

Wood exploitation and food supply at the border of the Roman Empire: the case of the *vicus* of Thamusida – Sidi Ali ben Ahmed (Morocco)

Emilia Allevato¹ , Mauro Paolo Buonicontri¹, Alessandra Pecci^{2,3}, Alessia D'Auria¹, Emanuele Papi⁴, Antonio Saracino¹, Gaetano Di Pasquale¹

¹Dipartimento di Agraria, Università di Napoli Federico II, via Università 100, I-80055 Portici, Italy, ²Equip de Recerca Arqueològica i Arqueomètrica, Universitat de Barcelona (ERAAUB), Spain, ³Dipartimento di Biologia Ecologia e Scienze della Terra, Università della Calabria, Italy, ⁴Dipartimento di Archeologia e Storia delle Arti, Facoltà di Lettere e Filosofia, Università degli Studi di Siena, via Roma 56, 53100 Siena, Italy

This paper presents the results of inter-disciplinary work drawing on archaeobotanical and archaeometric studies to trace the agroforestry landscape and the supply economy at the *vicus* of Thamusida in north-west Morocco at the border of the Roman Empire. The available data indicate the self-sufficiency of the settlement in both forestry and agricultural products throughout the period investigated from the 1st to the 3rd century AD. Charcoal data testify to the presence of a *Quercus suber* forest in the close surroundings of the site and its exploitation for a variety of forestry products such as timber, fuelwood, cork, and probably also leaves and acorns to feed livestock. The overwhelming presence of *Q. suber* in the archaeological layer investigated clearly indicates that this forest was under human influence prior to Roman occupation and was already partially degraded. Charred seed and fruit remains suggest that the diet of both troops and civilians was mainly based on locally grown products and that all the inhabitants of the site had access to good cereals such as barley, naked wheats and pulses with large seeds such as horse bean and pea; quality fruits, such as olive and grape, were also produced locally for fresh consumption. Organic residue analyses of the contents of ceramic vessels and plastered vats allowed archaeobotanical data to be complemented, thereby shedding light on some of the imports at Thamusida. Despite the remote location of this settlement, imported goods such as oil and wine were transported here in amphorae from different parts of the Empire.

Keywords: Multi-functional forest, Cork oak, *Quercus suber*, Barley, Northern Africa, Charcoal analysis, Archaeobotany

Introduction

No ancient trade matched in structure, scale and intensity of the trade economy of the Roman World. An important ancillary outcome of this globalised trade system was an unprecedented extension of settlements along the network, especially in northern Africa, Western and Central Europe, and Asia Minor (Hitchner 2008).

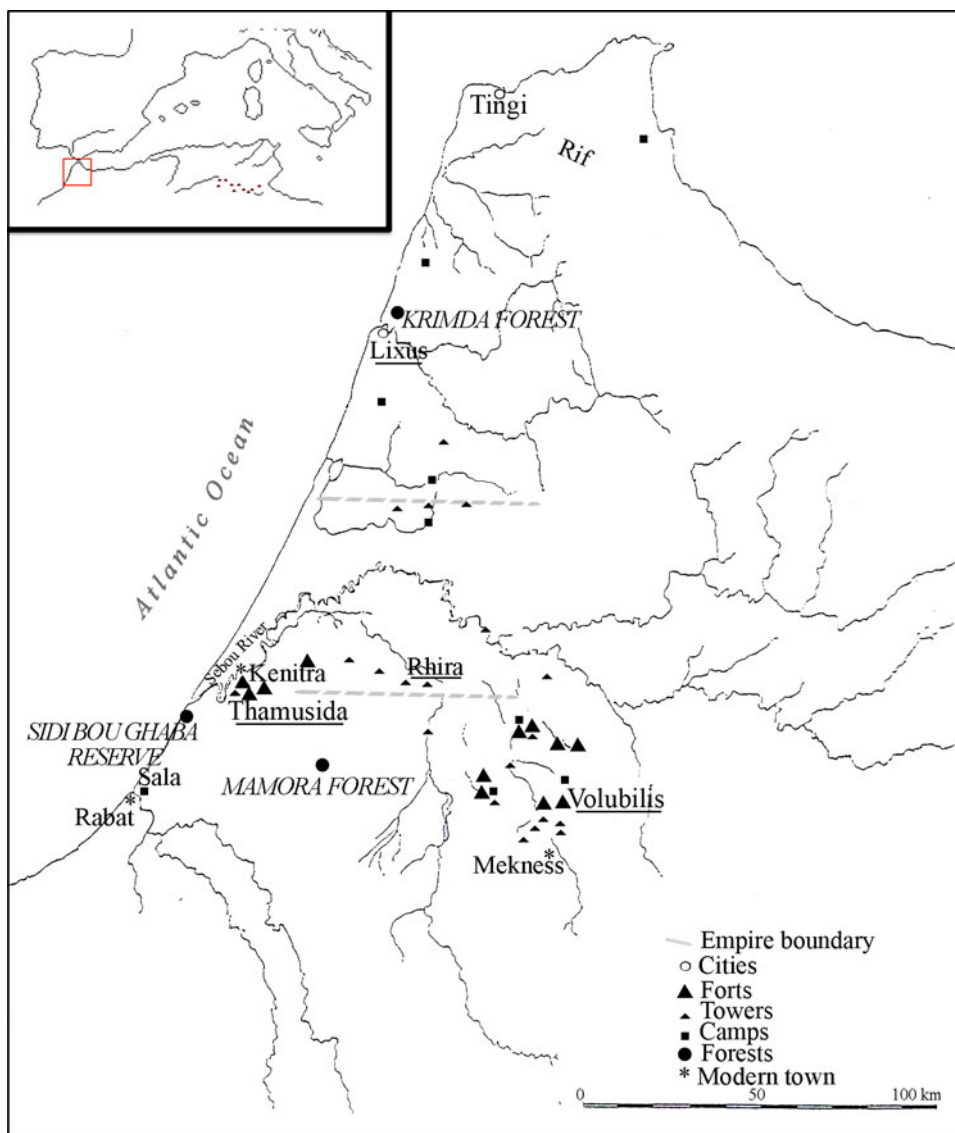
The archaeological site of Thamusida – present-day Sidi Ali ben Ahmed – is situated in north-western Morocco (34°19'N–6°29'W) about 50 km away from the city of Rabat and about 30 km from the Atlantic coast (Fig. 1). The site was discovered early on at the 19th century, and three archaeological excavations at

the site were carried out by a French mission between 1930 and 1960 (Akerraz and Papi 2008). Since 1999 more extensive and systematic exploration has been carried out by the University of Siena in collaboration with the Institut National de Sciences de l'Archéologie et du Patrimoine de Rabat (INSAP).

The 15-hectare site is located on a low hill near the left side of the Sebou river. It consists of a military quarter with an adjacent civil settlement, namely, the *vicus*, with all the main private and public infrastructures such as houses, thermal baths, temples, taverns, shops and workshops. It was built in the 1st century AD, following the establishment of *Mauretania Tingitana* as a Roman province. At the end of the 3rd century AD, after the withdrawal of the Roman army, Thamusida continued to be inhabited until the Arab conquest (7th–8th century AD).

Correspondence to: Emilia Allevato, Dipartimento di Agraria, Università di Napoli Federico II, via Università 100, I-80055 Portici, Italy.
E-mail: ellevat@unina.it

115
120
125
130
135
140
145



170
175
180
185
190
195
200

Colour online, B/W in print

Figure 1 Study site and main sites cited in the text. Modified from Akerraz et al. 1995.

Here, we present the results of inter-disciplinary work using archaeometric and archaeobotanical studies in order to map out the supply economy at the vicus of Thamusida. Charred archaeobotanical remains (seed and fruit remains and charcoal) were analysed in order to provide information on the plant environment, and on the exploitation of woodland as well as the production and consumption of food in the area.

Chemical analyses of the contents of ceramic vessels (dolia and amphorae) recovered in a warehouse in the military quarter were carried out to identify the organic residues preserved in them and provide information on the import and consumption of wine, oil or fish sauces. Moreover, the plastered coatings of two vats excavated at the site were carried out to identify any substances contained in them and therefore ascertain whether they were used in the production of wine, oil or fish sauces (Pecci et al. 2013a), and whether they suggested the existence of production structures at the site.

The present-day environment of Thamusida

The coastal region of Kenitra-Rabat is subject to a thermomediterranean sub-humid bioclimate: the mean annual precipitation is 600 mm and the rainiest periods are in winter (mainly in November and December). Easterly sea breezes in the summer, carrying wet air masses from the Atlantic Ocean. The mean annual temperature is 17.2°C, with a seasonal average temperature of 13°C in winter and 27°C in summer (Kabbour et al. 2006). Soils are mainly marshy and saline (Cavallar 1950).

The current vegetation in the vicinity to the site is represented by the prevailing *Chamaerops humilis* and scattered shrubs of *Ziziphus lotus* and *Olea europaea*. Along the Sebou river, riparian vegetation consists of scattered plants of *Vitex agnus-castus* and *Crataegus monogyna*. Along the coast, 20 km away from the site, the “Biological Reserve of Sidi Bou Ghaba” (Fig. 1) includes shrubby formations with *Juniperus phoenicea*, *Phillyrea angustifolia*, *Pistacia lentiscus*, *Rhamnus oleoides* and *Retama monosperma*.

225 Riparian vegetation with prevailing *Populus alba*
 characterises the surrounding area of the Merja
 (lagoon) of Sidi Bou Ghaba. The Mamora forest
 (Fig. 1) is located a few kilometres away from the
 site; it is at present one of the most degraded forests
 230 in Morocco with few woody taxa (Rejdali 2004).
Quercus suber is the only tree taxon and is
 accompanied by few shrubby species, such as the
 endemic *Pyrus mamorensis* and sporadically *O. euro-*
paea, *Phillyrea latifolia* and *Teline linifolia*.

235 Materials and methods

Charcoal

240 Sediment samples were collected from deposits archae-
 ologically dated between the end of the 1st century BC
 and the beginning of the 4th century AD. The
 sampling strategy followed Chabal *et al.* (1991), each
 A Q1 sample ranging between 5 and 10 kg according to
 the thickness and surface area of the stratigraphical
 unit (SU). All the collected sediments were floated
 245 on a sieve column with a mesh size of 4.0 and
 2.0 mm and then dry sieved. Further, two trenches
 (namely, trench 39,000 and trench 40,000), close to a
 hill described as a productive area, were excavated
 and sampled. The charcoal fraction >4 mm was
 250 sorted by the naked eye while fragments > 2 < 4 mm
 were sorted with the help of a dissecting stereomicro-
 scope with a low magnification (10X–40X). All char-
 coal fragments were analysed with an incident light
 microscope (100X–1000X) and identified by referring
 255 to wood anatomy atlases (Neumann *et al.* 2001;
 Schweingruber 1990; Vernet *et al.* 2001), as well as
 to our reference collection.

In a previous paper, 2610 charcoal fragments from
 50 SUs were analysed and presented (Allevato *et al.*
 260 2013). Charcoal analysis at the site was then carried
 out by Bellavia (2011).

265 After in-depth examination of the function of the
 context and further refinement of archaeological
 dating of all analysed layers, we used for our recon-
 struction only those layers which were well constrained
 chronologically so as to avoid bias in the representa-
 tiveness of the assemblages due to ambiguous proven-
 270 nance of the charcoal. A total of 4354 charcoal
 fragments from a total of 70 SUs are now presented
 in this definitive paper.

Carpological remains

275 At least 201 of sediment samples were taken from 50
 archaeological layers, which are referred to here as
 stratigraphic units (SUs), related to 10 archaeological
 structures (Table 2). By the term “archaeological
 structure”, we indicate the presumed function of the
 features in the settlements, such as barracks and forti-
 280 fied walls. Sediment samples were labelled according
 to the SU and the structure identification follows the

same numbering sequence as the excavation plan.
 SUs cover a chronological range between the end of
 the 1st century BC and the beginning of the 4th
 century AD.

285 The samples were processed by flotation and macro-
 remains were recovered from mesh sizes 4, 2, 1, 0.50
 and 0.25 mm. All recovered plant remains were well
 preserved under a charred condition. They were
 observed and separated into “individuals” and “frag-
 290 ments”, and then counted. We use the term “individ-
 ual” when the fragments had diagnostic features that
 allowed us to count them as entire, following the prin-
 ciple of the “minimum number of individuals”
 (Antolin and Buxò 2011; Jones 1990). Identified frag-
 295 ments without these characteristics were counted and
 classified as fragments.

Taxonomic identification was carried out by using a
 reference seed collection for comparison, atlases and
 the specialist literature (e.g. Hubbard 1992; Maier
 1996; Neef *et al.* 2012; Renfrew 1973; Schoch *et al.*
 300 1988). Since grain remains of naked wheat cannot be
 identified at a species level (Alonso Martinez 2005;
 Jacomet 2008; Maier 1996; Ruas 2005), the term
Triticum aestivum/durum is used in accordance with
 305 Jacomet (2008).

All percentages and frequencies were calculated for
 each taxon by considering the minimum number of
 individuals (MNI) according to Antolin and Buxó
 (2011); rachis forks were included as individuals in
 percentage calculations for cereals, as well as floret
 310 in weeds. For *O. europaea*, since only fragments were
 present, they were considered as individuals following
 Alonso Martinez (2005). The percentage of each taxo-
 nomic group out of MNI recovered is reported in
 Fig. 2. The general proportions of the food plants in
 315 Thamusida (cereals, pulses and fruits), excluding
Hordeum/Triticum, *Pisum/Vicia*, and undifferen-
 tiated pulses, are reported in Fig. 3.

In order to observe spatial distribution of the carpo-
 logical remains in the settlements, to detect the differ-
 320 ences between the archaeological structures and to
 explain the use of crops, we selected only 4 out of
 10 archaeological structures recording >30 MNI.
 The percentages of MNI of the taxa from the total
 sum of cereals, pulses and fruits of these four selected
 325 structures are reported in Fig 4.

Residue analysis

330 A total of 15 samples were analysed for the organic
 residue analysis (Table 3). Two samples were recovered
 from the plastered coatings of two small vats with the
 objective of ascertaining whether they could be related
 to the presence of small production structures at the
 site. In fact, the study of vats can provide information
 on food production at archaeological sites (Pecci *et al.*
 335 2013a, Pecci and D’Andria 2014). One sample was

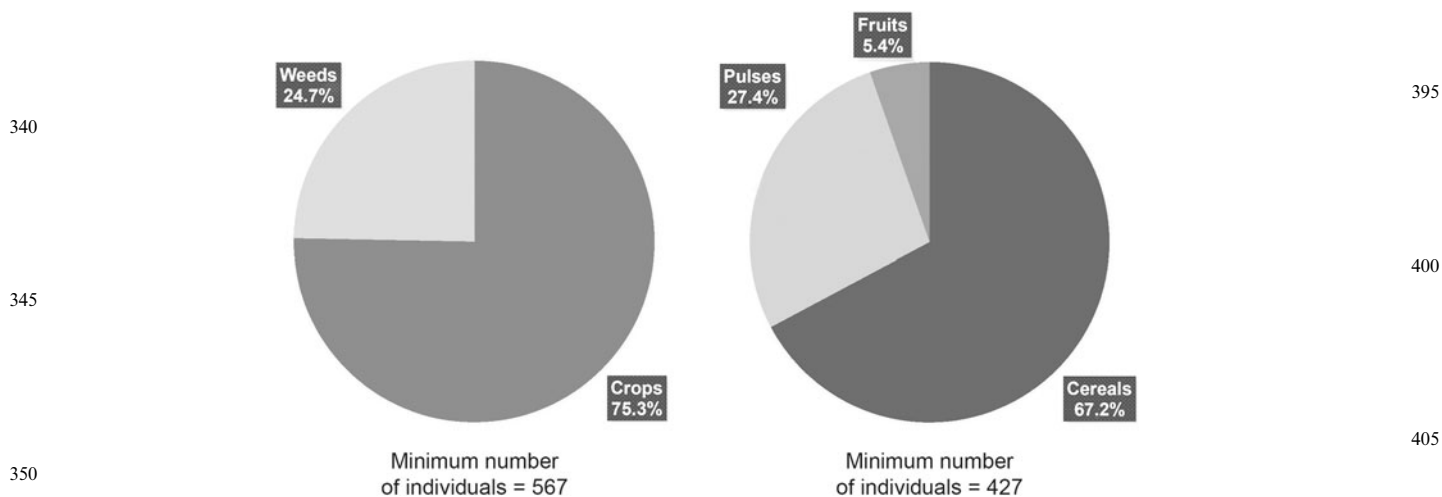


Figure 2 Crop plants from Thamusida: percentages of each taxonomic group out of the minimum number of individuals recovered.

recovered from the plastered coating of a vat possibly related to a domus dated to the Flavian period (sample 1, Table 3) and another was recovered from a vat located nearby (sample 2, Table 3) and related to a probable re-use of the area between the end of the 2nd and the beginning of the 3rd century AD.

Samples 3 and 4 were taken from two Dressel 20 amphorae coming from one production structure (Salvini et al. 2007). The other materials analysed come from the military quarter: they were recovered in a storage room where amphorae and *dolia* were abandoned between the end of the 3rd and the

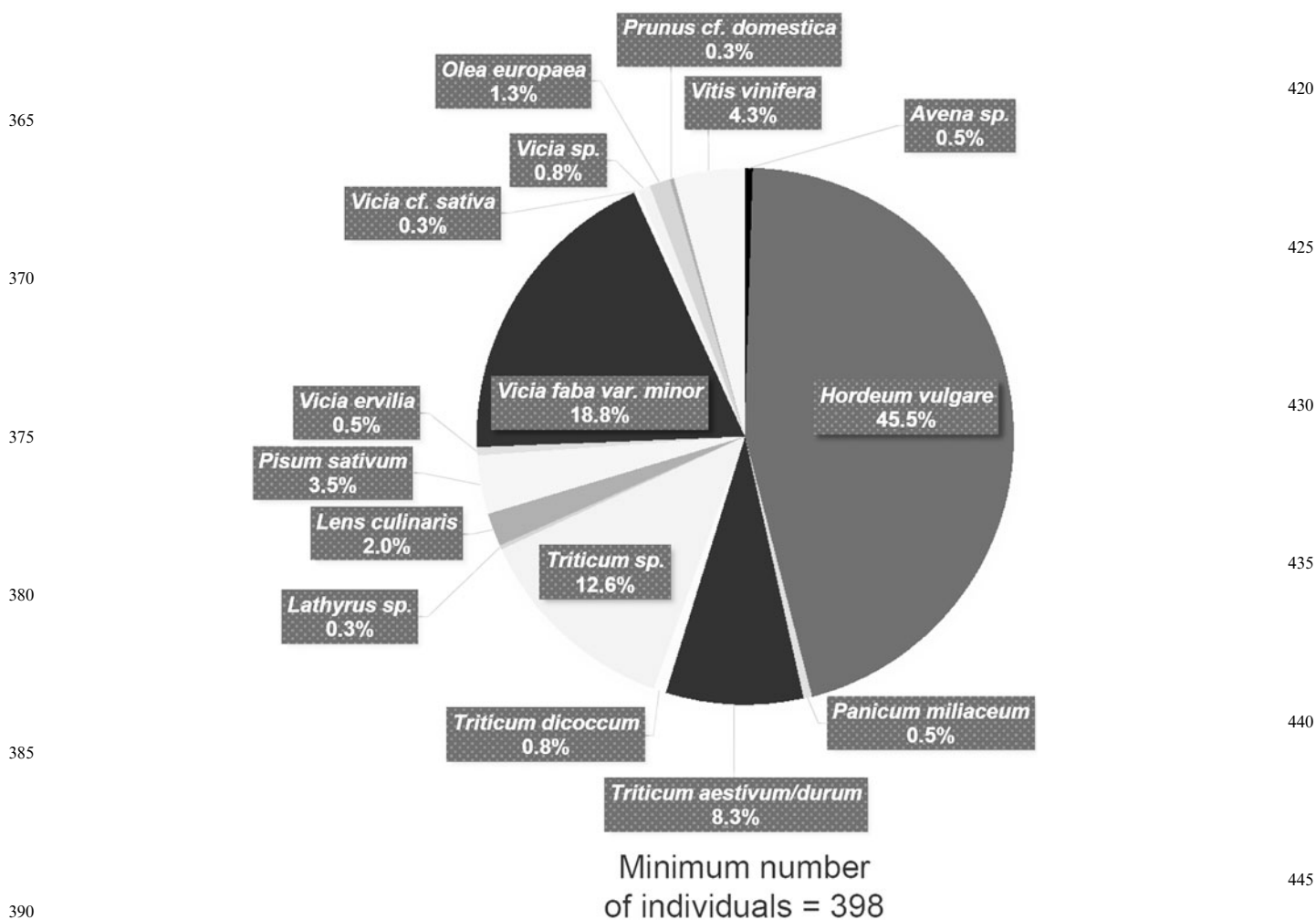


Figure 3 Food plants in Thamusida: percentages of each taxonomic group out of the minimum number of individuals considered.

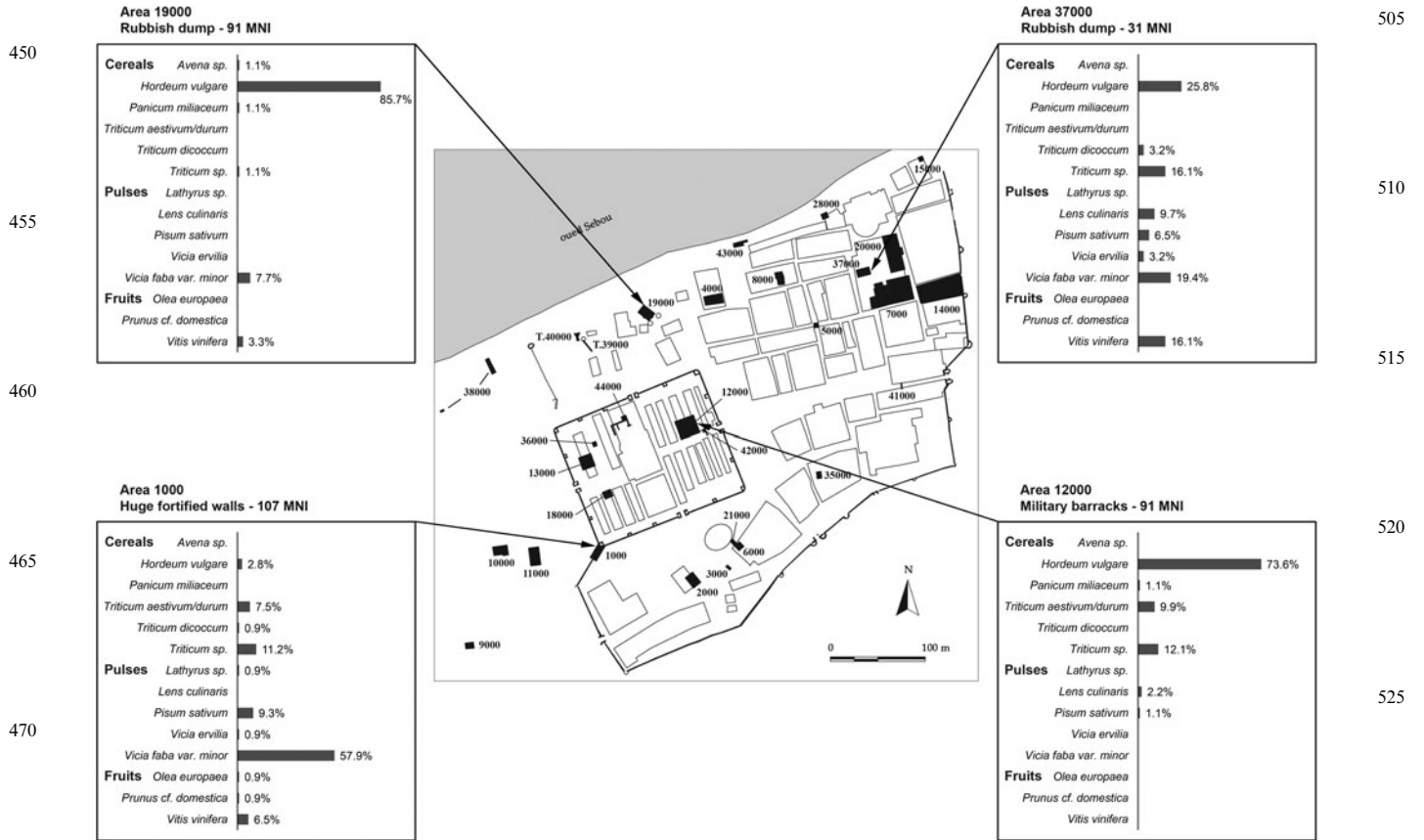


Figure 4 Food plants in Thamusida by archaeological structures with more than 30 minimum number of individuals. Percentages of MNI of the taxa from the total sum of cereals, pulses and fruits, excluding *Hordeum/Triticum*, *Pisum/Vicia*, and undifferentiated pulses.

beginning of the 4th century AD (area XII). The materials consist of one Dressel 20, one Dressel 30, five *amphorae* Africana (three provisionally identified as Africana IID, one Africana IIB and one Africana II non-id.) and four *dolia* (Table 3).

The samples were mechanically cleaned with a scalpel and then ground. Each powdered sample was submitted to three extractions: (a) lipid extraction following the procedure described by Mottram et al. (1999); (b) after total lipid extraction the solid residue was extracted following Pecci et al. (2013b); (c) to identify wine markers the extraction method proposed by Pecci et al. (2013c) was followed.

All the extracts were derivatised by adding 25 µl of *N,O*-bis(trimethylsilyl)trifluoroacetamide (BSTFA, Sigma-Aldrich) and heating at 70°C for 1 h. Analyses were carried out in collaboration with the Chemistry Department of the University of Siena at the Centre for Analysis and Structural Determinations (CIADS) using instruments and parameters reported in Giorgi et al. (2010).

Results

Charcoal

Out of a total of 4354 analysed charcoal fragments from 70 SUs, 23 taxa were identified. The percentage

of each taxon is represented in Table 1. Percentages were calculated from the total number of charcoal fragments in the coeval SU grouped by functional hypothesis. The number of SUs and the count of charcoal fragments are indicated for each period and typology. The results for 16 SUs comprising furnaces, kilns and ovens are not represented in the figure because only charcoal belonging to the *Quercus* genus (mainly *Q. suber*) was present therein (861 fragments).

The most abundant charcoal fragments belong to the *Quercus* genus: along the entire investigated period and in all functional contexts *Q. suber* is always dominant; *Q. suber-ilex* and *Quercus* are also present among the identified taxa. Charcoal fragments were attributed to *Q. suber* only when we were able to observe the transition from early to late wood in large and complete growth rings (Schweingruber 1990). Additional testing was also performed by measuring vessel diameter following Vernet et al. (2001). Alternatively, charcoal fragments were attributed to *Q. suber-ilex* and *Quercus*. However, the absence in the identifications of *Quercus* charcoal identifiable at a species level other from *Q. suber* strongly suggests that all the charcoal fragments belong exclusively to the latter.

Additional analysis of two trenches (namely, trench 39,000 and trench 40,000, Fig. 4), close to a hill

Table 1 Percentages of charcoal fragments grouped by dating and functional type of the excavated contexts.

Chronology	Context	Excavation areas	US (count)	Analysed charcoal (count)	<i>Quercus suber</i>	<i>Quercus suber-flex</i>	<i>Quercus</i>	<i>Frankenia</i>	<i>Gymnospermae</i>	<i>Tetraclinis articulata</i>	<i>Pinus pinaster</i>	<i>Pinus</i>	<i>Daphne-Thymelaeae</i>	<i>Erica</i>	<i>Ceratonia siliqua</i>	% cf. <i>Prunus</i> sp.	<i>Cistus</i>	<i>Prunus</i>	<i>Crataegus</i>	<i>Olea europaea</i>	<i>Vitis vinifera</i>	<i>Pistacia lentiscus</i>	<i>Populus</i>	<i>Fabaceae</i>	<i>Juglans</i>	<i>Arbutus unedo</i>	<i>Rosaceae maloidaeae</i>	Undetermined
End 3rd AD-Beg. 4th AD	Collapses	12,000	5	354	29.38	19.49	17.23	2.26	0.85	5.37	-	-	0.28	0.56	-	0.85	-	-	1.13	1.13	-	0.28	-	-	-	0.28	-	21.75
Second half 3rd century AD	Living floors	5000, 7000	4	97	77.17	16.30	5.43	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.09
Second half 3rd century AD	Living floors	14,000	5	157	42.04	51.59	1.91	-	-	1.27	-	-	-	-	-	-	-	-	0.64	0.64	0.64	-	-	-	-	-	1.91	
First half 3rd century AD	Accumulations	14,000	1	16	-	87.50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12.50	
First half 3rd century AD	Accumulations	4000, 14,000	2	63	33.33	42.86	-	-	-	0.75	4.48	0.75	-	-	-	-	-	-	7.94	7.94	0.10	-	-	-	-	-	15.87	
Mid-2nd century AD	Living floors	15,000	7	262	23.13	48.84	3.73	-	-	-	-	-	-	-	-	-	-	-	2.65	2.65	-	-	-	-	-	-	15.57	
Mid-2nd century AD	Living floors	15,000	2	86	5.81	81.40	-	-	-	-	-	-	-	-	-	-	-	-	4.65	4.65	-	-	-	-	-	-	8.14	
Mid-2nd century AD	Accumulations	1000, 14,000	2	144	40.28	40.28	3.47	-	-	0.69	-	-	-	-	-	-	-	-	2.08	2.08	0.69	-	-	-	-	-	11.81	
AD-Beg. 3rd century AD	Waste discharges	1000, 37,000	3	1033	96.03	0.29	0.68	-	0.10	0.39	-	-	0.10	-	0.48	-	-	-	0.19	0.19	-	-	-	-	-	-	1.84	
AD	Living floors	4000, 5000, 12,000	3	171	38.60	11.11	7.60	0.58	1.17	0.58	0.58	-	-	-	-	-	1.17	3.51	0.58	-	1.17	-	0.58	0.58	-	0.58	2.34	
Flavian Age (AD 69-96)	Living floors	5000	4	324	70.06	8.64	6.48	0.31	0.31	-	0.31	-	-	-	-	-	-	-	0.93	0.93	0.31	-	-	-	-	-	12.04	
AD	Accumulation	1000	1	73.42	10.13	7.59	2.53	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.33	
AD	Collapses	20,000	2	34	26.47	41.18	23.53	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.82	
End 1st cent BC-Beg. 1st century AD	Accumulations	1000, 4000	2	155	58.06	11.61	10.97	1.29	-	-	5.81	-	-	-	-	-	-	-	-	5.16	5.16	-	-	-	-	-	7.10	
BC	Living floors	4000, 5000	7	488	74.59	8.40	7.38	0.82	-	0.20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.61	
End 1st AC-Beg. 1st century AD	Living floors	5000	1	109	14.68	16.51	11.01	-	11.93	15.60	-	-	-	-	-	-	-	-	-	3.67	3.67	-	-	-	-	-	22.94	
Total	Furnaces and ovens with Quercus 100%	19,000, 35,000	51	3493																								
	Trenches	139,000, 140,000	2	-																								
	Total		70	4354																								

Notes: Percentages were calculated from the total number of charcoal fragments in the coeval SUs grouped by functional hypothesis (i.e. by archaeological structure). Provenience areas of the excavated layers are also listed.

Table 2 Carpological (seed and fruit) remains from Thamusiida.

Archaeological structure	1000	4000	5000	7000	12,000	14,000	19,000	20,000	36,000	37,000
Huge fortified walls										
Samples (SU)	1025, 1035, 1040	4053, 4060, 4061	5018, 5019, 5020, 5021, 5024, 5026, 5028, 5051, 5052	7044, 7078, 7091, 7098, 7100, 7112, 7113	12,112, 12,113, 12,121, 12,119, 12,126, 12,155, 12,174	14,112, 14,118, 14,127, 14,144, 14,147, 14,202, 14,203	19,002, 19,003, 19,006, 19,008, 19,018, 19,041, 19,050, 19,056	20,116	36,007, 36,012	37,012, 37,015, 37,026
Cereals										
<i>Avena</i> sp.			1				1			
<i>Hordeum vulgare</i>	3	3		6	37	3	47	1	5	6
<i>Hordeum vulgare</i> fragm				3	60	1	62	3	5	3
<i>Hordeum vulgare</i> fragm			1							
<i>Panicum miliaceum</i>										
<i>Triticum aestivum</i> /durum	8		5	6	1		1	1	1	
<i>Triticum aestivum</i> /durum fragm			1		5			1		
<i>Triticum</i> cf. <i>aestivum</i> /durum			1							
<i>Triticum dicoccum</i>	1		1							1
<i>Triticum</i> sp.	12	2	4	1	3	1	1	1	1	3
<i>Triticum</i> sp. fragm			18	3	15	2	2	2		3
<i>Hordeum</i> / <i>Triticum</i> fragm				2						11
Pulses										
<i>Lathyrus</i> sp.	1									
<i>Lens culinaris</i>			1	1	1					3
<i>Lens culinaris</i> fragm	3			1	1					
<i>Pisum</i> / <i>Vicia</i>	3					1				1
<i>Pisum</i> / <i>Vicia</i> fragm	9			2						
<i>Pisum sativum</i>	10	1			1					2
<i>Vicia ervilia</i>	1									1
<i>Vicia faba</i> var. <i>minor</i>	15						3			4
<i>Vicia faba</i> var. <i>minor</i> fragm										
<i>Vicia</i> cf. <i>sativa</i>	94						7			4
	Seed			1						
	Seed									

(Continued)

840 835 830 825 820 815 810 805 800 795 790 785

Table 2 Continued

Archaeological structure	1000	4000	5000	7000	12,000	14,000	19,000	20,000	36,000	37,000
	Huge fortified walls	Granary	Street	Street	Military barracks	Inhabited layer	Rubbish dump	Accumulation	Military bread oven	Rubbish dump
<i>Vicia</i> sp.				3						
Pulses undiff.			1	1						
Fruits										
<i>Olea europaea</i>	2						3			
Endocarp fragm										
<i>Prunus</i> cf.	1									
<i>domestica</i>										
<i>Vitis vinifera</i>	2	1	1			3				5
<i>Vitis vinifera</i> fragm	10									
Weeds										
<i>Carex</i> sp.					3					
Chenopodiaceae		1								
Cyperaceae	2	1						1		1
<i>Hordeum</i> cf.					3					
<i>secalinum</i>										
<i>Hordeum</i> cf.					1					
<i>secalinum</i>										
<i>Lolium</i> sp.				2						
Malvaceae	30				20		1			
Seed					7	4			2	2
Seed					3		2			
<i>Medicago</i> sp.				3	7	1	2			
<i>Phalaris</i> sp.	3	1		1	7		2			
<i>Rumex</i> sp.				1	17					
<i>Sherardia arvensis</i>					1					
Endocarp		1								
<i>Vicia</i> cf. <i>cracca</i>				1		1				
<i>Vicia</i> cf. <i>cracca</i>					1					
fragm										
<i>Vicia</i> sp.							2			
Poaceae undiff.				2						
Caryopsis	3	5	4	1	7		10			
Unidentified					1					
Unidentified fragm			1		1					
Total	213	15	41	39	202	14	150	15	16	49

Absolute values grouped by archaeological structures of settlement. Heading of the structures with more than 30 minimum number of individuals are in bold.

895 890 885 880 875 870 865 860 855 850 845

Table 3 Samples analysed and summary of the results of the organic residue analyses of amphorae, dolia and vats from Thamusida

Sample Id.	Typology	Content			
		Oil	Wine	Animal fats	Pinaceae
1	Plaster coating of a vat				
2	Plaster coating of a vat				
3	Dressel 20				
4	Dressel 20				
5	Dressel 20				
6	Dressel 30				
7	Africana IID				
8	Africana IID		Fermentation markers		
9	Probable Africana IID				
10	Africana IIB				
11	Africana non id				
12	Dolium				
13	Dolium				
14	Dolium				
15	Dolium				

Notes: Dark grey squares indicate presence; light grey indicates probable presence of the substance.

identified as a presumed production area and consisting of several levels of ash mixed with soil and pottery fragments, revealed the presence of five layers entirely constituted by partially charred *Q. suber* cork separating the levels. Overall, the constant presence of *Q. suber* cork in almost all contexts is noteworthy.

Carpological remains

The results are given as absolute counts and grouped by the 10 archaeological structures. From the 752 charred remains recovered, 26 taxa were identified of which 14 were cultivated or cultivable taxa and 12 weed taxa (Table 2). Considering the MNI, crop plants were the most common remains with 75.3% (Fig. 2).

Crops

Cereals represent 67.2% of the crop plant individuals (Fig. 2). *Hordeum vulgare* in its hulled form dominates the carpological assemblage (45.5%), followed by *T. aestivum/durum* (8.3%) and *Triticum* sp. (12.6%) (Fig. 3). *Avena* sp., *Panicum miliaceum* and *T. dicoccum* are also present.

Pulses account for 27.4% of the crops (Fig. 2), with the cultivated *Vicia faba* var. *minor* (18.8%), *Pisum sativum* (3.5%), and *Lens culinaris* (2.0%) (Fig. 3). *Vicia* sp., *Lathyrus* sp., *V. ervilia*, and *V. cf. sativa* are scarcely present. Only three taxa (5.4%) are attributable to fruit plants (Fig. 2); among them, *Vitis vinifera* and *O. europaea* are the most important (respectively 4.3% and 1.3%). *Prunus* cf. *domestica* is also reported.

Weeds and wild plants

Twelve wild plant taxa were identified (Table 2), representing 24.7% of plant individuals (Fig. 2). Poaceae, such as *Phalaris* sp., *Lolium* sp. and *Hordeum* cf. *secalinum*, and Fabaceae of the genus *Vicia* were the most

commonly attested taxa; wild plants consisted mainly of ruderals, and weeds of cultivated fields and wetlands, such as *Rumex* sp.

Residue analysis

Analysis of the plaster coating from the first vat of the Flavian period (sample 1, Table 3) shows no residues. These results are consistent with the fact that the vat can be interpreted as a fountain related to the triclinium of a Roman *domus* present at the site. Therefore, the presence of a structure for the production of food for the Flavian period in this area can be excluded. By contrast, analysis of the sample of the plastered coating of the other vat from a later re-use of the area (sample 2, Table 3 and Fig. 5) shows the presence of β -sitosterol and abundant C_{18:1} that is higher than C_{18:0} in all the extracts. Besides, in extract (b) azelaic acid is the highest among the dicarboxylic acids and C₉ is the highest among the short-chain fatty acids. These data are compatible with the presence of a vegetable oil, possibly olive oil, in the vat. The presence of dehydroabietic acid suggests the existence of an organic coating of the vat made of *Pinaceae* products, as already suggested for vats in production structures in other archaeological sites (Allevato et al. 2012; Pecci et al. 2013a). The presence of cholesterol, marker of animal products, suggests that some fats could have been added to the plaster for the coating.

Analysis of the two Dressel 20 amphorae (samples 3 and 4, Table 3) coming from the production structure show the presence of β -sitosterol and abundant C_{18:1} acid, while in the hydrolyses there is azelaic acid together with other acids related to the presence of oil (Pecci et al. 2013b; Salvini et al. 2007). Also in the Dressel 20 amphorae from the storehouse of the military quarter (sample 5, Table 3), there is abundant

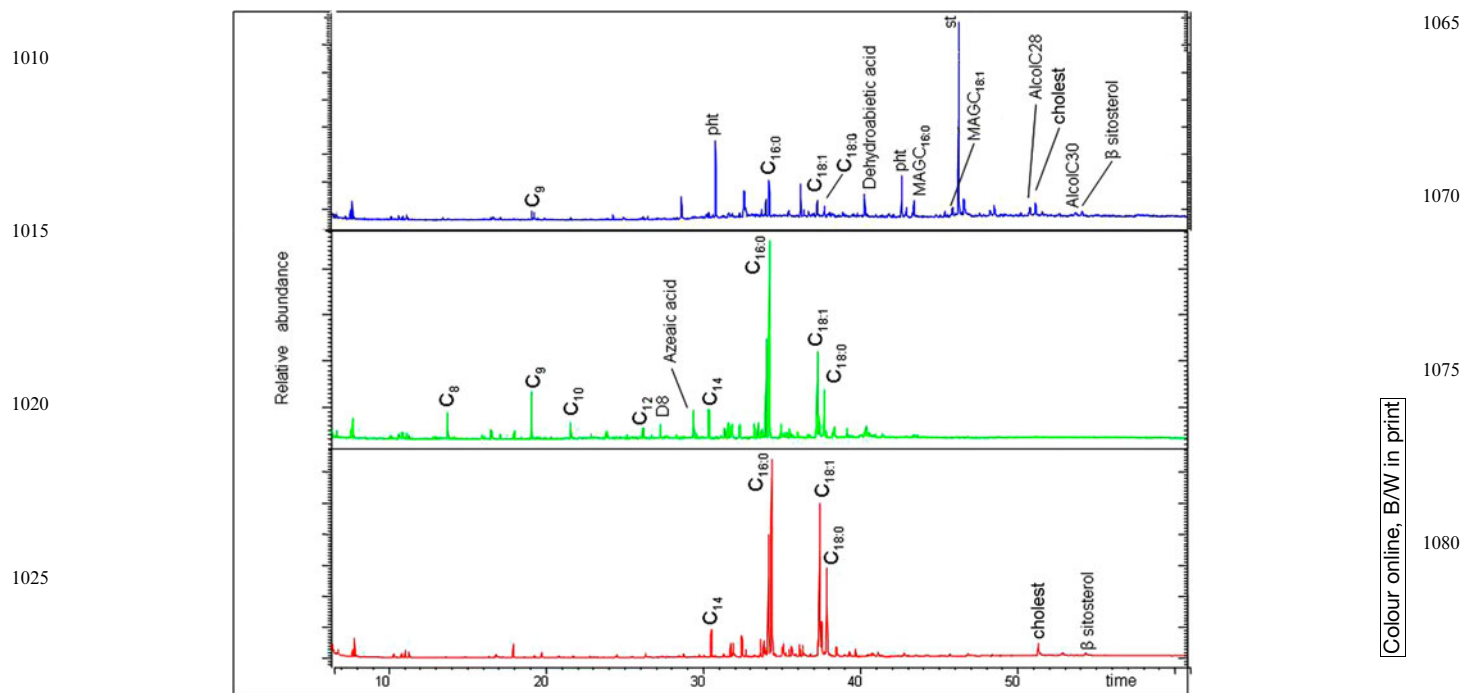


Figure 5 Chromatograms of the analysis of the total lipid extract (upper), the extract for the identification of wine markers (middle) and the hydrolysis on the solid residue after total lipid extraction of sample 2.

azelaic acid, which is the relatively highest among the dicarboxylic acids. Further, among the short-chain fatty acids C₉ is the relatively most abundant, and there are other acids usually present in oil (Pecci et al. 2013a, Figs. 13 and 14). These data confirm the archaeological hypothesis of an oil content for this type of amphora.

The presence of dehydroabiatic acid and methyldehydrobietate in the samples suggests that the amphorae were coated with *Pinaceae* pitch, extracted

directly from the wood (Colombini et al. 2005). This is consistent with the recently demonstrated idea that also amphorae for oil were coated with an organic coating (Garnier et al. 2011; Pecci and Cau 2010; Pecci et al. 2010; Romanus et al. 2009; Salvini et al. 2007).

As for the Dressel 30 amphorae, also from the military quarter (sample 6, Table 3 and Fig. 6), the presence of traces of tartaric acid, together with malic and succinic acids confirms that wine (or its

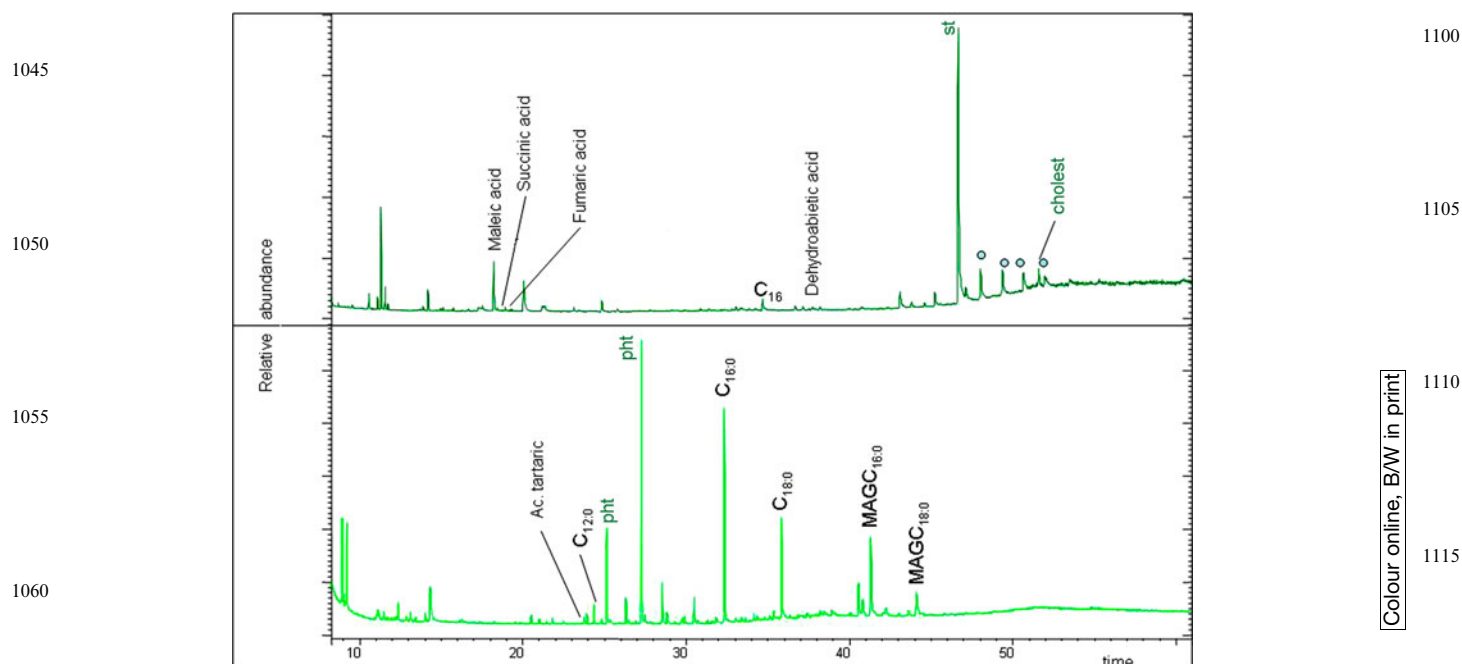


Figure 6 Chromatograms of the total lipid extract (upper) and of the extract for the identification of wine markers (lower) of sample 6.

derivatives) was contained in the amphorae. The traces of dehydroabiatic acid may be related to the presence of a coating of *Pinaceae* products.

As for the *Africana* amphorae, wine was contained in one probable *Africana* IID, in one probable *Africana* IIB and in a non-identified *Africana* (samples 7, 10 and 11, Table 3). Indeed, in the *Africana* IID (sample 7, Table 3), total lipid extract traces of malic, fumaric, succinic and hydroxycinnamic acids are detected and in the extraction for the identification of wine markers tartaric acid is present. Although other fruits also contain tartaric acid (Barnard et al. 2011), these acids can be considered to be markers of wine and its derivatives (Pecci et al. 2013c). *Pinaceae* products could be associated with an organic coating of the amphora, while the traces of cholesterol (marker of animal products) could indicate an animal content of the amphora or the mixing of animal fats for the softening of the coating. In the probable *Africana* IIB (sample 10, Table 3), there are traces of tartaric acid together with malic, vanillic and succinic acids, suggesting that wine was held within the amphora. Dehydrabiatic acid indicates that *Pinaceae* products were used to coat the amphora. Here as well, the presence of cholesterol suggests the presence of animal fats either mixed to the *Pinaceae* products or contained in the amphora, suggesting a possible re-use. In the *Africana* amphora not identifiable precisely (sample 11, Table 3), the results of the analysis show the presence of tartaric, malic, maleic and succinic acid, that are related to the wine content of the amphora. Dehydroabiatic acid is present only in traces, and may be connected with the use of *Pinaceae* products for the coating. The presence of β -sitosterol, azelaic

acid and C_9 higher than the other short-chain fatty acids suggests the presence of an oil, possibly from olives. Here as well the traces of cholesterol indicate the presence of animal origin fats perhaps mixed with *Pinaceae* products or re-use of the amphora.

In another *Africana* IID (sample 8, Table 3), there are traces of an organic coating of the amphora with *Pinaceae* products (dehydrabiatic acid). The abundance of cholesterol and MAGs as well as stearic acid suggests the presence of animal fats, while the presence of β -sitosterol, higher azelaic acid contents compared to other dicarboxylic acids and higher C_9 compared with the other short-chain fatty acids also suggests the presence of vegetable fats, possibly oil. Malic, glutaric and hydroxyglutaric acids are also present in the sample.

In the last *Africana* amphora (sample 9, Table 3), a possible *Africana* IID, there are traces of organic coating with *Pinaceae* products (dehydrabiatic and isopimaric acids), while there are no traces of wine. Here, there is abundant cholesterol, suggesting the presence of animal fats, either mixed with *Pinaceae* products in the coating or related to an animal content of the amphora.

As for the *dolia*, the presence of tartaric, malic, fumaric and succinic acids in sample 12 and the presence of tartaric and succinic acids in sample 14 suggest the presence of wine (Table 3 and Fig. 7). In sample 12, the abundant dehydroabiatic acid (Fig. 7) is related to a coating of the dolium with *Pinaceae* products, which are present in traces also in sample 14 (Table 3). There are also β -sitosterol and long-chain hydrocarbons in sample 12, suggesting the presence of waxes. In the other two *dolia* (samples 13 and 15, Table 3), there is only the presence of an organic

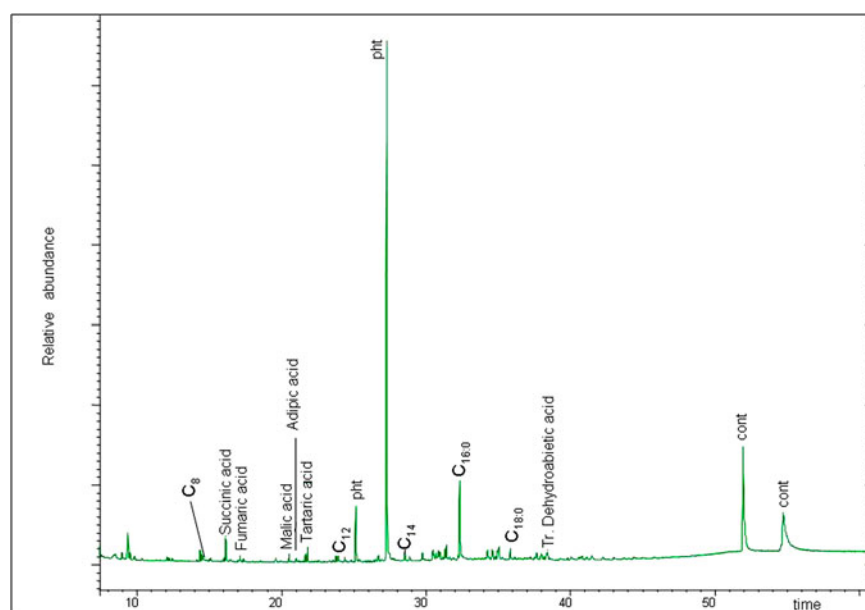


Figure 7 Chromatogram of the analysis of the extract for the identification of wine markers of sample 12,

1235 coating, which is very abundant in sample 15, suggesting that the *dolia* were used for solid contents such as grains that do not leave any traces.

Discussion

The multi-functional role of the ancient Mamora forest

1240 *Q. suber* is the most abundant taxon throughout the period in question. Its presence does not seem to be related to specific usages since it was found in each analysed layer regardless of the functional type of the sampled context. Taken together, this evidence testifies to the intense and continuous use of this wood both for fires and also for structures. Two interesting comparisons of extensive use of *Q. suber* come from Sicily (Italy): at Segesta (W. Sicily) this tree species was widely used for building purposes in the Middle Ages (Castiglioni and Rottoli 1997); in the necropolis of the Greek colony of Himera (648–409 BC, N. Sicily) cork oak was the main fuel used for funeral pyres (Di Pasquale, unpublished data). In this respect, it is noteworthy that in these areas, alongside the traditional use of cork, *Q. suber* plays a significant role as a timber product, clearly related to its abundance in the landscape.

1260 The almost constant presence of cork fragments in the investigated contexts attests to its habitual harvesting. The layers with charred cork between the levels of ash, soil and fragments of pottery in the two trenches also constitute clear evidence of the extensive use of cork, which was related to its great availability in the close surroundings of the site. Unfortunately, it is far from straightforward to interpret the function of this context since no archaeological comparisons are available to our knowledge.

1270 Archaeozoological data from the site of Thamusida attest that during the whole period cattle, sheep/goat and pig were the three main domestic animals (De Grossi Mazzorin and De Venuto 2010). Thus, it is also supposable that further uses of this cork forest were related also to grazing and to the gathering of acorns and foliage for feeding livestock. To sum up, it seems that cork oak forests represented multi-functional forests used for cork harvesting, wood exploitation and livestock farming just like nowadays (Pastor-López et al. 1997; Quézel and Médail 2003).

1280 In Morocco, cork oak forests constitute huge forest resources occupying 347,000 ha, accounting for approximately 15.4% of the cork oak forests in the Mediterranean area (Pastor-López et al. 1997). This forest is judged to be very old (Emberger 1928a; Sauvage 1961) and probably extended on the Atlantic plane at least from the Holocene optimum (Ballouche and Damblon 1988).

Isolated individuals of *Q. suber* in proximity of Thamusida were still present in the 1960s, on the

opposite shore of the Sebou river (Sauvage 1961). These trees can be considered remnants of a forest, suggesting that the cork oak wood probably extended up to the close surroundings of the site. This assumption fits well with the greater cork oak forest cover revealed by pollen analysis on a larger scale in Morocco at least until the middle Holocene (Ballouche and Damblon 1988). Also Emberger (1928b, 1934) hypothesised a previous greater acreage of *Q. suber* forest in northern Morocco. The nearby Mamora forest (Fig. 1) seems to have been the most probable area supplying both wood and cork. At present, this forest covers 60,000 ha and despite the massive exploitation suffered in recent centuries (Oubrahim et al., 2015) and the huge reforestation programme with exotic species, it remains the largest cork oak forest in the world (Fraval and Villemant 1997).

Recent floristic impoverishment and canopy cover reduction of Mamora cork oak open woodland due to overexploitation have been revealed by ecological studies, in which this forest is considered one of the most degraded in Morocco (Bugalho et al. 2011; Natividadae 1950; Rejdali 2004; Sauvage 1961). For the Iberian Peninsula, Carrion et al. (2000) consider monospecific cork oak forests as a result of human impact and suggest that, in its absence, *Q. suber* would share the tree layer both with other sclerophyllous and deciduous *Quercus* and *Pinus* species. Thus, the scarcity of other tree taxa in the charcoal assemblages from Thamusida, although an effect of human selection has to be taken in account, leads us to believe that, at least in the close surroundings of the site of the *vicus*, human-driven degradation processes had already started at the time of the Roman occupation when the tree layer was already mainly composed by cork oak. Therefore our data testify to overexploitation of cork oak during the Roman occupation of the site. In this respect it is interesting that at Lixus, 160 km north of Thamusida, the degradation of sclerophyllous oak forests and their replacement by scrub bushes and pine-covered areas was already evident during the Punic period (Grau Almeru, 2011).

Certain taxa, namely *Cistus*, *P. lentiscus*, *Erica*, *Daphne-Thymelaea* and *Arbutus unedo* recorded in the charcoal assemblages could have been used as kindling cuttings used for fuel, like in the present day, and most probably represented the understorey of the cork oak forest. That said, they could also represent the shrubland formation growing at present on the costal dunes together with *P. lentiscus* and *Frankenia*. If we interpret the presence of these taxa as a proxy of a multilayer cork oak open forest, their scarcity documents the eradication process of the shrub layer followed by the expansion of a grassland layer composed by annual winter terophytes. A

1345 biodiversity reduction of the *Q. suber* forest under-
storey in Morocco under high slashing, cutting and
grazing pressure is widely documented (Marañón
et al. 1999; Montoya Oliver 1986).

1350 The presence of *Erica arborea* and *E. scoparia* is well
documented until the second half of the last century in
the Mamora forest (Métro and Sauvage 1955). A few
years later the disappearance of *E. arborea* and a
severe reduction in *E. scoparia* cover were attested
(Sauvage 1961). A more recent floristic survey (Aafi
et al. 2005) pointed out that they are now both
1355 extinct in the Mamora cork oak forest.

A different situation can be mapped out for the
coastal cork oak forest of Krimda (Fig 1), where
pollen analysis shows that human impact did not
affect the extent and composition of the forest until
1360 the 11th century AD and *E. arborea* still persists
(Damblon 1991), indicating a different history of
forest resource exploitation. In the Thamusida site,
since *Tetraclinis articulata* is present in a variety of
1365 contexts, a specific use cannot be ascertained. At
present, it occurs widely in northern Africa, on the
slopes of the Atlas Mountains, on the Central
Plateau, from the Rif to the Anti-Atlas (Fennane
et al. 1984). *T. articulata* is considered a valuable tree
because its wood is highly prized for its homogeneity
and natural beauty and is used for marquetry and
cabinet work, especially burls produced by repeated
fires (Sánchez Gómez *et al.* 2011). Wood of *T. articu-*
1370 *lata* identified from furniture in the Vesuvius area
(Herculaneum, Italy) in the 1st century AD (Mols
2002) testifies to its wide circulation around the
Mediterranean area during Roman times due to it
being highly prized in craftwork employment.

A small amount of *Pinus pinaster* charcoal was
1380 found both in occupation layers and in “accumu-
lation” layers; the presence of maritime pine in the
site surroundings is very improbable since this tree
grows at present on the Rif and in the Middle Atlas
between 1200 and 2000 m a.s.l. Thus, we suppose
1385 that the recovered charcoal could belong to imported
woodwork from one of these north African mountains
or from Iberia.

Populus charcoal was found in only one context – a
living floor in a granary (<1%) – and could belong to
1390 *P. alba*, today found around the coastal lake of Sidi
Bou Ghaba. It may have been common in the riparian
vegetation along the Sebou river. The few charcoal
fragments referable to *Juglans regia* could well
belong to wooden objects present in the site.
According to Quézel (2003), walnut has now spread
1400 in the wild in a few areas of Morocco (Rif and High
Atlas), having escaped from ancient cultivation. Only
Ballouche (1991) suggests an indigenous origin of
J. regia since walnut is present in the pollen record
of Eastern Morocco since Early Holocene. However,

this tree has a long history of cultivation and in
Roman times it was already very widely grown
(Zohary and Hopf 2000). At present, it is widely culti-
vated in Morocco in remote upland areas between 800
and 1800 m a.s.l. (Lansari *et al.* 2001). *Ceratonia*
1405 *siliqua* was found uniquely in a waste layer dated to
the mid-2nd century AD–early 3rd century AD.
Thus, its presence is improbable in the surrounding
of the site. Its origin remains unclear, with recent dom-
estication only since Roman times of the plant as a
1410 consequence of the introduction of grafting (Zohary
and Hopf 2000). However, the carob tree is still an
important economic resource for Morocco’s rural
populations, also being used in reforestation pro-
grammes and in exploiting marginal lands (Sidina
1415 *et al.* 2009).

Food supply at the border of the Empire

Spatial distribution of food plants at the site was
assessed for those structures where more than 30 indi-
1420 viduals were only found (Fig. 4). Here, the calculated
ratio among the taxa can be considered representative.
Based upon the results from four structures and 320
MNIs, barley (*H. vulgare*) predominates in three out
of the four structures considered: inside the military
1425 quarter (area 12,000) as well as in the two rubbish
dumps of the vicus (areas 37,000 and 19,000). In
these three contexts, naked wheat (as naked wheat
we consider *T. aestivum/durum* and *Triticum* sp.) is
present as the second most commonly represented
1430 cereal, while it is predominant in the layer close to
the huge fortified walls (area 1000). Interestingly,
although the total number of carpological remains is
very low and they have to be considered with
caution, naked wheat prevails on two street floors of
1435 the vicus (areas 5000 and 7000) and barley predomi-
nates in a bread oven zone (area 36,000) (Table 2).
The regular presence of naked wheat in the sampled
contexts suggests a widespread use of this cereal, but
it is worth pointing out that the greatest presence of
1440 wheat was found in the area of the fortified walls of
the military quarter (Fig. 4), suggesting the privileged
access of Roman troops to better cereals such as naked
wheat.

Carpological analysis carried out in *Mauretania*
1445 *Tingitana* showed an agriculture based on barley and
naked wheat already existed from the Phoenician
period (8th century BC). However, with the transition
to the Roman Age (mid-1st century AD), the presence
of wheat was gradually more important due to dietary
1450 and commercial considerations (Grau Almero *et al.*
2001; Grau Almero 2005). The literature on the
Roman military diet describes wheat as the foundation
of the military diet, adding that barley was used either
for horses (Marcone 2002; Zohary and Hopf 2000), or
1455 normally given to soldiers as a punishment ration

(Davies 1971). Since barley was not highly favoured as human food from a Roman perspective, we would not expect to find it as food, but at Thamusida hulled barley was found in the military barracks and the bread oven, strongly suggesting that it was intended for human consumption and probably for making bread. Furthermore, the ubiquity of the finds could suggest that barley was a common food in the diet of both civilians and soldiers. In the human diet barley plays a well-known subordinate role to wheat, particularly in bread making: characterised by poor gluten, barley is unable to confer sufficient elasticity in the rising phase. However, Syrian soldiers in the first military contingent headquartered until the 2nd century AD would not have disapproved of barley since the cereal is one of the most ancient staple foods in the region (Zohary and Hopf 2000) and the preference of Syrian and African soldiers for barley is well documented (Vossen and Groot 2009). Interestingly, even today in some north African cultures the use of barley for food is still important (Baik and Ullrich 2008).

Human consumption of barley is attested in the quarrying district of Mons Porphyrites in Egypt (Van der Veen and Tabinor 2007). Further, recent research into the consumption of cereals in Romano-British military sites from the analysis of cereal bran fragments in faecal material showed that barley was commonly consumed by troops, especially in soups and stews (Britton and Huntley 2011). Another aspect suggesting barley consumption in Roman Thamusida is linked to environmental considerations. According to Cavallar (1950), the area of Thamusida and the low valley of Sebou are characterised by a fluvial-lagoon plain with a semi-arid climate and phenomena of salinity (Billaux and Bryssine 1967). Compared with barley, wheat is less resistant to abiotic stress: barley withstands drier conditions, poorer soils and higher salinity levels. Therefore, barley could be the most suitable arable crop cultivated in proximity of the site. Furthermore, barley completes its life cycle in a shorter time than wheat and matures before the summer drought that affects the area around Thamusida. On the whole, barley was the most cultivable cereal in hostile environmental conditions, such as those in south-western *Mauretania Tingitana*. This evidence agrees well with the widespread use of barley in human consumption at Thamusida, probably also related to the abundance of this locally grown cereal. A further example of human consumption of barley is attested in four military forts in the Eastern Desert of Egypt, a region where the environmental conditions were unfavourable for local production of other cereals (Van der Veen and Tabinor 2007). Wheat cultivation would have been limited to more appropriate areas, such as

the hilly soils close to the settlement. In order to complement the local production, foreign supplies are even conceivable, as suggested by the presence of a granary near the Sebou, for collecting *annona* from the south-western areas of *Mauretania Tingitana*.

As regards other crops, our data show that, among pulses, horse bean (*V. faba* var. *minor*) and pea (*P. sativum*) were common in several structures at the site, suggesting an important role in farming (Fig. 4). These pulses grow well in both warm, dry Mediterranean environments, and in clay and light drained soil. Hence, they could be sown close to the settlement of Thamusida. The highest presence of horse bean and pea was found close to the walls of the military quarter (area 1000) and to a rubbish dump (area 37,000) in the *vicus* (Fig. 4). This suggests the use of the best pulses with larger seeds in the whole settlement. The fact that two *dolia* from the military quarter did not show residues of wine, oil, or fish products, suggesting the presence of solid contents, could be related to the storage of cereals and pulses for the troops lodged at the military quarter.

Lentils were also found (*L. culinaris*). Because of the crop's characteristics, it is conceivable that it may well have been sown on the poorest soils. Other cereals, such as oats (*Avena*), emmer (*T. dicocum*), millet (*P. miliaceum*) and pulses, such as bitter vetch (*V. ervilia*) and red/grass pea (*Lathyrus*) were found in such low percentages that our data are insufficient to support the hypothesis of their cultivation at the site and/or exclude their presence as contamination of the cereal crops.

In general, crops were carefully processed before being stored in the settlement, since very small amounts of spikelet forks and rachis were found. Instead, Malvaceae, Poaceae and Fabaceae weeds were widely found and they belonged mainly to ruderals and weeds of wetland and cultivated fields. Seed sizes of the recovered Poaceae weeds, such as *Lolium* sp. and *Phalaris* sp., are generally very similar to those of cultivated cereals, which complicates their elimination from the grain during both sieving and hand cleaning (Hillman 1981, 1984; Jones 1984).

Among fruit trees growing at Thamusida, both charcoals of *O. europaea* and *Vitis vinifera* were found, suggesting their presence in the surroundings of the site. It is widely known that the spread of grape and olive growing in northern Africa took place after the Phoenician expansion (Brun 2003). In Morocco, archaeobotanical data from contexts between the 8th and the 1st century BC show the presence of charcoals and seeds of olive and wine grape, suggesting their cultivation (Grau Almero 2005; Jordà 2005; Grau Almero et al. 2001). In the Thamusida area, the oleaster is present in the wild,

1570 associated with *P. lentiscus* in low scrub. Nevertheless,
 1575 the scarce presence of olive charcoal and five frag-
 1580 ments of olive stones indicate that *O. europaea* was
 1585 also scantily cultivated in the site surroundings and
 1590 was probably intended for self-consumption of fresh
 1595 fruits in the military quarter as well as in the vicus
 1600 (Tab. 1). A limited production of oil is likely to have
 1605 occurred since chemical analyses identified oil residues
 1610 in the small vat (sample 2, Table 3) which was built as
 1615 part of the restructuring of the Flavian *domus* dated to
 1620 the end of the 2nd/beginning of the 3rd century AD.
 To sum up, botanical and chemical evidence indicates
 very limited olive growing and oil production at
 Thamusida, while archaeological data show the pres-
 ence of equipment for huge olive oil production
 between the 2nd and 3rd century AD in the nearby
 Roman site of *Volubilis* (Fig. 1) (Akerraz and Lenoir
 1982). At Thamusida imports probably fulfilled the
 demand for oil as confirmed by the identification of
 oil traces in three Dressel 20 amphorae, possibly in
 one Africana IID and in one non-id. Africana
 amphora.

With regard to *Vitis*, it is considered sub-spon-
 taneous in the Moroccan flora (Fennane et al. 2007)
 while, according to Zohary and Hopf (2000), wild
 grape is spontaneous in north-west Africa. The
 almost constant presence of grape charcoal from the
 Flavian Age and the recovery of 12 pips in our archae-
 obotanical record could suggest the beginning of a
 scant cultivation of grape in the surroundings of the
 site, probably for consumption of fresh fruits by both
 civilians and soldiers, as the spatial analysis suggests
 (Fig. 4). The presence of grapes is not necessarily
 linked to wine production. This beverage was probably
 imported, as the results of the residue analysis of some
 amphorae show: wine was contained in the Dressel 30
 amphora and in three of the Africana amphorae ana-
 lysed and in two of the four dolia analysed from the
 military quarter storeroom (Table 2). Although these
 amphorae could have been reused, these data suggest
 that imports had an important role in fulfilling the
 demand for wine.

Conclusions

The data on the whole amply documents the self-suffi-
 ciency of the settlement both in forestry and agricul-
 tural products. Charcoal data illustrate the intensive,
 multi-functional use of the cork oak *Mamora* forest
 throughout the Roman occupation of the site,
 between the 1st and the 3rd century AD, testifying
 to a variety of forest products such as timber, fuel-
 wood, cork, and probably leaves and acorns to feed
 livestock. The dominance of *Q. suber* in the tree
 layer clearly indicates that this forest was being
 exploited prior to the Roman occupation.

Archaeobotanical data demonstrate that the diet in
 the vicus was mainly based on locally grown products.
 Local resources satisfy the food needs both the troops
 and civilians, and both of them have access to good
 cereals such as barley, naked wheat and to pulses
 with large seeds such as horse bean and pea. Quality
 fruits, such as olives and grapes, were also locally pro-
 duced for fresh consumption. Barley was locally culti-
 vated and was the main cereal consumed in the diet,
 due either to its abundance or to food preferences of
 soldiers coming from areas where it was a staple
 crop. Analysis of organic residues suggests a small
 local production of oil. For the most part, oil and
 wine would have been imported from different parts
 of the Empire; wine mostly from Africa and oil from
Baetica.


In general, the integration of archaeobotanical and
 organic residue analyses was able to shed light on
 the local production and consumption of food as
 well as on some imports at this settlement situated at
 the border of the Roman Empire.

Acknowledgements

The archaeological project at Thamusida was carried
 out by the University of Siena in collaboration with
 the Institut National de Sciences de l'Archéologie et
 du Patrimoine de Rabat (INSAP). The chemical ana-
 lyses were carried out as part of the activities of the
 Archaeometry Laboratory of the Department of
 Archaeology and Art History of the University of
 Siena at Grosseto conducted between 2006 and 2009
 by A. Pecci in collaboration with the Department of
 Chemistry of the same university.

This paper is part of the activities of the
 Dipartimento di Biologia, Ecologia e Scienze della
 Terra, Università della Calabria, in the ERAAUB,
 Consolidated Group (2014 SGR 845) funded by the
 Comissionat per a Universitats i Recerca del DIUE
 of the Generalitat de Catalunya and the Ramon y
 Cajal contract (RYC 2013-13369) funded by the
 Ministerio de Economía y Competitividad. E.A. and
 M.P.B. were partially funded by the NURSE project
 granted to A.S. at the Department of Agriculture,
 University of Naples Federico II.

ORCID

Emilia Allevato  <http://orcid.org/0000-0003-0667-1027>

References

- Aafi, A., Achhal, E. K. A., Benabid, A. and Rouchdi, M. 2005.
 Richesse et diversité floristique de la subéraie de la Mamora
 (Maroc). *Acta Botanica Malacitana* 30, 127–138.
 Akerraz, A., Brouquier-Reddé, V. and Lenoir, E. 1995.
 L'occupation antique de la plaine du Gharb, pp. 235–91 in
 Troussset, P. (ed.), *Colloque International sur l'archéologie et
 l'histoire de l'Afrique du nord*, 25–29 octobre 1993, Pau.

- Akerraz, A. and Lenoir, E. 1982. Les huileries de Volubilis. *British Archaeological Reports* **14**, 69–120.
- Akerraz, A. and Papi, E. 2008. *Sidi Ali ben Ahmed- Thamusida. I contesti*. Roma: Quasar.
- 1685 Allevato, E., Buoincontri, M., Vairo, M., Pecci, A., Cau, M. A., Yoneda, M., De Simone, G. F., Aoyagi, M., Angelelli, C., Matsuyama, S., Takeuchi, K. and Di Pasquale, G. 2012. Persistence of the cultural landscape in Campania (Southern Italy) before the AD 472 Vesuvius eruption: archaeoenvironmental data. *Journal of Archaeological Science* **39**, 399–406.
- 1690 Allevato, E., Pecci, A., Papi, E. and Di Pasquale, G. 2013. Evidence from charcoal analysis for the extensive exploitation of cork-oak (*Quercus suber*) forest in the Roman imperial period: the vicus of Thamusida (NW Morocco), pp. 11–7 in Damblon, F. (ed.), *Proceedings of the Fourth International Meeting of Anthracology Brussels*. 8–13 September 2008, Royal Belgian Institute of Natural Sciences, British Archaeological Report S2486.
- AQ4
^ Alonso Martinez, N. 2005. Agriculture and food from the Roman to the Islamic Period in the North-East of the Iberian peninsula: archaeobotanical studies in the city of Lleida (Catalonia, Spain). *Vegetation History and Archaeobotany* **14**, 341–361.
- 1695 Antolin, F. and Buxò, R. 2011. Proposal for the systematic description and taphonomic study of carbonized cereal grain assemblages: a case study of an early Neolithic funerary context in the cave of Can Sadurni (Begues, Barcelona province, Spain). *Vegetation History and Archaeobotany* **20**, 53–66.
- 1700 Baik, B. K. and Ullrich, S. E. 2008. Barley for food: characteristics, improvement, and renewed interest. *Journal of Cereal Science* **48**, 233–242.
- Ballouche, A. 1991. Probabilité de l'indigénat du Noyer (Juglans L.) au Maroc, d'après l'analyse pollinique, pp. 185–90 in Ballouche, A. and Maley, J. (eds), *Proceeding of the first symposium of African palynology – Paleocology of Africa and the surrounding islands*, Rabat 15–21 May.
- AQ5
1705 Ballouche, A. and Damblon, F. 1988. Nouvelles données palynologiques sur la végétation Holocène du Maroc, pp. 83–90 in *Actes du Dixième Symposium de l'Association des Palynologues de Langue Française*, Bordeaux: Institut Français Pondichéry.
- 1710 Barnard, H., Dooley, A. N., Areshian, G., Gasparyan, B. And Faull, K. F. 2011. Chemical evidence for wine production around 4000 BCE in the Late Chalcolithic Near Eastern highlands. *Journal of Archaeological Science* **38**, 977–984.
- Bellavia, V. (2011). Il territorio di Sidi Ali Ben Ahmed-Thamusida tra 6. secolo a. C. e 8. secolo d. C. : analisi antracologica per una ricostruzione archeoambientale. PhD thesis, Università di Siena.
- 1715 Billaux, P. and Bryssine, G. 1967. Les sols du Maroc. *Cahiers de la Recherche Agronomique* **1**, 59–101.
- Britton, K. and Huntley, J. 2011. New evidence for the consumption of barley at Romano-British military and civilian sites, from the analysis of cereal bran fragments in faecal material. *Vegetation History and Archaeobotany* **20**, 41–52.
- 1720 Brun, J.-P. 2003. *Le vin et l'huile dans la Méditerranée antique: viticulture, oléiculture et procédés de transformation*. Paris: Errance.
- Bugalho, M. N., Caldeira, M. C., Pereira, J. S., Aronson, J. and Pausas, J. G. 2011. Mediterranean cork oak savannas require human use to sustain biodiversity and ecosystem services. *Frontiers in Ecology and the Environment* **9**, 278–286.
- 1725 Carrion, J. S., Parra, I., Navarro, C. and Munuera, M. 2000. Past distribution and ecology of the cork oak (*Quercus suber*) in the Iberian Peninsula: a pollen-analytical approach. *Diversity and Distributions* **6**, 29–44.
- Castiglioni, E. and Rottoli, M. 1997. I macroresti vegetali, pp. 235–57 in Molinari, A. (ed.), *Segesta II, Il castello e la Moschea*. Scavi 1989–1995. Palermo: Flaccario.
- Cavallar, W. 1950. Esquisse Préliminaire de la Carte des Sols du Maroc. Direction de l'Agriculture, du Commerce et des Forêts du Maroc, Division de l'Agriculture et de l'Elevage.
- 1730 Colombini, M. P., Modugno, F. and Ribechini, E. 2005. Direct exposure electron ionization mass spectrometry and gas chromatography-mass spectrometry techniques to study organic coatings on archaeological amphorae. *Journal of Mass Spectrometry* **40**, 675–687.
- Damblon, F. 1991. Contribution pollenanalytique à l'histoire des forêts de chêne liège au Maroc: La subéraie de Krimda. *Palaeoecology of Africa* **22**, 171–190.
- 1735 Davies, R. W. 1971. The Roman military diet. *Britannia* **2**, 122–142.
- De Grossi Mazzorin, J. and De Venuto, G. 2010. Ricerca archeozoologica a Thamusida (Marocco): allevamento, alimentazione e ambiente di un insediamento mauro e di una città romana, pp. 389–93 in Tagliacozzo, A., Fiore, I., Marconi, S. and Tecchiati, U. (eds.), *Atti del 5 Convegno Nazionale di Archeozoologia*, Rovereto 10-12 novembre 2006. Rovereto: Museo civico di Rovereto.
- 1740 Emberger, L. 1928a. L'importance du chêne liège dans le paysage marocain avant la destruction des forêts. *Revue géographique marocaine* **7**, 121–124.
- Emberger, L. 1928b. Les limites naturelles de la forêt de la Mamora. *Bulletin Société Scientifique Naturelle Marocaine* **8**, 220–222.
- Emberger, L. 1934. *Les plantes fossiles dans leurs rapports avec les végétaux vivants*. Paris: Masson.
- 1745 Fennane, M., Barbero, M. and Quézel, P. 1984. Le thuya de Berbérie au Maroc: aperçu phytogéographique et écologique. *Bulletin de l'Institut Scientifique de Rabat* **8**, 115–134.
- Fennane, M., Ibn Tattou, M., Mathez, J., Ouyaha, A. and El Oualidi, J. 2007. *Flore pratique du Maroc*, Vol. 2., Rabat: Travaux de l'Institut Scientifique, série botanique.
- Fraval, A. and Villemant, C. 1997. La Mamora et ses ennemis. *Les Dossiers de l'environnement de l'INRA* **15**, 133–146.
- 1750 Garnier, N., Silvino, T. and Bernal Casasola, D. 2011. The identification of the content of amphorae: oils, salsamenta and pitch, pp. 397–416 in *Proceedings of the Congress SFEACG Arles*, June 2011, Arles: French Society for the Study of Archaeological Ceramics from Gallia.
- Giorgi, G., Salvini, L. and Pecci, A. 2010. The meals in a building yard during the Middle Age. Characterization of organic residues in ceramic potsherds. *Journal of Archaeological Science* **37**, 1453–1457.
- 1755 Grau Almero, E. 2005. Estudio antracológico, in Aranegui, C. (ed.), *Lixus 2 Ladera Sur. Excavaciones arqueológicas Marroco-Españolas en la colonia fenicia. Campañas 2000–2003*. Saguntum Extra 6, 219–220.
- 1760 Grau Almero, E. 2011. Charcoal analysis from Lixus (Larache, Morocco), in Badal, E., Carrión, Y., Grau, E., Macías, M. and Ntinu M. (eds.), *Saguntum Extra* **11**, 107–108.
- Grau Almero, E., Pérez Jordà, G., Iborra Eres, M. P., Rodrigo, M. J., Rodriguez, C. G. and Carrasco, V. M. 2001. Gestión de recursos y economía, in Aranegui, C. (ed.), *Lixus. Colonia fenicia y ciudad Púnico-Mauritana. Anotaciones sobre su ocupación medieval*. *Saguntum Extra* **4**, 191–230.
- 1765 Hillman, G. C. 1981. Reconstructing crop husbandry practices from charred remains of crops, pp. 123–62 in Mercer, R. (ed.), *Farming practice in British prehistory*. Edinburgh: Edinburgh University Press.
- Hillman, G. C. 1984. Interpretation of archaeological plant remains: the application of ethnographic models from Turkey, pp. 1–42 in Van Zeist, W. and Casparie, W. A. (eds.), *Plants and ancient man: studies in the palaeoethnobotany*. Rotterdam: Balkema.
- 1770 Hitchner, R. B. 2008. Globalization avant la lettre: globalization and the history of the Roman Empire. *New Global Studies* **2**, 2.
- Hubbard, R. N. L. B. 1992. Dichotomous keys for the identification of the major Old World crops. *Review of Palaeobotany and Palynology* **73**, 105–115.
- 1775 Jacomet, S. 2008. Identification of cereal remains from archaeological sites, third ed. IPNA Basel, <http://ipna.unibas.ch/archbot/pdf/>. Accessed 18 March 2015.
- Jones, G. 1984. Interpretation of archaeological plant remains: ethnographic models from Greece, pp. 43–61 in Van Zeist, W. and Casparie, W. A. (eds.), *Plants and ancient man: studies in palaeoethnobotany*. Rotterdam: Balkema.
- 1780 Jones, G. 1990. The application of present-day cereal processing studies to charred archaeobotanical remains. *Circaea* **6**, 91–96.
- Jordà, G. P. 2005. Estudio paleocarpológico, in Aranegui, C. (ed.), *Lixus 2 Ladera Sur. Excavaciones arqueológicas Marroco-Españolas en la colonia fenicia. Campañas 2000–2003*. *Saguntum Extra* **6**, 221–227.
- 1785 Kabbour, B. B., Zouhri, L., Mania, J. and Colbeaux, J. P. 2006. Assessing groundwater contamination risk using the DASTI/IDRISI GIS method: coastal system of western Mamora, Morocco. *Bulletin of Engineering Geology and the Environment* **65**, 463–470.
- Lansari, A., El Hassani, A., Nabil, D. and Germain, E. 2001. Preliminary results on walnut germplasm evaluation in Morocco. *Acta Horticulturae* **544**, 27–35.
- 1790 Maier, U. 1996. Morphological studies of free-threshing wheat ears from a Neolithic site in southwest Germany, and the history of the naked wheats. *Vegetation History and Archaeobotany* **5**, 39–55.

- Marañón, T., Ajbilou, R., Ojeda, F. and Arroyo, J. 1999. Biodiversity of woody species in oak woodlands of southern Spain and northern Morocco. *Forest Ecology and Management* **115**, 147–156.
- 1795 Marcone, A. 2002. Alimentazione, pp. 447–456 in Forni, G. and Marcone, A. (eds.), *Storia dell'agricoltura italiana*. I. L'età antica. 2. Italia romana. Firenze: Edizioni Polistampa.
- Métro, A. and Sauvage, C. 1955. *Flore des végétaux ligneux de la Mamora*. Collection la nature au Maroc. Rabat: Société des sciences naturelles et physique du Maroc.
- 1800 Mols, S. T. A. M. 2002. Identification of the wood used in the furniture at Herculaneum, pp. 225–34 in Jashemski, W. F. and Meyer, F. G. (eds.), *The Natural History of Pompeii*. Cambridge: Cambridge University Press.
- Montoya Oliver, J. M. 1986. Model for a new silvo-pastoral system in the Mamora cork-oak forest. *Landscape and urban planning* **13**, 55–63.
- 1805 Mottram, H. R., Dudd, S. N., Lawrence, G. J., Stott, A. W. and Evershed, R. P. 1999. New chromatographic, mass spectrometric and stable isotope approaches to the classification of degraded animal fats preserved in archaeological pottery. *Journal of Chromatography*, **833**, 209–221.
- Natividade, J. V. 1950. Subercultura. Lisboa: Ministerio da Economia, Pescas e Alimetacao, Direccao Geral das Florestas e Aquicolas.
- 1810 Neef, R., Cappers, R. T. J. and Bekker, R. M. (eds.), 2012. *Digital atlas of economic plants in archaeology*. Groningen: Barkhuis.
- Neumann, K., Schoch, W., Détienne, P. and Schweingruber, F. H. 2001. *Woods of the Sahara and the Sahel / Bois du Sahara et du Sahel/Hölzer der Sahara und des Sahel*. Birmensdorf, Eidg. Forschungsanstalt WSL. Bern, Stuttgart, Wien: Haupt.
- 1815 Oubrahim, H., Boulmane, M., Bakker, M. R., Augusto, L. and Halim, M. 2015. Carbon storage in degraded cork oak (*Quercus suber*) forests on flat lowlands in Morocco. *iForest-Biogeosciences and Forestry* 998.
- Pastor López, A., Taïqui, L., Bouziane, H., Riadi, H. and Martín Martín, J. 1997. Structure of *Quercus suber* forests in Chefchaouen basin (NE Morocco): implications on management at a landscape scale. *Mediterránea. Serie de Estudios Biológicos* **16**, 65–78.
- 1820 Pecci, A. and Cau, M. A. 2010. Análisis de residuos orgánicos en ánforas. El problema de la resina y del aceite pp. 593–600 in Blázquez, J. Ma. and Remesal, J. (eds.), *Estudios sobre el Monte Testaccio (Roma) V*, Instrumenta. Barcelona: Universitat de Barcelona, 35.
- 1825 Pecci, A. and D'Andria, F., 2014. Oil production in Roman times: residue analysis of the floors of an installation in Lecce (southern Italy). *Journal of Archaeological Science*, **46**, 363–371.
- Pecci, A., Salvini, L., Cirelli, E. and Augenti, A. 2010. Castor oil at Classe (Ravenna, Italy): residue analysis of some Late Roman amphorae coming from the port, pp. 617–622 in Menchelli, S., Santoro, S., Pasquinucci, M. and Guiducci, G. (eds.), LRCW3. Late Roman Coarse Wares, Cooking Wares and Amphorae in the Mediterranean. Archaeology and Archaeometry. BAR International Series, Oxford 2185.
- Pecci, A., Cau, M. A. and Garnier, N. 2013a. Identifying wine and oil production: analysis of residues from Roman and Late Antique plastered vats. *Journal of Archaeological Science* **40**, 4491–4498.
- 1835 Pecci, A., Cau, M. A., Valdambri, C. and Inserra, F. 2013b. Understanding residues of oil production: chemical analyses of floors in traditional mills. *Journal of Archaeological Science* **40**, 883–893.
- 1850 Pecci, A., Giorgi, G., Salvini, L. and Cau, M. A. 2013c. Identifying wine markers in ceramics and plasters with gas chromatography-mass spectrometry. Experimental and archaeological materials. *Journal of Archaeological Science* **40**, 109–115.
- Quézel, P. and Médail, F. 2003. *Ecologie et Biogéographie des Forêts du Bassin Méditerranéen*. Collection Environnement, Paris: Elsevier.
- 1855 Rejdali, M. 2004. Forest cover changes in the Maghreb countries with special reference to Morocco, pp. 13–20 in Mazzoleni, S., Di Martino, G. and Rego, F. (eds.), Recent dynamics of the Mediterranean vegetation and landscape. Chichester: Wiley & Sons Ltd.
- Renfrew, J. M. 1973. *Palaeoethnobotany*. New York: Columbia University Press.
- 1860 Romanus, K., Baeten, J., Accardo, S., Degryse, P., Jacobs, P., De Vos, D. and Waelkens, M. 2009. Wine and olive oil permeation in pitched and nonpitched ceramics: relation with results from archaeological amphorae from Sagalassos, Turkey. *Journal of Archaeological Science* **36**, 900–909.
- Ruas, M.P. 2005. Aspects of early medieval farming from sites in Mediterranean France. *Vegetation History and Archaeobotany* **14**, 400–415.
- 1865 Salvini, L., Pecci, A., Papi, E. and Cerri, L. 2007. Analisi dei residui organici assorbiti in due anfore romane (Thamusida, Morocco): GC-MS ed ESI-MS, pp. 741–749 in D'Amico, C. (ed.), *Atti del IV Congresso nazionale dell'Associazione Italiana di Archeometria* (Pisa 2006). Bologna: Patron Editore.
- Sánchez Gómez, P., Stevens, D., Fennane, M., Gardner, M. and Thomas, P. 2011. *Tetraclinis articulata*. The IUCN Red List of Threatened Species. Version 2014.3. <www.iucnredlist.org>. Downloaded on 29 March 2015.
- 1870 Sauvage, C. 1961. *Recherche géobotaniques sur les subéraies marocaines*. Rabat: Travaux de l'Institut Scientifique Chérifien, Séries botanique.
- Schoch, W. H., Pawlik, B. and Schweingruber, F. H. 1988. *Botanische Makroreste*. Bern: Paul Haupt.
- 1875 Schweingruber, F. H. 1990. *Anatomy of European woods*. Stuttgart and Berne: Paul Haupt Berne and Stuttgart Publishers.
- Sidina, M. M., El Hansali, M., Wahid, N., Ouattmane, A., Boulli, A. and Haddioui, A. 2009. Fruit and seed diversity of domesticated carob (*Ceratonia siliqua* L.) in Morocco. *Scientia horticul-turae* **123**, 110–116.
- Van der Veen, M. and Tabinor, H. 2007. Food, fodder and fuel at Mons Porphyrites: the botanical evidence, pp. 84–139 in Peacock, D. and Maxfield, V. (eds.), *The Roman Imperial Quarries: Survey and Excavation at Mons Porphyrites 1994–1998*, The Excavations (Vol. 2). London: Egypt Exploration Society.
- 1880 Vernet, J. L., Ogereau, P., Figueiral, I., Machado Yanes, C. and Uzquiano, P. 2001. *Guide d'identification des charbons de bois préhistoriques du sud-ouest de l'Europe*. Paris: CNRS.
- 1885 Vossen, I. and Groot, M. 2009. Barley and Horses: Surplus and Demand in the civitas Batavorum, pp. 89–104 in Driessen, M., Heeren, S., Hendriks, J., Kemmers, F. and Visser, R. (eds.), *TRAC 2008. Proceedings of the 18th annual Theoretical Roman Archaeology Conference held at Amsterdam*, 4–6 April, 2008. Oxford: Oxbow.
- 1890 Zohary, D. and Hopf, M. 2000. *Domestication of plants in the Old World*. Oxford: Oxford University Press.