Quaternary International 706 (2024) 1–6

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

The timber trade in the Vesuvian area before 79 AD as inferred from dendrochronological research at Moregine site

Mauro Bernabei

CNR-IBE, Institute for BioEconomy, National Research Council, S. Michele all'Adige, TN, Italy

ARTICLE INFO

Keywords:
Moregine
Pompei
Dendroarchaeology
Dendroprovenance
Silver fir
Timber trade

ABSTRACT

The substantial volume of timber recovered from the aftermath of the eruption of Vesuvius in 79 AD offers a valuable resource for gaining insights into the timber trade during Roman times. Silver fir emerges as the dominant species in construction within the Vesuvian region. While this species once thrived more abundantly along the Apennines, it now exists only in small, isolated groups, raising the possibility that the Romans contributed to its scarcity. Nevertheless, the origins of the substantial quantity of silver fir wood discovered in Pompeii, Herculaneum, and the surrounding areas remain unclear. This study examines 35 wood samples obtained during the excavation of the Moregine site, an ancient commercial port located a mere 600 m to the south of Pompeii's walls. Dendrochronological analysis successfully dated 19 out of the 35 samples. Despite silver fir not being the ideal species for dendroprovenancing analysis, certain observations can be made regarding its likely foreign origin. The correlation with chronologies of different species of Central European origin, the presence of species such as spruce/larch among the structural material and the existence of different groups among the material analysed are strong indications that demonstrate the foreign origin of at least some of the timber. Dendrochronological data further support that the wood trade played a strategically significant role in the economy of ancient Rome.

1. Introduction

The abundance of wood samples that have come down to us in the wake of the eruption of Vesuvius in 79 AD is immense, presenting a truly unparalleled opportunity for in-depth study. This extensive collection offers a detailed glimpse into the diverse uses of wood, the technical expertise of the time, and the economic resources available in one of the most prosperous regions of antiquity.

During Roman times, the region of Campania thrived exceptionally, adorned with opulent villas that served as hubs for the arrival of a wide array of goods through its ports. The fertile hinterland of the region yielded the finest natural products (De Vos and De Vos, 1982).

Among the myriad wood species unearthed in Vesuvian excavations, a fascinating array of local and imported varieties emerges, frequently harmoniously interwoven in finely crafted furniture and intricately turned decorative elements. These creations astonish with their skilful utilization of woodworking techniques, as highlighted by Mols (2008). Particularly noteworthy is the extensive use of silver fir (*Abies alba* Mill.) in structural components. Vitruvius, in his treatise "De architectura" (II, chap. 9–10; 30–15 BCE), clearly elucidates why silver fir held a preferred status in construction: it boasts lightweight wood (with a density of 450 kg/m^3 at standard humidity of 12%, as opposed to, for instance, oak's 820 kg/m^3), resulting in lengthy, unblemished trunks with minimal knots. In the Vesuvian region, the prevalence of silver fir in structural applications is so significant that "… (it) was employed for almost all of the different building elements" (Moser et al., 2018).

Presently, silver fir can be found in central and southern Italy, where it grows in small clusters within the Apennines, primarily at elevations exceeding 1000 m above sea level (Fig. 1; Wolf, 2003), but it can also reach lower altitudes, up to around 500 m above sea level, as in some small woodlands in Tuscany, often the result of monastic cultivation (Bernetti, 1995). However, despite its current scattered distribution, the wealth of archaeobotanical and palaeoecological data available for central and southern Italy unmistakably reveals that, until the Late Holocene, silver fir inhabited a broader expanse of Italy than it does today (Mercuri et al., 2012; Di Pasquale et al., 2014a). This decline is likely attributable to human exploitation of timber, as corroborated by several authors (e.g., Tinner et al., 2013; Di Pasquale et al., 2014b; Sadori et al., 2015). Historical data also indicate that silver fir once grew at lower altitudes than it does today, coexisting with deciduous oaks

E-mail address: mauro.bernabei@ibe.cnr.it.

https://doi.org/10.1016/j.quaint.2024.05.011
Received 3 April 2024; Received in revised form 9 May 2024; Accepted 27 May 2024
Available online 30 May 2024

(*Quercus* spp.) and other mesophilic broadleaves (Di Pasquale et al., 2014a; Palli et al., 2023). Traces of a greater spread at lower elevations also result from archive documents or toponymic evidence (Bernetti, 1995). These observations suggest that the substantial quantity of silver fir utilized in the Vesuvian region for construction purposes – spanning beams, planks, posts, cladding, door and window frames – resulted from the exploitation of nearby Apennine silver fir forests. Anthropogenic disturbance may have mainly affected low-elevation forests and thus be the cause of the current fragmentation and retreat of silver fir to higher, more isolated sites (cf. Tinner et al., 2013).

Nonetheless, the dendrochronological investigations conducted on the silver fir specimens unearthed in the Pompeii and Herculaneum excavations shed light on an additional dimension. Remarkably, these studies have unveiled exceedingly strong statistical correlations between the tree-ring patterns of Vesuvian fir woods and reference series originating from regions beyond the Alps, notably from Austria (Kuniholm, 2002). Consequently, these findings suggest the long-distance importation of a substantial volume of silver fir timber for use in construction within Pompeii and Herculaneum.

Building upon the insights derived from dendrochronological analysis of the timbers discovered at the Moregine excavation site, this study endeavours to re-evaluate the prospect of substantial silver fir timber imports. Furthermore, the findings will be scrutinized for their implications concerning the timber trade and the economic dynamics of the Roman era. This study, based on unpublished data, finally aims to emphasise the great value of archaeological wood finds, which can greatly enrich our understanding of many aspects of life in antiquity.

2. Material and methods

2.1. The Moregine site

The site of Moregine is situated approximately 600 m south of the walls of Pompeii, near the mouth of the River Sarno and the ancient trading port. It was discovered in 1959 during construction work on the Naples-Salerno motorway. The excavation unveiled a porticoed courtyard, which was overlooked by at least five frescoed triclinia and baths that were still under construction at the time (Scarano Ussani, 2005). These paintings can be dated back to the Neronian age and were produced by the same workshop that decorated the more famous House of the Vettii in Pompeii. The building was owned by the Sulpicii family, who maintained accounting archives in this area and provided accommodations for small groups of patrons and merchants (Guzzo and Mastroroberto, 2003).

In addition to the paintings, valuable metal objects were also unearthed at the site. The presence of a shallow water table posed challenges for handling and preserving the paintings. However, it facilitated the preservation of numerous wood samples, which remain in excellent condition. In 2000, all excavated items were reburied beneath the lanes of the motorway due to the difficult conditions of maintaining

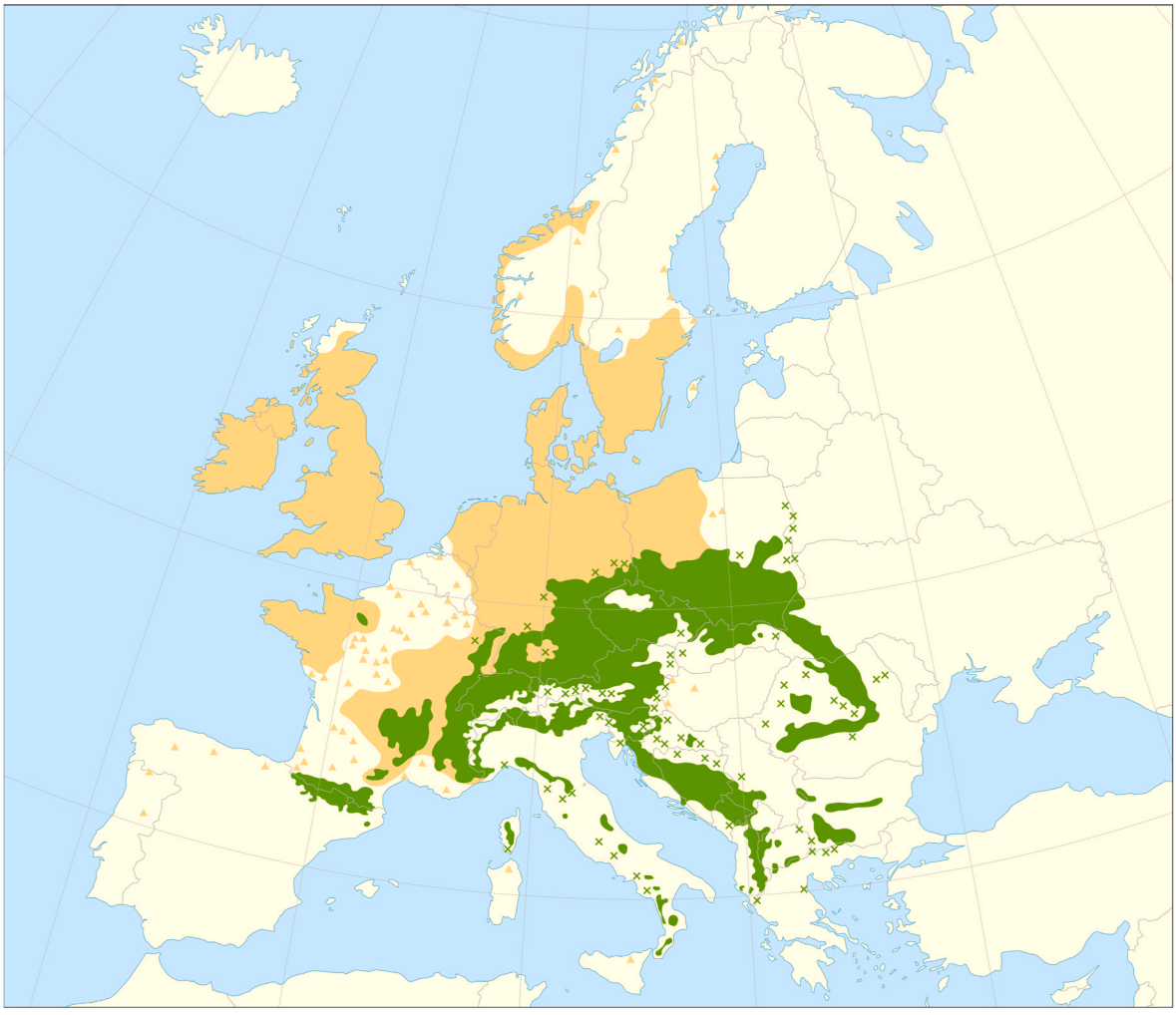

Fig. 1. European fir distribution range (from https://www.euforgen.org/species/abies-alba/). Native continuous range in green, X (green) isolated population. Continuous orange and X: introduced and naturalized (synanthropic) continuous range and isolated population.

the excavation caused by the high water table underground. Subsequently, excavation efforts were resumed during the construction of the third lane of the Salerno-Reggio Calabria motorway. This renewed excavation not only revealed the archaeological structures but also uncovered materials of significant interest. Among these finds were waxed tablets, perfectly preserved architectural and decorative wooden elements, and an extraordinary collection of high-quality silverware (Scarano Ussani, 2005).

2.2. Wood samples

A total of 35 samples were analysed, including boards, poles, and various small mixed materials that had been stored for an extended period in a tank with water or an impregnating agent. Identifying the wood species presented some challenges, primarily relying on the observation of anatomical features using a digital microscope directly on the raw surfaces of the wood. Slides and sections were not prepared to preserve the integrity of the samples.

The analysed fir boards had average dimensions of approximately 50 cm in width, 3 cm in thickness, and variable lengths of up to approximately 150 cm (Fig. 2). The ancient craftsmanship of the boards was clearly visible, with the larger surfaces displaying a perfect radial section and remaining absolutely flat and smooth (Fig. 2E). This exceptional state of preservation could be attributed to the high moisture content.

Ring-width analysis was conducted on the radial surfaces of the larger plates using the VTT device (Bernabei et al., 2010). This device combines a portable dendrochronograph with a high-resolution digital camera, enabling the measurement of growth rings without any manipulation or damage to the wood. It also allowed for the immediate assessment of the sampling quality and the preservation of the most significant images, which proved valuable in cases where doubts arose during the interpretation of the tree-ring series.

For each sample, a minimum of two dendrochronological series were measured. Radial sections of the boards underwent tree-ring measurements at various heights, while transverse sections of the round timber were subject to analysis along two opposing radial paths. Furthermore, measurements were taken repeatedly to capture as many rings as possible while minimizing errors that could result from potential grain deformation.

The fir tree-ring series were compared to one another to identify coeval groups. When strong correlations were observed, the individual series were averaged to enhance the environmental signal present in the growth rings. The resulting mean tree-ring series were then compared to reference chronologies from various species and regions applicable to the period under study. Notably, the reference chronology for silver fir created by P. J. Kuniholm at Herculaneum, as reconstructed by L. A. Larsson and available at http://www.cybis.se/forfun/dendro/, proved to be highly valuable.

The construction and analysis of the tree-ring series were conducted using the PAST4 program (Knibbe, 2011), and the statistical test values are based on this software. Photographic images were analysed using the CooRecorder and CDendro programs (Maxwell and Larsson, 2021).

2.3. Reference chronologies

In dendrochronology, a general rule holds true: the further back in time one goes, the more challenging it becomes to locate reference series suitable for comparison. These reference series must meet specific criteria, including being sufficiently lengthy, reliable, well-replicated, and, ideally, already published. While it is possible to absolutely date ancient series thanks to the availability of robust European reference series (Brown and Baillie, 1992; Friedrich et al., 2004; Nicolussi et al., 2009), their scarcity poses a significant challenge to the feasibility of dendroprovenancing analysis.

Another complicating factor is a species-specific issue. The silver fir, in particular, poses challenges for dendroprovenance analyses owing to its auto-ecological characteristics. Consequently, it frequently exhibits dependable correlations even across significant distances. It is not unusual to observe strong correlations within an extensive region, extending from central Italy to the Alps and even further northwards,

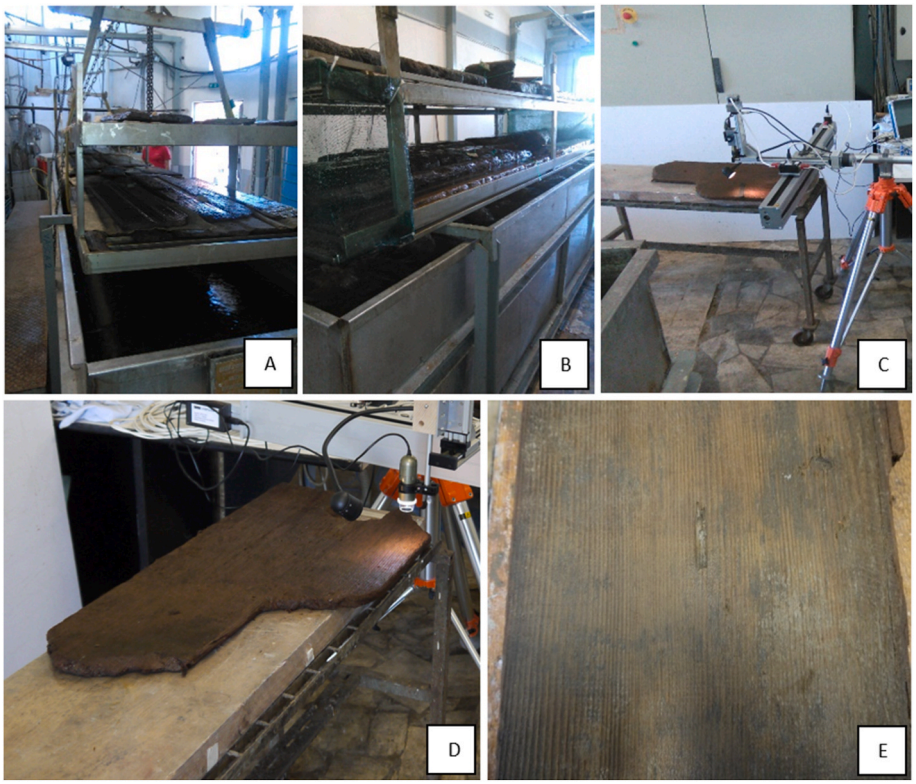

Fig. 2. Preservation of silver fir boards in wet tank (A and B), tree rings measurement (C and D), and example of board surfaces (E).

provided that the series is both lengthy and well-replicated (Bernabei et al., 2016).

Reference series from the Roman period are scarce on a European scale, and when it comes to peninsular Italy, they are entirely absent (Bernabei et al., 2019). Several factors contribute to the absence of reference chronologies in the Italian peninsula, including challenges related to the preservation of wood in archaeological excavations within the Mediterranean environment. Additionally, there have been instances of mishandling archaeological wood during and after excavation. Given these challenges, this study relied on European reference series for silver fir, spruce, and oak, as listed in Table 1.

3. Results

The larger boards are all made of silver fir, while a few smaller samples and elements that can be traced back to pile fragments are made of oak (*Quercus* sp.). Out of 35 samples, 17 displayed significant correlations with each other or with reference chronologies. However, 16 samples with fewer than 50 rings proved unsuitable for dendrochronological analysis.

When measuring the growth rings on the largest face of the boards, we frequently observed deformations in the shape of the rings near the pith, causing them to take on a more tangential form (Fig. 3). Consequently, the early portion of the series was often truncated when compared to the others, affecting the construction of the mean tree-ring chronology. The final mean tree-ring series spans 176 rings, a reduction from the total length of 240 rings, but it exhibits strong correlations with several reference chronologies for the year 49 CE (period 127 BCE - 49 AD, Table 2).

Two samples exhibited strong correlations with each other but demonstrated weak correlations with the remaining material. Their combined mean series encompasses 127 tree rings and dates back to 32 AD. This series also displays noteworthy correlations with the spruce reference chronology of the Central Alps (including TPCAB, T_{BP} 4.24, T_{HO} 4.72, Glk 69.70***, OVL 117) and the mixed conifer chronology G1 (T_{BP} 3.70, T_{HO} 4.24, Glk 70.10***, OVL 117).

Table 1
Reference series used in this study. * Ring width data retrieved from curves figures in Kuniholm (2002) by Lars-Åke Larsson and Torbjörn Axelson. (https://www.cybis.se/forfun/dendro/herculaneum/index.htm). ** Personal data exchange.

Code	Species	Length	Start year	Final year	Site	Author
ANLRJ	ABAL	287	−111	176	indeterminate	Jansma E. **
BA NEF	ABAL	433	−192	241	indeterminate	Tegel W.**
BP NEF	PCAB	206	−117	89	indeterminate	Tegel W.**
G1	MIX conifers	3003	−984	2019	Central Alps	Bernabei et al. (2018)
HERC	ABAL/ PCAB	361	−289	72	Herculaneum/ Pompei	Kuniholm, 2002*
HOLL	QUSP	2698	−724	1974	Germany	Hollstein (1980)
NEM	QUSP	997	−426	570	NE France Middle	Tegel et al. (2016)
NEW	QUSP	1279	−594	684	NE France West	Tegel et al. (2016)
NFE	QUSP	485	−271	213	NE France East	Tegel et al. (2016)
RMC1	QUSP	320	−280	40	Jura (France)	Bernabei et al. (2019)
TPCAB	PCAB	3003	−984	2019	Central Alps	Bernabei et al. (2018)

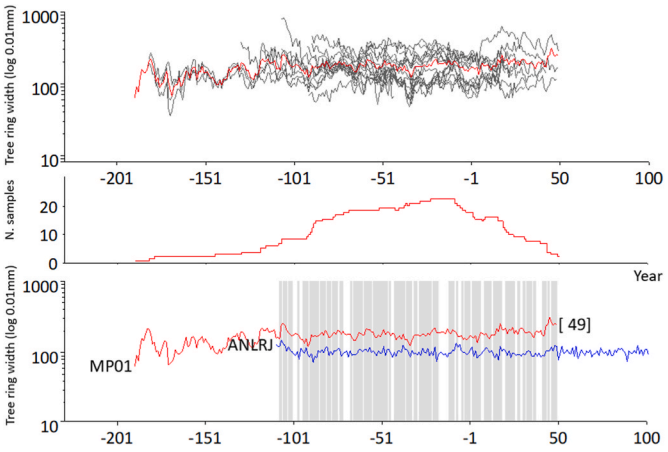

Fig. 3. (A) The visual comparison of all dated tree-ring series of Moregine fir. (B) The replication in each year. (C) The visual cross-matching of the Moregine mean chronology (in red) and ANLRJ reference chronology (Table 1) for the major replication years. OVL 160 years. T_{BP} 7.15, T_{HO} 7.14, Glk 69.70***. The grey-coloured areas indicate the periods with the same sign of the growth (Glk).

4. Discussion

The date established through dendrochronology, 49 AD, aligns seamlessly with the anticipated timeframe, culminating in 79 AD, the year of Vesuvius' eruption. When we incorporate the outermost rings, which were lost during the processing of the planks and corresponded to several years, along with a brief period of seasoning, we come remarkably close to the cutoff date.

As anticipated for the silver fir, the average tree-ring series of the Moregine boards demonstrates robust correlations with several chronologies for the same year, most notably Kuniholm's reference series from 2002 for the silver fir of Herculaneum. Kuniholm had traced the origin of this timber to Western Austria, and indeed, his chronology exhibits striking similarities with the Austrian reference series. It also bears resemblance to series from other Central European species, such as the German oak reference chronology by Hollstein (1980), T_{BP} 5.74, T_{HO} 6.30, Glk 61.50***, OVL 269.

In addition to the Herculaneum series, the mean tree-ring series of the Moregine silver fir also demonstrates strong correlations with the reference chronologies ANLRJ and BA NEF (Table 1). These chronologies are derived from fir wood used in the construction of barrels found in Central-Northern Europe. These barrels travelled alongside their contents throughout ancient Europe, often being made from reused timber (Van Lanen et al., 2016). Consequently, the dendrochronological series constructed from these barrels are not suitable for dendroprovenance analyses, as highlighted by Čufar et al., in 2019.

However, it is unlikely that the wood from Dutch or German barrels could have originated from the Southern Apennines, as we can speculate for the Moregine timber. Equally intriguing is the significant correlation between the Moregine mean sequence and the oak chronology from Northeastern France, as detailed in Table 2. This is particularly remarkable considering it involves a different species from a geographically distant region compared to the Vesuvian area.

Furthermore, the mean tree-ring series, comprised of only two samples and spanning 127 rings, exhibits strong correlations with spruce from the central Alps (including TPCAB T_{BP} 4.27, T_{HO} 4.76, Glk 69.70***, OVL 117). This suggests the use of different sources of timber within the same structure, with some logs likely originating from the Alpine region.

In summary, the wood used in Moregine is of a first-class craftsmanship quality and probably comes from various geographical regions, such as the Alpine or Central European region, although precise origins remain elusive. These observations contribute to a better understanding

Table 2
Results of statistical correlation tests of the MP01 chronology, consisting of 17 samples, with the various reference chronologies for the year 49 AD. Standard cross-dating parameters: TBP, *t*-test adapted from Baillie and Pilcher (1973); THO, *t*-test adapted from Hollstein (1980); Glk, Gleichläufigkeit represents the percentage of the agreement between the sign of growth from one year to another (Eckstein and Bauch, 1969); the statistical significance of Glk at the levels of 95.0%, 99.0% and 99.9%, indicated with the symbols *, ** and ***, respectively. OVL: overlap. The t-threshold above which a correlation was considered significant is 4.5, corresponding to a correlation coefficient of 0.41 and a significance level of 0.1% with an overlap of 100 tree rings.

Code	Species	Site	Author	T_{BP}	T_{HO}	Glk	OVL
HERC	ABAL/PCAB	Herculaneum/Pompei	Kuniholm (2002)	6,85	8,49	71,00***	176
ANLRJ	ABAL	indeterminate	Jansma E.	7,15	7,14	69,70***	160
BA NEF	ABAL	indeterminate	Tegel W.	7,46	7,21	67,90***	176
NFE	QUSP	NE France	Tegel et al. (2016)	4,30	4,73	58,50*	176
NEW	QUSP	NE France	Tegel et al. (2016)	3,57	2,27	56,50*	176
NEM	QUSP	NE France	Tegel et al. (2016)	2,89	2,97	60,20**	176
HOLL	QUSP	Germany	Hollstein (1980)	2,45	3,11	59,40**	176
TPCAB	PCAB	Central Alps	Bernabei et al. (2018)	2,45	2,27	58,50	176
BP NEF	PCAB	indeterminate	Tegel W.	2,34	2,49	56,30	166
G1	MIX conifers	Central Alps	Bernabei et al. (2018)	2,11	2,09	56,00	176
RMC1	QUSP	Jura (France)	Bernabei et al. (2019)	0,54	0,84	50,00	167

of the importance of wood in the economy and trade of ancient Rome.

Wood held a fundamental and strategically vital role in the operation of the Roman Empire (Veal, 2017). It served not only in the construction of buildings but also in a myriad of other indispensable activities, including shipbuilding, city and bath heating (Janssen et al., 2017), metalworking, and numerous other critical functions for the Roman economy. Pliny eloquently conveyed this in his writings, stating, "*Mille praetera sunt usus earum,* sine *quis vita degi non possit*", which translates to "Their (woods) uses are countless, without which life would not be possible" (Naturalis Historia XVI, 1–5).

Especially during the early centuries AD, the Roman logistical machinery operated at its zenith, enabling the sourcing of timber from the most remote corners of the Empire for various purposes wherever a wealthy clientele demanded it (Bernabei et al., 2019). This likely led to extensive deforestation activities, not limited to Italy alone. It was precisely during this period that one of the earliest environmental protection decrees in history was promulgated. In 118 AD, Emperor Hadrian prohibited the harvesting of the famed cedars of Lebanon (Shackley, 2004), prized for their wood's exceptional durability, particularly in saltwater environments, which was highly coveted for shipbuilding.

The preferred building material, as instructed by Vitruvius, was fir, and acquiring it from the Alps or even beyond for patronage as affluent as Pompeii was undoubtedly feasible. Supporting this notion are not only the dendrochronological series that exhibit correlations with Central European reference series (as demonstrated earlier, including fir with spruce and fir with oak), but also the presence of other species such as spruce (Kuniholm, 2002; Seiler et al., 2011) or spruce/larch (Moser et al., 2018) used as structural wood alongside fir.

Distinguishing between the two species, spruce (*Picea abies* Karst.) and larch (*Larix decidua* Mill.), based solely on wood anatomy, is challenging (Bartholin, 1979), leading to some inherent uncertainty in their differentiation. However, both species are typically associated with Alpine regions: larch is strictly confined to the Alps, while spruce extends slightly into the northern Apennines with two small cores (Schmidt-Vogt, 1977). Consequently, the presence of spruce/larch timber utilized alongside fir for the same structural purposes strongly indicates the importation of fir as well.

5. Conclusions

Dendrochronological analysis of the timbers recovered from the ancient trading port of Moregine, situated on the outskirts of Pompeii, enabled the dating of these timbers to 49 AD, marking the *terminus post quem*. Notably, the tree-ring series of the timber used in Moregine showed similarities with several chronologies of other species of Central European origin, such as oak from France or Germany. This leads one to surmise that among the timbers discovered at Moregine, there exist groups with distinct geographical origins, albeit not yet definitively discernible. These findings underscore the pivotal role that wood played in Roman society and illuminate the remarkable organizational prowess of its logistical apparatus (Bernabei et al., 2019; Bellotti et al., 2016). In conclusion, when we contemplate resource utilization in ancient Rome, our view is distorted by envisioning the challenges that transportation and trade might have posed for such an ancient society. We tend to assume that their usage was confined to the regions proximate to their sources. However, scientific evidence, including dendrochronology, unequivocally demonstrates that the Roman logistical apparatus adeptly facilitated the movement of materials (referred to as "*materia*" in Latin, denoting structural wood) from every corner of the Empire to locations where affluent patrons could procure it.

Data availability

Tree ring data will be provided upon request.

CRediT authorship contribution statement

Mauro Bernabei: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, 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.

Acknowledgements

The Author would like to thank Esther Jansma, Willy Tegel and Tomasz Ważny for their suggestions and for sending long and well replicated reference series.

References

Baillie, M.G.L., Pilcher, J.R., 1973. A simple cross-dating program for tree-ring research. Tree-Ring Bull. 33, 7–14.
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'Orefice, M., Esu, D., Ferrari, K., 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.
Bernabei, M., Bontadi, J., Quarta, G., Calcagnile, L., Diodato, M., 2016. The baptistry of saint john in florence: the scientific dating of the timber structure of the dome. Int. J. Architect. Herit. 10 (6), 704–713.
Bernabei, M., Bontadi, J., Nicolussi, K., 2018. Observations on Holocene subfossil tree remains from high-elevation sites in the Italian Alps. Holocene 28 (12), 2017–2027.

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. https://doi.org/10.1371/journal.pone.0224077.
Bernabei, M., Bontadi, J., Rossi Rognoni, G., 2010. A dendrochronological investigation of stringed instruments from the collection of the Cherubini Conservatory in Florence, Italy. J. Archaeol. Sci. 37, 192–200.
Bernetti, G., 1995. Selvicoltura Speciale. UTET, Torino. ISBN: 8802048673.
Brown, D.M., Baillie, M.G.L., 1992. Construction and dating of a 5000-year English bog oak tree-ring chronology. Lundqua Report 34, 72–75.
Čufar, K., Horvat, J., Tolar, T., Berden, T., Merela, M., 2019. Research potential of wood of barrel from Roman water wells. Les/Wood 68 (1), 47–60.
De Vos, A., De Vos, M., 1982. Pompei, Ercolano, Stabia. Editori Giuseppe Laterza e figli. Bari-Roma, ISBN 88-420-2001-X.
Di Pasquale, G., Allevato, E., Cocchiararo, A., Moser, D., Pacciarelli, M., Saracino, A., 2014a. 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.
Di Pasquale, G., Buonincontri, M.P., Allevato, E., Saracino, A., 2014b. Human-derived landscape changes on the northern Etruria coast (western Italy) between Roman times and the late Middle Ages. Holocene 24 (11), 1491–1502.
Eckstein, D., Bauch, J., 1969. Beitrag zur Rationalisierung eines dendrochronologischenVerfahrens und zur Analyse seiner Aussagesicherheit. Forstwiss. Centralbl. (Hamb.) 88, 230–250.
Friedrich, M., Remmele, S., Kromer, B., Hofmann, J., Spurk, M., Kaiser, K.F., Orcel, C., Küppers, M., 2004. The 12,460-year Hohenheim oak and pine tree-ring chronology from central Europe—a unique annual record for radiocarbon calibration and paleoenvironment reconstructions. Radiocarbon 46 (3), 1111–1122, 2004.
Guzzo, P.G., Mastroroberto, M., 2003. Auditorium Arte. Pompei. Le Stanze Dipinte. Mondadori Electa, p. 88.
Hollstein, E., 1980. Mitteleuropäische Eichenchronologie. Trierer dendrochronologische Forschungen zur Archäologie und Kunstgeschichte. Trierer Grabungen u. Forsch. 11 (Mainz 1980.
Janssen, E., Poblome, J., Claeys, J., Kint, V., Degryse, P., Marinova, E., Muys, B., 2017. Fuel for debating ancient economies. Calculating wood consumption at urban scale in Roman Imperial times. Journal of Archaeological Science Reports 11, 592–599.
Knibbe, B., 2011. PAST 4. Personal Analysis System for Tree-Ring Research, p. 159. Instruction Manual. Wien, Version 4.3.
Kuniholm, P.I., 2002. Dendrochronological investigations at Herculaneum and Pompeii. In: Jashemski, W.F., Meyer, F.G. (Eds.), The Natural History of Pompeii. Cambridge University Press, Cambridge, pp. 235–239.
Maxwell, S.R., Larsson, L.-A., 2021. Measuring tree-ring widths using the CooRecorder software application. Dendrochronologia 67, 125841.
Mercuri, A.M., Bandini Mazzanti, M., Torri, P., et al., 2012. A marine/terrestrial integration for mid-late Holocene vegetation history and the development of the cultural landscape in the Po Valley as a result of human impact and climate change. Veg. Hist. Archaeobotany 21, 353–372.
Mols, S., 2008. Ancient roman household furniture and its use: from Herculaneum to the rhine. An Murcia 23–24, 145–160.
Moser, D., Nelle, O., Di Pasquale, G., 2018. Timber economy in the Roman Age: charcoal data from the key site of Herculaneum (Naples, Italy). Archaeol. Anthropol. Sci. 10, 905–921.
Nicolussi, K., Kaufmann, M., Melvin, T.M., van der Plicht, J., Schießling, P., Thurner, A., 2009. A 9111 yearlong conifer tree-ring chronology for the European Alps: a base for environmental and climatic investigations. Holocene 19, 909–920.
Palli, J., Mensing, S.A., Schoolman, E.M., Solano, F., Piovesan, G., 2023. Historical ecology identifies long-term rewilding strategy for conserving Mediterranean mountain forests in south Italy. Ecol. Appl. 33, e2758.
Sadori, L., Allevato, E., Bellini, C., Bertacchi, A., Boetto, G., Di Pasquale, G., Giachi, G., Giardini, M., Masi, A., Pepe, C., Russo Ermolli, E., Mariotti Lippi, M., 2015. Archaeobotany in Italian ancient Roman harbours. Rev. Palaeobot. Palynol. 218, 217–230.
Scarano Ussani, V., 2005. Moregine. Suburbio "portuale" di Pompei. Loffredo Editore, p. 157.
Schmidt-Vogt, H., 1977. Die Fichte Band I. Taxonomie-Verbreitung-Morphologieökologie-Waldgesellschaften. Paul Parey, Hamburg and Berlin.
Seiler, F., Märker, M., Kastenmeier, P., Vogel, S., Esposito, D., Heussner, U., Boni, M., Balassone, G., Di Maio, G.D., Joachimski, M., 2011. Interdisciplinary approach on the reconstruction of the ancient cultural landscape of the Sarno River Plain before the eruption of Somma-Vesuvius A.D. 79. Tag Landesmus Vor. Halle 6, 1–10.
Shackley, M., 2004. Managing the cedars of Lebanon: botanical gardens or living forests? Curr. Issues Tourism 7 (4–5), 417–425.
Tegel, W., Vanmoerkerke, J., Hakelberg, D., Büntgen, U., 2016. Des cernes de bois à l'histoire de la conjoncture de la construction et à l'évolution de la pluviométrie en Gaule du Nord entre 500 BC et 500 AD, pp. 639–653. G. Blancquaert/F. Malrain (Hrsg.), Évolution des sociétés gauloises du Second âge du Fer, entre mutations internes et influences externes. Actes du 38e colloque de l'AFEAF. Revue Archéologique de Picardie n. spécial 30, Amiens.
Tinner, W., Colombaroli, D., Heiri, O., Henne, P.D., Steinacher, M., Untenecker, J., Vescovi, E., Allen, J.R.M., Carraro, G., Conedera, M., Joos, F., Lotter, A.F., Luterbacher, J., Samartın, S., Valsecchi, V., 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.
van Lanen, R.J., Jansma, E., van Doesburg, J., Groenewoudt, B.J., 2016. Roman and early-medieval long-distance transport routes in northwestern Europe: modelling frequent-travel zones using a dendroarchaeological approach. J. Archaeol. Sci. 73, 120–137.
Veal, R., 2017. The politics and economics of ancient forests: timber and fuel as levers of Greco-Roman control. In: Derron, P. (Ed.), Économie et inégalité: ressources échanges et pouvoir dans l'antiquité classique, pp. 317–357. Vandoeuvres 2017).
Wolf, H., 2003. *Abies alba*. Technical guidelines for genetic conservation and use for silver fir. Euforgen accessed online at. https://www.euforgen.org/species/abies-alba/the16.10.2023.