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Which are Southern Italy's fastest growing tree species? Lessons from the past for future perspectives, with a special focus on Sicily

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ABSTRACT Fast growing tree species can generate high wood production in a short time frame. However, maximum productivity is dependent on environmental and management conditions as well as intrinsic plant traits. Within this framework, our research was into tree species with the highest Mean Annual Increments (MAIs) in southern Italy, particularly in Sicily. *Eucalyptus* spp., *Acacia saligna* (Labill.) H. L. Wendl., *Ailanthus altissima* Mill. (Swingle), *Pinus halepensis* Mill. (including *Pinus brutia* Ten.), *Pinus canariensis* C.Sm. and *Pinus radiata* D. Don. were identified. In particularly suitable conditions, the MAI of eucalypt coppices ranged from 8 to 12 m^3 ha^{-1}, and from 13 to 19 m^3 ha^{-1}, in Fvdbzqvt *camaldulensis* Dehnh. and Fvdbzqvt hpcvvt Labill., respectively. The MAI of *E. camaldulensis* high forests was slightly over 6 m^3 ha^{-1}, while that of *E. globulus* high forests was very similar to its coppice value. Considering the preliminary data, *Acacia saligna* can achieve good wood production. *Pinus halepensis* and *Pinus brutia* Ten. achieved MAIs of 5-7 m^3 ha^{-1}. The other species discussed may be promising but either data is very limited or their invasive potential requires careful consideration. This historical review has shown that with optimal tree species-planting site-cultivation technique combinations, tree species can achieve wood yields typical of fast-growing species in Mediterranean Italy, too.

KEYWORDS: *Acacia, Ailanthus*, *Eucalyptus*, timber and wood production, wood arboriculture.

Introduction

The history of forest plantations in Southern Italy and Sicily, and related wood production, are strongly bound up with the historical reasons underlying the use of forest species in these regions. Firstly, tree species were historically largely used in Mediterranean contexts in massive afforestation which shaped the landscape and vegetation features across large areas. In the Mediterranean basin, the introduction of exotic forest species for afforestation was the most significant forest phenomenon of the last century (Corona et al. 2009, Nyssen et al. 2016). Exotic woody taxa were extensively used due to their expected rapid growth, considerable resistance to abiotic stresses and capacity to survive in poor soil conditions (Le Floc'h 1991, Pausas et al. 2004, Vallejo et al. 2012). Tree genera such as *Acacia* spp., *Eucalyptus* spp. and *Pinus* spp. were mainly used for the primary goal of rapidly restoring hydrological soil processes, thus protecting against soil erosion (La Mantia 2013, Nadal-Romero et al. 2016, Sferlazza et al. 2017a), and also acting as preparatory species fostering the development of more complex, resilient and stable forest stands (Pausas et al. 2004, Vallejo et al. 2012, Badalamenti et al. 2017, Sferlazza et al. 2017b). In many Mediterranean countries, including Italy, such forest plantations were also expected to respond to significant demands for wood for heating, domestic and industrial purposes until at least the 1960s (Scarascia-Mugnozza et al. 2000, La Mantia 2002 and 2009, La Mela Veca et al. 2016, Sferlazza et al. 2018). In Italy, particularly, the need to produce large amounts of biomass in a relatively short time via the cultivation of Fast Growing Species (FGS) has long been considered more important than searching for higher-value wood tree species (Pavari 1916 and 1940, Palazzo and Palazzo 1932). In this context, extensive experimentation with and dissemination of exotic forest species in Italy, from the 1920s onwards, powerfully boosted the identification of fast-growing species, subspecies, hybrids or clones (Pavari 1916). Subsequently, since the 1950s intensive FGS cultivation systems have progressively spread and consolidated (Facciotto and Bergante 2011). These systems, collectively referred to as Short Rotation Forestry (SRF), were predominantly economic and productive in purpose, especially in the very early stages of experimentation (Facciotto 2012). However, they have recently attracted special attention for their potential to increase the use of wood as a renewable energy source, in the place of fossil fuels, thus helping to mitigate the effects of climate change (Dimitriou and Rutz 2015). To respond to such a wide range of needs, tree species were primarily required to be fast growing. Regardless of the main purpose, our aim was to identify the FGS best suited to Sicily and Southern Italy, in the light of both past experiences and future perspectives. After species identification and selection, productivity data recorded over the last fifty years throughout Italy was summarized.

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Materials and Methods

Our bibliographic research was designed to find the fastest growing tree species in Sicily and Southern Italy, including native and exotic species. Part of the literature consulted fell under the so-called 'grey literature' category, outside traditional commercial or academic publishing. As regards wood productivity data, the main parameter used in the text is Mean Annual Increment/s (MAI/MAIs) which indicates average wood production (in m^3) on a yearly basis per hectare, and this is the most frequently used at a national and international level. Since our interest was assessing fast juvenile growth, we only considered plantations which were 25 years old or less (Ciancio et al. 1980). It is important to highlight that many national papers use Pavari's phytoclimatic classification (1916) which, conversely, is seldom adopted at the international level. It should be considered that Pavari's Lauretum basically corresponds to the thermo-Mediterranean bioclimatic belt(Rivas-Martinez 1996). In Mediterranean Italy, all vegetation aspects dominated by evergreen sclerophyllous woody species are encompass, such as Mediterranean maquis, with *Quercus ilex* L. being the dominant tree species (Gianguzzi et al. 2016). Pavari's Castanetum mostly corresponds to the meso-Mediterranean bioclimatic belt (Rivas-Martinez 1996) which is dominated by deciduous oaks, primarily *Quercus pubescens* Willd s.l., and also includes notable hardwood species such as ash, chestnut, maple, etc.

Results

Overall, six forest species were chosen and characterized for their effective or potential fast growth in Southern Italy, particularly Sicily. We selected *Eucalyptus* spp., *Acacia saligna Labill.* H. L. Wendl., and *Ailanthus altissima* Mill. (Swingle) in the broadleaf category, and *Pinus halepensis* Mill. (including *Pinus brutia* (Ten.) Holmboe), *Pinus canariensis* C. Sm. and *Pinus radiata* D. Don in conifer terms. The highest performance of these species in terms of MAI, as well as ecological information regarding cultivation sites and techniques, is shown in Table 1. No soil working whatsoever was done in any of the plantations, except in the experimental *A. saligna* trial where soils were ploughed and harrowed (25-30 cm deep) before planting (Facciotto and Nervo 2011).

Hardwood species

Eucalyptus spp.

Although eucalypts, along with poplars, have been the most promising broadleaved species in Italy's long forest tree experimentation, they have generally not met expectations, with numerous failures, while still maintaining good productive valorisation potential. The *Eucalyptus* genus includes more than 700 species (Slee et al. 2006), almost exclusively trees of various habitats, ecology and morphology coming from Australia. Eucalypts have spread massively outside their native range (FAO 1981, Silva-Pando and Pino-Pérez 2016), and currently represent the main hardwood species genus used in wood plantations worldwide, with a total area approaching 18 million hectares (Carle et al. 2002). One specific feature of eucalypt introduction history has been the variety of environments in which they have been cultivated, which is linked to their use versatility including as agricultural crop protection windbreaks, swamp area reclamation, ornamental use in urban villas and gardens and reforestation of bare, sterile and unproductive soils, as well as wood and cellulose production (Pavari 1940, La Mantia 2013, Badalamenti et al. 2018a). Eucalypts were indicated as the most suitable species for the thermophilous belts of Southern Italy and the islands early on, for their ability to grow even in the presence of powerful constraints such as poor and superficial soils, and prolonged summer drought, where native species were considered unsuitable. Pavari (1916) argued that (o.t.) "*... without any doubt the gen.* Eucalyptus *can be considered the most important type of exotic broadleaved trees for our Lauretum*", also affirming that (o.t.) "*for the rapidity of growth the eucalypts compete with the poplar and sometimes rival it*" (Pavari 1937). Despite the considerable number of species in the genus, only *E. camaldulensis* Dehnh. and *E. globulus* Labill. were historically considered particularly promising for productive purposes (Pavari and de Philippis 1935). In Italy, experiments with eucalypts began in 1923 with 30 experimental plots being set up by Florence's Experimental Forestry Station (Giordano 1970). Notable traits associated with eucalypts are their rusticity and remarkable adaptability to varied ecological conditions, but also their high, relatively short term wood production potential (Pavari and de Philippis 1941a). The potential for hybridizing different eucalypt species to obtain more productive or stress-resistant hybrids was also soon hypothesized, effectively anticipating what has happened since the end of the last century: (o.t.) "*Hybridization can often be an advantage because hybrids are usually more vigorous than progenitors. For example, many hybrids of the genus* Eucalyptus, Populus, Salix, Cupressus, Abies, *etc.*" (Pavari and de Philippis 1941a). Giordano (1970) reported that a (o.t.) "*Comparative study of 24 origins of* E. camaldulensis, *obtained from seeds collected at sites located at different latitudes in Australia*" showed differences in terms of "*resistance to low temperatures and summer drought, adaptability to calcareous soils, and attitude to rooting*". In Sicily, eucalypt plantations for large-scale wood production started only in the 1950s, for the purposes of supplying pulp for a local paper supply chain encouraged by the high MAIs recorded in some plantings. However, this was absolutely preliminary data, regarding the first coppicing experiments and often in areas which were not representative of average conditions in Sicily (de Philippis 1962, Giordano 1970). In Bosco Bellia (Piazza Armerina), in highly fertile sites, on deep and fresh soils, MAIs higher than 10 m^3 ha^{-1} and 19 m^3 ha^{-1} in *E. camaldulensis* and *E. globulus*, respectively, were recorded (Cantiani 1976). For a historical review of the heated debates and discussions concerning eucalypt productivity in Sicily, see La Mantia (2013).

Table 1 - Tree species with the highest mean annual increments recorded in Sicily (stand age < 25 years). Sicilian provinces: AG = Agrigento, CL = Caltanissetta, CT = Catania, EN = Enna. (n.a. = data not available). MAI = Mean Annual Increment.

Species	Locality (Province)	Age (years)	Mean altitude (m a.s.l.)	Temperature (°C)	Annual rainfall (mm)	Soil texture	MAI (m^3 ha^{-1} $year^{-1}$)	Reference
Acacia saligna	Mussomeli (CL)	2	n.a.	n.a.	500	n.a.	19.50	Facciotto and Nervo (2011)
Eucalyptus camaldulensis coppices	Aidone, Enna, Piazza Armerina (EN), Mazzarino (CL)	13 (First agamic cycle)	650-850	15.0	850	Sandy and clay	10.70	Cantiani (1976)
	Piazza Armerina (EN)	10	600	15.8	477	Sandy and clay	9.55	Ciancio et al. (1981)
	Mazzarino (CL)	12	485	15.8	477	Sandy and clay	9.26	Ciancio et al. (1981)
	Mazzarino (CL)	14	400	15.8	477	Sandy and clay	9.39	Ciancio et al. (1981)
	Enna (EN)	15	700	14.9	820	Sandy and clay	8.86	Ciancio et al. (1981)
	Aidone (EN)	22	815	14.9	805	Sandy and clay	8.47	Ciancio et al. (1981)
	Mazzarino (CL)	13 (Second agamic cycle)	480	14.9	734	Sandy	12.50	Barbera et al. (2001)
Eucalyptus camaldulensis high forests	Mazzarino (CL), Niscemi (CL), Piazza Armerina (EN)	14	400	15.9	505	Sandy and clay	6.29	Ciancio et al. (1981)
	Aidone (EN)	22	850	14.9	805	Sandy and clay	6.20	Ciancio et al. (1981)
Eucalyptus globulus coppices	Aidone, Enna, Piazza Armerina (EN), Mazzarino (CL)	8 (First agamic cycle)	650-850	15.0	850	Sandy and clay	19.04	Cantiani (1976)
	Piazza Armerina (EN)	10	600	15.8	477	Sandy and clay	14.63	Ciancio et al. (1981)
	Aidone (EN)	13	800	14.9	805	Sandy and clay	13.83	Ciancio et al. (1981)
	Enna (EN)	15	700	14.9	819	Sandy and clay	16.81	Ciancio et al. (1981)
	Mazzarino (CL)	7 (Second agamic cycle)	550	14.9	734	Sandy and clay	6.64	Barbera et al. (2001)
Eucalyptus globulus high forests	Caltagirone (CT)	21	200	16.0	532	Sandy and clay	18.21	Ciancio et al. (1981)
	Mazzarino (CL)	24	500	15.8	477	Sandy and clay	12.21	Ciancio et al. (1981)
Pinus brutia	Bivona (AG)	24	650-750	16.7	819	Clay	6.71-7.50	Garfi et al. (1998)
Pinus halepensis	Bivona (AG)	24	650-750	16.7	819	Clay	4.95-5.53	Garfi et al. (1998)
	Caltagirone (CT)	21	70-250	16.0	532	Sandy and clay	6.96	Ciancio et al. (1981)

**The MAI was derived from the annual biomass production (12.4 Mg dry matter ha^{-1}), applying the basic wood density of* A. saligna.

Subsequent systematic surveys showed a prevalent failure of most eucalypt plantings in Italy and Sicily (Ciancio et al. 1981, and 1981-1982, Barbera et al. 2001). Nationally, two-thirds of plantations achieved low MAI levels, between 3 and 5 m^3 ha^{-1}, while only one third achieved MAIs of 6-7 m^3 ha^{-1} (Ciancio et al. 1981-1982). Fewer than a quarter of Sicilian plantations achieved a MAI of 5 m^3 ha^{-1}, a minimum threshold identified for worthwhile production levels. Hence, most Sicilian eucalypt plantings should be replaced by more complex and stable forest stands, dominated by native species (Ciancio et al. 1981, Barbera et al. 2001). However, by appropriately changing cultivation modules, adopting rotations shorter than 8 years and carrying out necessary tending operations, such plantations were expected to achieve MAIs of 7-9 m^3 ha^{-1} (Ciancio et al. 1981). Effectively, in the best suited conditions (i.e. flat valleys, loose, deep soils, and an average annual rainfall of at least 700 mm), the *E. globulus* plantations achieved these production levels (Barbera et al. 2001). Field surveys carried out approximately 20 years ago confirmed the low productivity of Sicilian eucalypt plantings, as less than 10% exceeded a MAI of 5 m^3 ha^{-1} (Barbera et al. 2001). These enquiries enabled the main causes of failure to be identified and potential solutions for more appropriate land use to be obtained. Some of the reasons for failure were the pre-eminently protective purpose of the plantations, unsuitable ecological conditions in most of the planting sites and the limited attention paid to propagation material origin, as well as to varied *Eucalyptus* species autoecology (Ciancio et al. 1981-1982). Such problems could be overcome and eucalypts (o.t.) "… *if properly cultivated…are able to provide results that are clearly superior to any other exotic species*". Indeed, *E. camaldulensis*, *E. globulus*, *E. botryoides* Smith, *E. maidenii* F. Muell., and *E gomphocephala* A. Cunn. ex DC. successfully passed the experimental phase and could be used in larger areas (Ciancio et al. 1981-1982). It was seen as essential not to repeat the mistakes of the past, adopting cultivation techniques specific to wood arboriculture on small, suitable areas and using high-quality propagation material (Ciancio et al. 1981). To achieve these goals, an extensive program of genetic improvement, individual selection and controlled crossings was implemented in the 1990s at the CRA-PLF (now the CREA Research centre for forestry and wood). The provenance of *E. camaldulensis* from Lake Albacutya (Victoria, SW Australia) was identified as the most suitable for the pedoclimatic conditions of Mediterranean Italy, and a special arboretum with seeds of known origin was established. Hybrid clones were selected for their high production potential and resistance to biotic and abiotic stresses (Mughini et al. 2014). By hybridizing *E. camaldulensis* mother plants and the pollen of *E. globulus* subsp. *globulus*, *E. globulus* subsp. *bicostata*, *E. viminalis* Labill and *E. grandis* W. Hill (from individuals of known origin), six particularly promising clones were selected and proposed for patenting (Mughini et al. 2011), with the Viglio and Velino clones showing the highest wood production potential (Mughini et al. 2014). Two possible cultivation modules were identified: a model with a density of 5,000-5,500 plants ha^{-1} and rotations of 2-3 years, and a model with a density of 1,100-1,600 plants ha^{-1} and 5-6 year rotation cycles. The field trials showed higher productivity from hybrid clones as compared to parental *E. camaldulensis*. In thermophilous sites (at Cosenza, Calabria), with adequate water availability and limited pathogen presence, on average the clones achieved 22.2 and 16.1 Mg of dry matter ha^{-1} $year^{-1}$, compared to 18.8 and 12.8 Mg ha^{-1} $year^{-1}$ in parental trees, in the two cultivation modules respectively (Mughini et al. 2011). The main problems related to the use of eucalypts in short-rotation coppices are linked to technical and cultural aspects, as well as ecological issues. Firstly, persistence over time of sprouting ability and growth rates will need evaluating over time, considering that a decrease in the growth performances of clones from first to second production cycles (Mughini et al. 2014), and significant changes in productivity in subsequent agamic cycles in *Eucalyptus occidentalis* Endl. and *Eucalyptus x trabutii* Vilm. have been observed (Avolio 2008). Obtaining adequate wood production levels will require significant consideration of water and nutrient requirements as the most productive clones are notably resource-demanding, thus posing a potentially high soil fertility and stability risk (Gonçalves et al. 2008). A possible solution might be the use of agricultural, zootechnical or urban residue water. Another is the use of urban wastewater pretreated, using the purification method developed by the Basilicata University's Department of Engineering and Environmental Physics (Mughini 2016). However, this solution may be applicable only to plantations close to populated areas, which is not very common in the Sicilian inland areas where the eucalypts have mainly been planted. Last but not least, it should be remembered that the eucalypts might potentially lead to profound changes in the ecological and landscape features of large swathes of the Mediterranean, where their natural regeneration has been increasingly observed in recent decades. We would, however, highlight that such a risk is relevant only near rivers and streams as riparian vegetation and habitats are particularly threatened by eucalypt invasion (Badalamenti et al. 2018a). Finally, we would argue, in common with other authors (Scarascia-Mugnozza et al. 2007, Bisoffi et al. 2009, Facciotto 2012, Romano et al. 2013), that it is still possible to enhance the productive function of the eucalypt plantations established in suitable ecological conditions, also in order to feed new small biomass plants for a local forest-wood-energy supply chain. The eucalypts currently occupy an area of almost 40,000 hectares in Sicily

(Camerano et al. 2011), more than half of the whole Italian area (Ciancio and Nocentini 2000). Therefore, before deciding on their total replacement, the *pros* and *cons* of such a definitive choice must be carefully evaluated, from the environmental, social and economic perspectives. Recent data on eucalypt coppices in Calabria have shown promising results in relation to their potential use for energy purposes (Mendicino and Nicolaci 2008). In the second agamic cycle, with a 9-year rotation period, the MAI of *E. occidentalis* and *E. x trabutii* (a hybrid of *E. camaldulensis* and *E. botryoides*) plantations ranged from 3.5 to 8.0 m^3 ha^{-1}, and from 5.1 to 9.5 m^3 ha^{-1}, respectively. After 10 years, *E. x trabutii* achieved MAIs as high as 12-15 m^3 ha^{-1} after the first agamic cycle (Avolio 2008). A virtuous example of productive use of eucalypts in Southern Italy comes from the Massanova estate in Cilento (Campania), where a MAI of 12.1 m^3 ha^{-1} was achieved after 20 years (Arcidiaco et al. 2000), confirming the good growth rate initially found 4-5 years after the planting (Ciancio et al. 1992a). Ultimately, we believe that a sufficient wealth of technical and cultural knowledge, supported by past experience, is available, and productive and sustainable use of the wood from eucalypt plantings is still possible, provided that certain critical issues are overcome.

Acacia saligna

The *Acacia* genus has been widely used in the afforestation of arid and semi-arid Mediterranean areas, as well as for dunes and backdune consolidation. By contrast, there are few examples of the use of Acacias in wood plantations or in SRF. In Italy, the most promising *Acacia* species has been *A. saligna*, which was included early among the twelve hardwood taxa worthy of further testing (Pavari and de Philippis 1941a). Later, Allegri (1962) considered the Australian acacias to be incapable of providing good wood production but excellent for coastal dune fixation and creating afforestation fire barriers in Southern Italy and the islands. According to La Mantia (2011), the same main uses apply to the species in Sicily, where it has also been used in polluted and contaminated site restoration (Quatrini et al. 2003) as well as in afforestation (La Mantia and Pasta 2001), where it currently causes ecological problems due to its high invasive potential (Crosti 2008, Badalamenti et al. 2018b). Other *Acacia* species used in Sicily did not achieve high productivity levels and showed highly invasive tendencies (Badalamenti et al. 2014). The revival of interest in a productive use of *A. saligna* follows Ciancio et al. (1981-1982) who suggested testing it in coppice systems for the production of carbon and firewood due to its rapid juvenile growth, as its (o.t.) "*sprouting ability, as well as the height increment, declines rapidly so it is best to adopt rotation periods of 5-10 years*". For these reasons, the species passed the trial phase and could be used on larger areas (Ciancio et al. 1981-1982). Despite the large scale use of *A. saligna* in Sicily and its high suitability to its environmental conditions, very little wood production data on it exists. Recently, *A. saligna* productivity was compared with that of *E. camaldulensis*, *E. globulus*, *Robinia pseudoacacia* L. and the poplars, in experimental plots in inland hilly areas (Facciotto and Nervo 2011). After two growing seasons at Mussomeli (Caltanissetta), *A. saligna* achieved the highest production, 12.4 Mg ha^{-1} $year^{-1}$ of dry matter, compared to values between 3.9 and 5.3 Mg ha^{-1} $year^{-1}$ for the eucalypts, and less than 2 Mg ha^{-1} $year^{-1}$ for the black locust and the poplars. Considering *A. saligna*'s basic wood density (634.7 Kg m^{-3}, Mmolotsi et al. 2013), this biomass production would correspond to a very high MAI, 19.5 m^3 ha^{-1}. The notably lower productivity (about 2.1 Mg ha^{-1} $year^{-1}$) recorded at a different site (Misteci, Caltanissetta), in similar experimental trials, showed the crucial role played by soil water availability. In fact, the *Acacia* plants were subject to markedly different irrigation regimes, ranging from 30 mm at Misteci to 450 mm at Mussomeli. Indeed, considerable wood production increases as a function of water availability are very marked in this species (Hobbs et al. 2009). Although these are preliminary data, they do provide valuable information about the possible use of the species for productive purposes in Sicily. Interestingly, the amount of biomass produced at Mussomeli corresponds to the upper productivity threshold recorded by *A. saligna* in Southern Australia (3-12 Mg of aboveground dry matter ha^{-1} $year^{-1}$), where it is considered one of the trees with the best potential for biomass production in areas with reduced rainfall, less than 650 mm per year (Hobbs et al. 2009). Not for nothing, *A. saligna* is considered one of the most useful wood production species (for example, for particleboard) in the arid and sub-arid areas of North Africa (El-Lakany 1987). However, production continuity and sprouting ability persistence in other sites and the Sicilian environment will need verifying. To ensure high levels of productivity, a critical aspect is that *A. saligna* needs high water input, a factor which is not negligible given average conditions in Sicily, particularly vulnerable to desertification.

Ailanthus altissima

In Mediterranean environments, including Sicily, one of the tree species which is most commonly associated with the concept of rapid growth, is certainly *Ailanthus altissima*. It is a dioecious and medium-sized Asian tree which has been widespread outside the native range since the second half of the 18^{th} century, firstly in Europe and then in North America. This species has successfully invaded the temperate and Mediterranean regions of the world (see Badalamenti et al. 2012 for the Italian species introduction history). Some of *Ailanthus*'s biological traits were discovered early: the positive ones (hardiness, ecological plasticity, rapid growth, etc.) justified its use for productive purposes, the negative ones (irregular growth, marked invasiveness) probably contributed to preventing its use. In effect, *Ailanthus*'s dual nature would seem to have coexisted until the present day. It was soon regarded as a (o.t.) *"markedly invasive species"* (Pavari 1916) but, at the same time, was included among the exotic species which possess the (o.t.) *"to quickly produce large quantities of wood!"* (Pavari and de Philippis 1941a). It also showed its potential to produce pulpwood and cellulose (Palazzo and Palazzo 1932), although (o.t.) *"the extent and regularity of wood production on the area unit"* needed verifying (Pavari 1937). However, as Allegri (1962) stated (o.t.) "Ailanthus *periodically feeds great hopes"*, but it has not been subject to special experimentation, so its use for productive purposes is unlikely to increase. Interest in productive use of the species has decreased over time and awareness of its negative ecological impact in invaded areas has correspondingly increased. Indeed, *Ailanthus* has successfully invaded various habitat types in the Mediterranean, threatening biodiversity and changing natural ecosystem characteristics (Vilà et al. 2006, Badalamenti et al. 2015), including in forests (Maetzke 2005, Badalamenti and La Mantia 2013). Recently, it has been cited as a species usable in SRF in Mediterranean environments (Bianco et al. 2014), but its ability to spread into new areas a long way from cultivation sites constitutes a high risk factor. For these reasons, Crosti (2010) has proposed fixing buffer zones at least 100 metres wide, to be ploughed at least once every three years. Experimental trials at the University of Palermo (SAAF Department) tested *Ailanthus*'s vegetative propagation potential, in order to minimize its anemochoric dissemination. In detail, grafting was performed on 39 young *Ailanthus* individuals, with a mean basal diameter of 2.3 cm, using only scions from mature male *Ailanthus* individuals. To the best of our knowledge, this was the first time that grafting was trialled as a means by which to stop seed production in this invasive species while ensuring wood production. Tests results were encouraging, both in terms of survival (80-100% of the scions) and growth rates, which maintained an exponential trend for the first year of growth, recording mean height increments of 0.7-0.8 cm per day^{-1} (Badalamenti 2017). In marginal and unproductive areas, with no specific ecological and/or scientific value, and where eradicating *Ailanthus* would seem to be impractical and pointless, productive biomass use may represent a valuable management option in species control (Sitzia et al. 2016). According to the Virginia Department of Forestry (2009): "*…we are in no way implying that this invasive weed should be cultured for profit.* Ailanthus *plantations would not be a profitable enterprise for landowners and would only contribute to further spread and proliferation of this species. Market development as a means of mitigating impacts of invasive tree species is a novel approach that may hold promise for addressing multiple problems.*" Outside such restricted and specific conditions, we believe that the disadvantages of *Ailanthus* cultivation far exceed the potential advantages.

Softwood species

Pinus halepensis *(including* Pinus brutia*)*

The Aleppo pine was not practically considered for productive purposes until recently, although it was the preferred reforestation species for soil protection on a massive scale in the Mediterranean basin in the last century. However, its rapid juvenile growth, up to 20-25 years, and notable resistance to drought and strong pioneering character have been known for a long time (Ciancio et al. 1981, Eccher et al. 1986), as has the importance of tending operations such as thinning and pruning to enhance its inherent fast growth (Ciancio et al. 1981). In fact, (o.t.) "*The inaccurate knowledge of the productive capacities of many species*, *and the generalization of data collected in populations of natural origin*, *have been the limiting elements for the use and spread of many native species*, *including the Aleppo pine and the stone pine*, *not considered suitable for such purposes*" (Ciancio et al. 1981). The limited productivity data in the literature mostly refers to protective reforestation not affected by ordinary cultivation treatments. Such evidence, also supported by recent experimental data, has led several authors to judge the productive potential of the species favourably, especially in Mediterranean thermophilous belts, up to 500 m a.s.l., even on poor and superficial soils, provided that intensive cultivation modules, specific to wood arboriculture are adopted (Gentile et al. 2007). Ciancio et al. (1981) stated that Aleppo pine MAIs can reach 7-9 m^3 ha^{-1}. In effect, the lower presumed range limit had been achieved by some plantations surveyed by these same authors in Enna province. A constraint on productive use of the species is the shape of its main trunk and branches which are often irregular, twisted and excessively branched (Eccher et al. 1986). From this point of view, a comparison with the Turkish pine or Brutia pine (*Pinus brutia*) is relevant with the latter being so taxonomically close to *P. halepensis* that it is considered a subspecies (*Pinus halepensis* subsp. *brutia* (Ten.) Holmboe) by some authors (e.g. Sarris et al. 2011). The Turkish pine has a typical pyramidal crown, with thin, mostly horizontal branches. Historical data suggested higher growth potential for *Pinus brutia* than for *P. halepensis*, with MAIs of 6.3-9 m^3 ha^{-1} and 6.3-7 m^3 ha^{-1} respectively at 20-25 years and at the culmination of the mean increment (Eccher et al. 1986). In a comparison carried out in the Sicilian Sicani mountains, Aleppo pine and Turkish pine MAIs were between

4.9-5.5 and 6.7-7.5 m^3 ha^{-1}, respectively (Garfì et al. 1998). Although *P. brutia* grew more slowly than the Aleppo pine in its early years of life, from its tenth year onwards it began recording increasing longitudinal growth, (o.t.) "*reaching at 24 years old values higher by 28% compared to the Aleppo pine*" (Garfì et al. 1998).

We believe that the Turkish pine is worthy of further consideration for its (o.t.) "*marked superiority…from the point of view of the shape and structure of the trunk*", as well as its potential for producing (o.t.) "*better woody assortments, both qualitatively and quantitatively, than those obtainable from the Aleppo pine*". In the Mediterranean, it is estimated that both species could achieve high MAIs, up to 12-15 m^3 ha^{-1} (Fady et al. 2013). The most recent data from wood arboriculture plantings present in Southern Italy fully confirm *P. halepensis*'s productive potential. At Massanova estate (Salento, Campania), the species was planted by Lu.Ca.For. S.p.A. using funding from Cassa per gli Interventi Straordinari nel Mezzogiorno (CISM)[1]. At 19-20 years, annual productivity was quite good, 11.1 m^3 ha^{-1} (Arcidiaco et al. 2000). Garfì et al. (2002) in nearby areas within the Cilento basin (Campania) found MAIs ranging from 9.1 m^3 ha^{-1} to 9.5 m^3 ha^{-1} in 19-20 year old plantations subject to ripping and multi-directional tillage, respectively. Greater differences were found between plantings subject to *multi-directional tillage*, but differing in planting types (in settonce or rectangular) and plant density (1,473 vs. 2,222 plants ha^{-1}, respectively). MAIs were 29% lower in the lower-density areas, i.e. 10.0 m^3 ha^{-1} vs. 14.1 m^3 ha^{-1}. This positive wood production shows the importance of maintaining sufficient planting densities, which can be ensured with adequate initial densities and/or low mortality rates. Water-saving cultivation systems aimed at maximizing soil water availability should also be adopted, especially in the early phases of cultivation (e.g. during soil preparation and processing) (o.t.) (Garfì et al. 2002, Gentile et al. 2007). In conclusion, "*the high MAIs confirm that the Corsican pine and the Aleppo pine behave like FGS*" (Garfì et al. 2002). Finally, Gentile et al. (2007) assessed the productivity of six wood arboriculture plantations established with CISM funds at Mazzone estate (Cosenza, Calabria). Average annual rainfall at the study sites is slightly over 600 mm and the planting site takes place in warmer, more summer drought prone areas than those previously surveyed by Garfì et al. (2002) whose annual rainfall exceeds 1,000 mm, and may significantly benefit from high atmospheric humidity due to the nearby Tyrrhenian Sea. Indeed, the Calabrian plantations have MAIs of 7.6 m^3 ha^{-1} (Gentile et al. 2007). However, this is probably the highest wood production potentially achievable in these pedo-climatic contexts, since an intensive cultivation module has been adopted, an adequate road system has facilitated regular tending operations (soil preparation, pruning, thinning, etc.) until harvesting, and the land is virtually flat. Ultimately, in agreement with Gentile et al. (2007), we believe that the Aleppo pine (o.t.) "*has proven capable of appropriate valorization even in the wood arboriculture plantations in the Mediterranean environment*". With this aim, the selection of proper forest stands for seed collection and propagation material will be one of the near future's more challenging issues.

1 *The Italian acronym CISM means Extraordinary Intervention Funding Agency for Southern Italy. It was a state-owned agency funding structural intervention in marginal areas of Southern Italy until the late 1980s.*

Pinus canariensis

Pinus canariensis. (Canary Islands pine), endemic to the Canary island archipelago, has long been considered to be one the conifers potentially usable in the Lauretum phytoclimatic area. According to Pavari (1916), the species (o.t.) "*prefers granitic and sandy soils and is notable for its shape, rapid growth and quality of wood*". Pavari (1937) argued that *P. canariensis* was one of the (o.t.) "*pines worthy of full consideration for the Mediterranean region*". Subsequently, Allegri (1962) considered it a rather humidity-demanding species, a feature that strongly limited its use to a few locations, although he still considered that it could generate (o.t.) "*interesting results if used in limited special environments*". Giordano (1970) considered it a species of uncertain results for which further research was needed. However, for Morandini (in Giordano 1970) (o.t.) "*the experimentation is complex because in the native range the climate is on average warmer than the Mediterranean regions, with rainfall prevailing during the summer months, and due to the extreme difficulty in supplying the seed*". Ciancio et al. (1981-1982) were the first to find promising data, considering that the species could provide (o.t.) "*promising woody increments at 20-30 years, ranging between 5.7 and 14.1 m^3 ha^{-1} $year^{-1}$. The potential for setting up short-term plantations, for ease of asexual reproduction and rapidity of growth of coppice shoots, is to be verified in order to obtain shredding material*". *P. canariensis* has therefore been considered a species with specific purpose potential (windbreaks, street trees, etc.) and/or for very limited wood arboriculture areas (Ciancio et al. 1981-1982). One very promising trait for Mediterranean-climate regions is its high adaptability to wildfire and ability to produce new shoots very soon after fire (Climent et al. 2004). The recent naturalization of the species in Sicily proves its excellent adaptability to local conditions, opening up new perspectives for further investigation (Badalamenti et al. 2013). Height growth rates of almost 1 m per year have also been observed in individuals from xeric sites with average annual rainfalls lower than 350 mm (Climent et al. 2004). Taking into account the extreme variability of both altitudinal range (300-2,000 m a.s.l.) and precipitation regime (250-700 mm of annual rainfall) characterizing the *P. canariensis* (Climent et al. 2004, Grill et al. 2004) native area, a crucial aspect for the possible productive use of the species is seed coming from areas compatible with planting sites.

Pinus radiata *(=* Pinus insignis *Douglas ex Loudon)*

The Monterey pine (Insignis pine or Radiata pine), native to the Monterey Bay in California, was identified very early on as one of the most promising FGS for Italy. Here, although the first plantation took place in 1914, experimentation began in 1924 in 18 experimental plots, mainly located in the central-southern regions and the islands (Pavari and de Philippis 1941b). This interest was due to the remarkable results achieved by the species in different southern hemisphere countries, primarily New Zealand, Chile and South Africa. From the first half of the last century onwards, New Zealand has supplied most of the Radiata pine seed used in reforestations and productive plantings outside the native range (Pavari and de Philippis 1941a). Pavari (1937) wrote that *Pinus radiata* was capable of (o.t.) "*producing in 12-15 years even 300 m^3 ha^{-1} of excellent wood for cellulose*" corresponding to MAIs of 20-25 m^3 ha^{-1} (Pavari and de Philippis 1941a). Pavari and de Philippis (1941b) stated that (o.t.) "*The insignis pine occupies one of the "best places as a tools" for intensive forestry with a very rapid production cycle*". However, its rapid dissemination in wood plantations across the southern hemisphere has not been accompanied by a similar process in Italy, where productive plantings date back only to the end of the 1970s (Ciancio et al. 2006). This is probably due to the species' specific ecological characteristics, such as its high humidity requirements. For this reason, and owing to the negative effect of wildfires, the total area covered by the species in Italy, from previously higher values, has decreased to 18,000 hectares (Eccher 1997 in Ciancio et al. 2006). Whilst Radiata pine growth rates seem to be inherently faster than those of Mediterranean pines (Giordano 1970, Ciancio et al. 1980), this superiority may come to fruition only in fully suitable areas. A *P. radiata* plantation, established in the Lauretum in the Camaro forest (Messina) simultaneously showed its potential advantages and the many difficulties involved in making effective use of this exotic species in Sicily. At this site, despite its poorly developed soils, adequate water availability ensured by a favourable precipitation regime (annual average of 1,200 mm with around 50 mm in summer), allowed for MAIs of 10.8 m^3 ha^{-1} at 13 years (Gambi 1958). A decade later, Eccher (1969) produced a map of ecological limitations verifying potential cultivation areas for the species in Sicily through the overlapping of climatic and edaphic parameters assessing whether limited areas located on the north-eastern slopes of the island, between 500 and 900 m a.s.l., in fresh and deep soils, were suitable. Indeed, optimal areas for productive purposes, where (o.t.) "*at the culmination of the mean increment, annual wood production may even exceed 20 m^3 ha^{-1}….altogether represents less than 1% of the regional area*" (Eccher 1969). Taking into account the greater profitability of agricultural crops in many of these areas, the author came to the natural conclusion that (o.t.) "*its spread on the island can only be limited*". This is, in fact, what happened in Sicily where Monterey pine plantations are very rare and localized and pursue protective purposes only. By contrast, interest in the species has fluctuated over time in Italy as a whole. On the basis of good results observed in experimental plots, Allegri (1962) argued that experimentation with *P. radiata* (o.t.) "*deserves to be resumed and extended*". With this goal in mind, the Rome Agricultural and Forestry Experimentation Center set up approximately 50 plots comparing production performances from different provenances (Giordano 1970). *P. radiata* was considered one of very few exotic species (o.t.) "*capable of ensuring rapid growth and high productivity at the end of the rotation period*" (Ciancio et al. 1980) and for which ample opportunities for productivity increases based on careful choice of planting areas using high-quality planting material and adopting appropriate cultivation treatments exist (Ciancio et al. 1980, 1981-1982). Accordingly, it was regarded as one of the species best suited to wood arboriculture (Ciancio et al. 1980, and 1981-1982) and (o.t.) "*among the conifers it is the fastest growing*" (Ciancio et al. 1981-1982). Such expectations have been corroborated by productivity data from historic Italian plantings, where MAIs between 15 and 18 m^3 ha^{-1} at 20-25 years have been reported (Eccher et al. 1986), as well as by recent data. At Massanova, at altitudes of 100-300 m a.s.l., MAIs were 19.8 m^3 ha^{-1}, in 19-20 years old plantations (Arcidiaco et al. 2000). In cooler and more humid sites in the same regions (altitudes of 700-800 m a.s.l.), higher production levels, rather homogeneous growth rates and excellent morphological characteristics of tree trunks have been found. This difference has been attributed to the fact that (o.t.) "*decrease in the duration of the vegetative stage, following increase in altitude, is offset by shorter critical summer period length, when rainfall is rather scarce*". In effect, mortality rates were found to be lower at higher altitudes. At Cemola estate (Campania), it has been reported considerably increased MAIs from 9.2 m^3 ha^{-1} in 9-10 year old plantations (Ciancio et al. 1992b) to 26.3 m^3 ha^{-1} in 19-20 year old plantations (Arcidiaco et al. 2005). In addition, more than 39% of the tree population fell within the good fertility class (basal area > 67.8 m^2 ha^{-1}). Using these latter and other historical data (Maetzke 1992), Ciancio et al. (2006) compared the wood production recorded in six tree farms located near Salerno (Campania), in Mediterranean climate areas, at varying altitudes between 100 and 800 m a.s.l., and under favourable rainfall regimes (at least 1,000 mm per year). MAIs ranged from 15.8 to 26.3 m^3 ha^{-1}, and 19.3 to 20.5 m^3 ha^{-1}, in 19 and 20 year old plantings respectively. In tree populations belonging to the good fertility class (basal area > 50 m^2 ha^{-1}), MAIs were significantly high, ranging from 21.6 to 32.7 m^3 ha^{-1}. Even in the low fertility class, MAIs never dropped below 11 m^3 ha^{-1}. The significant positive effect of cultivation practices, especially soil tillage and irrigation, on increasing *P. radiata* productivity was detected early (Giordano 1970). Furthermore, (o.t.) "*the use of carefully selected plant material…the implementation of the first cultural operations and thinning, to limit losses due to auto-thinning, are essential measures*" (Ciancio et al. 2006). Considering the main limiting factors (low temperatures and limited air humidity) for *P. radiata* growth (Ciancio et al. 2006), the most suitable areas for productive purposes have Mediterranean climates with oceanic features, mild winters and relatively cool, humid summers, mostly in Lauretum and hot Castanetum belts (Eccher et al. 1986). Combining site suitability and proper cultivation practices, the MAI of Italian *P. radiata* plantations (12-16 m^3 ha^{-1}) fall within the global range, which is between 12 and 34 m^3 ha^{-1} (Mead 2013).

Discussion and conclusions

This paper confirmed that maximum FGS productivity in Sicily is affected by intrinsic species traits, environmental characteristics and cultivation techniques (Table 1). Although the area estimated to be covered by wood arboriculture plantations in Sicily is a small percentage in national terms (Centro di Ricerca Foreste e Legno 2017) (Table 2), such plantations may effectively occupy larger areas and show great future development potential. This review focused on tree species considered, either effectively or potentially, most important for Sicily and Southern Italy in terms of early fast growth and wood production. Other restricted ecological niche species in Sicily, such as poplar (Clerici and Asciuto 1991, Cassarà 2001), black locust (La Mantia et al. 1999) and other acacias, which have not been considered in the current research, may also generate interesting results. This research supplements recent work in Sicily to define the ecological suitability of woody species for the various Sicilian environments (Maetzke et al. 2008 and 2017, La Mela Veca 2009) and it may help avoid repeating past errors and mistaken choices (La Mantia et al. 2000 and 2004, La Mantia 2002). In the most suitable and fertile sites, the two most widespread eucalypt species on the island, namely *E. camaldulensis* and *E. globulus*, achieved high MAIs. In ecologically suitable sites, and applying arboriculture for biomass production cultivation techniques, eucalypts seem to stand out among the broadleaved species. Although long-term consolidated knowledge and robust experimentation is lacking, some hybrid clones are generating promising high growth rates and outstanding wood production (Mughini et al. 2014). However, suitable sites are neither common nor particularly representative of the average environmental conditions in which eucalypts were extensively planted in Sicily. Indeed, in inland hilly areas, particularly vulnerable to summer drought, with poor and/or poorly developed soils, eucalypt plantation MAIs are considerably lower. In such limited ecological conditions, it is worth remembering that "*enabling the species to express the productive potential*" often entails use of significant energy or water inputs. Hence, careful and in-depth consideration of the effective environmental sustainability of intensive cultivation systems is needed. Other promising broadleaves (e.g. *A. altissima* and *A. saligna*) suffer from the far from negligible drawback of being harmful invasive species which may spread and invade natural habitats of particular scientific interest. Therefore, their exploitation should be limited to areas in which they are already present, as an alternative way of control, or those considerably far away from ecologically important to areas. Although the search for exotic species at a national level has mainly regarded conifers, few of these have provided satisfactory results in Sicily and Southern Italy. On the contrary, the most suitable species are probably native species which are already widespread at a regional level. In strongly limited ecological contexts, such as xeric environments, on nutrient-poor and shallow soils, including clayey soils, from sea level up to 500 m a.s.l., the Aleppo pine seems to be the species best suited to meeting both environmental and productive needs. In better ecological conditions such as high and medium hilly areas on sufficiently developed soils, *P. brutia* seems preferable as it can produce a higher quantity of wood of presumably better quality as a consequence of the good shape and structure of its main trunk and branches. Two conifers which could be used on specific sites are the Radiata pine and the Canary Island pine. The former is well suited to thermophilous areas with high atmospheric humidity, from 500 to 900 m a.s.l. Knowledge of the productive potential of the latter is still limited, but some of its characteristics are interesting.

In conclusion, the productivity data collected seems to confirm that wood arboriculture is feasible even in Mediterranean contexts (o.t.) "*provided that intensive cultivation modules are adopted and that fast-growing forest species are used in areas with characteristics corresponding to their ecological needs*" (Arcidiaco et al. 2000).

Table 2 - Wood arboriculture plantations in Sicily (Centro di ricerca Foreste e Legno 2017, modif.).

Type	Most common species[1]	Area (ha)	Relative contribution to National area (%)
Specialized poplar plantations	*Populus* spp.	25	0.1
Wood plantations of other hardwood species	*Juglans regia* L., *Prunus avium* L., *Ceratonia siliqua* L.	2,725	6.6
Wood plantations of chestnut	*Castanea sativa* Mill.	100	2.1
Wood plantations of softwood species	*Pinus halepensis* Mill., *Cupressus* spp., *Pinus pinea* L.	2,575	59.2
Total		**5,425**	**5.6**

1: Information is from Hofmann et al. (2011).

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References

Allegri E. 1962 - *La introduzione e la sperimentazione in Italia di specie forestali esotiche a rapido accrescimento*. Monti e Boschi 13 (1): 507-519.

Arcidiaco L., Ciancio O., Garfì V., Mendicino V., Menguzzato G. 2000 - *Arboricoltura da legno in ambiente mediterraneo: l'Azienda Massanova (Salerno)*. L'Italia Forestale e Montana 56 (5): 285-306.

Arcidiaco L., Ciancio O., Garfì V., Mendicino V., Menguzzato G. 2005 - *Pino insigne e douglasia nell'arboricoltura da legno su terreni marginali all'agricoltura*. L'Italia Forestale e Montana 60 (3): 317-326.

Avolio S. 2008 - *Rinnovazione agamica e produttività degli eucalitteti di* E. occidentalis *e di* E. x trabutii *della fascia ionica crotonese nei primi quattro cicli colturali*. Annali CRA, Centro di Ricerca per la Selvicoltura 35: 69-86.

Badalamenti E. 2017 - *L'utilizzo di specie alloctone invasive per la produzione di legno: rischio o opportunità?* In: Proceedings of the XI SISEF National Congress, "La Foresta che Cambia: Ricerca, qualità della vita e opportunità in un paese che cambia", Fares S., Alivernini A., Ferrara C., Marchi M., Sallustio L., Chianucci F., Bucci G. (eds.), Rome (Italy), 10-13 September 2017. Abstract-book, Paper #c11.19.0.

Badalamenti E., Barone E., Pasta S., Sala G., La Mantia T. 2012 - Ailanthus altissima *(Mill.) Swingle (fam. stampato) in Sicilia e cenni storici sulla sua introduzione in Italia*. Il Naturalista siciliano S. IV XXXVI (1): 117-164.

Badalamenti E., La Mantia T. 2013 - *Stem-injection of herbicide for control of* Ailanthus altissima *(Mill.) Swingle: a practical source of power for drilling holes in stems*. iForest 6: 123-126.

Badalamenti E., La Mantia T. Pasta S. 2013 - *Primo caso di naturalizzazione di* Pinus canariensis *C. Sm. (Pinaceae) per la Sicilia e prima stazione di* Acacia cyclops *G. Don (Fabaceae) sull'isola maggiore*. Il Naturalista siciliano S. IV 37 (2): 497-503.

Badalamenti E., Novara A., Gristina L., La Mantia T., Lauteri M., Pasta S., Fernandes P., Correia O. Máguas C. 2014 - *Relationship between recruitment and mother plant vitality in the alien species* Acacia cyclops. Forest Ecology and Management 331: 237-244. http://dx.doi.org/10.1016/j.foreco.2014.08.016 0378-1127/

Badalamenti E., La Mantia T., Quatrini P. 2015 - *Arbuscular mycorrhizal fungi positively affect growth of* Ailanthus altissima *(Mill.) Swingle seedlings and show a strong association with this invasive species in Mediterranean woodlands*. Journal of the Torrey Botanical Society 142 (2): 127-139.

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.

Badalamenti E., Cusimano D., La Mantia T., Pasta S., Romano S., Troìa A., Ilardi V. 2018a - *The ongoing naturalisation of* Eucalyptus *spp. in the Mediterranean Basin: new threats to native species and habitats*. Australian Forestry 81 (4): 239-249.

Badalamenti E., da Silveira Bueno R., Campo O., Gallo M., La Mela Veca D.S., Pasta S., Sala G., La Mantia T. 2018b - *Pine stand density influences the regeneration of* Acacia saligna *(Labill.) H.L.Wendl. and native woody species in a Mediterranean coastal pine plantation*. Forests 9: 359. doi:10.3390/f9060359

Barbera G., La Mantia T., La Mela Veca D.S., Marchetti M., Scalzo G. 2001 - *Productivity of* Eucalyptus *spp. in different environmental condition and silvicultural systems in Sicily - An updating description*. In: Proceedings of the International Conference "Eucalyptus in the Mediterranean basin: perspectives and new utilization", Cannata F. (a cura di), Taormina e Crotone, October 15-19, 2000, CNR – IUFRO, Firenze: 291-299.

Bianco P., Ciccarese L., Jacomini C., Pellegrino P. 2014 - *Impacts of short rotation forestry plantations on environments and landscape in Mediterranean basin*. Rapporti 196/14. ISPRA – Istituto Superiore per la Protezione e la Ricerca Ambientale, Roma. 115 p. ISBN 978-88-448-0618-7.

Bisoffi S., Minotta G., Paris P. 2009 - *Indirizzi colturali e valorizzazione delle produzioni legnose fuori foresta*. In: "Atti III Congresso Nazionale di Selvicoltura", Accademia Italiana di Scienze Forestali, Taormina, 16-19 ottobre 2008: 729-736.

Camerano P., Cullotta S., Varese P. 2011 - *Strumenti conoscitivi per la gestione delle risorse forestali della Sicilia. Tipi forestali*. Regione Siciliana, Litograf Editor srl, Città di Castello, Italy. 192 p.

Cantiani M. 1976 - *I cedui di Eucalitto (*E. camaldulensis *ed* E. globulus*) nella Sicilia centrale*. L'Italia Forestale e Montana 31 (2): 33-48.

Carle J., Vuorinen P., Del Lungo E. 2002 - *Status and trends in global forest plantation development*. Forest Products Journal 52: 1-13.

Cassarà M. 2001 - *La pioppicoltura in Sicilia: analisi della produttività del pioppo "Armerino" nel territorio di Piazza Armerina*. Tesi di Laurea in Scienze Forestali ed Ambientali (Relatore T. La Mantia).

Centro di ricerca Foreste e Legno 2017 - *INARBO.IT - Inventario degli impianti di arboricoltura da legno in Italia*. https://www.reterurale.it/flex/cm/pages/ServeAttachment.php/L/IT/D/e%252Fe%252Fd%252FD.b30837125f4042db1acd/P/BLOB%3AID%3D18647/E/pdf

Ciancio O., Eccher A., Gemignani G. 1980 - *Eucalitti, pino insigne, douglasia e altre specie forestali a rapido accrescimento*. L'Italia agricola, Legno e Cellulosa Anno 117 (1): 190-218.

Ciancio O., Iovino F., Maetzke F.G., Menguzzato G. 1981 - *Gli eucalipti in Sicilia: problemi tecnici ed economici*. Quaderni Forestali INSUD, Roma. 157 p.

Ciancio O., Mercurio R., Nocentini S. 1981-1982 - *Le specie forestali esotiche nella selvicoltura italiana*. Annali dell'Istituto sperimentale per la Selvicoltura, Arezzo XII-XIII. 731 p.

Ciancio O., Maetzke F.G., Menguzzato G., Portoghesi L. 1992a - *L'arboricoltura da legno in ambiente mediterraneo: Il piano colturale dell'azienda Massanova*. Annali Istituto Sperimentale per la Selvicoltura, Arezzo XXI: 5-56.

Ciancio O., Maetzke F., Menguzzato G., Portoghesi L. 1992b - *Il piano colturale delle aziende Cemola, Mazzavacche, Palazza, Pinto e Zerilli*. Valorizzazione energetica di materiali legnosi nel Lazio. Enea – Università della Tuscia, Viterbo: 221-273.

Ciancio O., Nocentini S. 2000 - Eucalyptus *in Italy: cultivation and management*. In: Proceeding of the International Conference "*Eucalyptus* in the Mediterranean basin: perspective and new utilization", Cannata (ed.), CNR, Italy and IUFRO: 75-79.

Ciancio O., Garfì V., Iovino F., Menguzzato G. 2006 - *Il pino insigne nell'arboricoltura da legno: analisi di interventi realizzati nell'Italia meridionale*. L'Italia Forestale e Montana 61 (3): 217-231.

Clerici E., Asciuto A. 1991 - *La pioppicoltura di Piazza Armerina – aspetti auxometrici ed economici*. Cellulosa e Carta 42 (2): 31-42.

Climent J., Tapias R., Pardos J., Gil L. 2004 - *Fire adaptations in the Canary Islands pine (Pinus canariensis)*. Plant Ecology 171: 185-196.

Corona P., Ferrari B., Iovino F., La Mantia T., Barbati A. 2009 - *Rimboschimenti e lotta alla desertificazione in Italia*. Aracne Editrice, Roma. 281 p.

Crosti R. 2008 - *Potenziale invasività delle specie utilizzate per biofuel. Il caso dell'acacia e del cardo per biomassa. Le specie alloctone in Italia: censimenti, invasività e piani di azione*. Memorie della Società Italiana di Scienze Naturali e del Museo Civico di Storia Naturale di Milano XXXVI (I): 53.

Crosti R. 2010 - *Invasiveness of biofuel crops and potential harm to natural habitats and native species*. Convention on the Conservation of European Wildlife and Natural Habitats, Standing Committee, 30th meeting Strasbourg, 6-9 December 2010, T-PVS/Inf: 6.

de Philippis A. 1962 - *Gli eucalitti*. Monti e Boschi 13 (1): 616-628.

Dimitriou I., Rutz D. 2015 - *Sustainable Short Rotation Coppice - A Handbook*. WIP Renewable Energies, Munich, Germany. 104 p. ISBN: 978-3-936338-36-2

Eccher A. 1969 - Pinus radiata *D. Don in Sicilia*. Cellulosa e Carta 10: 3-11.

Eccher A., Fusaro E., Gemignani G., Mughini G. 1986 - *Schede informative sulle specie arboree da legno ad elevata produttività*. Quaderni dell'Intervento straordinario nel Mezzogiorno 11: 1-110.

El-Lakany M.H. 1987 - *Use of Australian acacias in North Africa*. In: Proceedings of "Australian Acacias in developing countries, Proceedings of an International Workshop", Turnbull J.W. (ed.), Gympie, Qld, Australia, 4-7 August 1986, ACIAR Proceedings no. 16. Australian Centre for International Agricultural Research, Canberra: 116-117.

Facciotto G. 2012 - *Storia della SRF e suo sviluppo in Italia*. Progetti di ricerca SUSCACE e FAESI. Recenti acquisizioni scientifiche per le colture energetiche. Sherwood 183 (2): 26-30.

Facciotto G., Bergante S. 2011 - *Selezione di cloni di pioppo per la destinazione da biomassa*. Lo sviluppo delle colture energetiche in Italia. Il contributo dei progetti di ricerca SUSCACE e FAESI: 31-44.

Facciotto G., Nervo G. 2011 - *Biomass production of fast growing species in a short rotation coppice in Sicily (Italy)*. In: Proceedings of the 19th European Biomass Conference and Exhibition, Berlin, 6-10 June 2011: 612-614.

Fady B., Semerci H., Vendramin G.G. 2013 - *EUFORGEN Technical Guidelines for genetic conservation and use for Aleppo pine (*Pinus halepensis*) and Brutia pine (*Pinus brutia*)*. International Plant Genetic Resources Institute, Rome, Italy. 6 pp.

FAO 1981 - *Eucalypts for planting*. Forestry Series 11. FAO, Rome. 677 p. ISBN-10: 9251005702

Gambi G. 1958 - *Il pino insigne*. Monti e Boschi 9: 410-420.

Garfì G., La Mela Veca D.S., Saporito L. 1998 - *Analisi degli accrescimenti di* Pinus brutia *Ten. e* Pinus halepensis *Mill. in popolamenti artificiali sui monti Sicani (AG)*. In: Proceedings of "Atti II Congresso Nazionale di Selvicoltura, Accademia Italiana di Scienze Forestali", Venezia, 24-27 giugno 1998, Vol. IV: 271-278.

Garfì V., Iovino F., Menguzzato G., Nicolaci A. 2002 - *Preparazione del suolo e densità di impianto in rimboschimenti di pino d'Aleppo e di pino laricio: analisi e primi risultati*. L'Italia Forestale e Montana 57 (4): 319-338.

Gentile F., Mendicino V., Menguzzato G., Pelle L. 2007 - *Il pino d'Aleppo nell'arboricoltura da legno in ambiente mediterraneo. Un caso di studio: l'Azienda Mazzone (Cosenza)*. L'Italia Forestale e Montana 62 (4): 231-248.

Gianguzzi L., Papini F., Cusimano D. 2016 - *Phytosociological survey vegetation map of Sicily (Mediterranean region)*. Journal of Maps 12 (5): 845-851. DOI: 10.1080/17445647.2015.1094969

Giordano E. 1970 - *Le specie forestali a rapido accrescimento*. In: "L'Italia forestale nel centenario della fondazione della Scuola di Vallombrosa", Accademia Italiana di Scienze Forestali, Firenze: 153-184.

Gonçalves J.L.M., Stape J.L., Laclau J.-P., Bouillet J.-P., Ranger J. 2008 - *Assessing the effects of early silvicultural management on long-term site productivity of fast-growing eucalypt plantations: the Brazilian experience*. Southern Forests 70: 105-118.

Grill D., Tausz M., Pöllinger U., Soledad Jiménez M., Morales D. 2004 - *Effects of drought on needle anatomy of* Pinus canariensis. Flora 199: 85-89.

Hobbs T.J., Bennell M., Bartle J. (eds.) 2009 - *Developing Species for Woody Biomass Crops in Lower Rainfall Southern Australia – FloraSearch*. 3ª Publication Nº. 09/043 Project Nº. UWA-98A, RIRDC publications. 252 p.

Hofmann A., Cibella R., Bertani R., Miozzo M., Fantoni I., Luppi S. (a cura di) 2011 - *Strumenti conoscitivi per la gestione delle risorse forestali della Sicilia. Sistema Informativo Forestale*. Assessorato Territorio e Ambiente, Regione Siciliana. 208 p.

La Mantia T. 2002 - *L'arboricoltura da legno nel paesaggio siciliano*. Rimboschimenti e piantagioni nelle trasformazioni del paesaggio. Quaderni IAED 15: 135-153.

La Mantia T. 2009 - *La biodiversità delle formazioni naturali e seminaturali in Sicilia: cambiamenti e ipotesi di gestione*. In: Proceedings of "Atti del Terzo Congresso Nazionale di Selvicoltura". Taormina (ME), 16-19 ottobre 2008. Accademia Italiana di Scienze Forestali, Firenze: 199-204.

La Mantia T. 2011 - *I rimboschimenti delle dune*. In: "I cambiamenti nell'ecosistema della Riserva Naturale di Vendicari e gli effetti sull'avifauna", Ientile R., Rühl J., La Mantia T., Massa B. (a cura di), Edizioni Danaus, Palermo: 97-109.

La Mantia T. 2013 - *Storia dell'eucalitticoltura in Sicilia*. Naturalista siciliano XXXVII (2): 587-628.

La Mantia T., Cullotta S., La Mela Veca D.S 1999 - *Analisi degli accrescimenti di* Robinia pseudoacacia *L. sui Monti Peloritani (ME)*. In: Proceedings of "Atti del secondo congresso S.I.S.E.F. - Applicazioni e prospettive per la Ricerca Forestale Italiana", Società Italiana di Selvicoltura ed Ecologia Forestale, Bologna 20-22 ottobre, Ed. Avenue media, Bologna: 77-79.

La Mantia T., Columba P., Scalzo G. 2000 - *Considerazioni sull'applicazione del Regolamento CEE 2080/92 in Sicilia*. In: "Atti della Tavola Rotonda Selvicoltura ed Arboricoltura da legno: quale gestione?", Palermo, 25 marzo 1999, Collana Sicilia Foreste 7: 89-106.

La Mantia T., Pasta S. 2001 - *La rinaturalizzazione dei rimboschimenti: proposte metodologiche e ipotesi di intervento nella Riserva Naturale "Grotta di Santa Ninfa"*. Naturalista Siciliano S. IV XXV (Suppl.): 299-323.

La Mantia T., Cutino I., Maggiore C.V. 2004 - *Limiti e prospettive dell'arboricoltura da legno in Sicilia*. In: Proceedings of "Atti del Convegno La selvicoltura da legno strumento di rilancio del territorio e dell'economia montana", Borgetto (PA), 20 aprile 2004: 87-105.

La Mela Veca D.S. 2009 - *Ecologia e Selvicoltura dei Boschi Artificiali di Conifere dei Monti Sicani (Sicilia)*. In: Proceedings of "Atti III Congresso Nazionale di Selvicoltura", Accademia Italiana di Scienze Forestali, Taormina, 16-19 ottobre 2008. pp. 205-212.

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. doi: 10.3390/land5010003

Le Floc'h E. 1991 - *Invasive plants of the Mediterranean Basin*. In: "Biogeography of Mediterranean Invasions", Groves R.H., Di Castri F. (eds.), Cambridge University Press: 67-80.

Maetzke F.G. 1992 - *Osservazioni sperimentali sulla mortalità in popolamenti di eucalitti, pino insigne e pino d'Aleppo in Campania*. L'Italia Forestale e Montana XLVII (6): 348-360.

Maetzke F.G. 2005 - *Il problema del controllo delle specie forestali invasive: alcune osservazioni condotte su ailanto e robinia, alcune proposte*. In: Proceedings of "Atti del Convegno - Foreste Ricerca Cultura: scritti in onore di Orazio Ciancio", Accademia Italiana di Scienze Forestali (a cura di): 339-354.

Maetzke F.G., Cullotta S., La Mantia T., La Mela Veca D.S., Pizzurro G.M. 2008 - *Individuazione di aree ecologicamente omogenee e di un sistema di aree a priorità di intervento per l'ampliamento della superficie forestale in Sicilia*. Forest@ 5: 280-295.

Maetzke F.G., La Mela Veca D.S., La Mantia T., Badalamenti E., Sferlazza S. 2017 - *The use of species in plantations: renaturalisation and reforestation in Sicily*. In:Proceedings of "Atti del convegno - Sustainable restoration of Mediterranean forests - Analysis and perspective within the context of bio-based economy development under global changes", Palermo, 19-21 aprile 2017. Flora Mediterranea 27: 19-20.

Mead D.J. 2013 - *Sustainable management of* Pinus radiata *plantations*. FAO Forestry Paper No. 170. Rome. 246 p.

Mendicino V., Nicolaci A. 2008 - *Valutazione della biomassa legnosa ritraibile per usi energetici in cedui di eucalitti della costa ionica della Calabria*. In: Proceedings of "Atti III° Congresso Nazionale di Selvicoltura per il miglioramento e la conservazione dei boschi italiani", Accademia Italiana di Scienze Forestali, Taormina (ME), 16-19 ottobre 2008, Firenze, Vol. 2: 858-863.

Mmolotsi R.M., Chisupo O., Mojeremane W., Rampart M., Kopong I., Monekwe D. 2013 - *Dimensional relations and physical properties of wood of* Acacia saligna, *an invasive tree species growing in Botswana*. Research Journal of Agriculture and Forestry Sciences 1 (6): 12-15.

Mughini G. 2016 - *Suggerimenti per una eucalitticoltura clonale sostenibile nelle aree a clima Mediterraneo dell'Italia centro-meridionale*. Forest@ 13: 47-58.

Mughini G., Rosso L., Bergante S. 2011 - *Selezione di cloni di eucalitto per la selezione da biomassa*. Lo sviluppo delle colture energetiche in Italia. Il contributo dei progetti di ricerca SUSCACE e FAESI: 45-52.

Mughini G., Gras M., Salvati L. 2014 - *Growth performance of selected eucalypt hybrid clones for SRWC in Central and Southern Italy*. Annals of Silvicultural Research 38 (1): 7-12.

Nadal-Romero E., Cammeraat E., Serrano-Muela M.P., Lana-Renault N., Regüés D. 2016 - *Hydrological response of an afforested catchment in a Mediterranean humid mountain area: a comparative study with a natural forest*. Hydrological Processes 30: 2717-2733.

Nyssen B., Schmidt U.E., Muys B., van der Lei P.B., Pyttel P. 2016 - *The history of introduced tree species in Europe in a nutshell*. In: "Introduced tree species in European forests: opportunities and challenges", Krumm F., Vítková L. (eds.), European Forest Institute: 44-54.

Palazzo F.C., Palazzo F. 1932 - *Il carbone di ailanto*. Annali del Regio Istituto Superiore Agrario e Forestale (Firenze) II 4: 160-170.

Pausas J.G., Bladé C., Valdecantos A., Seva J.P., Fuentes D., Alloza J.A., Vilagrosa A., Bautista S., Cortina J., Vallejo R. 2004 - *Pines and oaks in the restoration of Mediterranean landscapes of Spain: New perspectives for an old practice – a review*. Plant Ecology 171: 209-220.

Pavari A. 1916 - *Studio preliminare sulla coltura di specie forestali esotiche in Italia*. Annali del Regio Istituto Superiore Forestale Nazionale 1 (1914-1915): 160-379.

Pavari A. 1937 - *Le risorse legnose nazionali per la produzione di cellulosa*. Cellulosa 1-2: 7-12.

Pavari A. 1940 - *Cifre fatti e considerazioni sulle specie legnose a rapido accrescimento per la produzione di cellulosa*. Cellulosa 4: 185-191.

Pavari A., de Philippis A. 1935 - *Cenni monografici sugli eucalitti più importanti per la selvicoltura italiana*. L'Alpe: rivista forestale italiana 22: 210-228.

Pavari A, de Phillippis A. 1941a - *La sperimentazione di specie forestali esotiche in Italia. Risultati del primo ventennio*. Annali della Sperimentazione Agraria 38: 9-96.

Pavari A., de Phillippis A. 1941b - *La sperimentazione delle specie forestali esotiche in Italia*. Annali della Sperimentazione Agraria 38: 283-310.

Quatrini P., Scaglione G., Incannella G., Badalucco L., Puglia A.M., La Mantia T. 2003 - *Microbial inoculants on woody legumes to recover a municipal landfill site*. Water, Air and Soil Pollution: Focus. Special Issue: Bioremediation I (3): 189-199.

Rivas-Martínez S. 1996 - *Classificación Bioclimatica de la Tierra*. Folia Botanica Matritensis 16: 1-32.

Romano S., Cozzi M., Viccaro M., di Napoli F. 2013 - *The green economy for sustainable development: a spatial multi-criteria analysis - ordered weighted averaging approach in the siting process for short rotation forestry in the Basilicata Region, Italy*. Italian Journal of Agronomy 8 (3) e21: 158-167.

Sarris D.,·Christodoulakis D., Körner C. 2011 - *Impact of recent climatic change on growth of low elevation eastern Mediterranean forest trees*. Climatic Change 106: 203-223.

Scarascia-Mugnozza G., Oswald H., Piussi P., Radoglou K. 2000 - *Forests of the Mediterranean region: gaps in knowledge and research needs*. Forest Ecology and Management 132: 97-109.

Scarascia-Mugnozza G., Sabatti M., Paris P. 2007 - *La produzione di biomassa da colture arboree: realtà italiana e prospettive*. Nuove frontiere dell'arboricoltura italiana. A cura di S. Sansa-vini. Perdisa Editore, Bologna: 517-534.

Sferlazza S., Maetzke F.G., Miozzo M., La Mela Veca D.S. 2017a - *Resilience of Mediterranean Forests to Climate Change*. Mediterranean Identities - Environment, Society, Culture, Fuerst-Bjeliš B (Ed.). InTech: 263-282. http://dx.doi.org/10.5772/intechopen.68943

Sferlazza S., La Mela Veca D.S., Miozzo M., Fantoni I., Maetzke F.G. 2017b - *Linee guida per la valutazione della resilienza delle foreste Mediterranee* [Guidelines for assessing the Resilience of Mediterranean Forests to Climate Change]. Palermo University Press. 128 p. ISBN 978-88-99934-42-2

Sferlazza S., Maetzke F.G., Iovino M., Baiamonte G., Palmeri V., La Mela Veca D.S. 2018 - *Effects of traditional forest management on carbon storage in a Mediterranean holm oak (*Quercus ilex *L.) coppice*. iForest 11: 344-351. doi: 10.3832/ifor2424-011

Silva-Pando F.J., Pino-Pérez R. 2016 - *Introduction of* Eucalyptus *into Europe*. Australian Forestry 79 (4): 283-291.

Sitzia T., Campagnaro T., Kowarik I., Trentanovi G. 2016 - *Using forest management to control invasive alien species: helping implement the new European regulation on invasive alien species*. Biological Invasions 18: 1-7.

Slee A.V., Brooker M.I.H., Duffy S.M., West J.G. 2006 - *Euclid, eucalypts of Australia*. 3rd ed. (DVD-Rom). Canberra: Centre for Plant Biodiversity Research.

Vallejo V.R., Allen E.B., Aronson J., Pausas J.G., Cortina J., Gutiérrez J.R. 2012 - *Restoration of Mediterranean-type woodlands and shrublands*. In: "Restoration Ecology: The New Frontier, Second Edition", van Andel J., Aronson J. (eds.), Blackwell Publishing Ltd: 130-144.

Vilà M., Tessier M., Suehs C.M., Brundu G., Carta L., Galanidis A., Lambdon P., Manca M., Médail F., Moragues E., Traveset A., Troumbis A.Y., Hulme P.E. 2006 - *Local and regional assessment of the impacts of plant invaders on vegetation structure and soil properties of Mediterranean islands*. Journal of Biogeography 33: 853-861.

Virginia Department of Forestry 2009 - *Control and Utilization of Tree-of-Heaven - A Guide for Virginia Landowners*. USDA Forest Service, Forest Health Protection Program. 15 p. http://www.dof.virginia.gov/infopubs/Control-And-Utilization-of-TOH-2009-05_pub.pdf