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ORIGINAL ARTICLE

The past distribution of *Abies nebrodensis* (Lojac.) Mattei: results of a multidisciplinary study

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Abstract

The present study provides a critical review of the available historical data on the distribution of *Abies nebrodensis*, a fir tree endemic to Sicily. The only (somewhat ambiguous) references to its occurrence on Mount Etna date back to the 1st century BC and refer back to the 3rd century BC. Although the botanical and forestry literature and the very few surviving herbarium specimens do not prove that *A. nebrodensis* grew outside the Madonie mountain range, several indications suggest its past occurrence on other Sicilian mountain ranges such as the Erei, Nebrodi, and probably also Sicani mountains. The results of the most recent pollen investigations (still ongoing) point to the disappearance of *Abies* from most of Sicily by the 1st century BC, and at least since the Middle Ages *A. nebrodensis* had become extremely rare even on the Madonie mountains. Publications focused on the wooden artefacts from archaeological excavations and the restoration of architectural heritage have provided some information on the past use of fir wood in Sicily, but the species identity of the firs being used remain unresolved. The present review of the past occurrence and distribution of *A. nebrodensis* suggests that it may have previously occupied a wider ecological niche.

Keywords Sicily · Documentary sources · Medieval history · Forestry resources · Endemism · Pollen · Wood anatomy · Archaeobotany

Introduction

With only 30 natural mature individuals able to reproduce sexually, *Abies nebrodensis* (Lojac.) Mattei is the rarest conifer in the European flora. It is listed in Annex I and II of the Habitats Directive of Council Directive 92/43/EEC and despite the positive outcome of a LIFE Project (Raimondo and Schicchi 2005), it is considered actually in category 'CR' (=Critically Endangered) due to its small distribution range and the low number of reproductive individuals (Pasta and Troia 2017).

Most authors believe that *A. nebrodensis* was widespread in the mountains of Sicily until a few centuries ago. In contrast to this, data obtained from pollen investigations carried out over the last 15–20 years show the frequent occurrence of pollen of *Abies*, but always in very small amounts, even in the Madonie mountains. These contradictory lines of evidence prompted us to carry out a multidisciplinary study looking for a clear proof of the past presence and distribution of the Sicilian fir on the island.

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Materials and methods

To fulfil our aim we have used the information from scientific literature as well as historical evidence from the humanities. Place names were searched for on modern maps of the Istituto Geografico Militare Italiano (Italian Geographic Military Institute, IGMI) related to the following plant names 'abet-e/i', 'abit-u/o/i', 'cropan-o/u/i', 'pign-u/o/i', 'pin-u/o/i', 'zappin-u/o/i' and their variants. We also tried to clarify the use and the common meaning of the dialect terms 'cròpana', 'cròpanu', 'pignu', 'zappinu', 'abitu, 'arbitu', 'arvulu cruci cruci', 'arvulu cacciadiavuli' and their variants reported in Piccitto (1977) and Pirrone (1990). Furthermore, various publications have been consulted for Berber and Arabic plant names referring to conifers (*Abies*, etc.) in North Africa (Foureau 1896; Trabut 1935; Emberger 1938; Bellakhdar 1997; Charco García 2001), and for Greek names in the Hellenic area (Tsintides et al. 2002; Hadjikyriakou 2007) and in southern Calabria (Spampinato et al. 2017). Botanical and forestry literature from the 17th to the 21st century was consulted as well. Additionally, herbarium specimens of *A. nebrodensis* were researched in several European herbaria (G, FI, PAL, NAP, CAT; acronyms according to Thiers 2016 onwards). As regards the palaeo- and archaeobotanical data, systematic research was carried out on pollen records, as well as those on the macroremains and fragments of wood and/or charcoal of *Abies* from Sicily.

Results and discussion

Evidence from coins

The plant represented on the *Tetradrachma of Aitna* (ESM Fig. S1), a coin from the Greek colony of Catana-Aetna (Salinas 1867), has been interpreted in the past as a fir or a cedar by several researchers (for example, Pace 1958). Its shape actually resembles a pine species with a similar pyramidal habit, *Pinus laricio* Poir. ssp. *calabrica* (Loudon) Cesca & Peruzzi, which is still found growing on Mt. Etna, or a spruce, *Picea abies* (L.) H.Karst., which does not occur in Sicily or central-southern Italy and is not found among the place names around Mt. Etna (Calafiore 1975).

Why literary sources cannot be 'taken literally'

In *Bibliotheca historica*, Siculus (1988), who lived in Sicily around the 1st century BC, wrote that in 399–398 BC Dionisius I, tyrant of Siracusa, "having obtained the right to export timber from Italy, sent half of his woodcutters to Mount Etna, rich at that time in precious pines and firs". Diodorus Siculus uses two different terms, πεύκη (peúkē) and ἐλάτη (elátē), unequivocally referring to pines and firs (A. Cozzo, I. Vogiatzakis and C.S. Christodoulou, personal communication; Rocci 1980). Therefore, two different conifers were being used for their timber on the island at that time.

Since ancient times, fir wood has been used extensively for building ships, as evidenced by the fact that the Greek word ἐλάτη (=elatē) and the Latin word 'abies' have been used to indicate both trees and hulls or ships (Rocci 1980). In reference to the battle of Milazzo, in 260 BC during the First Punic War, Brancati and Olivati (1957) observed that "thousands and thousands of trees were felled for the construction of the hull, bridge …, etc.; […]". These opinions, however, do not allow us to judge if firs in Sicily were used at that time, since pines could also have been used.

Sources in Arabic (consulted mostly through the translations made by Amari 1982) as well as a number of medieval texts in Latin, mention the wealth of woods in Sicily. For example, the *Laus Siciliae*, contained in the *Life of Saint Filareto of Seminara* and written by a monk named Nilo (Nilo Doxapatres according to Caruso 1991) around AD 1000, states, referring to Sicily in general: "Also the nature of the trees is valuable: cedars—I mean—cypresses and pines to obtain torches […]" (Martino 1993). In his *History of Muslims in Sicily*, Amari (1982) writes about the use of timber gathered on the Sicilian mountains for the construction of ships, as well as Corrao (1988, 1989) with regard to the Norman period.

For Etna, Yaqût Múġam wrote in the 12th century that the volcano is home to "[fruit] trees and woods, mostly chestnut, hazelnut, pine and cedar" and the same is later reported by several other Arab authors. Citing them, Corrao (1989) writes about a "great variety of trees used for the construction of ships" and mentions "an ambiguous *nemus sapidum*—perhaps a corruption of *sapetum*, or fir wood". Further on Corrao (1989) argues that "in some areas and at higher altitudes in the Madonie and Nebrodi mountains, and on Etna, the fir woods take the place of the oak". Again, it is simple conjecture, based on the subjective interpretation of the vernacular names used for the trees, which are often ambiguous. Without doubt, since the 8th century AD the lack of timber drove the Arabs of Maghreb to make frequent raids in order to cut down trees on the islands and along the northern coast of the Mediterranean (Lombard 1959, also quoting the use of *Pinus laricio* [ssp. *calabrica*, authors's note]).

Actually, there is not a single written text that refers to woodlands dominated by firs, or that records their local abundance. Arena (1960b) states (without citing any source) that the destruction of the high altitude woods in the Madonie mountains occurred at the end of the 18th century, when massive land use changes led to the cultivation of pastures at lower levels, which forced shepherds

to move with their flocks to graze at higher altitudes. Summarizing, the only clear reference to the presence and felling of firs in Sicily relates to the Etna area and dates back to the classical antiquity.

Cadastres, archives and maps

The numerous sources consulted (Lombard 1958; Higounet 1966; von Falkenhausen 1980; Bresc 1983; Forni 1988; Dentici Buccellato 1994; Gangemi 1996, 2001; Ventura 2001) do not mention the presence or use of fir woods in Sicily, either linked to the Monti Madonie or any other Sicilian mountain range. This lack of information on use of the local woodlands suggests a marked decrease in woods on Sicily and may implicitly confirm the extreme rarity of *A. nebrodensis,* at least since the Middle Ages. Over-use of remnant woodland resources is also a recurrent theme in documents concerning woodland owners until the 15th century AD (H. Bresc, personal communication). In this regard, Bresc (1975) wrote "In 1400, the large trees needed were already absent from the Madonie and few references refer to their use". To underline the scarcity of trees suited for ship building, Bresc wrote: "Pine and fir seemed to be lacking almost everywhere; they could be found only on Etna in the Mascali pinewood and Maletto fir wood and in the Iblei mountains". He then further remarked "larch and fir were necessarily imported from eastern Sicily or from abroad". The decline in the shipbuilding industry following the Muslim period is symptomatic of a shortage of timber and "the decline of Palermo was due to the distance of the city from the nearest sources of wood supply" (Corrao 1987). As already said, any reference to firs and larches occurring in Sicily (see also Evans 1835) is probably erroneous, given that larches do not grow south of the Alps (Da Ronch et al. 2016). Bresc (1986) provided a list of the few coniferous woods mentioned in the available legal and ecclesiastical documents, namely the pine woods and pitch furnaces of Mascali (in 1125, 1305 and 1335), the pine wood of Buccheri (1158) and the wood of Maletto (1435).

Many maps of Sicily printed between the 16th and 18th centuries (Militello 2004) offer an accurate representation of the woodland cover only for the Etna and Nebrodi mountains. Considering that in those times woodland maps only included trees and tall woodland stands which were useful for shipbuilding and other purposes, like cork oak groves and pine woods, the lack of information about the Madonie mountains suggests that at least by the 17th century all local woods were coppiced and were therefore without firs, which are unable to regenerate in this way.

The contribution of cultural anthropology: plant names, place names and magical or religious uses

Of the Sicilian place names of possible Greek origin, none are known which are clearly related to the presence of firs in particular or conifers in general. The only term that seems to derive from the ancient Greek word δαίς, -ίδος (dais, daidos = torch, origin of the Latin *taeda*) is the term *ddeda* or *deda*, which was used to indicate pines on Pantelleria (Gussone 1844–1845) and in the Etna region (Filoteo degli Omodei 1591; Scuderi 1828); today, this word is very uncommon and is absent from official maps. Similarly, no trace is left in local place names of Berber and Arab plant names referring to useful conifers.

Terms referring (only or also) to conifers in the Sicilian dialect dictionaries that we consulted are 'cròpana', 'cròpanu', 'pignu', 'zappinu', 'abìtu, 'arbìtu', 'arvulu cruci cruci', 'arvulu cacciadiavuli' and their variants (ESM Table S1). It has not been possible to trace the origin of the dialect term 'cropanu', which seems to have been used in the past indiscriminately for both firs and *Ostrya carpinifolia* Scop. (hophornbeam). Interestingly, most of the texts consulted (ESM Table S1) add very little to the information first provided by Cupani (1696), the only author who provides definite dialect names referring exclusively to *A. nebrodensis*: "Abies alba, seù fœmina C.B.P. [= Bauhin 1623, authors' note] Abies fœmina, sivè elatè Thilia I.B. [= Bauhin and Cherler 1650–1651] vulgò *Erva di S. Filippu*, *ò Arvulu cruci, cruci*, *Arvulu caccia diavuli*". However, references to another three conifers made by the same author are much more ambiguous. *Larix decidua* L. ("Larix C.B.P. folio deciduo, conifera I.B. vulgò *Autanu, di lu quali si fannu Tavuli*"), a tree whose occurrence in Sicily appears very unlikely, as well as two 'varieties' of spruce, "Abies rubra, sivè Picea maior I. C.B.P. Picea Latinorum, sivè elati arrhen Abies mas Theophr. I. B. vulgò *Cropanu, di cui si fannu tavuli*" [= used to make boards] and "Abies rubra, minor, Picea minor C.B.P. Picea pumila I.B. vulgò *Cropanu minuri, di cui si fannu li tavuli matti*" [= used to make rough boards]. Also for *Picea abies* neither its occurrence in Sicily nor being grown there seem likely; it is more probable that the trunks were imported for timber, and possibly they were confused with local native pine species. The same opinion was held by Gussone (1844–1845), who excluded both spruce and larch from the Sicilian flora and mentioned them in the appendix only.

Concerning the plant names, caution is necessary since almost all conifers were used indiscriminately as timber and many of them for the extraction of resin for pitch (with the exception of firs). Additionally, plants with similar habits are often named in the same way; this might explain why the pines from the Etna woods were called 'firs'. Chiarelli (1789), for example, writes: "among the coniferous trees the larch, called *Pinus larix*, is found throughout the Val

di Noto, and we name it *autanu*". Actually, the only native conifer taxon still growing there (roughly corresponding to the plateau of Iblei in southeastern Sicily) is *Pinus halepensis* Mill. On the oldest available map published by the Istituto Geografico Militare Italiano (IGMI 1877), a "Cozzo di Pino" (northwest of Petralia Sottana), "Pizzo di Pino" (southeast of Petralia Soprana) and a "Cozzo Coppano" (probably a distortion of 'cropano') southwest of Monte San Salvatore can be found, whilst it is not possible to identify the exact location of the place name "Colma dei Pini", quoted by many scholars during the 19th century.

We carried out cross-checks using the database of the place names on the modern 1:25000 IGMI maps (ESM Table S2). They are comparable with the plant names 'cropan-o/u/i' and 'pin-u/o/i', and to the term 'cedro (=cedar?)'. The distribution of these place names connected with plants in Sicily is shown in Fig. 1. In particular, the occurrence of a 'Pizzo di Pino' at Petralia confirms the previous presence there of *Pinus* or *Abies*, and also elsewhere on the Madonie, while 'Case Cropane' in the area of Santo Stefano di Camastra may show the past presence of an unspecified and perhaps introduced conifer, probably similar to a fir, at relatively low altitudes. Finally, the name 'Pizzo Pinazzo' at Antillo deserves special attention, because in dialect, the derogatory form (pine + '*azzo*' in the case of Pinazzo) is often used to indicate something which is strange, or atypical in some way, somehow different from something familiar. Indeed, various references to the presence of 'cedro' in the Cesarò and Patti area suggest the historical presence of a conifer with perhaps an unfamiliar shape or leaves; this would explain the use of such an unusual name which suggests a genus (*Cedrus*) that has never been observed growing wild in Sicily. It should, however, be noted that 'kedros' in Greek is used for various species within the genus *Juniperus* (I. Vogiatzakis, personal communication) and, therefore, in our case, the name could have been referring to *Juniperus communis* L. ssp. *hemisphaerica* (C.Presl) Nyman.

The vernacular names of *A. nebrodensis* ('arvulu cruci cruci' means cross-rich tree, while 'arbulu cacciadavuli' means devil-banishing tree) reported by Cupani (1696) referred to the use that was made of the plant at the monastery of San Filippo d'Argirò, nowadays Agira. Although in Indo-European, Central American and Siberian mythology and symbolism, firs in general, and *Abies* in particular, are often identified as trees linked to the birth of the divine child (Christmas tree) or connected to lunar cycles, 'rebirth' or 'restored fertility' and springtime in nature (Cattabiani 1996), the use of fir branches in Europe against misfortune is quite unusual. The upright arrangement of *A. nebrodensis* branches recalls the Christian cross, yet the silver fir is also used for this same religious symbolism; the use of these branches to ward off evil is, therefore, an element of great interest and originality in magical and religious studies about Sicily and Italy. Such use deserves some anthropological research to look for the presence of similar rites in the eastern Mediterranean area, in particular where the cult of St. Philip of Agira is still alive. St. Philip was a Syrian monk who is also still revered in Thrace (now northern Greece,

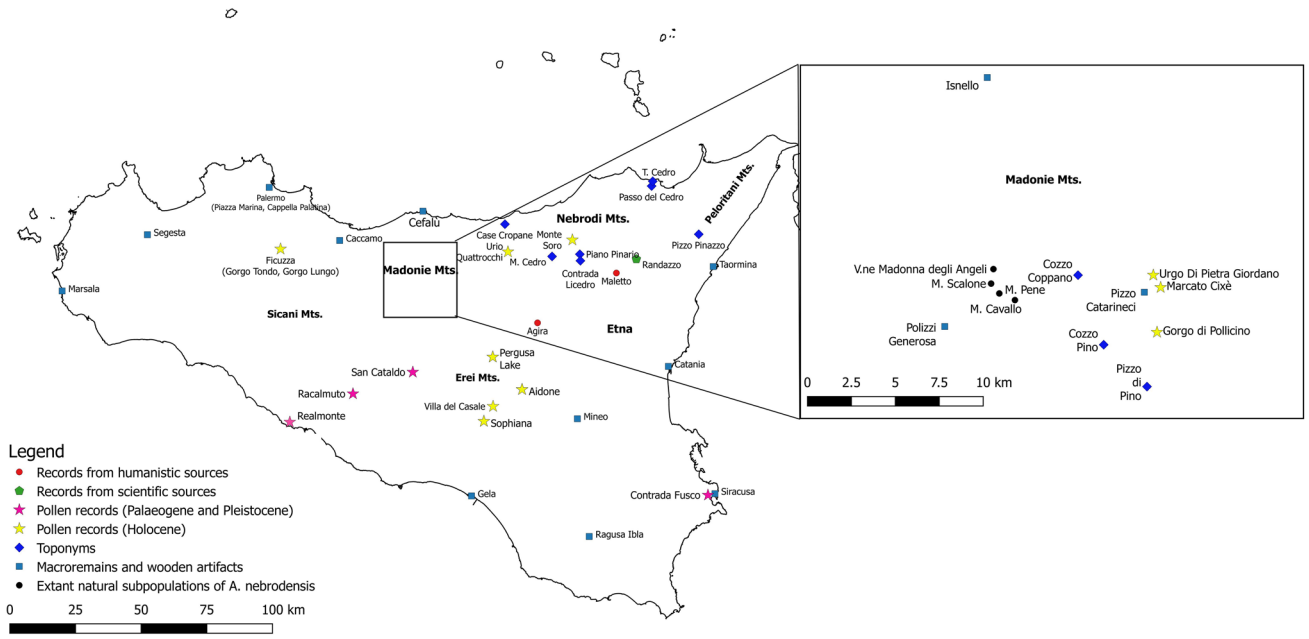

Fig. 1 *Abies* records in Sicily based on wood identifications and pollen records (scientific), and from documentary sources quoted in the text, place names and records with no direct confirmation (humanistic, toponyms) for Etna, Randazzo and Agira

European Turkey and southern Bulgaria), where he lived after the diaspora before settling in Sicily in the 8th century AD. According to recognized tradition (http://www.santiebeati.it/dettaglio/96414), St. Philip performed exorcisms in Agira, and this town in Enna hosted such rituals long after his death. As an example, the historian Tommaso Fazello (1560) described celebrations of the patron saint and rituals that he had personally witnessed in 1541. Clear traces of the magical or religious use of fir branches lasted until at least the 19th century. In fact, Pitrè (1889), referring to '*Abies pectinata*', writes "Remedy of the obsessed, the possessed, etc.", while Pitrè (1900) reports "… St. Philip, who considered the fir (*Abies pectinata*) as sacred and against-evil, thereby giving rise to the name of *arvulu caccia-diavuli*, *arvulu di S. Filippu*" (devil-banishing tree or St. Philip's tree). In Agira, fir branches were most probably used in two ways, either they were blessed and exhibited (the same as current use of palm or olive leaves on Palm Sunday) or they were used to beat people possessed by evil spirits to free them (F.M. Provitina, personal communication). The second use could represent a revival of pre-Christian rites. Some spring fertility rites in ancient Greece and central-southern Italy involved beating women with fir branches to 'bring on' the beginning of spring (Cattabiani 1996). Indeed, the period of the celebration of St. Philip, which takes place in the first half of May, would support this second explanation.

Presence and distribution of *Abies nebrodensis* according to botanical and forestry literature

The Madonie mountains

Despite knowing the Madonie mountains and their vascular flora very well, the botanist Silvio Boccone (1633–1704) did not mention the presence of *Abies* in any of his works. This suggests that the conifer was already extremely rare on the Monti Madonie. In the same period, Cupani (1696) reported the presence of fir there, the first clear evidence of its occurrence in Sicily, 1,800 years after Diodorus. Lagusi (1743) mentions the 'Sicilian' fir tree for the mountainous areas of the island and the use of its foliage for medical purposes, while da Ucria (1789) reported that *Pinus abies* "habitat in Monte Maronis a li Pini".

With the only exception of a herbarium specimen collected at Agira in 1805 by Giuseppe Tineo (F.M. Provitina, personal communication), all 19th century dry specimens cited by Mattei (1908) refer to places that fall exclusively within the areas of Polizzi and Petralia. Almost certainly between the late 18th and early 19th centuries, *A. nebrodensis* was already extremely localized: this hypothesis is supported by the lack of any reference to it in the few forestry works of that period (Balsamo 1799–1800). Although plenty of naturalists visited the Monti Madonie in that period, very few of them had the chance to observe Sicilian fir in the field. For example, despite visiting the Madonie, the Bohemian naturalist Presl (1826) only reported *Abies excelsa* as growing in Sicily in general, while, on the basis of data provided by the botanists of Palermo, Scinà (1819) simply indicated that "*Pinus abies* grows on the high mountains in front of Polizzi". Bivona Bernardi, one of the few botanists able to personally observe and sample *A. nebrodensis* during his excursions across the Madonie during the first two decades of the 19th century, does not mention it in his works on forestry (Bivona Bernardi 1845). The Sicilian fir is not even found in the list of plants growing on the highest peaks of the Madonie mountains (amongst which Colma Grande is explicitly mentioned), compiled by Malvica (1835) with the help of another botanist working in Palermo, Gasparrini. Gussone explored the Madonie with Tineo in June 1817 (Pasquale 1871); regarding *A. nebrodensis,* in his *Synopsis Florae Siculae*, he remarks "[it grows] on the top of Monti Madonie, but nowadays [it is] almost completely destroyed" (Gussone 1844–1845). In his monograph on Italian conifers, the Danish botanist Schouw (1845) mentioned '*A. pectinata* DC.' for the Madonie, according to information communicated by Tineo, which seems to confirm that its distribution was very local. Actually, during his stay in Sicily in the summer of 1819, Schouw visited Polizzi Generosa to buy several plates of illustrations from Cupani's *Panphyton Siculum*. If the fir tree had been common or easy to observe, in all probability Schouw, who was interested in altitudinal gradients of vegetation, would have deliberately sought to visit the nearby mountains.

The occurrence of the Sicilian fir is not mentioned by Power (1839, 1842), a reliable source of information for foreign visitors and scientists. The German botanist Theodor von Heldreich visited Sicily and the Madonie with Parlatore in 1841 and 1842 but he seems not to have collected *A. nebrodensis* on either occasion. Over 20 years after spending an entire month in the Madonie mountains, Parlatore (1867–1868) writes about '*Pinus abies* Dur.' that it is found "Growing indeed at the top of the Madonie mountains in Sicily at an altitude of approximately 2,000 m at the Serra dei Pini, where it is, however, rare—having been largely destroyed—and where I saw it small and without fruit, near Petralia Sottana and elsewhere". Indeed, he only quotes its presence on the top of Serra dei Pini as 'rare and rarely reproductive'. At that same time, in De Candolle's Prodromus (Parlatore 1868) he shares the sad awareness of its irreversible demographic decline.

Calcara (1851) indicates 'Curma Grandi di li Pini' as "the only place where *Abies pectinata* thrives". Despite having thoroughly explored the peaks near Polizzi such as Serra Cavallo and Colma Grande in March-July 1855, and coming back to the Madonie in March-June 1856, the French brothers Alfred and Edouard Huet du Pavillon, who botanized

in Sicily on behalf of the Geneva museum, never collected samples of *A. nebrodensis* (Briquet 1914). Viola (1852) mentions the presence of a few remnant fir seedlings in the Monte Cavallo area, where woodland cover was destroyed to fulfil local needs for firewood. Two decades later, Virga (1878) generically mentions *Pinus abies* Du Roi in the plant catalogue for the Isnello area. Meanwhile, in the geographical description contained in the introduction to *Flora der Nebroden*, Strobl (1878a) cites among others the place names 'Colma dei Pini' and 'Cozzo dei Pini', but does not associate them with the presence of the fir; the same goes for the place name 'Vallone Madonna degli Angeli', which today is home to most of the surviving individuals of the species. Strobl (1878b) writes: "There are no—or at least no more—woods of coniferous trees in the Madonie. The shrunken and isolated firs of Cozzo dei Pini near Petralia are the only survivors of the fir woods once widespread on the steepest slopes", and further on he remarks that those woods "have been destroyed to facilitate the spread of the yet more competitive beech trees. The beech therefore, formerly a simple companion of the fir tree […] assemblages, has become a dominant species by the hand of man, and its altitudinal range, between 1,300 and 1,850 m, may be considered the same as previously probably occupied by fir". Such a rapid extinction of Mediterranean fir woods is not unprecedented. In fact, the *Abies alba* populations of Corsica had more or less the same fate: currently rather rare on that island (Gamisans 1999), at the time of Theophrastus (4th-3rd century BC) silver fir grew there healthier and taller than in any other region of central-southern Italy (Thanos 2003). Strobl (1878c) reports: "*Abies pectinata"* DC., … *Abies excelsa* Presl not DC., […]: the fir woods of the past have been completely ripped out; today only a few shrunken trees protected by Minà survive, between 1,100 and 1,400 m, such as a 70 year old tree in the Capuchin monastery at Petralia Sottana, or another protected by a hedge at the foot of Serra dei Pini (Minà!) and one at Cozzo dei Pini (1,300 m, Calcara!). […] They never fructify…".

When describing the taxon as a distinct variety of silver fir, Lojacono-Pojero (1904–1907) reported its presence "On the highest ranges of the Nebrodi (Madonie) at Colma dei Pini (*locus classicus*!), Polizzi. Presl! Guss.! Parl.! Today completely disappeared. Found in the Vallone dei Pini, on Monte dei Cervi, near Polizzi". The reliability of this latest report was dubious even to Lojacono-Pojero himself, who highlighted how the place name was not, in fact, known either to himself who explored the Madonie for 40 years, or to local people. Mattei (1908) reported that Antonio Borzì, director of the Palermo botanical gardens, commissioned one of his students, Rosalba Mirabello, to verify the presence of surviving individuals of *A. nebrodensis*. She noted that "the centuries-old fir tree (which) grew in the Cappuccini wood near Petralia Sottana" was dead, but she managed to obtain, from a certain Giuseppe Di Maria, branches of the only surviving *Arvulu cruci–cruci*, located, according to the Madonie farmer, "on Monte Cervo, near Valle dei Pini, in the area of Polizzi Generosa". It is possible, however, that a single wild adult tree was actually found in those years, as De Gregorio (1909–1910) generically reported having obtained samples from "the only tree that exists in Sicily; it is three metres high; the trunk has a diameter of 50 cm. It is old and not very lush. It is located on the top of Madonie".

The Swiss Hermann Ross, who made numerous collections of Sicilian plants at the turn of the 20th century, told Mattfeld (1925) that the last individuals of *A. nebrodensis* grew exclusively on the Madonie, though he admitted that he had never observed them personally. The French botanists Viguié and Gaussen (1929) claimed to have observed, during a field trip carried out in 1928, a single adult tree in good condition, while Frei (1938) counted approximately 20 individuals (including three reproductive ones) in 1937 on Cozzo dei Pini, near Petralia Sottana. In the spring of 1955, Köstler observed only eight individuals, six of which were growing in the wild and extremely damaged by browsing on Monte Cavallo, in the Polizzi Generosa area and two in the grounds of Villa del Barone Casale in Polizzi (Köstler 1956). Field surveys carried out in subsequent decades led the finding of several new individuals (Geraci 1979) and to mapping of as many as 30 individuals, whose development and reproductive success has been regularly monitored (Morandini 1969; Morandini et al. 1994; Virgilio et al. 2000). The remaining trees are distributed on the Scalone, Cavallo and Pene (Pini) mountains and in the Vallone Madonna degli Angeli. Various projects to grow specimens of *A. nebrodensis* in public and private gardens such as at Villa Lanza near Gibilmanna and the above mentioned Villa Casale, have ensured that Sicilian fir is now also present in several places on the Monti Madonie, such as Piano Zucchi and Isnello (Venturella et al. 1997) and in a public woodland in the same area (Raimondo and Schicchi 2005; Schicchi et al. 2013, 2014).

The Erei mountains

Intriguing, yet controversial is the small amount of information available on the historical presence of *A. nebrodensis* in the vast area that includes the Erei and the Nebrodi (or Caronie) mountain ranges. Mattei (1908) guessed that the name "Arvulu di San Filippu", referring to *A. nebrodensis,* could refer to its past presence at San Filippo d'Argirò/Agira. This theory is supported by Provitina (2009), and according to a manuscript by Antonio Mongitore preserved at the Palermo Municipal Library, it seems that up to the 18th century in the area of Agira, a species of fir was common enough to collect plenty of fronds from it to be sent to Palermo so that the faithful of

the church of San Filippo, located near present-day Casa Professa, could use them against evil spirits.

The open farmed landscape of present-day Agira now appears a totally unsuitable environment for mesophilous woodland and firs. However, until the beginning of the 16th century, Agira owned a much larger area. Indeed, the maps of that time show that the old municipal area bordered with Castrogiovanni (present-day Enna), Nicosia, Traina (= Troina), Adernò (= Adrano), Caltagirone and Piazza (= Piazza Armerina), thus adjacent to the north with the southern Nebrodi mountains and to the east with Etna and to the southeast with the Iblei area (F.M. Provitina, personal communication). Therefore the idea that *A. nebrodensis* could have grown in this whole vast area sounds far more plausible. Additionally, we must take into consideration that in the inner part of Sicily, which nowadays is almost devoid of woodland cover, there are still some rare woody plants typical of mesophilous woodland plant assemblages, like *Cornus sanguinea* L., very rare in Sicily but quite common in the Enna area (Lo Giudice and Cristaudo 2004).

Unfortunately, there is no information on the historical evolution of the natural landscape of the surroundings of Agira. The most ancient source, Diodorus Siculus, who lived there, mentions the presence of sacred woods in the adjacent area, and the coinage of the ancient Graeco-Roman city often contains images of plants including trees such as *Quercus pubescens* (downy oak) on Agira medals, published by Castelli (1781). However, there are no references to the presence of firs in the Enna area, which was probably already deprived of its woods and the land used for extensive cereal cultivation and pasture by the time when the Siculi started to rule the area three thousand years ago. It is known that this part of the Sicilian inland was among the most productive grain growing areas in the whole Roman Empire (Di Matteo 2006).

In the centuries that followed, the Enna area gave birth to many famous doctors who might have recorded woods; however neither Apulejo Celso (1st century) from Centuripe, nor Fortunato Fedele (1550–1630) from Agira, nor Filippo Arena (1708–1789) from Piazza Armerina mentioned either firs or woods. Attardi (1742) discussed the reclamation of some woods of Agira when he referred to the hermitages of the Basilian period, while Di Bérenger (1859–1863) referred to forestry and practices related to the presence of woods in the Agira area. In the 1970s, during the restoration of the local castle, samples were collected from wooden artefacts from the Palatine Chapel of San Pietro in Vincoli in order to submit them to laboratory analysis to check for the presence of wood of *A. nebrodensis*. Unfortunately, this material, delivered to Prof. Emilia Poli Marchese (Catania University), was never analysed and is currently missing (F.M. Provitina, personal communication).

The Nebrodi mountains and Etna

It is unlikely that any Pinaceae other than *Pinus* have grown on the Nebrodi or other mountains of northeastern Sicily (once called 'Valdemone') over the last three to four centuries. It is worth remembering that the city of Messina played a dominant role in Sicilian culture in the 17th and 18th centuries. Many famous naturalists, who were professors in medicine and pharmacy at the University of Messina and who helped build one of the first botanical gardens in Italy there, undoubtedly would have mentioned the occurrence of fir trees on the mountains of Valdemone had they still existed there. In contrast, as mentioned above, Cupani and Ucria who were both born in this area, and Boccone who knew the mountains of Valdemone very well, did not mention it for this area between the end of the 17th and the end of the 18th century. In relatively recent times, the first monograph on the flora of northeastern Sicily (Nicotra 1878) does not make any reference to the presence of *Abies* either on the Nebrodi or on the Peloritani mountains. There are only two annotations, both inaccurate and rather doubtful, concerning the presence of *A. nebrodensis* on the Nebrodi mountains. The first is from Borzì (1879–1880), who reports in a rather generic and imprecise way that it grows "on the mountains around Randazzo"; this is information that should have deserved greater emphasis and much more precise detail as a hitherto unknown population. A few years later, in the foreword to his *Flora Sicula*, Tornabene (1887) attributes the disappearance of '*Abies pectinata*' from Sicily to clearance of woodland which took place in the Madonie "and in the Caronie"; however, further on in the same work, in the section dedicated to Sicilian fir is stated that it grew only on the top of the Madonie mountains.

In the occasional lists of vascular plants growing on Mt. Etna published between the 16th and 18th centuries, neither Barthelsen (1663), nor Ray (1673a, b), nor Sestini (1777) report *Abies* growing on the volcano. A first ambiguous mention of the presence of firs there is provided by Rafinesque Schmaltz (1813–1815) in his *Chloris Aetnensis*, where he reported an unidentifiable '*Pinus picea* L.—Pignu' as a species distinct from '*Pinus sylvestris* L.—Zappinu' (probably *Pinus laricio* ssp. *calabrica*). However, it should be noted that the list made by the eclectic American naturalist during his stay in Sicily contains numerous and sometimes gross inaccuracies, and proves on the whole rather unreliable, as indicated by his contemporary, Ferdinando Cosentini (1830), a meticulous expert of the area. Regarding the wooded area on Etna, Smyth (1824), possibly using the work of Rafinesque Schmaltz, wrote: "The woods are unevenly distributed, […] above Nicolosi and Milo grow small oaks, firs, beeches, corks, hawthorns and plum trees; […]". On the other hand, no mention is made of the presence of the fir on Etna either in the works of Scuderi (1828) or Strobl (1881).

In his overview of the knowledge and botanical investigations carried out on the volcano, Tornabene (1890–1892) mentioned 17th century plant lists that do not include *Abies*.

Herbarium specimens

The 19th century *exsiccata* herbarium specimens once preserved in the herbarium of Palermo University were collected at 'Agira' by Giuseppe Tineo, perhaps in 1805 (F.M. Provitina, personal communication), from 'Polizzi' (Vincenzo Tineo), 'Serra dei Pini' (Bivona Bernardi) and 'Colma dei Pini' (Minà-Palumbo), but they were lost at some time between when they were seen by Lojacono-Pojero (1904–1907) and by Mattei (1908), and the late 1950s, when the director in charge of the Botanical Garden of Palermo, Francesco Bruno, remarked on their disappearance (Messeri 1959). Yet a few years before then, Alessandro De Philippis had been able to see abundant material collected by Domenico Lanza (Messeri 1959) in the herbarium of Palermo (PAL). The loss of this precious material has been verified by us and also confirmed by the recent work of Di Gristina et al. (2017) who, in the absence of any references to the specimens cited in the prologue of Lojacono-Pojero (1904–1907), were forced to select one kept in the herbarium of Naples (GUSS-NAP) as a type specimen. Although the naturalist Francesco Minà-Palumbo made great efforts for the conservation of *A. nebrodensis* trees, there are no dried specimens of Sicilian fir in his herbarium, now kept in the natural history museum of Castelbuono, nor in the herbarium of Francesco Tornabene (http://www.dipbot.unict.it/herbarium/erbario.aspx), or in the herbarium at Florence (FI) (C. Nepi, personal communication), or in the Conservatoire et Jardin Botaniques de Genève (G) (C. Christe, personal communication).

Pollen records

The oldest record of pollen from *Abies* sp. in Sicily dates back to 6–3 million years ago: it was found in the sediments of the Gessoso-Solfifera series in San Cataldo (Bertolani Marchetti and Del Chicca 1966), Realmonte and Racalmuto (Bertini et al. 1998). The few *Abies* pollen grains found from the paleontological site of Contrada Fusco near Siracusa (Syracuse) (Arobba 1996) date back to the upper Pleistocene (147,000–29,000 years ago). The presence of *Abies* pollen in Sicily during the Holocene is of crucial importance, as it may be the most valid indication of its presence during the past 12,000 years, when temperature conditions were similar to those of today. However, it has to be underlined that information from pollen studies still has two major weaknesses: (1) it is not possible to distinguish *Abies* pollen at species level (Fægri et al. 1989; Moore et al. 1991; Beug 2004), and (2) there are few estimates on the pollen productivity and dispersal range of *Abies* pollen; the ones that have been made in central Europe refer to *A. alba* (Mazier et al. 2008; Sjögren et al. 2015). Firs produce pollen abundantly, but airborne dispersal is moderate. *Abies* pollen is probably able to spread a maximum distance of 20 km, with a maximum fallout between 100 and 1,000 m from the source (van der Knaap et al. 2019).

As regards the Madonie mountains, pollen studies carried out at Gorgo di Pietra Giordano provide a continuous vegetational record between 7,000 and the present, but *Abies* pollen occurs there only in small but regular, almost continuous amounts. At Gorgo di Pollicino a minor presence of *Abies* pollen has been recorded around 2,200 years ago, while at Gorgo di Marcato Cixè there are two isolated presences dated to around AD 1100 and 1850 (Tinner et al. 2016a). Pollen from *Abies* has also been found in the sediments of Urio Quattrocchi near Mistretta in the Nebrodi mountains, and the investigations carried out by Bisculm et al. (2012) suggest that fir occurred close to the local permanent pond between 10,000 and 5,000 and between 4,000 and 3,000 years ago, while its discontinuous presence, recorded between 3,000 years up to a few centuries ago, could represent airborne dispersal from nearby mountain ranges. Regarding pollen abundance, the findings are comparable to those of Pietra Giordano (Tinner et al. 2016a).

In the Nebrodi mountains, recent preliminary studies on a permanent pond near the top of Monte Soro, which need to be verified by further pollen analysis, suggest instead a massive presence of *Abies*, with 5–10% compared to 0.5–2% at other sites during the Holocene (Bautzmann and Hoehn, personal communication; Table 1). The pollen evidence also suggests a sudden local extinction with the total absence of pollen during last two millennia, most probably related to increased land use, similarly as observed at Pietra Giordano. If confirmed, the Monte Soro results would reveal, in an unambiguous manner, the historic occurrence of dense and large fir woods in Sicily.

Analysis of lake sediment samples from Lago di Pergusa near Enna revealed a rather slight and discontinuous presence of *Abies* pollen around 11,700–10,000, 7,000–4,000 and ca. 2,000 years ago (Sadori and Narcisi 2001; Sadori et al. 2013). In the recent past, small amounts of *Abies* pollen have been detected in several other inland areas of Sicily, not far from Enna and Agira (Fig. 1), and also from inside the 'Venere di Morgantina' statue, dating back to the 5th century BC, believed to have come from a Sicilian city near the modern-day Aidone (Chester 2009), at Villa del Casale (2nd to 6th century AD) near Piazza Armerina, and at Sophiana (3rd to 7th century AD) in the Mazzarino area (Mercuri et al. 2019). It should, however, be noted that records from archaeological sediments are, in all likelihood, unreliable because the *Abies* pollen could have been introduced there by humans.

Table 1 Holocene pollen records of Abies in Sicily, by time period, mountain range and site. x = presence of pollen <3%; o = presence of pollen 3-10%. Sites, PGi = Pietra Giordano; Pol = Gorgo Pollicino; Cix = Marcato Cixè; GLu = Gorgo Lungo; GTo = Gorgo Tondo (Tinner et al. 2016a); Qua = Urio Quattrocchi (Bisculm et al. 2012); Mor = Mogantina (Chester 2009); Per = Pergusa (Sadori and Narcisi 2001); Cas = Villa del Casale; Phi = Philosophiana or Sophiana (Mercuri et al. 2019). Sor = M. Soro (source: Bautzmann, personal communication)

	Madonie			Sicani		Nebrodi		Erei			
Yrs BP	PGi	Pol	Cix	GLu	GTo	Qua	Sor	Mor	Per	Cas	Phi
0–500			x								
500–1000						x					
1000–1500					x	x	x				x
1500–2000				x		x	x			x	
2000–2500	x	x			x	x	o		x		
2500–3000	x				x	x	o	x	x		
3000–3500	x					x	o				
3500–4000	x					x	o				
4000–4500	x					x	o				
4500–5000	x					x	o	x			
5000–5500	x					x	o	x			
5500–6000	x					x	o				
6000–6500	x					x	o				
6500–7000	x					x	o				
7000–7500						x	x				
7500–8000							x				
8000–8500							x				
8500–9000							x				
9000–9500							x				
9500–10000							x				

The presence of *Abies* pollen from Gorgo Lungo (about 1,500 years ago) and from Gorgo Tondo (between 3,000 and 2,400 years ago and again around AD 1000) in the Ficuzza wooded area (Tinner et al. 2016a) is interesting because this finding suggests that firs may also have occurred on the Sicani mountains as late as the Middle Ages.

Macroremains and wooden artefacts

Despite a number of studies on the plant material found in the pyroclastic (volcanic) deposits of Etna (Tornabene 1860, 1892; Pampaloni 1904; De Stefani 1947; Cortesi et al. 1988), no traces of *Abies* wood or fir cones have ever been found. Scientific literature on the analysis of wooden artefacts from submerged shipwrecks, archaeological excavations or the restoration of architectural heritage buildings has provided a wealth of information on the use of *Abies* wood in Sicily, leaving, however, the question of its species identity still unresolved.

Arena (1960a) is the only author who points out some anatomical traits which could be useful in order to distinguish the wood of *A. nebrodensis* from that of *A. alba*. Among the diagnostic criteria proposed, the most significant ones appear to be: (1) the length of the rays (up to 87 cells in *A. nebrodensis* compared to a maximum of 45 cells in *A. alba*), (2) the length of tracheids (4,030 µm in earlywood and 4,305 µm in the latewood of *A. nebrodensis* compared to 2,246 µm and 3,321 µm in *A. alba*), (3) the presence of crystals, abundant in the tracheids of *A. nebrodensis* and rare in those of *A. alba*, and 4) the presence of starch in the radial parenchyma, abundant in *A. nebrodensis*, but much less in *A. alba*. Biondi and Raimondo (1980) report the presence of subfossil trunks of both *A. nebrodensis* and *A. alba* in the bogs of Pizzo Catarineci. After studying these findings, a few years later, Biondi confirmed the larger size of both the tracheids and the rays of *A. nebrodensis* (Bertolani Marchetti et al. 1984). A recent biostratigraphic and chronological analysis of the site suggests erroneous dating (too old by approximately 5,000 years) of the wood found at Urgo di Pietra Giordano, which is probably just 5,000–4,000 instead of ca. 10,000 years old (Tinner et al. 2016a). Castiglioni and Rottoli (2008) report the discovery of carbonized fragments of *Abies* sp. dating back to the Archaic and Classical periods (7th to 5th centuries BC) from the sanctuary of the Palici near Mineo. The analysis of a wreck discovered near Gela, dating back to 490 BC, showed that some parts of it were made of fir wood (Terranova and Valenti 2005). Analysis of charcoal from the archaeological site of Segesta, northwestern Sicily, led to the identification of numerous fragments of charcoal dating back to the 6th-12th centuries AD which belonged to over 20 taxa, amongst which were *Pinus nigra*-type and *Abies* (Castiglioni and Rottoli 1997). The former could be *Pinus laricio* ssp. *calabrica*, belonging to the *Pinus nigra* species complex. Based on the size of the rays and with reference to Biondi

(in Bertolani Marchetti et al. 1984) and Schweingruber (1990), Castiglioni and Rottoli (1997) prefer to assign the fir specimens to *A. alba/nebrodensis*.

Both pine and fir trunks could easily have been transported by sea from distant areas to the *Emporium Segestanum*, the harbour of Segesta, modern-day Castellamare del Golfo. Branches of fir were also found in abundance at the site of the timber yard at Segesta, but their use remains unclear. Such large quantities suggest the storage of branches for a specific purpose, unfortunately not indicated by the archaeological evidence. Since the logs were cleaned to facilitate their transport, Di Pasquale et al. (2014) believe that such a copious presence of small branches is not consistent with the current distance of approximately 150 km from the nearest populations of *Abies* and therefore assume that there must have been some firs growing somewhere much closer to Segesta. This interpretation, however, deserves confirmation, as small branches could easily have been transported over land. Moreover, if they played an important role in some ceremony, such as for the rituals for avoiding evil mentioned earlier, they could certainly have been transported for this purpose in bundles, separately from the logs. Analysing the structures of two shipwrecks found at Lido Signorino, Marsala, dating back to the 12th century AD, Ferroni and Meucci (1996) found evidence of boat parts made of *Abies* cf. *alba.*

As many as 69% of the 150 samples from the 12th century AD wooden ceiling of the Palatine Chapel of Palermo, analysed by Romagnoli et al. (2007), belong to the genus *Abies*, and based on diagnostic characters defined by Arena (1960a), 35 (that is 23%) of the analysed fragments appear to belong to *A. nebrodensis.* Another excavation carried out in the centre of Palermo at Piazza Marina in 2006 led to the discovery of a beam, dated between AD 891 and 1153, identified as *Abies* sp. (Spatafora et al. 2012). They also report that the Bioarchaeological Research Laboratory in Palermo has found the use of fir wood in the cathedral of Cefalù. This would correct the observations made by Rutelli (1922). During the ceiling restoration, he noticed the use of "solid Sicilian pine wood beams" as well as fir and *Quercus robur* L. (oak) wood.

The use of *A. alba* to build the wooden ceilings in the 15th century church of Santa Maria degli Angeli in Caccamo has been ascertained, too (Sebastianelli et al. 2009). The authors' statement that it would be "locally felled" is not supported by any documentary evidence. Romagnoli et al. (2006) also claim to have found fir wood with anatomical traits similar to *A. nebrodensis* in the ceiling of the cathedrals of Taormina (14th-15th century) and Siracusa (16th-17th century). If confirmed, these discoveries would be of crucial importance in showing that some timber from Sicilian fir was still available and being used between the 14th and 17th centuries. According to Palazzolo (2007), around 90 beams of *Abies* were used around the mid 1500s for the construction of the city walls of Palermo, and *Abies* cf. *alba* was used in the 17th century church of Sant'Agata in Ragusa Ibla (Cristaudo et al. 2009). Moreover, based on results of Castorina (2001), Lo Monaco et al. (2006) report that *A. alba* and *Picea abies* were identified among the timbers used to make the ceiling and the floor of the Benedictine monastery of San Nicolò l'Arena in Catania (1544–1623). Additionally, documents preserved at the monastery show that the *A. alba* timber came from Calabria. Around 1680, large beams (15.6 m in length), boards and small beams made from "Zappini delli cropani" were bought for the construction of the church of Santa Maria della Pietà in Palermo (P. Scibilia, personal communication). Finally, a study by Arena and Gramuglio (1975) is of fundamental importance, as it shows quite the opposite of what has been stated for decades by inattentive readers: the fact that the beams of San Domenico (16th century) and the portal of Santa Maria Maggiore (c. 1690) in Polizzi Generosa, a town situated a few kilometres far from the last surviving individuals of the species, were probably made of *A. alba* rather than *A. nebrodensis*, which suggests that the Sicilian fir was already extremely rare at least one or two centuries earlier than had been thought up to now. Once again in 1793, "*zappino* wood" was purchased for the church of Annunziata in Isnello (Anselmo 2009). Unfortunately, it has not been possible to verify whether this material came from the Madonie or from Etna (where the term '*zappino*' is mostly used for *Pinus laricio* ssp. *calabrica*), or even from the Italian peninsula.

New perspectives on the ecological niche of *Abies nebrodensis*

Based on its present occurrence data, growing outside real woodland communities, Brullo et al. (2001) considered *A. nebrodensis* as a characteristic for the Junipero-Pinetea sylvestris (Rivas-Mart. 1965 corr. Guarino et al. 2017), a phytosociological vegetation class which includes Mediterranean mountain woodland assemblages with a markedly relict character. On the basis of the previous occurrence and distribution of *A. nebrodensis* discussed here, we instead suggest that the last survivors occupy an extremely small portion of the potential ecological niche and former range of Sicilian fir. Hence, the role and the climatic needs of *A. nebrodensis* should be reconsidered. In fact, in perfect agreement with the theory of Di Pasquale et al. (2014), the Sicilian fir may have grown not only within montane Mediterranean beech woods which were floristically and structurally similar to current ones belonging to the class Carpino-Fagetea sylvaticae Jacuks and Passarge (1968), but also in the sub-Mediterranean mixed woods, mainly deciduous but often also including evergreen trees such as *Quercus ilex*, *Ilex aquifolium*,

Taxus baccata and *Laurus nobilis* (Quercetea ilicis Br.-Bl. ex A. Bolòs and O. de Bolòs in A. Bolòs y Vayreda 1950). Moreover, such behaviour appears quite similar to those of *Abies numidica* de Lannoy ex Carrière and *A. maroccana* Trab. in the mountain ranges of northwest Africa (Quézel and Médail 2003), and that of *A. alba* on the mountains of Corsica (Gamisans 1999).

Conclusions

Our research has enabled us to create a critical synthetic map showing all the known records of *Abies* in Sicily according to various types of information (Fig. 1). Yet despite several interesting results presented here, only the improvement of laboratory techniques for distinguishing pollen grains, wood and/or DNA (ancient DNA analysis is still in progress) of *A. alba* from those of *A. nebrodensis* will allow substantial refinement of the reconstruction of the past occurrence and distribution of Sicilian fir. However, recent pollen-based vegetation history reconstructions suggest that in the past *Abies* was more widespread throughout the region, even at lower altitudes than currently until 1000–100 BC. The dramatic reduction and definitive local extinctions of Sicilian firs occurred on most mountain ranges at least since the beginning of the Middle Ages. Even if, according to written sources, firs still occurred on the slopes of Etna during antiquity, they must have disappeared from there before the 17th century. The existence of specific dialect place names for the Sicilian fir suggests that *A. nebrodensis* was still well known and probably grew on the southern slopes of the Nebrodi and on the top of the Erei mountains until a few centuries ago. Similarly, as for the Madonie, *A. nebrodensis* became almost extinct at latest during the 18th century, and probably long before then.

Our interpretation is that *A. nebrodensis* had an original altitudinal range which included both sub-Mediterranean vegetation zones (today mostly deciduous oak-dominated, between 900 and 1,200–1,300 m) and the montane Mediterranean ones (today beech-dominated, in mountains above 1,200–1,300 m). This seems to provide a better reconstruction of its past presence in the mountain ranges of Sicily. This main finding is of enormous interest for two reasons: (1) it advises planting *A. nebrodensis* in other new Sicilian locations subject to a lower risk of inbreeding with other *Abies* species and with suitable mesoclimatic conditions, as has been successfully tried recently with other relict taxa (Garfì et al. 2017), and (2) it suggests growing Sicilian fir in plantations elsewhere in Europe, where *A. nebrodensis* may complement other European conifers to reduce global warming which is now having an effect on forestry (Tinner et al. 2016b).

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