Feddes Repertorium 2018, *129,* 25–37 DOI: 10.1002/fedr.201700009

RESEARCH PAPER

Criteria to identify old-growth forests in the Mediterranean: A case study from Sicily based on literature review and some management proposals

E. Badalamenti[1], *S. Pasta*[2], *T. La Mantia*[1], *D. S. La Mela Veca*[1]

[1] Department of Agricultural, Food and Forest Sciences, University of Palermo, Viale delle Scienze Ed. 4, I-90128, Palermo, Italy
[2] Departement de Biologie, Université de Fribourg, Chemin du Musée, 10 CH-1700, Fribourg, Switzerland

Submitted: July 26, 2017
Revised: November 17, 2017
Accepted: November 28, 2017

Old growth forests are increasingly considered and studied all around the world. However, the knowledge of such important forest systems is still limited in some bioclimatic regions, such as in the Mediterranean Basin. Starting from the knowledge acquired elsewhere, our research was carried out with the aim to select the most effective criteria to identify potential old-growth forests in Mediterranean ecosystems (Sicily, Italy). Four key proxy indicators were considered: deadwood amount, tree size, structural traits, and tree species richness. A preliminary classification of the local forest stands level in three classes of old-growthness (high, medium and low) has also been proposed. The main threats to woods conservation, as well as their biological value were considered. Twenty-one forest stands have been detected and characterized; among them, seven forest stands were close to old growth conditions. Although the selected forest stands are located in protected areas, browsing due to farming and feral ungulates represent a widespread threat. The information provided for each forest stand may represent a starting point for further and in-depth investigations in similar Mediterranean forest ecosystems.

Keywords:
forest management, old-growthness, forest resilience, woodlands

1 Introduction

Since historical times, most of the forests at a global level have been exploited and deeply altered by man for the primary goal of obtaining timber and non-timber goods (Parviainen 2005; Garbarino et al. 2015). This is a quite general pattern; however, it has been more pronounced where human pressure has been historically higher, like in Europe and in the Mediterranean Basin (Torras et al. 2012; La Mela Veca et al. 2016). Productive forests have been managed for centuries according to traditional silvicultural practices, aimed at maximizing profits from timber production. The long-lasting work of selection in favor of the most profitable tree species, the elimination of shrubs and secondary tree species, as well as the systematic removal of deadwood led to deep changes in the original features of forest ecosystems (Spies et al. 2006), particularly in the Mediterranean basin (Bengtsson et al. 2000; Barbati et al. 2012). A prolonged human impact caused a pronounced simplification of the forest structure, a considerable change in the floristic richness, the alteration of tree species abundance and distribution, and a severe impact on biodiversity at any level (Burrascano et al. 2009; Martin-Queller et al. 2013). Accordingly, in Europe very few remnants of primary forests still exist, chiefly confined to small and restricted mountain areas, within natural parks or strict reserves (Parviainen 2005). It is estimated that the area covered by such forests accounts for only 4% of the total European forest area, excluding the Russian

Correspondence: Tommaso La Mantia, University of Palermo, Viale delle Scienze Ed. 4, I-90128 Palermo, Italy.
E-mail: tommaso.lamantia@unipa.it

Federation (Forest Europe 2015). After a historically long period of significant decrease in the extension (Paillet et al. 2010), the European forest cover has gradually and steadily increased over the last decades (Young et al. 2005). This was mainly due to the widespread process of abandonment of traditional agro-pastoral practices, resulting in an encroachment by woody species, and the concurrent increase in protection measures specifically targeted to forest ecosystems (Lasanta-Martínez et al. 2005; Torras et al. 2012). However, such pattern did not lead to a parallel development of mature, complex, resilient and biologically rich forest stands (Sferlazza et al. 2017). Nevertheless, some isolated forest stands, left unmanaged for a long time and/or no more subject to relevant forms of human disturbance, tended to recover structural and functional features resembling those of the primary forests; such stands may be termed, under certain conditions, old-growth (Hilbert & Wiensczyk 2007; Chirici & Nocentini 2010). In the last decades, research efforts have been increasingly dedicated to the definition, detection and characterization of old-growth forests (OGFs) in Europe and elsewhere (Keenan & Ryan 2004), due to their widely recognized role in the conservation of biological diversity, the storage of atmospheric carbon and the preservation of natural landscapes (Luyssaert et al. 2008). Despite including a wide range of ecological and/or management conditions, OGFs may share some common features: the occurrence of large-size and old trees, the coexistence of different woody species of various size and age, both in the tree layers and in the understory, the occurrence of deadwood with a differentiation in terms of amount, type and decay class, as well as a certain degree of structural heterogeneity and peculiar biological diversity (Spies 2004). Structural attributes, relatively easy to assess, may provide useful information on the development stage of the forest stand, as well as on its suitability to host specific taxonomic groups which are strictly dependent on the tree size and distribution patterns of woody vegetation (La Mantia et al. 2014; Friedel et al. 2006). The most frequently considered structural parameters are those related to large living trees exceeding a specific DBH threshold, their contribution to total live biomass, quadratic mean diameter and deadwood characteristics (Nilsson et al. 2002; Burrascano et al. 2013). Deadwood plays a key role for the stability, functionality and biodiversity of natural forest systems. Hence, its investigation in terms of total amount, type (standing or lying) and decay class (Lombardi et al. 2010) is widely regarded as essential to identify potential OGFs (Christensen & Emborg 1996; Müller et al. 2007; Sefidi & Etemad 2015). Deadwood provides information about the past management, the time elapsed since last human disturbance, and the amount of potentially available microhabitats for wildlife. Living organisms with limited dispersal ability, which need sufficient ecological continuity, i.e. long time under steady ecological conditions and low disturbance, may be used as reliable proxy bioindicators of old growth forest systems (Nordén & Appelqvist 2001; Blasi et al. 2010). In Italy, although the intensive exploitation of forest resources dates back at least to Roman times (Chirici & Nocentini 2010), it is estimated that old growth forests cover about 160.000 ha. They account for 1.6% of the national forest cover (Marchetti et al. 2010), and are mainly localized in less accessible contexts and steep slopes and/or in areas subject to a special protection regime (Motta 2002; Barbati et al. 2012). The relative contribution of old growth stands to total forest cover may range from about 0.3% in the Southern countries of USA (Davis 1996) to more than 3% in Australia (Keenan & Ryan 2004). Despite the increasing body of knowledge in temperate ecosystems worldwide, including Europe and Italy, still limited information is available for many Mediterranean forest ecosystems, such as those dominated by *Quercus ilex* L. and *Quercus pubescens* Willd. s.l. (Richard et al. 2004; Badalamenti et al. 2017). Filling this gap of knowledge is the first mandatory step if we are to plan and adopt concrete actions for the protection and long-term conservation of these valuable and biologically-rich natural ecosystems (Barbati et al. 2012). Our research is focused in Sicily (Mediterranean Basin), where the knowledge about old growth forests is still at a very preliminary stage. Only recently a dedicated field survey has detected a downy oak stand showing typical old growth traits (Badalamenti et al. 2017). Sicilian forest stands are in most cases young and with a simplified structure, far from late developmental forest phases (Maetzke et al. 2009; Hofmann et al. 2011). During preliminary investigations carried out within the most updated Regional Forest Inventory (Camerano et al. 2011), 18 forest stands considered to hold old-growth traits have been identified. They entirely fall within the regional Natura 2000 network of protected sites (Amato & Traina 2011). However, parameters as reported were not stand specific. These data need to be summarized into stand specific parameters so that old growth characteristics can be better evaluated for each stand. Such information may be of prominent importance for forest management, because it would allow a differentiation of the necessary actions according to the specific conditions of the stand. The main purpose of this study is to identify the most suitable criteria to identify forest stands showing old-growth traits in the Mediterranean, according to the most common features associated to such peculiar forest stands at a national and international level (e.g. Hilbert & Wiensczyk 2007). Moreover, to the old-growthness of the selected Sicilian forest stands has been given one out of three possible scores: high, medium and low. For each score, different management options are provided in order to foster the stand development towards more structurally-complex and biologically-rich ecosystems, tending to old-growth conditions.

2 Materials and methods

Stands Selection

The forest stands that were suspected to hold some old-growth traits were identified according to peer opinion, considering the knowledge acquired during about twenty years of field investigation, and by consulting the most relevant literature concerning Sicilian tree species and forest vegetation (see La Mantia & Pasta 2005; Amato & Traina 2011, Guarino & Pasta, 2017, and references therein).

Key indicators

On the basis of the international and national literature, four key proxy indicators of old-growth status were considered: deadwood, tree size, structural characteristics and tree species richness. Similar parameters have been considered in USA (Ducey et al. 2013) and Australia (Keenan & Ryan 2004) for identifying old growth forests. According to the compliance with the selected parameters, a preliminary classification in three old growth classes has been proposed, distinguishing forest stands next to old-growth conditions (high), potentially old-growth stands (medium) and stands that are still far from old-growth status (low).

Deadwood

Deadwood includes all the non-living woody biomass occurring in a forest, including standing dead trees, snags, stumps, coarse woody debris and fine lying elements (Forest Europe 2015). Due to the lack of quantitative data for most of the Sicilian forest stands, we estimated the occurrence of deadwood using an ordinal scale and on the basis of personal field observations. Such scale ranges from 0 (negligible occurrence) to 2, when abundant amount of deadwood, varying in terms of size, type and decay class has been observed.

Tree size

As long as forest management and disturbance cease, a corresponding increase of tree size is expected to occur. As a consequence, a sufficient number of large size trees is recognized as one of the most reliable proxy indicators of old-growth conditions. We considered as large those trees with DBH reaching 50 cm, the recommended threshold diameter for temperate and Mediterranean OGFs (Torras et al. 2012; Burrascano et al. 2013; Ducey et al. 2013).

Structural characteristics

For what concerns forest structure we considered the four main characteristics providing a diversification of the forest stand:

- ➢ the vertical and horizontal stratification of the woody layers;
- ➢ the occurrence of a shrub layer;
- ➢ the age and size unevenness of trees (Lindenmayer et al. 2000);
- ➢ the occurrence of gaps or of areas with reduced woody cover (Kern et al. 2014).

Tree species richness

Tree species richness has to be considered, since regularly managed stands are usually even-aged and characterized by only one dominant tree species (Hansen et al. 1991; Bengtsson et al. 2000). Although the co-occurrence of several tree species is not a feature common to all the old-growth stands, for instance, many tree species are found in the dominant layer and in the understory of old growth forests in USA (Beane et al. 2010) and Australia (Keddy & Drummond 1996). Within the Mediterranean basin, natural woodlands have been deeply altered, and the occurrence of a mono-specific tree layer (for instance *Fagus sylvatica* or *Quercus ilex* pure forest stands) is largely the consequence of the intense and long-lasting human management addressed to favor the most profitable tree species and to eliminate the other ones, including secondary tree species (Torras & Saura 2008; Martín-Queller et al. 2013). In the absence of forest management, natural disturbance factors are likely to create suitable conditions (e.g. small gaps) for the establishment of light-demanding woody (tree and shrub) species, thus diversifying both biologically and structurally the forest stand. Hence, the occurrence of more than one tree species may result from decades or even century-long dynamics of the forest stand under the prevailing influence of natural rather than anthropic factors. Also, as OGFs do not necessarily show a higher species-richness with respect to young forests, woody plant richness alone is not diagnostic of old-growth traits. We considered as sufficient the occurrence of at least 3 tree species, each estimated to represent at least 10% of the total tree individuals. Considering the peculiarity of Sicilian forest stands, we think that the use of such minimum threshold is acceptable.

Biological value

In order to get an in-depth characterization of the selected stands, their role for the conservation of native forest biodiversity was considered, particularly as concerns endangered and/or threatened species or species with a particular biogeographical value, such as plant and bird species (e.g. La Mantia et al. 2014). To assess this, the management plans of the Sites of Community Importance (SCI's) hosting such forest stands (available at: http://www.artasicilia.eu/old_site/web/pdg_definitivi/index.html), the Habitat Directive 92/43/EEC, the National Red Lists (for plant species: Conti et al. 1997) and International Conventions were primarily consulted. The occurrence of plant taxa within selected forest stands was assessed through peer opinion and consulting the most updated inventories of the Sicilian endangered plants (Raimondo et al. 2011), as well as the most recent regional vascular plant checklist (Giardina et al. 2007). As far as birds and other vertebrates are concerned, we considered the most recent inventory on vertebrata fauna in Sicily (Aa. Vv. 2008) as well as some recent researches on this issue (Bonaviri 2012; La Mantia et al. 2014).

Risk assessment

We also assessed which are at present the main threats for the conservation of each forest stand. Anthropogenic disturbances of various kinds (illegal logging, resin extraction, fruit harvesting, tourism pressure, etc.), forest utilization, grazing and/or the presence of feral ungulates and wildfires are considered by far the most relevant factors affecting Sicilian forest stands.

3 Results and discussion

Our research allowed us to identify 21 Sicilian forest stands displaying at least one old growth trait (Table 1). Such stands may be clearly distinguished from younger and simplified stands (Unep/Cbd/Sbstta 2001). Selected woods were equally divided among high, medium and low old growth class, each being represented by 7 forest stands. However, as a consequence of the deep and widespread human impact on regional forest resources, no forest stand can be actually considered as a real old-growth. Such a result was somehow expected since in the Mediterranean, and in Sicily as well, primary forests are no longer present, and old-growth forests are extremely rare (Richard et al. 2004). In the coastal and hilly areas of the Mediterranean basin, woodlands have been more extensively and for longer time exploited as compared to inner mountainous areas (Paletto et al. 2014; Paillet et al. 2015). Accordingly, they had less chance to develop mature and complex forest structures. This is confirmed by our research, as only two cork oak stands fall within the thermomediterranean bioclimatic belt. In mountain areas, the decade-long abandonment played an important role in fostering the development of structures and processes typical of late successional forests and triggered the natural dynamics of tree regeneration (Fabbio et al. 2003; Lasanta-Martínez et al. 2005). Among forest types, some variability was found, as nine dominant tree species were found in the selected forest stands. Downy oak (*Quercus pubescens* including *Quercus congesta* C. Presl.) stands were the most common (6 woods), followed by beech (5 woods), cork oak (3 woods), and holm oak (3 woods). *Ilex aquifolium* L., *Quercus petraea* subsp. *austrotyrrhenica* Brullo, Guarino and Siracusa, *Pinus nigra* subsp. *calabrica* (Loud.) A.E. Murray and *Quercus cerris* L. were each represented by only one forest stand. All selected forest stands fall within the Sicilian network of protected areas, including Natura 2000 sites (Sites of Community Importance and Special Protection Areas), Regional Parks and Regional Nature Reserves. It is not surprising as the crucial role played by regional protected areas for the conservation of woody species of particular biogeographical and conservation value is widely acknowledged (La Mantia et al. 2004). However, the protection regime applied in Sicily was limited, in fact, to the interruption of logging and the reduction of the overall human impact as compared to the past. Indeed, grazing and feral ungulates are still widespread, being present in about 70% of the selected stands. They represent by far the most serious bias for the natural dynamics and the conservation of Sicilian woods. This is not surprising as overgrazing is widely considered to be one of the main biases for the development of woodlands in the Mediterranean Basin (Bengtsson et al. 2000; Bagnato et al. 2012). In coastal and hilly areas, even wildfires continue to seriously threaten the stability of forests and the conservation of the associated biological communities. For example, in the Gibilmanna wood, frequent wildfires have encouraged the spread of generalist species such as rats and reduced the presence of species typical of mature forests such as the edible dormouse (*Glis glis* L.) and the hazel dormouse (*Muscardinus avellanarius* L.) (Sarà & Milazzo 2007). As concerns old-growth traits, almost all the forest stands were found to have a sufficient number of large trees (Table 2). This result represents a positive sign of the absence of significant human impact since long time. The reduction of the average tree size is one of the most common consequences of long-lasting forest management (Burrascano et al. 2013; Motta et al. 2015; Tíscar & Lucas-Borja 2016). Conversely, no longer managed forest stands generally display higher values of basal area (Motta et al. 2015; Paillet et al. 2015), live biomass (Burrascano et al. 2013; Motta et al. 2015) and density of large trees (Torras & Saura 2008; Burrascano et al. 2013; Motta et al. 2015; Paillet et al. 2015; Tíscar & Lucas-Borja 2016) than regularly managed forests. Deadwood occurrence was sufficient in about half of the woods; it was abundant only in four woods and almost absent in six woods. Hence, the amount of deadwood is

Table 1. Overview and main characteristics of the old-growth forests candidate in Sicily. Data for common names followed by an asterisk are from HOFMANN et al. (2011, modified). Protected areas: SPA = Special Protection Area, SCI: Sites of Community Importance, RNR = Regional Nature Reserve, RP = Regional Park

Id number	Common name	Locality	Municipality (Province)	Forest type (dominant tree species)	Bioclimatic belt[a]	SPA	SCI[b]	RNR or RP
1	Bosco Granza*	Bosco Granza	Sclafani Bagni (PA)	Inner cork oak wood (*Quercus suber*)	Mud		ITA020032	"Bosco della Favara e Bosco Granza" RNR
2	Bosco comunale di Monticelli*	Contrada Bosco	Castelbuono (PA)	Mesoxerophilous holm oak wood (*Quercus ilex*)	Mlh	X	ITA020016	"Madonie" RP
3	Bosco di Orippotto*	Contrada Montaspro	Isnello (PA)	Mesoxerophilous holm oak wood (*Quercus ilex*)	Mlh	X	ITA020017	
4	Bosco di Gibilmanna*	Contrada Pianetti	Gratteri (PA)	Xerophilous downy oak (*Quercus pubescens*) wood growing on siliceous substrata	Mls	X	ITA020002	
5	Bosco di Calatamauro*	Santa Maria del Bosco	Contessa Entellina (PA)	Mesomediterranean xerophilous holm oak wood (*Quercus ilex*)	Mus	X	ITA020035	"Monti Sicani" RP
6	Bosco di Gurgo	Santa Maria del Bosco	Contessa Entellina (PA)	Mesoxerophilous downy oak wood (*Quercus pubescens*)	Mus	X		
7	Bosco di Rifesi	Contrada Rifesi	Palazzo Adriano (PA)	Mesoxerophilous downy oak wood (*Quercus pubescens*)	Mus		ITA020025	
8	Bosco del Fanuso*	Contrada Fanuso	Godrano (PA)	Mesoxerophilous downy oak (*Quercus pubescens*) wood	Mus	X	ITA020007	"Bosco della Ficuzza, Rocca Busambra, Bosco del Cappelliere e Gorgo del Drago" RNR
9	Monte Carcaci*	Monte Carcaci	Castronovo di Sicilia (PA)	Mesoxerophilous downy oak (*Quercus pubescens*) wood	Sus	X	ITA020034	"Monti Sicani" RP
10	Agrifogli di Piano Pomo*	Piano Pomo	Petralia Sottana (PA)	Holly (*Ilex aquifolium*) stands	Slh	X	ITA020004	"Madonie" RP
11	Bosco di Pomieri*	Contrada Pomieri	Petralia Sottana (PA)	Sessile oak (*Quercus petraea* subsp. *austrotyrrhenica*) wood	Slh	X		
12	Faggeta di Cozzo Luminario*	Cozzo Luminario	Castelbuono (PA)	Mesophilous basiphilous beech (*Fagus sylvatica*) wood	Slh	X	ITA020004 and ITA020016	

Table 1. Continued

Id number	Common name	Locality	Municipality (Province)	Forest type (dominant tree species)	Bioclimatic belt[a]	SPA	SCI[b]	RNR or RP
13	Bosco di Santo Pietro*	Contrada Molara	Caltagirone (CT)	Thermomediterranean coastal cork oak (*Quercus suber*) wood	Tld		ITA070005	"Bosco di S. Pietro" RNR (currently inactive)
14	Querceto di Monte Arso*	Monte Arso	Bronte (CT)	Xerophilous downy oak (*Quercus congesta*) wood growing on siliceous substrata	Sus	X	ITA070017	"Etna" RP
15	Pineta di Ragabo*	Piano Pernicana	Linguaglossa (CT)	Pine (*Pinus nigra* subsp. *calabrica*) wood	Slh		ITA070013	
16	Faggeta di Monte Colla*	Monte Colla	Randazzo (CT)	Mesophilous beech (*Fagus sylvatica*) wood growing on siliceous substrata	Sus	X	ITA030035	"Nebrodi" RP
17	Cerreta di Sant'Antonio*	Contrada S. Antonio	Capizzi (ME)	Turkey oak (*Quercus cerris*) wood	Sus	X	ITA030014	
18	Bosco della Tassita*	Monte Pomiere	Caronia (ME)	Mesophilous beech (*Fagus sylvatica*) wood growing on siliceous substrata	Mlh			
19	Faggeta di Mangalaviti	Contrada Mangalaviti	Longi (ME)	Mesophilous beech wood growing on siliceous substrata (*Fagus sylvatica*)	Slh		ITA030038	
20	Bosco di Malabotta*	Contrada Faggita	Montalbano Elicona (ME)	Mesophilous beech wood growing on siliceous substrata (*Fagus sylvatica*)	Mus		ITA030005	"Bosco di Malabotta" RNR
21	Sughereta di Niscemi*	Contrada Pisciotto	Niscemi (CL)	Thermomediterranean coastal cork oak wood (*Quercus suber*)	Tld		ITA050007	"Sughereta di Niscemi" RNR

[a]According to Rivas-Martínez (2004); T = Thermomediterranean; M = Mesomediterranean; S = Supramediterranean; u = upper; l = lower; d = dry; h = humid; s = subhumid;
[b]The extended name of the SCI's may be found at http://www.artasicilia.eu/old_site/web/pdg_definitivi/index.html

Table 2. Old-growth traits and selected woods. **Deadwood amount** - 0: negligible occurrence; 1: low quantity; 2: considerable quantity and occurrence of different decay classes. **Relevant aspects** - B: biodiversity conservation; L: landscape and/or cultural value; P: phytogeographical and/or floristic value (including bryophytes, lichens, ferns and fungi); **Main threats to conservation** - A: anthropogenic pressure of different kinds (e.g. illegal logging, resin extraction, harvesting of fruits, tourism pressure, etc.); F: forest utilization; G: grazing and/or feral ungulates; W: wildfires. **Old-growthness class** – H: high; M: medium; L: low.

Common name	Deadwood	Large-size trees	Structural characteristics	Tree species richness	Relevant aspects	Main threats to conservation	Old-growthness class	References
Bosco Granza (1)	1	X	X	X	P	A	H	Cascio 2013
Bosco comunale di Monticelli (2)	0	X		X	P	G	L	Schicchi & Raimondo 1999
Bosco di Orippotto (3)	2	X	X	X	P	G	H	
Bosco di Gibilmanna (4)	0	X	X	X	P	G, W	M	Milazzo 2006; Sarà & Milazzo 2007
Bosco di Calatamauro (5)	1	X	X		L; P	F, G	H	
Bosco di Gurgo (6)	1	X				G	L	
Bosco di Rifesi (7)	1	X			P	G, W	M	Marcenò et al. 1985; Venturella et al. 1991
Bosco del Fanuso (8)	2	X	X	X	P	G	H	Gianguzzi & La Mantia 2004; La Mantia et al. 2010; Falci et al. 2012; Rapuzzi & Sparacio 2012; Badalamenti et al. 2017
Monte Carcaci (9)	1		X	X	P	G	M	Gianguzzi et al. 2007
Agrifogli di Piano Pomo (10)	0	X			L, P	A, G	L	Di Martino 1974; Padula & Raimondo 1979
Bosco di Pomieri (11)	1	X	X		P	A, G	H	Schicchi et al. 2000; Bagnato et al. 2012; Compagno et al. 2014; Venturella et al. 2014
Faggeta di Cozzo Luminario (12)	1	X				G	L	
Bosco di Santo Pietro (13)	1	X		X	L, P	W	M	De Marco & Furnari 1976
Querceto di Monte Arso (14)	0	X	X	X			L	

Table 2. Continued

Common name	Deadwood	Large-size trees	Structural characteristics	Tree species richness	Relevant aspects	Main threats to conservation	Old-growthness class	References
Pineta Ragabo (15)	1	X		X	B, L, P	A, F	M	Lo Valvo et al. 1993; Brullo et al. 2001; Baviera & Sparacio 2002; Baviera et al. 2005; Turrisi 2007; Barreca et al. 2010
Faggeta di Monte Colla (16)	1	X				G	M	
Cerreta di Sant'Antonio (17)	0	X	X	X		G	L	
Bosco della Tassita (18)	2	X	X	X	L, P		H	Ilardi et al. 2000; Mazzola & Domina 2006
Bosco di Mangalaviti (19)	1	X			P	G	M	Gianguzzi et al. 2004
Bosco di Malabotta (20)	2	X	X	X	P	G	H	Ronsisvalle & Signorello 1977; Pasta et al. 2010
Sughereta di Niscemi (21)	1	X		X	L; P	F, W	M	Costanzo et al. 1998; Rühl et al. 2005; Pasta 2007; Rapuzzi & Sparacio 2012

considerably deficient in many Sicilian forest stands and more efforts should be addressed to enhance it. The simultaneous presence of large trees and the low amount of deadwood may indicate that elapsed time has not been enough to cause the mortality of dominant plants or to trigger disturbance events at least at local scale. Even the prolonged removal of deadwood, often continued also after the cessation of silvicultural interventions, has contributed to further deplete Sicilian woods from this valuable ecological resource (Maetzke et al. 2009). About 62% and 52% of the selected Sicilian forest stands, respectively, were diversified in terms of tree species richness and were characterized by a certain degree of structural complexity. Although information on the biological diversity of Sicilian forest ecosystems is still lacking and/or limited, most of the considered woods were found to be host to a relevant native flora and fauna, thus playing a major role in the conservation of regional biodiversity (See Supplementary Material). For example, the Mangalaviti wood hosts one of the few populations of *Petagnaea gussonei* (Sprengel) Rauschert, a rare plant endemic to Sicily (Gianguzzi et al. 2004).

4 Conclusions and management proposals

In Sicily, potentially old growth stands have been detected only under particular conditions. The lack of quantitative data for most of the selected indicators allowed us to make only a preliminary classification. However, the research is one of the first attempts to detect and characterize potential OGFs within Mediterranean insular ecosystems. Filling this gap of knowledge is a crucial step if we are to ensure long-term preservation of the most intact forest resources and their outstanding biological heritage. There is also the potential to achieve an old-growth status under appropriate management strategies and protection regime, at least in a long-term perspective. The elimination of the still present anthropogenic pressure is the first preliminary condition, despite being not sufficient per se in most cases. After human disturbance has ceased, the question as to which is the best approach to enhance the structural complexity and biological diversity of forests is currently under debated, especially in the Mediterranean (Fabbio et al. 2003). On the one hand, forests may be left to natural development; on the other hand, some regulated forms of forest management may be necessary. The current conditions of the site, along with its disturbance and management history are essential factors to be taken into account. The onset of old-growth traits after the abandonment of traditional forestry activities has been observed in European temperate forests. In France, woods abandoned for about 46 years, showed a significantly higher living and dead aboveground biomass as compared to regularly managed forest stands (Paillet et al. 2015). The living volume and number of very large trees (DBH $>$ 67 cm) increased the longer they had been abandoned, while stumps showed an opposite trend, being a typical evidence of past management (Sweeney et al. 2010; Motta et al. 2015). Similarly, Swiss beech forests left unmanaged and undisturbed for about 40 years showed higher values of basal area, standing deadwood and variability of tree diameter classes, indicating the increasing structural diversification of the stand (Heiri et al. 2009). In temperate beech and oak forests, the natural accumulation of deadwood after management ceasing appears to be a rather quick process, with a mean annual accumulation rate ranging from 2.59 to 3.10 m^3 ha^{-1} (Vandekerkhove et al. 2009). However, in other contexts the required time seems to be much longer. In the Italian alpine forests, 50-60 years have not been sufficient (Motta et al. 2015). In several countries, direct interventions consisting in the girdling or felling of living trees are regularly planned within forest management plans in order to increase snags and logs, respectively (Corace et al. 2013). In the Mediterranean, the knowledge of deadwood dynamics is so far quite limited. As a consequence of the peculiar bioclimatic conditions and the different management history of each stand, a strongly site-specific response could be expected. Moreover, here forest management has been found to play a more important role than environmental factors in explaining the differences between managed and unmanaged Mediterranean forests (Tíscar & Lucas-Borja 2016). Low-intensity human interventions, localized in small areas, spatially and temporally differentiated, could be a recommended management option to enhance the structural complexity and biological diversity of Mediterranean forests (Torras & Saura 2008; Barreca et al. 2010; Martín-Queller et al. 2013). Such interventions may favor the coexistence of ecologically different living organisms due to the increased availability of potential ecological niches (Torras et al. 2012; Horak et al. 2014). An excessively dense canopy, resulting from the abandonment after forest management, is widely recognized as a cause of biodiversity loss in Mediterranean forests (Gil-Tena et al. 2007; Barreca et al. 2010). A key limiting factor is the availability of light in the understory. A more open canopy and gaps occurrence may allow the survival of shade-intolerant plants and their associated biological communities (Heiri et al. 2009), with specific taxa of beetles and birds particularly favored (Gil-Tena et al. 2007). A rational choice has to be made since the increase of several biodiversity indicators in many forest types has been observed in Spain, following the abandonment of traditional silvicoltural practices for about a decade (Torras et al. 2012). However, the same authors found that selective cuts seem to favor the abundance and richness of shrub species. As concerns our selected woods, the management option of direct interventions has to be restricted to forest stands falling within the medium or low old-growthness classes. On the contrary, for stands falling in the high class, full protection from any form of anthropogenic disturbance, especially from overgrazing, appears to be the most suitable management strategy. A good solution could be to subdivide the whole stand in two areas; the core and most integral area to be reserved for full protection, and an outer area where the adoption of specific measures to encourage the natural development of the forest should be planned. Our investigation allowed us to make a preliminary selection of the Sicilian forest stands that hold some old-growth traits and which could evolve towards old-growth conditions under appropriate management strategies. In this regard, the current lack of in-depth knowledge is still a major limitation for most of Mediterranean forest types (Badalamenti et al. 2017). Such a preliminary assessment will need to be corroborated by field data on forest structure and biological communities, following the latest protocols specifically developed to investigate OGFs (e.g.: Calamini et al. 2011). The comparison with thresholds values recently considered for Mediterranean forest stands (Lombardi et al. 2012), will serve as an important benchmark for the identification, management and future investigations of potentially old growth regional forests.

The research was carried out within the national research project PRIN2012 "Development of Innovative methods for Forest Ecosystem Monitoring by Remote Sensing". We are particularly grateful to Giovanni Giardina, Giovanna Sala, Antonio Cairone and Simone Di Prima for their valuable support during field surveys.

5 References

Aa. Vv. 2008: Atlante della Biodiversità della Sicilia: Vertebrati terrestri. Studi e Ricerche. – Arpa Sicilia, Palermo.

Amato, F. & Traina, G. 2011: Boschi vetusti. – In: P. Camerano, S. Cullotta & P. Varese (a cura di), Strumenti conoscitivi per la gestione delle risorse forestali in Sicilia. Sistema Informativo Forestale Regionale, – Litograf Editor S.r.l., Perugia, pp. 190–192.

Badalamenti, E.; La Mantia, T.; La Mantia, G.; Cairone, A. & La Mela Veca, D. S. 2017: Living and dead aboveground biomass in Mediterranean forests: Evidence of old-growth traits in a *Quercus pubescens* Willd. s.l. stand. – Forests **8** (6): 187. https://doi.org/10.3390/f8060187. available at: www.mdpi.com/1999-4907/8/6/187/pdf

Bagnato, S.; Merlino, A.; Mercurio, R.; Solano, F.; Scarfò, F. & Spampinato, G. 2012: Le basi conoscitive per il restauro forestale: il caso di Bosco Pomieri (Parco Regionale delle Madonie, Sicilia). – Forest@ **9**: 8–19.

Barbati, A.; Salvati, R.; Ferrari, B.; Di Santo, D.; Quatrini, A.; Portoghesi, L.; Travaglini, D.; Iovino, F. & Nocentini, S. 2012: Assessing and promoting old-growthness of forest stands: lessons learnt from research experiences in Italy. – Plant Biosyst. **146**: 167–174.

Barreca, L.; Marziliano, P. A.; Menguzzato, G. & Scuderi, A. 2010: Avifauna e struttura nella pineta Ragabo (Linguaglossa, CT). – Forest@ **7**: 223–233.

Baviera, C.; Bella, S. & Turrisi, G. F. 2005: *Acanthocinus aedilis* (Linnaeus, 1758) nuovo per la fauna siciliana (Coleoptera Cerambycidae). – Il Naturalista siciliano **29**: 77–81.

Baviera, C. & Sparacio, I. 2002: Descrizione di una nuova specie di *Buprestis* Linnaeus della Sicilia (Coleoptera, Buprestidae). – Il Naturalista siciliano **26**: 93–99.

Beane, N. R.; Heitzman, E. & Schuler, T. M. 2010: Stand dynamics of an old-growth eastern hemlock-hardwood forest in West Virginia. – Nat. Area. J. **30**: 64–72.

Bengtsson, J.; Nilsson, S. G.; Franc, A. & Menozzi, P. 2000: Biodiversity, disturbances, ecosystem function and management of European forests. – Forest Ecol. Manage. **132**: 39–50.

Blasi, C.; Marchetti, M.; Chiavetta, U.; Aleffi, M.; Audisio, P.; Azzella, M. M.; Brunialti, G.; Capotorti, G.; Del Vico, E.; Lattanzi, E.; Persiani, A. M.; Ravera, S.; Tilia, A. & Burrascano, S. 2010: Multi-taxon and forest structure sampling for identification of indicators and monitoring of old-growth forest. – Plant Biosyst. **144**: 160–170.

Bonaviri, L. 2012: Valutazione della naturalità dei sistemi agro-forestali attraverso lo studio delle comunità ornitiche. PhD thesis, Università degli Studi di Palermo.

Brullo, S.; Giusso del Galdo, G. & Guarino, R. 2001: The orophilous communities of the *Pino-Juniperetea* class in the Central and Eastern Mediterranean area. – Feddes Repert. **112**: 261–308.

Burrascano, S.; Keeton, W. S.; Sabatini, F. M. & Blasi, C. 2013: Commonality and variability in the structural attributes of moist temperate old-growth forests: A global review. – Forest Ecol. Manage. **291**: 458–479.

Burrascano, S.; Rosati, L. & Blasi, C. 2009: Plant species diversity in Mediterranean old-growth forests: A case study from central Italy. – Plant Biosyst. **143**: 190–200.

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**: 365–381.

Camerano, P.; Cullotta, S. & Varese, P. 2011: Strumenti conoscitivi per la gestione delle risorse forestali della Sicilia. Tipi Forestali. Assessorato Territorio e Ambiente, Regione Siciliana, Litograf Editor S.r.l., Perugia.

Cascio, G. 2013: Il pascolo nelle aree protette in Sicilia: il caso studio Bosco della Favara e di Granza. Bachelor's thesis, Facoltà di Scienze Agrarie e Forestali, Università degli Studi di Palermo.

Chirici, G. & Nocentini, S. 2010: Old-growth forests in Italy: recent research developments and future perspectives. – L'Italia Forestale e Montana **65**: 475–480.

Christensen, M. & Emborg, J. 1996: Biodiversity in natural versus managed forests. Forest Ecol. Manage. **85**: 47–51.

Compagno, R.; Grisafi, F.; Mannino, A. M.; Ottonello, D.; Alaimo, M. G.; La Rosa, A.; Gargano, M. L. & Venturella, G. 2014: Investigation on old-growth forests of Sicily: preliminary results: 40-40. Proceedings of the 109th Convegno della Società Botanica Italiana, International Plant Science Conference (IPSC), Florence.

Conti, F.; Manzi, A. & Pedrotti, F. 1997: Liste Rosse Regionali delle Piante d'Italia. – Società Botanica Italiana e Associazione Italiana per il World Wildlife Fund, Camerino (MC).

Corace, R. G. III.; Stout, A. T.; Goebel, P. C. & Hix, D. M. 2013: Snag benchmarks and treatment options for mixed-pine forest restoration in eastern upper Michigan. – Restor. Ecol. **21**: 608–616.

Costanzo, E.; Furnari, F. & Tomaselli, V. 1998: La sughereta di Niscemi con carta della vegetazione (1:25.000) (Sicilia Sud-Orientale). – In: Atti 6° Workshop Progetto strategico "Clima, Ambiente e Territorio nel Mezzogiorno". – Taormina (Italy), pp. 563–586.

Davis, M. B. 1996: Eastern old-growth forests: prospects for rediscovery and recovery. – Island Press, Washington D.C.

De Marco, G. & Furnari, F. 1976: Lineamenti della vegetazione di S. Pietro (Caltagirone) a commento della carta in scala 1:25.000. – Atti Accademia Gioenia di Scienze Naturali Catania **7**: 3–15.

Di Martino, A. 1974: Piante madonite da proteggere. Gli *Ilex aquifolium* di Piano Pomo. – Lavori dell'Istituto Botanico e Giardino Coloniale di Palermo **25**: 28–38.

Ducey, M. J.; Gunn, J. S. & Whitman, A. A. 2013: Late-Successional and Old-Growth Forests in the Northeastern United States: Structure, Dynamics, and Prospects for Restoration. – Forests **4**: 1055–1086.

Fabbio, G.; Merlo, M. & Tosi, V. 2003: Silvicultural management in maintaining biodiversity and resistance of forests in Europe — the Mediterranean region. – J. Environ. Manage. **7**: 67–76.

Falci, A.; Livreri Console, S.; Giardina, G.; Lo Duca, R. & La Mantia, T. 2012: I Lepidotteri Ropaloceri (Insecta Lepidoptera) del bosco della Ficuzza. – Il Naturalista siciliano **36**: 435–451.

Forest Europe. 2015: State of Europe's Forests 2015. Ministerial Conference on the Protection of Forests in Europe, Liaison Unit Madrid, Madrid.

Friedel, A.; Oheimb, G. V.; Dengler, J. & Härdtle, W. 2006: Species diversity and species composition of epiphytic bryophytes and lichens – a comparison of managed and unmanaged beech forests in NE Germany. – Feddes Repert. **117**(1–2): 172–185.

Garbarino, M.; Marzano, R.; Shaw, J. D. & Long, J. N. 2015: Environmental Drivers of Deadwood Dynamics in Woodlands and Forests. – Ecosphere **6**(3): 1–24.

Gianguzzi, L. & La Mantia, A. 2004: Le serie di vegetazione della riserva "Bosco Ficuzza, rocca Busambra, Bosco del Cappelliere e Gorgo del drago" (Provincia di Palermo). – Il Naturalista siciliano **28**: 265–326.

Gianguzzi, L.; La Mantia, A. & Lo Presti, R. M. 2004: Distribuzione, ecologia e status conservativo di *Petagnaea gussonei* (Sprengel) Rauschert (Apiaceae). – Il Naturalista siciliano **28**: 205–242.

Gianguzzi, L.; Spennati, B. & La Mantia, A. 2007: La vegetazione di Monte Carcaci, Sito d'Interesse Comunitario dei Monti Sicani (Sicilia occidentale). – Fitosociologia **44**: 195–199.

Giardina, G.; Raimondo, F. M. & Spadaro, V. 2007: A catalogue of plants growing in Sicily. – Bocconea **20**: 5–582.

Gil-Tena, A.; Saura, S. & Brotons, L. 2007: Effects of forest composition and structure on bird species richness in a Mediterranean context: Implications for forest ecosystem management. – Forest Ecol. Manage. **242**: 470–476.

Guarino, R. & Pasta, S. 2017: Botanical Excursions in Central and Western Sicily. Field Guide for the 60th IAVS Symposium (Palermo, 20-24 June 2017), 606 pp. https://www.unipapress.it/UPP/Data/Books/Admin20170619184100/Escursioni.pdf ISBN online: 978-88-99934-45-3

Hansen, A. J.; Spies, T. A.; Swanson, F. J. & Ohmann, J. L. 1991: Conserving biodiversity in managed forests. Lessons from natural forests. – BioScience **41**: 382–392.

Heiri, C.; Wolf, A.; Rohrer, L. & Bugmann, H. 2009: Forty years of natural dynamics in Swiss beech forests: Structure, composition, and the influence of former management. – Ecol. Appl. **19**: 1920–1934.

Hilbert, J. & Wiensczyk, A. 2007: Old-growth definitions and management: A literature review. – BC J. Ecosyst. Manage. **8**: 15–31.

Hofmann, A.; Cibella, R.; Bertani, R.; Miozzo, M.; Fantoni, I. & Luppi, S. 2011: Strumenti conoscitivi per la gestione delle risorse forestali della Sicilia. Sistema Informativo Forestale. Assessorato Territorio e Ambiente Regione Siciliana, Litograf Editor S.r.l., Perugia.

Horak, J.; Vodka, S.; Kout, J.; Halda, J.; Bogusch, P. & Pech, P. 2014: Biodiversity of most dead wood-dependent organisms in thermophilic temperate oak woodlands thrives on diversity of open landscape structures. – Forest Ecol. Manage. **315**: 80–85.

Ilardi, V.; Schicchi, R. & Raimondo, F. M. 2000: Gli alberi monumentali della Tassita dei Nebrodi (Sicilia nord-orientale). – Quaderni di Botanica ambientale e applicata **8**: 127–137.

Keddy, P. A. & Drummond, C. G. 1996: Ecological properties for the evaluation, management and restoration of temperate deciduous forest ecosystems. – Ecological Applications **6**(3): 748–762.

Keenan, R. J. & Ryan, M. F. 2004: Old growth forests in Australia: conservation status and significance for timber production: Bureau of Rural Sciences, Dept. of Agriculture, Fisheries and Forestry, Science for decision makers, Canberra.

Kern, C. C.; Montgomery, R. A.; Reich, P. B. & Strong, T. F. 2014: Harvest-created canopy gaps increase species and functional trait diversity of the forest ground-layer community. – Forest Sci. **60**: 335–344.

La Mantia, T.; Bellavista, M.; Giardina, G. & Sparacio, I. 2010: Longhorn beetles of the Ficuzza woods (W Sicily, Italy) and their relationship with plant diversity (Coleoptera, Cerambycidae). – Biodiversity Journal **1**: 15–44.

La Mantia, T.; Bonaviri, L. & Massa, B. 2014: Ornithological communities as indicators of recent transformations on a regional scale: Sicily's case. – Avocetta **38**: 67–81.

La Mantia, T.; Pasta, S. & Barbera, G. 2004: Il ruolo delle aree protette siciliane nella conservazione del patrimonio delle specie legnose d'interesse forestale ed agrario. – Il Naturalista siciliano **28**: 351–364.

La Mantia, T. & Pasta, S. 2005: The Sicilian phanerophytes: still a noteworthy patrimony, soon a lost resource?. – In: IUFRO Conference, Monitoring and indicators of forest biodiversity in Europe - from ideas to operationality", EFI Proceedings, – Firenze, pp. 515–526.

La Mela Veca, D. S.; Cullotta, S.; Sferlazza, S. & Maetzke, F. G. 2016: Anthropogenic Influences in Land Use/Land Cover Changes in Mediterranean Forest Landscapes in Sicily. – Land **5**(3): 1–13. (available at: www.mdpi.com/2073-445X/5/1/3/pdf).

Lasanta-Martínez, T.; Vicente-Serrano, S. M. & Cuadrat-Prats, J. M. 2005: Mountain Mediterranean landscape evolution caused by the abandonment of traditional primary activities: A study of the Spanish Central Pyrenees. – Applied Geography **25**: 47–65.

Lindenmayer, D. B.; Margules, C. R. & Botkin, D. B. 2000: Indicators of biodiversity for ecologically sustainable forest management. – Conservation Biology **14**: 941–950.

Lo Valvo, M.; Massa, B. & Sarà, M. 1993: Uccelli e paesaggio in Sicilia alle soglie del terzo millennio. – Il Naturalista siciliano **17**: 1–373.

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**: 481–504.

Lombardi, F.; Lasserre, B.; Chirici, G.; Tognetti, R. & Marchetti, M. 2012: Deadwood occurrence and forest structure as indicators of old-growth forest conditions in Mediterranean mountainous ecosystems. – Ecoscience **19**: 344–355.

Luyssaert, S.; Schulze, E. D.; Börner, A.; Knohl, A.; Hessenmöller, D.; Law, B. E.; Ciais, P. & Grace, J. 2008: Old-growth forests as global carbon sinks. – Nature **455**: 211–213.

Maetzke, F.; Barbera, G.; Cullotta, S.; La Mantia, T.; La Mela Veca, D. S. & Pizzurro, G. M. 2009: La Selvicoltura in Sicilia: problemi e prospettive. – In: Terzo Congresso Nazionale di Selvicoltura "Per il miglioramento e la conservazione dei boschi italiani", Accademia Italiana di Scienze Forestali, 16-19 ottobre 2008, – Taormina (Sicilia, Italia), pp. 828–836.

Marcenò, C.; Colombo, P. & Princiotta, R. 1985: Ricerche climatologiche e botaniche sui Monti Sicani (Sicilia Centro Occidentale). La flora. – Il Naturalista siciliano **8**: 69–133.

Marchetti, M.; Tognetti, R.; Lombardi, F.; Chiavetta, U.; Palumbo, G.; Sellitto, M.; Colombo, C.; Iovieno, 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 Biosyst. **144**: 130–147.

Martín-Queller, E.; Diez, J. M.; Ibáñez, I. & Saura, S. 2013: Effects of silviculture on native tree species richness: Interactions between management, landscape context and regional climate. – J. Appl. Ecol. **50**: 775–785.

Mazzola, P. & Domina, G. 2006: Distribution and conservation perspectives of *Taxus baccata* L. (Taxaceae) in Sicily. – Bocconea **19**: 209–215.

Milazzo, A. 2006: La perturbazione da incendio nella comunità di vertebrati terrestri dei boschi mediterranei. PhD thesis, Università degli studi di Palermo, Dipartimento di Biologia Animale (Tutor: Maurizio Sarà).

Motta, R. 2002: Old-growth forests and silviculture in the Italian Alps: the case study of the strict reserve of Paneveggio (TN). – Plant Biosyst. **136**: 223–232.

Motta, R.; Garbarino, M.; Berretti, R.; Meloni, F.; Nosenzo, A. & Vacchiano, G. 2015: Development of old-growth characteristics in uneven-aged forests of the Italian Alps. – Eur. J. For. Res. **134**: 19–31.

Müller, J.; Hothorn, T. & Pretzsch, H. 2007: Long-term effects of logging intensity on structures, birds, saproxylic beetles and wood-inhabiting fungi in stands of European beech *Fagus sylvatica* L. – Forest Ecol. Manage. **242**: 297–305.

Nilsson, S. G.; Niklasson, M.; Hedin, J.; Aronsson, G.; Gutowski, J. M.; Linder, P.; Ljungberg, H.; Mikusìnski, G. & Ranius, T. 2002: Densities of large and dead trees in old-growth temperate and boreal forests. – Forest Ecol. Manage. **161**: 189–204.

Nordén, B. & Appelqvist, T. 2001: Conceptual problems of ecological continuity and its bioindicators. – Biodivers. Conserv. **10**: 779–791.

Padula, M. & Raimondo, F. M. 1979: Piano Pomo. – In: Gruppo di Lavoro per la Conservazione della Natura della Società Botanica Italiana (a cura di), Censimento dei biotopi di rilevante interesse vegetazionale meritevoli di conservazione in Italia, vol 2(XIX), – Savini-Mercuri, Camerino, pp. 473–474.

Paillet, Y.; Bergès, L.; Hjältén, J.; Ódor, P.; Avon, C.; Bernhardt-Römermann, M.; Bijlsma, R. J.; de Bruyn, L.; Fuhr, M.; Grandin, U.; Kanka, R.; Lundin, L.; Luque, S.; Magura, T.; Matesanz, S.; Mészáros, I.; Sebastià, M. T.; Schmidt, W.; Standovár, T.; Tóthmérész, B.; Uotila, A.; Valladares, F.; Vellak, K. & Virtanen, R. 2010: Biodiversity differences between managed and unmanaged forests: Meta-analysis of species richness in Europe. – Conserv. Biol. **24**: 101–112.

Paillet, Y.; Pernot, C.; Boulanger, V.; Debaive, N.; Fuhr, M.; Gilg, O. & Gosselin, F. 2015: Quantifying the recovery of old-growth attributes in forest reserves: A first reference for France. – Forest Ecol. Manage. **346**: 51–64.

Paletto, A.; De Meo, I.; Cantiani, P. & Ferretti, F. 2014: Effects of forest management on the amount of deadwood in Mediterranean oak ecosystems. – Ann. For. Sci. **71**: 791–800.

Parviainen, J. 2005: Virgin and natural forests in the temperate zone of Europe. – Forest Snow Lands. Res. **79**: 9–18.

Pasta, S. 2007: Appendice B. Lista delle piante vascolari note per il comprensorio di Niscemi. – In: D. S. La Mela Veca, F. Maetzke & S. Pasta (eds.), La Gestione Forestale Sostenibile nelle Aree Protette: il caso di studio della Riserva Naturale Orientata Sugherete di Niscemi (CL), Collana Sicilia Foreste, n° 31, – Azienda Regionale Foreste Demaniali Regione Siciliana, pp. 198–210.

Pasta, S.; Di Leo, C.; Contrino, P. & Lo Duca, R. 2010: Studio di incidenza relativamente ai SIC ITA030005 "Bosco di Malabotta" e ITA030020 "Fiume San Paolo" relativo al Progetto definivo di ottimizzazione della esistente strada provinciale "Malabotta", funzionale al costruendo parco eolico denominato "Alcantara".

Raimondo, F. M.; Bazan, G. & Troìa, A. 2011: Taxa a rischio nella flora vascolare della Sicilia. – Biogeographia **30**: 229–239.

Rapuzzi, I. & Sparacio, I. 2012: *Carabus (Eurycarabus) faminii* Dejean, 1826 (Coleoptera, Carabidae) in Sicily: distribution and taxonomic considerations with description of a new taxon. – Biodiversity Journal **3**: 85–90.

Richard, F.; Moreau, P.; Selosse, M. & Gardes, M. 2004: Diversity and fruiting patterns of ectomycorrhizal and saprobic fungi in an old-growth Mediterranean forest dominated by *Quercus ilex* L. – Can. J. Botany **82**: 1711–1729.

Rivas-Martínez, S. 2004: Global Bioclimatics (Clasificación Bioclimática de la 678 Tierra). URL: http://www.globalbioclimatics.org. (Accessed on 12 June 2017).

Ronsisvalle, G. A. & Signorello, P. 1977: Interesse naturalistico e fitosociologico della faggeta del bosco di Malabotta (Montalbano Elicona, Monti Peloritani). – Bollettino dell'Accademia Gioenia di Scienze Naturali Catania **13**: 62–71.

Rühl, J.; Chiavetta, U.; La Mantia, T.; La Mela Veca, D. S. & Pasta, S. 2005: Land cover change in the Nature Reserve "Sughereta di Niscemi" (SE Sicily) in the 20th century. – In: S. Erasmi, B. Cyffka & M. Kappas (eds.), Proceedings of Remote Sensing and GIS for Environmental Studies: applications in geography, 7-8 October 2004, – Göttingen, Germany, pp. 54–63.

Sarà, M. & Milazzo, A. 2007: The effect of wildfires on glirids (*Muscardinus avellanarius* and *Glis glis*) living in Mediterranean ecosystems. – In: V European Congress of Mammalogy, Vol. I, – Siena, pp. 165–166.

Schicchi, R.; Mangione, M.; Dia, M. G. & Raimondo, F. M. 2000: Un nuovo modello di gestione per il biotopo "Querceti di Pomieri, Piano Farina e Piano Costantino" (Parco delle Madonie, Sicilia). – Quaderni di Botanica ambientale e applicata **8**: 65–100.

Schicchi, R. & Raimondo, F. M. 1999: Contributo alla conoscenza degli alberi monumentali delle Madonie (Sicilia centro-settentrionale). – Il Naturalista siciliano **13**: 229–314.

Sefidi, K. & Etemad, V. 2015: Dead wood characteristics influencing macrofungi species abundance and diversity in Caspian natural beech (*Fagus orientalis* Lipsky) forests. – Forest Syst. **24**(2): 1–9.

Sferlazza, S.; Maetzke, F. G.; Miozzo, M. & La Mela Veca, D. S. 2017: Resilience of Mediterranean forests to climate change: 263-282. – In: B. Fuerst-Bjelis (a cura di). Mediterranean Identities - Environment, Society, Culture, InTechOpen. (available at: https://cdn.intechopen.com/pdfs-wm/55350.pdf)

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

Spies, T. A.; Hemstrom, M. A.; Youngblood, A. & Hummel, S. 2006: Conserving old-growth forest diversity in disturbance-prone landscapes. – Conserv. Biol. **20**: 351–362.

Sweeney, O. F. M.; Martin, R. D.; Irwin, S.; Kelly, T. C.; O'Halloran, J.; Wilson, M. W. & McEvoy, P. M. 2010: A lack of large-diameter logs and snags characterises dead wood patterns in Irish forests. Forest Ecol. Manage. **259**: 2056–2064.

Tíscar, P. A. & Lucas-Borja, M. E. 2016: Structure of old-growth and managed stands and growth of old trees in a Mediterranean *Pinus nigra* forest in southern Spain. – Forestry **89**: 201–207.

Torras, O.; Gil-Tena, A. & Saura, S. 2012: Changes in biodiversity indicators in managed and unmanaged forests in NE Spain. – J. For. Res. **17**: 19–29.

Torras, O. & Saura, S. 2008: Effects of silvicultural treatments on forest biodiversity indicators in the Mediterranean. – Forest Ecol. Manage. **255**: 3322–3330.

Turrisi, G. F. 2007: *Xyela curva* Benson, 1938 (*Hymenoptera Xyelidae*), specie nuova per la fauna siciliana. – Il Naturalista siciliano **31**: 69–76.

Unep/Cbd/Sbstta, 2001: Main Theme: Forest Biological Diversity. Report of the Ad Hoc Technical Expert Group on Forest Biological Diversity. Subsidiary Body for Scientific, Technical and Technological Advice, Seventh Meeting, Montreal.

Vandekerkhove, K.; De Keersmaeker, L.; Menke, N.; Meyer, P. & Verscheide, P. 2009: When nature takes over from man: dead wood accumulation in previously managed oak and beech woodlands in North-western and Central Europe. Forest Ecol. Manage. **258**: 425–435.

Venturella, G.; Compagno, R.; La Rosa, A. & Gargano, M. L. 2014: Fungal biodiversity in old-growth forests of Sicily: preliminary results. – In: XX Convegno Nazionale di Micologia (eds.), – Unione Micologica Italiana, Bologna, pp. 35–35.

Venturella, V.; Mazzola, P. & Raimondo, F. M. 1991: Aspetti distributivi e sinecologici di *Ostrya carpinifolia* Scop. in Sicilia. – Quaderni di Botanica Ambientale e Applicata **1**: 211–246.

Young, J.; Watt, A.; Nowicki, P.; Alard, D.; Clitherow, J.; Henle, K.; Johnson, R.; Laczko, E.; McCracken, D.; Matouch, S.; Niemela, J. & Richards, C. 2005: Towards sustainable land use: identifying and managing the conflicts between human activities and biodiversity conservation in Europe. – Biodivers. Conserv. **14**: 1641–1661.

Supporting information

Additional supporting information may be found in the online version of this article at the publisher's web-site:

Species of particular conservation and/or biogeographical value occurring in the selected woods.

