



Contents lists available at ScienceDirect

# Quaternary International

journal homepage: [www.elsevier.com/locate/quaint](http://www.elsevier.com/locate/quaint)

## Humans, forests, and timber production in southern Italy 2000 years ago: Insights from Herculaneum on the unknown “Wood Age”

Alessia D’Auria<sup>a,\*</sup>, Daniela Moser<sup>b,1</sup>, Salvatore Pasta<sup>c</sup>, Gaetano Di Pasquale<sup>a</sup><sup>a</sup> Department of Agricultural Sciences, University of Naples Federico II, Portici, 80055, Italy<sup>b</sup> Institute for Ecosystem Research, Paleocology Unit, Kiel University, 24118, Kiel, Germany<sup>c</sup> Institute of Biosciences and BioResources, National Research Council, Unit of Palermo, Palermo, 90146, Italy

### ARTICLE INFO

#### Keywords:

*Abies alba*  
Roman Age  
Archaeobotany  
Buildings  
Beams

### ABSTRACT

The city of Herculaneum (Naples, southern Italy), buried by the eruption of Vesuvius in AD 79, is a key site for understanding the relationship between man and forest timber economy during the Roman period. This is possible thanks to the large amount of wood samples, both charred and waterlogged, which belong to building structures as well as furniture. Our work consisted both in a review of published data and in the identification of 62 new waterlogged wood remains. The literature permitted to collect information on various types of building elements and wooden furniture. In total, 641 samples (charcoal and waterlogged wood) were counted. Softwood is by far the preferred timber for both building purposes and furniture. *Abies alba* Mill. is especially used, this fact suggesting a more important role played by this species in southern Italian forests during the recent Holocene; its decline is probably due to the overexploitation characteristic of the Roman period. The significant presence of *Cupressus sempervirens* L., mainly used for poles production, confirms that this tree was cultivated in plantations for timber production in the Vesuvius area. The presence of *Picea abies* (L.) H. Karst indicates the importation of timber from the Alps. Regarding wood for furniture, despite the abundance of artifacts, available data are too limited to perceive specific uses for furniture. Finally, the low percentages of deciduous *Quercus*, *Castanea sativa* Mill. and *Fagus sylvatica* L. suggest that their use was reserved for other purposes.

### 1. Introduction

Wood is a composite material that includes various chemical (cellulose, lignin, and hemicellulose) and structural components; this specific structure determines very peculiar properties of great interest from different points of view, unmatched by other natural materials and many human-made products (Toumpanaki et al., 2021). Due to these characteristics, wood is our oldest construction material.

Curiously, wood has never had a “dedicated era” in the study of the interaction between man and natural resources in ancient times; indeed, in the traditional chronological subdivision of the Stone/Bronze/Iron Ages used to define prehistoric periods in Europe (e.g., Coles et al., 1978), the possibility of an era devoted to this essential resource has rarely been considered, even though it is hard to imagine for these epochs weapons or tools made without wooden components.

Due to its unique features, wood has been utilized by humans since

ancient times; however, the problem in reconstructing this history lies in the rarity of the remains that document this long history of usage because the wood is an organic material and therefore it is subject to degradation. Wood remains are preserved especially under anaerobic conditions (e.g., submerged in water or in very humid environments) or through partial combustion, which transforms them into charcoal. Less frequently, wood can also be preserved in glaciers (thanks to low temperatures; Oeggl, 2009), under extreme arid conditions (Chemello and Davis, 2014) or through mineralization processes resulting from contact with metals.

Despite this evident “disadvantage”, it is possible to date the beginning of a Wood Age to the epoch when the ability to control fire was acquired; today, we know that this knowledge was firmly established at least 200,000 yrs ago. However, in about a dozen sites across Africa and Eurasia, evidence is attested much earlier, between 500,000 and 1 million yrs ago (Stepka et al., 2022). The very recent discovery in central

This article is part of a special issue entitled: Archaeobotany of the Area Buried by the 79 AD Eruption published in Quaternary International.

\* Corresponding author.

E-mail addresses: [alessia.dauria@unina.it](mailto:alessia.dauria@unina.it) (A. D’Auria), [salvatore.pasta@ibbr.cnr.it](mailto:salvatore.pasta@ibbr.cnr.it) (S. Pasta), [gaetano.dipasquale@unina.it](mailto:gaetano.dipasquale@unina.it) (G. Di Pasquale).

<sup>1</sup> deceased.

<https://doi.org/10.1016/j.quaint.2025.109744>

Received 29 October 2024; Received in revised form 4 March 2025; Accepted 12 March 2025

Available online 28 March 2025

1040-6182/© 2025 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Africa, dated to 470,000 yrs ago, provides what is currently considered the oldest evidence of wood use and processing for structural purposes (Barham et al., 2023).

All these data demonstrate an important fact: the knowledge of certain wood properties was already present in communities of hominid species. Thus, it can be affirmed that the Wood Age began long before the appearance of “*H. sapiens*” and is comparable to the Stone Age.

The human-wood interaction continued with written history; classical texts and archaeological evidence agree in providing a picture of a well-established rationalization of trades (Diosono, 2023) and specific uses for different wood taxa, to which correspond specific types of forest landscapes.

A demonstration of the level of knowledge acquired in classical times also comes from the etymology of the terms used in Latin for this resource: *lignum*, derived from *lĕgere* (to gather, collect), referred to firewood, while *materia* was the term used for timber used for structural purposes (Diosono, 2023). *Materia*, therefore, indicated the raw material in general used to build, a building, a ship, a bridge, or other structures. Thus, we can observe that, for the Romans, wood was “The Material par excellence”; from this primary meaning, *materia* will become, in many languages, the term used to indicate a general material.

For the Roman period, there are a few regional case studies focused on the interaction between human and wood resources, both for Italy (e.g., Veal, 2014), central Europe (Roman Gaule; Blondel and Girardclos, 2018), and the southeastern Mediterranean (Roth et al., 2019).

From this perspective, Herculaneum represents an absolutely unique case that concerns the amount and heterogeneity of this type of remains across the whole Roman world. From the first archaeological excavation in Herculaneum, carried out in 1738 by Charles III Bourbon, king of t Naples (Guidobaldi, 2006; Wallace-Hadrill, 2011), charred and uncharred wooden remains were found in huge amounts everywhere on the site, spanning from different kinds of building material (e.g. Moser et al., 2018; Rizzi, 2005) to different pieces of interior furniture (Mols, 1999), and other wooden objects (i.e. tablets and sculptures).

By reviewing previously published data and then identifying and

analysing novel wood remains recovered in the Casa del Rilievo di Telefo, specifying which trees are used in the construction of the roof and the ceiling, the main objectives of this paper are, therefore, 1) to understand if woods are locally available or imported ones; 2) to investigate the level of knowledge about the properties of timber during the Roman Age; and 3) to evaluate the level of organization and rationalization in the use of wood resources in this area of the central Mediterranean.

In general, the aim is to assess the current state of knowledge regarding human-wood-forest interaction 2000 yrs ago and the level of rationalization in the use of different tree species based on their applications in Herculaneum, a coastal city located in the central Mediterranean and not far from Rome.

## 2. Study area

### 2.1. Herculaneum

The ancient city of Herculaneum is located along the Bay of Naples at the foot of the western slope of Mount Somma-Vesuvius in the modern town of Ercolano (40°48'49"N, 14°21'49"E; Fig. 1). This wealthy Roman city was buried, like Pompeii, during the 79 AD eruption. The resulting 16–30 m thick volcanic deposit allowed the preservation of various types of organic material (Wallace-Hadrill, 2011).

Today, the landscape around the study area is strongly modified by human settlements, as the entire Bay of Naples is nowadays densely populated. On the south-western slope of Mount Somma-Vesuvius a pine forest plantation with dominance of *Pinus pinea* L. prevails, while on the north-eastern slope a mixed mesophilous forest dominated by *Quercus pubescens*, *Ostrya carpinifolia* and *Fraxinus ornus* L. is present together with *Castanea sativa* woodlands. On the top of the Somma slope, mixed small stands with *Populus tremula* L., *Alnus cordata* (Loisel.) Duby and *Betula pendula* Roth grow, while *Quercus ilex* L. and other evergreen shrubs, such as *Arbutus unedo* L., *Phillyrea latifolia* L. and *Myrtus communis* L. are present on the steepest inland slopes (Cona and Di Pasquale,

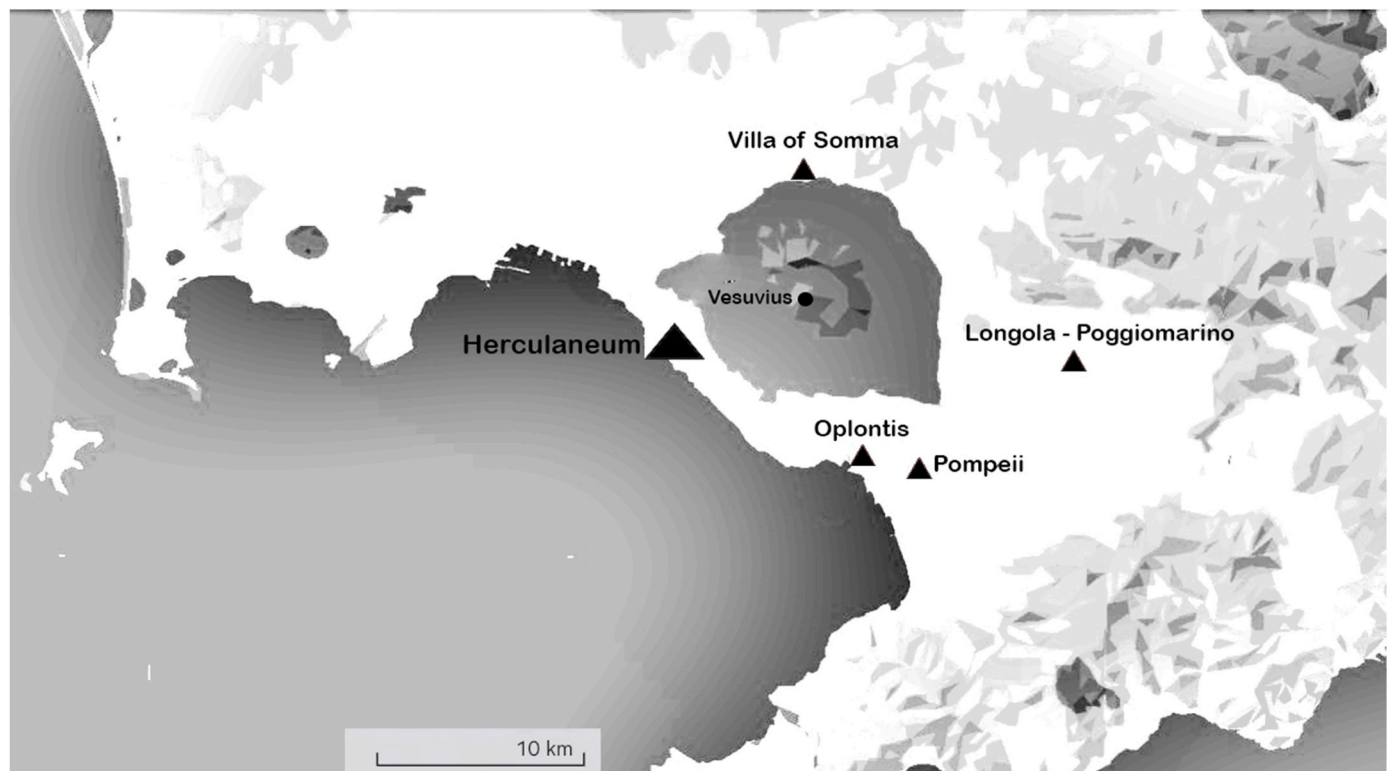


Fig. 1. Map showing the location of the study area.

2007). On the Lattari Mountains, south of the investigated site, *C. sativa* and *A. cordata*, together with *O. carpinifolia* and *Fagus sylvatica* populate the medium and high elevations, while *Quercus ilex*, *F. ornus* and *Q. pubescens* together with the evergreen shrubs mentioned above, grow on the lower belt.

Today Herculaneum is characterized by a Mediterranean climate; the mean minimum temperature in the coldest month (January) is 6,8 °C while the mean maximum temperature in the hottest month (August) is 25,7 °C. Mean annual precipitation is 865 mm, with a maximum in November at 126 mm and a minimum in July at 16 mm (Università degli Studi di Napoli Federico II weather station, 50 m a.s.l., 10 km from the study site).

Among the numerous unearthed remains, a significant part consists of both wooden furnishings (i.e. beds, sculptures, tables, cupboards) and structural timber used in building construction. In this regard, Herculaneum represents a unique case for this type of finding, made possible by the temperatures of around 500 °C that developed during the initial phase of the eruption, followed by the dynamics of subsequent burial (Pensa et al., 2023). As for artifacts and structures, in many cases this process allowed to remain intact despite the fragility of wood when charred.

Despite this unusual but evident abundance of finds, an extreme scarcity of observations and studies dedicated to archaeological wood has been noted until the second half of the 20th century. Only from the last century onward we record an increase in data on the recovery of wooden artifacts or structures; however, in the vast majority of cases, this interest remains marginal. Additionally, in the few instances where some furniture objects were recovered, there was a lack of knowledge regarding conservation and consolidation techniques, with the consequent rapid deterioration of those materials.

## 2.2. The Casa del Rilievo di Telefo

The Casa del Rilievo di Telefo is located on the eastern side of the Insula Orientalis I.

The original building was demolished and rebuilt during the Augustus Age (27 BC – 14 AD): its large size and the preciousness of its frescoes, floors and decor clearly indicates the nobility of its inhabitants. The marble room, from which the roof and ceiling come, is a rich *triclinium* (dining room) overlooking the sea and can be dated to the third quarter of the 1st century AD based on the marble decoration of the walls (Guidobaldi, 2006). The roof and ceiling of the marble room were discovered in 2009 in the southern corner of the *Antica spiaggia*, the ancient seashore of Herculaneum, where they were blown by the blast of the eruption. The timber elements were embedded in two different layers: in the upper layer, the wooden remains were carbonized, while in the lower level they were preserved in waterlogged conditions (Camardo et al., 2015). The findings allowed the reconstruction of the entire structure, which was composed by a tie-beam truss roof (for a detailed description of this technique see Adam, 1988), a false ceiling made of flat boards and the coffered ceiling with a cornice and different types of lacunars (Camardo et al., 2015).

## 3. Material and methods

In total 62 new samples of waterlogged wood from the Casa del Rilievo di Telefo were collected out of about 250 recovered timber elements from the marble room of this building. The difficult issue related to their conservation did not allow so far the sampling of the whole structure. 6 samples belong to the framework or timber wood of the room and the remaining 56 to the window or door framing and ceiling. Among the latter 51 belong to the false ceiling and the coffered ceiling and, in particular, 10 to the ceiling frame, 6 to the cornice and 23 to flat boards. 12 pertain to the boards of different type of lacunars: 7 to

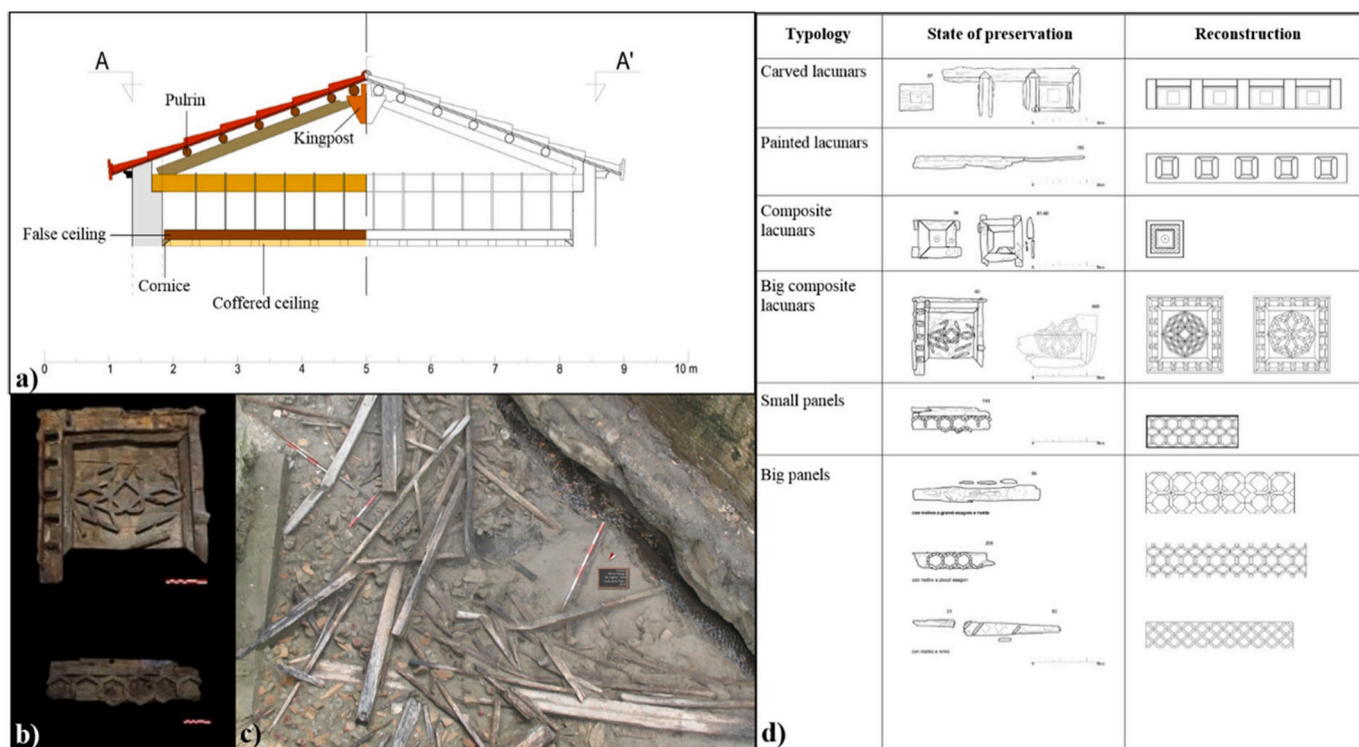


Fig. 2. The roof and ceiling of the Casa del Rilievo di Telefo. a) graphic reconstruction of the structure with the indication of the analyzed elements; b) pictures of a big composite lacunar (above) and of a panel (below) of the coffered ceiling; c) the roof and the ceiling at the moment of their discovery in the southern corner of the Antica Spiaggia; d) typology, state of preservation and reconstruction of the different lacunars composing the coffered ceiling (author's photocomposition with material of Herculaneum Conservation Project).

composite lacunars, 2 to carved lacunars, 1 to a painted lacunar and 2 to decorated panels (Fig. 2). The samples were first prepared in thin sections with the help of a cryo-microtome, then the taxonomic identifications were made with a transmission light microscope at magnifications of 100x, 200x and 400x and using the reference of the Lab of Archaeobotany and Wood Anatomy at the University of Naples Federico II and wood anatomy atlases (Nardi Berti et al., 2006; Greguss, 1955, 1959; Schweingruber, 1990). The nomenclature of the woody plants mentioned in the text follows Pignatti et al. (2017–2019).

Moreover, a study on literature data was conducted using online search engines, grey literature and other archaeobotanical data (only charcoal and waterlogged wood) from the ancient Vesuvius area buried by the AD 79 eruption.

#### 4. Results

##### 4.1. The Casa del Rilievo di Telefo

Concerning the Casa del Rilievo di Telefo, of the 62 analyzed samples, 61 were identified at a species or genus level leading to the identification of 5 taxa (Tables 1 and 2). The preservation status of one sample did not allow to assess with certainty whether it was *Abies* or *Cupressus*.

The most used timber in the roofing and ceiling is *Abies* which constitutes 64.51% of the identified elements. Fir is employed in all the structures: the kingpost of the roof and one of the purlins, part of the frame, cornice and flat boards of the false ceiling and the painted and composite lacunars and a panel of the coffered ceiling. Although wood anatomy does not allow the distinction between the different species of this genus present in the Mediterranean (Quézel and Médail, 2003), we can reliably attribute our samples to *Abies alba* Mill., due to its wider distribution along the Italian peninsula (Piotti et al., 2017). *Cupressus sempervirens* follows at 14.51%; it is used for 3 of the purlins, for part of the frame, cornice and flat boards of the false ceiling and for a carved

lacunar and a decorated panel of the coffered ceiling. *C. sativa* constitutes the 8% of the material and it is used for the frame and the flat boards of the false ceiling. Deciduous *Quercus* (especially *Q. pubescens* Willd. s.l.) reaches the 9.6% and it is employed for the flat boards of the false ceiling, together with *Juniperus* that, anyway, constitutes only 1.6% of the total. Silver fir, deciduous oak and cypress are also used in the framing of doors/windows.

##### 4.2. Analysis of literature data

The analysis of available literature allowed us to collect relevant information related to different typologies of studies on wood remains from the city of Herculaneum. In total, 579 archaeological wood samples were counted, of which 474 were timbers (Table 1), while the remaining 105 were wood for furniture and other non-structural elements (Table 2).

The analyses conducted by Macchioni et al. (2016) focused on the roof and ceiling of the Casa del Rilievo di Telefo, comprising a total of 40 wood samples, including 7 structural wood samples. Among these, 6 samples were identified as poles of *C. sempervirens*, and 1 as *C. sativa*; the remaining data concerned 33 elements of the coffered ceiling, mainly composed of *A. alba* (81%). This study also documented the use of wood from deciduous taxa such as *Prunus*, *Tilia*, and *Acer* (Tables 1 and 2).

In the same period, various samplings aimed at dendrochronological investigations were conducted on the roof structures of Telefo; unfortunately, specific types of samples chosen are not specified, but it can be presumed that elements with a high number of rings were considered, likely focusing on larger structural timbers (Camardo et al., 2015). The cited work specifies that 78 samples were analyzed, of which 73 (96.3%) are *A. alba*, one identified as *Picea abies* (L.) H. Karst., another as *Quercus*, and 3 remain unidentified (Table 1).

For the entire urban area the work by Moser et al. (2018) is undoubtedly the most comprehensive. It considered 435 samples of

**Table 1**  
Frequencies of the identified taxa among the structural elements.

References	Tot. Samples x cited paper	Taxa										
		<i>Abies alba</i>	<i>Cupressus sempervirens</i>	<i>Picea abies</i> + <i>Picea/Larix</i>	<i>Pinus pinea</i>	<i>Pinus sylvestris</i> type	<i>Castanea sativa</i>	<i>Fagus sylvatica</i>	<i>Juglans regia</i>	<i>Quercus deciduous</i>	<i>Ulmus</i>	<i>Olea europaea</i>
A Casa di Telefo	6	3 2 kingpost 1 purlin	3 3 purlin									
B	7		6 6 poles						1			
C*	75	73		1						1		
D	389	251 93 beams 71 squared joist 4 squared slat 9 poles 74 planks	62 3 beams 4 squared joist 55 poles	42 24 beams 9 squared joist 9 plank	1 1 squared joist	1 1 plank	14 6 beam 4 squared joist 4 plank	3 1 pole 2 plank	3 1 2 plank	7 2 squared just 1 squared slat	4 2 squared joist 2 plank	1 1 squared joist
E**		°	°	°						°		
TOT	480	370	71	33	1	1	15	3	3	8	4	1

A = this paper; B = Macchioni et al. (2016); C = Camardo et al. (2015); D = Moser et al. (2018); E = Kuniholm (2002).

C\* Authors do not specify the type of timber sampled.

E\*\* In this work Kuniholm only mentions a woodpile with “a mixture of fir, spruce and pine, occasional cypress and a bit of oak”. The symbol ° indicates the presence of these taxa.

**Table 2**  
Frequencies of the identified taxa among the non-structural elements.

References	Tot. Samples x cited paper	Taxa	Abies alba	Cupressus sempervirens	Abies/Cupressus	Picea + Larix	Juniperus	Gymnosperma	Castanea sativa	Deciduous Quercus	Prunus	Tilia	Juglans	Carpinus	Acer	Cf. Alnus	Buxus	Olea europaea
A	56	Telefo roof	37	6	1	1	1		5 false and coffered ceiling	6								
B	36		34 false and coffered ceiling 3 frames	5 false and coffered ceiling 1 frames				3 false and coffered ceiling		1 frames	4 false and coffered ceiling	1 false and coffered ceiling				1 false and coffered ceiling		
C	25		18 frames			3 frames		1 frames		2 tenon								1 frames
D	44		39 planks							1 plank			1 table top	1 table leg	1 Chest plank		1 table leg	
TOT	161		121	6	1	3	1	4	5	9	4	1	1	1	1	1	1	1

A = this paper; B = Macchioni et al. (2016); C = Moser et al. (2018); D = Mols (1999).

charred wood, primarily sourced from intact structural elements, with 110 still *in situ* and 325 preserved in storerooms.

Here, *A. alba* represents more than 60% of the analyzed samples of beams, squared timbers, and boards, and together with *C. sempervirens*, spruce (*Picea abies*) and spruce/larch (*Larix decidua* Mill.), these taxa cover about the 90% of the total of samples studied.

The distinction between *Picea abies* (Norway spruce) and *Larix decidua* (European larch) is complicated, the only distinguishing feature for small fragments is the shape of pit exterior borders in ray tracheids (Anagnost et al., 1994; Bartholin, 1979; Talon, 1997; Schweingruber, 1990). At Herculaneum, the very good preservation of the samples allowed in some cases the attribution to *P. abies*. Among the hardwoods, *C. sativa* is the most represented, but its presence does not exceed 5%.

Additional data come from early dendrochronological research conducted in Herculaneum (Kuniholm, 2002); unfortunately, these data are incomplete because the author did not indicate neither the number of samples analyzed nor a complete list of the identified taxa. Only 120 timbers sampled between 1996 and 1997 are mentioned, along with the presence of fir, spruce, pine, cypress, and oak (Table 1).

Finally, it is important to mention the work of Stephan Mols (1999), a Dutch archaeologist who dedicated his doctoral thesis to the study and cataloguing of the wooden furniture of Herculaneum. In total, 44 samples of charred wood, collected from 20 furnishing elements, were identified; beds, sofas, and similar items were the focus of 35 analyses. Of the 44 samples, 39 (88.6%) are white fir (*A. alba*). The hardwoods are represented by only five samples (11% of the total): a slat from a cradle made of oak (*Quercus*), a leg and a tabletop respectively made of boxwood (*Buxus sempervirens* L.) and walnut (*Juglans regia* L.), a leg from a second table made of hornbeam (*Carpinus*), and finally, a board from a chest made of maple (*Acer*).

## 5. Discussion

### 5.1. The Casa del Rilievo di Telefo

Among the many findings brought to light in Herculaneum, the roof and the coffered ceiling of the marble room in the so-called *Casa del Rilievo di Telefo* surely play a prominent role. Indeed, no other examples of a wooden roof with its coffered ceiling exist for the entire Roman world (Adam, 1988; Ulrich, 2007), except for an important discovery in France of a Gallo-Roman sanctuary that has a fir-wood ceiling and sculpted limewood moldings (<https://archeologie.chartres.fr/decouvertes/sites-archeologiques/le-sanctuaire-gallo-romain>). A multidisciplinary study (see Camardo and Notomista, 2010; Camardo et al., 2015; Macchioni et al., 2016) of this artifact is therefore essential to gain information about the roof and ceiling building techniques of the Romans in the 1st century AD.

Its discovery offers the opportunity to tangibly see what before it was only possible to imagine: in fact, our knowledge of Roman wooden roofing and ceiling techniques was so far based on – very few – literary descriptions and iconographic representations. Regarding the latter, the roof models inside the Etruscan underground graves in central Italy provide a good example of the evolution of roof building techniques from the 7th to the 2nd century BC, while the sectional drawing of the “San Paolo fuori le mura” cathedral in Rome informs us about the roofing techniques of the 4th century AD (Adam, 1988). With regard to the Latin literature, we can mostly count on Vitruvius’ “*De Architectura*” for the descriptions of roofing techniques (*De Architectura* 4.2.1 and 5.1.6–10: Krohn, 1912). Concerning the coffered ceiling, expressed in Latin with the words laquearia or lacunaria, we have indications of the use of this particular kind of ceiling both in public and private buildings. The presence of gilded coffered ceilings is attested by Statius (*Silvae* 4.2.31: Mozley, 1928) in one of the halls of the Domitianus’ palace in Rome and by Manilius (*Astronomicum* 5.288–92: Goold, 1977) in temples and sanctuaries. The latter mentions that gilded coffered ceilings were also used in private homes. This fact is confirmed also by Cicero (*De*

*Legibus* 2.2: de Plinval, 1959) and Pliny the Elder (*Naturalis Historia* XXXIII,19: Mayhoff, 1906) who complain about the habit of rich people to build very expensive coffered ceiling in their villas (for a complete review of the literary data see Ulrich, 2007). If the presence of coffered ceilings in the Roman houses is documented in the written sources, nothing is said about the timber employed for their building. Actually, only Vitruvius (*De Architectura* 2.9.13: Krohn, 1912) briefly mentions the timber used in the Temple of Diana at Ephesus and in other temples: “The cedar and the juniper tree have the same uses and good qualities, but, while the cypress and pine yield resin, from the cedar is produced an oil called cedar-oil. The foliage of this tree is like that of the cypress but the grain of the wood is straight. The statue of Diana in the temple at Ephesus is made of it, and so are the coffered ceilings both there and in all other famous fanes, because that wood is everlasting”. From this brief review, it is clear that there is a lack of data regarding this specific aspect of Roman building techniques and, thus, the importance of the roof and ceiling of the *Casa del Rilievo di Telefo* in this field of studies.

The *Casa di Telefo* is a highly luxurious residence, and thus, one might expect a selection of specific wood taxa. However, data related this house show no substantial differences compared to other buildings in Herculaneum; indeed, also in the town silver fir is the most widely used tree, both for timber (86.8%) and for other uses (70.3%; Tables 1 and 2).

## 5.2. *Abies alba* and other softwoods

Silver fir was undoubtedly the “King of Wood” in Herculaneum, because it was extensively used for both structural purposes and furniture, particularly for elements like planks and boards, with a frequency (76.6%) higher than all other species combined. However, this was certainly not the only species available for the uses attested by research; thus, its selection must have had specific reasons. The most plausible is the presence of this tree in the forests of ancient Campania. Today, in Italy, it is found in small, natural populations, mainly at higher altitudes along the entire peninsula, whose southernmost stand is located on Calabrian mountains (Piotti et al., 2017). However, these data cannot be used to know the distribution of this species 2000 yrs ago. Archaeobotanical data from Iron Age to the Middle Ages indicate the presence of wood and charcoal of this species in various lowland sites in peninsular Italy, suggesting that fir must also have been present in hill and lowland forests until recent times (Di Pasquale et al., 2014; Pasta et al., 2020). More generally, the ability of *A. alba* to spread near the Mediterranean coasts in the absence of intense human disturbance has been well demonstrated for at least a decade (Tinner et al., 2013; Walder et al., 2021).

This is an important information, but it is not conclusive to answer the initial question because it is essential to consider the historical period in question. In other words, it cannot be excluded that the massive use of silver fir timber also reflects the existence of an organized supply system operating over long distances, even from regions far away from ancient Campania.

On this purpose, a study on some worked timbers from artifact located in Rome provided some interesting clues. These dendrochronological data concern several deciduous oak planks obtained from trees approximately 300 yrs old, felled between 40 and 60 AD in the Jura region (Bernabei et al., 2019). The authors hypothesized that timbers were floated down the Saône and then the Rhône to the Mediterranean, eventually reaching the Lazio coast by ship.

From this perspective, it is worth mentioning the conclusions regarding dendrochronological data from Herculaneum (Camardo et al., 2015), obtained from the analysis of various types of silver fir samples, mainly structural elements.

The dendrochronological curves derived from these samples show an excellent synchronization with chronologies of firs from southern Germany and the Alps, as previously highlighted by Kuniholm (2002) in initial studies on this topic. However, the lack of master chronologies for

*A. alba* in central and southern Italy prevents definitive conclusions. Additionally, it is known that the growth of *A. alba* mainly reflects macro-regional climatic signals, systematically obscuring local signals (Bernabei, 2024 in this issue).

An argument against the hypothesis of imported fir is its systematic use in all investigated contexts regardless of construction period or wood assortment (e.g. beams, boards, planks). This suggests a large and continuous availability of timber, likely not reliant solely on sourcing from distant regions.

Interestingly, at the Longola site in Poggiomarino (Fig. 1), dating from the Bronze and Iron Ages (15th–13th centuries BC) to the early 6th century BC, located on the plain southeast of Vesuvius, fir planks were frequently found in a context dominated by deciduous oak timber (Cicirelli and Albore Livadie, 2012). On the other hand, several pollen analyses confirm the presence of silver fir in this area (Florenzano et al., 2025 in this issue). The Herculaneum data could then also be interpreted as evidence of a rationalized strategy that involved a systematic exploitation of *A. alba* from low to mid-altitude areas not far from Herculaneum. In addition, the presence of fir wood dated to the 3rd century BC at the Villa of Somma site, on the northern slope of Vesuvius (Fig. 1), clearly indicates that this tree was still present in the vicinity of the volcano some centuries after the AD 79 eruption (Di Pasquale et al., 2010).

On the other hand, the identification of Norway spruce and Norway spruce/European larch, representing 8.9% of the total structural timber (Table 1), demonstrates that a supply system from very distant regions also existed at the time. In fact, European larch is an alpine species typically found at high altitudes (above 1800 m a.s.l.), as is spruce, although it grows at lower altitudes and also exists as a small population in the northern Apennines (Pignatti et al., 2017–2019). These data confirm the use of imported timber in the Vesuvius area during Roman times, as indicated by the timber (only one a beam) from the Villa of Poppaea at Oplontis, not far from Herculaneum (Moser et al., 2013). The finding of European larch is even rarer, having been documented only in Herculaneum (Fioravanti and Caramiello, 1999).

Kuniholm (2002) documents the presence of a carpenter workshop in Herculaneum, describing and sampling a “wood pile with a mixture of fir, spruce, and pine, occasional cypress, and a bit of oak, with some timbers showing signs of use and reuse”. If the order of species listed reflects their respective amounts, the reference to spruce suggests it was not a minor component.

It is important to remember that long-distance timber transport is already documented for much earlier periods in the ancient world by Meiggs in the chapter dedicated to the timber transport (Meiggs, 1982), who refers to trunks floated down the Euphrates from Lebanon to reach Babylon.

Regarding Greece, he cites Theophrastus, who lists the best timber-sourcing regions for the Greek world in this order: Macedonia, followed by the Pontus region and in particular the southern coast of the Black Sea, and finally the Rhynacus River region (now Mustafake-malpasha) in the south of the Sea of Marmara (Meiggs, 1982). During the early Roman period in Jerusalem, data clearly shows the use of local conifers (pines and cypresses) as well as imported conifers (Lebanon cedar) for construction purposes (Roth et al., 2019).

It is known that Pliny the Elder describes 30 m long trunks dragged down from the Apennines by ten or fifteen mules, then transported to Rome on the Tiber (Diosono, 2023); is this an implausible exaggerated claim? In our opinion, it is clear that timber, even large trunks, could travel long distances because, throughout the ancient world, there were skills and technologies—of which we likely have little idea—comprising machines, systems, and methods that allowed transport by river, sea, and land, as well as knowledge of different types of timber and the forests in which they grew, enabling the supply of necessary wood in both quality and quantity.

By the first century BC, in Italy and not far from Rome, this combination of resources was available. One only needs to consider how much

more complex technical challenges were tackled and resolved during these centuries, such as those related to constructing large buildings, requiring architects skilled in construction practices and machines capable of moving and lifting tons of stone, transported to Rome by ships suitable for the sea and able to carry truly heavy loads. In fact, Pliny the Elder defines the transport of Egyptian obelisks to Rome “*miracula romana*” considered such a hard task to induce to store in the port of Pozzuoli the ship which first achieved it (Di Pasquale, 2018). Compared to this type of problems, fulfilling Tiberius’s order to transport large larch trunks from the Raetian Alps (Eastern Alps) to Rome (Meiggs, 1982) would not have been particularly difficult to accomplish.

Overall the data clearly indicate that silver fir was by far the most widely used species and that it was present in the area even a few centuries after the eruption. It is plausible that the collapse of *A. alba*, which disappeared around the mid-Holocene from coastal and lowland forests in various areas of the Tyrrhenian coast due to human impact (Tinner et al., 2013 and references therein; Bellotti et al., 2016; Clò et al., 2024; Furia et al., 2024), occurred here a few millennia later. The presence of timber in Herculaneum with a confirmed Alpine origin leaves open the possibility of sourcing from regions far from the Vesuvius area, though this seems unlikely from an economic standpoint, as such a substantial and systematic import from far regions would make little sense given the availability of excellent hardwoods locally abundant both on the Vesuvius and in surrounding forests.

In Herculaneum, the second most used taxa for structural timber is cypress, representing 14.7% and used almost exclusively as poles (Table 1). In other non structural uses, its presence drops to 3.7%. Also in this case this finding is unexpected because botanists have traditionally considered cypress to be native to the Middle East and eastern Mediterranean, believed to have been introduced to Italy in ancient, unspecified times (Pignatti et al., 2017-2019), primarily for its ritual significance (Weick et al., 2023). Interestingly *C. sempervirens* is recently classified as “naturalised archaeophyte” (Galasso et al., 2018). However, recent genetic analyses have hypothesized that cypress might be a native species in Italy that today lives exclusively in the Fontegreca forest on the southern slopes of the Matese, in the southern Apennine (Bagnoli et al., 2009). A recent archaeobotanical review of *C. sempervirens* highlighted that it indeed was present in various Italian regions until historical times (D’Auria et al., 2020). Returning to Herculaneum, the use of this tree for supplying unshaped poles suggests that these trees may still have been locally available.

Where? A possible and unexpected answer is found in a scientific report titled “*Rapporto alla Reale Accademia delle Scienze intorno a taluni alberi trovati nel bacino del Sarno*” dated September 7, 1858 (Tenore et al., 1858). This truly multidisciplinary research work was carried out by a group of professors from the University of Naples: Luigi Palmieri, seismologist and volcanologist; Arcangelo Scacchi, geologist; Oronzo Gabriele Costa, zoologist; and Michele Tenore, botanist. The reason: the discovery during the construction of the new channel of the Sarno River near Scafati, not far from Herculaneum, of about a hundred tree trunks buried by the AD 79 eruption. In the chapter dedicated to botany (*Notizie botaniche*), Tenore describes the method used to identify the species of these trees, specifying that it was finally possible “with the help of new powerful microscopes”.

This is a very interesting document because it attests to the presence of a cypress plantation likely intended for timber production. Here, it is worth quoting Pliny the Elder: “*both male and female cypresses produce poles and stakes sold at one denarius each, making it a tree that yields a significant profit relative to the investment required for its cultivation; the ancients called cypress plantations dowry for the daughter*”. The quincunx planting identified 166 yrs ago near Scafati thus provides a possible answer to the question of the origin of the cypress beams used in Herculaneum; overall, the data seem to document an example of arboriculture intended for pole production.

As regards the other conifers, no definitive conclusions can be drawn on the significance of their presence due to the scarce available data.

### 5.3. Hardwoods

Overall, hardwoods represent only 7% of the structural wood samples and 15% of samples of no structural uses. These are extremely low values when considering the percentages of each taxon, but however it is possible to attempt an interpretation of this data. Let’s consider the three species that were common in the surrounding forests in the past and that provide excellent timber: deciduous oaks, chestnut (*C. sativa*), and beech (*F. sylvatica*). For structural uses, chestnut accounts for 3.1% of the total samples analyzed, deciduous oaks 1.6%, and beech 0.6%. For non structural uses, beech is absent, while deciduous oaks and chestnut reach values of 5.5% and 3.1%, respectively.

It is important to note that in most of Europe during Roman times, deciduous oak remained a highly valued and widely used hardwood for construction timber (Bernabei et al., 2019; Durand, 2002; Haneca et al., 2009; Krebs et al., 2022; Tegel et al., 2022).

Data on the use of firewood of Pompeii (Veal, 2014) provides further useful information; both the taxa, *Quercus* deciduous and *F. sylvatica*, are well represented, especially the last constituted about 50% of the fuel supply. Notably, beech was very common also at lower elevations than its current distribution even in this area until recent times (Buonincontri et al., 2023). *Q. pubescens*, likely the most common deciduous oak 2000 yrs ago, was probably used not only for firewood but also to produce acorn for pig farming (e.g., MacKinnon, 2001) and this explains its scarce presence.

The very limited use of chestnut wood is coherent with the general framework provided by archaeobotanical data relating to Vesuvian coastal sites; *C. sativa* remains is notably scarce, even as carpological remain (D’Auria and Di Pasquale, 2025 in this issue). However, anthracological data from two sites on the northern slope of Vesuvius, buried by the eruption of AD 472, indicate a significant and consistent use of this wood from the 1st to the 5th century AD, both for structural purposes and for fuel (Di Pasquale et al., 2010), suggesting a locally abundant presence of chestnut.

Regarding wood used for furniture, therefore for furnishing artifacts that could also include wood of particular value, the available data are too scarce (Mols, 1999); it is reasonable to hypothesize that some hardwoods in this case found more use, given their better workability and superior aesthetic characteristics.

It is important to underline that the work of Mols (1999) aimed to focus on formal aspects of furnishings, thus the data concerning the wood used have a relative importance for the author. Furthermore, Mols primarily analyzes beds, sofas, and similar items, examining boards and small planks, which, in any case, could not effectively be useful to identify the use of high quality woods and again confirms the large use of fir.

The samples of walnut (*Juglans regia*) and boxwood (*Buxus sempervirens*) used for the legs of a table represent, in a certain sense, the only two truly useful data points for interpreting the cabinetmaker’s work from the perspective of wood selection; both species provide particularly valuable woods in terms of workability and aesthetic yield, confirming a profound and specific knowledge of the properties of various woods in the field of cabinetmaking. Despite the limited data, it is already evident that for his work, the cabinetmaker also utilized trees cultivated in the surrounding countryside, and perhaps, as suggested by the presence of boxwood, also small trees from gardens (Florenzano et al., 2025 in this issue).

Walnut was introduced approximately 4000 yrs ago and more recently around 2800-2500 yrs ago in Western Europe and subsequently in Italy; this tree is well represented in the palynological records of the Po Plain since the Middle Bronze Age (Florenzano et al., 2025 in this issue; Mercuri et al., 2013, 2015; Pollegioni et al., 2017). It is well known that in the countryside around Vesuvius, it was commonly cultivated for walnut production at the time of the eruption (see also the papers by D’Auria, Di Pasquale, and Mariotti Lippi in this volume); the characteristics of its wood, which is fine grained, easy to work and

aesthetically valued, were well known to artisans of the time.

In the case of boxwood, the situation is different because it is a shrub or small tree that is extremely rare in Italy in nature, both now and 2000 yrs ago (Di Domenico et al., 2011). Boxwood rarely reaches 4 m in height and grows very slowly, limiting the use of this wood to the creation of small objects. Its main characteristics include a light-yellow colour, very fine grain, and hardness, making it a highly sought-after carving wood. The use of boxwood for the creation of prestigious objects is very ancient and is well documented throughout the archaeological areas of the Near East (Meiggs, 1982).

In the Roman Jerusalem, the presence of boxwood is interpreted as “occurrence of prestigious imported tree species (Roth et al., 2019).” It is also interesting to note a similar use in central France at the Roman site of Augustonemetum (Blondel and Mille, 2020; Blondel et al., 2021), as well as in Populonia on the Tuscan coast in a context from the 1st century B.C., where it was used for the leg of a stool (Mauro Paolo Buonincontri, pers. comm.).

Overall, the data suggest a highly rationalized use of wood from various species, predominantly of silver fir, which, in our view, must have still been abundant in the surrounding forests. Deciduous oaks and beech were likely managed for firewood production, which explains the low percentages recorded for both taxa.

The use of wood, as derived from our data, provides fairly precise indications regarding the management of forests during that time: it is likely that beech forests were managed through coppicing, while for oak groves predominantly composed of *Quercus pubescens*, we can imagine stands for acorn production intended for grazing. The presence of cypress plantations is an extremely interesting piece of information because it confirms the level of specialization in timber production achieved 2000 years ago in these territories. Finally, regarding the silver fir, our hypothesis is that for the ‘local’ origins, one could imagine a mixed forest where this tree grew alongside other mesophilic broadleaf species.

## 6. Conclusions

Our data indicate that in Herculaneum the use of wood was characterized by a high level of organization, both in terms of taxon selection and supply chain management. The available data have clearly highlighted that, in this region, silver fir wood was by far the preferred choice for crafting everything, from small furniture pieces to large structural timbers for building construction. This is an unexpected finding for a species that is currently considered montane in Italy.

The provenance of this timber is still unknown; however, the presence of *Picea* and *Larix* in the structural timber suggests that the possibility of transport from distant regions, such as the Alps, should also be considered. In general, the strong preference of ancient carpenters for softwoods is evident; in fact, the second most used species was cypress, which was mainly employed for small poles in roofing structures. It is interesting to note that this tree was likely cultivated in the plains surrounding Vesuvius.

The extremely limited use of hardwoods is also surprising, given that it is well documented that deciduous oaks, chestnut, and beech were present and abundant in the Vesuvius area and its surroundings. On the other hand, we know that beech was selectively used as firewood, while the scarcity of oak timber might indicate that these trees were primarily preserved for acorn production to feed pigs.

The overall picture suggests a significant rationalization in the use of forest resources, with specific purposes likely relying both on timber supply from forests located in regions near or far and on local cultivation. At present, we do not know whether this model of forest resource use should be considered local to the ancient Campania region or if it is applicable to a broader territorial area. A more precise reconstruction will likely only be possible once we understand the forests from which the silver fir timber originated, which, as demonstrated, accounts for almost 80% of the samples considered in this study. This will be

achievable in the future using techniques such as ancient DNA analysis, strontium isotopes, and, not least, a more extensive and systematic dendrochronological approach.

## CRedit authorship contribution statement

**Alessia D'Auria:** Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Conceptualization. **Salvatore Pasta:** Writing – review & editing, Validation, Formal analysis. **Gaetano Di Pasquale:** Writing – review & editing, Validation, Supervision, Conceptualization.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

The author is an Editorial Board Member/Editor-in-Chief/Associate Editor/Guest Editor for *[Quaternary International]* and was not involved in the editorial review or the decision to publish this article.

## Acknowledgements

The authors fondly remember the memory of Daniela Moser.

We would like to express our gratitude to the Archaeological Park of Herculaneum for their support and for granting us access and study their invaluable wood material.

We wish also thanks the Organizing Committee of the Conference “79 d.C., Il contributo della botanica alla più grande avventura archeologica della storia” for giving us the opportunity to present this study. Finally we sincerely thank the reviewers for their valuable comments and suggestions, which have helped improve the quality of our work.

## References

- Adam, J.-P., 1988. *L'arte di costruire presso i romani. Materiali e tecniche*. Longanesi, Milano.
- Anagnost, S.E., Meyer, R.W., de Zeeuw, C., 1994. Confirmation and significance of Bartholin's method for the identification of the wood of *Picea* and *Larix*. *IAWA J.* 15 (2), 171–184.
- Bagnoli, F., Vendramin, G.G., Buonamici, A., Doulis, A.G., Gonzales-Martinez, C., La Porta, N., Magri, D., Raddi, P., Sebastiani, F., Fineschi, S., 2009. Is *Cupressus sempervirens* native in Italy? An answer from genetic and palaeobotanical data. *Mol. Ecol.* 18, 2276–2286.
- Barham, L., Duller, G.A.T., Candy, I., Scott, C., Cartwright, C.R., Peterson, J.R., Kabukcu, C., Chapot, M.S., Melia, F., Rots, V., George, N., Taipale, N., Gethin, P., Nkombwe, P., 2023. Evidence for the earliest structural use of wood at least 476,000 years ago. *Nature* 622, 107–111. <https://doi.org/10.1038/s41586-023-06557-9>.
- Bartholin, T., 1979. The *Picea-Larix* problem. *IAWA (Int. Assoc. Wood Anat.) Bull.* 7–10.
- Bellotti, P., Calderoni, G., Dall'Aglio, P.L., D'Amico, C., Davoli, L., Di Bella, L., D'Orfice, M., Esu, D., Ferrari, K., Bandini Mazzanti, M., Mercuri, A.M., Tarragoni, C., Torri, P., 2016. Middle-to late-Holocene environmental changes in the Garigliano delta plain (Central Italy): which landscape witnessed the development of the *Minturnae* Roman colony? *Holocene* 26, 1457–1471. <https://doi.org/10.1177/0959683616640055>.
- Bernabei, M., Bontadi, J., Rea, R., Büntgen, U., Tegel, W., 2019. Dendrochronological evidence for long-distance timber trading in the Roman Empire. *PLoS One* 14–12, e0224077.
- Bernabei, M., 2024. The timber trade in the Vesuvian area before 79 AD as inferred from dendrochronological research at Moregine site. *Quat. Int.* 706, 1–6. <https://doi.org/10.1016/j.quaint.2024.05.011>.
- Blondel, F., Girardclos, O., 2018. Approche dendroarchéologique de l'approvisionnement de la ville antique d'Augustonemetum en bois d'œuvre et exploitation forestière. *ArchéoSciences* 42, 17–33.
- Blondel, F., Mille, P., 2020. Les mobiliers antiques en bois découverts à Clermont-Ferrand (Puy-de-Dôme). *Grands ensembles de petit mobilier: méthodes et résultats, actes de la table ronde Corpus. Clermont-Ferrand* 67, 59–67.
- Blondel, F., Cabanis, F., Guittou, V., Lecomte-Schmitt, B., 2021. La place et l'utilisation du buis durant l'Antiquité en Gaule. 14e rencontres d'archéobotanique “Actualité, expérimentation, frontières, synergies”. Bruxelles, Belgique. Hal-03508540.
- Buonincontri, M.P., Bosso, L., Smeraldo, S., Chiusano, M.L., Pasta, S., Di Pasquale, G., 2023. Shedding light on the effects of climate and anthropogenic pressures on the disappearance of *Fagus sylvatica* in the Italian lowlands: evidence from archaeo-anthropology and spatial analyses. *Sci. Total Environ.* 877, 162893. <https://doi.org/10.1016/j.scitotenv.2023.162893>, 15.

- Camardo, D., Casieri, M.B., D'Andrea, A., Heussner, K.U., Kastenmeier, P., Notomista, M., 2015. Study of the wood from the roof and ceiling of the house of the Telephus relief in Herculaneum. *Mitteilungen des Deutschen Archäologischen Instituts Römische Abteilung* 121, 269, 31.
- Camardo, D., Notomista, M., 2010. Lo scavo e il recupero del tetto in legno dell'amb. 18 della Casa del Rilievo di Telefo. *Riv. Studi Pompei*. 21, 154–155.
- Chemello, C., Davis, S., 2014. Dry/Desert conditions: preservation and conservation. In: Smith, C. (Ed.), *Encyclopedia of Global Archaeology*. Springer, New York, pp. 465–493. [https://doi.org/10.1007/978-1-4419-0465-2\\_493](https://doi.org/10.1007/978-1-4419-0465-2_493).
- Cicirelli, C., Albore Livadie, C., 2012. L'abitato protostorico di Poggiomarino: Località Longola, campagne di scavo 2000–2004. *L'Erma di Bretschneider*, Roma.
- Clò, E., Furla, E., Florenzano, A., Mercuri, A.M., 2024. Flora-vegetation history and land use in Medieval Tuscany: the Palynological evidence of a local biodiversity heritage. *Quat. Int.* 705, 1–15.
- Coles, J., Heal, S., Orme, B., 1978. The use and character of wood in prehistoric Britain and Ireland. *Proc. Prehist. Soc.* 44, 1–45. <https://doi.org/10.1017/S0079497X0000996>.
- Cona, F., Di Pasquale, G., 2007. I boschi del Parco Nazionale del Vesuvio. In: Nardi, G., Vomero, V. (Eds.), *Artropodi del Parco Nazionale del Vesuvio: ricerche preliminari. Conservazione Habitat Invertebrati*, vol. 4. Cierre Grafica Editore, Verona, pp. 39–51.
- 109745, 1–11 D'Auria, A., Di Pasquale, G., n.d.. The Unknown Archaeobotany. The great "Collezione dei Commestibili e degli Avanzi Organici" of the National Archaeological Museum of Naples (southern Italy). *Quat. Int.*
- D'Auria, A., Teobaldelli, M., Di Pasquale, G., 2020. The late Holocene history of cypress (*Cupressus sempervirens* L.) in the Italian peninsula: new perspectives from archaeobotanical data. *Holocene* 30–2, 210–217.
- de Plinval, G., 1959. De Legibus. *Belles Lettres*, Paris. <http://www.perseus.tufts.edu>. (Accessed 10 April 2014).
- Di Domenico, F., Lucchese, F., Magri, D., 2011. Late glacial and Holocene history of *Buxus sempervirens* L. in Italy. *Ann. Bot. Roma* 1, 45–58.
- Di Pasquale, G., Allevato, E., Russo Ermolli, E., Coubray, S., Lubritto, C., Marzaioli, F., Yoneda, M., Takeuchi, K., Kano, Y., Matsuyama, S., De Simone, G.F., 2010. Reworking the idea of chestnut (*Castanea sativa* Mill.) cultivation in Roman times: new data from ancient Campania. *Plant Biosyst.* 144, 865–873. <https://doi.org/10.1080/11263504.2010.491974>.
- Di Pasquale, G., Allevato, E., Cocchiara, A., Moser, D., Pacciarelli, M., Saracino, A., 2014. Late Holocene persistence of *Abies alba* in low-mid altitude deciduous forests of central and southern Italy: new perspectives from charcoal data. *J. Veg. Sci.* 25, 1299–1310. <https://doi.org/10.1111/jvs.12196>.
- Di Pasquale, G., 2018. Traiano, Apollodoro e Roma. In: Di Pasquale, G. (Ed.), *L'arte di costruire un capolavoro: la colonna traiana*. Giunti, Firenze, pp. 90–101.
- Diosono, F., 2023. The timber trade and transport in Roman Italy. In: Bentz, M., Heinzlmann, M. (Eds.), *Archaeology and Economy in the Ancient World* 54. Propylaeum, Heidelberg, pp. 153–170. <https://doi.org/10.11588/propylaeum.1005.c13480>.
- Durand, A., 2002. Elements for a cultural history of wood in southern France (Xth–XVIII centuries). In: Thiébaud, S. (Ed.), *Charcoal Analysis. Methodological Approaches, Palaeoecological Results and Wood Uses, Proceedings of the Second International Meeting of Anthracology*. Archeopress, Paris, pp. 261–266. Paris, 13th–16<sup>th</sup> September 2000.
- Fioravanti, M., Caramiello, R., 1999. Il legno e la sua lavorazione. In: Ciarallo, A., De Carolis, E. (Eds.), *Homo faber. Natura, scienza e tecnica nell'antica Pompei*. Electa, Milano, pp. 85–86.
- Florenzano, A., Torri, P., Bosi, G., Clò, E., Caprio, P., Mercuri, A.M., 2025. Snapshots from the past: biodiversity of the Vesuvian area before AD 79 from new archaeopalynological studies. *Quat. Int.* 719, 109669. <https://doi.org/10.1016/j.quaint.2025.109669>.
- Furla, E., Clò, E., Florenzano, A., Mercuri, A.M., 2024. Human-induced fires and land use driven changes in tree biodiversity on the northern Tyrrhenian coast. *Quat. Int.* 705, 37–52. <https://doi.org/10.1016/j.quaint.2023.12.002>.
- Galasso, G., Conti, F., Peruzzi, L., Ardenghi, N.M.G., Banfi, E., Celesti-Grappo, L., Albano, A., Alessandrini, A., Bacchetta, G., Balelli, A., Bandini Mazzanti, M., Barberis, G., Bernardo, L., Blasi, C., Bouvet, D., Bovio, M., Cecchi, L., Del Guacchio, E., Domina, G., Fascetti, S., Gallo, L., Gubellini, L., Guiggi, A., Iamonicò, D., Iberite, M., Jiménez-Mejías, P., Lattanzi, E., Marchetti, D., Martinetto, E., Masin, R.R., Medagli, P., Passalacqua, N.G., Peccenini, S., Pennesi, R., Pierini, B., Podda, L., Poldini, L., Prosser, F., Raimondo, F.M., Roma-Marzio, F., Rosati, L., Santangelo, A., Scoppola, A., Scortegagna, S., Selvaggi, A., Selvi, F., Soldano, A., Stinca, A., Wagensommer, R.P., Wilhelm, T., Bartolucci, F., 2018. An updated checklist of the vascular flora alien to Italy. *Plant Biosyst.* 152, 556–592. <https://doi.org/10.1080/11263504.2018.1441197>.
- Goold, G.P., 1977. *Manilius. Astronomica*. Harvard University Press, Cambridge.
- Greguss, P., 1955. Identification of Living Gymnosperms on the Basis of Xylotomy. *Akadémiai Kiado, Budapest*.
- Greguss, P., 1959. *Holzanatomie der Europäischen Laubbölzer und Sträucher*. Akadémiai Kiadó, Budapest.
- Guidobaldi, M.P., 2006. Ercolano. In: Pesando, F., Guidobaldi, M.P. (Eds.), *Pompei Oplontis Ercolano Stabiae*. Editor Laterza, Roma-Bari, pp. 287–407.
- Haneca, K., Cufar, K., Beckmann, H., 2009. Oaks, tree-rings and wooden cultural heritage: a review of the main characteristics and applications of oak dendrochronology in Europe. *J. Archaeol. Sci.* 36, 1–11.
- Krebs, P., Ulmke, F., Tinner, W., Conedera, M., 2022. The Roman legacy on European chestnut and walnut arboriculture. *Environ. Archaeol.* <https://doi.org/10.1080/14614103.2022.2137648>.
- Krohn, F., 1912. *On Architecture*. Teubner, Lipsiae. <http://www.perseus.tufts.edu>. (Accessed 10 April 2024).
- Kuniholm, P.L., 2002. Dendrochronological investigation at Herculaneum and Pompeii. In: Jashemski, W.F., Meyer, F.G. (Eds.), *The Natural History of Pompeii*. Cambridge University Press, Cambridge, pp. 235–239.
- Macchioni, N., Pizzo, B., Capretti, C., Pecoraro, E., Sozzi, L., Lazzeri, S., 2016. New wooden archaeological finds from Herculaneum: the state of preservation and hypothesis of consolidation of the material from the House of the Relief of Telephus. *Archaeometry* 58, 1024–1037. <https://doi.org/10.1111/arc.12213>.
- MacKinnon, M., 2001. High on the hog: linking zooarchaeological, literary, and artistic data for pig breeds in Roman Italy. *Am. J. Archaeol.* 105, 649–673. <https://doi.org/10.3764/aja.105.4.649>.
- Mayhoff, K.F.T., 1906. *Naturalis Historia*. Teubner, Lipsiae. <http://www.perseus.tufts.edu>. (Accessed 10 April 2024).
- Meiggs, R., 1982. *Trees and Timber in the Ancient Mediterranean World*. Clarendon Press, Oxford.
- Mercuri, A.M., Bandini Mazzanti, M., Florenzano, A., Montecchi, M.C., Rattighieri, E., 2013. *Olea, Juglans and Castanea*: the OJC group as pollen evidence of the development of human-induced environments in the Italian peninsula. *Quat. Int.* 303, 24–42. <https://doi.org/10.1016/j.quaint.2013.01.005>.
- Mercuri, A.M., Montecchi, M.C., Pellacani, G., Florenzano, A., Rattighieri, E., Cardarelli, A., 2015. Environment, human impact and the role of trees on the Po plain during the Middle and Recent Bronze Age: pollen evidence from the local influence of the *terramare* of Baggiovara and Casalballo. *Rev. Palaeobot. Polynol.* 218, 231–249. <https://doi.org/10.1016/j.revpolbo.2014.08.009>.
- Mols, S.T.A.M., 1999. *Wooden Furniture in Herculaneum. Form, Technique and Function*. Gielen, Amsterdam.
- Moser, D., Allevato, E., Clarke, J.R., Di Pasquale, G., Nelle, O., 2013. Archaeobotany at Oplontis: woody remains from the Roman villa of Poppaea (Naples, Italy). *Veg. Hist. Archaeobotany* 22, 397–408.
- Moser, D., Nelle, O., Di Pasquale, G., 2018. Timber economy in the Roman Age: charcoal data from the key site of Herculaneum. *Archaeol. Anthropol. Sci.* 10, 905–921. <https://doi.org/10.1007/s12520-016-0406-0>.
- Mozley, J.H., 1928. *Stattus*, vol. 1. William Heinemann, London. <http://www.perseus.tufts.edu>. (Accessed 10 April 2024).
- Nardi Berti, R., Fioravanti, M., Macchioni, N., 2006. La struttura anatomica del legno ed il riconoscimento dei legnami italiani di più corrente impiego. CNR, Firenze.
- Oeggli, K., 2009. The significance of the tyrolean iceman for the archaeobotany of central Europe. *Veg. Hist. Archaeobotany* 18, 1–11.
- Pasta, S., Sala, G., La Mantia, T., Bondi, C., Tinner, W., 2020. The past distribution of *Abies nebrodensis* (Lojac.) Mattei: results of a multidisciplinary study. *Veg. Hist. Archaeobotany* 29–3, 357–371. <https://doi.org/10.1007/s00334-019-00747-0>.
- Pensa, A., Giordano, G., Corrado, S., et al., 2023. A new hazard scenario at Vesuvius: deadly thermal impact of detached ash cloud surges in 79CE at Herculaneum. *Sci. Rep.* 13, 5622. <https://doi.org/10.1038/s41598-023-32623-3>.
- Pignatti, S., Guarino, R., La Rosa, M., 2017–2019. *Flora D'Italia*, second ed. Edagricole - Business Media, Bologna - Milano, 4 vols.
- Piotti, A., Leonarduzzi, C., Postolache, D., Bagnoli, F., Spanu, I., Brousseau, L., Urbinati, C., Leonardi, S., Vendramin, G.G., 2017. Unexpected scenarios from Mediterranean refugial areas: disentangling complex demographic dynamics along the Apennine distribution of silver fir. *J. Biogeogr.* 44 (7), 1547–1558.
- Pollegioni, P., Woeste, K., Chiocchini, F., Del Lungo, S., Ciolfi, M., Olimpieri, I., et al., 2017. Rethinking the history of common walnut (*Juglans regia* L.) in Europe: its origins and human interactions. *PLoS One* 12, e0172541. <https://doi.org/10.1371/journal.pone.0172541>.
- Quézel, P., Médail, F., 2003. *Ecologie et biogéographie des forêts du bassin méditerranéen*. Elsevier, Paris.
- Rizzi, G., 2005. Il problema degli antichi elementi lignei ad Ercolano. In: Tampone, G. (Ed.), *Conservation of Historic Wooden Structures. Proceeding of the International Conference (Firenze, 22-27 February 2005)*. Collegio degli Ingegneri della Toscana, Firenze, pp. 50–51.
- Roth, H., Gadot, Y., Langgut, D., 2019. Wood economy in early Roman period Jerusalem. *BASOR* 382, 17–33. <https://doi.org/10.1086/705729>.
- Schweingruber, F.H., 1990. *Anatomy of European Woods*. Haupt, Bern.
- Stepka, Z., Azuri, I., Horwitz, L., Chazan, M., Natalio, F., 2022. Hidden signatures of early fire at evron quarry (1.0 to 0.8 mya). *Proc. Natl. Acad. Sci. USA* 119, e2123439119. <https://doi.org/10.1073/pnas.2123439119>.
- Talon, B., 1997. Etude anatomique et comparative de charbons de bois de *Larix decidua* Mill. and *Picea abies* (L.) Karst. *Compte Rendu à l'Académie des Sciences de Paris. Sciences de la vie* 320, 581–588.
- Tegel, W., Muigg, B., Skiadaresis, G., Vanmoerkerke, J., Seim, A., 2022. Dendroarchaeology in Europe. *Frontiers in Ecology and Evolution* 10, 823622.
- Tenore, M., Scacchi, A., Costa, O.G., Palmieri, L., 1858. Rapporto alla Reale Accademia delle Scienze intorno a taluni alberi trovati nel bacino del Sarno. *Annali delle Bonificazioni che si vanno operando nel Regno delle Due Sicilie* 1, 2.
- Tinner, W., Colombaroli, D., Heiri, O., Henne, P.D., Steinacher, M., Untenecker, J., et al., 2013. The past ecology of *Abies alba* provides new perspectives on future responses of silver fir forests to global warming. *Ecol. Monogr.* 83, 419–439. <https://doi.org/10.1890/12-2231.1>.
- Toupanaki, E., Shah, D.U., Eichhorn, S.J., 2021. Beyond what meets the eye: imaging and imagining wood mechanical-structural properties. *Adv. Mater.* 33, 2001613.
- Ulrich, R.B., 2007. *Roman Woodworking*. Yale University Press, New Haven and London.
- Veal, R., 2014. Pompeii and its hinterland connection: the fuel consumption of the house of the vestals (c. Third century BC to AD 79). *Eur. J. Archaeol.* 17, 27–44.

Walder, D., Krebs, P., Bugmann, H., et al., 2021. Silver fir (*Abies alba* Mill.) is able to thrive and prosper under meso-Mediterranean conditions. *For. Ecol. Manage.* 498, 119537. <https://doi.org/10.1016/j.foreco.2021.119537>.

Wallace-Hadrill, A., 2011. *Herculaneum. Past and Future*. Frances Lincoln, London.

Weick, C.W., Aamir, N., Reichart, J., 2023. The ethnobotanical evolution of the Mediterranean Cypress (*Cupressus sempervirens*). *Econ. Bot.* 77 (2), 203–221.