# Forest structure of a maple old-growth stand: a case study on the Apennines mountains (Southern Italy)

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**Abstract:** In Europe, very small forest areas can be considered to be old-growth, and they are mainly located in Eastern Europe. The typical structures of old growth forests infrequently occur in Mediterranean mountainous environments, since they have been affected by human activities for centuries. This study focused on a remote and almost pure Italian maple stand located in southern Italy, which has not been managed for long time due to its inaccessibility. The effects of natural evolution on the forest stand were evaluated through the analysis of the spatial and chronological structure and the regeneration patterns, then estimating the amounts and quality of deadwood occurrence. Across the whole stand, all the trees with DBH (diameter at breast height) larger than 50 cm (LLT, large living trees) were measured (DBH and height) and age was also determined through a dendrochronological approach. The diameters observed ranged between 50 and 145 cm with ages of 120 to 250 years. The Latham index calculated for trees within the sample plot highlighted a multilayered canopy with a dominant layer of large living trees (age > 120 years). The size-class distribution of stems had a reverse-J shape, and basal area was 52 m² ha⁻¹. Deadwood was exclusively constituted by standing dead trees and CWD and its volume was on average 31 m³ ha⁻¹.

Pure Italian maple forests are generally rare in Europe, and it was unexpected to find a forest stand characterized by a so complex structure with old growth attributes. The study of complex forest stand, even if small, could give precious information on the forest evolution, clarifying also diverse auto-ecological traits of tree species that usually are not common in our forests.

**Keywords:** Mediterranean mountainous ecosystems; Natural evolution; Stand characteristics; Deadwood; Unmanaged forests

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## Introduction

Old growth forests are subdivided into primary and secondary forest. While the first category, not managed since a long time (from centuries to millennia), is very uncommon in Europe and in Italy, the second one is much more frequent in the forest landscape.

In fact, old-growth forests, considered as stands never managed, disappeared during the last thousands years of reforestation after the ice age in many regions of Europe. This was mainly due to the increase of anthropogenic activities, thus only very small forest areas remains that can be considered old-growth (Spies 2004). In Europe, there are still approximately 3 million hectares of forests (FAO 2010) managed in the past but today left to natural evolution, which can be found in the remote mountainous areas of Eastern Europe (Spies 2004). Moreover, most of these old growth forests are located in natural reserves and national parks (Wirth et al. 2009).

However, a clear definition for old-growth forests has not yet universally defined (Wirth et al. 2009). Any definition should be supported by indicators easily applicable for the identification of standard old-growth conditions, also in terms of structural and functional forest complexity (Peterken 1996). Some structural attributes are often used to define old-growth forests as a tool for compositional and functional features detection (Franklin and Spies 1991). In Europe, many studies conducted on old-growth forests (Wirth et al. 2009) focused on the forest structure and composition (Emborg et al. 2000), the stand dynamics (Nagel et al. 2006), the age of the structure (Rozas 2003) and the deadwood presence (Siitonen et al. 2000). In fact, old-growth attributes include the large variation in tree dimension, the presence of big trees, multi-layered forest canopy and large amounts of necromass (Franklin and Spies 1991).

In Italy and all around the Mediterranean sea, forests have been managed since pre-Roman time and no old growth stands occur (Piovesan et al. 2005; Rackham 2008). Moreover, the typical structures of old growth forests rarely occur in Mediterranean mountainous environments, particularly in the Italian peninsula (Lombardi et al. 2012), where forests have been influenced by human activities for centuries (Motta and Edouard 2005; Marziliano et al. 2012; Marziliano et al. 2015). Human impacts involved for centuries grazing activities and forest clearing for agricultural, firewood and industrial purposes as well as for planting monocultures and exotic species (Coletta et al. 2016). These trends induced a strong simplification in forest structures, with a consequent depletion of specific habitats and a reduction of the relative abundance of species (McKane et al. 2002; Motta et al. 2006).

The isolation of these stands has left few small patches of forest supposed undisturbed by human activities, in contrast to neighboring less protected forest systems (Lertzman et al. 1996). These remote areas are characterized by high ecological trait, representing naturalness hotspots, often referring to very complex forest structures (Marchetti et al. 2012). Forest ecosystems with a high degree of naturalness could be a reference point of sustainability for forest managers (von Oheimb et al. 2005).

Indeed, the absence of silvicultural activities for decades has allowed forest dynamics to take successional trends mainly driven by natural dynamics and disturbance factors (Blasi et al. 2010). Under these conditions, forests can develop diversified stand structures, slowly approaching the level of a natural forest (Spies 2004).

Finally, a common definition of old-growth forest in the context of the Mediterranean forest environment can be: "*Forests in which human disturbances are absent or negligible, in which natural dynamics create a mosaic of all the forest regeneration phases, including the senescing one. Such phase is characterized by large old trees, deadwood and a vascular plant species composition that is consistent with the biogeographical context* [...]" (Blasi et al. 2010).

Moreover, forest structure should be used as a proxy of compositional features (Franklin et al. 2002). Some of the structural attributes used to define the level of oldgrowthness are the large variation in tree dimension, the occurrence of large living trees and multilayered canopy (Franklin and Spies 1991). Furthermore, individual trees develop structures through ecological processes of growth, senescence and death (Spies 2004); then, stands can reach complex structures (J shaped diameter classes distribution, vertical multi-layering, presence of gaps, large amounts of deadwood) which create an ecological substrate for a wide range of species (Sabatini et al. 2010; Ciancio and Nocentini 2011; Burrascano 2012).

In western Europe, the most studied old-growth forests are usually dominated by beech, sometimes mixed with silver fir and norway spruce, while old-growth forests characterized by other species were often less considered (Burrascano et al. 2013). Nevertheless, in Italy many other forest tree genuses occur, such as *Quercus*, *Carpinus*, *Fraxinus*, *Acer, Tilia* and *Ulmus* (Davies et al. 2004), which have high ecological values (Iovino and Menguzzato 1999) and developed for centuries without anthropic disturbances.

Mostly in Calabria Region, located in southern Italy, such forest stands were intensively managed for centuries, even if some of them located in isolated mountainous areas have been spared from anthropic impacts (Menguzzato 2013), nowadays reaching high levels of structural complexity.

In particular, this study focused on a remote and almost pure Italian maple (*Acer opalus* Mill. subsp. *obtusatum* (Waldst. & Kit. ex Willd.)) stand located in the Sila National park. In Italy, maple species do not usually form pure plant communities (Perrino et al. 2012), but they can be found in small groups or isolated in high fertility sites where soil and air moisture are higher. Considering the particularity of the study area, we aimed to evaluate the effects of natural evolution on the forest stand, analyzing the structural characteristics through the use of structural indices, but also studying the regeneration patterns and estimating the amounts and quality of deadwood occurrence.

## 1 Materials and Methods

### 1.1 Study area

The study was carried out in the context of the Sila National Park (Caritello-Viperaro municipalities), in southern Italy (Figure 1). The investigated forest stand is located in a steep valley (50%-70% slope) mainly facing southeast (39°03'06'' N, 16°38'32'' E), at the right bank of Finoieri stream, at an altitudinal range of 1100-1250 m a.s.l. The area did not undergo to logging activities for decades due to the extremely rugged topography. However, the last thinning operations were realized in the 40s of the last century (Carullo 1952; Menguzzato 2013). The climate is oceanic, upper supramediterranean, upper humid (Rivas-Martinez 1995). The mean annual temperature is 9.7°C and the mean annual precipitation is 1300 mm year$^{-1}$, occurring mainly in the autumn and winter seasons (70% of the total amount).

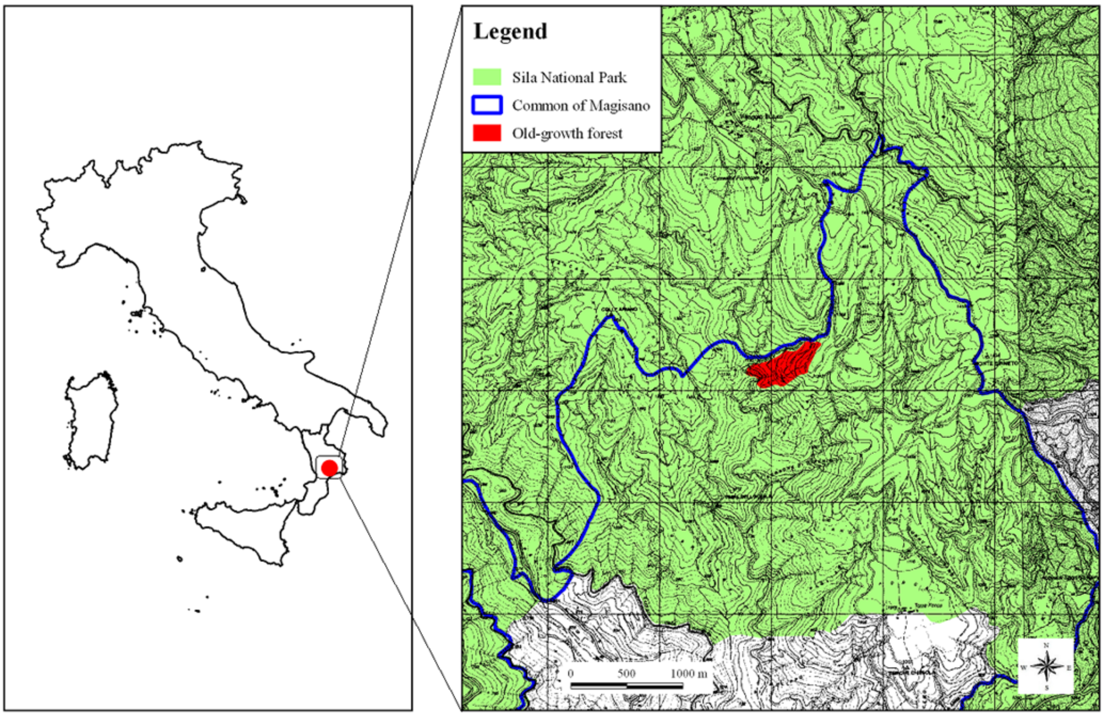


**Figure 1** Location of the study area in the Southern Appennines, Calabria Region (Italy).

According to FAO soils classification (1998), prevailing soils refers to the Humic Great Groups of Dystrudepts, while substrates, mainly acidic (pH=6.0-6.5), are characterized by igneous rocks (ARSSA 2003).

The whole valley extends on 15 hectare and it is dominated by a mesophilic mixed broadleaved forest species. Particularly, the investigated forest stand is characterized by a maple old-growth forest, extending on 5 ha. It was unmanaged for decades because of difficult accessibility, but also not affected by anthropic disturbances, such as forest fires. Thus, the forest structure nowadays observable, derives from decades of natural evolution where only disturbances of natural origin, such as strong wind and heavy snow, occurred (Carullo 1952; Menguzzato 2013).

### 1.2 Survey protocol and data analysis

In order to describe the forest stand and to verify the occurrence of high levels of naturalness, structural attributes commonly associated with different old-growth forests were considered (Bauhus et al. 2009; Burrascano et al. 2013). Moreover, they were implemented with the indicators already used for the specific Mediterranean mountain forest ecosystems (Lombardi et al. 2012). Therefore, the following indicators were considered: (I) the lack of anthropic disturbance for a sufficient prolonged time frame; (II) presence/absence of large and aged trees; (III) complexity of the stand structure; (IV) amount and decay of deadwood; (V) deadwood/live standing biomass ratio.

In detail, a square plot of 0.5-ha wide (70.7 m × 70.7 m) was established in the selected study area. The sampled plot is located in the core area of the whole stand (5 ha) at an altitude of 1200 m a.s.l.. The plot has a moderate slope (40%) and a south-east aspect.

The sampled area is representative of the whole stand, reflecting the main structural features occurring in the forest stand. The coordinates of the plots corners were acquired by a GPS of submetric precision, averaging 200 positions about and then computed with a GIS (Arc GIS 10.3). The plot size was also verified with field instruments (hypsometer Vertex III and compass). Moreover, a detailed structural analysis was performed for a rectangular transect of 15x90 meters. This transect was perpendicularly overlapped on the main square plot and south to north oriented. For this reason, the first and the last 10 meters of the transect fell outside the squared plot.

In detail, in the main square plot, the diameter at breast height (*DBH*) was measured for all the living trees, with diameter larger than 2.5 cm. Tree height was also measured only for sub-sample (about 30%), according to the different diameter size classes (Husch et al. 2003; van Laar and Akca 2008).

Moreover, in the same plot, information on deadwood were collected in order to assess both the amounts and the decay stages. Standing dead trees, dead downed trees, snags and stumps were measured when more than half base of their trunk lied within the plot. A threshold height of 1.3 m was used to distinguish stumps (less than 1.3 m) from snags (higher than 1.3 m). Snags were distinguished from standing dead trees, considering that branches and crown are not present in snags as in the standing dead trees. Coarse woody debris (*CWD*) were surveyed when more than half base of their thicker end lied within the plot. *DBH* and *height* were measured for standing dead trees and snags, diameter at half-length and total length were measured for *CWD*, base and top diameters were measured for stumps with top diameter larger than 5 cm. Both volume and biomass of standing and downed dead trees were calculated using the National Forest Inventory (INFC) double-entry volume equations (Tabacchi et al. 2011). The volume of stumps and coarse lying deadwood was derived by the use of the Huber's formula (Fridman and Walheim 2000):

$$v = s_{0.5} \times l \qquad (1)$$

where $l$ =length, and $s_{0.5}$ = median sectional area.

The decay stage of each deadwood component was determined through a visual analysis as reported by Koop (1989). The surveyed deadwood components are detailed in Table 1. Concerning the rectangular of 15 × 90 m, for each tree position was recorded and mapped. Afterwards, *DBH*, tree height, crown insertions as well as crown projections area were measured according to the cardinal points. Furthermore, to determine the conventional age for each tree, a core was taken by a Pressler borer at stem breast height on all the occurring standing tree (*DBH*>12.5 cm).

**Table 1** Deadwood attributes censed in the study sites (DBH: diameter at breast height; *H*: height; *L*: length; $D_{min}$: minimum diameter; $D_{max}$: maximum diameter; $D_{base}$: diameter at the base of the trunk; $D_{top}$: diameter at the top of the trunk; for deadwood decay classes, the Koop classification (1989) was used).

| Component sampled | | Dimensional threshold | Parameters recorded | Sampling unit |
|---|---|---|---|---|
| Deadwood components | Standing dead trees | *DBH*≥5cm, *H*≥130cm | Species, *DBH*, *H*, decay class | 0.5ha square plot |
| | Snags | *DBH* ≥5cm, *H*≥130cm | Species, $D_{base}$, $D_{top}$, *H*, decay class | 0.5ha square plot |
| | Dead downed trees | *DBH* ≥5cm, *H*≥130cm | Species, *DBH*, *L*, decay class | 0.5ha square plot |
| | Coarse woody debris | $D_{min}$≥5cm, *L*≥100cm | Species, $D_{min}$ and $D_{max}$, *L*, decay class | 0.5ha square plot |
| | Stumps | $D_{top}$≥5cm, *H*<130cm | Species, $D_{base}$, $D_{top}$, *H*, decay class | 0.5ha square plot |

**Table 2** Dendrometric results obtained in the study site

| Species | TD (n $ha^{-1}$) | Hd (m) | BA ($m^2$ $ha^{-1}$) | Vol ($m^3$ $ha^{-1}$) | AGB (Mg $ha^{-1}$) |
|---|---|---|---|---|---|
| *Acer opalus* Mill. subsp. *obtusatum* (Waldst. & Kit. ex Willd.) | 812 | 17.1 | 38.65 | 255.14 | 185.61 |
| *Alnus cordata* (Loisel.) Desf. | 28 | 21.9 | 5.32 | 46.05 | 26.29 |
| *Pinus nigra* J.F. Arnold subsp. *laricio* Maire | 48 | 21.0 | 3.96 | 40.18 | 16.86 |
| *Castanea sativa* Mill. | 32 | 19.0 | 1.93 | 17.18 | 10.53 |
| *Quercus cerris* L. | 20 | 17.2 | 1.86 | 15.15 | 12.24 |
| *Quercus ilex* L. | 8 | 9.2 | 0.14 | 0.59 | 0.56 |
| Total | 948 | | 51.86 | 374.29 | 252.09 |

**Notes:** TD: Tree density; Hd: Dominant height; BA: Basal area; Vol: Volume; AGB: Above-ground biomass.

In order to assess the vertical structure of the investigated forest stand, we used the Latham's index (Latham et al. 1998) which allows to group the sampled trees into discrete canopy layer. The applied algorithm determines a vertical height cut-off point, assigning the different trees to a specific vertical layer, basing on the heights of both the trees and related crowns (Baker and Wilson 2000; Latham and Tappeiner 2002; Motta et al. 2011; Marziliano et al. 2013). It is one of the most used index for the description of the vertical structure in the forest stands (Pommerening 2002). The SVS software (Standard Visualization System, USDA Forest Service 1999) was used to obtain a graphical representation of the vertical and horizontal forest structure, which take into account the tree specific composition. Furthermore, across the 5 hectares, GPS coordinates and tree height were acquired for all trees with *DBH* (diameter at breast height) larger than 50 cm (*LLT*, large living trees). Subsequently, the age of all the *LLT* was determined through a dendrochronological approach. In detail, for each tree, increment cores were taken with an increment borer (0.5 cm in diameter) uphill and at height of 1.3 m. Then, cores were mounted on channeled wood, seasoned in a fresh-air dry store and sanded a few months later. Tree rings were dated by counting from bark to pith, measured to the nearest 0.01 mm using the LINTAB-measurement equipment, coupled to a stereomicroscope (60x magnification; Leica, Germany). Where the trunk pith was absent due to the occurrence of wood cavities, the tree age was estimated considering the relationship between the number of visible rings and the whole tree diameter (Hellrigl 1986).

## 2 Results

In the Table 2 are reported the dendrometric results obtained in the 0.5 ha squared plot. Trees were 948 per hectare (86% Italian maple), with a basal area of 52 $m^2$ $ha^{-1}$ (75% Italian maple), with a volume of 374 $m^3$ $ha^{-1}$ (68% Italian maple) and biomass of 252 Mg $ha^{-1}$ (74% Italian maple) (Table 1). The distribution of the diameter classes ranged from 5 to 90 cm (Figure 2). Straight stems, few branches and small crowns characterized trees composing the dominant layer. The occurence of successful groups of regeneration confirmed a continuity in the forest natural development, well diversified and mainly constituted by Italian maple (*Acer opalus* Mill. subsp. *obtusatum* (Waldst. & Kit. ex Willd.), chestnut (*Castanea sativa* Mill.), holm oak (*Quercus ilex* L.) and beech (*Fagus sylvatica* L.). The shrub layer was constituted by dog-rose (*Rosa canina* L.), common bracken (*Pteris* *aquilina* L.), sweet peas (*Lathyrus venetus* (Mill.) Wohlf.) and a sporadic herb layer, which did not obstruct the tree regeneration.

Deadwood was exclusively constituted by standing dead trees and *CWD* (Figure 3), with a total volume of 30.9 m³ ha⁻¹. Neither stumps nor dead downed trees were detected. Dead standing trees belonged to the first three decay classes, with 47% of observations in the second class. *CWD* belonged to the second and third classes, with the 83% referring to the third class. Standing dead trees were 221 per hectare, mainly Italian maple, with a volume representing the 55% of the total deadwood (5.9 m³ ha⁻¹). *CWD* was the main deadwood component (84% of total), with a volume of 25 m³ ha⁻¹, mainly characterized by small branches (with diameters from 5 to 27 cm and length from 1 to 3.5 m). Finally, we found a deadwood to living volume ratio of about 10%.

Results obtained from the structural surveys carried out in the rectangular transect are shown in Figure 4 and Figure 5. In detail, Figure 4 illustrates the structure of the studied forest. Specifically, below the dominant layer of *LLT*, we observed a 65 years old tree layer dominated by Italian maple of gamic origin, developed without disturbance. Moreover, a regeneration layer with groups of small plants with age ranging between 10 and 20 years was also present (Figure 4).

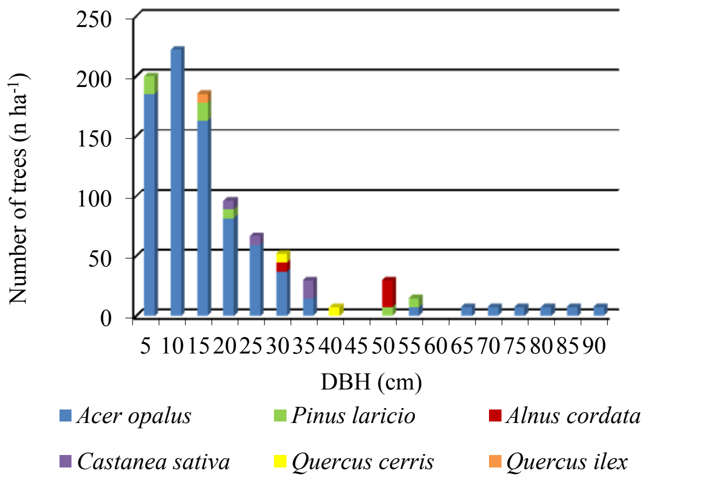


**Figure 2** Tree species distribution in relation to 5-cm diameter (DBH) classes observed in the sample plot.

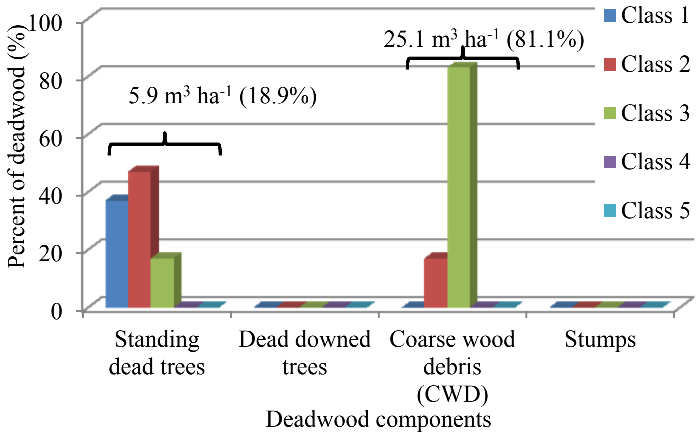


**Figure 3** Deadwood amounts (in percent) shared by each sampled component and related decay class (Koop 1989) classification scheme ranging from weakly (1) to highly decayed (5) wood. The total amount in m³ ha⁻¹ for each deadwood component is also reported (related to the sample plot).

Moreover, the Latham index pointed out four vertical layers (Figure 5): the first included the 26.5% of trees, with *LLT* and a part of the young high forest dominated by the Italian maple (taller trees), chestnut, Italian alder (*Alnus cordata* (Loisel.) Desf.) and calabrian pine (*Pinus nigra* J.F. Arnold subsp. *laricio* Maire) trees. This layer included the 80% of the total above-ground biomass. The second layer (36.8% of stand) was constituted by the young italian maple high forest (about 18% of total above-ground biomass), whereas the remaining two layers were natural regeneration groups (25 and 11.7% of stand respectively).

The results obtained in the 5 hectares area revealed the occurrence of more than one hundred of *LLT*, mainly referring to the italian maple (*Acer opalus* Mill. Subsp. *opalus*) and sessile oak trees (*Quercus petraea* (Mattuschka) Liebl), but also beech (*Fagus sylvatica* L.), italian alder (*Alnus cordata* (Loisel.) Desf) and calabrian pine (*Pinus nigra* J.F. Arnold subsp. *laricio* Maire). Generally, the diameters observed ranged between 50 and 145 cm (Figure 6). All these trees were older than a century, from 120 to 250 years. Italian maple trees were not so tall, with hollow stems, characterized by wide and branched crowns. The main branches started 2 meters from the ground, with a candle holder shape. Sessile oak trees had cylindrical stems, with large cicatrized knots and long lateral branches, forming deep and wide crowns.

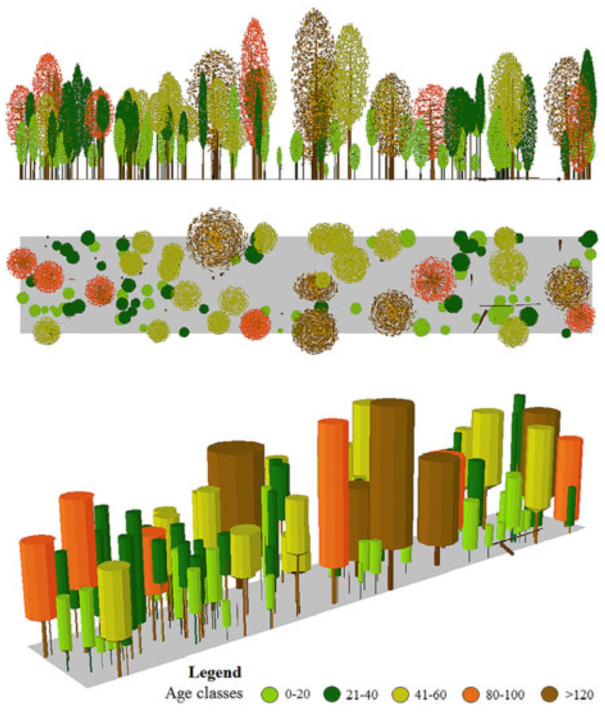


**Figure 4** Structural heterogeneity of the studied forest in a transect of 15×90 meters. Different colours refer to the occurring tree age classes.

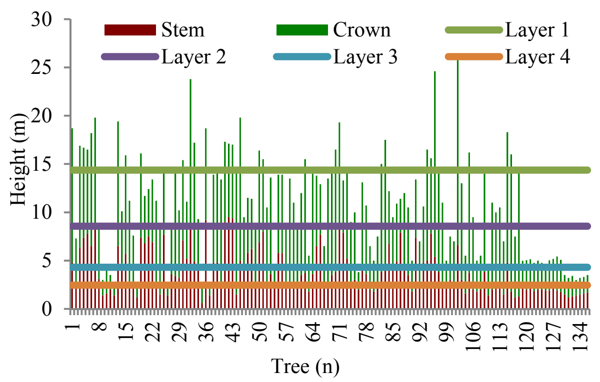


**Figure 5** Vertical tree stratification observed in the transect of 15×90 meters.

observe a multi-sized diameter distribution of living trees. In total, fifteen diameter classes of 10 cm were detected (Figure 7) with three main peaks occurring around 20-30, 80-90 and 130 cm; moreover, tree volume in relation to their diameters showed a high heterogeneity (Figure 7).

## 3 Discussion

In literature, it is well described how the European old growth forests are usually dominated by conifers and/or mixed deciduous broadleaf forest types characterized by beech, spruce, silver fir and, less often, oak species (Burrascano et al. 2013). However, in the Mediterranean mountainous areas, old growth forests are not common and dominated mainly by beech (Lombardi et al. 2012). Therefore, the forest stand analyzed in the present study should be considered a peculiarity due to its uncommon tree species composition. Indeed, mixed deciduous forest stands dominated by maple are generally rare in our Mediterranean environments. Moreover, our study area is highly valuable thanks to its complex structure, which is the results of decades of natural evolution. In Italy, the past extension of broadleaved forests dominated by maple species has been gradually reduced due to silvicultural approaches that promoted tree species more profitable for timber production. For this reason, very few stands dominated by maple can be found over the Apennines. On the contrary, in other geographical contexts, Paillet et al. (2008) reported how forests dominated by sycamore maple were less affected by past management than the surrounding mixed forests, due to their poor economic value and their role in soil protection. Moreover, the results obtained in the present study, revealed a strong diversification of tree size. The presence of large trees, together with the occurrence of natural regeneration and small trees are features already observed in different types of old-growth forests (Lombardi et al. 2012). Particularly, the presence of old trees allows, through the death of branches or trees, the establishment of new young individuals (Nagel et al. 2006). We in fact observed a strong regeneration capability and abundant establishment of new individuals.

In literature (Carullo 1952) is reported that a clearcutting was realized in the period 1929-1944, leaving only some reserves of maple, when the wood request increased a lot between the two world's war and during the second world war. However, even if the effect of the past management still influences the current forest structure, the absence of cutting activities from 70 years have induced an un-even aged structure, which reveal the prevalence of natural disturbance factors, such as wind and snow fall.

In a study carried out in France, Bouget et al. (2014) also showed that a short delay in harvesting (minimum 30 years) induced significant changes in the forest structure, increasing the structural complexity. Furthermore, in a wide investigation on old beech forest stand has been shown a higher biomass of fine roots (Montagnoli et al. 2012), coarse roots (Di Iorio et al. 2013) e carbon sequestration (Terzaghi et al. 2013, 2016). These works highlight that further studies are needed to analyze the biodiversity responses to the forest harvesting delay. Although the present study focused on a small forest stand, analyzing only forest structure parameters, can be fairly considered as an important reference for forest conservation purposes (Peterken 1996; Larrieu et al. 2014).

Our results revealed that the maximum diameter and height fell within the range reported for mesic broad-leaved forests with a canopy height of 25-45 m (Greenberg et al. 1997). Moreover, many trees had considerable diameters, ranging from 100 cm up to 145 cm (Figure 7). The basal area had a mean value of 51.86 $m^2$ $ha^{-1}$, which is within the control/normal category (>29 $m^2$ $ha^{-1}$) reported in Keddy and Drummond (1996) for old-growth deciduous forests. The above-ground biomass was 252 Mg $ha^{-1}$, in agreement with estimates for old-growth hemlock-northern hardwood forests in the USA, which ranged from 200 to 325 Mg $ha^{-1}$ (Mroz et al. 1985; Morrison 1990; Rutkowski and Stottlemyer 1993). Another important old-growth feature is linked to the density of large trees, which represents a large portion of total volume. According to Nilsson et al. (2002), tree density with *DBH* ≥ 70 cm should be at least 30 per hectare whereas, for Burrascano et al. (2013), the diameter threshold should be 50 cm. In our case, large living trees were 20 per hectare, with diameter from 50 to 145 cm. However, they contributed for about the 70% of the total biomass, which exceeded the range of variation established by Brown et al. (1997) for old-growth forests (20%-30% in trees > 70 cm *DBH*). Other authors found 16 *LLT*/ha in an old growth forest dominated by *Quercus mongolica* (Sano 1997), from 2.5 to 16.2 *LLT*/ha in a mixed conifer/broadleaved stand (Tyrrell and Crow 1994a; Tyrrell and Crow 1994b) and 26 *LLT*/ha in a mixed broadleaves old growth stand (Kupfer and Kirsch 1998). Moreover, we observed 10 trees/ha ≥ 75 cm in diameter, values similar to that observed in other studies (Greenberg et al. 1997; Burrascano et al. 2008).

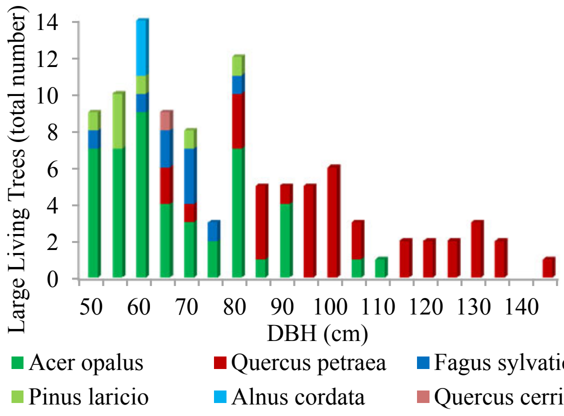


**Figure 6** Species distributions of Large Living Trees (LLT) in relation to diameter classes found in the whole stand.

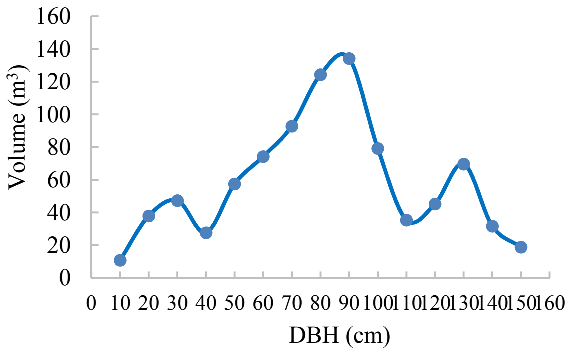


**Figure 7** Volume distribution in relation to 10-cm diameter (DBH) classes observed across the whole stand.

Our results confirm those from other studies, such as that reported by Bouget et al. (2014) who compared unmanaged with managed forest, showing that most of the stand characteristics they studied displayed higher tree volume and density values in long-established forest reserves than in the managed areas. However, in our study we found higher values of basal area (52 $m^2ha^{-1}$ *vs* 28 $m^2ha^{-1}$), but also a more significant number of *LLT* (20 $ha^{-1}$ *vs* 9 $ha^{-1}$) than those reported in Paillet et al. (2008) for unmanaged forest stands.

Another important feature we observed is that the size-class distribution of stems is quite complex, even if it is not a typical reverse-J shape, which has often been considered as an emergent property of natural forests (Motta et al. 2006).

In fact, in our study area, the diameter distribution still reveals the sign of past management and important deviation from a J shape model with an appreciable lack of middle size trees.

We here confirm that the investigated stand is in the early stage of old-growth development.

The genesis of such shape is complex because is affected by multiple processes such as stem recruitment, growth and mortality and by the time-span from the last disturbance event (Coomes et al. 2003). The stand was multi-layered, with the 80% of total above-ground biomass referring to the first forest layer.

Maple regeneration was predominant, especially in the first years after the occurrence of natural disturbances. Only in a second phase, also chestnut, both turkey and holm oaks and calabrian pine regenerated. These broadleaves, but also coniferous species, such as Calabrian pine, usually colonize the mesic zones in the Southern Italy and they can be usually observed in consociation also in absence of anthropic disturbance. In Italy, Chestnut was largely planted in the past and it is now able to naturally regenerate in mountain areas. Moreover, all these species don't require mature soil properties, but only a reasonable deep soil. These features largely occur in the study site. Furthermore, even if the Calabrian pine is a pioneer species, which should not regenerate in the advanced old-growth stages, it is characterized by a particular ecological behavior: it easily regenerates in gaps, often occurring in the old-growth stages, where the light occurrence is high, even if the litter accumulation is low (due to the steep slope).

This dynamic confirms how the forest development is especially ensured by leader tree species that survived after both natural and anthropic disturbance (clearcutting with reserves), rather than pioneer and brush species. This trend is in accordance with what reported in a study carried out in a broadleaved forest in USA (Barker Plotkin et al. 2012).

After the past silvicultural interventions, only trees of maple were left in the forest stand, often characterized by a candle holder shape. These results can support the hypothesis that the investigated forest was used as a pasture dominated by large trees, a tradition widespread across the Apennines in the past. Nowadays, two cohorts are present.

The younger trees are particularly abundant and we hypothesize that the mixture of different broadleaves species will be more evident in the next decades.

In particular, the natural evolution in the area should induce the creation of a mixed broadleaved forest dominated by *Quercus*, *Tilia* and *Acer*, already occurring in the regeneration phases. For the future forest dynamics, the ingression of other coniferous species, such as *Pinus nigra* J.F. Arnold subsp. *laricio* Maire and *Abies alba* Mill., is expected since the micro-climate is favorable for their auto-ecology.

Information on deadwood occurrence across European old growth stands are provided by many authors and recently reviewed by Burrascano et al. (2013). The total deadwood volume is usually higher for long-established montane reserves (220 $m^3$ $ha^{-1}$), followed by long-established lowland/ submontane reserves (131 $m^3$ $ha^{-1}$), then by recently-established lowland/submontane reserves (100 $m^3$ $ha^{-1}$) (Christensen et al. 2005). In our study, deadwood was quite low (31 $m^3$ $ha^{-1}$). However, the volume of deadwood generally occurring in Italian forests (mainly managed forest) is lower. Indeed, the National forest Inventory (INFC 2005) estimates deadwood occurrence in Italy equal to 8.8 $m^3$ $ha^{-1}$. The Mediterranean-type climate probably influences decay rates that can be faster due to higher temperatures (Hahn and Christensen 2004). For example, deadwood could decay faster in Mediterranean mountain climates than in forests occurring in colder climates (Lombardi et al. 2008). The deadwood dynamics are largely influenced by tree mortality and decay rates (Morrisey et al. 2014): they are strongly heterogeneous (Franklin et al. 1987) and affected by natural disturbances, stand structure, and site-specific ecological conditions (Harmon et al. 1986).

The dead to live wood ratio is usually applied to make results comparable (Wirth et al. 2009). According to the review by Burrascano et al. (2013), our values of around the 10% fall in the lower part of the range (6%-89%) of natural forests in the Mediterranean context.

In this study, *LLT* were not dense and, although they may contribute numerous *CWD* pieces, their cumulative low volume indicates a more ephemeral source of *CWD* because of the supposed effects of faster rates of decomposition

(Harmon et al. 1986; MacMillan 1988). Moreover, several studies showed low levels of *CWD* long after active management operations ceased (Bader et al. 1995; Sippola et al. 2001; Vandekerkhove et al. 2009).

Regarding the deadwood decay classes, mainly the first three decay stages were found, and particularly the third class, while the most advanced stages (classes 4 and 5) were absent. In general, decay rates is influenced by climatic factors and connected to the tree species and their physical characteristics. The deadwood sharing among many decay stages, supply microhabitats for many vertebrates and invertebrates and influences the levels of biodiversity occurring in a specific forest stand (Siitonen 2001). However, the prevalence of deadwood we observed in decay class 3 is similar with results obtained in other forest environments, where intermediate decay classes are dominant (Spetich et al. 1999). In our study, the first three decay classes were the most represented highlighting that the decay process is still at the beginning and that the structural dynamics within the stand are at an early stage.

## 4 Conclusions

Italian maple forests are generally rare in Europe and knowledge on these forest types remains rather poor across the European countries, even though their conservation status. In fact, they often occur in the frame of the sites of the ”Natura 2000 network”, as habitats of particular interest due to their ecological peculiarities.

Thus, the forest stand here presented has a high value since is characterized by a so complex structure and decades of natural evolution is observable. Moreover, we underline that also small forest areas could give precious information on the forest evolution, giving important insight on the diverse auto-ecological traits of tree species that usually are not common in our forests. This study provides information in identifying traits of potential old-growth forests in the Mediterranean context. The stand here investigated have reached a typical structural maturity of late successional forest dynamics. Traits of oldgrowthness are already visible and they could increase in the future if active management will be avoided. For this reason, it will be interesting to monitor the natural evolution for scientific purposes, in order to assess the time required for the development of real old-growth conditions.

An important open issue is the assessment of the time necessary for the development of old-growth conditions: in order to increase the old-growth traits, it will be useful to avoid any active management for the future, monitoring the natural evolution only for scientific and research purposes.

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