GIANFRANCO CALAMINI (*) (°) - ALBERTO MALTONI (*) - DAVIDE TRAVAGLINI (*)
FRANCESCO IOVINO(**) - ANTONINO NICOLACI (**) - GIULIANO MENGUZZATO (***)
PIERMARIA CORONA (****) - BARBARA FERRARI (****) - DANIELE DI SANTO (*****)
GHERARDO CHIRICI (******) - FABIO LOMBARDI (******)

# STAND STRUCTURE ATTRIBUTES IN POTENTIAL OLD-GROWTH FORESTS IN THE APENNINES, ITALY

(*) Dipartimento di Economia, Ingegneria, Scienze e Tecnologie Agrarie e Forestali, Università degli Studi di Firenze, via S. Bonaventura, 13, 50145 Firenze, Italy.
(**) Dipartimento di Difesa del Suolo Vincenzo Marone, Università degli Studi della Calabria, via P. Bucci Ed. 41B, 87036 Arcavacata di Rende (CS), Italy.
(***) Dipartimento Gestione dei Sistemi Agrari e Forestali, Università degli Studi Mediterranea, via Feo di Vito, 89100 Reggio Calabria, Italy.
(****) Dipartimento per la Innovazione nei Sistemi Biologici, Agroalimentari e Forestali, Università degli Studi della Tuscia, via San Camillo de Lellis, 01100 Viterbo, Italy.
(*****) Parco Nazionale Gran Sasso e Monti della Laga, via del Convento 1, 67010 Assergi (AQ), Italy.
(******) Dipartimento di Scienze e Tecnologie per l'Ambiente ed il Territorio, Università degli Studi del Molise, C.da Fonte Lappone, 86090 Pesche (IS), Italy.
(°) Corresponding Author; gianfranco.calamini@unifi.it

*The aim of this paper is to provide early feedback on stand structure attributes in Italian Apennines forests that could be considered Old Growth Forests in the Mediterranean Eco-Region. Few data are nowadays available relating to this Region. 10 forest reserves across the Apennines were selected and a census of trees and structural parameters was conducted in permanent plots (0.16-1.0 ha), one plot for each selected forest stand. Dimensional and structural characters indicate a large variability among the investigated forest stands.*

*The considered parameters are compared with those reported for other European countries. Old growth features and characteristics of each indicator should be revised and referred to the particular climatic and biogeographic context. The chosen forest study sites are to be considered old if related to common Apennine stands but, in some cases, their development stage is not so close to "truly" Old Growth Forest. Permanent plots allow future investigations on dynamic processes leading to real Old Growth Mediterranean Forests in Italian Apennines.*

*Key words:* Old-Growth Forests; unmanaged Mediterranean forests; structural attributes; sustainable forest management.
*Parole chiave*: foreste vetuste; foreste mediterranee non gestite; caratteri strutturali; gestione forestale sostenibile.

*Citazione* – CALAMINI G., MALTONI A., TRAVAGLINI D., IOVINO F., NICOLACI A., MENGUZZATO G., CORONA P., FERRARI B., DI SANTO D., CHIRICI G., LOMBARDI F., 2011 – *Stand structure attributes in potential Old-Growth Forests in the Apennines, Italy*. L'Italia Forestale e Montana, 66 (5): 365-381. http://dx.doi.org/10.4129/ifm.2011.5.01

## 1. INTRODUCTION

The occurrence of persistent woodlands represents an unique chance for forestry researchers involved in ecological studies. The absence of silvicultural activities for decades shows us dynamic processes according to the potential of the site. Evolution can lead to a diversification in terms of structure and biodiversity, approaching the level of a native forest (FRELICH and REICH, 2003; SPIES, 2004; LOMBARDI *et al.*, 2008). The characterization and localization of old growth forests allows effective conservation policies and ecological network implementation. Besides, old growth forests have also an important role in carbon storing (LUYSSAERT *et al.*, 2008).

Since there are many ways for a forest to grow old, it is probably not possible and not useful to try to provide a concise scientific definition of



doi: 10.4129/ifm.2011.5.01

Old-Growth Forest (WIRTH *et al.*, 2009). For this reason, we cannot find in literature a general and unambiguous definition of old growth forests (SPIES, 2004). We can try to recognize an Old-Growth Forest supported by indicators that can be easily referred to structural and functional complexity conditions (PETERKEN, 1996). Typical criteria to identify old-growth conditions are: large, old trees with regard to species and site; wide variation in tree size, age and spacing, large dead standing and fallen trees; multiple canopy layers; heterogeneous vertical and horizontal structure; canopy gaps and understory patchiness; abundant ferns, lichens and bryophytes; decadence in terms of broken and deformed tops or boles and root decay; canopy tree mortality mostly agent-based (i.e., from disease and wind) rather than competition-based (except within dense patches of regeneration in the understory).

In Europe research has been mainly directed towards boreal and temperate old-growth forests, where several surviving "virgin" reserves tend to have a longer protection history and were less influenced by human activities before designation (CHRISTENSEN *et al.*, 2005). Many studies were conducted on old growth forests, focusing on their structure and composition (e.g. KUULUVAINEN *et al.*, 1998; EMBORG *et al.*, 2000; TABAKU, 2000), on their structural dynamics and natural regeneration (e.g. KORPEL, 1982; KOOP and HILGEN, 1987; BJÖRKMAN and BRADSHAW, 1996; LINDNER *et al.*, 1997; LINDER, 1998; BOBIEC *et al.*, 2000; DIACI *et al.*, 2003; NAGEL *et al.*, 2006), on stand age structure (e.g. ROZAS, 2003) and dead wood occurrence (e.g. JONSSON, 2000; SIITONEN *et al.*, 2000; SANIGA and SCHUTZ, 2002).

In the Mediterranean region, forests have been exploited since ancient times: cutting, grazing and fire have all greatly simplified forest stand composition and structure; for this reason, Mediterranean old-growth forests are very rare and usually are found only inside strict forest reserves (PACI and SALBITANO, 1998) or in remote and impervious mountain areas (MOTTA and EDOUARD, 2005; PIOVESAN *et al.*, 2005; MOTTA *et al.*, 2006; PIOVESAN *et al.*, 2010).

Specifically in the Italian peninsula, since Roman time, all forests have been heavily affected by direct anthropogenic disturbances throughout periodic forest loggings or indirectly by many types of habitats management and manipulation (MOTTA and EDOUARD, 2005). However and almost everywhere the harvesting removed the trees before they reached their maximum dimensions at the end of the physiological cycle.

New social priorities had led after the Second World War to a reduction in silvicultural activities, especially in some remote areas on the mountain: as a result, many forests have developed naturally over the past few decades, even if their composition and structure still reflect past human activity (MOTTA *et al.*, 2006; CITTERIO *et al.*, 2007; BURRASCANO *et al.*, 2008). These forests could be so defined as persistent woodlands (MARCHETTI *et al.*, 2010). In 2006, natural forests within the Cilento and Vallo di Diano National Park (Southern Italy) were selected as a primary study site for biodiversity conservation efforts by the EU, where long-term-monitoring will estimate the time span required for disturbed forest to become equivalent to old-growth forests (MARCHETTI *et al.*, 2010). Studies carried on in persistent protected woodlands can give precious indications about the dynamics of forests that are developing without human influence (MASON, 2004).

Recently, several authors have identified some potential old-growth forests in Italy (CHIRICI and NOCENTINI, 2010). These are mainly located in mountain areas in the Alps (MOTTA, 2002; MOTTA and EDOUARD, 2005; MOTTA *et al.*, 2006), in the Apennine regions (PACI and SALBITANO, 1998; PIOVESAN *et al.*, 2005; BURRASCANO *et al.*, 2009) and also in the Mediterranean area (CITTERIO *et al.*, 2007; PUXEDDU *et al.*, 2010). However, studies in Mediterranean areas are still scarce and for this reason there is not a definition of old-growth supported by indicators that can be easily used for the individuation of old-growth forests in different forests types, furthermore considering that they can vary across the European ecoregions.

This paper introduces some of the results of the project "Innovative methods for the identification, characterization and management of old-growth forests in the Mediterranean environment" funded by the Italian Ministry for University and Research (PRIN 2007, proj. 2007TFREJ9).

The aim of this research is to contribute to redress the imbalance in knowledge on old growth forest definitions in the Mediterranean forest areas, considering how it was already stressed in Central and North European forests (PETERKEN, 1996; PEDLAR *et al.*, 2002; SIITONEN *et al.*, 2000; SPETICH *et al.*, 1999; WIRTH *et al.*, 2009). In so doing and then selecting appropriate indicators of "old-growthness" and research based thresholds for these indicators, it is possible to identify "potentially" old-growth forests and plan appropriate conservation measures (NOCENTINI, 2010).

In order to identify old-growth conditions in Mediterranean unmanaged forests by analyzing the living tree component from the dimensional and the structural point of view, 10 forest reserves across the Apennines in Italian peninsula were considered. In this paper attributes usually adopted to define old-growth forest such as large trees for the species and the site, wide variation in tree size, multiple canopy layer, J-reverse shape or rotated sigmoid diameter distribution were analyzed.

Data and discussion on dead wood occurrence in the same study areas can be found in LOMBARDI *et al.* (2010).

## 2. MATERIAL AND METHODS

### *2.1. Study sites*

The census was conducted in 10 forest sites located across the Apennines (Italy) (Figure 1). For each study area, forest type, altitude, main climatic data and years since last harvesting are reported in the brief description below.

1) *Cozzo Ferriero* – this is an almost pure *Fagus sylvatica* high forest stand where *Acer pseudoplatanus* presence increases with the rise of the humidity conditions; according to EEA (2006) the forest type is an *Apennine-Corsican montane beech forest*. Cozzo Ferriero area, undisturbed for 80 years, is located within the Pollino National Park, in Basilicata (a Southern Italy region), not so far from the village of Rotonda (Potenza district). The study site, West faced, is placed at 1700-1750 m a.s.l., on a bedrock made of Cretaceous limestone where dolomitic limestones are prevalent, with greensands and clay soils moderately deep that can be referred to the Typical Hapludolls (REGIONE BASILICATA, 2004); the mean annual temperature is 7.3 °C and the mean annual rainfall is 1180 mm.
2) *Fosso Cecita* – according to EEA (2006) this forest is a *Mediterranean and Anatolian black pine forest*; the prevalent species is *Pinus laricio* with presence of *Quercus cerris.* The natural succession process of pine forest towards more complex structures has been delayed by the past human activities (IOVINO and MENGUZZATO, 1996). The Fosso Cecita forest area, undisturbed for 110 years, is located into Sila National Park, Calabria region (Southern Italy), managed by the National Forest Service and it's located at 1140-1200 m a.s.l. The climate of the study area is characterized by a mean annual temperature of 7.3 °C and a mean annual rainfall of 1180 mm; it's South-SouthWest faced and characterized by metamorphic and igneous rocks, with acid, moderately deep soils (ARSSA, 2003).
3) *Monte Sacro* – this area is a pure *Fagus sylvatica* high forest, not managed for more than 60 years because of its hard to reach location; EEA (2006) classifies it as an *Apennine-Corsican montane beech forest*. Monte Sacro, 1330-1550 m a.s.l., belongs to Cilento and Vallo di Diano National Park, in the municipality of Novi Velia (Salerno district), Campania region (Southern Italy). The study site is south-west facing, where Cretacic limestone, with greensands and clay deep soils, is prevalent (ISPRA, 2008).
4) *Val Cervara* – this stand is an almost pure *Fagus sylvatica* high forest, an *Apennine-*


*Figure 1* – Location of the study sites. Numbers refer to the area described in the *Material and Methods* section.

*– Localizzazione delle aree di studio. I numeri si riferiscono alle descrizioni delle aree riportate nel capitolo* Materiali e Metodi*.*

*Corsican montane beech forest* according to EEA (2006). The forest is located in an amphitheatre-shaped valley orientated from east to west and the absence of disturbance in the study area, located in the upper part of Val Cervara Forest (1730-1830 m a.s.l.), is due to its difficult access; summer grazing in higher elevation pastures may have been for centuries the main human activity. This stand is located within the Abruzzo, Lazio and Molise National Park, L'Aquila district, Abruzzo region (Southern Italy). The study site lays on a bedrock of Cretaceous limestone and soils can be referred to the brown group; the mean annual temperature is 7.2 °C and the mean annual rainfall is 1211 mm.

5) *Abeti Soprani* – the forest is an almost pure *Abies alba* stand, somewhere with *Fagus sylvatica* and *Quercus cerris*; other species

(*Acer pseudoplatanus*, *Acer campestre*, *Acer obtusatum*, *Tilia platyphyllos* and *Taxus baccata*) may occur. EEA (2006) defines it as a *Mediterranean* and *Anatolian fir forest*; even if last disturbance is dated 30 years ago, it can be considered as a relict stand representative of the past Appennine fir stands that survive only in small areas of the Italian peninsula (CIANCIO *et al*., 1985). The Abeti Soprani forest (1250-1450 m a.s.l.) is located near Pescopennataro (Isernia district, Molise Region, Southern Italy). The prevalent study area soils developed on a bedrock dominated by miocenic-clay soils and cretacic white limestone, on a north facing slope; Rendzina soils are also present. 8.4 °C is the mean annual temperature and 1124 mm the mean annual rainfall.

6) *Collemeluccio* – this stand, located between 900 and 1000 m a.s.l., is dominated by *Abies alba* mixed with *Quercus cerris*, *Fagus sylvatica*, *Carpinus betulus* and *Ilex aquifolium*; it is a *Mediterranean and Anatolian fir forest* according to EEA forest types (2006). The vegetation has recently been referred to *Aremonio agrimonioidis-Quercetum cerridis* subass. *abietetosum albae* (ALLEGREZZA and BIONDI, 2008). As the previous area this is a relict of the last stand survived from the last glacial period. The forest has been undisturbed since 1960 and it is situated in the MAB UNESCO Reserve of "Collemeluccio-Montedimezzo" (Isernia district, Molise Region, Southern Italy). The study area geology is characterized by the presence of a single Miocene formation, constituted by micaceous sandstones, shaly clays and marly limestones; the mean annual temperature is 9.2 °C and the mean annual rainfall is 960 mm.

7) *Montedimezzo* – the forest is dominated by *Fagus sylvatica* and the forest type is *Apennine-Corsican montane beech forest* (EEA, 2006). The beech forest is characterized by a significant presence of *Quercus cerris* at the lowest altitudes and, somewhere, *Acer pseudoplatanus*, *Acer obtusatum*, *Taxus baccata* and *Tilia platyphyllos* can also be found. Even if *Quercus cerris* is quite important in the censed area, the vegetation unit is the *Polistycho aculeati-Fagetum sylvaticae aceretosum pseudoplatani* (CARRANZA *et al*., 2006). As Collemeluccio, this stand belongs to the MAB UNESCO Reserve of "Collemeluccio-Montedimezzo" and the last disturbance action is dated 1950. The study area is located on a North facing slope, on a Cretacic limestone, with greensands and prevalent clay soils; the mean annual temperature is 8.6 °C and the mean annual rainfall is 1022 mm.

8) *Monti Cimini* – this forest (925-1150 m a.s.l.) is dominated by *Fagus sylvatica,* somewhere *Acer pseudoplatanus*, *Acer obtusatum*, *Castanea sativa*, *Sambucus nigra* can be found; the literature classifies Monti Cimini forest as *Polysticho-Fagetum aceretosum pseudoplatani* (SCOPPOLA and CAPORALI, 1998; FEOLI and LAGONEGRO, 1982) and EEA (2006) defines it as an *Apennine-Corsican montane beech forest*. The human activities haven't been practiced since 1950. The Monti Cimini area is placed on an isolated relief of volcanic origin located in Central Italy (Viterbo district, Lazio Region) and the soil is characterized by a very fertile soil with a mull horizon. The study site has a temperate oceanic semicontinental bioclimate, the mean annual temperature is 14.3 °C and the mean annual rainfall is 1300 mm.

9) *Fonte Novello* – this area (1340 m a.s.l.) is classified by EEA (2006) as an *Apennine-Corsican montane beech forest.* The vegetation of all the valley (Venacquaro Valley, Gran Sasso - Laga National Park, Abruzzo region, Central Italy) is dominated by beech forests, mainly pure but somewhere *Acer obtusatum*, *Acer pseudoplatanus* and *Sorbus aria* can be found. *Salix caprea* in the moister areas occurs, while on the unstable and warmer slopes *Ostrya carpinifolia* and *Laburnum anagyroides* are present. At lower altitudes the secondary species can be: *Quercus cerris*, *Quercus petraea*, *Ulmus montana* and *Acer platanoides*. The study area was left undisturbed for centuries

because of ownership disagreement between Pietracamela and Fano Adriano municipalities. Regarding the geological features, the area is dominated by 200-300 millions-year-old rocks of carbonatic genesis; soils are classified as Lithic Rendolls, derived from alteration of the calcareous rock. The study area, North oriented, has a temperate continental climate and 10.0 °C is the mean annual temperature and the mean annual rainfall consists of 1071 mm.

10) *Sasso Fratino* – as the previous, Sasso Fratino forest is defined by EEA (2006) as an *Apennine-Corsican montane beech forest*; the beech is the dominant species in the upper storey with an average dominant height of about 40 m; small groups (12-15 m tall) and single trees (2-5 m tall) of *Abies alba* locally occur (BIANCHI *et al.*, 2009). The study area (950-1050 m a.s.l.) is located in Central Italy (Emilia-Romagna Region) within Foreste Casentinesi, Monte Falterona and Campigna National Park. Sasso Fratino is a Strict Nature Reserve established in 1959; the Reserve area is 764 ha and it is managed by the National Forest Service. The study site has been left to natural evolution for more than seventy years. 9.0 °C is the mean annual temperature and the mean annual rainfall consists of 1041 mm.

### 2.2. Field methods

Fieldwork was carried out in 2009. In each study site, living trees were assessed within one plot by a standard field protocol. In seven sites, a square plot of almost 1 ha was established. In three sites, the size of the plot area was reduced because of the very steep slopes (Monte Sacro 0.20 ha; Cozzo Ferriero 0.16 ha; Fosso Cecita 0.45 ha). The size of sampled plots is of distinctive relevance (CORONA *et al.*, 2010). If too small, plots cannot effectively provide an overall, meaningful picture of the stand structure: they might not truly reflect the proportions of the following stages and thus might overrepresent certain structural features. Small plots are prone to sampling vagaries if probabilistic repeated sampling is not adopted, and even in this case there is the risk to create artifacts, as shown by RUBIN *et al.* (2006). In each plot, the coordinates of the corners were acquired by a GPS, then the plot area was computed with a GIS.

The following attributes have been recorded for each sampled living tree: position, obtained by measuring horizontal distances and azimuth from points acquired by GPS; species; diameter at breast height (DBH) (from a minimum threshold of 3 cm); height.

The volume of each tree was computed using double-entry volume equations (CASTELLANI *et al.*, 1984). The volume and the basal area of each tree were summed up at plot level in order to obtain the total volume in cubic meter per hectare and the basal area in square meter per hectare. Diameter distribution for each site was represented adopting 5-cm diameter classes.

Finally a representation of vertical structure was elaborated. For each study site four vertical layers (same width equal ¼ maximum height) were defined and each plant was assigned to the reached layer.

## 3. RESULTS

### 3.1. Tree size and structural traits

The main results are reported in Table 1. Number of trees per hectare ranged between 177 in "Sasso Fratino" stand and 675 in "Fosso Cecita" site. The highest values are shown by the conifer dominated stands ("Abeti Soprani", "Collemeluccio" and "Fosso Cecita").

Dimensional traits, such as mean and maximum DBH, number of large trees and height of tallest plants, indicate a large variability among the investigated forest stands. Mean DBH ranged between 15.5 cm in "Fosso Cecita" area and 56.2 cm in "Sasso Fratino" site and exceeded 30 cm in 6 study areas. The maximum DBH ranged between 80.0 cm in "Abeti Soprani" area and 150.0 cm in "Fonte Novello" site and exceeded 1 m in 4 study areas.

In order to quantify the number of large trees two different DBH thresholds were considered: 50 cm and 70 cm. Large trees with DBH > 50 cm

*Table 1* – Dimensional and structural features of studied sites. In brackets the average volume value for the dominant forest types in the administrative regions.

*– Principali caratteristiche dendrometriche e strutturali dei popolamenti oggetto di indagine. Tra parentesi viene riportato il valore del volume medio riportato dall'Inventario Nazionale delle Foreste e dei Serbatoi Forestali di Carbonio (www.ifni.it) per le categorie forestali di boschi alti e le regioni amministrative di appartenenza delle aree oggetto delle aree di studio.*

| | Fonte Novello | Val Cervara | Monte Sacro | Cozzo Ferriero | Sasso Fratino | Monti Cimini | Abeti Soprani | Collemeluccio | Monte di Mezzo | Fosso Cecita |
|---|---|---|---|---|---|---|---|---|---|---|
| *DBH minimum threshold* (cm) | 10 | 10 | 3 | 3 | 3 | 3 | 10 | 10 | 10 | 3 |
| *Censed tree species* | 1 | 1 | 1 | 1 | 4 | 4 | 8 | 10 | 8 | 6 |
| *Number per ha* | 391 | 239 | 548 | 460 | 177 | 196 | 589 | 573 | 351 | 675 |
| *Large trees DBH > 50 cm* (N $ha^{-1}$) | 97 | 50 | 31 | 141 | 112 | 72 | 66 | 58 | 80 | 29 |
| *Large trees DBH > 70 cm* (N $ha^{-1}$) | 20 | 12 | 19 | 31 | 68 | 42 | 14 | 10 | 5 | 11 |
| *Mean DBH* (cm) | 40.6 | 29.0 | 18.0 | 36.2 | 56.2 | 37.8 | 30.8 | 27.4 | 35.6 | 15.5 |
| *Maximum DBH* (cm) | 150.0 | 88.0 | 92.6 | 97.1 | 125.8 | 149.0 | 80.0 | 83.0 | 84.0 | 127.3 |
| *Basal area* ($m^2$ $ha^{-1}$) | 60.40 | 25.76 | 30.50 | 97.36 | 57.38 | 42.44 | 56.17 | 46.42 | 44.99 | 53.29 |
| *Maximum height* (m) | 40.8 | 35.8 | 36.3 | 32.5 | 44.8 | 37.6 | 32.4 | 35.0 | 41.0 | 34.9 |
| *Volume total* ($m^3$) | 1030.3 (230.9) | 363.6 (230.9) | 469.3 (294.3) | 1383.3 (271.5) | 1189.1 (210.9) | 783.8 (247.3) | 569.8 (260.8) | 557.9 (260.8) | 702.5 (264.4) | 583.9 (322.7) |
| % *volume Large trees DBH > 50* (cm) | 54.1 | 75.6 | 63.1 | 73.4 | 95.5 | 92.5 | 38.0 | 42.9 | 57.8 | 60.9 |
| % *volume Large trees DBH > 70* (cm) | 25.6 | 25.4 | 49.9 | 27.9 | 73.7 | 72.6 | 11.7 | 10.8 | 6.1 | 35.9 |

ranged between 29 ha$^{-1}$ in "Fosso Cecita" stand and 141 ha$^{-1}$ in "Cozzo Ferriero" site and almost everywhere are more than 50 ha$^{-1}$. Large trees with DBH > 70 cm exceed the number of 20 only in 3 study areas ("Sasso Fratino", "Monti Cimini" and "Cozzo Ferriero") and the values ranged between 5 ha$^{-1}$ in "Monte di Mezzo" stand and 68 ha$^{-1}$ in "Sasso Fratino" site.

The census was carried out on trees of more than 40 m in height in "Fonte Novello", "Sasso Fratino" and "Monte di Mezzo" study areas. Everywhere maximum height is remarkable (more than 30 m).

Basal area and total living trees volume are dissimilar among the investigated sites. Particularly, "Cozzo Ferriero" is the site with the highest living tree volume (1383 m$^3$ha$^{-1}$) and basal area (97,4 m$^2$ha$^{-1}$), while "Val Cervara" is characterized by the lowest values (364 m$^3$ha$^{-1}$ and 25,8 m$^2$ha$^{-1}$ respectively). The volume exceeded 1000 m$^3$ ha$^{-1}$ in "Sasso Fratino", "Fonte Novello" and "Cozzo Ferriero" sites too.

Large trees account for a large portion of total volume. Range of contribution for trees DBH>50 is 38.0%-95.5% ("Abeti Soprani" and "Sasso Fratino" respectively) with values more than 60 % in 6 study areas. Range of contribution for trees DBH>70 is 6.1%-73.7% ("Monte di Mezzo" and "Sasso Fratino" respectively) with values exceeding 25 % in 7 study areas.

### *3.2. DBH distribution*

Figures 2 and 3 show the diameter distribution in each study site. In all study areas a wide variation in tree diameter was observed. Bimodal or rotated sigmoid curve like distributions were observed in 6 areas: "Val Cervara", "Monte Sacro", "Cozzo Ferriero", "Sasso Fratino", "Monti Cimini" and "Monte di Mezzo".

Reverse-J distributions were observed in

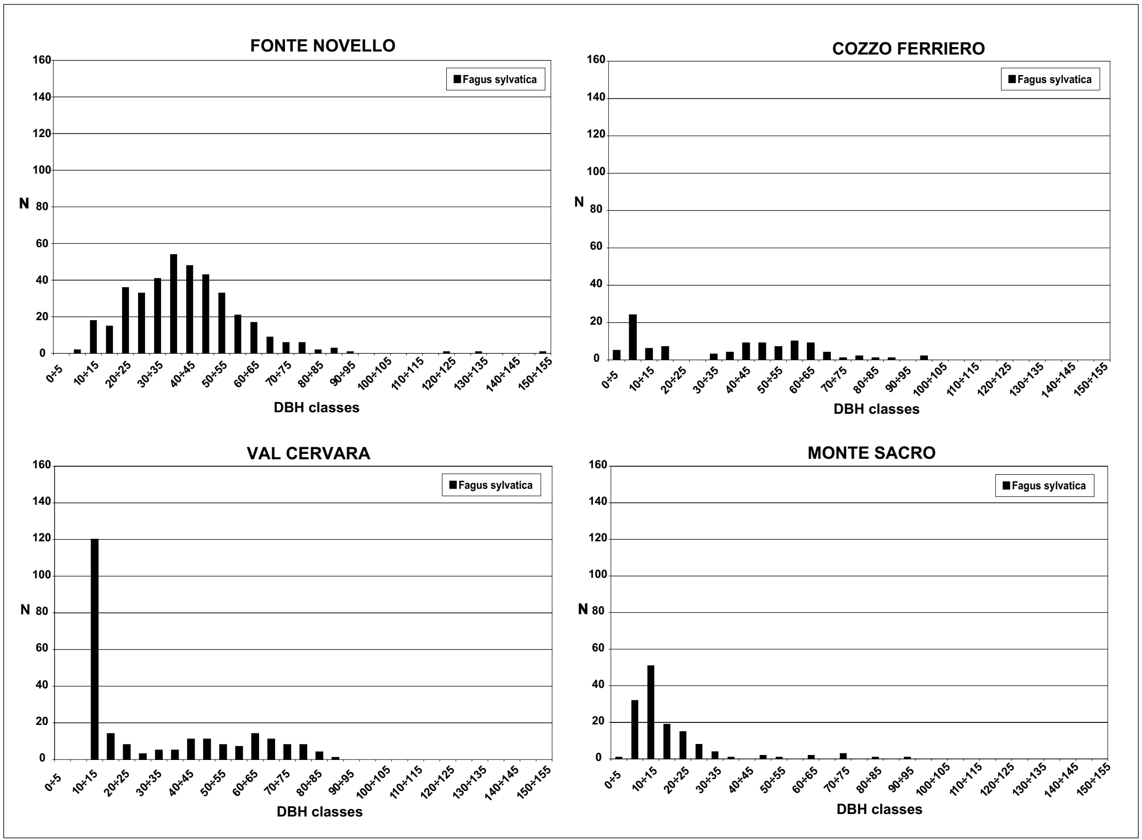


*Figure 2* – Diameter distribution in pure beech studied stands (5 cm classes).
*– Distribuzione dei diametri in classi di 5 cm nelle faggete pure oggetto dell'indagine.*

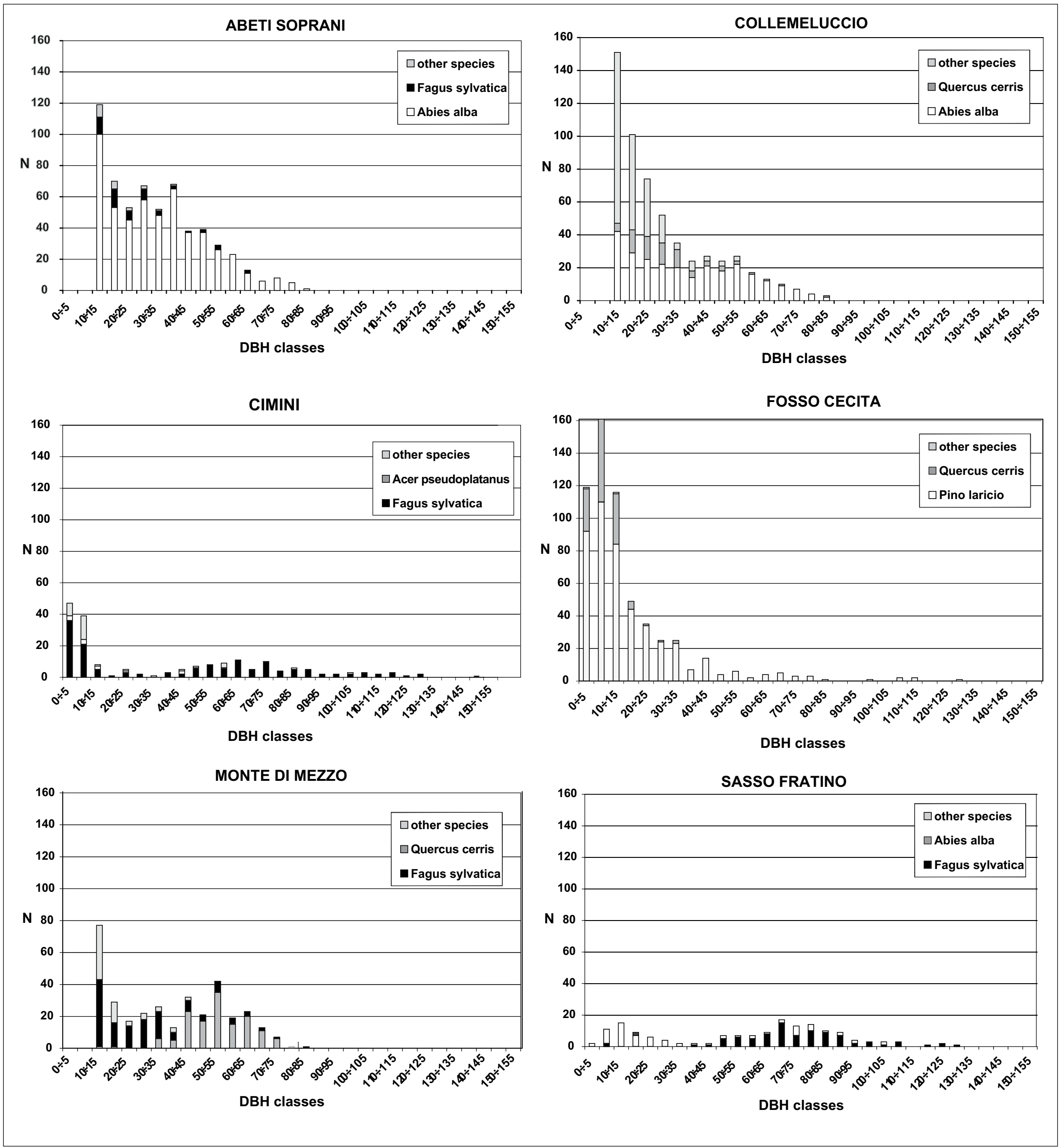


*Figure 3* – Diameter distribution in mixed beech or other species studied stands (5 cm classes).
– *Distribuzione diametrica in classi di 5 cm nei rimanenti popolamenti oggetto dell'indagine.*

conifer dominated study sites "Abeti Soprani" and "Fosso Cecita". Lack of information on plants DBH<10cm make uncertain the distribution in "Collemeluccio" site. "Fonte Novello" study area shows a typical even-aged distribution.

### *3.3. Vertical structure*

In each site, 4 strata were considered, on the basis of the height of the tallest tree. The study areas show many differences in stratification (Figures 4 and 5). Cohorts of growing plants growing to the highest stratum are present in pure beech stands ("Val Cervara", "Cozzo

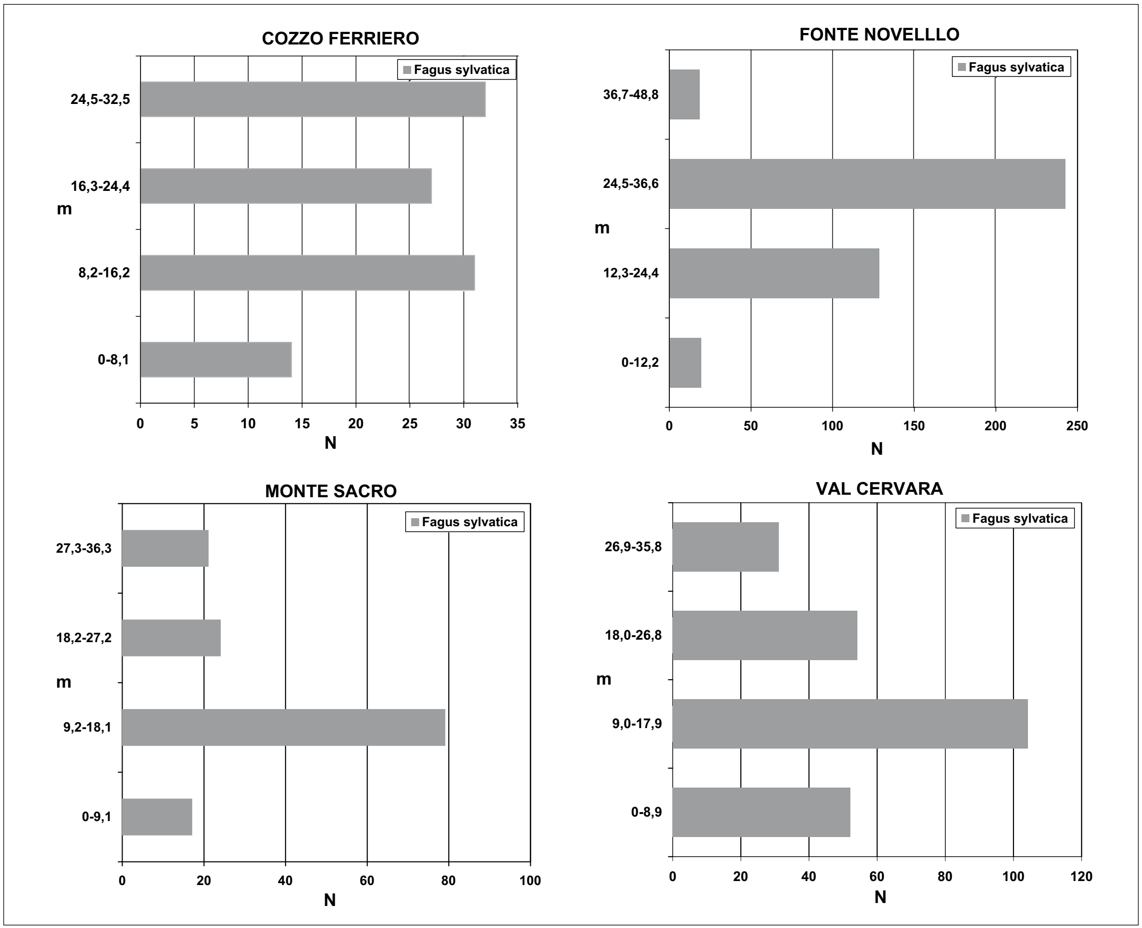


*Figure 4* – Vertical layers in pure beech studied sites; amount of plants reaching each layer.
*– Struttura verticale delle faggete pure oggetto dell'indagine; consistenza, in numero di piante, degli strati.*

Ferriero" and "Monte Sacro") and in silver fir dominated stands ("Abeti Soprani" and "Collemeluccio"). The largest amount of plants in the lowest stratum was found in "Fosso Cecita". In "Sasso Fratino" stand most of the plants are part of the upper stratum.

## 4. Discussion

Results indicate a large variability in dimensional features but anywhere the attribute "large tree for species and site" that distinguish old growth from younger managed growth is found.

It is possible to compare the collected data in *Fagus* pure or *Fagus* dominated study stands with those of European old Growth Forest stands in Table 2. For both basal area and volume, almost all the study areas present "old growth" values. In all the study sites volume is many times greater than the average volume estimated by the National Forest Inventory (www.ifni.it) for the corresponding forest type and administrative region (in brackets in Table 1).

Summarizing the work of various authors, a general model of forest succession can be described as a four stages process: establishment, thinning, transition, and shifting mosaic. The first two stages dominate managed forest stands (young even-aged stands). When succession continues beyond the thinning phase, the original overstorey begins to slowly break up, promoting understorey development and recruitment

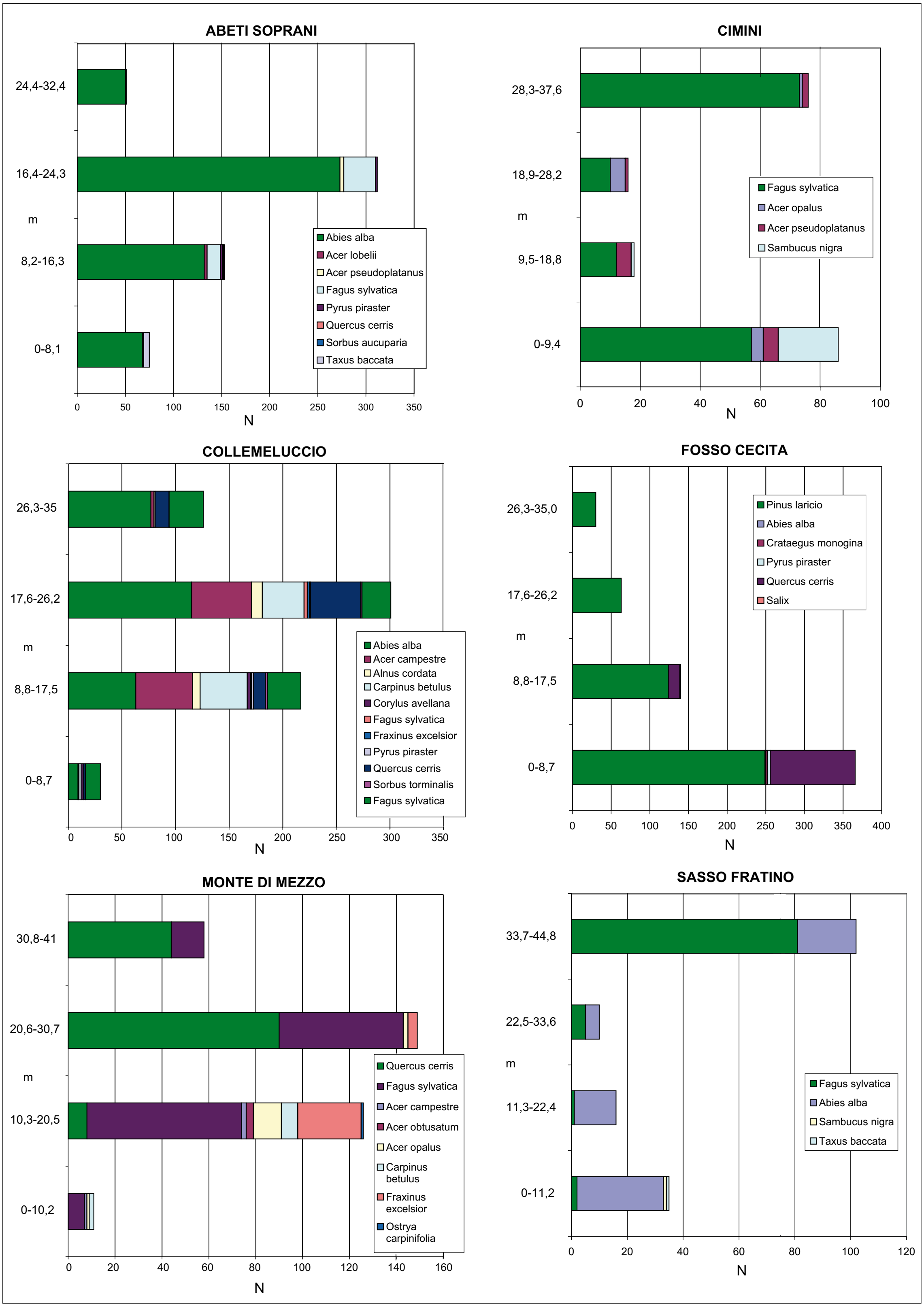


*Figure 5* – Vertical layers in mixed beech or other species studied sites; amount of plants reaching each layer.
– *Struttura verticale dei rimanenti popolamenti oggetto dell'indagine; consistenza degli strati in numero di piante.*

*Table 2* – Comparison of structural variables for pure and mixed *Fagus* stands in different European countries.
– *Variabili strutturali in faggete, pure e miste, europee.*

| *Country* | *Min DBH cm* | *N* | *G* $m^2\ ha^{-1}$ | *Volume* $m^3\ ha^{-1}$ | |
|---|---|---|---|---|---|
| PURE *FAGUS* FORESTS | | | | | |
| Italy, Fonte Novello | 10 | 391 | 60 | 1030 | This study |
| Italy, Val Cervara | 10 | 239 | 26 | 364 | This study |
| Italy, Cozzo Ferriero | 3 | 460 | 97 | 1383 | This study |
| Italy, Monte Sacro | 3 | 548 | 30 | 469 | This study |
| Italy, Lateis | 2.5 | 878 | 40 | 533 | PIOVESAN *et al.*, 2010 |
| Italy, Trelli | 2.5 | 741 | 29 | 319 | PIOVESAN *et al.*, 2010 |
| Italy, Timau | 7.5 | 568 | 40 | 647 | PIOVESAN *et al.*, 2010 |
| Italy, Gracco | 17.5 | 336 | 34 | 302 | PIOVESAN *et al.*, 2010 |
| Italy, Cleulis | 2.5 | 430 | 35 | 394 | PIOVESAN *et al.*, 2010 |
| Italy, Val Cervara | 2.5 | 1590 | 41 | 497 | PIOVESAN *et al.*, 2010 |
| Italy, Coppo del Principe | 2.5 | 296 | 44 | 715 | PIOVESAN *et al.*, 2010 |
| Italy, Fonte Regna | 2.5 | 317 | 42 | 540 | PIOVESAN *et al.*, 2010 |
| Italy, Monte Cimino | 2.5 | 197 | 48 | 707 | PIOVESAN *et al.*, 2010 |
| Italy, Valle Cervara | 2.5 | 1590 (272-3857) | 41 (31-53) | 497 (381-654) | PIOVESAN *et al.*, 2005 |
| Poland | 8 | 160-288 | 33-32 | 611-632 | JAWORSKI *et al.*, 2002 |
| Poland | 8 | 158-288 | 33-35 | 600-610 | JAWORSKI *et al.*, 2002 |
| Slovakia, Stužica | 7 | | | 549-709 | SANIGA and SCHÜTZ, 2002 |
| Slovakia, Stužica | 7 | | | 481-677 | SANIGA and SCHÜTZ, 2002 |
| Slovakia | 16 | 112-272 | | 490-778 | KORPEL, 1989 |
| MIXED *FAGUS* FORESTS | | | | | |
| Italy, Abeti Soprani | 10 | 589 | 56 | 570 | This study |
| Italy Monte di mezzo | 10 | 351 | 45 | 702 | This study |
| Italy, Cimini | 3 | 196 | 42 | 784 | This study |
| Italy, Sasso Fratino | 3 | 177 | 57 | 1189 | This study |
| Sweden | 10 | 402-445 | 37-40 | | NILSSON *et al.*, 2003 |
| Slovakia | 10 | 173 | 37 | | NILSSON *et al.*, 2003 |
| Spain | 2 | 1081-1169 | 32 | | ROZAS, 2003 |
| Poland | 8 | 183 | 32 | 547 | JAWORSKI *et al.*, 2002 |
| Poland | 8 | 189 | 33 | 578 | JAWORSKI *et al.*, 2002 |
| Poland | 8 | 145-324 | 34-44 | 442-691 | JAWORSKI and PALUCK., 2002 |
| Poland | 8 | 140-346 | 35-44 | 464-693 | JAWORSKI and PALUCK., 2002 |
| Slovakia, Sitno | 7 | | | 530-661 | SANIGA and SCHÜTZ, 2002 |
| Slovakia, Sitno | 7 | | | 346-617 | SANIGA and SCHÜTZ, 2002 |
| Slovakia, Hrončokowský grŭń | 7 | | | 839-1102 | SANIGA and SCHÜTZ, 2002 |
| Slovakia, Hrončokowský grŭń | 7 | | | 702-1115 | SANIGA and SCHÜTZ, 2002 |
| Slovakia, Badin | 7 | | | 648-968 | SANIGA and SCHÜTZ, 2002 |
| Slovakia, Badin | 7 | | | 502-736 | SANIGA and SCHÜTZ, 2002 |
| Slovakia, Dobroč | 7 | | | 565-1075 | SANIGA and SCHÜTZ, 2002 |
| Slovakia, Dobroč | 7 | | | 600-853 | SANIGA and SCHÜTZ, 2002 |
| Slovenia | 10 | 265 | | 799 | BONCINA, 2000 |
| Slovakia | 16 | 179-594 | 37-56 | 251-1046 | KORPEL, 1989 |

of new cohorts to the overstorey. LYNDS and LEDUC (1995) define this stage as Immature Old Growth. The transition period progresses into the shifting mosaic phase, in which stands persist in a dynamic uneven-aged condition dominated by gap formation and recruitment from a developed multi-layered understorey; the shifting mosaic state is generally regarded as a true old-growth condition (OLIVER and LARSON 1996).

In many study areas the Immature Old Growth stage is recognizable; vertical structure shows the occurrence of abundant regeneration layer within canopy gaps in "Fonte Novello" and "Monti Cimini" sites. In some stands, more patches of the same forest should be analyzed in order to evidence shifting mosaic state: e.g. in "Sasso Fratino" study area were not found those gap dynamics described in the forest by BIANCHI *et al.* (2009). Also "Val Cervara" site characteristics differ from those reported for the same forest in previous scientific paper (PIOVESAN *et al.*, 2005; PIOVESAN *et al.*, 2010)

Since the forest type varied only slightly among the study areas, with the exception of three sites ("Abeti Soprani", "Collemeluccio" and "Fosso Cecita"), the following stages of each stand, species composition, the forest history and exogenic disturbances can be considered as the main factors explaining the very different structural features observed.

The main question of this study was to ascertain if easy to measure dimensional and structural features can be used as indicators of naturalness in Apennines forest areas, with special focus on woodland that could evolve to old growth traits in the following decades. Many results of the present project can help to answer. Other investigated aspects can confirm the old growthness of the study areas.

The volume of deadwood generally occurring in Italian forests (mainly managed forest) is markedly lower (INFC, 2009; PIGNATTI *et al.*, 2009) than values observed in the considered study areas (LOMBARDI *et al.*, 2010). This aspect suggests how all the investigated forests are nowadays characterized by high levels of naturalness (HANSEN *et al.*, 1991).

"Fonte Novello" area was compared by SABATINI *et al.* (2010) with beech forest of Tassete - Grotta delle Fosse (a high forest located on the eastern slope of Monte Cima Alta, at the head of Rio San Giacomo valley). This area was chosen for its similarity and closeness (5.6 km) to Fonte Novello stand. Species richness at stand level was higher in the old-growth stand than in the managed one (78 vs 67 species). The high vertical and horizontal structural heterogeneity of the studied old-growth stand modulates the ecological factors the species of the understorey have to face. As the environmental heterogeneity increases, species with different ecological requirements are able to coexist in a finegrained mosaic of microhabitat, in accordance with the niche diversification hypothesis (CONNNELL, 1978). Some other indications on old growthness come from genetic analysis too. Old-growth forests are considered important pools for species conservation not only because they provide special habitats for an array of forest dependent wildlife but also because they can represent a reservoir of reproductive fitness as superior seed sources and gene pools (RAJORA, 2003). VETTORI *et al.* (2010) made a comparison with a managed mature beech stand close to the study site. Differences between the potential old growth stand and managed one are very evident in terms of diameter distribution and basal area; furthermore genetic diversity is significantly lower in the managed beech stand.

Regarding "Monte Sacro" e "Cozzo Ferriero" sites, the results show a great difference in structural characters. A detailed analysis on structural features (IOVINO *et al.*, 2010) and deadwood occurrence (LOMBARDI *et al.*, 2010) confirm that the study areas show the typical mature phases in forest dynamics. For this reason the 2 areas could be considered as Old-Growth in terms of age, structure and biomass.

"Collemeluccio" and "Abeti Soprani" support a very interesting lichen flora (RAVERA *et al.*, 2010).

In the "Fosso Cecita" site a complex vertical structure was pointed out by the Latham Index (LATHAM *et al.*, 1998) analysis. In close forests a similar structure of small group uneven-aged pine forests is instead the consequence of small group selection felling, i.e. elimination of groups of 2 or 3 big trees, together with limited intervention on nearby dense groups. Results confirm how small group uneven aged Calabrian pine forests show a kind of structure that, while linked to anthropic activity, resembles that of Calabrian pine old growth forests. (CIANCIO *et al.*, 2010)

Finally, vertical structure can also provide some information on trend in species composition based on differences in the proportion between living and dead wood volumes of different species. In "Abeti Soprani", the percentage of silver fir dead wood is higher than its living volume, while hardwoods (in this case, beech) are almost absent as dead wood; on the contrary, what observed in "Collemeluccio" is opposite. This aspect reveals that probably the "Abeti Soprani" stands are evolving towards a mixed forest (of silver fir and beech) while "Collemeluccio" stands are evolving towards a pure silver fir forest (LOMBARDI *et al.*, 2010).

## 5. CONCLUDING REMARKS

Considering that indicators of old-growth features can vary across the European eco-regions, this paper provides early feedback to identify some easy to measure traits of Old Growth Forests in the Mediterranean Eco-Region. Distinctively, three attributes appear to be directly effective for characterizing old-growthness of forest stands in Mediterranean environments (BARBATI *et al.*, 2011): number of tree distribution vs. stem diameter at breast height (DBH); deadwood; species richness. Other attributes like the amount of standing basal area or wood volume appear to be more controversial, since there are true old-growth forest stands with lower standing wood volume (or basal area or wood biomass) than managed stands under comparable environmental and compositional conditions. Even the number of large trees is not in itself a proof of old-growthness since their presence is very much related to the past management of the stand: a typical example is the clearcut with retention of some trees applied in Southern Italy that have originated stands, still managed or not, characterized by the presence of many large trees.

Typical rotated sigmoid DBH distribution (i.e. diameter distributions characterized by steep decreases in tree density in the smallest and largest diameter classes and a plateau in the middle diameter classes that becomes more pronounced when displayed on semilogarithmic axes, see JANOWIAK *et al.*, 2008) has been observed only in the oldest beech stands on the Apennines, like Val Cervara and Monti Cimini in this study. In the same study sites LOMBARDI *et al.* (2010) highlighted that, under the investigated conditions, three main deadwood features have proven to characterize old-growthness of forest stands: a ratio of dead to living wood higher than 10%; lying deadwood much more abundant than the standing one; large range of deadwood size and decay classes across all the deadwood components, which can guarantee availability of microhabitats in time and space for the saproxylic fauna, fostering the stand naturalness.

The structure-based approach provides a snapshot inventory of structural attributes commonly associated with old-growth forests. This approach allows us to identify forests to be protected and studied during their evolution to old growth. Identification, characterization and monitoring in time of forest areas where direct human disturb has been very low or has stopped for a long period of time is the basis for planning preservation of such areas (NOCENTINI, 2010).

Further research is necessary to combine forest structural features with those data obtained in other scientific disciplines (e.g. lichenology, zoology) in order to have complete and clear understanding to come to a definition of an Old Growth Mediterranean forest.

## ACKNOWLEDGEMENTS

This paper presents part of the results of the project "Innovative methods for the identification, characterization and management of old-growth forests in the Mediterranean environment" funded by the Italian Ministry for University and Research

(PRIN 2007, proj. 2007TFREJ9), national scientific coordinator: prof. G. Chirici. We thank Administration of all the protected areas where the study sites are located for supporting this research. Moreover, we thank the Italian State Forest Corp for technical support and finally, we are grateful to the people (students, PhDs, researchers) that made the complex and stressful field activities possible.

## RIASSUNTO

*Caratteri strutturali di potenziali foreste vetuste appenniniche: risultati preliminari*

Lo scopo del lavoro è quello di fornire risultati preliminari su alcune caratteristiche strutturali di boschi appenninici che per la loro complessità strutturale potrebbero essere considerati come esempi di foreste vetuste o potenzialmente tali nella Eco-Regione Mediterranea. Ad oggi per questa Regione i dati di riferimento disponibili sono relativamente scarsi e la definizione di parametri indicatori di vetustà è complicata dalla forte e prolungata, fin da tempi remoti, azione di disturbo da parte dell'uomo. Il presente studio ha preso in considerazione 10 foreste appenniniche, da tempo sottoposte a vincoli di protezione, nelle quali si osservano significative differenze rispetto a popolamenti attivamente gestiti dal punto di vista selvicolturale. In ogni foresta è stata costituita un'area di studio permanente di dimensioni variabili fra 0,16 e 1 ha e si è proceduto al censimento della componente arborea viva e al rilievo dei parametri dendrometrici secondo un protocollo unico. Le caratteristiche dimensionali e strutturali hanno mostrato un'ampia variabilità fra le aree considerate.

I parametri analizzati sono stati confrontati con quelli riportati in letteratura per popolamenti forestali europei mettendo in evidenza come nelle aree esaminate il grado di complessità strutturale raggiunto sia rilevante. In ogni caso va sempre considerato che le caratteristiche strutturali e i parametri utilizzati per l'individuazione di boschi vetusti devono essere riferiti al particolare contesto climatico e biogeografico. I popolamenti oggetto di indagine possono essere considerati potenzialmente vetusti. La costituzione delle aree di studio permanenti permetterà di studiare nel corso degli anni i processi dinamici che portano, in ambiente appenninico, ad una Foresta Mediterranea Vetusta.

## REFERENCES

ALLEGREZZA M., BIONDI E., 2008 – *Studio fitosociologico sull'area forestale "Abeti soprani" (Alto Molise - Appennino Meridionale)*. Fitosociologia, 45 (1): 161- 176.

ARSSA - SERVIZIO AGROPEDOLOGIA, 2003 – *I suoli della Calabria*. Rubbettino Industrie Grafiche ed Editoriali, Soveria Mannelli (Catanzaro).

BARBATI A., SALVATI R., FERRARI B., DI SANTO D., QUATRINI A., PORTOGHESI L., TRAVAGLINI D., NOCENTINI S., 2011 – *Assessing and promoting old-growthness of forest stands: lessons learnt from research experiences in Italy*. Plant Biosystems (in the press).

BIANCHI L., BOTTACCI A., PACI M., QUILGHINI G., 2009 – *Struttura e dinamismo forestale nella Riserva Naturale Integrale di Sasso Fratino*. In: Bottacci A. (ed.), "La Riserva Naturale Integrale si Sasso Fratino: 1959-2009. 50 anni di conservazione della biodiversità". Corpo Forestale dello Stato, Ufficio territoriale per la Biodiversità di Pratovecchio.

BJÖRKMAN L., BRADSHAW R.H.W, 1996 – *The immigration of* Fagus sylvatica *L. and* Picea abies *(L.) Karst into a natural forest stand in Southern Sweden during the last 2000 years*. Journal of Biogeography, 23: 235-244. http://dx.doi.org/10.1046/j.1365-2699.1996.00972.x

BOBIEC A., VAN DER BURGT H., MEIJER K., ZUYDERDUYN C., HAGA J., VLAANDEREN B., 2000 – *Rich deciduous forests in Bialowiezça as a dynamic mosaic of developmental phases: premises for nature conservation and restoration management*. Forest Ecology and Management, 130: 159-175. http://dx.doi.org/10.1016/S0378-1127(99)00181-4

BURRASCANO S., LOMBARDI F., MARCHETTI M., 2008 – *Old-growth forest structure and dead wood: Are they indicators of plant species composition? A case study from central Italy*. Plant Biosystems, 142 (2): 313-323. http://dx.doi.org/10.1080/11263500802150613

BURRASCANO S., ROSATI L., BLASI C., 2009 – *Plant species diversity in Mediterranean old-growth forests: a case study from central Italy*. Plant Biosystems, 142 (2): 313-323. http://dx.doi.org/10.1080/11263500802709699

CARRANZA M.L., LOY A., DI LISIO L., DI CASTRO G., BARILE M., PRESTI G., STANISCI A., 2006 – *Un modello di rete ecologica per vegetazione e fauna. Il caso dell'Alto Molise.* Biogeographia, vol. XXVII.

CASTELLANI C., SCRINZI G., TABACCHI G., TOSI V., 1984 – *Inventario Forestale Nazionale Italiano (I.F.N.I.) Tavole di cubatura a doppia entrata*. Ministero dell'Agricoltura e delle Foreste. Direzione Generale per l'Economia Montana e per le Foreste. Istituto Sperimentale per l'Assestamento Forestale e per l'Alpicoltura (I.S.A.F.A.). Trento.

CHIRICI G., NOCENTINI S., 2010 – *Old-growth forests in Italy: recent research developments and future perspectives.* L'Italia Forestale e Montana, 65 (5): 475-480. http://dx.doi.org/10.4129/ifm.2010.5.01

CHRISTENSEN M., HAHN K., MOUNTFORD E.P., ODOR P., STANDOVAR T., ROZENBERGAR D., DIACI J., WIJDEVEN S., MAYER P., WINTER S., VRSKA T., 2005 – *Dead wood in European beech (*Fagus Sylvatica*) forest reserves*. Forest Ecology and Management, 210: 267-282. http://dx.doi.org/10.1016/j.foreco.2005.02.032

CIANCIO O., IOVINO F., MENGUZZATO G., MIRABELLA G., 1985 – *L'abete (*Abies alba *Mill.) in Calabria: possibilità e limiti di diffusione e ridiffusione*. Ann. Ist. Sper. Selv., 16: 7-249.

CIANCIO O., IOVINO F., MENGUZZATO G., NICOLACI A., VELTRI A., 2010 – *Stand structure of Calabrian pine old-growth forest: indications for the forest management and forest landscape preservation.* L'Italia Forestale e Montana, 65 (5): 529-544. http://dx.doi.org/10.4129/ifm.2010.5.05

CITTERIO G., PUXEDDU M., GIANNINI R., 2007 – *La foresta relitta di roverella dei Monti del Gennargentu, Sardegna*. Forest@, 4 (1): 11-18. http://dx.doi.org/10.3832/efor0443-0040011

CONNELL J.H., 1978 – *Diversity in tropical rain forests and coral reefs - high diversity of trees and corals is maintained* *only in a non-equilibrium state*. Science, 199: 1302-1310. http://dx.doi.org/10.1126/science.199.4335.1302

CORONA P., BLASI C., CHIRICI G., FACIONI L., FATTORINI L., FERRARI B., 2010 – *Monitoring and assessing old-growth forest stands by plot sampling*. Plant Biosystems, 144: 171-179. http://dx.doi.org/10.1080/11263500903560710

DIACI J., ROZENBERGAR D., BONCINA A., 2003 – *Interactions of light and regeneration in Slovenian Dinaric Alps: patterns in virgin and managed forests*. In: Commarmot, B., Hamor, F.D. (Eds.), "Natural Forests in the Temperate Zone of Europe-Values and Utilisation". Birmensdorf, Swiss Federal Research Institute WSL; Rakhiv, Carpathian Biosphere Reserve, Mukachevo, Ukraine, p. 154-160.

EEA, 2006 – *European forest types. Categories and types for sustainable forest management reporting and policy.* European Environment Agency Technical Report No. 9/2006.

EMBORG J., CHRISTENSEN M., HEILMANN-CLAUSEN J., 2000 – *The structural dynamics of Suserup Skov, a near-natural temperate deciduous forest in Denmark.* Forest Ecology and Management, 126: 173-189. http://dx.doi.org/10.1016/S0378-1127(99)00094-8

FEOLI E., LAGONEGRO M., 1982 – *Syntaxonomical analysis of beech woods in the Apennines (Italy) using the program package IAHOPA*. Vegetatio, 50: 129-173. http://dx.doi.org/10.1007/BF00364109

FRELICH L.E., REICH P.B., 2003 – *Perspectives on development of definitions and values related to old-growth forests.* Environmental Review, 11: 9-22. http://dx.doi.org/10.1139/a03-011

HANSEN A.J., SPIES T.A., SWANSON F.J., OHMANN J.L., 1991 – *Conserving Biodiversity in Managed Forests.* BioScience, 41 (6): 382-392. http://dx.doi.org/10.2307/1311745

INFC, 2009 – *I caratteri quantitativi 2005 - Parte 1, versione 2* (Gasparini P., De Natale F., Di Cosmo L., Gagliano C., Salvadori G., Tabacchi G., Tosi V. eds.). Inventario nazionale delle foreste e dei serbatoi forestali di carbonio, MiPAAF - Ispettorato Generale Corpo Forestale dello Stato, CRA-MPF, Trento, Italy. [online] http://www.sian.it/inventarioforestale/doc/INFC_I%20caratteri%20quantitativi_maggio_2009.pdf

IOVINO F., MENGUZZATO G., 1996 – *La gestione forestale per il ritorno alle formazioni complesse.* In: "Il Bosco e l'Uomo", a cura di O. Ciancio. Accademia Italiana di Scienze Forestali, Firenze, p. 215-224.

IOVINO F., MARZILIANO P.A., MENGUZZATO G., NICOLACI A., 2010 – *Strutture delle faggete vetuste del Cilento e del Pollino.* L'Italia Forestale e Montana, 65 (6): 657-678. http://dx.doi.org/10.4129/ifm.2010.6.01

ISPRA, 2008 – *Carta geologica d'Italia alla scala 1:50.000, Campania*. http://www.apat.gov.it/media/carg/campania.html).

JANOWIAK M.K., NAGEL L.M., WEBSTER C.R., 2008 – *Spatial scale and stand structure in northern hardwood forests: implications for quantifying diameter distributions*. Forest Science 54 (5): 497-506.

JAWORSKI A., KOLODZIEJ Z.B., PORADA K. 2002 – *Structure and dynamics of stands of primeval character in selected areas of the Bieszczady National Park*. Journal of Forest Science, 48: 185-201.

JAWORSKI A., PALUCH J., 2002 – *Factors Affecting the Basal Area Increment of the primeval forests in the Babia Gora National Park, southern Poland*. Forstwiss. Centralbl., 121: 97-108. http://dx.doi.org/10.1046/j.1439-0337.2002.00097.x

JONSSON B.G., 2000 – *Availability of coarse woody debris in a boreal old-growth* Picea abies *forest*. Journal of Vegetation Science, 11: 51-6. http://dx.doi.org/10.2307/3236775

KOOP H., HILGEN P., 1987 – *Forest dynamics and regeneration mosaic shifts in unexploited beech (*Fagus sylvatica*) stands at Fontainebleau (France).* Forest Ecology and Management, 20: 135-150. http://dx.doi.org/10.1016/0378-1127(87)90155-1

KORPEL S., 1982 – *Degree of equilibrium and dynamical changes of the forest on example of natural forests of Slowakia*. Acta Fac. For. Zvolen, 24: 9-30.

KORPEL S., 1989 – *Pralesy Slavenska*. Academia Bratislava, SL.

KUULUVAINEN T., SYRJÄNEN K., KALLIOLA R., 1998 – *Structure of a pristine* Picea abies *forest in northeastern Europe*. Journal of Vegetation Science, 9: 563-574. http://dx.doi.org/10.2307/3237272

LATHAM P.A., ZUURING H.R., COBLE D.W., 1998 – *A method for quantifying vertical forest structure.* Forest Ecology and Management, 104: 157-170. http://dx.doi.org/10.1016/S0378-1127(97)00254-5

LINDER P., 1998 – *Structural changes in two virgin boreal forest stands in central Sweden over 72 years*. Scandinavian Journal of Forest Research, 13: 451-461. http://dx.doi.org/10.1080/02827589809383006

LINDNER M., SIEVANEN R., PRETZSCH H., 1997 – *Improving the simulation of stand structure in a forest gap model.* Forest Ecology and Management, 95: 183-195. http://dx.doi.org/10.1016/S0378-1127(96)03967-9

LOMBARDI F., CHERUBINI P., LASSERRE B., TOGNETTI R., MARCHETTI M., 2008 – *Tree rings used to assess time-since-death of deadwood of different decay classes in beech and silver fir forests in the central Apennines (Molise, Italy).* Canadian Journal of Forest Research, 38: 821-33. http://dx.doi.org/10.1139/X07-195

LOMBARDI F., CHIRICI G., MARCHETTI M., TOGNETTI R., LASSERRE B., CORONA P., BARBATI A., FERRARI B., DI PAOLO S., GIULIARELLI D., MASON F., IOVINO F., NICOLACI A., BIANCHI L., MALTONI A., TRAVAGLINI D., 2010 – *Deadwood in forest stands close to old-growthness under Mediterranean conditions in the Italian Peninsula.* L'Italia Forestale e Montana, 65 (5): 481-504. http://dx.doi.org/10.4129/ifm.2010.5.02

LUYSSAERT S., DETLEF SCHULZE E., BÖRNER A., KNOHL A., HESSENMÖLLER D., LAW B.E., CIAIS P., GRACE J., 2008 – *Old-growth forests as global carbon sinks.* Nature, 455: 213-215. http://dx.doi.org/10.1038/nature07276

LYNDS A., LEDUC J., 1985 – *Old Forest of Nova Scotia.* Nova Scotia Department of Natural Resources Occasional Papers No 1, 18 p.

MARCHETTI M., TOGNETTI R., LOMBARDI F., CHIAVETTA U., PALUMBO G., SELLITTO M., COLOMBO C., IOVINO P., ALFANI A., BALDANTONI D., BARBATI A., FERRARI B., BONACQUISTI S., CAPOTORTI G., COPIZ R., BLASI C., 2010 – *Ecological portrayal of old-growth forests and persistent woodlands in the Cilento and Vallo di Diano National Park (Southern Italy).* Plant Biosystems, 144 (1): 130-147. http://dx.doi.org/10.1080/11263500903560470

MASON F., 2004 – *Dinamica di una foresta della*

*Pianura Padana, Bosco della Fontana*. Seconda edizione con linee di gestione forestale. Rapporti scientifici 1. Centro Nazionale Biodiversità Forestale "Bosco Fontana",Verona. Arcari Editore, Mantova, 224 p.

MOTTA R., 2002 – *Old-growth forests and silviculture in the Italian Alps: the case-study of the strict reserve of Paneveggio (TN)*. Plant biosystems, 136: 223-232. http://dx.doi.org/10.1080/11263500212331351129

MOTTA R., BERRETTI R., LINGUA E., PIUSSI P., 2006 – *Coarse woody debris, forest structure and regeneration in the Valbona Forest Reserve, Paneveggio, Italian Alps*. Forest Ecology and Management, 235: 155-163. http://dx.doi.org/10.1016/j.foreco.2006.08.007

MOTTA R., EDOUARD J.L., 2005 – *Stand structure and dynamics in a mixed and multilayered forest in the Upper Susa Valley (Piedmont, Italy)*. Can. J. For. Res., 35: 21-36. http://dx.doi.org/10.1139/x04-153

NAGEL T.A., SVOBODA M., DIACI J., 2006 – *Regeneration patterns after intermediate wind disturbance in an old-growth* Fagus-Abies *forest in southeastern Slovenia*. Forest Ecology and Management, 226: 268-278. http://dx.doi.org/10.1016/j.foreco.2006.01.039

NILSSON S.G., NIKLASSON M., HEDIN J., ARONSSON G., GUTOWSKI J.M., LINDER P., LJUNGBERG H., MIKUSINSKI G., RANIUS T., 2003 – *Densities of large and dead trees in old-growth temperate and boreal forests.* Forest Ecology and Management, 161: 189-204. http://dx.doi.org/10.1016/S0378-1127(01)00480-7

NOCENTINI S., 2010 – *Old growth forests in Italy: inputs for forest management and planning in areas with long-standing human impact*. L'Italia Forestale e Montana, 65 (5): 545-555. http://dx.doi.org/10.4129/ifm.2010.5.06

OLIVER C.D., LARSON B.C., 1996 – *Forest Stand Dynamics*. John Wiley & Sons, New York.

PACI M., SALBITANO F., 1998 – *The role of studies on vegetation dynamics in undisturbed natural reserves towards the need of knowledge for close-to-nature silvicultural treatments: the case study of Natural Reserve of Sasso Fratino (Foreste Casentinesi, Northern-Central Apennines).* AISF-EFI International Conference on "Forest Management in Designated Conservation & Recreation Areas (Morandini R., Merlo M. and Paivinnen R. eds.), 7-11 october 1998, Florence, Italy. University of Padua Press, p. 145-156.

PEDLAR J.H., PEARCE J.L., VENIER L.A., MCKENNEY D.W., 2002 – *Coarse woody debris in relation to disturbance and forest type in boreal Canada*. Forest Ecology and Management, 158: 189-94. http://dx.doi.org/10.1016/S0378-1127(00)00711-8

PETERKEN G.F., 1996 – *Natural Woodland. Ecology and Conservation on Northern temperate Regions*. Cambridge University Press, 522 p.

PIGNATTI G., DI NATALE A., GASPARINI P., PALETTO A., 2009 – *Il legno morto nei boschi italiani secondo l'Inventario Forestale Nazionale*. Forest@, 6: 100-111.

PIOVESAN G., DI FILIPPO A., ALESSANDRINI A., BIONDI F., SCHIRONE B., 2005 – *Structure, dynamics and dendroecology of an old-growth* Fagus *forest in the Apennines*. Journal of Vegetation Science, 16: 13-28.

PIOVESAN G., ALESSANDRINI A., BALIVA M., CHITI T., D'ANDREA E., DE CINTI B., DI FILIPPO A., HERMANIN L., LAUTERI M., SCARASCIA MUGNOZZA G., SCHIRONE B., ZIACO E., MATTEUCCI G., 2010 – *Structural patterns, growth processes, carbon stocks in an Italian network of old growth beech forests*. L'Italia Forestale e Montana, 65 (5): 557-590. http://dx.doi.org/10.4129/ifm.2010.5.07

PUXEDDU M., CITTERIO G., GIANNINI R., 2010 – *The last Gennargentu downy oak giants*. L'Italia Forestale e Montana, 65 (6): 783-788.

RAJORA OM.P., 2003 – *Genetic diversity impacts of forest fires, forest harvesting, and alternative reforestation practices in black spruce (*Picea mariana*)*. Theor Appl Genet, 106: 1203-1212.

RAVERA S., GENOVESI V., FALASCA A., MARCHETTI M., CHIRICI G., 2010 – *Lichen diversity of old-growth forests in Molise (Central-Southern Italy)*. L'Italia Forestale e Montana, 65 (5): 505-517. http://dx.doi.org/10.4129/ifm.2010.5.03

REGIONE BASILICATA - DIPARTIMENTO AGRICOLTURA, SVILUPPO RURALE, ECONOMIA MONTANA, 2004 – *Carta dei suoli della Basilicata in scala 1:250.000.* http://www.basilicatanet.it/suoli/carta2

ROZAS V., 2003 – *Regeneration patterns, dendroecology, and forest-use history in an old-growth beech-oak lowland forest in Northern Spain*. Forest Ecology and Management, 182 (1-3): 175-194. http://dx.doi.org/10.1016/S0378-1127(03)00070-7

RUBIN B.D., MANION P.D., FABER-LANGENDOEN D., 2006 – *Diameter distribution and structural sustainability in forests.* Forest Ecology and Management, 222: 427-438. http://dx.doi.org/10.1016/j.foreco.2005.10.049

SABATINI F.M., BURRASCANO S., BLASI C., 2010 – *Niche heterogeneity and old-growth forests conservation value.* L'Italia Forestale e Montana, 65 (5): 621-636. http://dx.doi.org/10.4129/ifm.2010.5.10

SANIGA M., SCHÜTZ J.P., 2002 – *Relation of dead wood course within the development cycle of selected virgin forests in Slovakia.* Journal of Forest Science, 48: 513-528.

SCOPPOLA A., CAPORALI C., 1998 – *Mesophilous woods with* Fagus sylvatica *L. of Northern Latium (Tyrrhenian Central Italy): synecology and syntaxonomy*. Plant Biosystems, 132: 151-168.

SIITONEN P., MARTIKAINEN P., PUNTTILA P., RAUH J., 2000 – *Coarse woody debris and stand characteristics in mature and oldgrowth boreal mesic forests in Southern Finland*. Forest Ecology and Management, 128: 211-25. http://dx.doi.org/10.1016/S0378-1127(99)00148-6

SPETICH M.A., SHIFLEY S.R., PARKER G.R., 1999 – *Regional distribution and dynamics of coarse woody debris in Midwestern old growth forests*. Forest Science, 45: 302-13.

SPIES T.A., 2004 – *Ecological concepts and diversity of old-growth forests*. Journal of Forestry, 102: 14-20.

TABAKU V., 2000 – *Struktur von Buchen-Urwäldern in Albanien im Vergleich mit deutschen Buchen-Naturwaldreservaten und Wirtschaftswäldern*. Cuvillier Verlag, Göttingen.

VETTORI C., PAFFETTI D., CIANI L., GIANNINI R., 2010 – *Fonte Novello old-growth forest.* L'Italia Forestale e Montana, 65 (5): 637-651. http://dx.doi.org/10.4129/ifm.2010.5.11

WIRTH C., MESSIER C., BERGERON Y., FRANK D., FANKHÄNEL A., 2009 – *Old-growth forests definitions: a pragmatic view.* In: Wirth C. *et al.* (eds.), "Old-growth forests", Ecological Studies, Springer-Verlag, Berlin Heidelberg. http://dx.doi.org/10.1007/978-3-540-92706-8_2