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Evidence of forestry management and arboriculture practices in waterlogged wood remains from three wells at the Roman and late antiquity sites of Iesso and Vilauba (Catalonia, Spain)

Eva Maria López Castillo [a,*], Oriol López-Bultó [a], Anna Berrocal Barberà [a], Pere Castanyer Masoliver [b], Joaquim Pera Isern [c], Esther Rodrigo Requena [c], Raquel Piqué Huerta [a]

[a] Prehistory Department, Universitat de Autònoma de Barcelona, Bellaterra, Barcelona, Spain
[b] Catalonian Archaeology Museum-Empúries. L'Escala, Girona, Spain
[c] Antiquity and Middle Age Sciences Department, Universitat Autònoma de Barcelona, Bellaterra, Barcelona, Spain

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ABSTRACT

The aim of this paper is to provide new data on forest management and arboricultural practices in the Roman and Late Antique periods in the north-eastern Iberian Peninsula. In this study, the waterlogged branches found in three wells at the sites of Iesso and Vilauba in the northeast of the Iberian Peninsula were analysed. To determine management practices the roundwood method, based on the correlation between age and diameter, has been applied. The study has revealed the presence of a wide range of species collected on surrounding forests, especially in riparian forest. Moreover, it is remarkable the abundance of fruit trees at both sites, being the most abundant *Prunus* sp. The comparison of the archaeological branches with a reference collection of modern twigs from cultivated and non-managed individuals of the Prunaceae family, *Salix* sp. and *Sambucus nigra*, has provided clear evidence of management practices in these taxa. In addition, direct evidence of pruning was observed on some branches of *Vitis vinifera*.

1. Introduction

Plants have been used for food, technology and ideological purposes since prehistory (Antolín, et al., 2021; Berihuete-Azorín et al., 2022; Hardy and Kubiak-Martens, 2016; Valamoti et al., 2022). Different strategies and techniques have been developed over time to obtain, process and consume them, including such procedures as management, cultivation and domestication.

In the case of woody plants, forest management, silviculture and arboriculture are practices that have enabled the acquisition of vegetal resources with particular characteristics (Girardclos, et al., 2011, 2018; Rasmussen, 1990). The use of these techniques requires the application of knowledge that is largely related to processes and circumstances that promote tree growth, such as the soil, climate, and competition for nutrients, light and water (Castellano, 2021; Dotte-Sarout, 2016).

The knowledge needed to implement silviculture is usually divided into three broad groups: knowledge of reproduction, of ways to improve production and of ways to harvest the products (Visser, 2010). Practices applied on a large scale to areas of woodland can be equally applied to small patches of trees, such as fruit trees, and even to individual specimens. The application of arboriculture techniques can improve production by favouring and guiding growth and achieving high-quality produce (Krebs et al., 2022; Marzano, 2022).

Classic references to vegetal resources, biological characteristics and aspects of the use of plants in the north-east of the Iberian Peninsula and the Balearic Islands mainly date to the first two centuries before and after the change of Era (Cubero Corpas, 1994). Greek and Roman authors, particularly Theophrastus and Pliny the Elder, but also Hesiod, Marcus Porcius Cato, Varro and Columella described methods for cultivating plants, including trees (Catón, 2009; Columella, 2012; Teofrasto, 1988). The different treatises on agriculture and plants in general analyse the diverse uses of wood, demonstrating broad knowledge of the properties of different types and, for example, describing the best time of year for felling trees and the different ways of using them, as well as

* Corresponding author.
E-mail address: elopezcas68@gmail.com (E.M. López Castillo).

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providing information about growing fruit trees, grafting and pruning methods, and other techniques.

Several silviculture practices are thought to have been applied in the Roman period (Marzano, 2022; Visser, 2010), including clearing, selection, pruning and agrosilviculture. Some sources also mention grafting with wild shoots, and the application of techniques that would be of vital importance in agriculture, such as the use of animal manure (Buxó, 2005; Teira, 2013; Teofrasto, 1988).

As documented by Theophrastus, undergrowth removal (clearing), coppicing and the distribution of trees by type were the most commonly used silviculture techniques in antiquity (Teofrasto, 1988). Clearing is one of the most basic practices in silviculture and consists of regular cutting and thinning of woodland so that it can regenerate. Trees of different ages and diameters are selected in a certain area of woodland in order to use older plants to protect the younger ones and also to prevent soil erosion, especially after removing the undergrowth. Coppicing, which is based on the regenerative properties of certain tree species to promote the appearance of new shoots, was practiced in Roman times, as mentioned in classic sources, although some authors claim that such methods had been in use since the Neolithic, combined with the selection of species (Castellano, 2021; Visser, 2010). Agrosilviculture refers to the widespread practice in Roman times of combining the aforesaid techniques with crops and pastureland. The trees protected the crops as well as providing the branches that some plants needed to grow on. This practice was known as *silva glandaria* (Visser, 2010).

Romanisation was accompanied by intense use of plant resources, particularly forestry species, which led to significant deforestation. Palynological records show that a considerable amount of forest mass was cleared in the north-east of the Iberian Peninsula in order to plant olive trees and other xeric Mediterranean taxa (Riera and Palet, 2005). Woodlands were also heavily exploited for firewood. The anthracological record in north-east Iberia shows that shrubs and small trees were used but the species that appeared most frequently (Piqué, 2009) included oak (deciduous *Quercus* sp.) and pine (*Pinus sylvestris/nigra/halepensis*, depending on the geographic area) (Vila and Piqué, 2012).

Grapevines (*Vitis vinifera*) and olive trees (*Olea europaea*) were also grown, while arboreal crops that had only very rarely been documented before, such as peach, plum, cherry and walnut, were introduced for the first time to the region and co-existed with local species (Berrocal Barberà, 2021; Buxó et al., 2004, 2005; Peña-Chocarro and Zapata Peña, 1996; Teira, 2013).

Although archaeobotanical studies conducted in north-east Iberia have yielded significant information about the use of wood in Roman times (Piqué, et al., 2016), including firewood (Piqué, 2009), and the cultivation of fruit trees (Buxó, 2005), little is known about the practices involved in obtaining them. The archaeobotanical record is a vital reference for the correct interpretation of agrarian history, an understanding of forms of subsistence associated to plant-life, and for reconstruction of the socioeconomic foundations (López Sáez and Peña Chocarro, 2008). However, the methods of analysis used to detect anthropic pruning activity in woody remains are still at an experimental phase or have only been developed for very particular plants and do not yet cover the full diversity of possible species (López-Bultó, 2020; Out et al., 2017, 2020, 2023; Peña Chocarro and Zapata Peña, 1996).

The research described herein is focused specifically on the identification of possible forest management and arboriculture practices employed in the ancient and late antiquity periods (from the second century BC to the seventh century AD). The study is based on waterlogged wood remains at two archaeological sites located in the north-east of the Iberian Peninsula: Iesso (Guissona, Lleida) and Vilauba (Camós, Girona), which were occupied from the Roman era to the Late Antiquity. These remains were found inside wells and had therefore been submerged in water in anaerobic conditions, which meant they were conserved in an organic state. The main objectives of the study were to identify the main wood resources used at those sites and to document forest management and arboriculture practices by examining samples of wood from the two deposits.

Based on the archaeological and historical context, the working hypothesis for this research is that the archaeological remains of wood from the wells at Iesso and Vilauba will display evidence of woodland management and arboriculture. Wells at historic urban sites are outstanding archaeological structures because some of their archaeological levels may have been preserved under the water table, which favours the conservation of organic matter. The presence of water in wells increases the likelihood of any wood thrown in them, either building material or plant remains, being preserved, thus presenting a unique opportunity to study a kind of evidence that cannot usually be found at archaeological sites and which can provide valuable information about economic aspects of land use and wood production; (Alonso, et al., 2008; Piqué et al., 2016; Vila and Piqué, 2012).

2. The sites

2.1. Iesso (Guissona, Lleida)

The Roman town of Iesso is partly located under the modern town of Guissona (Lleida) in the Central Catalan Depression (Fig. 1). Archaeological research has documented a settlement with an irregular polygonal perimeter and a total surface area of nearly 18 ha (Guitart Durán, 2010). The town was founded in the late second or early first century BC over an older settlement of unclear origin that dates back to 700-550 BC. Following the Roman conquest, it was part of Rome's intention to control the territory of the Iberian Peninsula in general and the north-east in particular. The town remained occupied until the eighth century AD.

Excavations were concentrated on three sectors: one formed by the remains of the wall and the north gate with its defensive tower; a second sector containing the public baths, including a building and a courtyard with a large *natatio* or open-air swimming pool; and a third area containing the ruins of a noble house near the town wall (Guitart Durán, et al., 2015). Five wells were discovered in different parts of the town and four of these have been excavated. The first two were the subject of a monograph that presented the results of the archaeobotanical study (Buxó, et al., 2004). Here, remains from two other wells are studied, namely the Wall Well and the Baths Well.

The **Baths Well** was excavated in 2021. It is located in the baths complex of the town (Fig. 2). It is 4 m deep and between 90 and 100 cm

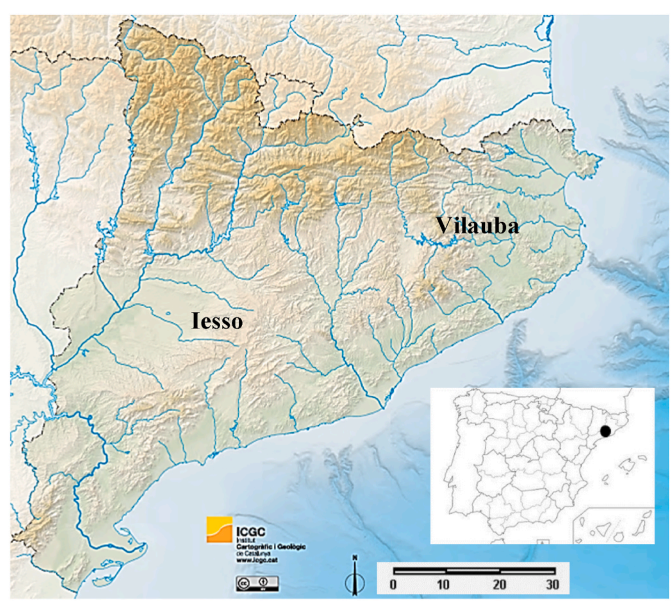


Fig. 1. Geographic location of the two sites studied here. Map source: https://www.icgc.cat/L-ICGC/Sobre-l-ICGC/Recursos-didactics/Mapes-fisics.

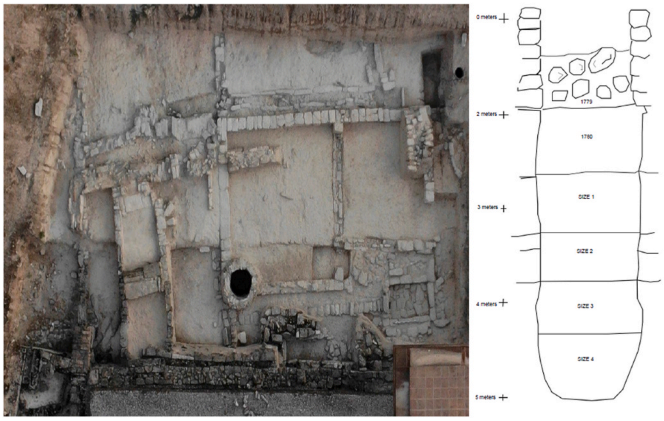


Fig. 2. From left to right: aerial view of the Baths area and stratigraphic section of Baths Well at Iesso. Source: (Romaní and Rodrigo, 2017).

wide. During the excavation process, it became evident that it slowly filled once the well had fallen into disuse. The filling was the result of the accumulation and sedimentation of dust and mud over the years, which is typical of wells that have been unused and uncovered for a long time. The scarcity of faunal and ceramic material supports this hypothesis as to how it was filled in. It seems that the well was gradually abandoned until it was completely full by the late first or early second centuries AD, this dating being based on a chronotypologic study of the archaeological ceramic materials recovered during the excavation (Guitart, et al., 2021). The branches studied here come from stratigraphic units (SU) 3 and 4, which are beneath the groundwater level that appears at a depth of 1.60 m.

The **Wall Well** was excavated in 2017. It is located in a building outside the town, next to the wall (Fig. 3) and its construction is dated to the late second-early third centuries AD (Guitart Durán, et al., 2015), using the same dating method as described for the previous well. The well is 6.30 m deep and between 80 and 120 cm wide. The groundwater level appears at a depth of 2.30 m. The architectural ensemble was destroyed by fire and the well was filled with building debris. Besides the rubble, the large number of archaeozoological remains found in the well confirmed the hypothesis that it was used as a waste dump after it fell into disuse as a well. Abundant organic material was recovered from the sediment layers beneath the water table, including remains of worked wood, branches of different sizes, and seeds and stones from different plant species (Romaní and Rodrigo, 2017). The remains of the branches found in stratigraphic units (SU) 6 are studied here.

2.2. Vilauba (Camós, Girona)

The rural settlement of Vilauba is located in the town of Camós, midway between the Pyrenees and the Mediterranean coast, in the lacustrine basin of Lake Banyoles, in the province of Girona (Fig. 1). The site is a key point of reference for research into rural life and land use in the region in the Roman era. The *villae* features a series of farm outbuildings including an olive press (*torcularium*) and a water tank, which attest that agriculture here was focused on olive crops and oil production.

The site is dated from between the first century BC to the seventh century AD, although most of the excavated remains belong to the first-third centuries AD, when the three wings of the residence were built in a 'U'-shape around a courtyard. A fire damaged the building in the late third century and led to a series of redevelopments that involved a complete transformation of the way that the *villae* was organised (Frigola, et al., 2021).

The well has been dated to the same era as the rest of the site (Fig. 4). It was 120 cm wide and 6.5 m deep at that time. A large number of branches, wooden objects and several pieces of leather were found,

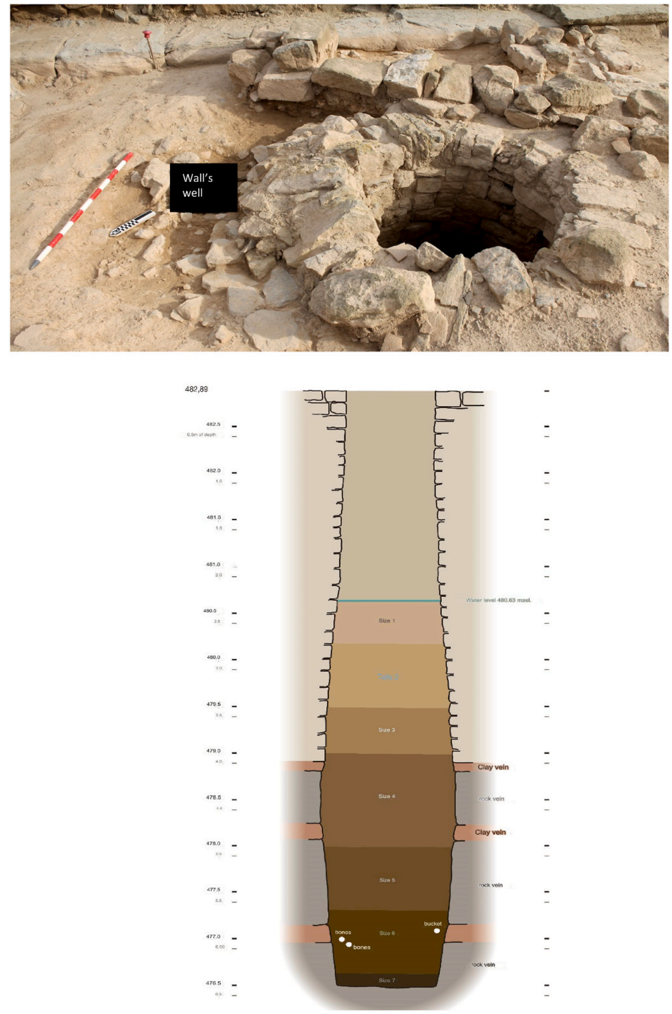


Fig. 3. From up to down: external view of the Wall Well and its stratigraphic section, from Iesso. Source: (Romaní and Rodrigo, 2017).

including a complete shoe (*calcei repandi* type) (Frigola, et al., 2021). Many of these remains were recovered during the excavation of stratigraphic units (SU) 1719 and 1720, beneath the groundwater level. Although archaeological artefacts that can be used to contextualise the well are not quantitatively abundant, C^{14} dating of organic materials suggests that it was filled during the sixth century AD (Frigola, et al., 2021).

3. Material and methods

3.1. Identification of taxa

The remains studied here are waterlogged wood in the form of a set of fragments of branches of different sizes from three wells, two at Iesso and one at Vilauba. At both sites, the branches have been preserved in an organic state because they were beneath the water table.

The large number of organic remains found in each well, namely thousands of fragments of branches and other larger pieces of wood, meant that guided sampling was necessary. Although fragments of wooden artefacts were recovered, they are not considered in the present study. The purpose of the sampling procedure was to select the broadest possible range of branch diameters in the assemblages.

In order to avoid any bias during the sampling process, the branches were first classified on the basis of their diameter. The following categories were established: Group 1: <5 mm, Group 2: 5–10 mm, Group 3:

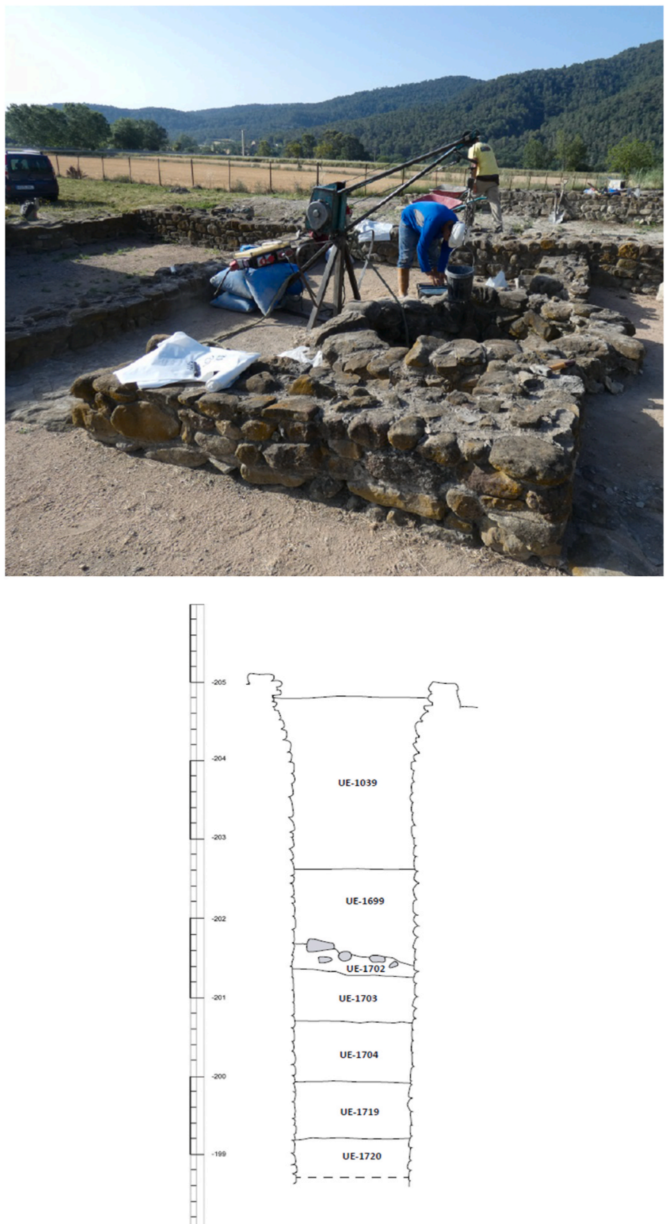


Fig. 4. From up to down: external view of the Vilauba's Well and its stratigraphy (Frigola, et al., 2021).

10–15 mm, Group 4: 15–20 mm, Group 5: 20–25 mm, Group 6: 25–30 mm and Group 7: >30 mm. The initial intention was to study a minimum of 50 fragments from each group, as this number was regarded as statistically significant (Limier et al., 2018; Out et al., 2017, 2023).

However, owing to the poor state of conservation of the wood, that number could not be reached in some groups. Finally, an assemblage of 487 pieces was studied, of which 222 are from the Wall Well, 141 from the Baths Well (both at Iesso) and 124 from the well at Vilauba (Table 1). In all cases, in each of the stratigraphic units and in each well, the groups for which 50 samples could not be reached correspond to the largest diameters, although in SU 1719 and 1720 at Vilauba and SU 3 in the Baths Well, this was because of the serious degradation of the wood.

Taxonomical determination was performed by observing the three anatomical planes of the wood with an Olympus BX43 transmitted light microscope with 4x to 100x lenses. The keys for the identification of European wood (Schweingruber, 1990) and the reference collection in the Archaeobotanic Laboratory at the Universitat Autònoma de Barcelona were used to classify the remains.

Table 1
Samples studied from each site and structure.

Site	Estructure	Stratigraphic unit	N
Iesso	**Walls well**	6	222
	Baths well	3	68
		4	73
			363
Vilauba	**Vilauba well**	1719	40
		1720	84
			124
Total			**487**

The diameter of each fragment was measured with callipers and the growth rings were counted with the aid of the microscope. The presence of bark, markings and alterations to the anatomy were also recorded so as to document, wherever possible, the season when the branch was cut, the age of the wood and any other alterations that might be related to woodland management (Schweingruber, 1996).

3.2. Roundwood method

The methodology used to explore the practice of woodland management is the roundwood method proposed by Out and colleagues, which is based on the study of the relationship between the diameter and growth rings of tree branches and trunks. This method can be used to support inferences as to whether the tree was managed anthropically or not and has been applied to different projects in European prehistory (López-Bultó, 2020; Out et al., 2013, 2017, 2020, 2023). It is based on a premise regarding branch growth patterns, namely the relationship between the age of the specimen or sample, as determined by the number of rings, and the diameter of the branches: the older the branch is (more growth rings), the larger its diameter will be. The second part of the premise is that branches from managed trees can be distinguished from non-managed branches because their diameter will be larger after the same number of years. This is because, at least in the early years of management, the first branches will benefit from better access to light, water and nutrients that favour growth, and the tree is likely to possess a better-developed root system (Out, et al., 2017). Based on these premises, patterns can be identified that are characteristic of trees that have been managed anthropically as opposed to trees that grow in the wild or naturally.

3.3. Experimental reference collection

With regards to the archaeological materials, an experiment was devised to create a reference collection of managed and non-managed fruit tree branches. This was achieved with the assistance of two horticulturists who grow these types of fruit trees in the province of Barcelona, which enabled the identification of species, date of sampling, origin and type of management applied. The species were those identified during the preliminary taxonomic study of the archaeological remains. Each branch was then sampled to extract discs from each of the main and secondary shoots, which represent the different years of growth (Fig. 5).

The experimental collection was taken from trees of the following species: *Prunus armeniaca* (apricot), *Prunus avium* (cherry), *Prunus domestica* (plum), *Prunus dulcis* (almond), *Prunus persica* (peach) and *Sambucus nigra* (elder) (Table 3).

From one tree of each species, one main branch with its second and third level stems was selected. All the stems were sampled, which resulted in a total of 144 wood discs. The difference in the numbers of discs is due to each branch providing a different number of secondary and tertiary stems. The samples were numbered in order of the hierarchy of the main, secondary and tertiary stems in each of the sampled

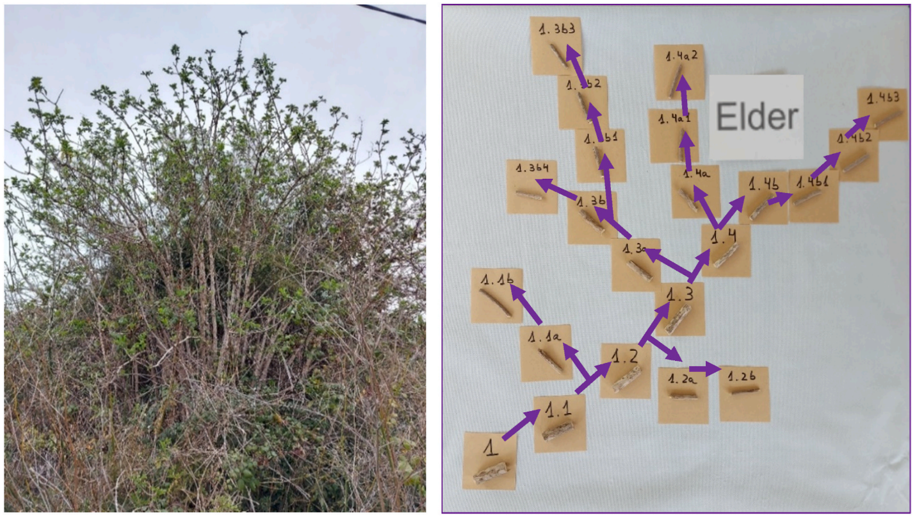


Fig. 5. *Sambucus nigra* (left) and diagram of the samples from the experimental elder branch (right).

Fig. 6. *Vitis vinifera* branches with cut marks that correspond to the removal of secondary branches, and the regrowth of wood around them.

branches. Each disc was polished and observed with a Dino-Lite 2.0 microscope and analysed with the corresponding software. As with the archaeological assemblage, data was recorded on the diameter, number of rings, season when cut and external alterations.

4. Results

4.1. Taxonomical study of the archaeological remains

4.1.1. Iesso: Wall Well and Baths Well

At Iesso, 15 taxa were identified (Table 2). The most abundant is the genus *Prunus* sp. although willow (*Salix* sp.) and elder (*Sambucus nigra*) are also present. Other species that appeared in smaller percentages are strawberry (*Arbutus unedo*), boxwood (*Buxus sempervirens*), bay (*Laurus nobilis*), some Leguminosae, Scots/black pine (*Pinus sylvestris/nigra*), deciduous oak (*Quercus* sp.), holm/kermes oak (*Quercus ilex/coccifera*), some Rosaceae/Maloideae, bramble (*Rubus* sp.), olive (cf. *Olea europaea*) and grapevine (*Vitis vinifera*).

Differences should be noted in the taxonomic composition of the two wells. *Prunus* sp. is clearly prominent in the Wall Well, followed by *Sambucus nigra* and deciduous *Quercus* sp., within a total of five taxa (Table 2). In the Baths Well, where there are 13 taxa, the predominant genus is *Salix* sp., followed by *Prunus* sp., some remains of Rosaceae/Maloideae and *Buxus sempervirens* (Table 2). The other taxa occur minimally, but the taxonomic variability is greater than for the Wall Well.

4.1.2. Vilauba well

At Vilauba, the number of taxa identified was 22, with only oak and willow accounting for over 10% of the fragments (Table 2). The assemblage is formed by alder (*Alnus* sp.), strawberry tree (*Arbutus unedo*), boxwood (*Buxus sempervirens*), dogwood (*Cornus* sp.), hazel (*Corylus avellana*), juniper (*Juniperus* sp.), beech (*Fagus* sp.), walnut (*Juglans regia*), fig (*Ficus carica*), *Prunus* sp., ash (*Fraxinus* sp.), olive (*Olea europaea*), bay tree (*Laurus nobilis*), some Leguminosae, Scots/black pine (*Pinus sylvestris/nigra*), deciduous oak (*Quercus* sp.), holm oak (*Quercus ilex/coccifera*), some Rosaceae/Maloideae, bramble (*Rubus* sp.), willow (*Salix* sp.), elm (*Ulmus* sp.) and grapevine (*Vitis vinifera*).

4.2. Study of the experimental reference collection

The number of rings for each species and the diameter range for the current wood collection are presented in the following tables and graphs.

The reference collection is composed of 144 remains, as shown in Table 3; first, the genus *Prunus* is represented by domestic and managed specimens (*Punus armeniaca*, *Prunus avium*, *Prunus domestica* and *Prunus persica*) and wild and non-managed specimens (*Prunus dulcis*) and second, the *Sambucus nigra*, a domestic, but non managed specimen.

In addition, almost 80% of the modern samples present a diameter range of between 0 and 15 mm, while at least 75% of the samples present between 2 and 5 rings (Tables 4–5 and Graph 1, A-B).

4.3. Age-diameter study of the archaeological remains

Age-diameter study of the archaeological sample was performed for fragments for which the number of rings and the diameter of the branch could be determined. Age could not be determined for 120 remains because of their deficient state of conservation, with signs of external pressure and/or deformity of the wood, which hindered ring counting.

Table 2
Taxonomic representation of the three wells under study, with the total number of samples analysed and the total number of samples for the application of the analysis method.

Taxa	Vegetation types	Wall well		Baths well		Vilauba well		Total N
		N	%	N	%	N	%	
Undeterminable conifer	Conifer			1	0,71%			1
Juniperus sp.	Conifer					1	0,81%	1
Pinus sylvestris/nigra	Conifer			4	2,84%	2	1,61%	6
cf. *Olea europaea*	Domestic species			3	2,13%			3
cf. *Vitis vinifera*	Domestic species					1	0,81%	1
Ficus carica	Domestic species					4	3,23%	4
Juglans regia	Domestic species					1	0,81%	1
Olea europaea	Domestic species					9	7,26%	9
Prunus sp.	Domestic species	147	66,22%	18	12,77%	3	2,42%	168
Prunus sp. cf. *avium*	Domestic species					5	4,03%	5
Vitis vinifera	Domestic species			4	2,84%	10	8,06%	14
Arbutus unedo	Deciduous/Mediterranean forest	5	2,25%	1	0,71%	1	0,81%	7
Buxus sempervirens	Deciduous/Mediterranean forest			13	9,22%	7	5,65%	20
cf. *Buxus sempervirens*	Deciduous/Mediterranean forest					1	0,81%	1
Fagus sp.	Deciduous/Mediterranean forest					1	0,81%	1
Leguminosae	Deciduous/Mediterranean forest			1	0,71%	6	4,84%	7
Quercus deciduous	Deciduous/Mediterranean forest	10	4,50%			21	16,94%	31
Quercus ilex/coccifera	Deciduous/Mediterranean forest			2	1,42%	1	0,81%	3
Quercus sp.	Deciduous/Mediterranean forest			2	1,42%			2
Rosaceae/Maloideae	Deciduous/Mediterranean forest	1	0,45%	17	12,06%	11	8,87%	29
Rubus sp.	Deciduous/Mediterranean forest			3	2,13%	3	2,42%	6
Alnus viridis	Riparian forest					2	1,61%	2
Cornus sp.	Riparian forest					1	0,81%	1
Corylus avellana	Riparian forest					11	8,87%	11
Fraxinus sp.	Riparian forest					2	1,61%	2
Laurus nobilis	Riparian forest			3	2,13%	1	0,81%	4
Salicaceae	Riparian forest					2	1,61%	2
Salix sp.	Riparian forest			69	48,94%	14	11,29%	83
Sambucus nigra	Riparian forest	59	26,58%					59
Ulmus sp.	Riparian forest					2	1,61%	2
Undeterminable	Undeterminable					1	0,81%	1
Total		**222**	**100,00%**	**141**	**100,00%**	**124**	**100,00%**	**487 100%**
Total roundwood method		**221**	**99,5%**	**78**	**55,3%**	**68**	**54,8%**	**367 75,35%**

Table 3
Species in the experimental collection and number of samples.

Taxa	Number of analized samples
Prunus armeniaca	**9**
Prunus avium	**20**
Prunus domestica	**21**
Prunus dulcis	**19**
Prunus persica	**53**
Specimen 1	11
Specimen 2	19
Specimen 3	23
Sambucus nigra	**22**
Total	**144**

Table 4
Diameter ranges and their percentage representation for the samples from the reference collection.

Diameter range	N	%
0–5 mm	47	33%
5–10 mm	52	36%
10–15 mm	18	13%
15–20 mm	10	7%
20–25 mm	6	4%
25–30 mm	3	2%
30 o més	8	6%
Total	**144**	**100%**

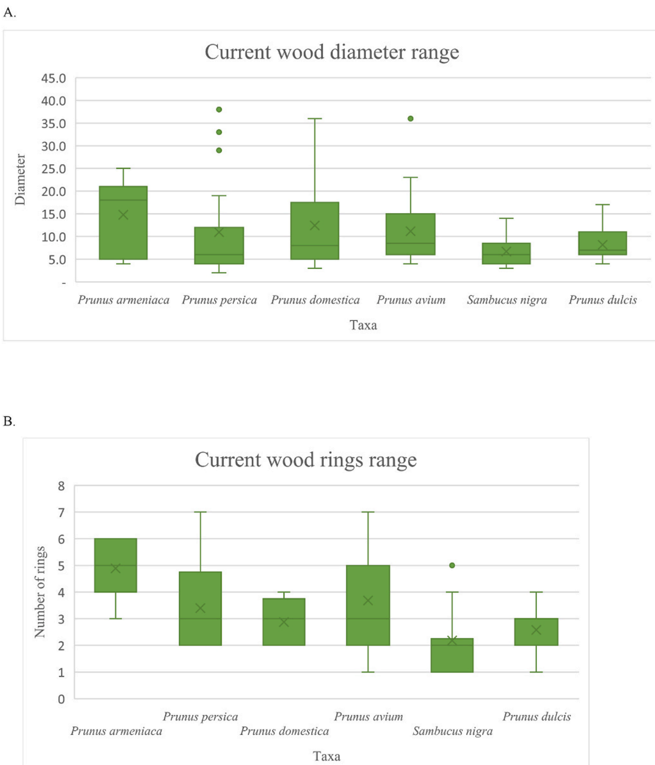
Table 5
Number of rings for each experimental specie.

Taxa/N of rings	1	2	3	4	5	6	7
Prunus armeniaca			3	8	15	18	
Prunus avium	1	10	12	12	15	6	14
Prunus domestica		6	9	8			
Prunus dulcis	1	16	24	8			
Prunus persica		16	15	8	10	12	7
Sambucus nigra	6	22	6	4	10		
Total	**8**	**70**	**69**	**48**	**50**	**36**	**21**

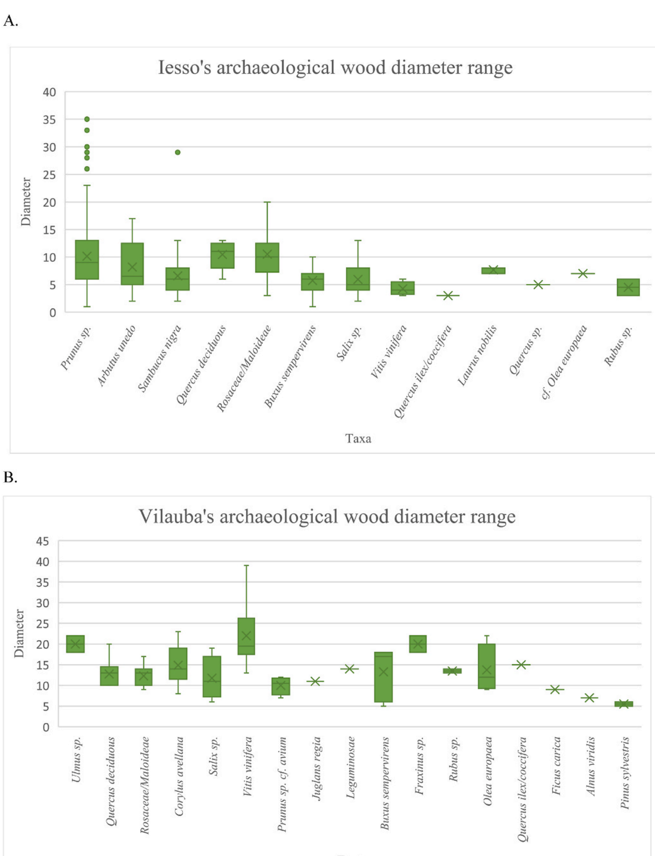
Therefore, the study is based on 367 samples, which is 75% of the total assemblage (Table 2). It should be noted that for the Wall Well, nearly all the fragments were counted (99.5%), as opposed to just 55% of those from the Baths Well and 54% from the well at Vilauba.

Most of the fragments belonged to the smaller diameter groups: 25% smaller than 5 mm and 43% between 5 and 10 mm (n = 92 and 156, respectively) (Table 6 and Graphs 3 and 4).

The range of diameters and number of rings in the archaeological set are presented in Table 7 and Graphs 5 and 6. The vast majority of the samples (n = 218) display a single annual growth ring, while branches with two or three rings are the second and third most abundant (n = 53 and 36, respectively). However, differences can be observed between species since practically all of the *Prunus* sp. branches display a single ring and greater diversity is observed among the other taxa.



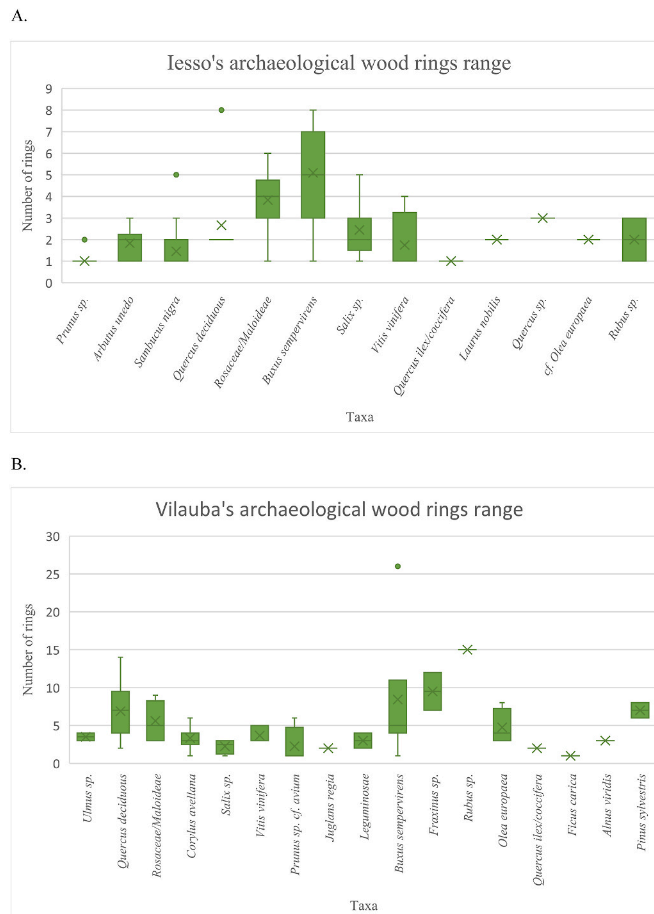
Graph 1. A. Ranges of diameters studied for the samples of the reference collection. B. Number of rings studied for the current experimental samples.



Graphs 2. A. Ranges of diameters studied for the Iesso samples. B. Ranges of diameters studied for the Vilauba samples.

Table 6
Diameter ranges and their percentage representation for the archaeological remains.

Diameter range	N	%
0–5 mm	92	25%
5–10 mm	156	43%
10–15 mm	71	19%
15–20 mm	30	8%
20–25 mm	8	2%
25–30 mm	7	2%
30 o més	3	1%
Total	**367**	**100%**



Graphs 3. A. Number of rings studied for the archaeological samples from Iesso site. B. Number of rings studied for the archaeological samples from Vilauba site.

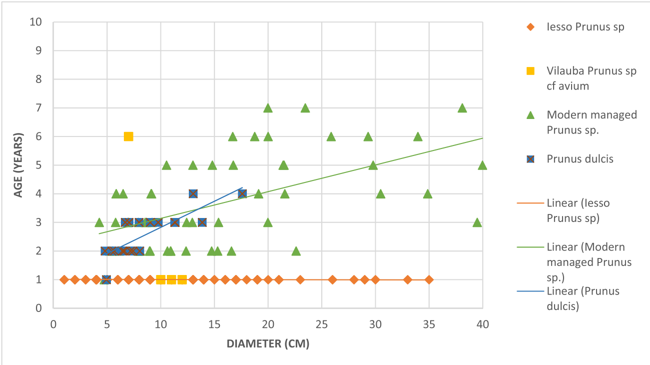
5. Discussion

5.1. Vegetation type

The best represented vegetation types, both qualitatively and quantitatively at both sites, are riparian woodland and domestic species, although significant differences are observed between the wells (Table 2).

Riverine species are most abundant in the Baths Well (Iesso) and are also well represented at Vilauba; willow, but also hazel at Vilauba, are the most representative taxa. It should be noted that greater diversity of riverbank taxa has been identified at Vilauba where alder, ash, dogwood, bay and elm are also present, which would suggest a more intense use of this type of space.

In contrast, elder (*Sambucus nigra*) has only been identified in the



Graph 4. Trends of archaeological *Prunus* sp. from both sites, with the experimental managed ones and the experimental non-managed *Prunus dulcis*.

Wall Well at Iesso. This tree is characteristic of riverbank vegetation but has also been planted, either as an ornamental tree or for use of the properties of its fruits (Romo Díez, 1997). Bay was detected in the Baths Well, it is a very common specie in riparian vegetation in the north-eastern Iberian Peninsula, but it has also been planted for its culinary and ornamental uses (Romo Díez, 1997).

The abundance of riparian species at the Vilauba and Iesso sites has been documented in previous studies. Both carpological and wood remains from Well 1 and 2 at Iesso (Buxó, et al., 2004) revealed evidence of willow, ash and elder, showing that these species may have also been used to make artefacts. The charcoal remains found at Vilauba (López-Bultó, 2019) are also evidence of the use of willow and bay trees as firewood.

Among the domesticated species, *Vitis vinifera*, *Olea europaea* and *Prunus* sp. have been detected at both sites. While *Prunus* sp. is especially abundant in the two wells at Iesso, *Olea europaea* and *Vitis* sp. are better represented in the well at Vilauba. Other fruit trees, like fig (*Ficus carica*) and walnut (*Juglans* sp.) have only been documented at Vilauba, which might be related to greater agricultural diversity at that site (Castanyer, et al., 2015).

A more precise taxonomic identification and confirmation of the species of cultivated is provided by the fruit remains. Previous carpological analysis at Iesso (Buxó, et al., 2004) indicated the wide range of fruits that were grown, including olives (*Olea europaea*), cherries, plums, almonds, peaches (*Prunus* sp.), grapes (*Vitis vinifera*), figs and walnuts. This would confirm the importance of those products among the townspeople.

In the case of Vilauba the carpological studies (Berrocal Barberà, 2021) of the same well also revealed the presence of cherries, peaches, grapes, walnuts and figs. In addition, in the study of charcoal remains (López-Bultó, 2019), remains of *Prunus* sp. and grapevines (*Vitis vinifera*) were found, indicating the use of these plants as fuel.

Species from broadleaf forests appear to be less important in the assemblages. Boxwood (*Buxus sempervirens*) and oak (deciduous *Quercus* sp.) have been documented at both sites. Remains of beech (*Fagus* sp.) have also been identified at Vilauba. Mediterranean taxa are only very marginally represented at both sites, and by the same species: brambles (*Rubus* sp.), holm oak (*Quercus ilex/coccifera*) and strawberry tree (*Arbutus unedo*).

Finally, some taxa could not be ascribed to a particular vegetation type as they were only identified on a family or sub-family level, such as some Leguminosae and Rosaceae/Maloideae. Representatives of both groups flourish in both broadleaf and Mediterranean woodland. Indeed, the Maloideae include several historically cultivated fruit trees, whose presence may also be due to cultivation purposes (Buxó, 2005; Figueiral, 1996). Despite their scarcity in the assemblages, they probably reflect the vegetation around the settlements, where deciduous and evergreen oaks would have formed mixed forests with shrub species like boxwood, strawberry tree and brambles forming the undergrowth, particularly in degraded places. Strawberry trees and brambles tend to colonise clearings and may therefore be indicative of an anthropogenic environment (Piqué, 2009; Rodíguez-Ariza and Montes Moya, 2010).

Conifers are poorly represented at both sites, and mostly occur in the form of *Pinus sylvestris/nigra*. Anthracological studies at the two sites showed that these species were also used as firewood, and to make artefacts at Iesso (Buxó, et al., 2004; López-Bultó, 2019). The carbonised remains correspond mainly to taxa used in manufacturing and carpentry, but also as building material or fuel.

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The wells at Vilauba and Iesso are unique in comparison with other

Table 7
Number of rings for each archaeological specie.

Taxa/N of rings	1	2	3	4	5	6	7	8	9	10	11	12	14	15	26	Total
Prunus sp.	155	1														156
Sambucus nigra	38	17	3		1											59
Salix sp.	9	15	7	3	2			1								37
Rosaceae/Maloideae	2		7	5	1	2		3	2							22
Buxus sempervirens	2		3	2	3		4	2			1				1	18
Quercus sp. deciduous		9		3			1	2	1	1			1			18
Vitis vinifera	3		4	1	2											10
Corylus avellana	1	1	3	3		1										9
Arbutus unedo	2	3	1													6
Olea europaea			2		1			1								4
Rubus sp.	1		1											2		4
Prunus sp. cf *avium*	3					1										4
Laurus nobilis		3														3
Leguminosae		1	1	1												3
Ulmus sp.			1	1												2
Quercus ilex/coccifera	1	1														2
Quercus sp.			2													2
Fraxinus sp.							1					1				2
Pinus sylvestris/nigra						1		1								2
Juglans regia		1														1
cf *Olea europaea*		1														1
Alnus viridis			1													1
Ficus carica	1															1
Total general	**218**	**53**	**36**	**19**	**10**	**5**	**6**	**10**	**3**	**1**	**1**	**1**	**1**	**2**	**1**	**367**

archaeobotanical assemblages from the same chronological context in the north-east of the Iberian Peninsula. Organic wood has only been found in a small number of wells, and some of those that have already been studied, such as Foneria (Barcelona) and Baetulo (Badalona), present concordance in terms of the types of vegetation represented among the species recovered (Piqué, et al., 2016). In the Foneria Well, the most represented taxa are compatible with the wet and marshy areas of the Llobregat river delta, as well as with Mediterranean forest, but a wide variety of agricultural species has also been found, represented by grapevines, walnut trees, fig trees and some varieties of Prunaceae. These data are not only supported by the taxonomy of organic wood, but also by the presence of carpological remains. However, in the case of Baetulo, wood was only recovered from the structure of the well itself, with oak being the main element used, demonstrating the exploitation of local resources.

5.2. Uses of wood resources

Both Iesso and Vilauba are notable for the quantity of remains and the diversity of taxa directly related to different uses, as shown in Table 8. The trees would have provided fresh or dried fruits, either cultivated or wild. As already mentioned, the importance of these species is confirmed by the fruit remains previously studied at both sites (Berrocal Barberà, 2021; Buxó et al., 2004). Fresh fruits are represented by *Prunus* sp., brambles (*Rubus* sp.), figs (*Ficus carica*) and grapes (*Vitis vinifera*). The carpological identification of cherries, plums and peaches is interesting because these fruits cannot be identified in the wood remains. However, they are mentioned in classical sources (Buxó, et al., 2004), as well as other species that have been identified: hazelnut, walnut and the products of wild species such as acorns, elderberries and blackberries, all of which form a large group of food resources that would have been consumed in various culinary preparations (Buxó, 2005).

The taxon *Prunus* sp. is by far the best represented, so procurement practices related to that fruit would have been commonplace, based on what some classical sources attest about the knowledge of the cultivation of such fruit trees, the practice of grafting and different types of pruning, among other techniques (Meiggs, 1982). Another fruit tree represented in the archaeological remains and documented in classic sources is the fig tree, which had been introduced in the Iberian Peninsula in an earlier period (Pérez-Jordà, et al., 2021). As figs can be preserved by drying, they provided an important food resource (Berrocal Barberà, 2021; Buxó et al., 2004).

Obtention of these products would not have been limited to mere opportunistic collection but would have been fully organised and would have required the use of appropriate technologies and specific knowledge of these forest environments. Therefore, knowledge of the characteristics of the various anatomical parts of trees and shrubs, their vegetative cycles and their geographical distribution, on the one hand, and the existence of specific tools for exploiting these resources, on the other, were essential for the development of strategies for exploiting the forest environment (Piqué, 2009). As already mentioned, these fruit trees were generally allochthonous species that were being introduced to the area for the first time, and which coexisted along with other local species. Therefore, they were very likely to have been used for food and trade, as supported by previous experience gained in other regions.

Some of the wood that has been identified may have been used for technological purposes, particularly the abundant remains of willow at both sites. This wood is flexible and was traditionally used in basketry. Remains of willow basketry have been found at Iesso (Buxó, et al., 2004).

The study of the wood remains and the above-mentioned carpological and anthracological studies all point to the widespread cultivation of vines and olives in the north-east of the Iberian Peninsula at that time, as confirmed by the remains from both sites, as well as the practices and consumption of different types of fruit trees (Alonso, et al., 2005; 2016).

5.3. Evidence of arboriculte practices

One important aspect of the assemblages from the three wells is the presence of branches of very different diameters. The abundance of remains raises the hypothesis that they are the result of different practices connected with woodland management and arboriculture. To determine whether these practices were applied at Iesso and Vilauba, the age and diameter of remains of the most abundant species in the archaeological assemblages were compared with experimental samples.This was done using the reference collection of cultivated *Prunus* sp., non-cultivated almond tree (*Prunus dulcis*) and cultivated but non-managed elder (*Sambucus nigra*) that was created specifically for the present study. In addition, data published in (Out, et al., 2013) were kindly provided by Welmoed Out, Caroline Vermeeren and Kirsti Hanninen, and this

Table 8
Documented uses for the species in the three wells. Source: (Garnatje, T., Gras, A., Parada, M., Parada, J., Sobrequés, X., Vallès, J. Desembre, 2020. Etnobotànica dels Països Catalans. Versió 1. https://etnobotanica.iec.cat); (Rivera and Obón de Castro, 1991).

Taxa	Food	Medicinal	Construction	Manufacturing	Tint	Forest regeneration	Oil	Fuel	Cosmetics	Fodder
Alnus viridis	X	X	X		X	X				
Buxus sempervirens		X	X	X	X					
Sambucus nigra	X	X	X	X	X	X				
Cornus sp.				X			X	X		
Corylus avellana	X	X		X			X		X	
Juniperus sp.	X	X	X				X			
Arbutus unedo	X	X		X				X		
Fagus sp.	X	X	X	X			X	X		
Deciduous *Quercus* sp.	X	X	X	X		X	X	X		X
Quercus ilex/coccifera	X	X	X	X		X	X	X		X
Juglans regia	X	X	X	X	X	X	X			
Laurus nobilis	X	X		X			X			
Ficus carica	X	X								
Olea europaea	X	X	X	X			X	X		X
Fraxinus sp.		X			X		X	X		
Pynus silvestris/nigra	X	X	X	X	X		X	X		
Prunus sp.	X	X		X	X			X		
Rubus sp.	X	X		X	X					
Salix sp.		X		X				X		
Vitis sp.	X	X		X	X		X	X		
Sambucus nigra	X	X		X	X	X		X	X	X
Rosaceae/Maloideae	X	X		X						
Leguminosae	X	X		X		X	X			X

information was compared with the willow remains (*Salix* sp.).

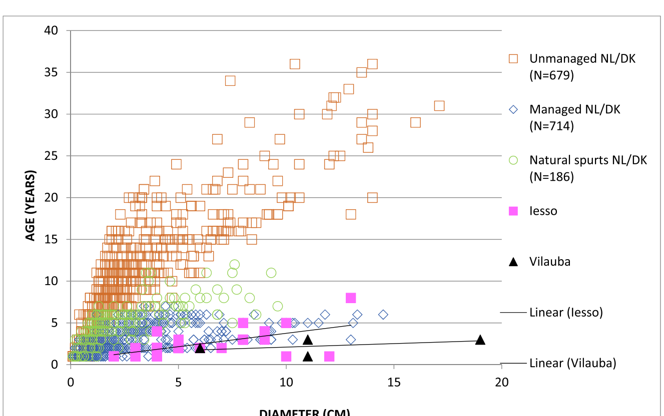
The comparison between the archaeological *Prunus* sp. at both sites with the experimental *Prunus* sp. samples managed by pruning to optimize fruit production is shown in Graph 4. This graph presents a similar trend in both the archaeological and experimental samples although with slight differences. The archaeological samples follow the distribution of managed specimens that tends towards horizontality due to an abrupt interruption in growth (Out, et al., 2013, 2017). The graph also shows that virtually all the archaeological *Prunus* sp. remains are of the same age. This is particularly unusual and suggests either over-management of the trees or a more invasive type of woodland management or arboriculture. In contrast, the scatter plot for modern *Prunus* species shows a wider distribution range. It has few old branches of large age and diameter, and many branches of small age and diameter.

The comparison between the archaeological *Prunus* sp. and the non-managed *Prunus dulcis* samples from the reference collection is shown in Graph 4. Here, different trends are observed. The unmanaged *Prunus dulcis* sample shows a more vertical and linear growth pattern, whereas the archaeological *Prunus* sp. distribution remains predominantly horizontal (Out, et al., 2013, 2017). These trends therefore confirm that archaeological remains were clearly managed.

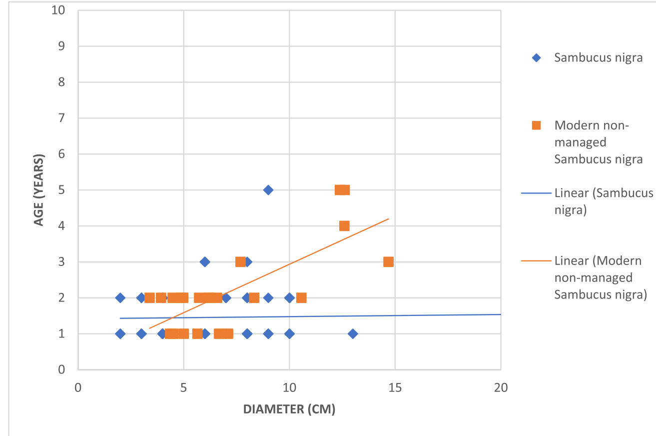
For the taxon *Salix* sp., the present study used the reference collection for managed and non-managed willows in Denmark and the Netherlands (Out, et al., 2013). Those samples therefore come from a different geographic area with different ecological and climate conditions. Nevertheless, it can be observed that the archaeological *Salix* sp. from Iesso and Vilauba display the same horizontal distribution pattern (Graph 5) as the managed *Salix* sp. from Denmark and the Netherlands. Based on the trends observed in the graph, it can be supposed that a management practice was applied to this taxon at the archaeological sites.

The results of the comparison between the archaeological and non-managed experimental samples of *Sambucus nigra*, which was only found at Iesso, are shown in Graph 6. Two trends are observed for both typologies of remains; the pattern tends to be horizontal in the case of the archaeological remains whereas it is linear for the experimental sample. The archaeological sample therefore displays the characteristics of woodland management, as opposed to the experimental sample, which would have been planted but not managed.

Therefore, these comparisons confirm that the archaeological samples of the three taxa, *Prunus* sp., *Salix* sp., and *Sambucus nigra*, exhibit the characteristics of trees that were managed through pruning. This would have been common practice at Iesso and Vilauba to obtain fruit in the case of *Prunus* sp. and elder, and wood of a specific size and shape in the case of willow, specifically for thin, long, flexible branches for basketry. Certain willow species, such as osier, were traditionally cultivated



Graph 5. Scatter plot of *Salix* sp. of the two sites under study, compared with data from Out et al. (2013).



Graph 6. Trend of *Sambucus nigra* from the Iesso site and experimental non-managed *Sambucus nigra*.

for this purpose, but also plants that grew naturally in riparian areas were used (Romo Díez, 1997).

It should be noted that fragments of branches with clear evidence of pruning were found among the samples from Vilauba (Fig. 6). These are *Vitis vinifera* branches with cut marks caused by the removal of secondary branches and the regrowth of wood around them, showing that the plant continued to grow after pruning. This evidence is extremely useful for contrasting the practices cited by Latin agronomists regarding pruning practices on this species.

6. Conclusions

The study of waterlogged wood remains found at the Roman sites of Iesso (Guissona) and Vilauba (Camós) has revealed the presence of a wide range of species collected on surrounding forests, moreover it is remarkable the abundance of fruit trees at both sites.

The abundance of branches suggests that trees and shrubs were managed by pruning. The study has provided clear evidence of forest management and arboricultural practices. On the one hand, the roundwood method, used to study the branches, successfully detected arboricultural practices applied to three taxa: *Prunus* sp., *Salix* sp. and *Sambucus nigra*. On the other hand, direct evidence of pruning was observed on some branches of *Vitis vinifera*. These practices, described in classical sources and traced in the archaeological record, represent an important contribution to the understanding of aspects of life in the Roman period, particularly knowledge of vegetation and tree cultivation.The main taxon of managed fruit trees at the site of Iesso was *Prunus* sp., whereas at Vilauba the taxonomic distribution was more disperse, with no taxon or typology of vegetation particularly predominant over any others. The reason for this diversity probably had to do with the rural function of the settlement at Vilauba, which may have permitted the management of a wider array of species within the agricultural practices at that time.

Regarding the methodology, it should be noted that a relatively recent method could be tested and contrasted on the basis of the reference collection prepared for this work. Furthermore, it was possible to apply this methodology to archaeological materials with satisfactory results, which further enriches and reinforces the methodology. This should lead to the proposal of new lines of research to further develop the method and contrast it in different chronologies and settlements and with different species to those studied here.

Data availability

Data is available as supplementary material of this paper.

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CRediT authorship contribution statement

Eva Maria López Castillo: Investigation, writing. **Oriol López-Bultó:** Conceptualization, Methodology, review. **Anna Berrocal Barberà:** review. **Pere Castanyer Masoliver:** review. **Joaquim Pera Isern:** review. **Esther Rodrigo Requena:** review, All authors have read and agreed to the published version of the manuscript. **Raquel Piqué Huerta:** Conceptualization, Methodology, review.

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.

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Appendix A. Supplementary data

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References

Alonso, N., 2005. Agriculture and food from the roman to islamic period in the northnorth-east of the Iberian Peninsula: archaeobotanical studies in the city of Lleida (Catalonia, Spain). Veg. Hist. Archaeobotany 14, pp341–361. https://doi.org/10.1007/s00334-005-0089-4.

Alonso, N., Buxó, R., Rovira, N., 2008. Archéobotanique des semences et des fruits de Lattara: bilan des recherches. Gallia 65, 193–200.

Alonso, N., Pérez Jordà, G., Rovira, N., López Reyes, D., 2016. Gathering and consumption of wild fruits in the east of the Iberian Peninsula from the 3rd to the 1st millennium BC. Quat. Int. 404, 69–85.

Antolín, F., Martin, L., Bouby, L., Rottoli, M., 2021. Archaeobotanical evidence of plant food consumption among early farmers (5700-4500 BC) in the western mediterranean region. Food Hist. 1–2 (19), 235–253.

Berihuete-Azorín, M., Martín Seijo, M., López-Bultó, O., Piqué Huerta, R., 2022. The Missing Woodland Resources: Archaeobotanical Studies of the Use of Plant Raw Materials. Barkhuis Publishing, Groningen.

Berrocal Barberà, A., 2021. Informe preliminar dels resultats de l'anàlisi carpològica de les mostres de sediment del jaciment de Vilauba (Banyoles, Pla de l'Estany). Universitat Autònoma de Barcelona (UAB), Barcelona, pp. 1–36.

Buxó, R., 2005. L'agricultura d'època romana: estudis arqueobotànics i evolució dels cultius a Catalunya. COTA ZERO (20), 108–120.

Buxó, R., Canal, D., Pera, J., Piqué, R., 2004. Excavació de dos pous d'època romana a Guissona. L'explotació dels recursos vegetals a la ciutat de Iesso als segles I aC-II dC. In: IESSO I. Miscel·lània Arqueològica. Institu d'Estudis Catalans i Patronat d'Arqueologia de Guissona, Barcelona, pp. 211–284.

Castanyer, P., Tremoleda, J., Colominas, L., Antolín, F., 2015. Després de les villae. La transformación del camp al nord-est català en els segles VI i VII a partir de l'exemple de Vilauba/Villa Alba (Pla de l'Estany). Estud. Hist. Agràr. 27, 43–65.

Castellano, L, 2021. A new anthracological sequence from Niğde-Kınık Höyük (Turkey): woodland vegetation and arboriculture in southern Cappadocia from the Late Bronze Age to the Ottoman Period. Archaeol. Anthropol. Sci. 13, 49.

Catón, M.P., 2009. De Agri Cultura. Tecnos, Madrid.

Columella, L.J.M., 2012. De re rustica. Vilafranca del Penedès: Edicions i propostes culturals Andana.

Cubero Corpas, C., 1994. Los recursos vegetales y su aprovechamiento en Hispania según los textos clásicos. *Pyrenae*, pp. 117–121.

Dotte-Sarout, E., 2016. Evidence of forest management and arboriculture from wood charcoal data: an anthracological case study from two New Caledonia Kanak pre-colonial sites. Veg. Hist. Archaeobotany 26, 195–211.

Figueiral, I., 1996. Wood resources in north-west Portugal: their availability and use from the late Bronze Age to the Roman period. Veg. Hist. Archaeobotany 5, 121–129.

Frigola, J., Castanyer, P., Tremoleda, J., 2021. Memòria de les excavacions arqueològiques i dels treballs de consolidació, restauració i adequació realitzats a la vil·la romana de Vilauba (Camós, Pla de l'Estany) 2018-2021, pp. 1–22.

Garnatje, T., Gras, A., Parada, M., Parada, J., Sobrequés, X., Vallès, Desembre, J., 2020. Etnobotànica Dels Països Catalans. Versió 1. https://etnobotanica.iec.cat. December 2023.

Girardclos, O., Billamboz, A., Gassmann, P., 2011. Abandoned Oak Coppice on Both Sides of the Jura Mountains: Dendroecological Growth Models Highlighting Woodland Development and Management in the Past. Orléans, Association for tree-ring research, pp. 71–78.

Girardclos, O., Dufraissie, A., Dupouey, J.L., Coubray, S., Ruelle, J., Rathgeber, C., 2018. Improving identification of coppiced and seeded trees in past woodlan management by comparing growth and wood anatomy of living sessile oaks (Quercus petraea). Quat. Int. (463), 219–231.

Guitart Durán, J., 2010. L'origen de les primeres ciutats romanes de Catalunya. Una aproximació de de l'Arqueologia. Catalan Historical Review (3), 147–162.

Guitart Durán, J., Ros Mateu, J., Gironés, T., Pera Isern, J., 2015. La ciutat romana de Iesso (Guissona, Segarra). Cap a la socialització de la recerca arqueològica. Tribuna d'Arqueologia 21–38.

Guitart, J., Pera, J., Trullàs, Ò., 2021. Informe de la intervenció arqueològica Parc Arqueològic de Guissona (Guissona, La Segarra). Guissona, Pla Quadriennal de Recerca 2018-2021: Projecte Quadriennal de Recerca en Arqueologia 2018-21 "Ciutat romana de Iesso. L'urbanisme i l'articulació dels espais públics i privats" (CLT009/18/00099), pp. 1–53.

Hardy, K., Kubiak-Martens, L., 2016. Wild Harvest: Plants in the Hominin and Pre-agrarian Human Worlds. Oxbow books, Oxford & Philadelphia.

Krebs, P., et al., 2022. The Roman Legacy on European Chestnut and Walnut Arboriculture. Environ. Archaeol. 1–22. https://doi.org/10.1080/14614103.2022.2137648.

Limier, B., et al., 2018. Documenting the history of the grapevine and viticulture: A quantitative eco-anatomical perspective applied to modern and archaeological charcoal. J. Archaeol. Sci. 100, 45–61.

López Sáez, J.A., Peña Chocarro, L., 2008. La huella humana en los paisajes pretéritos. Córdoba, XII Congreso de historia agraria, pp. 1–20, 2008.

López-Bultó, O., 2019. Informe de l'anàlisi antracològic del jaciment de Vilauba (Banyoles, Pla de l'Estany). Universitat Autònoma de Barcelona, Barcelona, pp. 1–27.

López-Bultó, O., 2020. Wood analysis and beyond: contribution of twice-neglected wooden procurement and transformation processes at La Draga (Banyoles, Spain). J. Archaeol. Sci.: Report 29, 102–122.

Marzano, A., 2022. Arboriculture, 'Botanical Imperialism', and Plants on the Move in *Plants, Politics and Empire in Ancient Rome*. Cambridge University Press. ISBN 9781009121958.

Meiggs, R., 1982. Trees and Timber in the Ancient Mediterranean World. Oxford University Press, Oxford.

Out, W., et al., 2020. Identification of woodland management by analysis of roundwood age and diameter: Neolithic case studies. For. Ecol. Manag. 467 (118136), 1–13.

Out, W., et al., 2023. Evidence of woodland management at the eneolithic pile dwellings (3700–2400 BCE) in the ljubljansko barje, Slovenia? Plants 12 (291), 1–19.

Out, W., Hänninen, K., Vermeeren, C., 2017. Usin branche age and diameter to identify wooland management: new developments. Environ. Archaeol. 1–14.

Out, W., Vermeeren, C., Hänninen, K., 2013. Branche age and diameter: useful criteria for recognaising woodland management in the present and past? J. Archaeol. Sci. 4083–4097.

Peña-Chocarro, L., Zapata Peña, L., 1996. Los recursos vegetales en el mundo romano: estudio de los macrorrestos botánicos del yacimiento calle Santiago de Irún (Guipúzcoa), pp. 119–134. AEspA.

Pérez-Jordà, G., Peña-Chocarro, L., Pardo-Gordó, S., 2021. Fruits arriving to the west. Introduction of cultivated fruits in the Iberian Peninsula. J. Archaeol. Sci.: Report 35, 102683.

Piqué, R., 2009. Wood in the Ancient Mediterranean : Forests, Fuelwood and Raw Materials. Sudies on the Rural World in the Roman Period, pp. 61–72.

Piqué, R., Ravotto, A., López-Bultó, O., 2016. Roman wells of north-eastern Iberian Peninsula: landscape and use of wooden resources. Quat. Int. 104–113.

Rasmussen, P., 1990. Pollarding of Trees in the Neolithic:often Pressumed, Dificult to Prove. En: Experimentation and Reconstruction in Environmental Archaeology. Oxford Books, Oxford (UK).

Riera, S., Palet, J.M., 2005. Aportaciones de la Palinología a la historia del paisaje mediterráneo: estudio de los sistemas de terrazas en las Sierras Litorales Catalanas. Transdiciplinary approach to a, pp. 55–74.

Rivera, D., Obón de Castro, C., 1991. La guía de Incafo de las plantas útiles y venenosas de la Península Ibérica y Baleares (excluídas medicinales). Incafo, Madrid.

Rodíguez-Ariza, M. & Montes Moya, E., 2010. Paisaje y gestión de los recursos vegetales en el yacimiento romano de Gabia (Granada) a través de la Arqueobotánica. Archivo Español de Arqueología, 83, pp. 85-107. ISSN: 0066 6742. doi: 10.3989/aespa.083.010.005.

Romaní, N., Rodrigo, E., 2017. Informe de la campanya d'excavacions al Parc Arqueològic de Guissona. Zona Muralla. Institut Català d'Arqueologia Clàssica, Guissona, pp. 1–18.

Romo Díez, A., 1997. *Árboles de la Península Ibérica y Baleares*, 1st edition. Ed. Planeta, Barcelona.

Schweingruber, F.H., 1990. Anatomie Europäischer Hölzer - Anatomy of European Woods. Bimensdorf, Bern. Eidgenössische Forschungsanstalt für Wald Schnee und Landschaft, Stuttgart, Haupt.

Schweingruber, F.H., 1996. Tree Rings and Environment Dendroecology. Birmensdorf, Swiss Federal Institute for Forest, Snow and Landscape Research. Berne, Stuttgart, Vienna, Haupt, p. 609. ISBN 3-258-05458-4.

Teira, A., 2013. Dentro y fuera del bosque. La gestión del Prunus avium/cerasus en época romana y medieval en el NW ibérico. Arkeogazte (3), 99–115.

Teofrasto, 1988. Historia de las plantas. Gredos SA, Madrid.

Valamoti, S.M., Dimoula, A., Ntinou, M., 2022. Cooking with plants in ancient Europe and beyond. Interdisciplinary Approaches to the Archaeology of Plants Foods. Sidestone Press Academics.

Vila, S., Piqué, R., 2012. Paisatge vegetal i gestió del combustible a la plana Occidental catalana entre el Neolític i l'Edat Mitjana: estat de la qüestió des de l'anàlisi antracològica. Revista d'Arqueologia de Ponent, pp. 9–36, 22.

Visser, R., 2010. Growing and felling? Theory and evidence related to te application of silvicultural systems in the Roman period. TRAC 2009, 11–22.