is clearly important to study present-day forests that are no longer cultivated and to establish permanent plots where the natural evolution of these forest stands can be observed in the absence of human intervention. These areas can be usefully exploited as a reference point for forest management.

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