



## The case study of Case Bastione: First analyses of 3rd millennium cal BC paleoenvironmental and subsistence systems in central Sicily

Claudia Speciale, Ilham Bentaleb, Nathalie Combourieu-Nebout, Gian Pietro Di Sansebastiano, Filippo Iannì, François Fourel, Enrico Giannitrapani

### ► To cite this version:

Claudia Speciale, Ilham Bentaleb, Nathalie Combourieu-Nebout, Gian Pietro Di Sansebastiano, Filippo Iannì, et al.. The case study of Case Bastione: First analyses of 3rd millennium cal BC paleoenvironmental and subsistence systems in central Sicily. *Journal of Archaeological Science: Reports*, 2020, 31, pp.102332. 10.1016/j.jasrep.2020.102332 . hal-02548634

**HAL Id: hal-02548634**

**<https://univ-lyon1.hal.science/hal-02548634>**

Submitted on 20 Nov 2020

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# **The case study of Case Bastione: first analyses of 3rd millennium Cal BC paleoenvironmental and subsistence systems in central Sicily**

**Claudia Speciale<sup>1,4</sup>, Ilhem Bentaleb<sup>2</sup>, Nathalie Combourieu-Nebout<sup>3</sup>, Gian Pietro Di Sansebastiano<sup>4</sup>, Filippo Ianni<sup>5</sup>, François Fourel<sup>6</sup>, Enrico Giannitrapani<sup>5</sup>**

1 INGV, Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Vesuviano, Naples (Italy)

2 ISE-M, University of Montpellier, Montpellier (France)

3 UMR 7194 HNHP, CNRS - Muséum National d'Histoire Naturelle, Paris (France)

4 Laboratorio di Botanica, Dipartimento di Scienze e Tecnologie Ambientali, Università del Salento, Lecce (Italy)

5 Arkeos s.c., Enna (Italy)

6 UMR 5023 LEHNA, University of Claude Bernard Lyon 1, Villeurbanne (France)

## **Abstract**

Archaeological investigations carried out at Case Bastione (Enna, central Sicily) provide a key insight into the cultural and environmental changes that occurred during the transition from the Copper Age to the Bronze Age. Preliminary data of an ongoing paleoenvironmental reconstruction through archaeobotanical analyses are here presented. The selective exploitation of vegetation, the adaptation of lifestyle to local resources, and changing climatic conditions are analysed using different on-site and off-site environmental and archaeological proxies. The environment around the site was constituted by mixed oak woodland. Dietary preferences were reconstructed through the analysis of carpo-remains. Isotopic values provide new data on the 4.2 ka BP event and its effects on vegetation in central Sicily. In a whole, first results from Case Bastione give new light to human choices of vegetal resources exploitation. Comparison of the local results with the regional pollen data support the hypothesis that the growth in population and settlement in the inland part of the island since the Late Copper Age may reflect changing climatic conditions in coastal areas.

## **1. Introduction**

This paper is the first attempt to investigate the nature of the relationship between later prehistoric communities and the landscape of central Sicily. Throughout the 3rd millennium BC, communities of Sicily and the wider Mediterranean basin experienced a substantial phase of cultural, social and climatic transition (McConnell 1997; Leighton 1999; Cazzella, Maniscalco 2012; Pacciarelli et al. 2015; Giannitrapani, Ianni in press). Paleoenvironmental reconstruction in the central part of Sicily provides an opportunity to apply multi-proxy records to study the nature of this transition.

The archaeobotanical record, with a specific focus on the analysis of wood charcoals, is a powerful tool for the investigation of paleovegetation (Asouti, Austin 2005; Astudillo 2018; Figueiral, Mosbrugger 2000; Pearsall 2019).

The comparison of on-site archaeobotanical data with off-site paleoenvironmental records is a crucial benchmark for paleoecological reconstruction. The interpretation of palynological data from archaeological sites and natural sequences (Mercuri, Sadori 2012; Mercuri et al. 2012) supports the evidence of a human influence on the

environment since prehistoric times (Behre, Jacomet 1991; Mercuri, Sadori 2013). This combination of studies by complementary disciplines demonstrates that the full integration of analysed datasets focused on anthropogenic and natural processes provides the most powerful way to understand human activity and adaptation to landscapes and environments (Marignani et al. 2016; Sullivan et al. 2017; Kabukcu 2018; Spengler 2018).

By taking a multidisciplinary approach to the study of the interaction between human societies and the natural environment, it is possible to view change in the context of long-term system dynamics (Redman 2005; Brand, Jax 2007; Collins et al. 2012; Raymond et al. 2013) and local factors (signals) driving change (Birks, John 2012; Messner, Stinchcomb 2014; Izdebski et al. 2016). For example, land use might have a low or high impact depending on the scale and duration of the human activity in any given territory (Ayala, French 2005; Mercuri et al. 2010, 2019; Rothacker et al. 2018; Stevens et al. 2019). Furthermore, the presence of some ecological and vegetational conditions, associated with past dynamics, geomorphological characteristics and water resources availability of an area played an important role in the choice of settlement sites; this is undoubtedly the case for communities based on subsistence strategies, especially those reliant on rain-fed agricultural techniques (Wilkinson et al. 2014; Crumley et al. 2017).

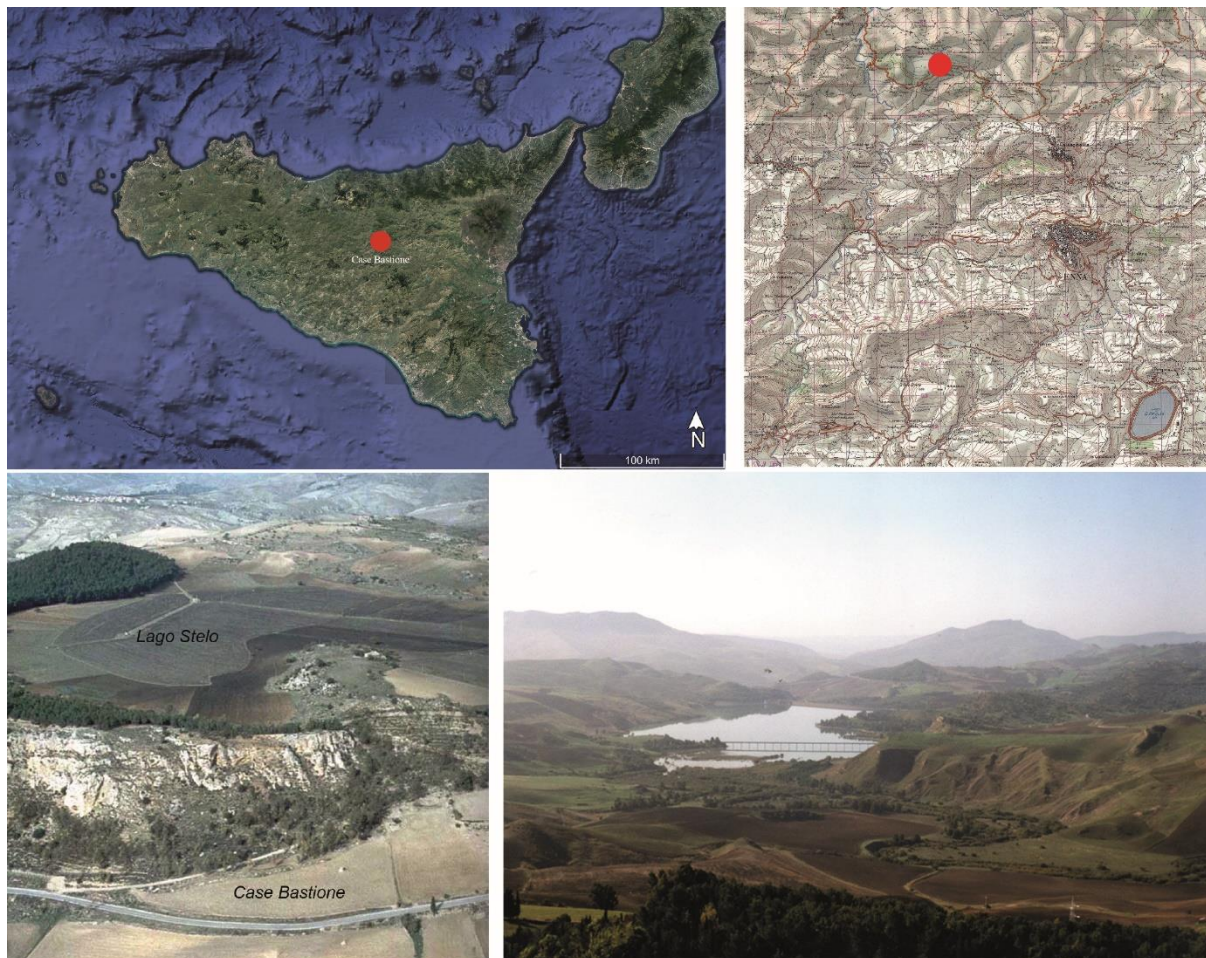
Published archaeological datasets have contributed to paleoecological research in Sicily by providing information about paleodemography and settlement patterns (Giannitrapani 2012, 2017; Giannitrapani, Ianni in press). The bioarchaeological dataset for prehistoric Sicily is not very dense. The analysis of macro- and micro-botanical remains (Costantini 1990; Martinelli et al. 2010; Ciaraldi in Leighton 2012; Ramsay in Leighton 2012; Speciale et al. 2016; Crispino 2018), and faunal remains (Chilardi in Giannitrapani et al. 2014; Crispino, Chilardi 2018) provides relevant insights in local hinterlands. On-site palynological studies have been used to measure human impact on the regional landscape (Rattighieri et al. 2012).

Paleoenvironmental data resulting from pollen and isotopic analyses of lacustrine deposits depicts a crucial insight of past climate and vegetation of Sicily and the whole Mediterranean area. Furthermore, the proximity of Lago di Pergusa (Sadori, Narcisi 2001; Sadori et al. 2013) to the site of Case Bastione provides a high-resolution environmental dataset for this period. Pergusa lacustrine sediment record includes the so-called “4.2 ka BP event”, interpreted as a period of 300 years of extreme drought at the transition from the Mid to Late Holocene, with diachronous impacts over the whole Mediterranean area (Walker et al. 2012; Weiss 2016; Di Rita et al. 2018; Bini et al. 2019).

The archaeological investigations carried out at Case Bastione, a large settlement situated in the inner core of Sicily (Fig. 1, upper left), provide a key opportunity to elucidate cultural and environmental changes during the transition from the Copper Age to the beginning of the Bronze Age.

This paper transforms the first data from archaeobotanical analyses as an opportunity to investigate vegetation and climatic change in the second half of the 3rd millennium BC. Interpretation of the preliminary data is integrated with isotopic analyses of the

archaeobotanical record and compared with other paleoenvironmental proxy records from across Sicily, with a specific focus on the nearby Lago di Pergusa, that represents a reference pollen record in central Sicily (Sadori et al., 2007, 2013).



*Figure 1 – Upper left. Geographic position of Case Bastione (Google Earth); Upper right. IGM (Istituto Geografico Militare) map portion of the western Erei upland; Lower left. The site seen from South, right beneath Lago Stelo, drained in the 1930s (photo by Arkeos); Lower right. Diga Ferrari and modern vegetation of the Morello valley (photo by Arkeos)*

### 1.1. Geographic setting and environmental context

Case Bastione (Villarosa, 37°36'42"N, 14°13'34"E, 610 m a.s.l.) is located in the western Erei uplands, about 13 km to the north of Enna (Fig. 1, upper right), in the valley of the Fiume Morello, a tributary of the Imera Meridionale (Giannitrapani et al. 2014). It is located at the foot of a cliff enclosing to the south the area of Lago Stelo, an endorheic basin (Fig.1, lower left). This lake - drained in the 1930s - is similar to the nearby Lago di Pergusa; its steep sandstone sides are marked by rock-cut graves, dating to the Bronze Age (Bernabò Brea in Albanese Procelli 1988-89, 395).

The archaeological area of Case Bastione extends almost 2 ha and is situated on a clay terrace, which is used for animal pasture. The site slopes southwards, towards the Diga Ferrari (Fig.1, lower right), a reservoir dam erected across the Morello valley

in the 1960s. In the last few decades, the site has been mechanically ploughed, leading to the destruction of the uppermost archaeological levels.

The central and western part of this hilly region is situated within the Caltanissetta Basin, a vast depression that occupies most of central-southern Sicily. The basin is infilled with thick clay deposits, which become more silty and sandy in their upper part (Decima, Wezel 1971). The landscape surrounding Case Bastione is also characterised by conglomerates of the Terravecchia Formation (Upper Tortonian), providing evidence of deltaic river sedimentation in this area over 20 million years ago (Butler et al. 2015).

The geological deposits of this part of inland Sicily have provided an important source of raw materials, such as sulphur and rock salt (or halite), and was known to be widely exploited by prehistoric communities (i.e. Castellana 1998; Harding 2013). Case Bastione is located halfway between the nearby sulphur mines of Agnelleria and Realmesi, active between the mid-19th and 20th centuries (Privitera 2000, 210), as well as the vast rock salt deposits of the Corvillo Basin (Maniscalco et al. 2010), also known in the past as the *Salina of Castrogiovanni* (Alessi 1825).

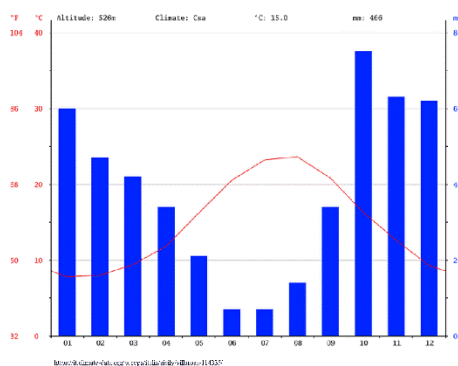


Figure 2 - Mean annual variation of monthly temperature and rain values at Villarosa (Enna, Sicily) (<https://it.climate-data.org/europa/italia/sicily/villarosa-114335/>)

Physiographically, this part of Sicily has a mean annual temperature of 15-16°C and mean annual precipitation of less than 500 mm (classed as semi-arid area according to De Martonne aridity index) (De Martonne 1926; Drago 2005; Viola et al. 2013) (Fig. 2). Modern vegetation of the closest woodland, Vallone Canalotto, is today characterised by garrigue (*Cisto-Micromerietea julianae*), xeric grassland and annual prairie. Wood species are represented by the pubescent oak woods (*Quercetalia pubescens* order such as *Quercus virgiliana* (Ten.) Ten., *Pistacia terebinthus* L., *Cornus sanguinea* L.), not very

common evergreen woody species of maquis and *Rhamno-prunetea* order (*Myrtus communis* L., *Olea europaea* var. *sylvestris* (Mill.) Lehr, *Rhamnus alaternus* L., *Pyrus spinosa* Forssk., *Sambucus nigra* L.), some elements of riparian forest (mostly *Populus nigra* L.) and naturalised fruit trees (Termine et al. 2014).

## 1.2. Archaeological background of the site

Prehistoric human occupation at Case Bastione lasted from the Late Neolithic to the Early Bronze Age (4th-2nd millennium Cal BC). After a long period of abandonment, the site was then reoccupied during the Late Antique and Byzantine periods (6th-9th century AD).



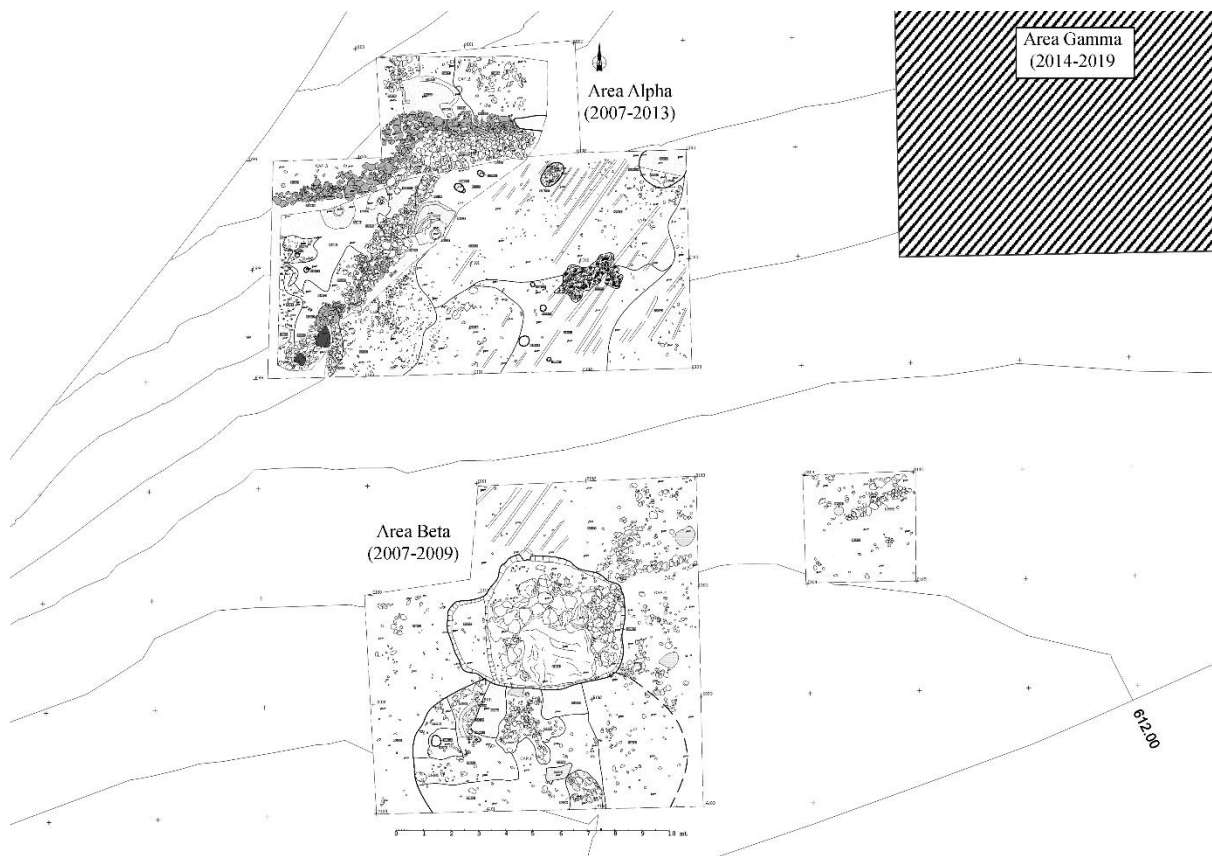


Figure 3 - The three areas of the archaeological site (graphic elaboration by Arkeos)

During the archaeological excavations, carried out at the site since 2007, two distinct zones, Area  $\alpha$  and Area  $\beta$  (Fig. 3), have been explored: the first is located at the northern edge of the site, while the second is approximately 15 m further south, associated with one of the largest concentrations of surface ceramic finds. In 2013 a geomagnetic survey was carried out across the entire settlement, while chemical and physical analyses have been performed to some of the architectural structures exposed in the first two trenches (Giannitrapani et al. 2014). Since 2014, a new trench, Area  $\gamma$ , located to the east of Area  $\alpha$ , has also been excavated alongside some test pits, to investigate some of the more significant geomagnetic anomalies (Giannitrapani et al. 2014).

Phases	Trenches			Absolute Bayesian chronology (95,4%)	
	$\alpha$	$\beta$	$\gamma$	Boundary start	Boundary end
Phase 0    Modern (top soil)	X	X	X		
Phase 1    Late Roman- Early medieval	X	X			
Phase 2    Abandonment	X				
Phase 3    Early Bronze a-c        Age (late phase)	X		X	2000-1830 cal BC	1930-1690 cal BC

Phase 4 a-b	Early Bronze Age (early phase)	X	X	X	2100-1950 cal BC	2010-1900 cal BC
Phase 4c	Abandonment	X		X		
Phase 5 a-b	Late Copper Age	X		X	2550-2200 cal BC	2300-2050 cal BC

*Table 1— All the phases from the archaeological site are here indicated from 0 (topsoil) to Phase 5 (Late Copper Age); in the last two columns, absolute chronology is indicated when obtained through AMS datings.*

Although the archaeological deposits of Case Bastione are more than 5 m thick, only the uppermost layers (ca. 0-1.80 m) have been investigated so far (tab. 1): a large trench (12x8 m) was opened in Area  $\alpha$  in 2007, following the natural NW-SE inclination of the slope. The exposed sequence comprises a series of archaeological levels, dating from the Late Copper Age to the present day. These are separated by layers of soil and sandstone debris (rocks) derived from the eroded cliff. In the central part of the trench, stone rubble created by the collapse of Early Bronze Age structures partially seals the older structures dating to the mid-3rd millennium BC. Late Copper Age levels have been exposed in fact in the lower part of Area  $\alpha$ , but also into the nearby Area  $\gamma$ , the latter characterised by a large structure named Hut 5, which is still under excavation. The upper part of Area  $\alpha$  and Area  $\beta$  have yielded evidence dating to the Early Bronze Age. In the latter area (12x12 m) a sizeable domestic structure, Hut 1, attributable to the Castelluccio Period has been fully exposed.

From these levels, 21 radiometric dates have been obtained, identifying three phases of activity during prehistoric times (tab. 1). The first prehistoric phase can be assigned to the Late Copper Age (2600-2300 Cal BC), which includes a craft area exposed in the lower part of Area  $\alpha$ , and includes various pits and furnaces, and Hut 5 nearby (phase 5 of the stratigraphic matrix). After a period of abandonment (phase 4c), the site was reoccupied in the Early Bronze Age. This second phase (4a-b) can be dated to between 2250 and 1900 Cal BC, as evidenced by structures exposed in Area  $\beta$  (Huts 1-4). Structures investigated in the upper part of Area  $\alpha$  (phase 3, Huts 2-3) can be attributed to a later phase of the Early Bronze Age (1900-1850 Cal BC) (Giannitrapani et al. 2014).

In Area  $\gamma$ , the western portion of an oval structure (Hut 5), oriented in an SW-NE direction, has been exposed. Although it is still the focus of the most recent excavation, its dimensions are at least 10x16 m (Fig. 4, upper left). This structure, unique in the known record of late Sicilian prehistoric sites for its monumental dimensions, has a clay floor, characterised by a series of lined pits embedded in it.

The perimeter of this very large feature is defined by a drystone wall to which an earthen bench and a series of post-holes have been added. The recovery of large quantities of burnt daub, which still preserves the imprints of wooden poles and reeds of various size appear to have been part of a wattle and daub curtain structure. Inside the hut, a series of internal post-holes parallel to those of the perimeter were identified with the remains of some charred poles but still *in situ* (Fig. 4, upper right). Within this central part of the structure, the floor was positioned at a lower level than the external

corridor. In this central area, large quantities of S. Ippolito wares together with a smaller number of Malpasso potsherds (Ianni in press) both attributable to the final stages of the Sicilian Copper Age have been recorded, together with various pits and productive features of different shape and typology. Taken all together, the archaeological evidence obtained so far from Hut 5 suggest that this sizeable Late Copper Age structure was used for the transformation and the production of agricultural and dairy products.

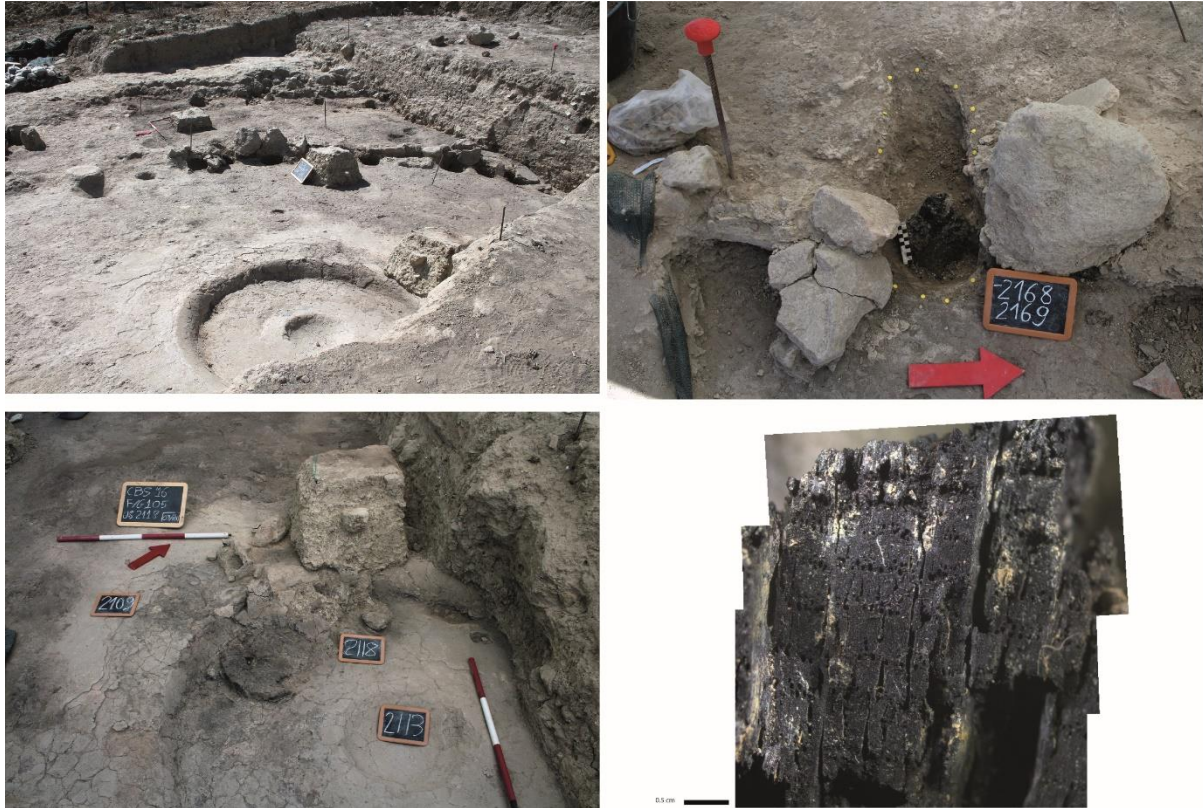


Figure 4 – Upper left. View of Hut 5 from East (photo by Arkeos); Upper right. One of the wooden poles of the Hut 5 (photo by Arkeos); Lower left. View of the pit 2113 during the excavation (photo by Arkeos); Lower right. Quercus cfr. virgiliana fragment with 9 growth rings from one of the wooden poles.



## 2. Materials and methods

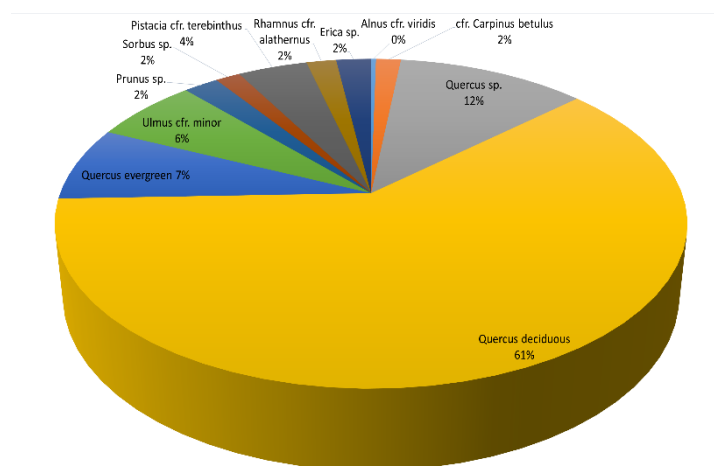
### 2.1. Wood charcoal samples and carpo-remains

For this paper, only wood charcoals and carpo-remains of the layers pertaining to Hut 5 are presented. The soil samples analysed in the study were collected during the 2017-2019 excavation campaigns. For each Stratigraphic Unit (SU), soil samples equal to about 10 litres per square per SU were collected. In some cases, for example, the layer of burnt soil relative to kilns/pits, total sampling of the entire layer was undertaken (in total, about 350 litres).

In Hut 5, 29 SUs were analysed (Table 2); most of the wooden poles (11) were singularly hand-picked during the excavation, together with the soil inside their associated pits; 13 soil samples (in total, around 150 litres), pertaining to phases of use were collected from two internal pits of the hut, together with those representing phases of collapse and abandonment of the structure.

The soil samples were sieved using water and two different sieve sizes (5 and 1 mm) to separate the clayey matrix. Subsequently, the samples were screened in three dimensions using a stereo-microscope ZEISS (Stemi 508); selected wood charcoals were mounted on aluminium stabs and sputter coated with three layers of gold before SEM observation using a ZEISS EVO HD 15 (Carl Zeiss Microscopy GmbH, Oberkochen, Germany). Some of the samples were photographed using an AxioCam ERc 5s ZEISS camera (Carl Zeiss Microscopy GmbH, Oberkochen, Germany).

Most of the tangential sections were, on average 6 mm long, however, the surfaces of the wooden poles ranged between 10 mm and 10 cm.



*Figure 4 - Percentages of wood species based on absolute number of anatomically identified wood fragments from Hut 5*

In the attempt to provide quantitative data about the presence/absence of different species for each SU, the volume of wood charcoal was evaluated in mm<sup>3</sup>. The volumetric parameter was used to correct the comparison based on the absolute number of fragments. The estimation of total volume reduces the incidence of differences due to wood fragmentation (Fig. 5). A significant fraction but not all the

wood charcoal found, have been observed in each SU, considering that the variability, exceeding 6-7 species, does not increase (Chabal 1992).

US	Poles											Pit 2113				Pit 2153	Collapse								Abandonment	
	2169-2170	2178	2179	2180-2190	2181-2191	2184-2196	2185	2192	2194-2195	2200	2202	2116	2117	2118	2119	2150	2106	2107	2123	2147	2164	2167	2186		TOTAL V	
VOLUMES	10	1	1	15	10	12	1	1	10	5	5	20	10	25	10	20	80	70	5	10	5	5	5	10	346	
SPECIES																									REMAINS	
<i>Alnus</i> cfr. <i>viridis</i>																				1					1	
<i>Carpinus betulus</i>												2								3					5	
<i>Quercus</i> sp.	4					5	4						3			7	4	8					3		38	
<i>Quercus</i> deciduous	15	16	5	25	27	4		18	20		5	1		14		7	4	34			6				201	
<i>Quercus</i> evergreen										2		4					10	4				4			24	
<i>Ulmus</i> cfr. <i>minor</i>		4							10					1			3	2		1					21	
<i>Prunus</i> sp.													1	1		1	3	1							7	
<i>Sorbus</i> sp.														1	1						3				5	
<i>Pistacia</i> cfr. <i>terebinthus</i>														6			3	5							14	
<i>Rhamnus</i> cfr. <i>alaternus</i>														1		1	1	3							6	
<i>Erica</i> sp.																1	1	4				1			7	
Not Identified													3	8	4	3	20	10	4	1	1			3	57	
TOTAL	19	20	5	25	27	9	4	18	30	2	5	7	4	35	5	20	49	71	4	6	10	5	3	3	386	

Table 2 - Wood charcoal results. In red, the number of stratigraphic units; in the first line, every colour indicates a context (wooden poles in yellow, Pit 2113 in light green, Pit 2153 in dark green, collapse layers in pink, abandonment phase in blue; in the line in grey, the total volumes of the samples stratigraphic units in litres; in the column in grey, name of the arboreal species; in the white boxes, the number of wood fragments for each stratigraphic unit.

The wood charcoals were identified in terms of family, genus, and where possible, species.

For the identification of genera / species, comparison of materials were made with standard reference atlases (Cambini 1967; Castelletti 1990; Schweingruber 1990; Nardi-Berti 2006; Cappiers, Neef 2012, 2016; Cappiers 2018), published scientific literature (i.e. Asouti et al. 2015), two on-line tools (InsideWood, <https://insidewood.lib.ncsu.edu>, Microscopic Wood Anatomy, [www.woodanatomy.ch](http://www.woodanatomy.ch)), and reference collection samples held at the Laboratory of Botany, University of Salento, Lecce, Italy (derived from *Xylotomotheca italica*, Adr. Fiori). When possible, the diameter of small branches from which charcoal originated were estimated. Other characteristics were identified including the presence of hyphae and signs of xylophagous, which provided additional information on taphonomic processes (Marguerie, Hunot 2007; Schweingruber 2007).

		Poles	Pit 2113	Pit 2153		Collapse		TOT	%
Part		2184	2118	2150	2105	2106	2107		
Cereals	Cerealia grain kernel		24			14	2	40	31,25
	Triticum sp. grain kernel		11			2		13	10,16
	Triticum sp. chaff (hulled)		4					4	3,13
	Triticum sp. Rachilla		1					1	0,78
	Triticum cfr. spelta grain kernel					1		1	0,78
	Triticum cfr. monococcum grain kernel		3					3	2,34
	Triticum cfr. dicoccum grain kernel		7			2		9	7,03
	Triticum cfr. dicoccum rachis internode		4					6	4,69
	Triticum cfr. aestivum grain kernel	2	5			1		8	6,25
	Triticum cfr. aestivum chaff		1					1	0,78
	Hordeum sp. Floret		3			1		4	3,13
	Hordeum vulgare ssp. vulgare floret	1	3	1				5	3,91
	Hordeum distichon floret		2			1		3	2,34
Pulses	Fabaceae >0.5 mm seed			1	4			5	3,91
	Fabaceae >0.5 mm pod		1					1	0,78
	Lathyrus sp. Seed					2		2	1,56
Fruits	cfr. Vitis vinifera		2					2	1,56
	cfr. Ziziphus lotus fruit					1		1	0,78
Weeds	Brassicacea cfr. Isatis tinctoria seed						1	1	0,78
	Lamiaceae seed		2					2	1,56
	Fabaceae seed						1	1	0,78
	Ind.	1	8	2		2	2	15	11,72
TOT		4	81	4	4	27	6	128	100

Table 3 – Total amount of seeds/fruit remains for each stratigraphic unit; in the first column, categories of carporemaines are divided into Cereals, Pulses, Fruits, Weeds. In the second column, each category is divided into genus and species. When possible the anatomical part of the seed/fruit is indicated.

## 2.2. Carbon, Nitrogen, Sulphur contents and isotopic ratios and C, N, S contents

Carbon, nitrogen and sulphur among other essential important chemical elements are utilised by living organisms for building their structural tissues and energy-harvesting activities. Plants retrieve these elements from the atmosphere, soil and water and thus participate in the global biogeochemical cycles of C, N, S involving oceanic, atmospheric and crustal rocks reservoirs. During the physiological processes of plant living organisms, isotopic fractionations between light and heavy isotopes of C ( $^{13}\text{C}$ ,  $^{12}\text{C}$ ) and N ( $^{15}\text{N}$ ,  $^{14}\text{N}$ ) occurs predictably. For instance, the carbon isotopic compositions of C3 (i. e. Trees) and C4 (i. e. Grasses) plants are significantly different due to the actions of different enzymatic activities involved in the inorganic carbon fixation through the Calvin Benson (RUBISCO enzyme) and Hatch-Slack (PEPC & RUBISCO) biochemical cycles.  $\delta^{13}\text{C}$  is recognised as an excellent proxy for identifying the C3 and C4 photosynthetic pathways of the plant.

Moreover, it is identified as a good indicator of the water use efficiency (see among other publications, Ferrio et al., 2005).  $\delta^{13}\text{C}$  tends to increase (decrease) in dry and/or cold (wet and/or warm) climate conditions due to stomata conductance (see Khon, 2010). Nitrogen isotopic ratios are related to the nitrogen biogeochemical cycle. The complexity of the nitrogen biogeochemical cycle makes the interpretation of the  $\delta^{15}\text{N}$  more difficult (see Ambrose 1991). According to Heaton (1987), the highest  $\delta^{15}\text{N}$  of plants appear to be associated with limited rainfall, or saline soils while the lowest is associated with moist forest. Values close to 0 ‰ are associated with leguminous plants fixing the atmospheric  $\text{N}_2$ . Recent studies have highlighted the interest of  $\delta^{15}\text{N}$  of soils in paleoecology studies. Bogaard et al., (2007) and Fraser et al., (2011) suggested  $\delta^{15}\text{N}$  increases in manured systems hence significantly increasing crop  $\delta^{15}\text{N}$  values.

The hypothesis we assume is that these processes are recorded in carbonised seeds and measuring these isotopic ratios offer an opportunity to reconstruct past conditions. Wood and carpological remains used for isotopic analyses were selected from different contexts at the site of Case Bastione in order to highlight potential differences in the three chronological phases identified through radiocarbon dating.

According to the macro-botanical remains available, a total of 24 samples were analysed for their C and C, N, and S isotopic ratios (tab. 4); these were collected from the three chronological phases identified through radiocarbon dating (8 samples from phase 4a-4b, 3 samples from phase 4c and 13 samples from phase 5). The selected materials included wood charcoal (*Pistacia* cfr. *terebinthus*, *Prunus* sp., *Sorbus* sp., *Quercus* cfr. *pubescens*, *Ulmus* cfr. *minor*), and pulses and cereal caryopses (*Vicia/Lathyrus* sp., *Hordeum* cfr. *vulgare*) to allow the comparison of as many different species as possible and therefore allow the identification of recurrent patterns. Each sample is represented by one grain, seed or fragment of wood charcoal.



Reference Name	Taxa	d <sup>15</sup> N (pm)	% N	d <sup>13</sup> C (pm)	%C	% S	C/N	C/S	Phase & Median probability Age Cal Yr BP
CB2	Ulmus sp.	7,9	0,3	-24,7	39,1	0,2	121	175	Phase 5 (4228 Yr)
CB3	Ulmus sp.	5,5	3,7	-21,1	45,2	0,2	12	199	
CB10	Hordeum cfr. vulgare	3,7	2,5	-22,0	49,1	0,2	19	266	
CB11	Vicia/Lathyrus sp.	1,8	5,4	-21,4	42,3	0,3	8	129	
CB20	Vicia/Lathyrus sp.	4,8	2,2	-20,3	39,0	0,2	18	201	
CB24	Vicia/Lathyrus sp.	6,5	1,6	-21,6	28,7	0,2	18	134	
CB19	Prunus sp.	7,3	0,4	-23,0	33,2	0,2	81	184	
CB18	Rosacea	6,8	0,6	-30,8	53,4	0,3	89	200	
CB22	Vicia/Lathyrus sp.	0,9	5,2	-24,6	42,0	0,2	8	226	Phase 4C (4155 Yr)
CB23	Vicia/Lathyrus sp.	7,7	0,5	-22,4	41,9	0,2	87	212	
CB13	Pistacia cfr. terebinthus	-0,9	0,2	-24,7	22,8	0,2	127	132	
CB1	Ulmus sp.	9,2	0,4	-23,2	48,5	0,2	135	239	Phase 4a-4b (3963 Yr)
CB4	Ulmus sp.	7,7	0,3	-23,3	47,9	0,2	151	286	
CB5	Quercus cfr. robur/cerris	7,4	0,3	-23,6	51,7	0,2	176	293	
CB6	Quercus cfr. robur/cerris	8,6	0,3	-22,7	48,4	0,1	157	341	
CB7	Quercus cfr. robur/cerris	8,8	0,5	-24,0	53,8	0,2	114	341	
CB8	Quercus cfr. robur/cerris	6,9	0,2	-22,9	43,7	0,3	272	129	
CB17	Quercus cfr. robur/cerris	7,2	0,6	-24,2	51,5	0,2	88	250	
CB9	Hordeum cfr. vulgare	6,4	3,7	-20,4	49,8	0,3	13	197	
CB21	Hordeum cfr. vulgare	8,4	4,3	-22,2	48,8	0,7	11	74	
CB12	Pistacia cfr. terebinthus	9,2	0,3	-23,3	49,9	0,2	160	240	
CB14	Pistacia cfr. terebinthus	9,9	0,3	-24,4	43,5	0,4	142	102	
CB16	Pistacia cfr. terebinthus	-	0,4	-24,4	50,5	0,7	113	77	
CB15	Prunus sp.	-	0,4	-24,9	46,4	0,8	125	59	

Table 4 - C, N, S contents (%) and C, N isotopic composition of vegetal macroremains; chronological phases are here indicated, for detailed chronology see tab. 1

All the identified, selected samples were prepared at ISEM Laboratory, (Montpellier) before isotopic analysis using the Mass spectrometer facilities of LEHNA laboratory (Lyon).

Over the last four decades, different pre-treatment protocols for isotopic composition analyses of charred seeds have been used over the last four decades (i.e. De Niro, Hastorf, 1985; Araus, Buxò 1993; Fraser et al., 2013; Masi et al., 2014; Vaiglova et al., 2014). According to the more recent published literature rinsing of charred seeds with ultrapure water (Millipore for molecular biology) is likely to result in less isotopic fractionation than using an acid-based treatment. We avoided the use of ultrasonication since we observed significant mass loss, as described by Vaiglova et al. (2014). Once rinsed with ultrapure water (Millipore), samples were dried overnight (40°C), before being crushed, homogenised and weighed (> 5 mg) into small tin cups (capsules).

Isotopic and elemental contents analysis for C, N and S (%) were conducted using the Isotopic Ratio Mass Spectrometry (IRMS) facilities of LEHNA laboratory. Samples contained into tin capsules were measured by dry combustion using a Pyrocube Elemental Analyser (EA, Elementar GmbH) connected online in continuous flow mode to an Isoprime 100 IRMS (Elementar). The methodological approach follows Fourel et al. (2014). Analytical precision is better than 0.1‰ for  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$ . Due to the meagre amount of S content (< 0.2 %), we were not able to measure the isotopic composition of sulphur ( $\delta^{34}\text{S}$ ). Data for C and N contents and isotopes were calibrated against international reference material IAEA-601, and for sulphur content against NBS-127 and IAEA S1.  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values are expressed in  $\delta$  notation, deviation from standards in parts per thousand (‰), relative to Vienna Pee Dee Belemnite (V-PDB) and atmospheric  $\text{N}_2$  (air), using the conventional delta ( $\delta$ ) notation:  $\delta$  (‰) =  $[(R_{\text{sample}}/R_{\text{standard}}) - 1] \times 1000$ , where  $R_{\text{sample}}$  and  $R_{\text{standard}}$  are the  $^{13}\text{C}/^{12}\text{C}$  or  $^{15}\text{N}/^{14}\text{N}$  ratios of the sample and standard, respectively. Results of elemental analysis are expressed as C, N and S in % and C/N and C/S ratios.

Several correction factors can be applied to the C and N isotopic ratios (i.e. Ferrio et al. 2005; Nitsch et al. 2015). Changes of the carbon isotopic composition of the atmospheric  $\text{CO}_2$  ( $\delta^{13}\text{C}_{\text{AIR\_CO}_2}$ ) over time must be taken into account in the comparison of samples from different periods (Ferrio et al. 2005). In our study, values are not adjusted for the  $\delta^{13}\text{C}_{\text{AIR\_CO}_2}$ , assuming that the  $\delta^{13}\text{C}_{\text{AIR\_CO}_2}$  of about -6.4 ‰ did not change significantly during the 3 phases (time range of 500 years).

We also did not correct for the effect of charring (+0.11 ‰ for the  $\delta^{13}\text{C}$  and +0.31 ‰ for the  $\delta^{15}\text{N}$ ) as suggested by Nitsch et al., (2015).

However, these correction factors are taken into account when comparing our data to the published literature as for calculating the carbon isotopic discrimination between plant seed and atmospheric  $\text{CO}_2$  ( $\Delta^{13}\text{C}$ ). We calculated the carbon isotopic discrimination ( $\Delta^{13}\text{C}_{\text{SEED-CO}_2}$ ) using the equation of Farquhar et al., (1982). We assessed the water input during grain filling (expressed in mm) using the model described in Ferrio et al., (2005). The isotopic results are presented using previously calibrated AMS (radiocarbon) dates as a framework for the subdivision into

chronological phases, re-calibrating the dates in absolute time (BP) chronology (Fig. 6).

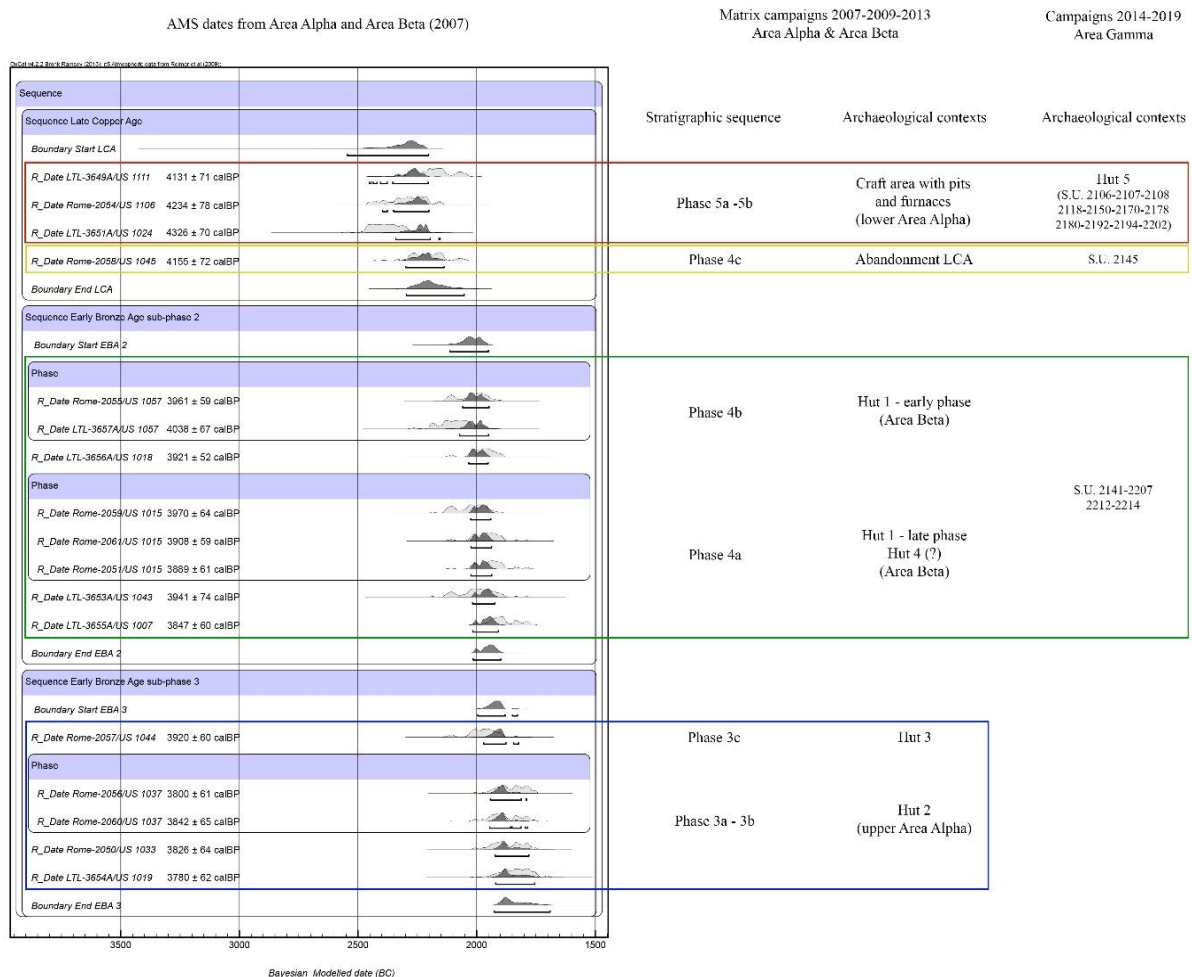


Figure 5 - AMS and relative chronology of the site; calibrated BP dates are indicated on the cal BC bayesian model. The phases included for isotopic analyses are 4a-b, 4c, 5. (Bayesian calibration by C. Alexander; chronology and phases elaborated after Giannitrapani et al. 2014).

### 3. Results

#### 3.1. Anthracology and Wood Species

In total, 386 fragments of wood charcoal were identified from Hut 5. Of the wood charcoal, 13% were not taxonomically identified, due to the small size of fragments or to the state of preservation, when heating/fire had strongly deformed the xylem was unrecognisable anymore, reduced to ash and clay and/or very small fragments composed of burnt clusters (0.5-2 cm diameter). Variability of the assemblage is not very high, with 11 genera/species identified (Table 2). A small presence of Betulaceae (birch family) is significant but quite rare in the record.

Oak is well represented, with a total of 263 fragments; most of them are deciduous or semi-deciduous species (61% of the total), the rest are evergreen oak (Fig. 7, upper row) (7%). However, the identification of oak can be challenging (Cambini 1967, Castelletti 1990) and in Sicily 9 different species of the *pubescens* group are present (Schicchi et al. 2000). Comparison with modern vegetation and the small part of

woodland still preserved within the area (Termine et al. 2014) allowed us to restrict the

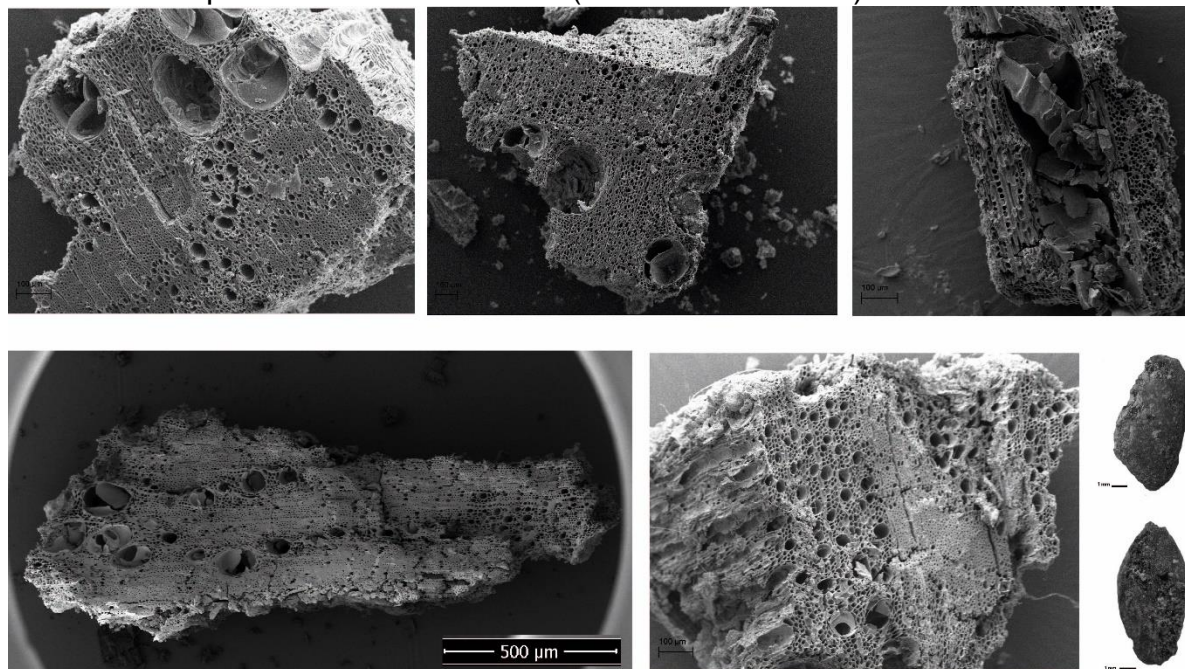


Figure 6 – ESM pictures. Lower right. Stereomicroscope pictures: all the scales are indicated for each picture. Upper left and central. Transversal section of a *Quercus* cfr. *virgiliana*; Upper right. Tangential section of a *Quercus* cfr. *virgiliana*; Lower left. Transversal section of a *Quercus* cfr. *ilex*; Lower central. Transversal section of *Rhamnus alaternus*; f. Lateral view of *Triticum* cfr. *dicoccum* grain kernel; g. Dorsal view of *Hordeum* cfr. *vulgare* floret.

identification of deciduous oak fragments to the species *Quercus virgiliana*. The third most abundant wood type recorded was elm (6%), while all the remaining wood types were poorly represented (black elder, common hornbeam, terebinth, alatern – second row, second picture, heather, plum trees) in the contemporary environment (between 0.5 and 4%). Wood charcoals identified inside Hut 5, considering the low variability of materials comprising the wooden poles, are quite heterogeneous. In percentage volume terms, deciduous oaks represent 20%, followed by terebinth (18%), evergreen oaks (12%), sorb trees (10%), heather (7%), plum trees (6%), alatern and hornbeam (5%) and elm (3%) (Fig. 8, lower right). Through the analysis of the distribution of the species according to the specific context, the wood fragments from the collapse phases in the centre of the hut are different (with all species identified as present). In contrast, in pit 2113, there is a predominance of oak, whilst in pit 2153, only a few species are present (Fig. 9). Oakwood is present on the surface of the clay plate of the hearth together with mixed burnt caryopses and pulses (see 3.2). The charcoal assemblage suggests that oak represents the species of woodland most exploited by the local inhabitants during the Late Copper Age, followed by riparian species and secondary vegetation/shrubs.



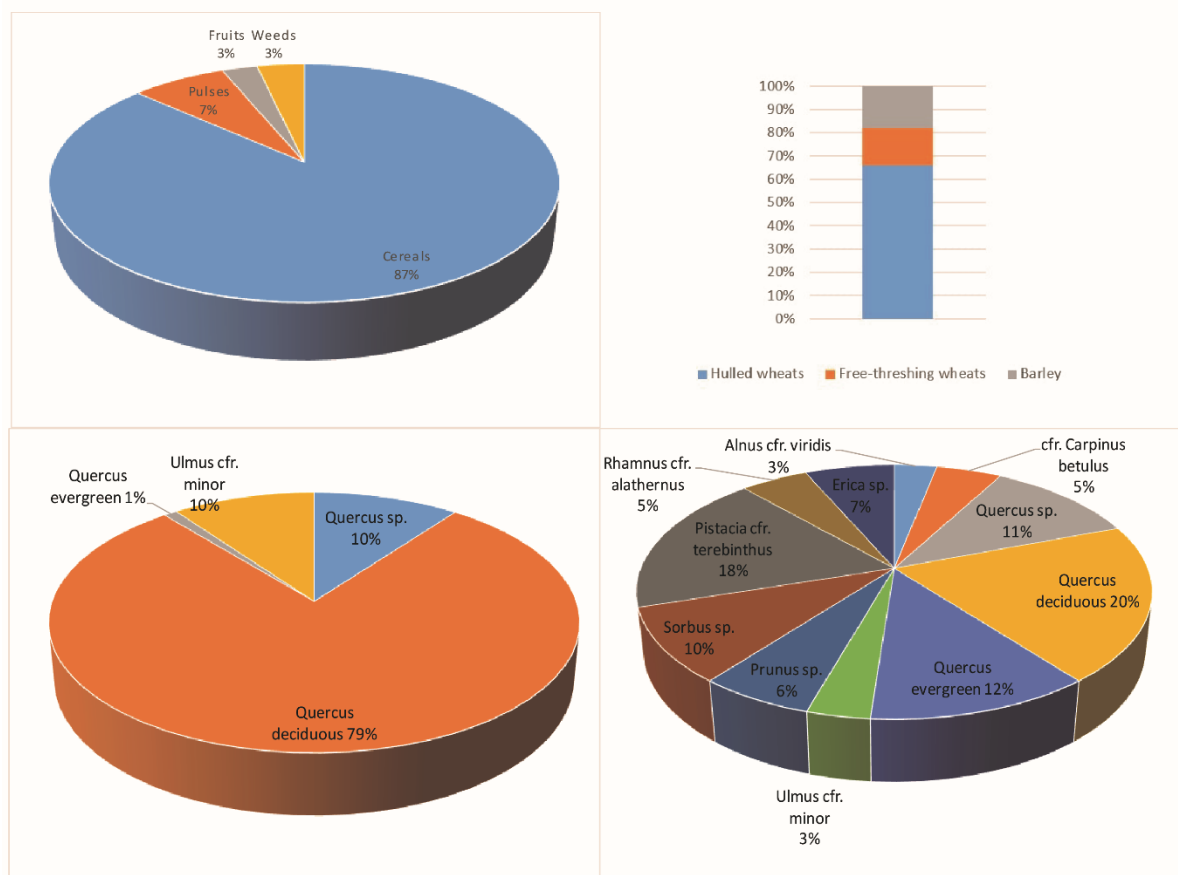


Figure 8. Upper left. Percentage of cereals, pulses, weeds and fruits from Hut 5; Upper right. Percentage of crop species from Hut 5; Lower left. Percentage of wood species within the pole pits; Lower right. Percentage of wood species inside the hut.

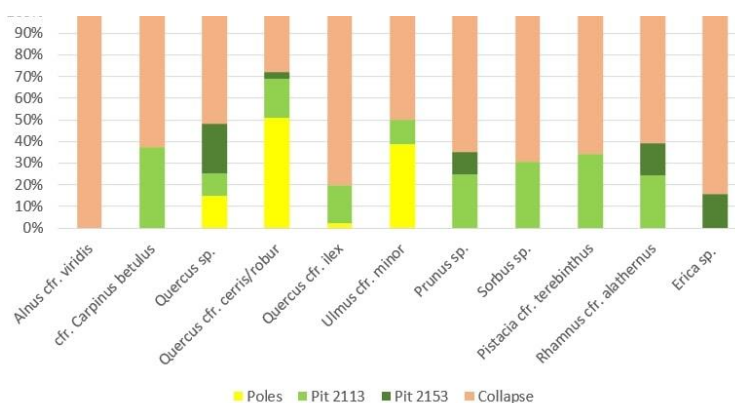


Figure 9. Percentage of the distribution of species according to stratigraphic units (wooden poles and inside the hut)

### 3.2. Seeds and fruits

Carpo-remains identified from Hut 5 belong to cereals, pulses, weeds and fruits (tab. 3) (Fig. 8, upper row). A total of 128 remains was found. Preservation conditions are averagely quite good. 12% of the carpo-remains were not taxonomically identified, whilst the remainder was

divided into cereals, pulses, fruits, weeds; cereals were subdivided further according to family, genera and species and then classified histologically (Table 3). Most of them are from the pit/hearth 2113, the phases of hut collapse and from one of the post-holes. The presence of cereals is dominant in SU 2118, with the remains of several different species of hulled wheat identified (*Triticum* cfr. *monococcum* and *Triticum* cfr. *dicoccum*, maybe *Triticum* cfr. *spelta*) (68%), free-threshing wheat (*Triticum* cfr.

*aestivum*) (14%) and hulled barley (*Hordeum vulgare*) (18%) (Figg. 7 lower right, 8 upper right). Several different parts of these plants were observed: kernels, florets, rachis and chaff, probably resulting from the process of de-hulling. Pulses were poorly represented in pit SU 2153, only containing fragments of *Lathyrus/Vicia* sp. Fruits are represented by two species: *Ziziphus* cfr. *lotus*, a drupe of buckthorn and *Vitis vinifera*, although it was very poorly preserved. One seed of Brassicaceae is tentatively identified (*Isatis* cfr. *tinctoria*) in the sediments from the collapsed phase of the building. Finally, some weed seeds from the family of Lamiaceae and Fabaceae are recorded.

### 3.3. Isotopes

C and N isotopic compositions and C, N, S contents are presented in Table 4. The charred seeds analysed have  $\delta^{13}\text{C}$  values ranging from -30.8 (Rosaceae) to -20.4 ‰ (*Hordeum*). *Pistacia*, *Prunus*, *Quercus* and *Ulmus* vary between -25 and -23 ‰. The  $\delta^{15}\text{N}$  values range from -0.9 to 9.9 ‰. On figure 10, we present the mean values and standard deviation of the  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  of the three phases.  $\delta^{15}\text{N}$  shows a decrease

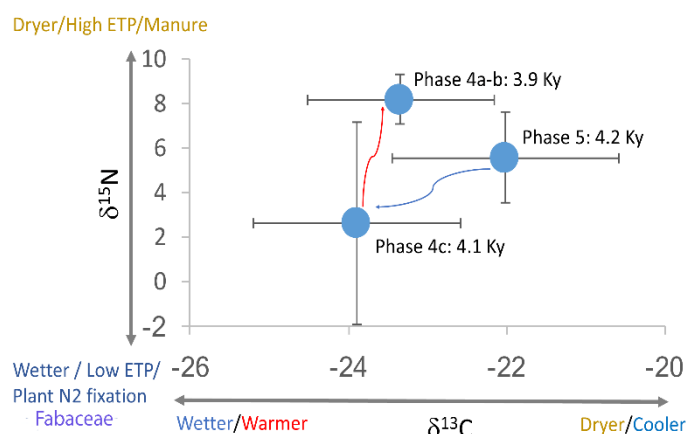


Figure 10 - Mean values and standard deviation of the  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  (‰) of the three phases. The highest  $\delta^{15}\text{N}$  mean values are registered during phases 4a-4b, whilst the lowest mean  $\delta^{15}\text{N}$  value is recorded during phase 4c; the highest mean  $\delta^{13}\text{C}$  value is registered during phase 5 and the lowest during phase 4c.

from phase 5 to 4c, before increasing during phase 4a-4b. The highest  $\delta^{15}\text{N}$  mean values are registered during phases 4a-4b ( $8.1 \pm 1.1$ ‰), whilst the lowest mean  $\delta^{15}\text{N}$  value is recorded during phase 4c ( $2.6 \pm 4.6$ ‰). This phase recorded the two lowest values ( $< 1$ ‰) and exhibited high variability range. Mean  $\delta^{15}\text{N}$  values during phase 5 registers an

intermediate value of  $5.5 \pm 2.0$ ‰ compared to the two other phases with values range ranging from 0.9 to 7.0 ‰. The highest mean  $\delta^{13}\text{C}$  value is registered during phase 5 ( $-22.0 \pm 1.4$ ‰) and the lowest ( $-23.9 \pm 1.3$ ‰) during phase 4c. Mean  $\delta^{13}\text{C}$  value of phase 4a-b ( $-23.3 \pm 1.2$ ‰) is slightly lower than that of phase 4c, but do not show significant changes to that period. C content (%) ranges from about 23% to 54 %, showing no specific trends over the period, but exhibits a higher variability during phase 5. S content across the samples is very low (0.1 to 0.8 %) and in contrast to the C% shows an increase in variability and amount during phase 4a-4b. N% varies from 0.2 to 5.4 %. The highest N content is measured in *Vicia* and *Hordeum* and one wood charcoal of *Ulmus*. Elemental ratios of C/N (from 8 to 272) and C/S (59 to 341) do not exhibit any trend over time; both ratios show the highest amplitude range during phases 4a-4b. The carbon isotopic discrimination ( $\Delta^{13}\text{C}$ ) of *Hordeum* and *Vicia* charred

seeds is generally lower than 16 ‰ while the  $\Delta^{13}\text{C}$  of *Pistacia*, *Prunus*, *Quercus*, *Ulmus* tree taxa range from 17 to 19 ‰ and reach 25 ‰ for Rosaceae. One charred seed of *Ulmus* and one of *Vicia* do not conform to this general observation. Following the methodology outlined in Ferrio et al. (2005), using the  $\delta^{13}\text{C}$  of *Hordeum*, the assessed amount of water input ranged between approximately 18 and 54 mm between 4.2 and 3.9 Cal ka BP.

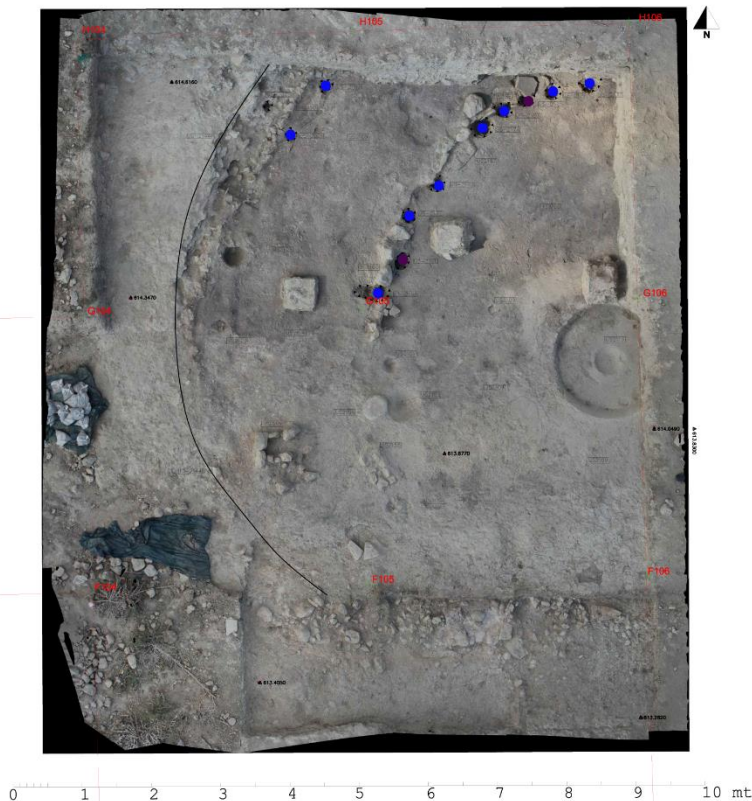


Figure 11 - Photoplan of Hut 5: blue post-holes contains only deciduous oaks wood; purple post-holes contain both deciduous oak and elm wood (photo by Arkeos; elaboration by C. Speciale)

#### 4. Vegetation resources, paleoenvironment and subsistence in 3rd millennium Cal BC

The first results of archaeological and wood charcoals analysis are discussed and interpreted to analyse architectural choices and woodland management into the broader framework of central Sicilian sites. Carpological remains are described to give light to the subsistence system, agricultural practices and dietary choices of this human community. Finally, archaeobotanical results are compared with on-site isotopic values and off-site paleoenvironmental data of the pollen record derived

from a sediment core from Lago di Pergusa (37°83'10" N; 14°81'80" E), around 12 km away. All these data are discussed to reconstruct environment and subsistence system of a site from central Sicily for the first time, in the broader picture of regional demography.

##### 4.1. Prehistoric architecture, wood technology and environmental management

The 11 wooden poles of the Hut 5 are quite exclusively made from deciduous oak, except for two poles where elm was used (SU -2171, SU -2175). The elm may have been used to reinforce other wood in the pole structure (Fig. 11). In terms of the oak itself, 79% of the material came from deciduous oaks with only 1% is identified as evergreen species (Fig. 8, lower left).

The evidence obtained so far from Case Bastione can be compared with other data from central Sicily, though this is challenging since very few other sites have been investigated (and published), mainly where a multidisciplinary approach has been

used. At La Muculufa (Butera, Caltanissetta), around 70 km from Case Bastione, two structures have post-holes: in Hut 2, a large post-hole has been identified lined with the perimetral bench (McConnell 1995: 15). A similar arrangement has been recorded during the excavations of Hut 1 at Tornambè, located 35 km north of La Muculufa; here, a series of large post-holes have been exposed in the centre of the structure and along the perimetral wall (Giannitrapani, Iannì 2011). Hut 3 of La Muculufa has also revealed the presence of two small post-holes (diameter: ca. 15 cm), similar to those observed at Case Bastione: on the floor of Hut 3 a piece of carbonised wood 20 cm long and 6 cm in diameter was recorded and radiocarbon dated to 2568-2329 cal BC, though its *taxon* has not been identified (McConnell 1995: 16-17). The Copper Age structure exposed at Casa Sollima, Troina (Enna) located in the northern part of the Erei uplands around 55 km from Case Bastione, has revealed various post-holes on the floor, within a context similar to Case Bastione (Malone, Stoddart 2000a, 2000b; Malone et al. 2001-2003). Other contemporaneous sites such as Serra del Palco (La Rosa 1984-85: LCA hut, phase 5) and Poggio dell'Aquila (Cavalier, Cultraro 2009) do not provide evidence of post holes; at Mezzebi, a small portion of the exposed hut has revealed the presence of only one perimetral post-hole (Privitera 1994). The exclusive use of oak for wooden poles was recorded for the Late Bronze Age huts of Morgantina (Aidone, Enna), around 40 km from Case Bastione (Ramsay in Leighton 2012).

Moving beyond Sicily onto the nearby Aeolian Islands, research has shown that the hut structures date from the Late Neolithic to the Bronze Age and are built mostly without the use of wooden poles (Martinelli et al. 2010, Speciale et al. 2016). The exception is the last phases of the Bronze Age on Lipari Island where oak and other species were used as wooden poles (Speciale 2017).

The use of deciduous oak wood for building in Case Bastione is clearly the result of its presence close to the site which is reinforced by the results from Lago di Pergusa pollen record, showing the dominance of deciduous and evergreen oaks in the Mediterranean forest at the same time, although tree formations already decreased progressively (Sadori et al. 2013). The dominant use of oak for construction but with other wood types available (elm) could suggest that wood selection and woodland management may have been a crucial feature of the landscape.

Due to the postulated presence of riparian vegetation around the archaeological site, which was once surrounded by wetlands, we can infer that there was the opportunity to exploit a broader range of vegetation resources.

We suggest that the presence of oak wood in the pits reflects its use as fuel from the re-use of architectural elements, together with some shrubs, notably terebinth (i.e. Piçornell et al. 2011). The exploitation of the resources such as the deciduous woodland and opening of these areas is most probably associated with the cultivation of crops (see 4.2) and pastoral activities, as testified by the faunal remains (Chilardi in Giannitrapani et al. 2014).

## **4.2. Staple sources and agricultural practises**



The data attest cultivation of cereals (mostly hulled wheat) and pulses. Barley was cultivated in its hulled variety, in percentages that are slightly lower than the Bronze Age average in Europe (Stika, Heiss 2013). Contextualising the data from Case Bastione is again challenging since Sicily is missing reliable, expansive archaeobotanical datasets for the Late Copper Age (see <http://brainplants.successoterra.net/>).

At the site of Muculufa (Costantini 1990), approximately 50 km to the South, a small record provides evidence for free-threshing wheat together with hulled wheat, but there is no record of barley. From Casa Sollima, around 40 km to the North-East, a brief and preliminary archaeobotanical analysis suggests the presence of mixed cropping taxa, such as wheat, barley, lentils and various beans (Malone et al. 2001-2003). Barley is absent in Paliké until Classic times; at this site, approximately 50 km to the South-East, the only carpological remains from the Late Copper Age are olive stones (Castiglioni 2008), whose presence are not detected at Case Bastione. At Morgantina, an area close to Case Bastione (30 km), dated to the Final Bronze Age, barley is missing from the archaeobotanical record, while emmer (*Triticum* cfr. *dicoccum*) is well represented (Ciaraldi in Leighton 2012). The percentage of barley identified in this study is quite low (22%) when compared, for example, to the site of Filo Braccio, dating to the Early Bronze Age (Aeolian Islands, 2200-1700 BC) (Speciale et al. 2016, Speciale 2017). At Case Bastione, *Triticum monococcum* (einkorn) is present, but its status as a commensal or a separate crop remains unclear (i.e. Valamoti 2009). The absence or low presence of barley and the presence of emmer and free-threshing wheat in datasets from other sites dated to the Late Copper Age/Early Bronze Age in central Sicily indicate favourable – or better not unfavourable conditions (low summer and springtime temperatures) for rain-fed agriculture during the 3<sup>rd</sup> millennium BC (Primavera et al. 2017). Plants of the family of Lamiaceae, Fabaceae and Brassicaceae are speculatively interpreted as arable weeds, despite their use as crops for fodder or human consumption (Bogaard et al. 2018).

The consumption of fruits is not indicated by the archaeobotanical records so far collated. However, the identification of wood charcoal of Maloideae and Prunoideae (total of 16%), whose families include most common fruit tree species, suggest the exploitation of fruit trees for consumption was a possibility. Our data bring up that wild resources such as *Vitis vinifera* and *Ziziphus* sp. may have been exploited; this last one is more common at areas where temperatures are higher (Pignatti 1982). *Olea europaea* is absent in the anthracological record. Despite its increased presence in natural sequences (Sadori et al. 2008) and its exploitation in other contexts of the same phases, *O. europaea* has spread widely across the rest of the central Mediterranean only in historic ages (Terral et al. 2004). Its use as a domesticated plant at Case Bastione can be excluded according to this first analysis.

An indication of manuring can be inferred from the  $\delta^{15}\text{N}$  values of *Hordeum* charred seeds, reaching 8.4 ‰ in the last phase (4a-4b) and could be a response of the local community and adaptation to some drier climatic conditions (see Fig. 12), but more data are needed to substantiate this working hypothesis.

Finally, the interpretation of Hut 5 as a place where collective, productive activities were carried out focused on community subsistence is corroborated by the presence of the central structure (SU 2113) where cereals were roasted (Giannitrapani, Ianni 2016).

### 4.3. Local environmental conditions

The reconstruction of a meso-thermophilous oak woodland around the site, as inferred by archaeobotanical data, is also suggested by the archaeozoological assemblage; the significant presence of deer at Case Bastione is unusual if we compare it to data from other known Bronze Age sites in eastern Sicily, particularly those of coastal areas (Chilardi in Giannitrapani et al. 2014).

In terms of the archaeobotanical evidence, one of the biggest fragments of *Quercus virgiliana* came from Hut 5 (Fig. 4, lower right). It contained nine growth rings, the first seven of which were regularly spaced and showed no signs of severe ecological stress (drought, widespread defoliation) (Schweingruber 2007); the latest two growth rings could have signs of woodland management (Kabukcu 2018).

During the Copper Age (4th-3rd millennium BC), paleoenvironmental trends show a shift towards drier environmental conditions from 3000 BC onwards, in all the sequences south of 40°N (Magny et al. 2013; Peyron et al. 2013). In Sicily, regional trends are the same with a marked switch to evergreen forest in south-east Sicily (Noti et al. 2009); however, in north-east Sicily, an increase of *Fagus* shows the persistence of humid conditions at higher elevations, although also a decrease of deciduous oaks and an augmentation of Poaceae at the end of the phase (Bisculm et al. 2012; Tinner et al. 2016). Data from speleothem records of Grotta Carburangeli (around 150 km to North-West) show a similar tendency towards drier conditions (Frisia et al. 2006). Considering the data from local area, the pollen record from Lago di Pergusa illustrates that from 5 to 3 ka BP, there were mildly repetitive oscillations between forest and herb vegetation and in the forest between mesophilous and Mediterranean type trees, although deciduous oak remains as one of the dominant *taxa* of the forest during this period (Sadori et al. 2008; Sadori et al. 2013). These characteristics probably relate to seasonal contrasts (Magny et al. 2012). Between 5 and 3 ka BP, Sicilian vegetation shows contrasts between dryer southern coastal regions, as recorded through a massive decrease in Mediterranean forest (Di Rita, Magri, 2019) and central territories, where decrease in the forest is less important. This phenomenon highlights seasonal contrast, with summer slightly humid and precipitation sharply decreasing in winter during the 4.2 ka BP event (Peyron et al. 2013; Bini et al. 2019). Furthermore, the Lago di Pergusa sequence, after 4.5 ka BP, shows an increase of  $\delta^{18}\text{O}$  in carbonate sediments, suggesting that at Late Copper Age and the beginning of the Bronze Age, Sicily was characterized by a phase of increasing dryness (Zanchetta et al. 2007).

Comparison of the wood charcoal record from Hut 5 with the overall pollen assemblage from Lago di Pergusa shows that the proportions of the individual key species are similar (fig. 12): deciduous oaks are well represented in both, even if in slightly decreased levels in the pollen record. The only exceptions are the consistent presence of terebinth in the archaeological record but not in the natural record. To date, olive

trees, as discussed above, are also absent in the archaeological record from Case Bastione,

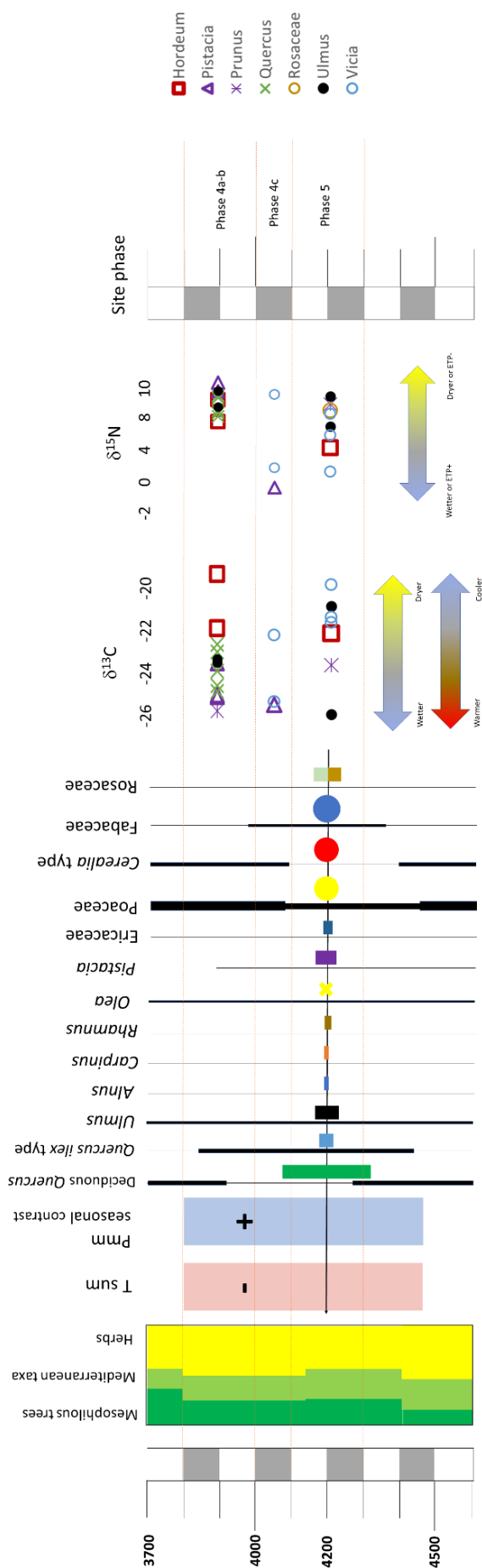


Figure 12. Comparison of the pollen, archaeobotanical and isotopic data; from the left, absolute BP chronology; in dark green, light green and yellow, indication of percentage of the three vegetation groups; pink bar indicates a phase of lower summer temperature; light blue bar indicates a phase of rain seasonal contrast; vertical black lines/bars indicate the percentage of pollen per each species/genus/family elaborated by Sadori et al. 2013 on PG2 core from Lago di Pergusa; thin line indicates <5%, medium-thin line 5>10%, medium bar 10>20%, large bar >20%; vertical coloured bars indicate the percentage of wood charcoals for each species/genus/family in the archaeobotanical record of Hut 5; circles and crosses indicate presence or absence in the record; values of  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  are indicated for phase and for species; finally, relative chronology of the site.



which may reflect either the selected use of woodland resources or the absence of large populations of *Olea* sp. nearby to the site.

The integration of the vegetation data with isotopic analyses shows that all charred remains belong to typical *taxa* of Mediterranean regions following the C3 (Calvin-Benson) pathway. The  $\delta^{13}\text{C}$  values of the C3 plants of Case Bastione are relatively high when compared to forested environments (-27 ‰) and could agree with the hypothesis of an opening anthropogenic landscape. Case Bastione  $\delta^{13}\text{C}$  averaging about -22 ‰ during the 4.2 ka BP event can be interpreted as a response to drier conditions to the other phases (high  $\delta^{13}\text{C}$  and relatively high  $\delta^{15}\text{N}$ ). The following short period (phase 4c) suggests wetter conditions, though the number of samples is far too small to interpret the data more precisely. Moreover, among the low values characterizing this period, an unusual *Pistacia*  $\delta^{15}\text{N}$  value suggests that this plant has the ability and the mechanism for atmospheric nitrogen fixation as recently suggested by Etminani and Harighi (2018) for *Pistacia atlantica*. The results from the latest phase (4a-4b) can be interpreted as a return to slightly drier conditions, with the local community hypothetically adapting through the use of better water management (as compared to phase 5), but also the use of manuring (which could explain the highest  $\delta^{15}\text{N}$  levels, while  $\delta^{13}\text{C}$  is not the highest value of the three periods).

## 5. Conclusions

The data discussed in this paper indicates that Case Bastione was a fundamental site of occupation during later prehistory. The comparison of archaeological, archaeobotanical, isotopic and pollen data from the site provides the first insight into the exploitation of vegetation and other local resources as well as paleoclimate.

According to the analysis of archaeological evidence from Hut 5 (phase 5, 4.3-4.2 ka BP, 2.4-2.3 ka BC), the building of huts within the village relied on the exploitation of woodland resources around the site, mostly deciduous oaks. Comparison of the assemblage of woody remains recovered from Case Bastione with the pollen record reconstructed from Lago di Pergusa, suggests that tree species may have been preferentially selected for specific purposes. The data presented here is considered preliminary since it is derived from a single context, however both environmental and dietary preferences support the idea of specific crop choices in Case Bastione, which may support the *ratio* of species (e.g. high emmer versus low barley) observed. First results of isotopic values from cereals, legumes and woody plants show drier conditions around the 4.2 ka BP, despite this did not affect vegetation significantly in the area.

This first comparison of data requires further investigation and analyses, from the same site but also from other contexts of the same phases and area, to understand the regional framework of demography and dynamics of human communities. So far, despite the timeframe of investigation including the 4.2 ka BP event, all the elements tend to minimize the influence of the drier conditions on local communities in this inland part of Sicily; however, in coastal areas, the impacts of climate change could have pushed the population and settlement increase in central Sicily from the Late Copper Age. The intensification of subsistence activities, increasingly focused on agricultural

production, accompanied by highly specialized pastoralism (Giannitrapani et al. 2014) in central Sicily, can be interpreted as a consequence of the higher population occupation.

Finally, the reconstructed vegetation picture of the area of Case Bastione around 6 ka years ago shows profound differences with the modern situation. Most of the changes passed in the last 2 ka (Sadori et al. 2015), despite the origin of this intertwined human-climatic process, can be detected since the Late Copper Age.

## Acknowledgements

C.S. and I.B. thank Eleni Filaiti for the laboratory preparation of the charred seeds. E. Filaiti was funded by the BIODIVMEX program CNRS Mistral (Working Group 4: Past, Present and Future Landscapes).

F.I. and E. G. thank the Superintendence for Cultural Heritage of Enna and the municipality of Villarosa for their constant scientific, technical and logistic support.

The authors thank the reviewers and the editor for their careful help and patience to improve the contents.

## References

- Ayala G., French C. 2005, *Erosion modeling of past land-use practices in the Fiume di Sotto di Troina river valley, north-central Sicily*, *Geoarchaeology* 20, 2, Special Issue: Landscape and Land Use - Geoarchaeological Approaches to Human Impact, pp. 149-167. <https://doi.org/10.1002/gea.20041>
- Albanese Procelli R. M. 1988-89, *Calascibetta. Le necropoli di Malpasso, Carcarella e Valle del Coniglio*, *Notizie degli Scavi XLII-XLIII*, pp. 161-225.
- Alessi G. 1825, *Descrizione fisica-mineralogica di Enna, or detta Castrogiovanni, e del suo territorio*, *Atti dell'Accademia Gioenia di Catania* I, 2: 99-146.
- Araus J.L., Buxó R. 1993, *Changes in carbon isotope discrimination in grain cereals from the north-western Mediterranean basin during the past seven millennia*, *Australian Journal of Plant Physiology* 20, pp. 117-128. [10.1046/j.1365-2486.1997.00056.x](https://doi.org/10.1046/j.1365-2486.1997.00056.x)
- Asouti E., Austin 2005, *Reconstructing woodland vegetation and its exploitation by past societies, based on the analysis and interpretation of archaeological wood charcoal macroremains*. *Environmental Archaeology* 10, pp. 1-18.
- Asouti E., Kabukcu C., White C.E., Kuijt I., Finlayson B., Makarewicz C. 2015, *Early Holocene woodland vegetation and human impacts in the arid zone of the southern Levant*, *The Holocene* 25, 10 10.1177/0959683615580199
- Behre K.E., Jacomet S. 1991, *The ecological interpretation of archaeobotanical data*, in Van Zeist W., Wasylyk K., Behre K. E. (eds.), *Progress in Old World Archaeobotany*, Rotterdam, Brookfield, pp. 81-108.
- Bini M., Zanchetta G., Persoiu A., Cartier R., Català A., Cacho I., Dean J.R., Di Rita F., Drysdale R.N., Finnè M., Isola I., Jalali B., Lirer F., Magri D., Masi A., Marks L., Mercuri A.M., Peyron O., Sadori L., Sicre M.-A., Welc F., Zielhofer C., Brisset E. 2019, *The 4.2 ka BP Event in the Mediterranean region: an overview*, *Climate of the Past* 15, pp. 555-577. <https://doi.org/10.5194/cp-15-555-2019>
- Birks H., John B. 2012, *Ecological paleoecology and conservation biology: controversies, challenges, and compromises*, *International Journal of Biodiversity Science, Ecosystem Services & Management* 8, 4, pp. 292-304.
- Bisculm M., Colombaroli D., Vescovi E., Van Leeuwen J.F.N., Henne P.D., Rothen J., Procacci G., Pasta S., La Mantia T., Tinner W. 2012, *Holocene vegetation and fire dynamics in the supra-mediterranean belt of the Nebrodi Mountains (Sicily, Italy)*, *Journal of Quaternary Science* 27, 7, pp. 687-698. <https://doi.org/10.1002/jqs.2551>
- Bogaard A., Mohammed Ater, Hodgson J.G. 2018, *Arable weeds as a case study in plant-human relationships beyond domestication*, in Stépanoff C., Vigne J.-D. (eds), *Hybrid Communities. Biosocial Approaches to Domestication and Other Trans-species Relationships*, London, Routledge, pp. 97-112. [10.4324/9781315179988-6](https://doi.org/10.4324/9781315179988-6)
- Brand F.S., Jax K. 2007, *Focusing the meaning(s) of resilience: resilience as a descriptive concept and a boundary object*, *Ecology and Society* 12, 1, art. 23.
- Butler R.W.H., Maniscalco R., Sturiale G., Grasso M. 2015, *Stratigraphic variations control deformation patterns in evaporite basins: Messinian examples, onshore and offshore Sicily (Italy)*, *Journal of Geological Society* 172, pp. 113-124. <https://doi.org/10.1144/jgs2014-024>
- Cambini A. 1967, *Riconoscimento microscopico del legno delle querce italiane*, in Giordano G. (ed), *Contributi scientifico-pratici per una migliore conoscenza del legno*. - C.N.R., Roma IO, 10, pp. 51-80.
- Cappers R.T.J. 2018, *Digital Atlas of traditional food made from cereals and milk*, Groningen, Barkhuis and Groningen University Library.
- Cappers R.T.J., Neef R. 2012, *Handbook of plant palaeoecology*, Groningen, Barkhuis and Groningen University Library.

Cappers R.T.J., Neef R. 2016, *Digital atlas of traditional agricultural practises and food processing*, Groningen, Barkhuis and Groningen University Library.

Castelletti L. 1990, *Legni e carboni in archeologia*, in Mannoni T., Molinari A. (eds), Scienze in archeologia, Il Ciclo di lezioni sulla ricerca applicata in archeologia. Certosa di Pontignano (Siena), 7-19 novembre 1988. Quaderni del Dipartimento di Archeologia e Storia delle arti - Sezione Archeologia - Università di Siena, Firenze, All'Insegna del Giglio, pp. 321-394.

Castiglioni E. 2008, *I resti botanici*, in Maniscalco L. (ed.), Il Santuario dei Palici. Un Centro di Culto nella Valle del Marge, Catania, Soprintendenza BB.CC.AA. di Catania, pp. 365-386.

Cavalier M., Cultraro M. 2009, *L'insediamento eneolitico sul Poggio dell'Aquila (Adrano): risultati preliminari*, in Lamagna G. (ed.), Tra Etna e Simeto. La ricerca archeologica ad Adrano e il suo territorio, Giarre, Biblioteca della Provincia Regionale di Catania, pp. 49-64.

Cazzella A., Maniscalco L. 2012, *L'età del Rame in Sicilia*, in Dai Ciclopi agli Ecisti. Società e Territorio nella Sicilia Preistorica e Protostorica, Atti della XLI Riunione Scientifica dell'Istituto Italiano di Preistoria e Protostoria, Firenze, I.I.P.P., pp. 81-104.

Chabal L. 1992, *La représentativité paléo-écologique des charbons de bois archéologiques issus du bois de feu*, In Vernet J.-L. (ed), Les charbons de bois, les anciens écosystèmes et le rôle de l'Homme, Actes du Colloque International, Montpellier, 10-13 septembre 1991, Bulletin de la Société botanique de France, 139, 2-4, pp. 213-236.

Collins P. M., Davis B.A.S., Kaplan J. O. 2012, *The mid-Holocene vegetation of the Mediterranean region and southern Europe, and comparison with the present day*, Journal of Biogeography, 39, pp. 1848-1861 <https://doi.org/10.1111/j.1365-2699.2012.02738.x>

Costantini L. 1990, *Report of vegetal remains*, in Holloway J., Joukowsky M.S., Lukes S.S. (eds), La Muculufa, the early bronze age sanctuary: the early bronze age village. Excavations of 1982 and 1983, Rhode Island, Brown University, pp. 66-67.

Crispino A. 2018, *Castelluccio (Noto, SR)*, Notiziario di Preistoria e Protostoria 5.1, pp. 98-102.

Crispino A., Chilardi S. 2018, *Un pozzo dell'età del Bronzo da Piazza Duomo di Siracusa*, Rivista di Scienze Preistoriche 68, pp. 359-384.

Crumley C., Lennartsson T., Westin A. (eds) 2017, *Issues and Concepts in Historical Ecology: The Past and Future of Landscapes and Regions*. Cambridge, Cambridge University Press. doi:10.1017/9781108355780

Decima A., Wezel F. C. 1971, *Osservazioni sulle evaporiti messiniane della Sicilia centro-meridionale*, Rivista Mineraria Siciliana 130-132, pp. 172-187.

De Martonne E. 1926, *Aréisme et indice d'aridité*. Comptes Rendus Académie des Sciences, 181, pp. 1395-1398.

De Niro M.J., Hastorf C.A. 1985, *Alteration of  $^{15}\text{N}/^{14}\text{N}$  and  $^{13}\text{C}/^{12}\text{C}$  ratios of plant matter during the initial stages of diagenesis: studies utilizing archaeological specimens from Peru*, Geochimica et Cosmochimica Acta 49, pp. 97-115.

Di Rita F., Magri D. 2019, *The 4.2 ka event in the vegetation record of the central Mediterranean*, Climate of the past 15, pp. 237-251. <https://doi.org/10.5194/cp-15-237-2019>

Di Rita F., Fletcher W.J., Aranbarri J., Margaritelli G., Lirer F., Magri D. 2018, *Holocene forest dynamics in central and western Mediterranean: periodicity, spatio-temporal patterns and climate influence*, Scientific Reports 8, Article number: 8929. [10.1038/s41598-018-27056-2](https://doi.org/10.1038/s41598-018-27056-2)

Drago A. 2005, *Atlante Climatologico della Sicilia – Seconda Edizione*, Rivista Italiana di Agrometeorologia 2, pp. 67-83.

Etminani F., Harighi B. 2018, *Isolation and Identification of Endophytic Bacteria with Plant Growth Promoting Activity and Biocontrol Potential from Wild Pistachio Trees*, Plant Pathology Journal 34, 3, pp.208-217. <https://doi.org/10.5423/PPJ.OA.07.2017.0158>

Farquhar G.D., O'Leary M.H., Berry J.A. 1982, *On the relationship between carbon isotope discrimination and the inter-cellular carbon dioxide concentration in leaves*, Australian Journal of Plant Physiology, 9, pp. 121-137.

Ferrio J.P., Araus J.L., Buxó R., Voltas J., Bort J. 2005, *Water management practices and climate in ancient agriculture: inferences from the stable isotope composition of archaeobotanical remains*, Vegetational History and Archaeobotany 14, pp.510-517. [10.1007/s00334-005-0062-2](https://doi.org/10.1007/s00334-005-0062-2)

Figueiral I., Bettencourt, A.M. 2004, *Middle/Late Bronze Age plant communities and their exploitation in the Cávado Basin (NW Portugal) as shown by charcoal analysis: the significance and co-occurrence of Quercus (deciduous) – Fabaceae*, Vegetation History and Archaeobotany 13, pp. 219-232. <https://doi.org/10.1007/s00334-004-0040-0>

Figueiral I., Mosbrugger V. 2000, *A review of charcoal analysis as a tool for assessing Quaternary and Tertiary environments: achievements and limits*, Palaeogeography, Palaeoclimatology, Palaeoecology 164, 1-4, pp. 397-407.

Fourel, F., Martineau, F., Seris, M., Lécuyer, C., 2014. *Simultaneous N, C, S stable isotope analyses using a new purge and trap elemental analyzer and an isotope ratio mass spectrometer*, Rapid Communications in Mass Spectrometry, 28, 23, pp. 2587-2594 <https://doi.org/10.1002/rcm.7048>

Fraser R., Bogaard A., Charles M., Styring A.K., Wallace M., Jones G., Ditchfield P., Heaton T. H. E. 2013, *Assessing natural variation and the effects of charring, burial and pre-treatment on the stable carbon and nitrogen isotope values of archaeobotanical cereals and pulses*, Journal of Archaeological Sciences, 40, 12, pp. 4754-4766. <https://doi.org/10.1016/j.jas.2013.01.032>

Frisia S., Borsato A., Mangini A., Spötl C., Madonia G., Sauro U. 2006, *Holocene climate variability in Sicily from a discontinuous stalagmite record and the Mesolithic to Neolithic transition*, Quaternary Research 66, pp. 388–400. <https://doi.org/10.1016/j.yqres.2006.05.003>

Giannitrapani E. 2012, *Aspetti culturali e dinamiche del popolamento di età preistorica della provincia di Enna*, in Studi, Ricerche, Restauri per la tutela del Patrimonio Culturale Ennese, Enna: Soprintendenza BB.CC.AA., pp. 145-181.

Giannitrapani E. 2017, *Paesaggi e dinamiche del popolamento di età preistorica nella Sicilia centrale*, in Anichini F., Gualandi M.L. (eds), MAPPA Data Book 2, Roma: Edizioni Nuova Cultura, pp. 43-64.

Giannitrapani E. 2018, *Le case dei vivi e le case dei morti. Architettura domestica e funeraria nella Sicilia centrale tra il IV e il II millennio a.C.*, Rivista di Scienze Preistoriche 68, pp. 191-228.

Giannitrapani E., Ianni F., 2011, *La tarda età del Rame nella Sicilia centrale*, in L'età del Rame in Italia. Atti della XLIII Riunione Scientifica dell'Istituto Italiano di Preistoria e Protostoria, Firenze, I.I.P.P., pp. 271-278.

Giannitrapani E., Ianni F. 2015, *Case Bastione, Villarosa (prov. di Enna): la campagna di scavo 2014*, Notiziario di Preistoria e Protostoria 2.II, pp. 52-55.

Giannitrapani E., Ianni F. 2016, *Case Bastione, Villarosa (prov. di Enna)*, Notiziario di Preistoria e Protostoria 3.III, pp. 72-76.

Giannitrapani E., Ianni F. in press, *Demographic dynamics, paleoenvironmental changes and social complexity in the late prehistory of central Sicily*, in Lachenal T., Roure R., Lemerrier O. (eds.), *Demography and Migration. Population Trajectories from the Neolithic to the Iron Age*. Proceedings of the XVIIIth UISPP World Congress (4-9 June 2018, Paris, France) Sessions XXXII-2 and XXXIV-8. Oxford: Archaeopress, pp. 43-64

Giannitrapani E., Ianni F., Chilardi S., Anguilano L. 2014. *Case Bastione: a prehistoric settlement in the Erei uplands (central Sicily)*, Origini, 36, pp. 181-212.

Kabukcu C. 2018, *Wood charcoal analysis in archaeology*, in Pişkin E., Marciniak A., Bartkowiak M. (eds), *Case studies in Environmental Archaeology. Interdisciplinary Contributions to Archaeology*, New York, Springer, pp. 133-154. [https://doi.org/10.1007/978-3-319-75082-8\\_7](https://doi.org/10.1007/978-3-319-75082-8_7)

Ianni F. in press. *La sequenza delle fasi del Castellucciano e la loro cronologia*, in Palio O., Todaro S., Turco M. (eds), *Vivere all'ombra del Vulcano. Giornata di studi dedicata alla memoria di Enrico Procelli*. Catania 19 ottobre 2016.

Izdebski A., Holmgren K., Weiberg E., Stocker S.R., Büntgen U., Florenzano A., Gogou A., Leroy S.A.G., Luterbacher J., Martrat B., Masi A., Mercuri A.M., Montagna P., Sadori L., Schneider A., Sicre M.-A., Triantaphyllou M., Xoplaki E. 2015, *Realising consilience: how better communication between archaeologists, historians and natural scientists can transform the study of past climate change in the Mediterranean*, Quaternary Science Reviews 136, pp. 5-22. <http://dx.doi.org/10.1016/j.quascirev.2015.10.038>

La Rosa V. 1984-85, *L'insediamento preistorico di Serra del Palco in territorio di Milena*, Kokalos II, 1, pp. 475-482.

Leighton R. 1999, *Sicily before History: An Archaeological Survey from the Palaeolithic to the Iron Age*, Ithaca (NY), Cornell University Press.

Leighton R. (ed.) 2012, *Prehistoric Houses at Morgantina. Excavations on the Cittadella of Morgantina in Sicily, 1989-2004*. Accordia Specialist Studies on Italy Vol.15. London, Accordia Research Institute.

Magny M., Peyron O., Sadori L., Ortu E., Zanchetta G., Vannière B., Tinner W. 2012, *Contrasting patterns of precipitation seasonality during the Holocene in the south- and north central Mediterranean*, Journal of Quaternary Sciences 27, pp. 290–296. [10.1002/jqs.1543](https://doi.org/10.1002/jqs.1543)

Magny M., Combourieu-Nebout N., de Beaulieu J.L., Bout-Roumazielles V., Colombaroli D., Desprat S., Francke A., Joannin S., Ortu E., Peyron O., Revel M., Sadori L., Siani G., Sicre M.A., Samartin S., Simonneau A., Tinner W., Vannière B., Wagner B., Zanchetta G., Anselmetti F., Brugiapaglia E., Chapron E., Debret M., Desmet M., Didier J., Essallami L., Galop D., Gilli A., Haas J.N., Kallel N., Millet L., Stock A., Turon J.L., Wirth S. 2013, *North-south palaeohydrological contrasts in the central Mediterranean during the Holocene: tentative synthesis and working hypotheses*, Climate of the Past 9, pp. 2043–2071. doi: 10.5194/cp-9-2043-2013

Malone C., Stoddart S. 2000a, *A house in the Sicilian hills*, Antiquity 74, pp. 471-472.

Malone C., Stoddart S. 2000b, *A contribution to the understanding of Serrafellicchio*, Sicilia Archeologica 98, pp. 98-103.

Malone C., Ayala G., Fitzjohn M., Stoddart S. 2001-2003, *Under the Volcano*, Accordia Research Papers 9, pp. 7-21.

Maniscalco R., De Guidi G., Pedley M., Sturiale G., Grasso M. 2010, *Geological map of the Corvillo and Mandre Basins (Caltanissetta Basin, Central Sicily): Explanatory notes*, Italian Journal of Geosciences 129, 2, pp. 316-326. doi: 10.3301/IJG.2010.04

Marguerie D., Hunot J.-Y. 2007, *Charcoal analysis and dendrology: data from archaeological sites in north-western France*, Journal of Archaeological Science 34, pp. 1417-1433. <https://doi.org/10.1016/j.jas.2006.10.032>

Marignani M., Chiarucci A., Sadori L., Mercuri A.M. 2016, *Natural and human impact in Mediterranean landscapes: An intriguing puzzle or only a question of time?*, Plant Biosystems - An International Journal Dealing with all Aspects of Plant Biology 151, 5, pp. 900-905. doi: 10.1080/11263504.2016.1244121

Martinelli M.C., Fiorentino G., Prodocimi B., Wolff N. 2010, *Nuove ricerche nell'insediamento sull'istmo di Filo Braccio a Filicudi. Nota Preliminare sugli Scavi 2009*, Origini 32, 4, pp. 285-314.

Masi A., Sadori L., Balossi Restelli F., Baneschi I., Zanchetta G. 2014, *Stable carbon isotope analysis as a crop management indicator at Arslantepe (Malatya, Turkey) during the Late Chalcolithic and Early Bronze Age*, Vegetation History and Archaeobotany, 23, 6, pp. 751-760.



- McConnell B.E. (ed.) 1995, *La Muculufa II. Excavation and Survey 1988-1991. The Castelluccian Village and Other Areas*, Louvain-La-Neuve, Archaeologica Transatlantica XII, A series in Mediterranean Archaeology.
- McConnell B.E. 1997, *Lo sviluppo delle prime società agro-pastorali: l'eneolitico*, in Tusa S. (ed.), *Prima Sicilia. Alle Origini della Società Siciliana*, Siracusa, Ediprint, pp. 281-297.
- Mercuri et al. 2012, *A marine/terrestrial integration for mid-late Holocene vegetation history and the development of the cultural landscape in the Po Valley as a result of human impact and climate change*, *Vegetation History and Archaeobotany* 21, 4-5, pp. 353-372
- Mercuri A.M., Sadori L. 2012, *Climate changes and human settlements since the Bronze age period in central Italy*, *Rendiconti Online della Società Geologica Italiana*, 18, pp. 32-34. DOI: 10.3301/ROL.2011.63.
- Mercuri A.M., Sadori L. 2013, *Mediterranean culture and climatic change: past patterns and future trends*, in Goffredo S., Dubinsky Z. (eds), *The Mediterranean sea: Its History and present challenges*, Dordrecht, Springer, pp. 507-527. [10.1007/978-94-007-6704-1\\_30](https://doi.org/10.1007/978-94-007-6704-1_30)
- Mercuri A.M., Sadori L., Blasi C. 2010, *Archaeobotany for cultural landscape and human impact reconstructions*, *Plant Biosystem: An International Journal Dealing with all Aspects of Plant Biology: Official Journal of the Società Botanica Italiana*, 144, 4, pp. 860-864 [10.1080/11263504.2010.514137](https://doi.org/10.1080/11263504.2010.514137)
- Mercuri et al. 2019, *From influence to impact: the multifunctional land-use in Mediterranean prehistory emerging from palynology of archaeological sites (8.0-2.8 ka BP)*, *The Holocene* 29, 5, pp. 830-846.
- Messner T.C., Stinchcomb G.E. 2014, *Peopling the environment: interdisciplinary inquiries into socioecological systems incorporating paleoclimatology and geoarchaeology*, in Marston J.M., D'Alpoim Guedes J., Warriner C. (eds), *Method and Theory in Paleoethnobotany*, University Press of Colorado, pp. 257-274. [10.5876/9781607323167.c013](https://doi.org/10.5876/9781607323167.c013)
- Nardi-Berti R. 2006, *La struttura anatomica del legno ed il riconoscimento dei legnami italiani di più corrente impiego*, Firenze, IRL-CNR, II edizione.
- Nitsch E.K., Charles M., Bogaard A. 2015, *Calculating a statistically robust  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  offset for charred cereal and pulse seeds*, *STAR: Science & Technology of Archaeological Research*, 1, 1, pp.1-8. <https://doi.org/10.1179/2054892315Y.0000000001>
- Noti R., Van Leeuwen J.F.N., Colombaroli D., Vescovi E., Pasta S., La Mantia T., Tinner W. 2009, *Mid- and late-Holocene vegetation and fire history at Biviere di Gela, a coastal lake in southern Sicily, Italy*, *Vegetation History and Archaeobotany*, 8, 5, pp. 371-387. doi: 10.1007/s00334-009-0211-0
- Pacciarelli M., Scarano T., Crispino A. 2015, *The transition between the Copper and Bronze Ages in southern Italy and Sicily*, in Meller H., Arz H.W., Jung R., Risch R. (eds), *2200 BC - A climatic breakdown as a cause for the collapse of the old world*, *Proceedings of the 7th Archaeological Conference of Central Germany*, Halle, 23-26 October 2014, Halle, Tagungen des Landesmuseums für Vorgeschichte, pp. 253-282.
- Pearsall D. M. 2019, *Case Studies in Paleoethnobotany: Understanding Ancient Lifeways through the Study of Phytoliths, Starch, Macroremains, and Pollen*. Abingdon, Taylor and Francis.
- Peyron O., Magny M., Goring S., Joannin S., de Beaulieu J.-L., Brugiapaglia E., Sadori L., Garfi G., Kouli K., Ioakim C., Combourieu-Nebout N. 2013, *Contrasting patterns of climatic changes during the Holocene across the Italian Peninsula reconstructed from pollen data*, *Climate of the Past*, 9, pp. 1233-1252. doi:10.5194/cp-9-1233-2013
- Picornell G.L., Asouti E., Martí E.A. 2011, *The ethnoarchaeology of firewood management in the Fang villages of Equatorial Guinea, central Africa: implications for the interpretation of wood fuel remains from archaeological sites*, *Journal of Anthropological Archaeology* 30, pp. 375-384. <https://doi.org/10.1016/j.jaa.2011.05.002>
- Pignatti S. 1982, *Flora d'Italia*, 1-3, Bologna, EdAgricole.
- Primavera M., D'Oronzo C., Muntoni I.M., Radina F., Fiorentino G. 2017, *Environment, crops and harvesting strategies during the II millennium BC: resilience and adaptation in socio-economic systems of Bronze Age communities in Apulia (SE Italy)*, *Quaternary International*, 436, B, pp. 83-95. <https://doi.org/10.1016/j.quaint.2015.05.070>
- Privitera F. 1994, *La stazione di Mezzebi nel contesto del Bronzo Antico del territorio di Milena*, in Tusa S. (ed.), *La Preistoria del Basso Belice e della Sicilia Meridionale nel Quadro della Preistoria Siciliana e Mediterranea*, Palermo, Società Siciliana per la Storia Patria, pp. 339-348.
- Privitera M. 2000, *Il Corpo delle Miniere e l'area dello zolfo in Sicilia. Secoli XIX-XX*, Caltanissetta, Ed. Lussografica.
- Rattighieri E., Florenzano A., Mercuri A.M., Levi S.T. 2012, *Palinologia applicata al sito di San Vincenzo-Stromboli (Bronzo Medio) per una ricostruzione archeoambientale*, in Vezzalini G., Zannini P. (eds.), *Atti del Congresso A.I.Ar. 2012 Modena, VII congresso nazionale di Archeometria*, 22-24 febbraio 2012, no pages.
- Raymond C. M., Singh G. G., Benessaiah K., Bernhardt J. R., Levine J., Nelson H., Turner N. J., Norton B., Tam J., Chan K. M. A. 2013, *Ecosystem Services and Beyond: Using Multiple Metaphors to Understand Human-Environment Relationships*, *BioScience*, 63, 7, pp. 536-546, <https://doi.org/10.1525/bio.2013.63.7.7>
- Redman C. 2005, *Resilience theory in archaeology*, *American Anthropologist* 107, 1, pp. 70-77. <https://doi.org/10.1525/aa.2005.107.1.070>
- Rothacker L., Dosseto A., Francke A., Chivas A.R., Vigier N., Kotarba-Morley A.M., Menozzi D. 2018, *Impact of climate change and human activity on soil landscapes over the past 12,300 years*, *Scientific Reports* 8, art. 247. doi: 10.1038/s41598-017-18603-4
- Sadori L., Narcisi B. 2001, *The Postglacial record of environmental history from Lago di Pergusa, Sicily*, *The Holocene* 11, 6, pp. 655-671. <https://doi.org/10.1191/09596830195681>
- Sadori L., Giardini M. 2007, *Charcoal analysis, a method to study vegetation and climate of the Holocene: the case of Lago di Pergusa (Sicily, Italy)*, *Geobios* 40, pp. 173-180. doi:10.1016/j.geobios.2006.04.002



- Sadori L., Zanchetta G., Giardini M. 2008, *Last Glacial to Holocene palaeoenvironmental evolution at Lago di Pergusa (Sicily, Southern Italy) as inferred by pollen, microcharcoal, and stable isotopes*, Quaternary International 181, pp. 4-14. [10.1016/j.quaint.2007.02.024](https://doi.org/10.1016/j.quaint.2007.02.024)
- Sadori L., Masi A., Ricotta C., 2015. *Climate driven past fires in central Sicily*, Plant Biosystems 149: pp. 166-173. doi:10.1080/11263504.2014.992996
- Sadori L., Ortu E., Peyron O., Zanchetta G., Vanni  re B., Desmet M., Magny M. 2013, *The last 7 millennia of vegetation and climate changes at Lago di Pergusa (central Sicily, Italy)*, Climate of the Past 9, pp. 1969–1984, <https://doi.org/10.5194/cp-9-1969-2013>.
- Schicchi R., Cullotta S., Berti S., Macchioni N. 2000, *Studies on the Quercus hybrids in Sicily: leaf micromorphology and xylem structure in Q. xfontanesii Guss.*, Flora Mediterranea 10, pp. 65-80.
- Schweingruber F.H. 1990, *Anatomy of European wood: an atlas for the identification of European trees, shrubs and dwarf shrubs*, Bern, Paul Haupt.
- Schweingruber F.H. 2007, *Wood structure and environment*, Springer-Verlag, Berlin Heidelberg <https://doi.org/10.1007/978-3-540-48548-3>
- Speciale C., D'Oronzo C., Stellati A., Fiorentino G. 2016, *Archaeobotanical data from the prehistoric village of Filo Braccio (Filicudi, Aeolian Archipelago): spatial analysis, crop production and paleoclimate reconstruction*, in UbiMinor... Le isole minori del Mediterraneo centrale dal Neolitico ai primi contatti coloniali, Scienze dell'Antichit   22, 2, pp. 281-296.
- Speciale C., 2017, *Human-environment dynamics during the Bronze Age: a paleodemographic model on the Aeolian Islands*, Unpublished PhD thesis, Lecce, Universit   del Salento.
- Spengler, R. N. III 2018, *Paleoethnobotany*, in L  pez Varela S.L. (ed.), The Encyclopedia of Archaeological Sciences, New York, John Wiley & Sons.
- Stevens et al. 2019. Archaeological assessment reveals Earth's early transformation through land use. Science 365(6456): 897-902'
- Stika H.-P., Heiss A. G. 2013, *Plant Cultivation in the Bronze Age*. Chapter 19 in Fokkens H., Harding A.(eds.), The Oxford Handbook of the European Bronze Age, Oxford University Press, Oxford, pp. 348-369.
- Sullivan A., Bird D., Perry G. 2017, *Human behaviour as a long-term ecological driver of non-human evolution*, Nature, Ecology & Evolution 1, 0065. doi:10.1038/s41559-016-0065
- Termine R., Pasta S., La Mantia T. 2014, *Some remarks on the vascular flora and vegetation of the archaeological site of "Vallone Canalotto" (Calascibetta municipality, Enna province, Central Sicily)*, Abstract dell'International Plant Science Conference, 109   Congresso Societ   Botanica Italiana, Florence 2-5 settembre 2014, p. 62.
- Terral J.-F., Alonso N., Bux   i Capdevila R., Chatti N., Fabre L., Fiorentino G., Marival P., P  rez Jord   G., Pradat B., Rovira N., Alibert P. 2004, *Historical biogeography of olive domestication (Olea europaea L.) as revealed by geometrical morphometry applied to biological and archaeological material*, Journal of Biogeography, 31, 1, pp. 63-77. <https://doi.org/10.1046/j.0305-0270.2003.01019.x>
- Tinner W., Vescovi E., van Leeuwen J. F. N., Colombaroli D., Henne P.D., Kaltenrieder P., Morales-Molino C., Beffa G., Gnaegi B., van der Knaap W. O., La Mantia T., Pasta S. 2016, *Holocene vegetation and fire history of the mountains of Northern Sicily (Italy)*, Vegetation History and Archaeobotany, 25, 5, pp. 499–519. doi.org/10.1007/s00334-016-0569-8
- Vaiglova P., Snoeck C., Nitsch E., Bogaard A.M., Lee-Thorp J. 2014, *Impact of contamination and pre-treatment on stable carbon and nitrogen isotopic composition of charred plant remains*, Rapid Communications in Mass Spectrometry 28, pp. 2497-2510. DOI: 10.1002/rcm.7044
- Valamoti S.M. 2009, *Plant food ingredients and 'recipes' from prehistoric Greece: the archaeobotanical evidence*. in Morel J.P., Mercuri A.M. (eds.), Plants and Culture: Seeds of the Cultural Heritage of Europe. Centro Europeo per i Beni Culturali Ravello, Edipuglia, Bari, pp. 25-38.
- Viola F., Liuzzo L., Noto L. V., Lo Conti F., La Loggia G. 2013, *Spatial distribution of temperature trends in Sicily*, International Journal of Climatology 34, pp. 1–17 DOI: 10.1002/joc.3657
- Walker M.J.C., Berkelhammer M., Bj  rck S., Cwynar L.C., Fisher D.A., Long A.J., Lowe J.J., Newnham R.M., Rasmussen S.O., Weiss H. 2012, *Formal subdivision of the Holocene Series/Epoch: a Discussion Paper by a Working Group of INTIMATE (Integration of ice-core, marine and terrestrial records) and the Subcommission on Quaternary Stratigraphy (International Commission on Stratigraphy)*, Journal of Quaternary Science 27, 7, pp. 649–659. doi: 10.1002/jqs.2565
- Weiss H. 2016, *Global megadrought, societal collapse and resilience at 4.2-3.9 ka BP across the Mediterranean and west Asia*, Pages Magazine 24, 2, pp. 62-63. <https://doi.org/10.22498/pages.24.2.62>
- Wilkinson T. J., Philip G., Bradbury J., Dunford R., Donoghue D., Galiatsatos N., Lawrence D., Ricci A., Smith S. L. 2014, *Contextualizing early urbanization: Settlement cores, early states and agro-pastoral strategies in the Fertile Crescent during the fourth and third millennia BC*, Journal of World Prehistory, 27, 1, pp. 43-109. [10.1007/s10963-014-9072-2](https://doi.org/10.1007/s10963-014-9072-2)
- Zanchetta G., Borghini A., Fallick A.E., Bonadonna F.P., Leone G. 2007, *Late Quaternary paleohydrology of Lake Pergusa (Sicily, southern Italy) as inferred by stable isotopes of lacustrine carbonates*, Journal of Paleolimnology 38, pp. 227-239. [10.1007/s10933-006-9070-1](https://doi.org/10.1007/s10933-006-9070-1)

Figure 1

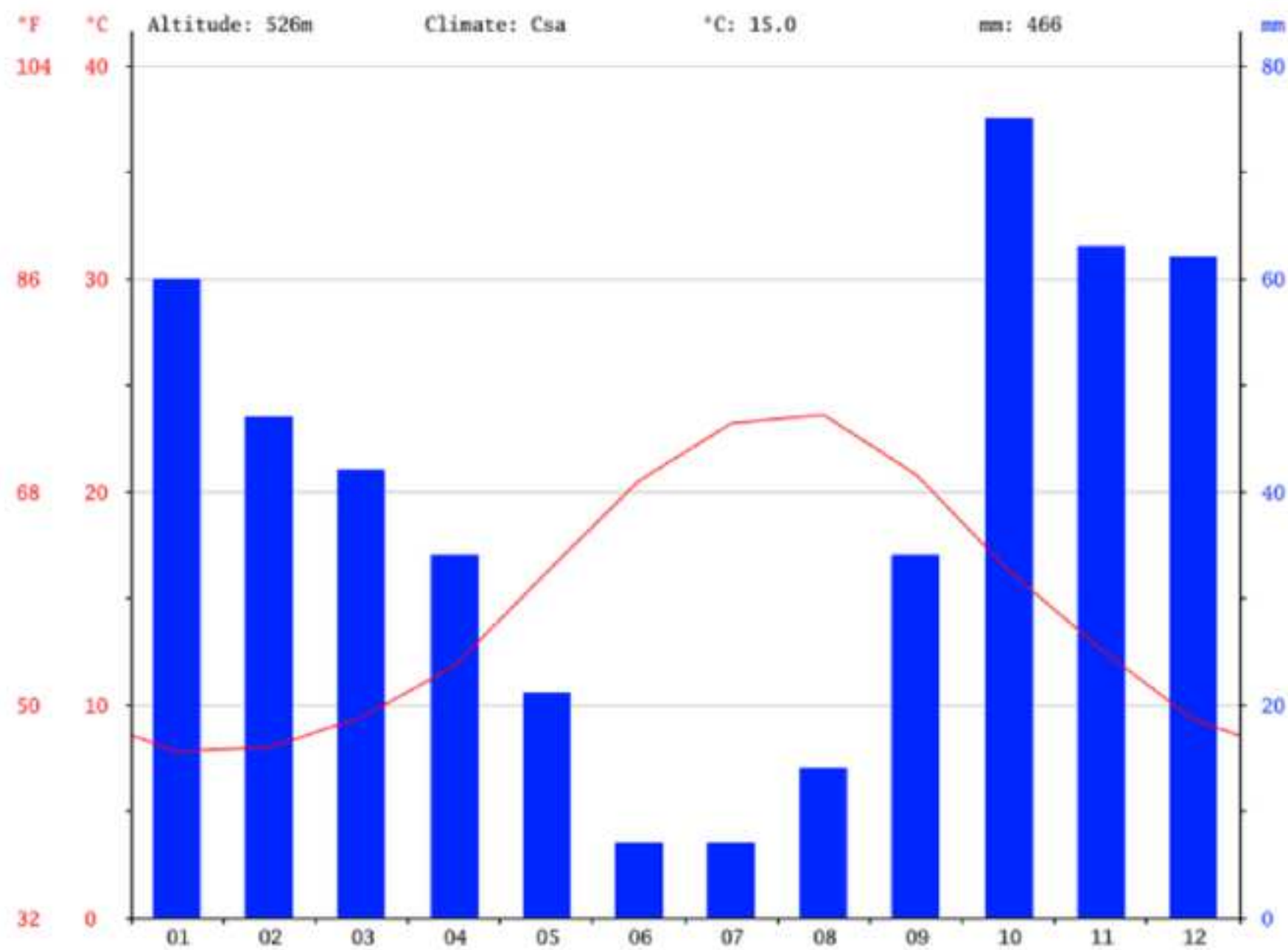
[Click here to access/download;Figure;Fig 1.tif](#)





Figure 2

[Click here to access/download;Figure;Fig. 2.tif](#)



<https://it.climate-data.org/europa/italia/sicily/villarosa-114335/>

Figure 3

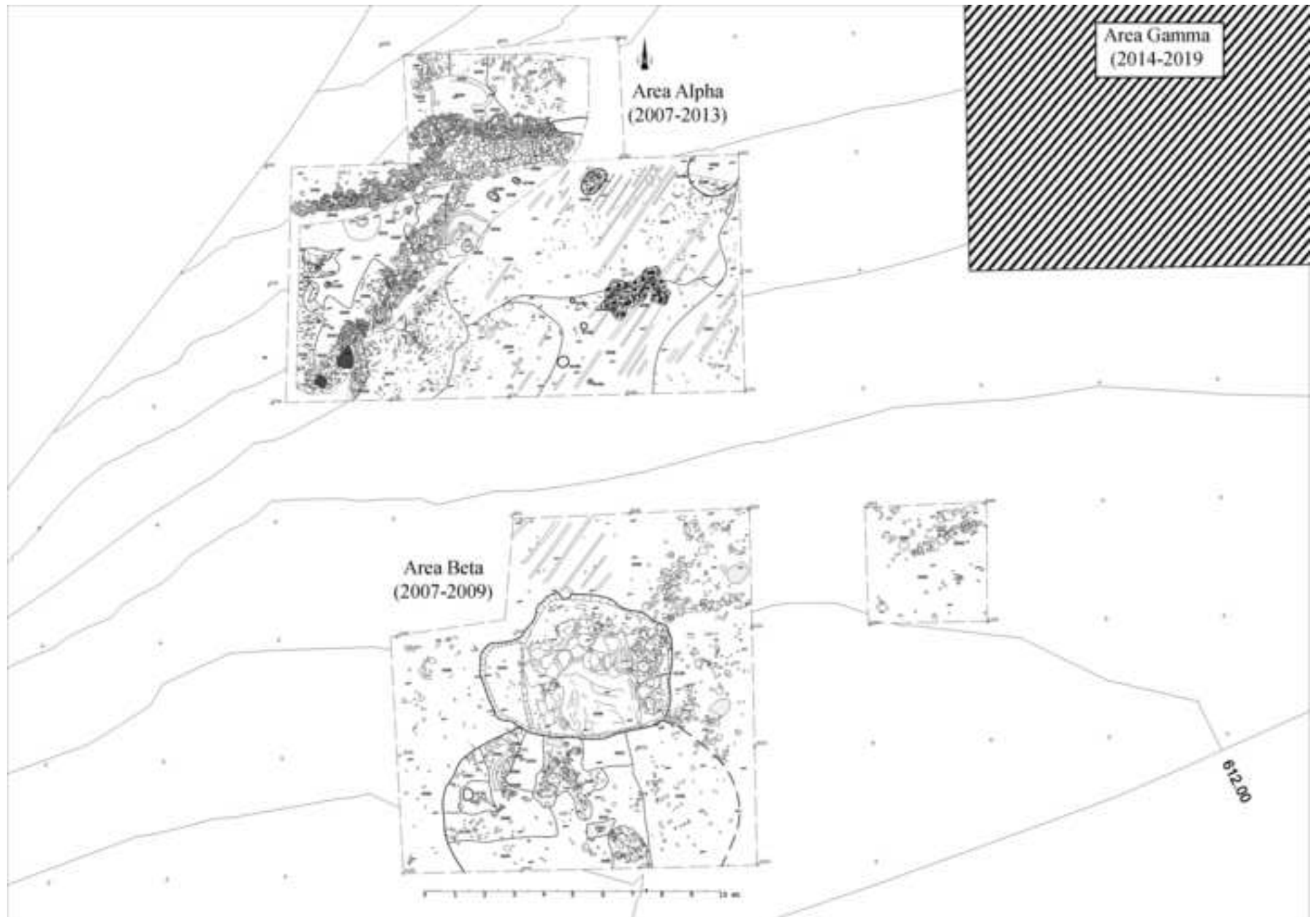


Figure 4

[Click here to access/download;Figure;Fig 4-02.tif](#)

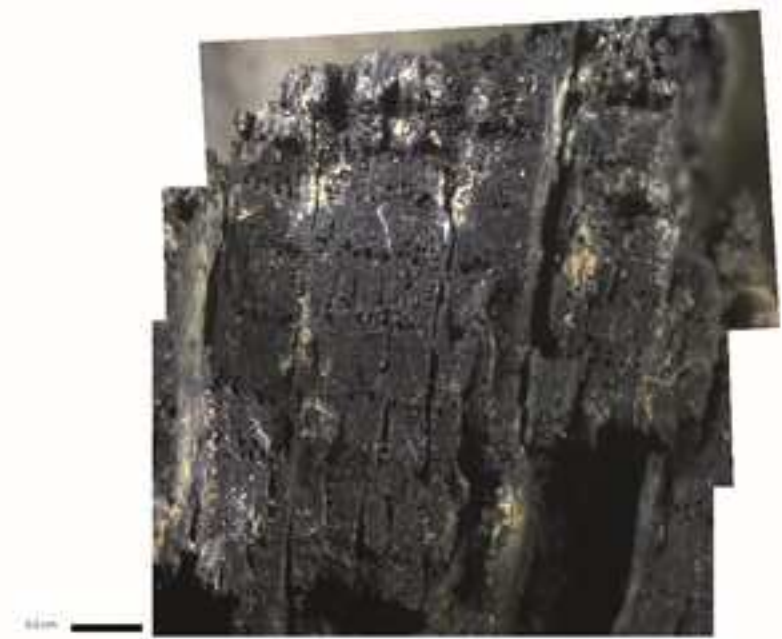
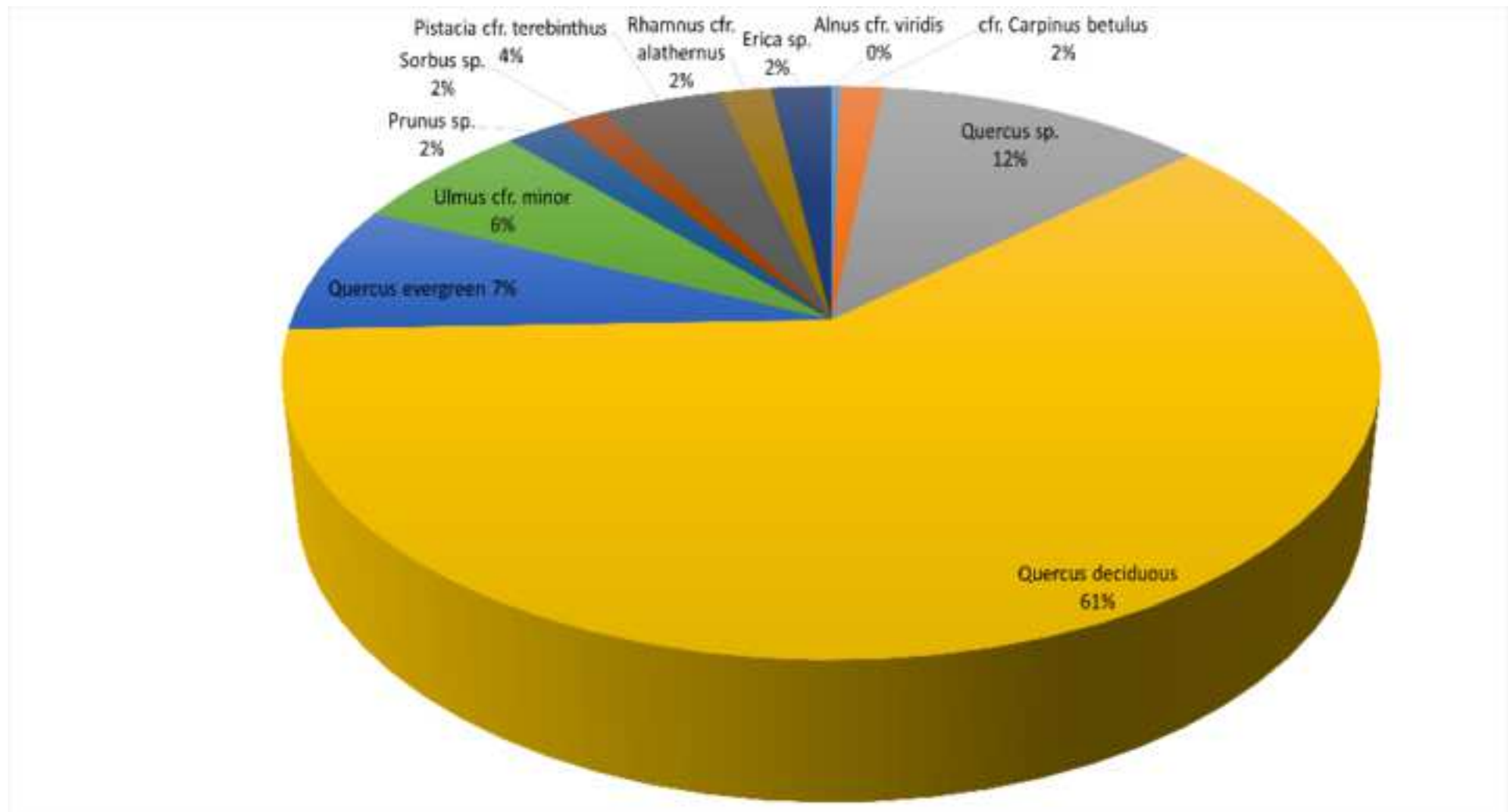


Figure 5





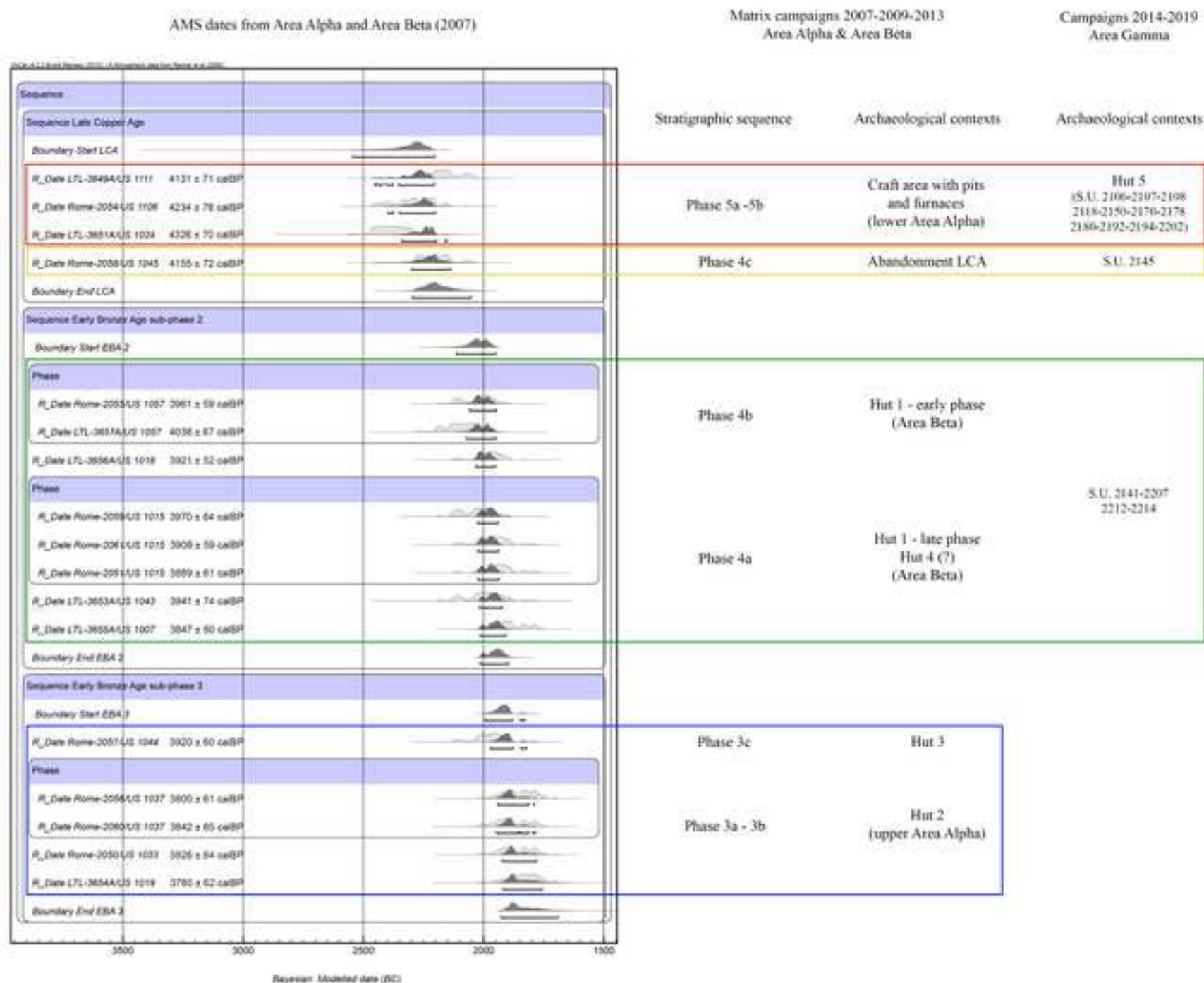


Figure 7

[Click here to access/download;Figure;Fig. 7.jpg](#) 

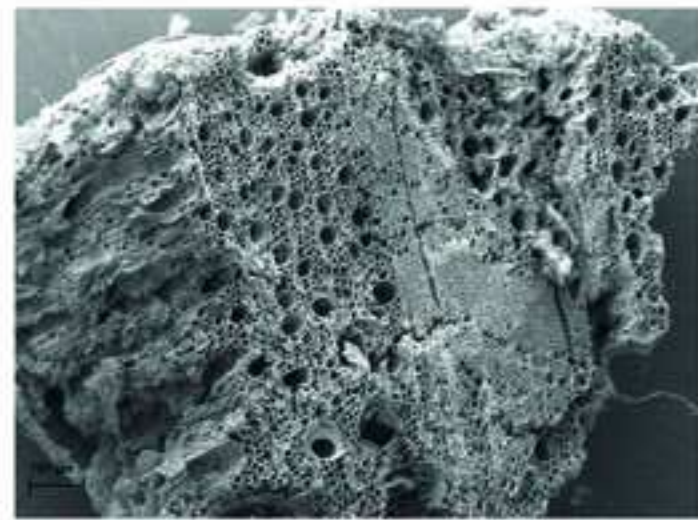
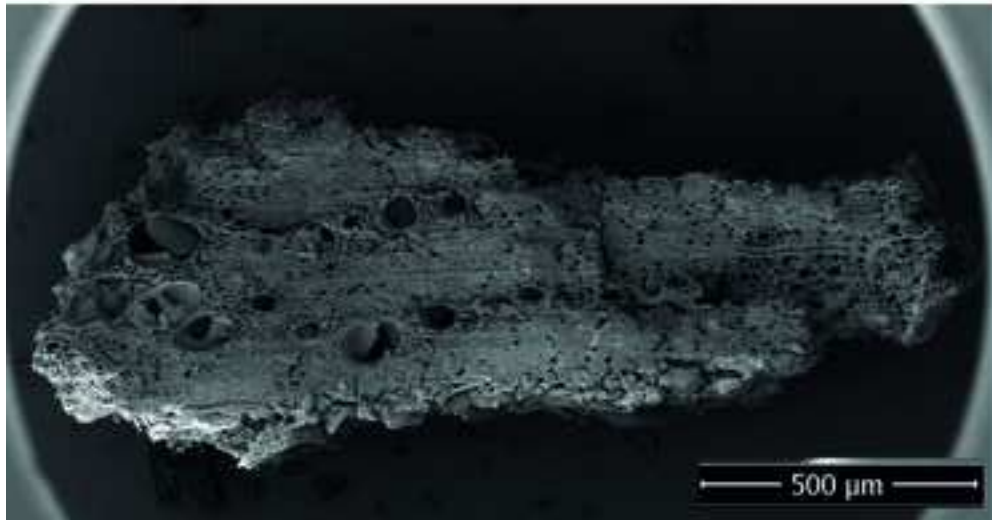
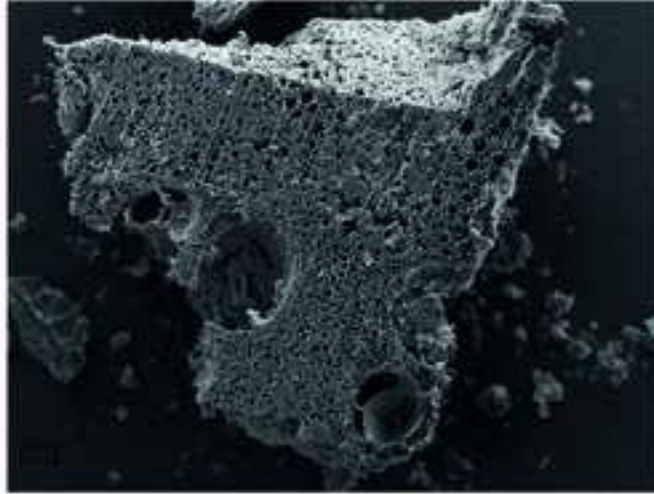
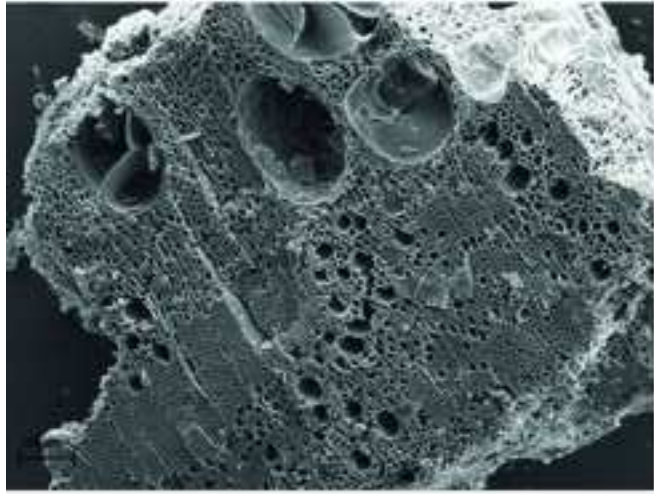


Figure 8

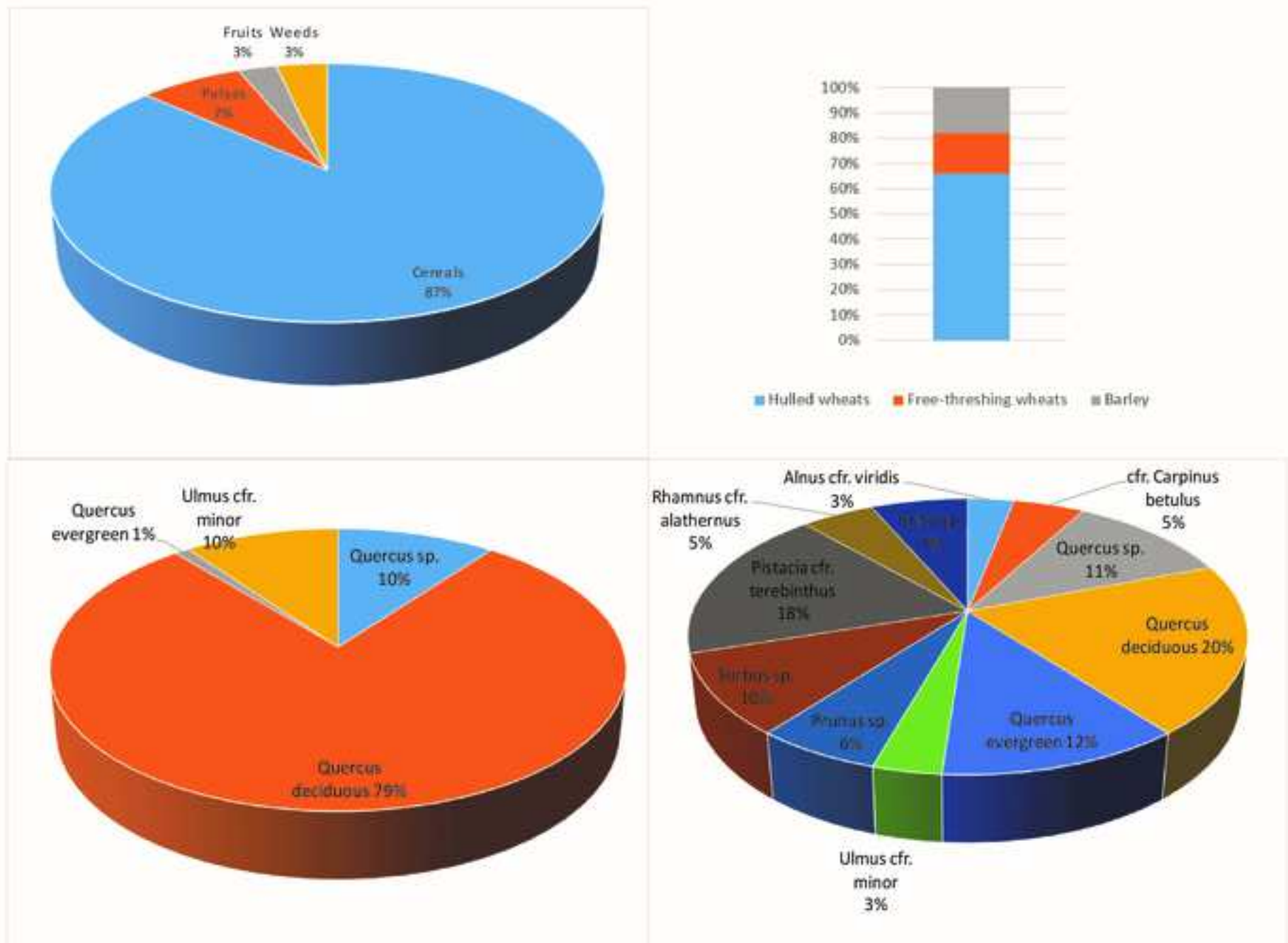
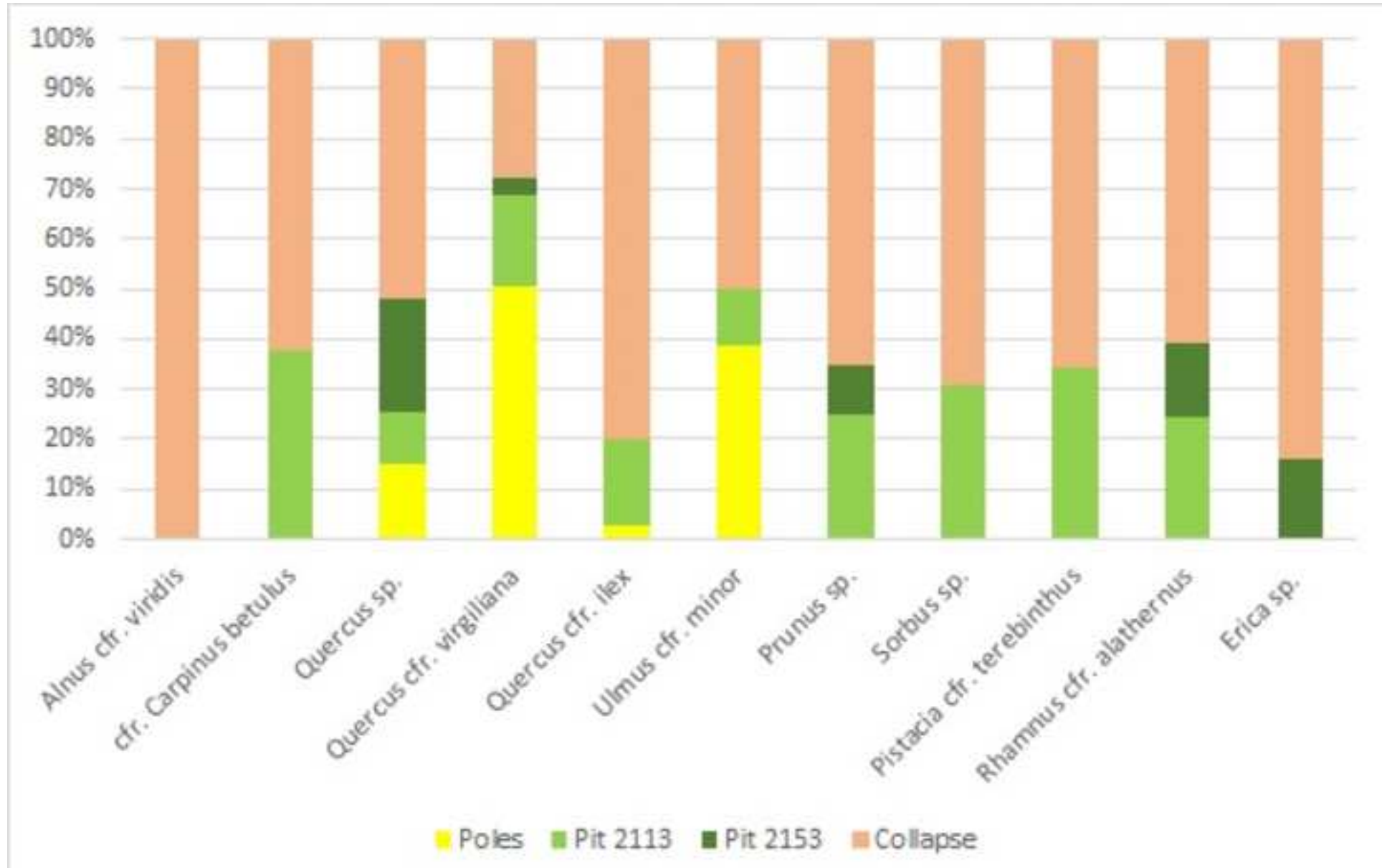
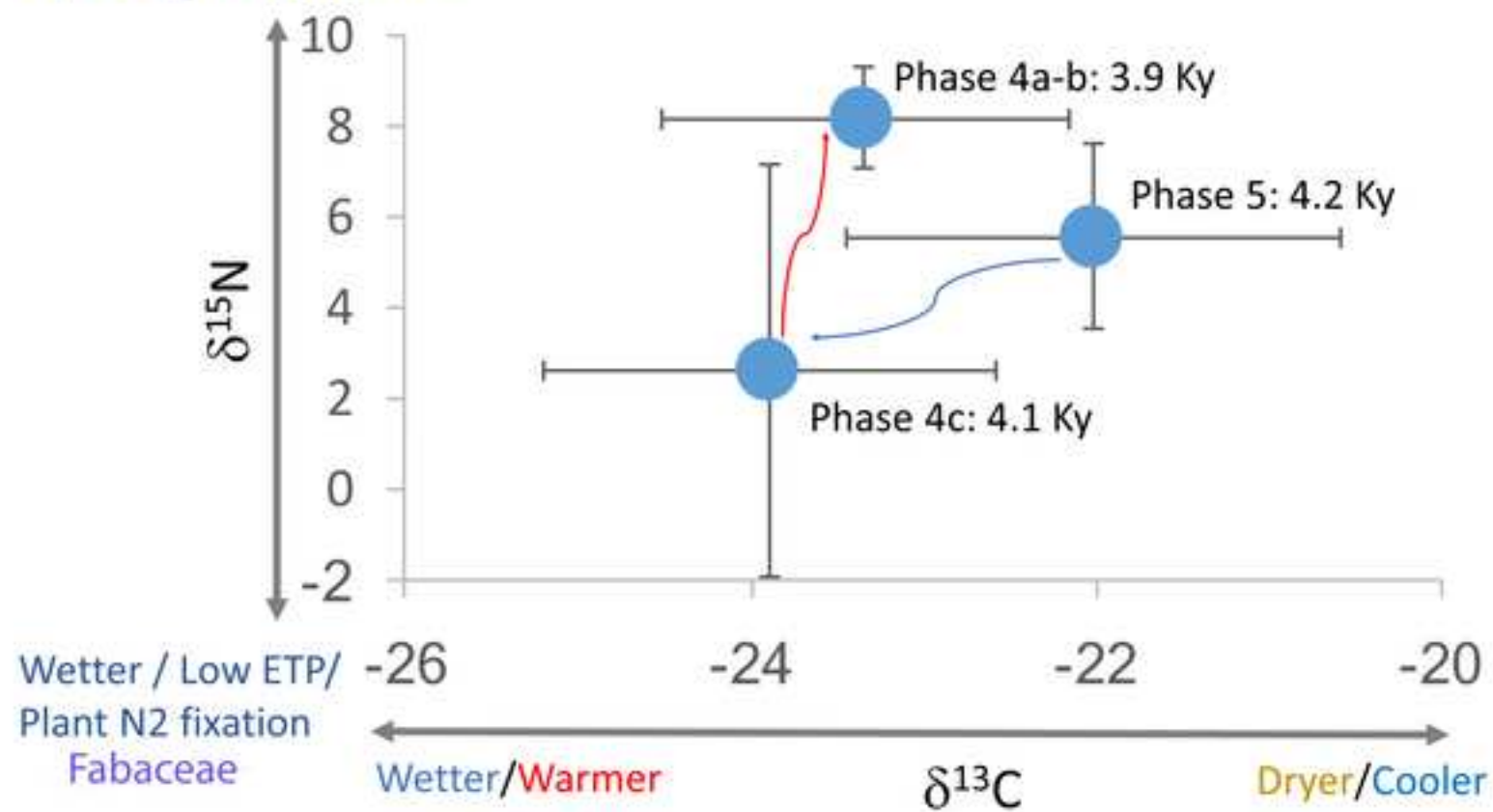


Figure 9





Dryer/High ETP/Manure



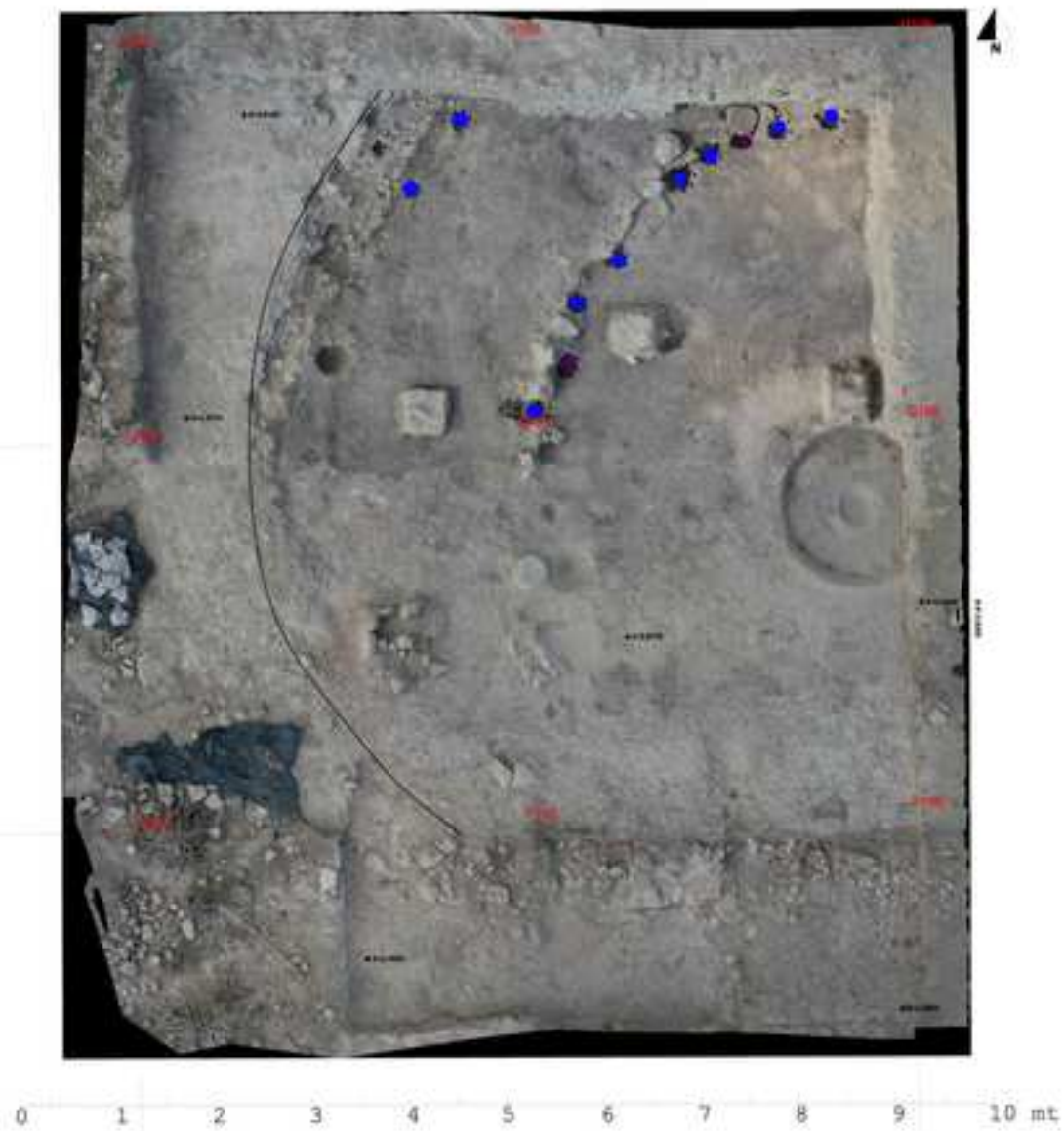
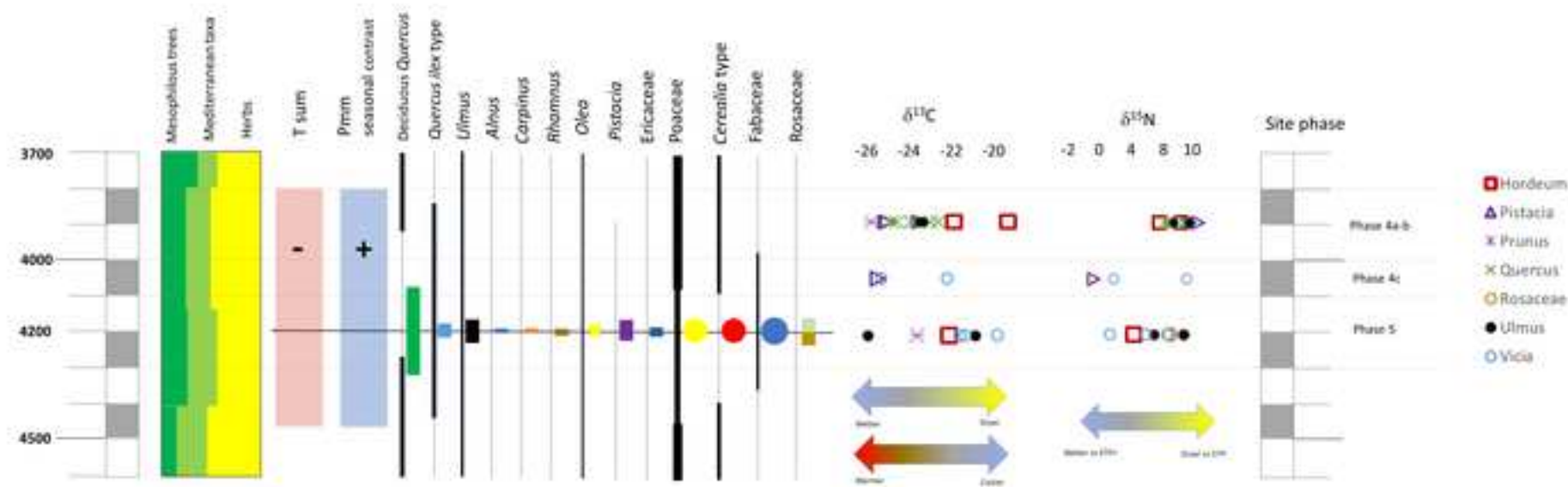




Figure 12









Click here to access/download  
**Table**  
**Tab 3.xlsx**



[Click here to access/download](#)

**Table**

**Tab 4.xlsx**



**Author Contributions:**

Conceptualization: C.S., E.G.; Methodology: C.S., E.G., I. B., N.C.N.; Formal analysis: C.S., G.D.S., I.B., F.F., N.C.N.; Archaeological Investigation: F.I., E.G.; Archaeobotanical investigation: C.S., G.D.S.; Isotopic analyses: I.B., F.F.; Pollen data interpretation: N.C.N.; Writing, Review & Editing: C.S., E.G., I.B., N.C.N.; Data Curation: C.S., G.D.S., I.B.; Project administration: E.G., F.I.; Funding acquisition: E.G., F.I., C.S., I.B. All authors have read and agreed to the published version of the manuscript ([CRediT taxonomy](#)).

**Acknowledgments:** C.S. and I.B. thank Eleni Filaiti for the laboratory preparation of the charred seeds. E. Filaiti was funded by the BIODIVMEX program CNRS Mistral (Working Group 4: Past, Present and Future Landscapes).

F.I. and E.G. thank the Superintendence for Cultural Heritage of Enna and the municipality of Villarosa for their constant scientific, technical and logistic support.

The authors thank the reviewers and the editor for their careful help and patience to improve the contents.

**Conflicts of Interest:** The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.