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Environmental settings of agricultural practices in Central Italy during the first half of the first millennium BCE

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Abstract

One of the main transformations in the western Mediterranean is the birth and surge of urban life during the first half of the 1st millennium BCE. This urbanization process is usually linked with an intensification of food production and changes in agricultural practices. However, it is not well known how the relationships between their different parameters were reshaped during this period.

This phenomenon was observed in Central Tyrrhenian Italy from the Bronze Age to the Archaic period (12th to 6th c. BCE). Over the span of a few centuries the sparse clusters of huts observed during the Bronze Age evolved into city-state urban centers such as Rome or Tarquinia. Some of the aspects of these changes are still under debate including what kind of agricultural practices sustained the development of these early urban centers. Importantly, there is much that we do not know about possible environmental factors that could have triggered or influenced these processes in multiple and complex ways. Climatic instability has been reconstructed for this period but its role in the social cultural development of the region has not yet been assessed. The present research question lies in the interplay between environment, climate, agriculture and urbanization processes that occurred in Central Tyrrhenian Italy during the first half of the 1st millennium BCE.

Three archaeological sites that underwent this process of urbanization (Palatine Hill located in Rome, Gabii and Tarquinia) were selected for this study. They all provided charred archaeobotanical material (seeds, fruits and wood) dated from the 10th to the 5th c. BCE. Two complementary methods were used to answer the research question: The first was the study of the archaeobotanical material which informs on crop production; The second was the use of carbon and nitrogen stable isotope analysis. This innovative method helps to gather information about the field environment and management. Specifically, it allows us to study the water availability in which plants grew with the measure of the $\Delta^{13}C$ as well as to identify possible application of manure through the $\delta^{15}N$ results.

The archaeobotanical study resulted in a total of about 30400 seeds, fruits and fragments from the three archaeological sites. The analysis showed a dominance of cereals, with barley and emmer being the main staples. Pulses were the second most important category represented mainly by fava beans and bitter vetch. Some differences in the proportions of crops were identified among sites suggesting cultural or economic preferences since the three sites lie in the same environmental region. Weeds of arable fields, which are good environmental indicators, were also identified in large quantities but due to their ubiquity, they were not discriminant.

Carbon and nitrogen stable isotope analyses ($\delta^{13}C$ and $\delta^{15}N$) were performed on 557 charred barley and emmer caryopses from the three archaeological sites. The results show some variation in water availability across time for both species. The $\delta^{15}N$ values are, overall, low and no difference across time or periods was identified. This suggests that no manuring practices were commonly used during this period.

A pilot study on 270 fragments of wood charcoal from Gabii to reconstruct the environment of the spontaneous flora in the region. Taxonomic identification shows a prevalence of deciduous oak forests and the surprising presence of beech which, according to the regional paleoenvironment studies, should not be present anymore in low altitudes. Ten charcoal fragments of deciduous oak were selected for isotope analysis. They were radiocarbon dated (^{14}C) and δ^{13}C was calculated to explore past natural environmental water availability. The comparison with the trends identified in the crops is used to discriminate environmental from anthropic factors. The^{14}C results obtained show a large range in terms of dating which was expected as the period of interest falls into the Hallstatt plateau, a flat area between the 9th and the 5th c. BCE on the reference curve used for calibration (Trias et al. 2020). This makes it challenging to put the charcoal fragments in sequence and consequently compare their trend with the cereal ones. Different methods to overcome this are currently being explored and the addition of more charcoal fragments should help.

It is the first time that this kind of work is undertaken in this region and for this period. It represents an innovative work which contributes greatly to the understanding of the complex mechanisms and evolution occurring during this period.

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Introduction

The relationship existing between past environments and climate conditions connected to the development of past cultures is one of the key subjects in cultural heritage studies. The influence of past populations on the ecosystem became more important during the Neolithic, when populations started to settle and understand better how to exploit their surrounding environment. The construction of settlements, forest management, agriculture and livestock farming had diverse repercussions on the ecosystem (Reitz and Shackley 2012). Agriculture is one of the practices that caused deforestation and soil erosion. Some later practices (Bronze Age) such as irrigation and manuring produced an even stronger impact. Traces of intense human impact can be uncovered through different analytical methods applied to archaeology. In the complex relationship between humans and their environment climate played and still plays an important role, determining some humans' behaviour and choices. The role of climate and environment in the rapid evolution of societies has also been stressed, evidencing the importance of sudden and short climatic changes which can take place in only a few decades (Berglund 2003; DeMenocal 2001; Finné et al. 2019; Goudeau et al. 2015; Mensing et al. 2015). A period of drought (Bini et al. 2019) according to some authors caused a societal collapse in the Mediterranean and Near East (Weiss, 2016; Weiss et al. 1993). It was followed by a period of depopulation and migration waves, the collapse of the Mycenaean culture, limited long-distance trades and smaller rural settlements, which is known as the Dark Age (Drake 2012; Kaniewski et al. 2010). This episode seems to be linked to a megadrought which could have impacted agriculture, which relied mostly on rain, food production, and lead to famines (Drake 2012). This example highlights the importance of climate in the evolution of past populations. The relationship between past populations and environment is close and depends on many factors which makes it complex to understand.

Some important changes are recorded in the Tyrrhenian region of Central Italy from the Late Bronze Age (10th c. BCE) to the Archaic period (6th c. BCE). Inhabitants underwent social, political and economic transformations as well as a population growth, which are all part of an urbanization process which led to the rise of powerful city-states like Rome (Fulminante and Stoddart 2013; Fulminante 2014). In this context, the need for feeding this growing and changing population gradually became more important, leading to the creation of roles dedicated to this activity. This process of urbanization must have had implications, for example the way inhabitants exploited the lands and fields, and some scholars think that it led to an intensification of agricultural production in order to increase food supply (Fulminante 2014). However, little is known about the processes used in crop production, as well as its possible changes during this period. The archaeobotanical studies which can inform us on agriculture are rather sparse in the region for this period, and the only existing evidence is mostly indirect (tools or texts written in later periods).

Additionally, it is necessary to understand the possible factors that could have triggered these kinds of changes. The importance of the Greek and Phoenician colonisation in the 6th c. BCE, which could have initiated the formation of city centres in this area, is stressed by some authors (Scheidel 2013) and confuted by others that highlight that the process of urbanization and the emergence of big city-centres started before the establishment of the first Greek colonies in South Italy (Fulminante and Stoddart 2013). This trend toward urbanization would rather come mostly from local impulses, encouraged by the elite aristocracy (Terrenato 2019). Another factor could also be the trade network developing through the Mediterranean area (Fulminante and Stoddart 2013). The role of climate and environmental changes is rarely mentioned as a possible trigger for these transformations. Holocene climate was, yet, punctuated by worldwide long-term millennial changes but also by short-term centennial to decennial events (Mayewski et al. 2004; Wanner et al. 2008). Some of them have been recorded in the Mediterranean region (Finné et al. 2019; Giraudi et al. 2011; Goudeau et al. 2015) and in Central Italy by different types of proxies such as pollen (Peyron et al. 2011; 2013; Sadori et al. 2011), lake sediments (Magny et al. 2007; 2012; 2013), or sea sediments (Combourieu-Nebout 2013; Desprat et al. 2013). These long or short-term events impacted not only the annual precipitations themselves but also their seasonality in the Mediterranean region (Peyron et al. 2017). This could have greatly impacted the rain fed agriculture of these past societies.

While a considerable amount of data on both climatic change and urbanization for the Mediterranean region and Central Tyrrhenian Italy exists, this information has never been set to the same scale, making a direct comparison challenging (Berglund 2003; Finné et al. 2019). Moreover, the climate drivers are numerous and complex and they can lead to different and non-synchronous responses at a regional or even local scale (Finné et al. 2019; Manning 2013; Pèlachs et al. 2011). Regarding the different natural proxies, each one gives information on a different aspect of climate, some will be more sensitive to seasonal changes or will inform on local trends while others will provide more global results (Finné & al. 2019; Magny et al. 2013). In addition, for some proxies such as pollen, in periods of strong human pressure, as is the case for our period and region of study (Mercuri and Sadori 2012), it becomes even more challenging to discriminate between climate variations and human influence. When it comes to comparing archaeological data with climatic trends the task is very complex. One of the major difficulties is that the time-scale covered by the climatic studies is usually longer and has a lower resolution than the archaeological studies (Berglund 2003; Mensing et al. 2015). It is therefore challenging to synchronize an archaeological event taking place over a few decades or centuries with a climatic one. The response of societies themselves can vary according to the political, economic, and specific characteristics of the society which add to another level of complexification (Manning 2013). As stressed by Berglund (2003) there is a necessity to find new proxies which could clarify the link between archaeological and climatic data.

This project aims to understand the complex relationships between increasing urbanization processes, the environment, and climate, as well as their effects on the agricultural practices during the transition between the 10th and 6th c. BCE in Central Tyrrhenian Italy.

The objectives of this study are:

- Acquiring information about the staple crops produced and consumed in the region, as well as their possible changes through time.

- Reconstructing agricultural practices and their possible changes through time.

- Obtaining new records of climate changes in the region.

- Looking at the changes through time and trying to explain if these changes are connected to cultural and economic behaviours or natural events or a combination of the two.

In order to answer these different questions, three archaeological sites (Gabii, Palatine Hill-Rome and Tarquinia), situated in the same region (Central Tyrrhenian Italy) and covering all together a period of time ranging from the 10th to the 6th c. BCE, were selected. They all provided new archaeobotanical material (seeds, fruits and wood) which, through their study, represents an opportunity to identify the plants produced, used and consumed by these past populations. These analyses resulted in about 30400 seeds, fruits and fragments coming from the three archaeological sites being identified, along with 263 charcoal fragments coming from Gabii. The present study represents a great advancement as it is the first time that such an amount of data was obtained for this region and this period. In order to understand the agricultural practices an innovative method that has never been used before for this region and for this period was applied, consisting of carbon and nitrogen stable isotope analyses of charred cereal grains coming from Gabii, Palatine hill and Tarquinia. Charcoal fragments coming from wild trees were retrieved at Gabii. The stable isotope analyses were done on hundreds (557) of cereals and grains and on 10 fragments of charcoals. This represents a robust dataset with a large quantity of values which is totally new for this region.

The background about the changes occurring in the central Tyrrhenian region and the urbanization process occurring from the 10th c. BCE is detailed in **Chapter 1: Setting the scene**. The details of the methods employed as well as the background for the understanding of the stable isotope analysis part can be found in **Chapter 2: Material and Methods**. **Chapter 3: Case study 1 - Crop husbandry at Gabii during the Iron Age and Archaic period: the archaeobotanical and stable isotope evidence** represents the first case study, which is an article and deals with the archaeological site of Gabii. **Chapter 4: Case study 2 - Growing Early Rome: agriculture and isotopes during the Iron Age** is another article about Palatine Hill. The results for Tarquinia combined with the ones from the other sites, as well as the discussion about the regional point of view, are included in **Chapter 5**: **A regional perspective**. **Chapter 6: Charcoals as environmental proxies** is about the identification and stable isotope analysis of Gabii’s charcoals. Finally, the **Conclusions and perspectives** draw a more global picture, retrace the main hypothesis of this study and give some perspectives for the future.

To achieve all these objectives, collaborations were made with different institutions, IGAG (Istituto di Geologia Ambientale e Geoingegneria) of the CNR (Consiglio Nazionale delle Ricerche) of Montelibretti, Rome, Italy for the carbon and nitrogen stable isotope analysis of the cereal grains. The Chrono centre of the University of Belfast (Ireland) was involved in the carbon stable isotope analysis and the dating of the charcoal fragments.

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Chapter 1

Setting the scene

In order to contextualize the study, this chapter presents the regional archaeological settings as well as the social, economic and political changes that happened during the first half of the 1st millennium BCE in Central Tyrrhenian Italy and that were part of this process of urbanization. Moreover, Gabii, the Palatine hill in Rome and Tarquinia, the archaeological sites of interest in this study, are briefly described here.

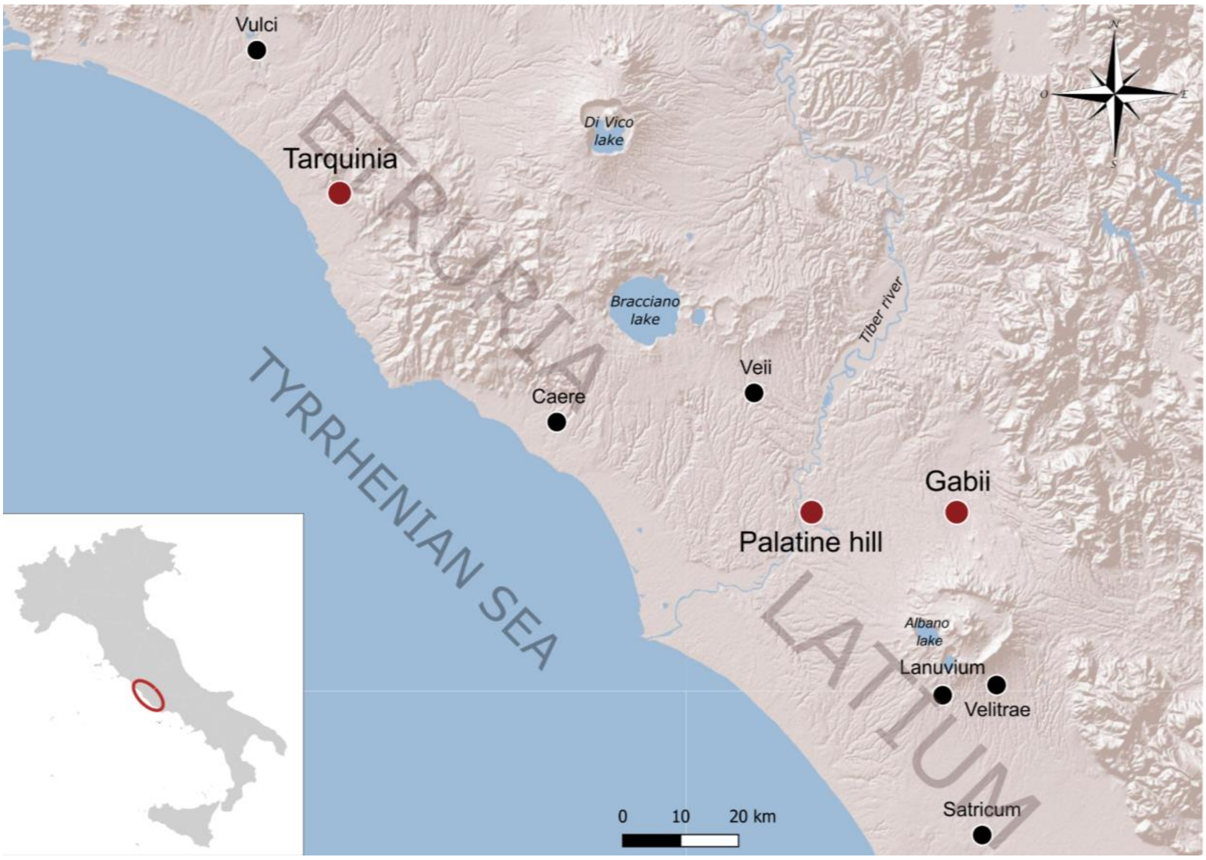

Figure 1.1: Map of Latium and Etruria with some of the most important archaeological sites for this period (ESRI Shaded Relief, QGIS).

The cultural context

During the Iron Age and the Archaic period **(Tab. 1.1)**, many urban centres developed along the Tyrrhenian coast. The method and timing of this urbanization process is still under debate, and some local differences can be identified among sites but an overall description can be drawn in order to understand the events happening during this period.

During the transition between the Bronze Age and the Early Iron Age (12th to the second half of the 10th c. BCE), different ethnicities started to be identifiable within the Central Tyrrhenian Italy area, among which were the Etruscan and the Latin cultures. It led to the distinction of two cultural regions, *Latium vetus* located to the south of the Tiber River and South Etruria, situated to the north of the river **(Fig. 1.1)** (Amoroso 2016; Fulminante 2017; Fulminante and Stoddart 2013). The two regions underwent a similar process towards urbanization even though some differences can be highlighted: the centres in *Latium vetus* are more numerous and smaller (Amoroso 2016) and the process seems to happen slightly later and more slowly than in South Etruria (Fulminante and Stoddart 2013).

In the course of the Middle and the Late Bronze Age (12th to the first half of the 10th c. BCE), in Central Tyrrhenian Italy, inhabitants started to abandon some of the small dispersed villages situated in non-defensible and open areas to gather on naturally defensible places such as large plateaux (Alessandri 2013). Until then, the society was characterized by regular splits and creations of new settlements to maintain an equilibrium in the size of the population of the community. In the course of the Early Iron Age, it evolved towards a more stable situation, the number of new settlements decreased but became bigger in size over time (Alessandri 2013). These changes are accompanied by a population increase (Alessandri 2013), an intensification of production (Cifani 2020) and the establishment of trade at a regional and supra regional scale (Blake 2014). This evolution towards a more urbanized organization is accompanied by a greater social complexity with the emergence of social hierarchy, elite and community rulers (Alessandri 2013; Terrenato 2019). During the Early Iron Age (second half of the 10th to the end of the 8th c. BCE), the mechanisms that led to the rise of the different cities in Central Tyrrhenian Italy were already in place. In continuation with the latest period, by the end of the 7th and during the 6th c. BCE, this process continues and indications of architectural development occur in the settlements. The wattle and daub huts are little by little replaced by stone-built houses (van't Lindehout 2013). From the 6th c. BCE, the construction of urban walls, public spaces, monumental buildings and religious spaces are also documented in many of these centres. In Rome, for instance, the temple of *Jupiter Capitolinus* was built (Cifani 2016). Similar patterns are observed in Tarquinia with the temple of the Area della Regina (Bonghi Bonghi Jovino 2010). Even if some debates still exist about the timing and how it took place, by the 6th c. BCE, most of the important centres in *Latium vetus* and Etruria which follow this process are already considered as urban centres.

Archaeological Period	Latial phase	Tarquinia	Years BCE	cal BP
Final Bronze Age	I	Protovillanovian	1025/1000 - 950/925	2975/2950 - 2900/2875
	IIA	IA	950/925 - 900-875	2900/2875 - 2850/2825
Iron Age	IIB	IB	900/875 - 850/825	1850/2825 - 2800/2775
	IIIA	II	850/825 – 775	2800/2775 - 2725
	IIIB	II	775 - 730/725	2725 - 2680/2675
	IVA1	IIIA	730/725 - 670/660	2680/2675 - 2620/2610
Orientalizing	IVA2	IIIB	670/660 - 640/630	2620/2610 - 2590/2580
	IVB	IV	640/630 – 580	2590/2580 - 2530
Archaic Period	AP	AP	580 – 509	2550 - 2459

Table 1.1: Archaeological, local, and absolute chronology for the investigated period. Modified from Fulminante and Stoddart (2013).

Land use, farming systems and food production

With the process of urbanization and the demographic explosion described previously, comes the question of how to feed this new growing and specialized population. Even if the soil of Etruria and *Latium vetus* are known to be very fertile and that rather large surfaces are available for the rainfed agriculture practiced by these past populations, some studies suggested that soon the territory controlled by each emerging city was not enough to sustain their inhabitants. It is not known precisely when and how fast this would have happened but during the Republican period and later, part of the main staples was imported in Rome for instance. Other scholars who place the urbanization process earlier during the 8th c. BCE, postulated that already by the 7th c. BCE the threshold of a sustainable balance between population and local agricultural resources was already passed (Fulminante 2014). In any case, the need to feed more people is generally linked with an intensification of agricultural production (Fulminante 2014). However, little is known about the agricultural practices of the populations of Central Italy during the Iron Age and the Archaic period. The evidence which could help us to understand them is rather sparse and comes mainly from archaeological surveys or later texts.

Evidence of land exploitation for farming was attested through pollen studies which show an intensification of the clearance activity already in the late Bronze Age. The food production practices in Latium and Etruria already established during the Bronze Age continued and evolved during the Archaic period and later on. The archaeozoological studies carried out in different sites in Latium and Etruria showed that it was characterized by the dominance of ovins and caprines as well as cattle. Pigs progressively increase in the archaeological records from the 8th c. BCE, especially with the development of the urban centres, as pigs are particularly suitable for this kind of environment (Trentacoste 2020). The Etruria region and the *Latium vetus* valleys are very fertile areas where crop production is essentially characterized by a polyculture of cereals, legumes, olives and grapes (Cifani 2002). The cereals are represented mainly by hulled barley and emmer. Some other crops, such as einkorn, spelt, naked wheat and millet, are also occasionally attested. The cereals are accompanied in the archaeobotanical records by faba beans, bitter vetch or lentils. There are some variations depending on community preferences, possibly visible in the proportion of each species found in the archaeological record (Motta and Beydler 2020). Pollen of grapes and olives increased during the Bronze Age which suggests their cultivation. These cash crops became very important economically, especially in Etruria, where starting in the 7th c. BCE there is ample evidence for trans Mediterranean trade (Riva 2017).

The archaeological surveys in Etruria and *Latium vetus* show that the rise of the urban centres during the archaic period was accompanied by a process of ruralisation that is particularly visible during the 6th c. BCE. A large number of villages, farms and rural buildings flourished in the countryside, they were linked to the urban centre and were in charge of the food production to feed the population of the urban centres (Attema et al. 2017; Cifani 2002). The buildings present different dimensions, from small farms to huge constructions capable of producing a huge number of resources, showing the involvement of people from diverse social horizons (Cifani 2002; Motta and Beydler 2020). While this ruralisation and its timing as well as social questions associated with it are still under debate, the appearance of rural infrastructure has been interpreted as a proof of an intensification of land exploitation (Attema et al. 2017). Evident testimony to the investment in the rural countryside of *Latium vetus* and Etruria is the development of an underground water system, allowing drainage or water supply to the lands (Cifani 2002).

The archaeological sites

The three selected sites: Palatine hill, located in the centre of modern Rome, Gabii and Tarquinia, are situated in the Central Thyrennian region. They were chosen because they all underwent this phase of urbanization and were very important urban centres for the region. The three archaeological sites are situated between the Tyrrhenian Sea at the west and the Apennines chain at the east. The archaeological site of Gabii is situated at 60 km from the sea while Palatine hill is at 40 km. Tarquinia is located closer to the coast, at only 10 km. Gabii and Palatine hill are situated at 18 km from each other in the ancient *Latium vetus* region. Tarquinia is located north of the Tiber in the ancient south Etruria region and belongs to the Etruscan culture **(Fig. 1.1)**. The Latins' and the Etruscans' socio-economic development followed the same chronological trajectory. Since the three sites are in similar environmental settings, under the influence of the same climate, it is possible to compare the stable isotopic data coming from the two cultures. But it needs to be noted that they are indeed two different cultures and each site has local micro-environmental specificities that could affect farming choices. Altogether the material coming from the three archaeological sites covers a period of time going from the 10th to the 5th c. BCE. Even if individually each site does not have the same chronology, they overlap for some parts which allow a comparison of the results. Gabii offered archaeobotanical material dated between the 8th and the 6th c. BCE, Palatine hill ranges from the 10th to the 7th c. BCE and finally Tarquinia covers a period of time between the 9th and the 5th c. BCE.

Regarding the geological setting, the sea left a thick succession of marine sediments throughout Pliocene and early Pleistocene times in the area of Rome, the so-called Campagna Romana. During the middle Pleistocene, the Monti Sabatini and Coli Albani volcanic units, which surround Rome, emerged (Luberti et al. 2017). The following millennia are characterized by the occurrence of volcanic episodes, along with deposition of gravel and clay by the paleo-Tiber, which was already present in the area (Luberti et al. 2017). These different depositions are responsible for the complex sequence of tufos, clays and gravels found at Rome (Luberti et al. 2017). Rome is also particular because of its morphology; the area is characterized by high hills separated by wide and deep valleys. The Palatine hill is one of these hills and lies on volcanic bedrock and on a deposit of clay, silt, sands and reworked volcanic material. It is also surrounded by alluvial deposits coming from the Tiber (Moscatelli et al. 2015). Gabii is situated on the edge of the former Castiglone crater which is part of the Colli Albani Volcanic District. Gabii is therefore situated on volcanic soils created by diverse lava flows, occurring over millennia, and more recent alluvial deposition in the crater and south of it (Florindo et al. 2018). Finally, Tarquinia was built on Lower Pleistocene marine sediments which consist of clays, limestone and yellow sand (Aureli et al. 2015).

Gabii, the Palatine hill and Tarqunia are situated in an eco-regional division which is at the limit between a Mediterranean and Temperate climate (Blasi et al 2014). While Gabii and Rome belong to a different sub-regional section than Tarquinia, their climates are still very similar. They are characterized by maximum precipitation during autumn and minimum precipitation during summer. The annual rainfall seems to be a bit higher for Rome and Gabii (660-1086mm) compared to Tarquinia (590-971mm). The summers are hot with temperatures going up to 30°C and the winters are warm with temperatures between 3 and 7°C. The annual temperature is between 13 and 17°C (Blasi et al 2014; Fratianni and Acquaotta 2017). The modern vegetation in the area is marked by the transitional aspect of the climate. It presents a dominance of mixed deciduous oak forests with *Quercus cerris*, *Quercus frainetto* and *Quercus virgiliana*, alternated with Mediterranean sclerophyll vegetation such as evergreen oaks, represented mainly by *Quercus ilex*, which are limited to coastal and more exposed and drier areas (Blasi et al. 2014). It is possible to have a glimpse of the past vegetation and its evolution in the region from the Bronze Age thanks to the multitude of palynological studies done on different lakes (mainly Albano, Mezzano and Vico lakes) (Magri and Sadori 1999; Mercuri et al. 2002; Sadori 2018; Sadori et al. 2004). The vegetation was dominated by deciduous oak forests; it was associated, like today, with evergreen oak in smaller proportion. Other taxa such as hazel, elms, hornbeam or alder were also present in different proportions. Beech was identified as well, it started to increase significatively during the early Holocene (9000 cal BP) to, then, decrease during the Bronze Age (3000 cal BP). From the Bronze Age, there is an important and abrupt decrease in the pollen concentration which would reflect a reduction in the forest cover, most likely due to human intervention. It is associated with an increase in the cultivated trees, cereals and weeds pollen which show the expansion of agriculture and the presence of fields in the environment (Mercuri and Sadori 2012).

For a detailed description and the history of each archaeological sites see **Chapter 3** for Gabii, **Chapter 4** for more information on the Palatine hill and **Chapter 5** for Tarquinia.

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Chapter 2
Material and Methods

The archaeobotanical material coming from the archaeological sites presented in **Chapter 1** consists of charred plant remains, i.e. fruits/seeds and wood fragments. Different but complementary approaches of the study of plant remains were proposed in order to obtain a reconstruction of plant production, consumption and use in the past, as well as understand the implications for the socio-economic history of the region of interest. The first step was the classical archaeobotanical analysis which was essential to identify which taxa and especially cereal crops were present at each site and across time. The second analytical method used was the carbon and nitrogen stable isotope analysis that informed us on past water availability and manuring practice.

Archaeobotany

Archaeobotany is a bio-archaeological discipline that focuses on the study of the relationships between plants and past-human populations. One of its ways to do so is to identify and quantify fossilized plant macro remains such as wood fragments, grains, fruits, fibers or inflorescences retrieved from archaeological contexts. This material can be preserved in diverse manners such as waterlogging, desiccation or mineralization (Miksicek 1987). However, the most common type of preservation appears to be carbonization, was also the case of the archaeobotanical material retrieved at Gabii, Palatine hill and Tarquinia. Carbonized macro-remains are the result of burning in low oxygen conditions and rather low temperatures (Miksicek 1987). This phenomenon can occur in a diverse array of contexts from cooking, preparation for storage purposes, campfires to more dramatic ones such as hut fires and even during a settlement fire. The identification of the remains present on site, when combined with the study of the archaeological contexts and deposit formation processes, can help the understanding concerning specific aspects of a site and its relative environment. It is, for example, possible to approach their economy, diet, trades or culture. Diverse practices related to building, agriculture and crafting activities can also be investigated along with the reconstruction of, at least in part, their surrounding environment and its exploitation (Weiss and Kislev 2007). From the field to the laboratory, archaeobotanical studies were implemented for Gabii, Rome and Tarquinia.

The field method

During the excavations of the 3 archaeological sites, soil samples were retrieved for the archaeobotanical studies. Diverse material collection strategies exist and the most appropriate one need to be selected to answer in the best way possible the aim of the research (Jones 1991). For this reason, the archaeological sites studied for this project do not present the same sampling strategy. For the Palatine hill and Gabii sites, a blanket total sampling was used, meaning that every stratigraphic unit (SU) was sampled. At Palatine hill, 6l of soil was taken for the majority of the SUs. At Gabii, 20l were usually collected but if the SUs had less than 20 litres of sediment the totality of the SU was sampled. At Tarquinia two sampling strategies, judgement and systematic, were adopted in different field seasons. For the first one, the archaeologists gave priority to strategic SUs such as hut floors, middens and ritual contexts. Through the years the collection of soil samples was not standardized and was variable as it could range between 1 and 2l.

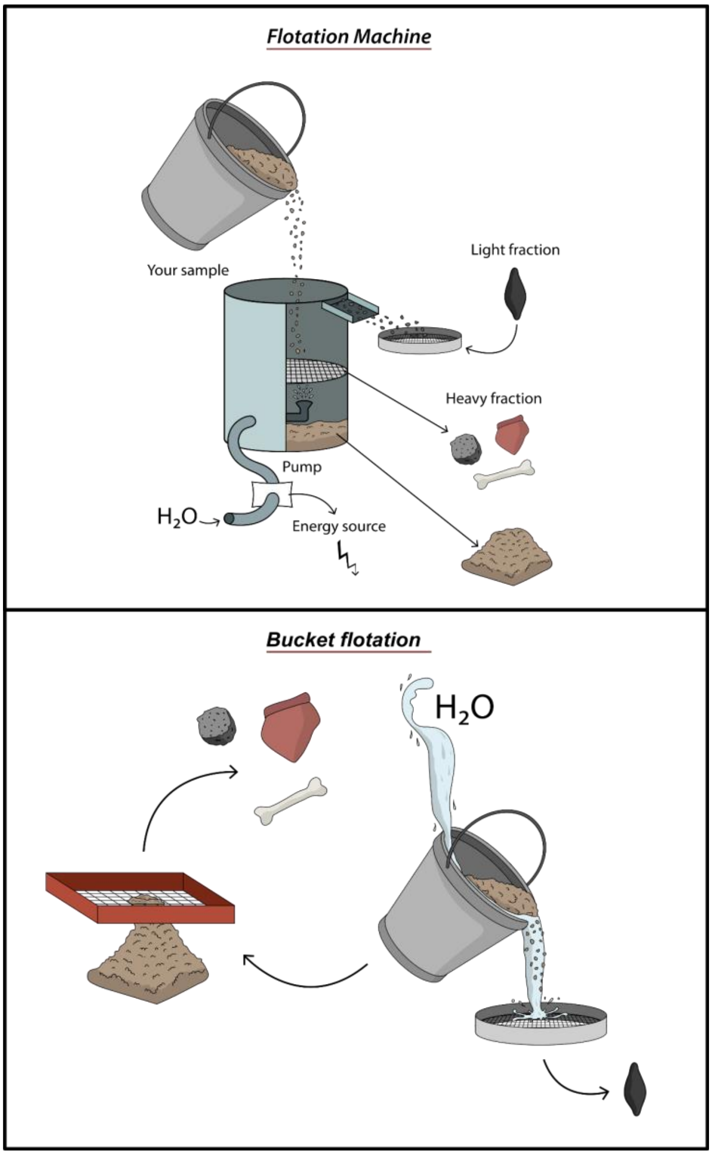

Figure 2.1: Flotation machine method (top) and bucket flotation method (bottom).

For Palatine Hill, given the high amount of clay it was necessary to use a chemical treatment in order to help its removal before the flotation step. The soil samples were mixed with a 10% solution of sodium bicarbonate and hot water and stirred until the soil was entirely soaked. The material coming from the 3 archaeological sites was floated in order to separate the charred plant parts from the heavier materials (rocks, ceramics fragments).

At Gabii and Tarquinia the same method was chosen and a flotation machine was used. The main body of the machine is composed of a PVC pipe (70cm tall and 37cm across, sealed by a pipe cap). At 25cm of the bottom, a metal water pipe enters the side of the machine and bends upwards at the centre of the centre body. The water pipe terminates with a shower head which sprays water up and creates considerable turbulence once the body is filled up. Around the outside of the upper edge, a sort of aluminium gutter, 6cm wide, collects the overflowing water and directs it into a 0.25mm mesh external sieve hanging underneath. The heavy fraction is collected in a removable 1mm mesh geological sieve that hangs inside the body at about 45cm from the bottom **(Fig. 2.1)**. However, at the Palatine a bucket flotation with overflow method was used. After the pre-treatment with the deflocculant, the sample is placed in a bucket with water. The water is then stirred and overflown into a sieve with a mesh of 0.25mm where the light fraction is caught, while the heavy fraction stays at the bottom of the bucket **(Fig 2.1)**. It was also wet sieved with a 1mm mesh at the end of the process. Even if two flotation methods were used at the different sites, the results obtained are comparable as in any case a 0.25mm external mesh and a 1mm internal mesh were used. Most of the material retrieved from the flotation process is constituted of charred seeds/fruits and relatively small fragments of wood charcoal. Several other methods were used for the retrieval of charcoal fragments in the different sites. A screening method, which consists of dry sieving the soil removed during the excavation through different sizes of meshes, was also used (Motta 2016). Some of them which were visible on the site were picked up directly in situ and wrapped in aluminium foil and others were recovered from the heavy fraction after flotation.

The laboratory methods

Once the light fraction is separated from the heavy one, it consists mainly of charred plant remains, modern plant parts and sediments. Each sample was weighed and the volume was measured. They were then dry sieved with 4 different meshes: 2, 1, 0.5 and 0.2 mm in order to retrieve the smallest grains, fruits and plant parts that are too often overlooked in archaeobotanical studies. This charred material was selected from the rest and identified under a reflected light stereomicroscope (10X-60X magnification) using the reference collections and seed atlases. Some pictures in **figure 2.2** shows some examples of archaeobotanical remains found at the different sites. This laboratory work was carried out at the Laboratory of Palaeobotany and Palynology (La Sapienza University of Rome, Italy). Different categories were created to overcome the poor preservation and fragmentation of the material, they were used for the 3 archaeological sites in order to have a consistent framework for the whole study.

- Cereals: contains the grains and fragments which present all the characteristics of cereals such as the size, the shape, the groove, the embryo, but which are too deformed or fragmented to be identified (**Fig. 2.2, E**).
- Cereals cf: contained the fragments which have the texture of the cereals.
- *Triticum* sp.: contains the grains and fragments belonging to the genus, for which further specific details were not available (**Fig. 2.2, D**).
- *T. dicoccum/spelta*: the difference between *T. dicoccum* and *T. spelta* can be tricky as they are very similar and their diagnostic characteristics can disappear because of the carbonization process. A *T. dicoccum/spelta* category was created to overcome this issue with grains having intermediate characteristics such as a more squared shape, parallel lateral sides and a bigger size.
- “Big Poaceae”: it contains all the caryopses and fragments of caryopsis which are too small to be classified as cereals (**Fig. 2.2, I**).
- *Lolium* sp.: regroups the grains and fragments belonging to the genus, for which further specific details were not available.
- *L. temulentum/multiflorum*: the difference between *L. temulentum* and *L. multiflorum* can be difficult to assess. They are similar, their characteristics are not always preserved and some grains present intermediate features.
- *Lathyrus/Vicia*: mostly includes large fragments or single cotyledons whose size and shape indicate both the genera.
- Fabaceae nid: this group contains small fragments of cultivated pulses (**Fig. 2.2, L**).
- *Phalaris/Alopecurus, Phalaris/Cynodon, Cynodon dactylon*: due to the preservation the distinction between *Phalaris* and *Alopecurus* was not possible (**Fig. 2.2, H**).

For the quantification of the cereals the ‘minimum number of individuals’ method was used. It means that (1) each complete cereal caryopsis was counted as one, (2) when a half of a caryopsis was found, and did not obviously belong to any other half, it was also counted as one. The fragments that were smaller than a half were counted as “fragments”. Legumes follow the same principle, not only was a seed composed of two cotyledons counted as one, but also one cotyledon alone if not marching with any other cotyledons. More fragmented cotyledons were counted as “fragments”. Chaff was counted according to glume bases and spikelet forks specimens. The chaff/seed ratio for *T. dicoccum* and *T. monococcum* was calculated according to the van der Veen method (2007) for the site of Palatine Hill where the material was more abundant. For the rest of the taxa, each item was counted as one and if broken they were considered as fragments. The heavy fraction was also checked because some charred remains can still be imprisoned in sediments and then not float. Mineralized material, especially fig achenes, were found. However, in the study the heavy fraction was checked only for charred material.

In the case of the charcoal, only a part of the fragments coming from Gabii were available for this study. Each available fragment larger than 1 mm was identified. They were identified with a differential interference contrast (DIC) microscope at the Laboratory of

Palaeobotany and Palynology (La Sapienza University of Rome, Italy) and at the University of Montpellier at ISEM (Institut des Sciences de l'Evolution de Montpellier). The identification was carried out using wood atlases and reference collections.

Figure 2.2: A: Palatine Hill. *H. vulgare*; B: Palatine Hill. *T. dicoccum*; C: Palatine Hill. *T. dicoccum/spelta*; D: Palatine Hill. *Triticum* sp.; E: Palatine Hill. Cereals; F: Gabii. *L. temulentum*; G: Gabii. *A. sativa*; H: Palatine Hill. Phalaris/Alopecurus; I: Gabii. big Poaceae; J: Palatine Hill. *V. faba*; K: Palatine Hill. *V. ervillia*; L: Palatine Hill. big Fabaceae; M: Gabii. *S. nigra*; N: Palatine Hill. *Gallium* sp., O: Gabii. *S. gallica*; P: Gabii. Malvaceae

Stable isotope analysis

The use of stable carbon isotope analysis on archaeobotanical remains was proposed for the first time in the 80s as a potential proxy to reconstruct past climate conditions from archaeobotanical remains (Marino and Deniro 1987). Since then, it has been developed and applied to several types of plant remains for different purposes: the study of stable carbon isotopes from charcoals, for example, has been used to reconstruct paleoclimate conditions (Aguilera et al. 2012), whereas its application on cereal grains has focused on the identification of ancient irrigation practices (Araus et al. 1997).

Carbon stable isotopes and water availability: background for C_3 plants

Carbon stable isotope composition ($\delta^{13}C$) in plant tissues reflects the environmental conditions in which the plants grew. There are two carbon stable isotopes (^{12}C and ^{13}C) and they are present in the air in different quantities. A fractionation in favor of the lighter isotope (^{12}C) takes place mainly during two steps of the photosynthesis process: the diffusion of the CO_2 through the stomata and the fixation of the CO_2 by the enzyme RuBisCO. Such a preferential use of ^{12}C by plants leads to an important discrimination of the heavier isotope (^{13}C), that is referred to as carbon isotope discrimination ($\Delta^{13}C$) and expressed with the equation proposed by Farquhar et al. (1982):

$$\Delta^{13}C = \frac{\delta^{13}C_{air} - \delta^{13}C_{plant}}{(1 + \frac{\delta^{13}C_{plant}}{1000})}$$

The $\delta^{13}C_{air}$ corresponds to the carbon isotope composition of atmospheric CO_2 for a specific period of time. It is estimated from isotopic data coming from Antarctic ice cores covering the end of the Last Glacial and the Holocene (Eyer et al. 2004; Francey et al. 1999; Indermühle et al. 1999; Leuenberger et al. 1992) and can be calculated thanks to the AIRCO2_LOESS system (Ferrio et al. 2005). On the other hand, the $\delta^{13}C_{plant}$ represents the carbon isotope composition of the plant and mainly depends on the environmental conditions in which the plant grew. In favorable conditions the diffusion of CO_2 in the intercellular space of the leaf is not limited and most of the fractionation process is led by the RuBisCO enzyme, which will strongly discriminate against ^{13}C causing a lower $\delta^{13}C_{plant}$ and therefore a higher $\Delta^{13}C$. Exposed to a stressful episode like drought, stomata close inducing a limitation of the CO_2 flow in the intercellular space of the leaf: since the RuBisCO needs to use the available isotopes, it will discriminate less against ^{13}C and produce higher $\delta^{13}C_{plant}$ values and lower $\Delta^{13}C$ (Farquhar et al. 1982) **(Fig. 2.3)**. Despite other influencing factors, such as leaf morphology, light availability and temperature, water availability is the main factor influencing $\delta^{13}C$ of plants (Farquhar et al. 1989).

It is in this context that some scholars started to measure $\Delta^{13}C$ on charred cereal grains coming from archaeological sites. To better understand the water input that corresponds with the $\Delta^{13}C$ values, some experiments were undertaken on modern barley and wheat cereal grains in arid and semi-arid regions. They led to the implementation of thresholds which inform on the water status of the plant: poorly, moderately and well-watered (Flohr et al. 2019; Wallace et al. 2013). Furthermore, they showed that, even under the same environmental conditions, different species of cereals do not have the same $\Delta^{13}C$ values. This would be due to their different growing season and implies that it is not possible to directly compare values coming from different species. In the absence of experiments on modern crops it is difficult to know if a species is actually in better water availability than another which can be a limitation for the understanding of the management practices of a past population. One possibility in this case would be to compare their trend over time; if they are similar, the two species were probably managed in the same way; if not they could have been submitted to different practices (e.g. Masi et al. 2014).

In these studies, other aspects and possible limitations of the $\Delta^{13}C$ interpretations are discussed. It is not clear if the $\Delta^{13}C$ measured in the grain originates solely from the water used by the plant during the grain filling period, as suggested by Araus et al. (1997) or if it reflects the total water input occurring throughout the growing season. Several studies have investigated this quandary (Flohr et al. 2011; 2019; Wallace et al. 2013). The results have not always been consistent, in some cases the strongest correlation was found between $\Delta^{13}C$ values and water input during the grain filling period (Flohr et al. 2019; Wallace et al. 2013) while, in others, the entire plant growing season was found to significantly impact $\Delta^{13}C$ values (Flohr et al. 2011). The cereal grains $\Delta^{13}C$ values give an idea of the water availability of a precise period of time during the year and this should be kept in mind when results are interpreted for climate studies.

Even if cereal water status can be assessed, another issue comes up when dealing with cultivated plants. Indeed, they are grown in fields which are environment controlled artificially (Heinrich and Hansen 2021) and while they are still largely influenced by natural water availability, they are also potentially impacted by an array of practices and choices, such as irrigation, in order to enhance plants' water supply. Distinguishing environmental and human influences can be challenging and $\Delta^{13}C$ values of charcoal fragments represent a great tool in this case. Their values refer to atmospheric humidity since the paleoenvironmental conditions in which plants are grown are not impacted by human activities. Therefore, carbon isotopic values coming from trees are a good proxy to evaluate fluctuations of climate over time (e.g. Aguilera et al. 2012; 2011; 2009; Ferrio et al. 2006; Masi et al. 2013(a); Masi et al. 2013(b); Vignola et al. 2018). The choice of the species studied is of crucial importance depending on the information that one wants to assess. For instance, deciduous and semi-evergreen trees do not photosynthesize during winter, thus their isotopic signal refers to the growing season only; on the contrary, the evergreen trees record $\Delta^{13}C$ for the whole year (Ferrio et al. 2006). The stable isotope analyses on cereal grains and charcoals are, therefore, complementary. By comparing the cereal $\Delta^{13}C$ trends over time to the ones of trees, it is possible to identify variations of the carbon isotope composition linked to oscillations in precipitation rather than changes of the water management system over time (e.g. Vignola et al. 2017).

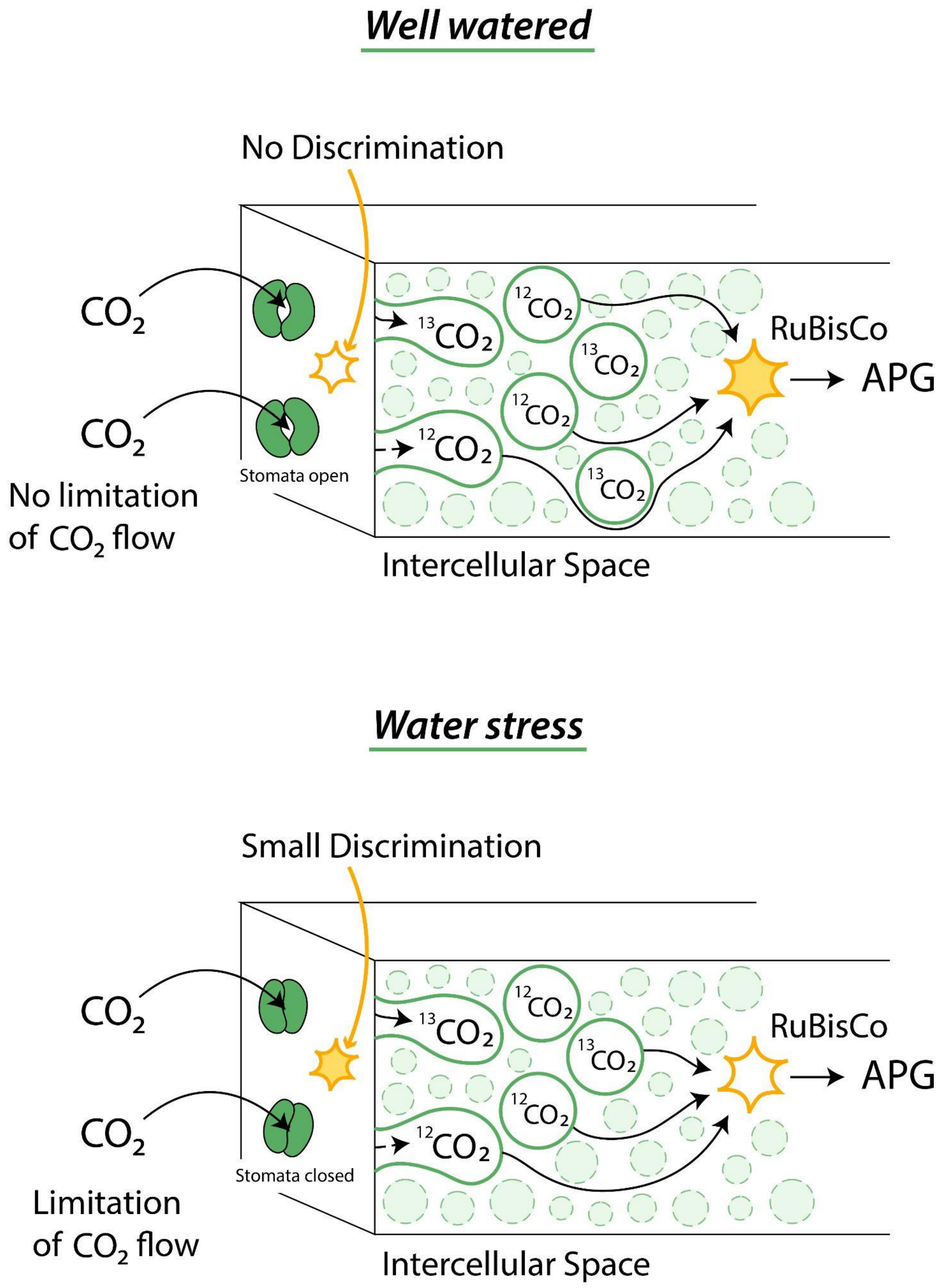

Figure 2.3: Scheme of the fractionation mechanism occurring during C_3 plant photosynthesis responsible for the $\delta^{13}C_{plant}$ variations under different water conditions.

Nitrogen stable isotopes and manuring practice: background for non-N_2-fixing plants

Nitrogen stable isotope composition ($\delta^{15}N$) of seeds/fruits can be used for the reconstruction of past conditions for plant growing, i.e. soil fertility. Studies based on experimental crop fields in northern Europe, submitted to different manure regimes, have shown that the application of animal manure leads to an increase of $\delta^{15}N$ values in non-fixing nitrogen plants (Bogaard et al. 2007; Bol et al. 2005; Fraser et al. 2011; Kanstrup et al. 2011). This is due to the preferential loss of the lighter nitrogen stable isotope (^{14}N) during the volatilization of the ammonia present in animal dung, leading to the enrichment in ^{15}N and the consequent increase of manure $\delta^{15}N$ (Bogaard et al. 2007). $\delta^{15}N$ values are also impacted by the duration of the application of manure: a pilot study demonstrated that it is necessary to apply manure during a long time period to see the effects in the nitrogen isotope composition of soil and, then, of plants (Fraser et al. 2011). The intensity of such application also has a remarkable influence on $\delta^{15}N$ values and different cereal crops (i.e. wheat and barley) record similar variations in $\delta^{15}N$ (Bogaard et al. 2013; Fraser et al. 2011).

However, because of the complexity of the nitrogen cycle, as well as the different physiological mechanisms occurring in the plants in response to the environment, the interpretation of changes in $\delta^{15}N$ of plants is still complicated (Amundson et al. 2003; Craine et al. 2015; Dawson et al. 2002; Evans 2001). Many parameters influence $\delta^{15}N$, such as N sources (NO_3-, NH_4+, N_2), plant-fungi interactions (Craine et al. 2009), temporal and spatial variation in N availability, as well as changes in plant demand (Dawson et al. 2002). Moreover, an increase of $\delta^{15}N$ is not necessarily linked to an application of manure, since $\delta^{15}N$ increases during the decomposition process, the organic-derived nitrogen tends to be isotopically enriched compared to that derived from mineral fertilizers or from atmospheric fixation by legume symbionts (Fiorentino et al. 2015). Furthermore, a lot of environmental parameters can affect the nitrogen isotope composition. As a matter of fact, several studies have stressed the negative correlation between MAP (Mean Annual Precipitation), water availability and plant $\delta^{15}N$, as well as the positive correlation on a global scale with MAT (Mean Annual Temperature) which would favor ammonia volatilization (Amundson et al. 2003; Fiorentino et al. 2015). Nonetheless, such a relationship between MAP, MAT and $\delta^{15}N$ can be more complicated for the interpretation of the soil conditions at a local scale due to many parameters (Fraser et al. 2011). It has been observed, as well, that salinity reduces $\delta^{15}N$ values (Virginia and Delwiche 1982).

These various influences can lead to a misinterpretation of $\delta^{15}N$ data. To avoid issues it would be, in an ideal situation, preferable to have the $\delta^{15}N$ baseline of the natural past-environment. However, this can be problematic to assess and diverse methods were proposed to approximate its value. The studies previously mentioned (Bogaard et al. 2013; Fraser et al. 2011) worked on the implementation of thresholds that would help to evaluate the manuring regime applied to the cereals (**Tab 2.1**). These categories, largely used by scholarship, need nonetheless to be implemented keeping in mind that they were calculated in a temperate climate. Yet other studies showed the variability that could exist in the $\delta^{15}N$ in different regions and periods of the year (Amundson et al. 2003). Another method to estimate the $\delta^{15}N$ baseline is the measurement of wild animal bone ratios found at the same archaeological site (e.g. Aguilera et al. 2018; Alagich et al. 2018; Styring et al. 2015). To do this it is then necessary to subtract 4‰ in order to compensate for the fractionating occurring during the assimilation of the plant by the animal (Styring et al. 2015). As animals migrate and can also eat a large diversity of plants with varying $\delta^{15}N$ values, they could show a signal that is not representative of the environmental baseline. Nonetheless, when combined with the thresholds, this could help to give a fair idea of $\delta^{15}N$ values not impacted by anthropic actions.

	No manuring	Medium manuring on a long period of time / Past manuring in large quantity / Beginning of manuring	Large manuring on a long period of time
Bogaard et al. (2013)	< 3‰	Between 3 and 6‰	> 6‰
Fraser et al. (2011)	< 2.5‰	Between 2.5 and 6‰	> 6‰

Table 2.1: Thresholds for manuring regime calculated by Bogaard et al. (2013) and Fraser et al. (2011)

Taphonomy, carbonization and corrections

Regarding the archaeobotanical remains and the taphonomic processes, which can impact on the reliability of stable isotope analyses from archaeological material, some methodological issues need to be clarified. Scholars showed that carbonization does not affect $\Delta^{13}C$ values significatively or directionally (Fraser et al. 2013; Styring et al. 2013), whereas the impact on $\delta^{15}N$ values is significant, directional and depends on the duration and intensity of the carbonization. Several studies propose different corrections: Nitsch et al. (2015) calculated a correction of 0.31‰, Fraser et al. (2013) a correction of 1‰, and Styring et al. (2013) a correction of 0.8‰; other studies do not find any influence to the data (Kanstrup et al. 2012). For this research, it has been decided to not apply any corrections to $\delta^{15}N$ values since those factors would have been essential if data were to be compared with non-charred material for palaeodietary models. In any case, all studies mentioned above agree that the archaeobotanical charred remains provide reliable results and represent a valuable proxy to assess the past environmental conditions in which plants grew.

Selection and dating of the archaeobotanical material

Cereals grains

The chronological horizon of the carpological assemblage was based on the stratigraphic sequences of the context. SUs were dated through ceramic typology that, for this period in Central Italy, gives a very precise chronology. In order to obtain isotopic records based on detailed chronological sequence, the criteria for selection of the archaeobotanical remains are of paramount importance. For cereal grains it is necessary to identify archeological contexts where crop remains refer to a short and defined period of time, in order to avoid as much as possible, the mixing of material. The ideal deposits are, therefore, closed primary ones that represent one single action and that were never disturbed after deposition, like storage pits. Unfortunately, this kind of archeological context is not very common and ubiquitous in archeological sites. Only a few samples coming from the Palatine, Gabii, as well as Tarquinia, referred to primary closed contexts and were available for this study. In order to overcome this issue, the depositional and taphonomic processes of carpological assemblages were assessed for each investigated SU. As a result, only archaeobotanical deposits representing single synchronous actions were selected for the stable isotope analyses. For instance, post holes or pits filled with domestic remains coming from the dismantlement of a hut having a short life span.

After choosing the appropriate context, it was necessary to select the cereal species that will undergo the stable isotope analyses. The archaeobotanical assemblages of the selected contexts are mainly composed of cereal grains, among which barley (*Hordeum vulgare* L.) and emmer (*T. dicoccum* Schrank.) prevail. Since these crops were found in all the investigated periods of occupation at the three sites, they have been chosen for stable isotope analysis. For each SU, several grains of each crop were selected. The method usually used to analyze charred cereal grains is to form bulks of 10-30 grains coming from the same archaeological context powdered together in order to correct the natural variability in isotopic ratios existing among a crop (e.g. Alagich et al. 2018; Aguilera et al. 2018; Bogaard et al. 2013). However, a different approach was chosen in the present study. Indeed, it was important to not mix the archaeobotanical material coming from different SUs even if they were identified as coming from the same archeological context or period, in order to interpret the variability inside each SU and to possibly reconstruct if it was caused by the mixing of materials from different fields and/or annual harvests. It was therefore decided to do a grain-by-grain analysis. The number of grains selected could vary due to the availability and preservation of the material in the SUs. A minimum of 3 up to 6 grains among the best preserved and cleanest specimens were taken from each SU and photographed in order to keep a record of them.

Charcoal fragments

For the selection and dating of the charcoals another approach was chosen for diverse reasons. The isotopic composition of wood remains varies from one tree ring to another since it is related to changes in precipitation throughout the plant life. In addition, the death of the tree (i.e. cut) does not correspond with its use in the archaeological context and the wood fragments of the archaeobotanical assemblages might have preserved annual rings of many years before, especially for long-lived species. Moreover, the charcoals are mainly residual material coming from long-term mix-deposits. This causes a problem of synchronicity between charcoals which does not allow us to refer to the ceramic chronology. For all these reasons, it was decided to radiocarbon date the charcoals selected for isotopic analysis, trying to find as much as possible the last preserved of tree rings (i.e. the youngest) in order to reduce the distance between the time of plant growth and the use of archaeological wood.

A total of 10 fragments were carefully chosen, the samples coming from the latest periods of occupation of Gabii were favoured to increase the chance of falling into the interval range that is interesting for this study. As for cereals, it was necessary to choose a tree taxon present in all the study sites covering the entire chronological sequence, from the 10th c. BCE to the 6th c. BCE: following such constraints, only remains of deciduous oaks (*Quercus deciduous*) were available for the stable isotope analysis.

Chemical pre-treatment, IRMS and AMS analyses

Cereal grains

Each cereal grain was chemically pre-treated in order to remove the contaminants potentially present in the soil, such as carbonates or humic acids impacting $\delta^{13}C$ and nitrates influencing $\delta^{15}N$ (Vaiglova et al. 2014). An Acid-Base-Acid treatment was applied, based on Vignola et al. (2018) protocol, and it took place at the Laboratory of Palaeobotany and Palynology of the Sapienza University of Rome (Italy). To avoid the loss of material each caryopsis was hot-sealed in filter bags (ANKOM mod. F57). A maximum of 20 bags were then put in a beaker and placed in a hot water bath heated at 70°C. They were soaked in HCl (1M) for 45 minutes to remove the carbonates, then in NaOH (1M) for 30 minutes to remove the humic acids and once again in HCl (1M) for 30 minutes to release the CO_2 which could have been trapped during the previous step. Each step of the treatment was followed by washing the samples with distilled water three times which participated in the removal of the nitrates. The bags were finally dried in an oven at 70°C for 12 hours. Each treated grain was then crushed into a homogenous powder to homogenised the isotopic signal of the entire caryopsis. The stable carbon and nitrogen isotope analyses were performed at the IGAG (Istituto Geologia Ambientale Geoingegneria - CNR of Montelibretti, Italy) with the IRMS method (Isotope-Ratio Mass Spectrometry). 1.30 mg of grain powder was weighed and analysed using a continuous-flow isotope ratio mass spectrometer (Thermo Flash 1112 Elemental Analyzer coupled to Finnigan Delta+ Mass Spectrometer). Both carbon and nitrogen analyses were conducted in a single run in order to use as little grain powder as possible allowing us to carry out two or three measurements for each sample. The large difference in carbon and nitrogen content in the grain (charred grains are poorer in nitrogen content in comparison with carbon content) required He dilution of CO2 produced in the combustion. Isotopic compositions were expressed in the usual δ notation, which represents the relative deviation, in part per thousand of the heavy isotope/light isotope ratios of the samples with respect to a reference standard (see equations below). Isotopic data were then normalised to the Vienna Pee-Dee Belemnite (V-PDB) scale for ^{13}C and AIR (Atmospheric air) scale for ^{15}N using IAEA standards (CH-6, CH-7, USGS-24 for C, and N-1, N-2, USGS25 for N). On the basis of measurement repetition of laboratory standards, the analytical error was <0.3-‰ for both C and N. As already stated, the δ^{13}C variation of atmospheric CO_2 during the Holocene was taken into consideration and the Δ^{13}C was calculated following Farquhar's equation (Farquhar et al. 1982). The %C and %N were also measured and C:N molar ratio was calculated.

Charcoal fragments

Each charcoal fragment was cleaned in order to mechanically remove sediments present on the sample surface. The charcoal samples were treated and analysed at the Chrono centre of the University of Belfast (Ireland) by Dr. Paula Reimer and Dr. Michelle Thompson. An ABA chemical pre-treatment, similar to the one of the cereal grains, is applied.

The samples were immersed in 50 mL of HCl (0.1M) in a beaker and placed on a 70°C hotplate for 20 minutes. NaOH (1%) was then added to the samples and warmed again on a 70°C hotplate for 20 minutes. Finally, 50mL of a stronger HCl (1M) was added and heated on a 70°C hotplate for 1 hour. Each step is followed by a rinse with deionised water until neutrality. The sample is then placed in an oven until dried. As already stated, both the radiocarbon dating and the stable isotope analysis on the selected wood fragments were performed by using the AMS (Accelerator Mass Spectrometry) method which allow to obtain both the radiocarbon dates and the δ^{13}C values on the same fragment of charcoal (Fiorentino et al. 2008; 2009; Fiorentino et al. 2015). Studies showed that even if small differences can exist, the stable isotope results obtained with the two methods (AMS and IRMS) can be compared without problem (Fiorentino et al. 2015).

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Chapter 3

Case study 1 - Crop husbandry at Gabii during the Iron Age and Archaic period: the archaeobotanical and stable isotope evidence.

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Crop husbandry at Gabii during the Iron Age and Archaic period: the archaeobotanical and stable isotope evidence.

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Abstract

Intensification of agricultural production to support demographic growth has been invoked as a necessary correlate to the important socio-economic changes involved in the urbanization process of Western Central Italy at the beginning of the 1st millennium BCE. Yet, the agricultural economy of the early urban centers in the region remains poorly understood. Ongoing excavations at Gabii provide a new substantial archaeobotanical dataset that allows the investigation of crop production and farming practices during the transitional period between the 8th and the 6th century BCE. This study presents a multi-proxy approach that integrates archaeobotanical data with carbon and nitrogen stable isotope analyses ($\Delta^{13}C$ and $\delta^{15}N$) on charred cereal grains to reconstruct Gabii's crop husbandry regimes.

Our results show an unexpected local combination of staples in which barley is the most important crop. No significant changes are visible throughout the period suggesting a remarkable consistency in crop selection and persistence of traditional practices. The stable isotope analysis has revealed low δ^{15}N values that we argue could be an indication of intercropping. A drop in the water availability during the 6th c. BCE could be related to a combination of environmental factors, human behaviours, and, possibly, production stress.

Keywords: Farming systems, agricultural intensification**,** Ancient Latium, urbanization, Carbon and Nitrogen isotope analysis, Iron Age Italy.

Introduction

During the Iron Age and Archaic period (10-6th c. BCE) western Central Italy underwent important social, political and economic transformations that led to the emergence of elites and complex social hierarchies**,** to new settlement patterns and to the rise of the earliest urban centers in the area (Attema et al. 2016; Fulminante 2014; Pacciarelli 2017; Terrenato 2019). In the span of a few centuries, the settlements changed from polynucleated communities, formed by discrete clusters of huts, to budding cities with stone buildings, monumental structures and public areas. These processes have been associated in the literature with demographic growth, intensification of production and specialized economies (Fulminante 2014; Riva 2017). Moreover, the appearance of small farms in the territory of the major centers during 6th c. BCE has been interpreted as a ruralisation of their hinterland and as a reorganization of farming systems geared towards a commercial economy (Cifani 2002; Riva 2017). Indeed, it has been assumed that intensification of agricultural production was needed to support, and at the same time was sustained by, an increasing and more specialized urban population (Ampolo 1980; Cifani 2020; Trentacoste 2020 for animal husbandry; see Motta 2011; Motta and Beydler 2020 for a discussion).

However, little is known about farming and land management for this period since plant and animal remains have been systematically sampled and investigated at a handful of sites only. In particular, the study of archaeobotanical macro remains has lagged behind and struggles to be included in mainstream scholarship. A recent synthesis of the limited data shows that the main staple crops in Central Italy were glume wheats and barley, complemented by pulses such as fava bean and bitter vetch, attested in variable proportion at different sites (Motta and Beydler 2020 and references therein).

New important evidence is available at Gabii, one of the emerging urban centers in the region, where ongoing excavations are paying particular attention to subsistence practices and economic records. Sampling for the recovery of archaeobotanical remains is an integral part of the research design (Motta 2016), and the site has produced the most abundant and complete dataset currently available for the reconstruction of crop husbandry regimes between the 8th and the 6th c. BCE. In this paper we present the results of the archaeobotanical and isotopic analysis of a subset of samples that provides a first insight into the agricultural economy at Gabii and allow us to explore changes in crop production and cultivation practices during this period as well as to identify possible environmental factors influencing them.

The site

The ancient Latin city of Gabii is located 18km east of Rome, at the intersection of a network of major communication routes which connected Gabii with the most important centers in the region. The settlement lies on a gentle slope following the curve of the southern edge of the Castiglione crater and faces to the south Pantano Borghese, a wetland that was reclaimed in the 19th century **(Fig 3.1)**.

Since 2009, the Gabii Project, promoted by University of Michigan, in coordination with the Soprintendenza Speciale Archeologia Belle Arti e Paesaggio di Roma (SS-ABAP-RM), has explored over one hectare of the site, allowing the reconstruction of the settlement's development through time. In its early phase of occupation, Gabii was one of the many polynucleated settlements typical of the area at the beginning of the urbanization process.

Figure 3.1. Map showing the location of the archaeological site of Gabii. Shaded area is the extent of the settlement included in the city walls.

Surface finds scattered on the slope and dated to the Late Bronze Age are the earliest material evidence, but, so far, no structure has been identified for this period. Recent excavations have uncovered Iron Age (8th –7th c. BCE) hut complexes that were replaced in the 6th century by stone-built structures providing evidence for architecture, funerary rites, and domestic activities. From the 5th to the 2nd c. BCE, Gabii faced a planned structural reorganisation resulting in an orthogonal urban layout with elongated city blocks occupied by private houses, public buildings and commercial activities. As Rome expanded in the Late Republican and Imperial time, Gabii's settled area contracted and eventually was abandoned and the area repurposed for agricultural use in medieval time (Johnstson and Mogetta 2020; Samuels et al. 2021(a); Samuels et al. 2021(b)).

Figure 3.2. Gabii. A) plan of the Gabii Project excavations with the location of area C and D. Insets: Phase map of area C and D: B) phase 1; C) phase 2; D) phase 3; E) phase 4. Illustration courtesy of the Gabii Project.

Material & Methods

The archaeobotanical material and its context

This study focuses on the 8th-6th c. BCE phases of occupation. The archaeobotanical material comes from areas C and D **(Fig. 3.2)**. These two excavation trenches comprise one cluster of the polynucleated configuration that defines the settlement in its early period, and provides evidence of occupation dated from the mid-8th c. BCE. Habitation gradually changed from a collection of several small huts to a bigger central hut and eventually, at the beginning of the 6th c. BCE, to a structure built with a stone foundation that included two rooms and that was enclosed by a precinct wall. Associated to the main structures were other features having multiple functions linked to social, productive and communal activities (Evans et al. 2019). A series of very rich infant burials situated around the sequence of buildings indicates the elite nature of this complex and provides evidence for social stratification (Mogetta 2020). At the end of the 6th c. BCE the complex was abandoned. Afterwards the area was briefly used as a burial ground and finally it was included in the planned orthogonal street grid but never re-occupied, leaving the area almost undisturbed until modern times (Evans et al. 2019).

The stratigraphic sequence is divided in four main chronological horizons that correspond to the different building phases **(Tab. 3.1)**. A blanket sampling strategy was implemented for the whole sequence. A sample of 20 L of sediment was collected from every Stratigraphic Unit (SU) and floated on site with a 0.25 mm mesh; the light fraction was processed and sorted in the lab with a 40x stereo microscope (Motta 2016; 2021). About 250 samples have been preliminarily screened for an assessment of the major crops; the full taxonomic identification of the archaeobotanical remains is still in progress. Among them we selected a subset of 37 samples for analysis. This subset is not homogeneously distributed across the phases **(Tab. 3.1)** and only the analysis of phase 4 has been almost completed (Bailey 2019).

Phases	**Years BCE**	**Contexts**	**Number of samples**	
			Archaeobotany	*Stable isotopes*
1	750-730/20	Multi-hut complex	8	3
2	730/20-640/30	Single hut compex	6	8
3	640/30-550	Stone building	2	6
4	550-500	Renovation of the stone building complex	21	5

Table 3.1. Gabii: Contexts and number of samples for each phase

Stable isotopes analysis: selection of the material and laboratory methods

Stable isotope ratio of certain chemical elements in plant tissues reflects the environmental and growing conditions in which they developed. In particular, research on modern cereals fields (mainly barley and naked wheat) shows that carbon stable isotope ratios ($\delta^{13}C$) can be used to assess water availability and to detect agricultural practices such as irrigation while nitrogen stable isotope measurements ($\delta^{15}N$) might reveal manuring practices (for the application of stable isotopes on archaeobotanical material see the exhaustive review work in Fiorentino et al. 2015; Ferrio et al. 2020). This information is preserved in the archaeobotanical remains, even after being buried and/or carbonized as demonstrated by experimental work (Fraser et al. 2013).

For the isotopic investigation of diachronic changes in farming practice at Gabii, it was of paramount importance to select crop remains that represented the growing conditions at the site through time, i.e. for each of the four phases of occupation. Previous case studies that applied this technique have focused on closed primary contexts such as storage containers and storerooms (for example Aguilera et al. 2018; Vignola et al. 2017). This could prove very challenging at Gabii, since primary contexts are not common and ubiquitous in multi-stratified urban sites where mixed secondary deposits are instead more frequent. Thus, for this research, priority has been given to the few closed contexts available including storage pits and negative features re-used as single dumps. When primary deposits were not available, the taphonomy and formation processes of the carpological assemblage was assessed for each SU. In addition, parameters such as unusually high density of charred crop remains and preservation index of the caryopses were used to identify contexts likely to represent single synchronous actions. According to these criteria, 22 SUs were selected for stable isotope analysis, spanning the whole chronological range. The nature and complexity of the stratigraphy, as well as the need for a detailed chronological resolution, lead to the decision to carry out grain-by-grain measurements to assess variability inside each context and in order to avoid averaging isotopic values coming from possible residual material. Barley *(H. vulgare*) and emmer (*T. dicoccum*) were chosen as they were the staple cereals in the region.

At least four caryopses for each taxon were selected in every SU. Each specimen was chemically treated in order to remove the contaminants potentially present in the soil (Vaiglova et al. 2014) using an Acid-Base-Acid treatment, based on Vignola et al. (2018) protocol adapted for cereal grains. The chemical treatment took place at the Laboratory of Palaeobotany and Palynology, Sapienza University of Rome, Italy. The treated caryopsis was then crushed into a homogenous powder to run the stable isotope analysis that was performed at the IGAG (Istituto Geologia Ambientale e Geoingegneria, CNR, Italy). Either two or three measurements were done on each grain. For each run 1.30 mg of grain powder was weighted and analysed using continuous-flow isotope ratio mass spectrometry (Thermo Flash 1112 - Elemental Analyzer coupled to a Finnigan Delta+ mass spectrometer). Isotopic compositions were expressed in the usual δ notation, which represents the relative deviation, in part per thousand of the heavy isotope:light isotope ratio of the samples with respect to a reference standard. Isotope data were normalised to the Vienna Pee-Dee Belemnite (V-PDB) scale for C and AIR (Atmospheric air) scale for N using IAEA standards (CH-6, CH-7, USGS-24 for C, and N-1, N-2, USGS25 for N). On the basis of repeated measurements of laboratory standards, the analytical error was

<0.3-‰ for both C and N. The $\delta^{13}C$ variation of atmospheric CO_2 during the Holocene was taken into consideration and the $\Delta^{13}C$ was calculated following Farquhar's equation (Farquhar et al. 1982). The %C and %N were also measured and C:N molar ratio was calculated.

Statistical analysis

Statistical analysis was performed on the dataset using the statistical program R (4.0). The Pearson correlation test was used to investigate correlation between %C - %N, and $\delta^{13}C$ - $\delta^{15}N$. The student test was applied to compare the mean of two groups with a normal distribution and the same variance. Finally, in order to compare the mean of multiple groups with normally distributed data and the same variance, a one-way ANOVA (analysis of variance) was used.

Results

The main crops

The preliminary screening of 250 samples, representing the four phases of occupation, provides information about the major agricultural products. It is not surprising that the frequency of taxa in the samples indicates that cereals are the most important crop and predominate in the assemblage **(Fig. 3.3)**. The main staples are hulled barley (*Hordeum vulgare* L.) followed by emmer (*Triticum dicoccum* Schrank), millets (*Panicum miliaceum* L. and *Setaria italica* L.) and finally some einkorn (*Triticum monococcum* L.). These taxa are common in all phases, even if einkorn is only represented by a few caryopses. Millet seems to increase in frequency through time and it is found in more than 50% of the samples of phase 4. However, this can be the result of a smaller number of phase 1 samples being screened and/or a preservation bias.

The second major group of staple crops, in proportion and ubiquity, are the pulses but they are not as abundant as cereals. The two main taxa identified are fava bean and bitter vetch (*Vicia faba* L. and *Vicia ervilia* (L.) Willd.) with fava bean being always the most common and abundant legume in all phases.

The analysis of the selected subset of 37 samples from area C and D has produced more than 11000 new carpological identifications. The preservation of most of the material is rather poor, the remains are fragmented and deformed by the process of carbonization. The range of taxa is limited and consistent throughout the samples**.** The results support the patterns shown in the ubiquity graph **(Fig 3.3)**, confirming the importance of barley, emmer, millet, bitter vetch and fava bean. A few grains of einkorn, the common pea, *Lathyrus oleraceus* Lam. (syn. *Pisum sativum* L.), and lentil, *Vicia lens* (L.) Coss & Germ. (syn. *Lens culinaris* Medik.) were also identified in different samples. The arboreal taxa are an extremely small fraction of the remains and include grape vine (*Vitis vinifera* L.), cornelian cherry (*Cornus mas* L.) and elderberry (*Sambucus* sp.). Specifically, *V. vinifera* is fairly ubiquitous but quantitatively not relevant. The assemblage is characterized by low proportions of crop processing debris and the variety of weed taxa is extremely scarce. The most recurrent, and quite numerous, is darnel (*Lolium temulentum* L.).

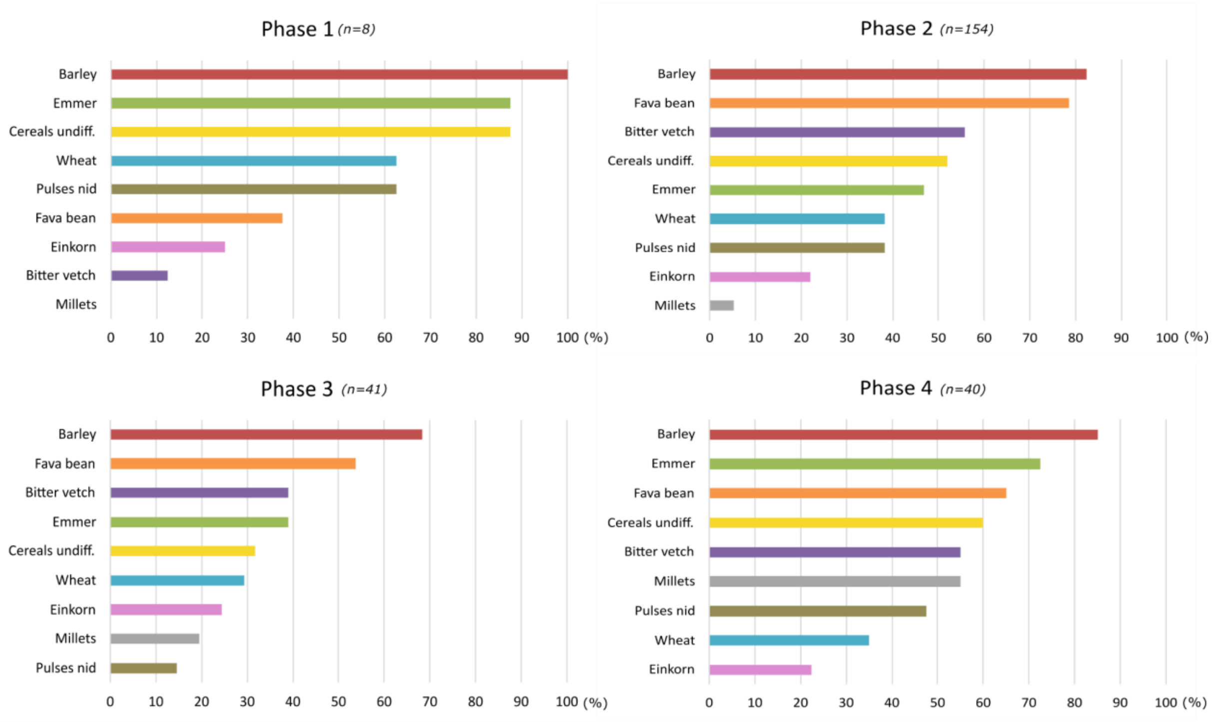

Figure 3.3. Gabii: Area C and D. Ubiquity of the main staple crops.

The C and N isotope analysis

The isotopic measurements are listed in table 1 supplementary material, while the means calculated by SU and by phases, are presented in **table 3.2 supplementary material**. The results of the statistical tests are summarized in table 3 supplementary material**.** The values range from -25.6 to -21‰ for δ^{13}C and from -3.9 to 8.2‰ for δ^{15}N which is consistent with values obtained on C_3 cereal plants non-fixing nitrogen (Bender 1971). The C:N ratio is consistent with the one observed in modern cereals with a mean of 32.5‰ for barley (against 33.3‰) and 28.1‰ for emmer (against 26.8‰) (Fraser et al. 2013; table 4 supplementary material). There is no statistical correlation between the different parameters tested in the assemblage (δ^{13}C, δ^{15}N, %C and %N; table 3 supplementary material) or within periods.

Variability within the assemblage

In this study the basic unit of investigation is a single cereal grain from contexts that are not necessarily representing a distinct stored harvest, requiring the assessment of the variability within each SU. Looking at figures 4 and 5, it is apparent that the variability within SUs is not consistent: the standard deviations range from 0 to 1.3‰ for Δ^{13}C and from 0.3 to 4.8‰ for

$\delta^{15}N$. In general terms, $\delta^{15}N$ seems to be more variable than $\Delta^{13}C$. A few SUs show extremely homogeneous data (for example SU 2901 for emmer, 2821 for barley).

The variability between SUs within each phase is also important to assess. While there are not enough data points in each SU to test if the variability is statistically significant, figures 4 and 5 show an apparent homogeneity between SUs in the same phase. Only SU 2903 for phase 1 and SU 3057 for phase 3 stand out with a higher $\Delta^{13}C$ for emmer.

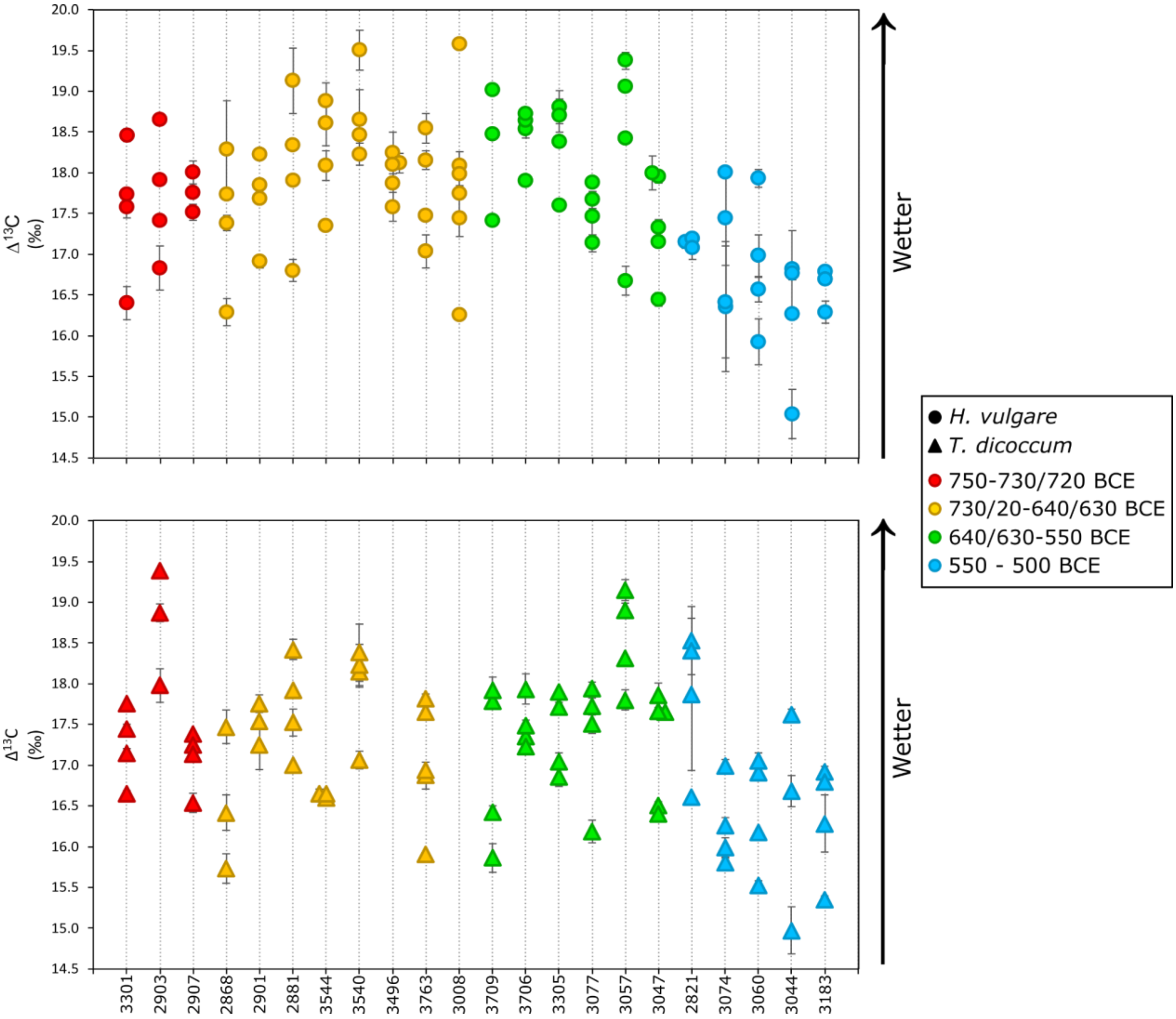

Figure 3.4. Gabii: Carbon stable isotopes results for barley and emmer. Each dot or triangle is the mean of the 2- 3 measurements on each grain.

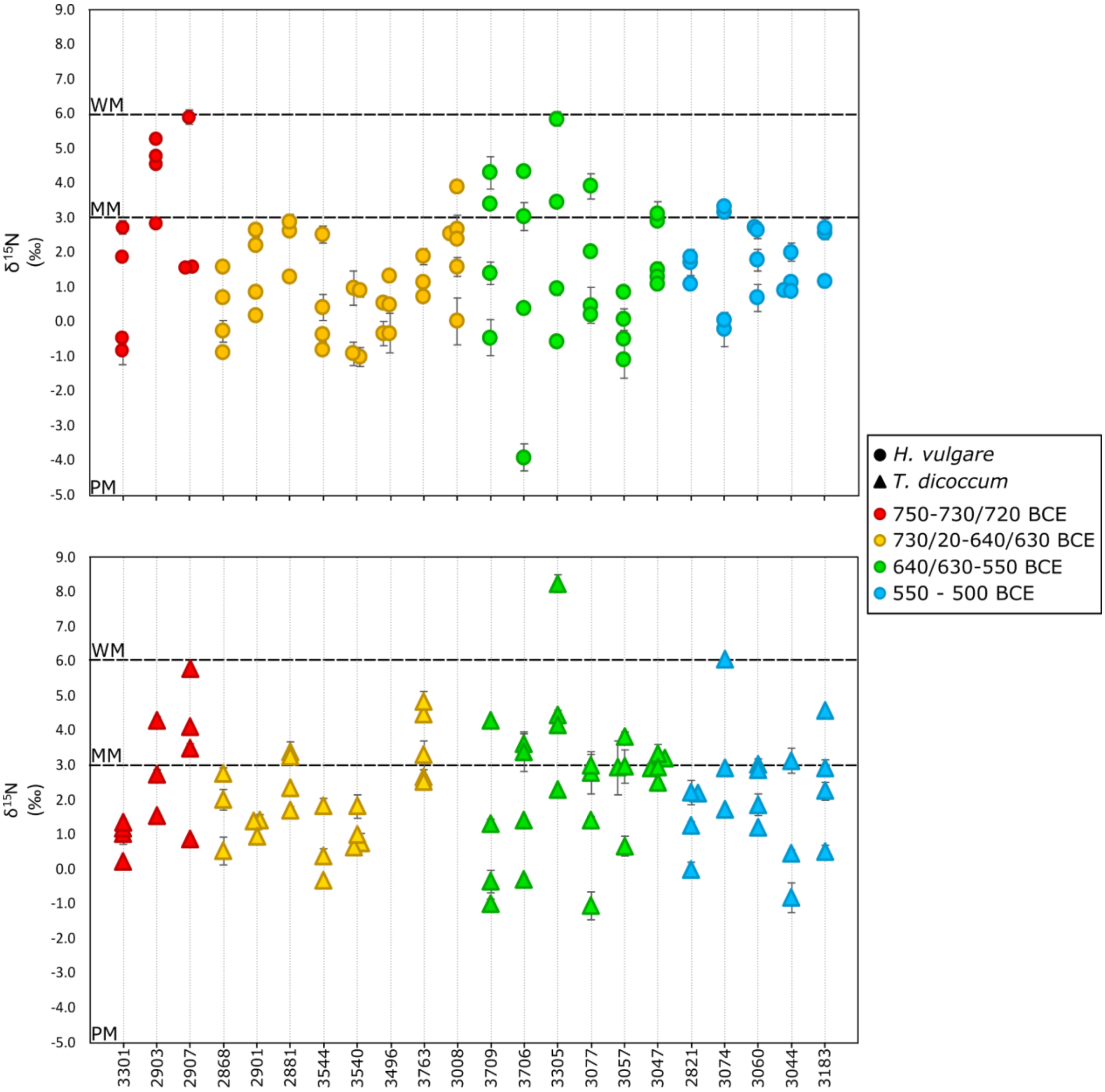

Figure 3.5. Gabii: Nitrogen stable isotopes results for barley and emmer. Each dot or triangle is the mean of the 3 measurements on each grain. Dashed lines represent the thresholds for manuring: PM, poorly manured; MM, moderately manured, WM; well manured (Bogaard et al. 2013).

Changes between phases

Both **figures 3.4** and **3.6** present a trend in the $\Delta^{13}C$ results. There is no clear difference for barley between phases 1, 2 and 3. However, the grains belonging to phase 4 show lower values compared to the other phases. This drop is statistically significant as confirmed by the ANOVA test **(Tab. 3.3 supplementary material)**. The same trend is visible for emmer with a $\Delta^{13}C$ lower in phase 4 than in all the other phases. However, its drop is less pronounced as only phase 1 and 3 are significantly different from phase 4 according to the statistical test. Differences in $\delta^{15}N$ are less noticeable. The $\delta^{15}N$ mean of barley in phase 2 is lower than in all the other phases. However, the only statistically significant difference is between phase 1 and 2. It does not seem that any distinction can be made across time for emmer **(Fig. 3.6)**.

Difference between barley and emmer

Overall, barley has a $\Delta^{13}C$ mean higher than emmer, as expected. Specifically, figure 6 shows that barley grains have a $\Delta^{13}C$ higher than emmer in each period except in period 4 where their means are similar. Statistically, the difference between emmer and barley is confirmed in phases 2 and 3 **(Tab. 3.3 supplementary material)**. Conversely, barley grains generally present lower $\delta^{15}N$ values than emmer **(Fig. 3.6)**. Looking at each phase, emmer has higher mean than barley in phase 2 and in phase 3, but not in phase 1 where it is actually lower.

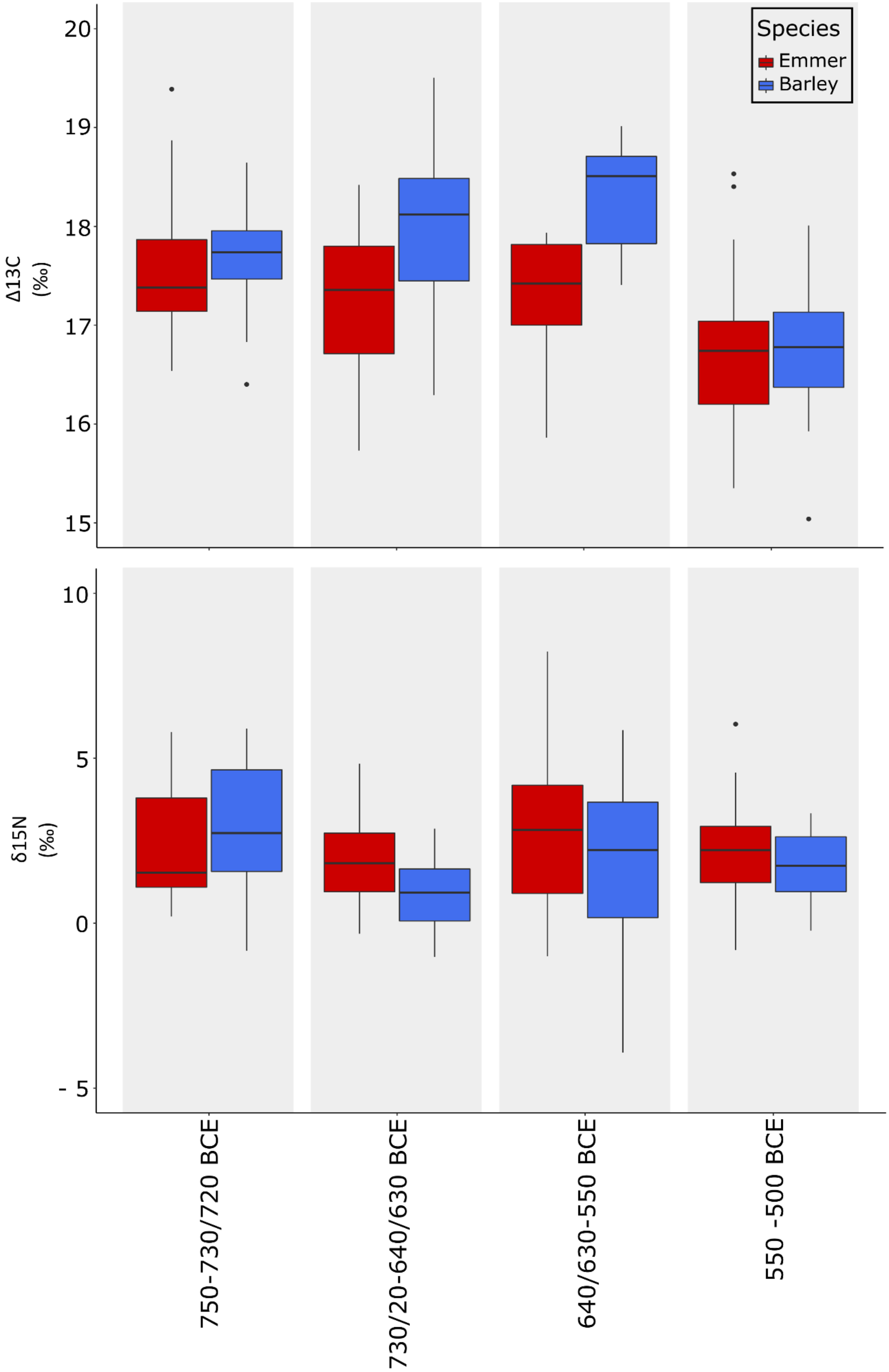

Figure 3.6: Gabii Carbon and nitrogen stable isotopes results for barley and emmer by periods. The dots represent outliers.

Discussion

The taxonomic identifications support, for the most part, previous findings from other minor Iron Age and Archaic archaeobotanical contexts from Gabii (Cullen 2016; Motta et al. 2021). No major shifts across time are visible in the proportion of staples; among the limited crop spectrum, barley remains the most common and abundant cereal throughout the period. Pulses and millet increase in frequency from phase 1 to phase 4. This trend might be biased, as suggested by the ongoing work on some phase 1 and 2 assemblages from area C (not included in this study) that are very rich in fava beans. The conspicuous amount of millet in phase 4, on the other hand, might be related to specific activity areas within the 6th c. BCE stone building complex. It is very interesting that three staple crops -barley, bitter vetch, and millet- deemed of minor importance in the later Roman diet by modern scholarship, play a major role at Gabii in the Iron age and Archaic period. In other contemporary urban contexts, emmer is instead more common, while bitter vetch is clearly a minor crop (i. e. Rome, Caere, and Tarquinii. Izzet 2000; Motta 2002; Rottoli 2005) and millet is represented only by a handful of seeds from Rome (Costantini and Giorgi 2009).

The main cereal crops, barley and emmer, show a wide range of Δ^{13}C and δ^{15}N values and their dispersion might be challenging to interpret in relation to changes in farming practices. Before looking at changes among phases, which group together many SUs, it is important to assess the variability within each SU since the means calculated on data with high standard deviation can mask trends through time. A few experimental comparative studies on modern samples, dealing with variability within and between harvests using a grain-by-grain approach, provide some perspective (Bogaard et al. 2007; Heaton et al. 2009). At Gabii, most of the Δ^{13}C standard deviations within a sample are below or equal to 0.7‰ **(Tab. 3.2 supplementary material)**. According to Heaton et al. (2009) this is the highest standard deviation identified between plants from the same field and among cereal grains randomly selected from a single harvest. It follows that a standard deviation above this value would indicate grains coming from different harvests. On the other hand, Δ^{13}C values close to each other might be inconclusive as they can still represent different geographical locations and different harvest years. In our dataset, very few SUs stands out for their higher standard deviation that in some cases is truly due to a wide range of values; in others, it is one single grain that is responsible for it; sometimes grain dispersion creates two clusters of values. This variability could represent not only mixing of cereals from multiple harvests and a different spatial or temporal origin of the grain, but also older reworked material.

The variability of δ^{15}N can be higher than the Δ^{13}C one depending if the fields were manured or not (Bogaard et al. 2007). Here, the standard deviations range from 0.3 to 3.6‰ within SUs, and are most of the time around 1.3‰. Thus, the variability in Gabii's grains could be consistent with the one observed between two plants coming from a manured plot or with grains coming from different periods or locations. Finally, it should be noted that, in addition to mixed and reworked material, other important factors could have influenced the values. The location of the crops at the top or at the bottom of a sloping field could affect the Δ^{13}C. The plants at the bottom might benefit from more water and thicker soil resulting in higher Δ^{13}C (Hartman and Danin 2010). Similarly, animal gathering might introduce some variability for the $\delta^{15}N$ in the same field. One other important source of variability in our contexts can be, of course, allochthonous imported material.

According to experiments carried out in modern cereal fields located in semi-arid regions barley plants with a $\Delta^{13}C$ over 18.5‰ reflect excellent water availability while suffering from hydric stress when values are under 17.5‰ (Wallace et al. 2013). If the same thresholds are applied to this study, during phases 1, 2 and 3 barley grains seem to have grown in an environment where the water supply was not limited. It should be noted, however, that Gabii is located in a different climatic region and these thresholds might be misleading. Still, it can be said that the water conditions in phases 1 to 3 did not change for barley. As $\Delta^{13}C$ values reflect all the different water inputs, it is not possible to determine if the water availability was environmental or related to agricultural practices (Flohr et al. 2011; 2019; Wallace et al. 2013). The drop in the $\Delta^{13}C$ values identified in phase 4 thus implies a worsening in water condition. Emmer follows the same trend as barley, even if the deterioration of the water availability observed in phase 4 is less evident. The fact that both plants are affected by this drop suggests a general event. A decrease in precipitation (annual or season) is an obvious consideration, however it is challenging to synchronize this kind of results with climate event. The scale covered by climatic studies is usually at a lower temporal and geographical resolution whereas $\Delta^{13}C$ is more suitable for local parameters (Flohr et al. 2011; 2019; Wallace et al. 2013). Even the rapid climate change (RCC) episodes that have been recently recognized in the Central Mediterranean and the phases of increased precipitation recorded between the 8th and 4th c. BCE in central Italian lakes (Magny et al. 2013) lack the chronological discrimination needed for a more precise correlation. The isotopic investigation of other contemporary contexts in the region will elucidate if the deterioration is related to a general environmental shift. Indeed, the drop might denote a more circumscribed phenomenon such as a variation in the water table due to improved drainage or to increased use of water resources. More simply, it might indicate water management practices in the previous periods that stopped to be implemented in phase 4.

The two staples display some expected pattern in their $\Delta^{13}C$ with barley values being higher. There is a little modern data available that compares $\Delta^{13}C$ ranges in emmer and barley grown in the same conditions. However, it is known that emmer is less tolerant to drought than barley (Riehl 2009), its values are then assumed to be lower under the same conditions. In phase 4, no significant difference in $\Delta^{13}C$ exists between barley and emmer as, instead, it should be expected **(Fig. 3.6)**. A similar pattern in phase 1 is not significant due to the dispersion of the data; see **Tab. 3.3 supplementary material** for the statistical tests). Together with the observed drop in values, this offers a stronger indication for a change in crop management compared to the other phases. Emmer cultivation could have benefited from a greater attention than barley in a situation of water stress. One possible explanation is that emmer could have been irrigated, though there is no structural evidence suggesting irrigation for this period in the hinterland of the settlement and the region has traditionally relied on rainfed agriculture. Otherwise, emmer could have been intentionally placed in fields having the highest water table. This supposition has been already advanced in other case studies (Masi et al. 2014).

We can only make conjectures about the location of the fields around Gabii. The flanks of the crater would have offered fertile soil for cultivation, but the slope would have been subject to erosion, runoff and surface water control issues as suggested by the common occurrence in the settlement of drainage features around built structures. On the other hand, naturally watered fields would have been available in the plain at Pantano Borghese, but with clay-rich, heavier soils. We do not have information about the extent of the wetland during the Iron Age and Archaic period, nor about the variation of the water table through time. We can assume that the transitional zone bordering the plain, between the foothill and the shore of the wetland, could have been an optimal location for agricultural fields with its rich colluvial volcanic soil and a high-water table. This multitude of field conditions might help explain the isotopic ratio variability in our assemblages.

The δ^{15}N are particularly low for both taxa, but still in the range observed in modern cereals (Bogaard et al. 2007; Fraser et al. 2011). No clear trend was identified through time except for the difference between periods 1 and 2 for barley with a higher δ^{15}N in period 1. This could be specifically due to SU 2903 which has particularly high values, being even above 6‰.

The value of δ^{15}N is a useful proxy when it is unusually high and then it is interpreted as evidence for manuring. Measurements on modern cereals (including *H. vulgare* and *T. dicoccum*) cultivated in N Europe offer the reference thresholds for manuring practices (Bogaard et al. 2013; Fraser et al. 2011). In contrast, the δ^{15}N at Gabii is in the medium to low range: most of the values obtained in our study are below 6‰ **(Fig. 3.5** and **3.6)** which suggest that barley and emmer did not receive high level and continuous application of manure. The majority of the data both for emmer and barley are even below 3‰ indicating plants that did not receive any manure (Bogaard et al. 2013). Some measurements correspond instead to the medium application of manure which could indicate either low level of manuring or a high application of manure but in a short period of time (Fraser et al. 2011).

Gabii values could in fact have multiple interpretations. The δ^{15}N could have been influenced by a panel of environmental parameters such as the pH, the nature of the soil, even the sloping topography (Amundson et al. 2003; Craine et al. 2015). Precipitation and water availability are also commonly invoked; however, in this study no correlation was found between the δ^{15}N and the δ^{13}C **(Tab. 3.3 supplementary material)** that might suggest that the low δ^{15}N is influenced by a particularly humid environment. Also, it is important to note that we do not currently have δ^{15}N for the non-cultivated environment at Gabii to establish a baseline, nor local reference thresholds available.

Moreover, the Gabines might have favoured other techniques to maintain the soil fertility in lieu of spreading animal manure that requires time and energy. Indeed, as Heinrich et al. (2021) point out, the absence of manuring evidence is not evidence for lack of enhancement of soil fertility. Other practices such as green manure or fallowing can improve N levels and fertility without affecting δ^{15}N. The use of pulses and wild fabaceae in green manure can even lead to a decrease in δ^{15}N in the soil and so in the plants cultivated in it (Riga et al. 1971). This is because plants of the legume family are able to form a symbiotic relationship with nitrogen-fixing soil bacteria hosted in nodules on the plant roots. The bacteria can convert the atmospheric nitrogen into ammonia that is then used by the plant (Wang et al. 2018). During the fixation of the atmospheric nitrogen (N_2) the isotope fractionation is very small (Kohl and Shearer 1980), leading to very low δ^{15}N in the plant, close to the value of atmospheric nitrogen which is around 0‰ (Virginia and Delwiche 1982). It is also very well possible that the bitter vetch and fava bean could have been grown either in rotation or together with the cereals in the same field in order to improve the quality of the soil; thus, this last practice could have affected the cereals $\delta^{15}N$. It was observed in different studies that the non-N_2 fixating plants (here cereals) growing together with pulses tend to have a lower $\delta^{15}N$ due to a transfer of nitrogen from the pulses to the non-legume plants growing nearby (Peoples et al. 2015). It should be added that the co-cultivation of wheat together with fabaceae used for fodder such as clover and grass pea is documented ethnographically in the mountains of Central Italy. After the harvest, the clover is left to grow in the field and the animals are allowed to graze in the stubble. Unfortunately, there are no specific wild fabaceae/weeds at Gabii that could help better understand the crop growing conditions. The most abundant weeds are *Lolium* sp. and *Avena sativa* which tolerate a wide range of environments.

Conclusion

A unique archaeobotanical dataset allows us to explore crop husbandry regimes at Gabii from the 8th to the 6th c. BCE. Major crops include a mix of cereals and pulses. No significant changes through time are observed; rather, the four phases of occupation of Area C/D show a noticeable consistency and persistence of traditional practices. The predominance of barley in the assemblages and the importance of bitter vetch and millet are noteworthy. The combination of staples observed at Gabii is different from the archaeobotanical data available in a few other early urban contexts in the area. It is a local mixture that does not seem dictated by major environmental constraints and that might be better explained by cultural preferences or specific exchange networks. While the settlement has a distinctive morphological setting with access to wetlands and, unlike other emerging urban centers, is located on a volcanic slope, rather than a plateau, this is not enough to warrant differential ecological requirements for the main staple crops. As a matter of fact, emmer would be better suited than barley to soils with poor drainage. It is not until later, in the 3rd-2nd c. BCE, that we can see a shift in crop preferences towards a crop blend more typical of Rome. The assemblage in area A at Gabii shows that the percentage of barley declines through time and in the Republican period there is a more pronounced preference for wheat. Millet and pulses decrease in importance as well (Motta et al. 2021).

Some hypotheses about crop management can be drawn from the results of the carbon and nitrogen stable isotope analysis. The cultivated plants appear to have grown in a good water status. Water availability does not seem to be linked to irrigation practices but more to the natural conditions at the site and the occurrence of fields with high water table. On the whole, the crops do not appear to have been manured and other techniques could have been used to improve the quality of the soil. We argue that crop rotation and intercropping pulses with cereals could have been one of such techniques.

The $\Delta^{13}C$ values attest to a shift in cultivation practices during the second half of the 6th c. BCE. A reduction in water availability affected both barley and emmer, but the latter was managed differently perhaps in order to maintain yields.

It is tempting to interpret these data as evidence of production stress to sustain urban expansion and demographic growth. Lodwick et al. (2021) define intensive agriculture, specifically in relation to cereal crops, as an increase of labor input in existing fields, while extensive methods increase the land under cultivation with low labour input per unit. The Gabines, thus, might have practiced intercropping with pulses to enhance productivity in their existing fields. On the other hand, since extensification involves an expansion of the farmed area, it is in reality the most suitable strategy to improve production on a large scale to meet demand of a growing population. Extensive agriculture is associated with the use of animal tillage, low manuring, and little weeding. The lack of evidence for manuring and the conspicuous presence of *Lolium sp.* described at Gabii could agree with this model. In this perspective, the drop in water availability recorded for phase 4 could be related to cultivation in new areas or in “second choice” fields (i. e. lower water table).

Yet, to better understand Gabii data, we need to move outside the intensification of agricultural production framework of economic growth for the early urban centers. The archaeological evidence does not substantiate a dramatic increase in population; the transition in building techniques, from huts to houses, does not correspond to a higher density of habitation in the settlement. The consistency of crop preferences across the entire period suggests continuity rather than necessary adjustments to meet increased demand. The same can be observed for animal husbandry that remains focused on ovi-caprines (Samuel et al 2021(b); for a regional overview and the importance of pigs, de De Grossi Mazzorin and Minniti 2017; Trentacoste 2020). At the very end of the 6th c. BCE the structures in area C/D are abandoned. There are some suggestions that the whole settlement entered a period of crisis possibly connected to regional warfare and internal factional strife (Johnston and Mogetta 2020). Conflict might have indeed affected the management of agricultural fields and we suggest that socio-political events -definitely not demographic pressure- could have determined the shift in cultivation practices.

This study is an important starting point. The agricultural economy of the urban transition in western central Italy should be considered a multifaceted story of local nuances that shaped a regional long-term process.

The crop preferences and management practices that we see at Gabii are not necessarily representative of other emerging urban centers. More settlements should be sampled and analysed to fully understand crop husbandry regimes in this period of rapid socio-economic transformation and a regional perspective will also clarify the role of environmental and climatic variables.

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data availability statement: the complete isotopic dataset is provided in the supplementary material files. Excavation records and data for individual stratigraphic units, artefacts and ecofacts are available from the project’s database at https://gabii.cast.uark.edu/data/

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Chapter 4

Growing Early Rome: agriculture and isotopes during the Iron Age

Introduction

In the last decades urban excavations in the core of modern Rome have revealed important evidence for the first phases of occupation of a proto-historic settlement system that shed new light on the nucleation processes of the ancient city. Whilst Iron Ages (IA) huts have been known since the early '900 on the eastern side of the Palatine hill, the recent investigations on the Capitoline hill (Cazzella et al. 2007), Forum of Caesar (De Santis et al. 2010) and Northern slope of the Palatine (Carafa and Carandini 1995) offer substantial traces of domestic, productive and ritual activities dated between the Final Bronze Age and the Orientalizing period. This evidence considerably expands what is known from Late Bronze Age funerary contexts. Particularly relevant seems to be the role of the Palatine Hill where, on the NE corner (Pendici Orientali), patches of undisturbed deposits were spared by the later Republican and imperial building activities. Here, new excavations revealed a series of superimposed huts, constituting the earliest and most complete stratigraphic sequence of the protohistoric settlement (Sagui et al. 2014). Particular attention has been paid to the retrieval of plant and animal remains to investigate the subsistence economy during this crucial formative period for the development of the settlement.

In this study we report a unique archaeobotanical dataset from domestic contexts spanning the first two centuries of habitation (10th-9th c, BCE) that allow a first insight on staple crop production at the dawn of urban life. We integrate the archaeobotanical results with carbon and nitrogen stable isotope analyses ($\Delta^{13}C$ and $\delta^{15}N$) on charred cereal grains dated between the 10th and the 7th c. BCE to reconstruct Early Rome's agricultural systems and their environmental settings.

The site

The archeological excavation at the NE slope of the Palatine Hill, conducted by Prof.ssa Panella, has exposed a complex stratigraphic sequence of habitation deposits. A series of huts with domestic function, as suggested by the internal hearth, faces the valley between the Palatine and the Velia towards the Colosseum. They are situated on a sloping area which underwent different episodes terracing and leveling in order to expand the buildable area. Several phases of hut construction and destruction have been identified, associated with large oval pits filled with discarded building material and with domestic waste; they are separated by obliteration and leveling fills. All the structures have a rectangular plan with an apse-shaped end and four supporting central posts. The first two huts are dated 925-875 BCE (blue phase in **figure 4.1**) based on ceramic typology. They are followed, roughly every 25 years, first by a single structure with the same orientation a little bit further north (green phase in **figure 4.1**). Later, and superimposed with a changed orientation, are the last two huts (orange and red in **figure 4.1**).

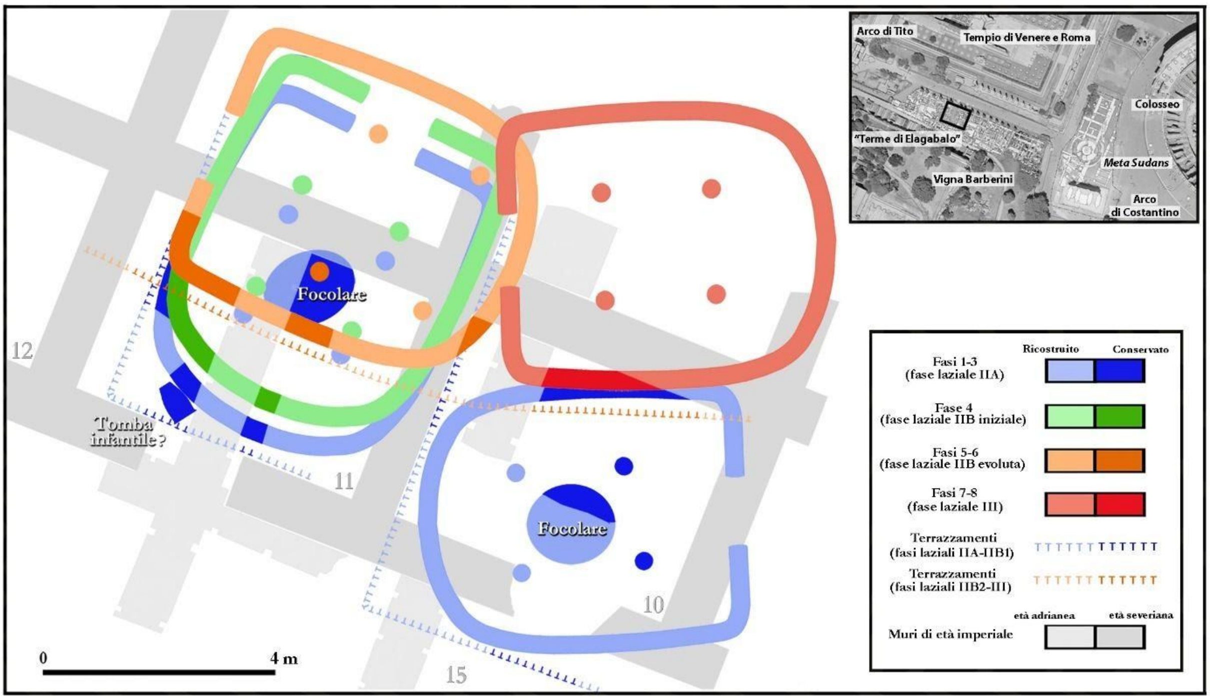

Figure 4.1: NE slope of the Palatine Hill, Vano 11.

Materials and methods

The archaeobotanical samples come from the different contexts described above located in the vano 11. In total 6 excavation phases, related to different activities in the construction, life and destruction of the huts, were documented; for this study they have been clustered according to three main chronological intervals that correspond to the superimposed periods of habitation (blue, green, and orange in **figure 4.1**; **table 4.1**). Samples from the Latial phase III (from vano 10, in red on **figure 4.1**), were not available for this study.

Dates	Latial periods	Excavation Phases	Sampled SUs		
			Archaeobotanical study	Stable isotope analysis	
				Barley	Emmer
925-875 BCE	IIA1-A2	1-3	45	22	17
875-850 BCE	IIB1	4	9	3	3
850-820 BCE	IIB2	5-6	17	12	12
770-730/20 BCE	III	*	*	3	1
730/20-630/20 BCE	IVA	*	*	3	4

Table 4.1: NE slope of the Palatine. Excavation phases 1-3 correspond to the blue hut phase in fig 1**;** phase 4 corresponds to the green phase; phases 5-6 correspond to the orange phase; ***** samples from the N slope of the Palatine excavations published in Motta (2011).

Phases	SU	Chronology	Description	Acronyms
1	40388	Latial phase IIA1 (925-900 c. BCE)	Fill pit 1	FILL P1
1	40546	Latial phase IIA1 (925-900 c. BCE)	Fill pit 2	FILL P2
1	40533	Latial phase IIA1 (925-900 c. BCE)	Fill pit 3	FILL P3
1	40544	Latial phase IIA1 (925-900 c. BCE)	Fill pit 4	FILL P4
1	40529	Latial phase IIA1 (925-900 c. BCE)	Fill pit 5	FILL P5
1	40530	Latial phase IIA1 (925-900 c. BCE)		
1	40535	Latial phase IIA1 (925-900 c. BCE)	Fill pit 6	FILL P6
1	40525	Latial phase IIA1 (925-900 c. BCE)		
1	40532	Latial phase IIA1 (925-900 c. BCE)	Infant burial	Burial
1	40524	Latial phase IIA1 (925-900 c. BCE)		
1	40539	Latial phase IIA1 (925-900 c. BCE)	Fill pit 7	FILL P7
1	40538	Latial phase IIA1 (925-900 c. BCE)		
1	40542	Latial phase IIA1 (925-900 c. BCE)	Fill pit 8	FILL P8
1	40513	Latial phase IIA1 (925-900 c. BCE)		
1 o 2	40527	Latial phase IIA1 (925-900 c. BCE)	Fill of a possible posthole	PH
1 o 2	40390	Latial phase IIA1 (925-900 c. BCE)	Fill pit 9	FILL P9
1 o 2	40470	Latial phase IIA1 (925-900 c. BCE)		
1 o 2	40473	Latial phase IIA1 (925-900 c. BCE)		
1 o 2	40469	Latial phase IIA1 (925-900 c. BCE)		
1 o 2	40389	Latial phase IIA1 (925-900 c. BCE)		
2	40510	Latial phase IIA1 (925-900 c. BCE)	Levelling fills for the construction of a hut	FILL LEV1
2	40509	Latial phase IIA1 (925-900 c. BCE)		
2	40508	Latial phase IIA1 (925-900 c. BCE)		
2	40507	Latial phase IIA1 (925-900 c. BCE)		
2	40506	Latial phase IIA1 (925-900 c. BCE)		
2	40505	Latial phase IIA1 (925-900 c. BCE)		
2	40503	Latial phase IIA1 (925-900 c. BCE)		
2	40502	Latial phase IIA1 (925-900 c. BCE)		
2	40501	Latial phase IIA1 (925-900 c. BCE)		
2	40500	Latial phase IIA1 (925-900 c. BCE)		
3	40512	Latial phase IIA2 (900-875 c. BCE)	Fill pit 10	FILL P10
3	40520=40517	Latial phase IIA2 (900-875 c. BCE)		
3	40519	Latial phase IIA2 (900-875 c. BCE)		
3	40515	Latial phase IIA2 (900-875 c. BCE)		
3	40514	Latial phase IIA2 (900-875 c. BCE)		
3	40511	Latial phase IIA2 (900-875 c. BCE)		
3	40439	Latial phase IIA2 (900-875 c. BCE)	Fill pit 11	FILL P11
3	40438	Latial phase IIA2 (900-875 c. BCE)		
3	40437	Latial phase IIA2 (900-875 c. BCE)		
3	40436	Latial phase IIA2 (900-875 c. BCE)		
3	40435	Latial phase IIA2 (900-875 c. BCE)		
3	40522	Latial phase IIA2 (900-875 c. BCE)	Fill pit 12	FILL P12
3	40521	Latial phase IIA2 (900-875 c. BCE)		
3	40463	Latial phase IIA2 (900-875 c. BCE)		
3	40446	Latial phase IIA2 (900-875 c. BCE)		
4	40407	Latial phase IIB1 (875-850 c. BCE)	Construction of the hut	FILL LEV2
4	40396	Latial phase IIB1 (875-850 c. BCE)		
4	40416	Latial phase IIB1 (875-850 c. BCE)		
4	40405	Latial phase IIB1 (875-850 c. BCE)	Life of hut	HUT
4	40399	Latial phase IIB1 (875-850 c. BCE)		
4	40379	Latial phase IIB1 (875-850 c. BCE)	Obliteration of the hut	OBL
4	40365	Latial phase IIB1 (875-850 c. BCE)		
4	40364	Latial phase IIB1 (875-850 c. BCE)		
4	40415	Latial phase IIB1 (875-850 c. BCE)		
5	40440	Latial phase IIB2 (850-820 c. BCE)	Setting of the terracing and traces of a similar structure but prior to phase 6	TR
5	40442	Latial phase IIB2 (850-820 c. BCE)		
5	40432	Latial phase IIB2 (850-820 c. BCE)		
5	40422	Latial phase IIB2 (850-820 c. BCE)		
5 o 6	40489	Latial phase IIB2 (850-820 c. BCE)	Fill pit 13	FILL P13
5 o 6	40487	Latial phase IIB2 (850-820 c. BCE)		
5 o 6	40486	Latial phase IIB2 (850-820 c. BCE)		
5 o 6	40485	Latial phase IIB2 (850-820 c. BCE)		
5 o 6	40484	Latial phase IIB2 (850-820 c. BCE)		
5 o 6	40483	Latial phase IIB2 (850-820 c. BCE)		
5 o 6	40452	Latial phase IIB2 (850-820 c. BCE)		
6	40391	Latial phase IIB2 (850-820 c. BCE)	Construction of the hut	FILL LEV3
6	40371	Latial phase IIB2 (850-820 c. BCE)		
6	40369	Latial phase IIB2 (850-820 c. BCE)		
6	40367	Latial phase IIB2 (850-820 c. BCE)		
6	40370	Latial phase IIB2 (850-820 c. BCE)		
6	40374	Latial phase IIB2 (850-820 c. BCE)		

Table 4.2: NE slope of the Palatine. SUs composition and chronology of the different contexts.

Sampling strategy and field methods

During the excavations, soil samples were retrieved for the archaeobotanical study using a blanket total method, which means that every stratigraphic unit (SU) was sampled. A standard volume of 6l of sediments was collected except for a few exceptions (**Tab. 4.3**). For this study, a total of 84 samples collected between 2017 and 2018 were selected, they are coming from 71 SUs and 21 contexts (**Tab. 4.2**).

Given the high amount of clay in the sediments, it was necessary to use a chemical treatment in order to help its deflocculation. The sediment samples were mixed with 10% sodium bicarbonate and hot water and stirred until the sediment was entirely soaked. The samples were then floated in order to separate the charred plant parts from the heavier materials (rocks, ceramics fragments) with the overflow method. The water is then stirred and poured over the edges of the bucket into a sieve with a mesh of 0.25 mm where the light fraction is caught while the heavy fraction stays at the bottom of the bucket and it is subsequently water screened on a 1 mm mesh.

Sorting, identifications and quantification of the plant remains

The light fraction, consisting mainly of charred remains, small roots and small parts of modern plants, was sorted under a stereomicroscope (10X-60X magnification) and when possible, the different charred fruits and seeds were identified using reference collection and atlases. The heavy fraction was also sorted in order to collect the charred legumes and cereals that could be still imprisoned by clay and therefore not have floated.

The preservation of the material was rather poor. This led to some difficulties in the identification and quantification of the material. In particular, cereal caryopsis were very often broken, their surface was damaged and eroded, their shape was deformed due to the carbonization and most of the time they were still dirty with some crust of sediment. The majority of the caryopses were placed in the “cereal nid” category because, whilst the presence of some characteristics allowed us to identify them as cereals (presence of a groove, shape, size, embryo), they were too destroyed to be identified to a more precise taxonomic level. An overrepresentation bias in favor of barley could exist between barley and emmer. The first is, indeed, more easily identifiable than the second one, for which the identification had to be done more carefully as other species of wheat, very difficult to distinguish, are also present. As a consequence, a lot of caryopses were attributed to the category *Triticum* sp. It is, therefore, possible that emmer was underestimated. The differentiation between spelt and emmer was challenging, especially due to the preservation of the material. Their shapes are similar and the chaff did not allow to clarify the proportion of each species as their preservation was also poor. A category *T. dicoccum*/*spelta* was then created in which the problematic caryopses were placed. Finally, due to the issues in preservation, the distinction between *Phalaris* sp. and *Alopecurus* sp. was not possible. They are regrouped in the group *Phalaris/Alopecurus*.

Cynodon dactylon represents an item measuring less than 1 mm. A group *Phalaris*/*Cynodon* for intermediate size and shape was also created.

For the quantification of the cereals the minimum number of individuals method was used. It means that (1) each complete cereal caryopsis was counted as one, (2) when a half of a caryopsis was found, and did not obviously belong to any other half, it was also counted as one. The fragments that were smaller than a half were counted as "fragments". Legumes follow the same principle, not only was a seed composed of two cotyledons counted as one, but also one cotyledon alone. More fragmented cotyledons were counted as "fragments". Chaff was counted according to glume bases and spikelet forks specimens. The chaff/seed ratio for *T. dicoccum* and *T. monococcum* was calculated according to the van der Veen method (2007). For the rest of the taxa each item was counted as one and as soon as it was broken it was considered as a fragment.

Stable isotope analysis

The cereal species selected for the stable isotope analysis are *T. dicoccum* and *H. vulgare* as they are the most abundant and ubiquitous crop remains among all the samples. The SUs investigated through the $^{13}C/^{12}C$ and $^{15}N/^{14}N$ ratios were chosen among the contexts analyzed for the archaeobotanical study. They are for the most part, pits that were filled with domestic waste and elements coming from the dismantlement of huts which had a lifespan of ca. 20 years. These contexts represent, therefore, a single action defined in time and the archaeobotanical material found inside comes from a limited period of time. In total 37 SUs were chosen for their higher densities of material and their better preservation.

Seven samples from previous excavations at the Northern slope of the Palatine and dated from the 8th and 7th c. BCE were added to this study to cover a broader chronological range. The addition of this material was motivated by the environmental reconstruction of the two areas where the huts were found, which demonstrated that they were benefiting from very similar conditions, with a similar setting, morphology and soil (**Fig. 4.11**). They were both situated at the lowest part of the slope of Palatine hill, near a creek, the one from the NE slope used to go toward the Colosseum valley while the one from the N slope used to flow toward the Forum. The excavations were under the direction of A. Carandini and preliminary carpological results were published by L. Motta (2011) (**Tab. 4.1**). A total of 43 contexts for barley and 37 contexts for emmer were analyzed, the number of grains by SU is variable and depend on the availability and preservation of the material. It ranges between 2 up to 10 grains with a majority of SUs having 4 grains analyzed.

Each caryopsis underwent an ABA chemical treatment, based on Vignola & al. (2018) protocol in order to remove the possible contaminants present in the soil. The chemical treatment took place at the Laboratory of Palaeobotany and Palynology (Sapienza University of Rome, Italy). The treated grain was then crushed into a homogenous powder to homogeneize the isotopic signal of the entire caryopsis. Two or three measurements were carried out for each sample. The stable carbon and nitrogen isotope analysis was performed at the IGAG (Istituto Geologia Ambientale Geoingegneria, CNR of Montelibretti, Italy) with IRMS (Isotope-Ratio Mass Spectrometry). For each run 1.30 mg of grain powder was weighted and analyzed using continuous-flow isotope ratio mass spectrometry (Thermo Flash 1112 - Elemental Analyzer coupled to a Finnigan Delta+ mass spectrometer). Isotopic compositions were expressed in the usual δ notation, which represents the relative deviation, in part per thousand of the heavy isotope:light isotope ratio of the samples with respect to a reference standard (. Isotope data were normalized to the Vienna Pee-Dee Belemnite (V-PDB) scale for C and AIR (Atmospheric air) scale for N using IAEA standards (CH-6, CH-7, USGS-24 for C, and N-1, N-2, USGS25 for N). On the basis of repeated measurements of laboratory standards, the analytical error was <0.3‰ for both C and N. The δ^{13}C variation of atmospheric CO_2 during the Holocene was taken into consideration and the Δ^{13}C was calculated following Farquhar's equation (Farquhar et al. 1982). The %C and %N were also measured and C:N molar ratio was calculated.

Archaeobotanical study

An overview of the archaeobotanical findings

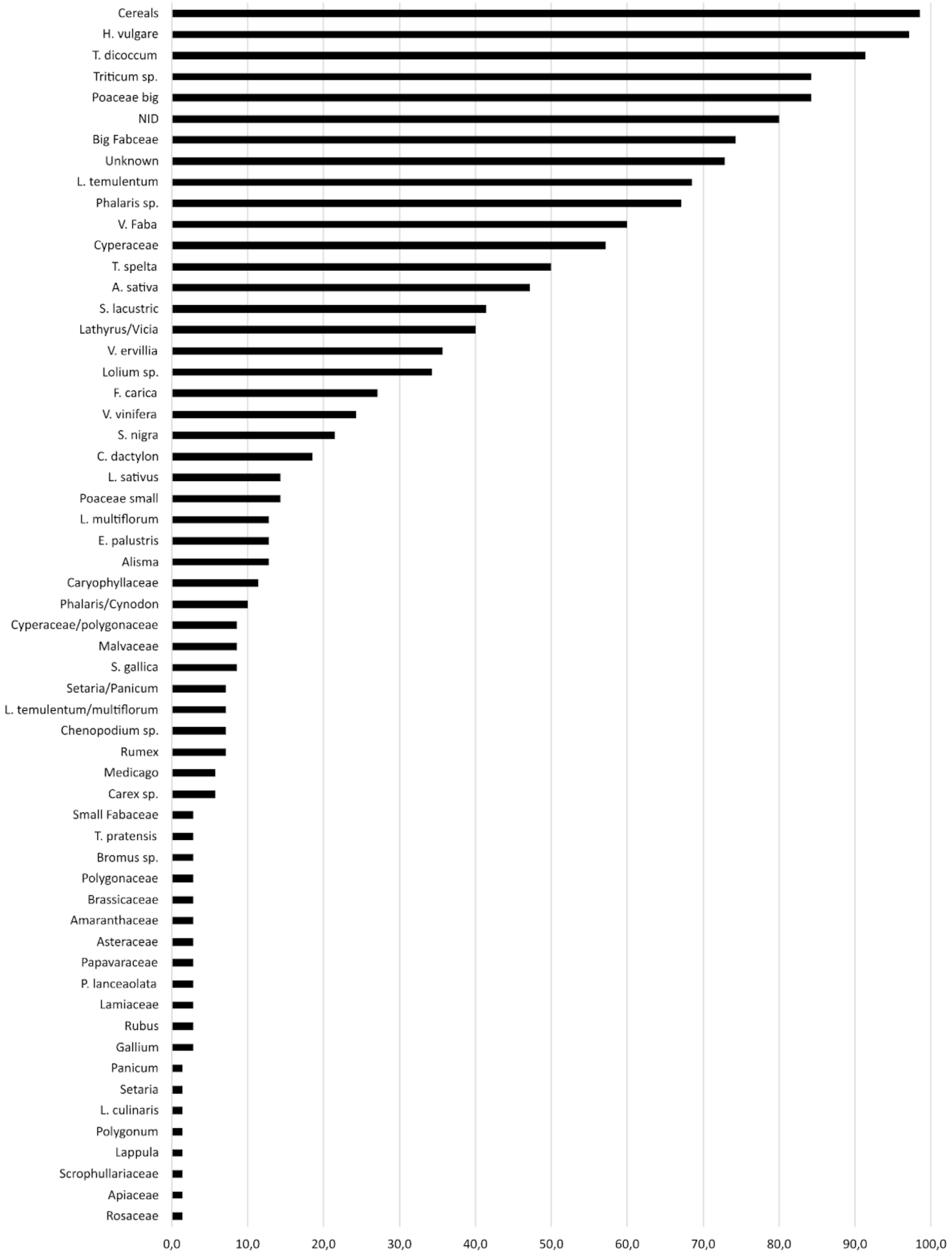

Figure 4.2: NE slope of the Palatine. Ubiquity graph.

The results of the archaeobotanical study show a prevalence of cereals, with hulled barley and emmer being the most common and abundant finding at the Palatine Hill in all periods (**Fig. 4.2**), as it was often observed at this period in other sites of the region (Costantini & Giorgi 2009; Gaveriaux et al. forthcoming; Motta 2011). At the Palatine Hill, some twisted barley caryopses were found which attested the presence of 6-row barley. It is described as low crop status which was used both for human consumption and animal fodder. However, the results in this study and the ones obtained from other studies in the region show a quasi-omnipresence and abundance of this crop which could indicate that its importance was in fact crucial (Motta and Beydler 2020). Emmer is considered as a key crop for the past populations and is very often described as the favorite crop of the Romans. Besides emmer, other hulled wheats, spelt and einkorn, as well as free threshing wheat which is a naked wheat, make an appearance but in rather small quantities and just in a few samples (**Fig. 4.2**). Einkorn is represented only by scarce caryopses in a few samples (**Fig. 4.2**). The proportion of emmer and einkorn might indicate that the latest was a weed of emmer (Motta 2011). It seems that the Latins did not make a difference between the different species of hulled wheats. This information and the little quantity and occurrence of spelt and einkorn could suggest that they were growing together with emmer and were then processed and treated the same way. Only a handful of millet and naked wheat were found in a few SUs (**Fig. 4.2**). This quasi absence of millet shows that some specificities exist among sites. At Gabii at the same period (8^{th} - 6^{th} c. BCE), millet is present in rather large quantities (Gaveriaux et al. forthcoming). In terms of crops, legumes were also identified, fava beans being ubiquitous in the assemblage even if not always abundant (**Fig. 4.2**). It seems that they were a non-negligible part of the human diet during this period. Other legumes, even though less ubiquitous and abundant than broad beans, were identified such as bitter vetch and grass pea. Unlike broad beans, it is less clear if the other legumes were used for human consumption seeing the scarce findings. It could have been used as an animal folder for example. Different weeds were also identified in the assemblage, such as *Lolium temulentum* and *L. multiflorum* which are present in most of the samples (**Fig. 4.2**). This is not surprising as *Lolium* is often found in association with emmer in carpological assemblages. *Phalaris*/*Alopecrus* seeds were also well represented in the assemblage. Finally, *Avena sativa* (oat) is also present and is represented both by awns and caryopsis (**Fig. 4.2**). Even if it can be cultivated, in this case, seeing the rather scarce results, oat seems to have grown together with emmer or barley as a weed. There are other findings such as a few Brassicaceae, Lamiaceae, Rosaceae, *Silene gallica* L., *Medicago* sp.. It is worth noticing that there is a persistent presence of Cyperaceae seeds among the stratigraphic units as well as phases and one stratigraphic unit (SU 40533) is unusually rich in *Eleocharis palustris* (L.) Roem. & Schult. (Common spike rush) and in *Scirpus lacustris* L. which are sedges that can be found alongside or within ponds, marshes, ditches and riversides (**Fig. 4.2**). Finally, seeds of *Vitis vinifera* L. were found in some of the samples (**Fig. 4.2**). The finding of grape grains raises the question of wine production which is attested since the Neolithic in Southern Italy. However, the small quantity and occurrence of seeds do not support this hypothesis, and would rather point toward an opportunistic consumption or use by humans of a native local vegetation.

Densities

The densities of the samples were calculated (number of crop items/l) and they are presented in **table 4.3**. As mentioned above, the preservation of the archaeobotanical material was poor. This influences the identification and quantification of the macro remains but also impacts the densities, explaining the heterogeneity observed in the results. The density varies between 0.3 and 115.3 items/l, 50% of the samples are between 9.7 and 26.9 items/l with a median equal to 16 items/l while 5% of the samples have a density under 2.1 items/l and another 5% have a density above 70.2 items/l. These last samples can be considerate as having peculiar densities in comparison with the rest of the assemblage. The extremely low densities were observed in different kinds of contexts (fills, burial, leveling for construction of a hut). They are therefore not linked to a specific type of context. They are explained by either the poor preservation of the material or just the fact that it was a sterile context in terms of archaeobotanical remains. The samples having an unusual density are all coming from the same context which is the pit fill P9. No trend was identified among the periods nor pattern related to the type of deposits regarding the dispersion of the densities.

Phases	**Contexts**	**SU**	**Flot volume (L)**	**Nb remains with fragments**	**Density with fragments**	**Nb remains**	**Density**
1	FILL P1	40388	12	763	63,6	467	38,9
	FILL P2	40546	6	120	20,0	35	5,8
	FILL P3	40533	12	308	25,7	204	17,0
	FILL P4	40544	3,5	19	5,4	10	2,9
	FILL P5	40529	6	215	35,8	103	17,2
		40530	6	15	2,5	6	1,0
	FILL P6	40535	6	196	32,7	68	11,3
		40525	6	264	44,0	99	16,5
	Burial	40532	12	309	25,8	158	13,2
		40524	6	159	26,5	77	12,8

	FILL P7	40539	6	17	2,8	9	1,5
		40538	6	114	19,0	39	6,5
	FILL P8	40542	6	236	39,3	159	26,5
		40513	6	187	31,2	85	14,2
1&2	PH	40527	6	201	33,5	87	14,5
	FILL P9	40390	12	1936	161,3	891	74,3
		40473	6	1604	267,3	692	115,3
		40469	6	753	125,5	470	78,3
		40389	5	968	193,6	458	91,6
2	FILL LEV1	40510	6	832	138,7	270	45,0
		40509	6	50	8,3	19	3,2
		40508	6	595	99,2	269	44,8
		40507	6	251	41,8	103	17,2
		40506	6	255	42,5	96	16,0
		40505	6	106	17,7	34	5,7
		40503	6	40	6,7	32	5,3
		40502	6	152	25,3	66	11,0
		40501	6	228	38,0	71	11,8
		40500	6	147	24,5	58	9,7

3	FILL P10	40512	6	237	39,5	88	14,7
		40520	6	252	42,0	120	20,0
		40517	6	1010	168,3	342	57,0
		40519	6	113	18,8	60	10,0
		40515	6	551	91,8	228	38,0
		40514	6	678	113,0	281	46,8
		40511	6	436	72,7	273	45,5
	FILL P11	40439	18	643	35,7	255	14,2
		40438	12	698	58,2	236	19,7
		40437	12	535	44,6	188	15,7
		40436	6	359	59,8	157	26,2
		40435	12	437	36,4	156	13,0
	FILL P12	40522	6	80	13,3	48	8,0
		40521	6	51	8,5	18	3,0
		40446	6	222	37,0	120	20,0
4	FILL LEV2	40407	6	36	6,0	12	2,0
		40396	6	62	10,3	31	5,2
		40416	6	265	44,2	117	19,5
	HUT	40405	6	111	18,5	47	7,8

		40399	6	147	24,5	76	12,7
	OBL	40379	6	257	42,8	105	17,5
		40365	6	208	34,7	67	11,2
		40364	6	144	24,0	91	15,2
		40415	12	259	21,6	114	9,5
5	TR	40440	12	793	66,1	418	34,8
		40442	6	150	25,0	76	12,7
		40432	6	619	103,2	267	44,5
		40422	6	464	77,3	179	29,8
5&6	FILL P13	40489	6	134	22,3	84	14,0
		40487	9	501	55,7	175	19,4
		40486	6	45	7,5	24	4,0
		40485	6	315	52,5	164	27,3
		40484	3	215	71,7	112	37,3
		40483	6	312	52,0	108	18,0
		40452	18	1129	62,7	318	17,7
6	FILL LEV3	40391	6	380	63,3	131	21,8
		40371	6	528	88,0	176	29,3
		40369	6	85	14,2	18	3,0

		40367	6	454	75,7	165	27,5
		40370	6	183	30,5	70	11,7
		40374	6	257	42,8	100	16,7

Centiles				
< 0.05	**0.05 - 0.25**	**0.25 - 0.5**	**0.5 - 0.75**	**> 0.95**

Table 4.3: NE slope of the Palatine. Densities of each sample.

Periods	Contexts	SU	Clean grains	Gb	Ratio
1	FILL P1	40388	108	301	2,8
	FILL P2	40546	19	11	0,6
	FILL P3	40533	67	6	0,1
	FILL P5	40529	27	36	1,3
	FILL P6	40535	14	12	0,9
		40525	17	2	0,1
	Burial	40532	30	64	2,1
		40524	24	21	0,9
	FILL P7	40538	17	0	0,0
	FILL P8	40542	107	0	0,0
		40513	39	2	0,1
1 & 2	PH	40527	51	0	0,0
	FILL P9	40390	239	474	2,0
		40473	123	526	4,3
		40469	322	11	0,0
		40389	237	37	0,2
2	FILL LEV1	40510	112	84	0,8

		40508	80	150	1,9
		40507	39	6	0,2
		40506	42	32	0,8
		40505	18	0	0,0
		40502	25	0	0,0
		40501	37	0	0,0
		40500	29	2	0,1
3	FILL P10	40512	26	49	1,9
		40517	117	151	1,3
		40520	74	0	0,0
		40519	25	1	0,0
		40515	88	52	0,6
		40514	111	102	0,9
		40511	64	166	2,6
	FILL P11	40439	37	83	2,2
		40438	26	24	0,9
		40437	18	25	1,4
		40436	65	2	0,0
		40435	40	27	0,7

	FILL P12	40522	24	0	0,0
		40521	12	0	0,0
		40446	43	13	0,3
4	FILL LEV2	40416	73	0	0,0
	HUT	40405	15	3	0,2
		40399	12	47	3,9
	OBL	40379	35	8	0,2
		40365	12	17	1,4
		40364	17	11	0,6
		40415	42	7	0,2
5	TR	40440	109	147	1,3
		40442	23	14	0,6
		40432	81	120	1,5
		40422	74	25	0,3
5&6	FILL P13	40489	18	91	5,1
		40487	68	92	1,4
		40485	71	56	0,8
		40484	25	70	2,8
		40483	48	11	0,2

		40452	189	21	0,1
6	FILL LEV3	40391	58	4	0,1
		40371	71	87	1,2
		40367	74	49	0,7
		40370	16	4	0,3
		40374	53	1	0,0

⬜	0 - 0.60	Clean grains
🟨	0.61 - 1.10	Spikelets
🟧	1.11 - 1.99	Spikelets and chaffs
🟥	> 2	Crop processing residues

Table 4.4: NE slope of the Palatine. Ratio chaff/grains for each sample applying Van der Veen (2007) thresholds. The calculus was done for the samples having more than 10 remains.

Contexts

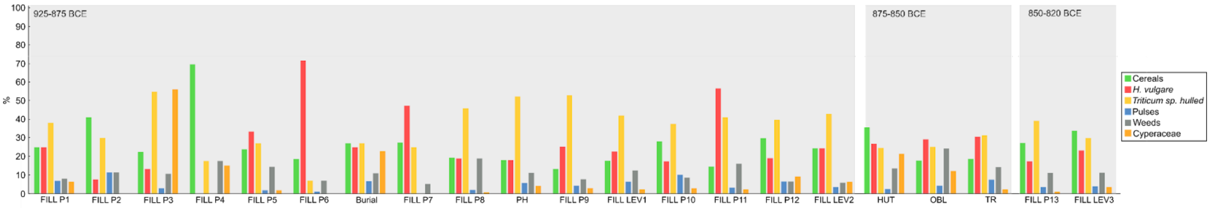

Figure 4.3: NE slope of the Palatine. Proportion of the main staples and the weeds by contexts ordered according to their chronology.

Most of the context analyzed are pits dug out to extract the clay for building the huts and reused as midden or to dispose of the previous hut remains. Thus, their fills represent an average of the domestic remains related to the life cycle of each hut. In **figure 4.3** the proportion of the major staple crops are plotted according to the different contexts (for the list of SUs in each context and their archeological phases see **table 4.2**).

As with the densities, there is not a clear pattern. Some pits are richer in barley (particularly in phase 3), others in emmer; nevertheless, some of the earliest pits in phase 1-3 show a preponderance of emmer together with a higher-than-average density, in particular the above mentioned P9 (**Tab. 4.3**). The ratio of clean grains versus chaff remains suggests the presence of crop processing debris and clean grains (**Tab. 4.4**). Pit P3 (SU 40533) is somehow different. It has a rather high density of material (**Tab. 4.3**); the remains include a majority of emmer caryopses indicating a clean crop (**Tab. 4.3**) and it is particularly rich in Cyperaceae (**Fig. 4.3**).

Among other contexts, the fill of the post hole in phase 1/2 should be mentioned. It contained a greater proportion of emmer clean grains, as it is often the case when these features are reused (**Tab 4.4**). The floor of the hut phase 4 includes a balanced proportion of barley, emmer, chaff and weeds that could be interpreted as evidence of the final stages of crop cleaning and grain preparation inside the hut (**Tab. 4.4**).

Periods

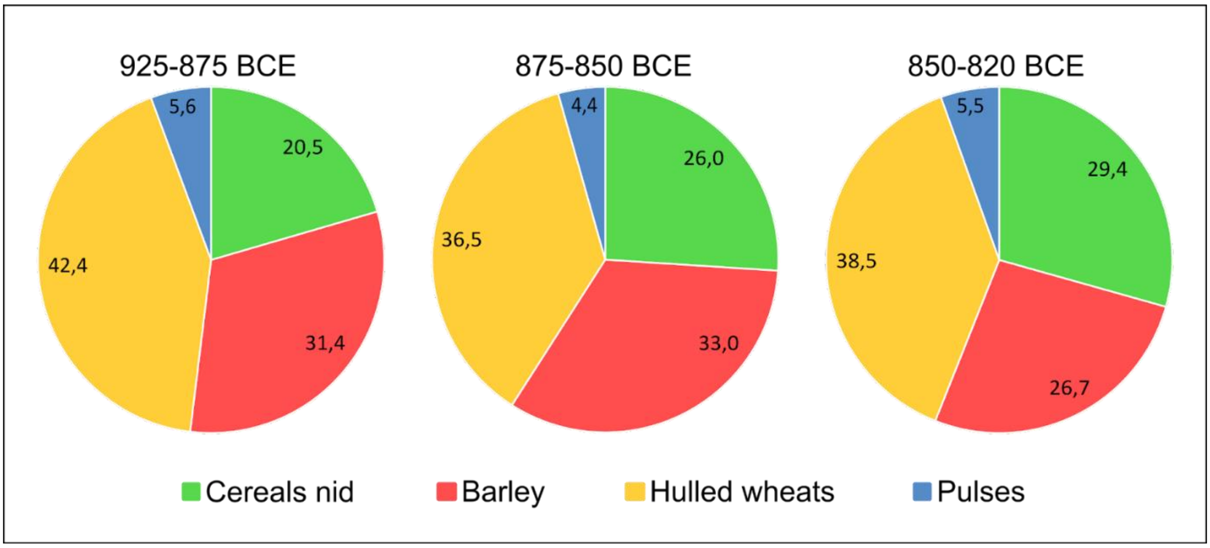

Figure 4.4: NE slope of the Palatine. Proportion of the main staples by periods

Figure 4.4 shows the proportions of the main staples for each of the three main chronological intervals. The different hulled wheats (*T. dicoccum*, *T. spelta*, *Triticum* sp.) have been grouped together for the reasons mentioned previously (ref). The category pulses includes *V. faba*, *V. ervillia*, *Lathyrus*/*Vicia* and the pulses nid.

The hulled wheats represent consistently the biggest proportion among the different crops, but the extent of its importance is variable between phases. At 925-875 BCE, the hulled wheats dominate clearly the other crops, they are followed by barley and cereals nid. The pattern is the same for the following period (875-850 BCE), but the difference in crop proportions becomes smaller with the percentages of hulled wheats and barley are more similar to each other. Finally, at 850-820 BCE, the cereals nid have more importance than barley, even if their percentages are similar, the hulled wheat stays larger in proportion than the other category. The pulses have always the lowest percentage that remains stable among the different phases. Overall, no pattern can be identified across time which suggests that the population did not change drastically the crops they were using and consuming every day. As mentioned previously, the preservation of the material was poor and barley, because of its morphological features is easier to recognize compared to hulled wheat grains. Consequently, most of the cereal unknown are probably hulled wheat grains. Keeping this assumption in mind and considering hulled wheats and cereals together, a slight decrease in barley grains can be detected over time.

PCA: SU archaeobotanical composition and formation process

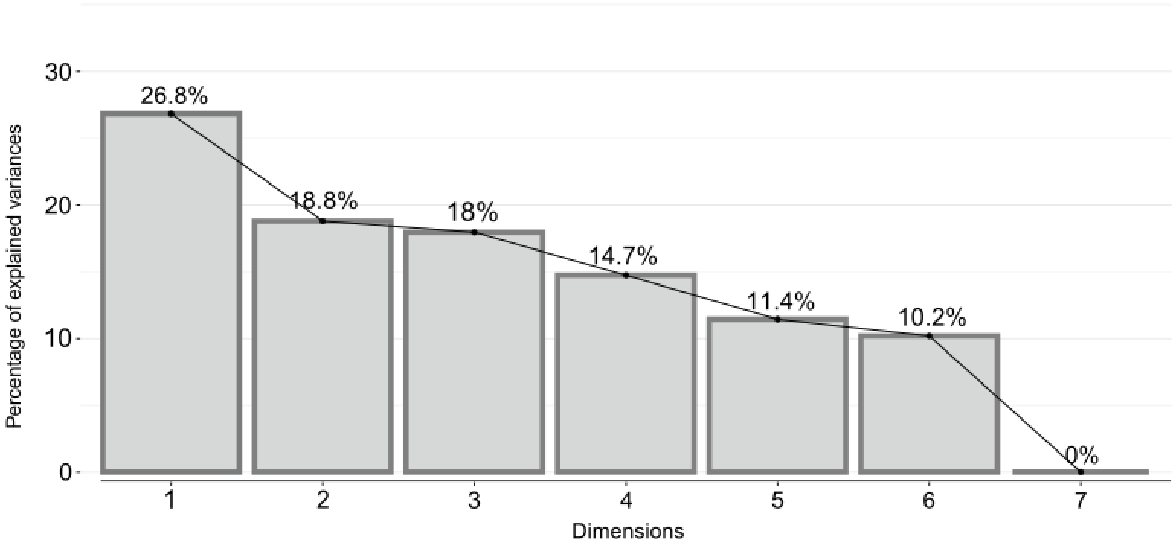

Figure 4.5: NE slope of the Palatine. Screeplot.

A principal component analysis (PCA) was conducted on the main archaeobotanical findings including cereals, barley, hulled wheats, big Poaceae, *Phalaris* sp., Cyperaceae and chaffs in order to explore the archaeobotanical composition of each SU and therefore reflect on the formation processes of the different archaeological contexts. In **figures 4.6** and **4.7** the samples are coloured according to the different periods and the shapes represent the type of contexts. The first two dimensions explain 45.6% of the variance (Dim1: 26.8% and Dim2: 18.8%). The first dimension is positively correlated to hulled wheat and, to a certain extent, to cereals and big Poaceae. Dim1 has also a strong negative correlation with chaffs which is isolated from the other variables. There is a strong positive correlation between the Cyperaceae and the second dimension, Big Poaceae and barley are also to a lesser extent correlated to this dimension. The scree plot (**Figure 4.5**) shows that Dim3 still explains a large part of the variance with 18%. It is correlated with the different types of cereals (barley, hulled wheat, cereals) and big Poaceae. Dim4 has a lower value with 14.7% but is highly correlated to *Phalaris* sp. which is relevant for the interpretation and therefore was also taken into consideration. In total 78.3% of the variance is explained by the four dimensions.

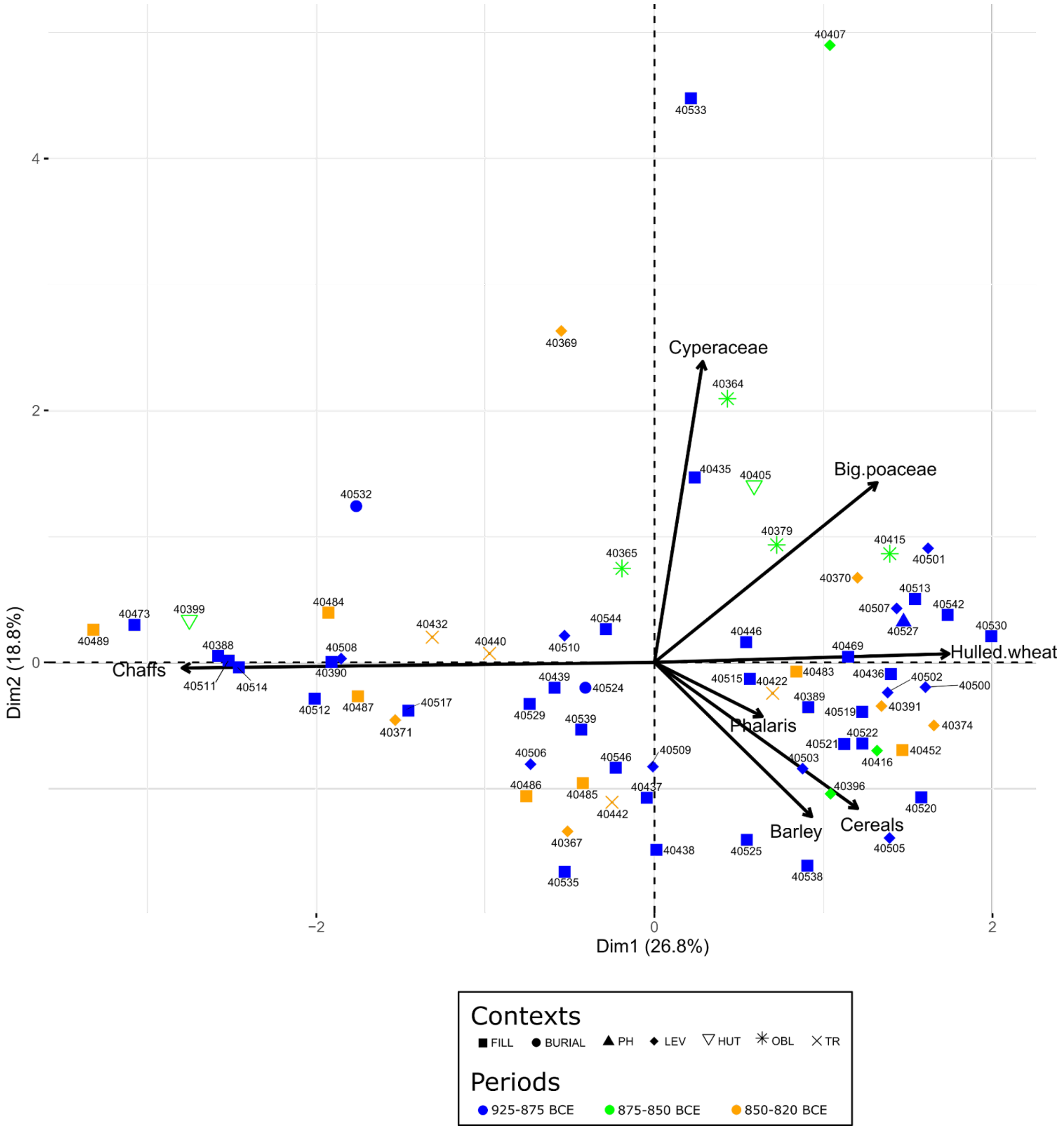

Figure 4.6: NE slope of the Palatine**.** PCA showing dimensions 1 (26.8%) and 2 (18.8%) and taking into account barley, hulled wheat, cereals, big Poaceae, *Phalaris* sp. and chaff. FILL: pit fills; BURIAL: burial; PH: Post Hole; LEV: leveling level; HUT: life of the hut; OBL: hut obliteration; TR: terracing (**Tab. 4.2**).

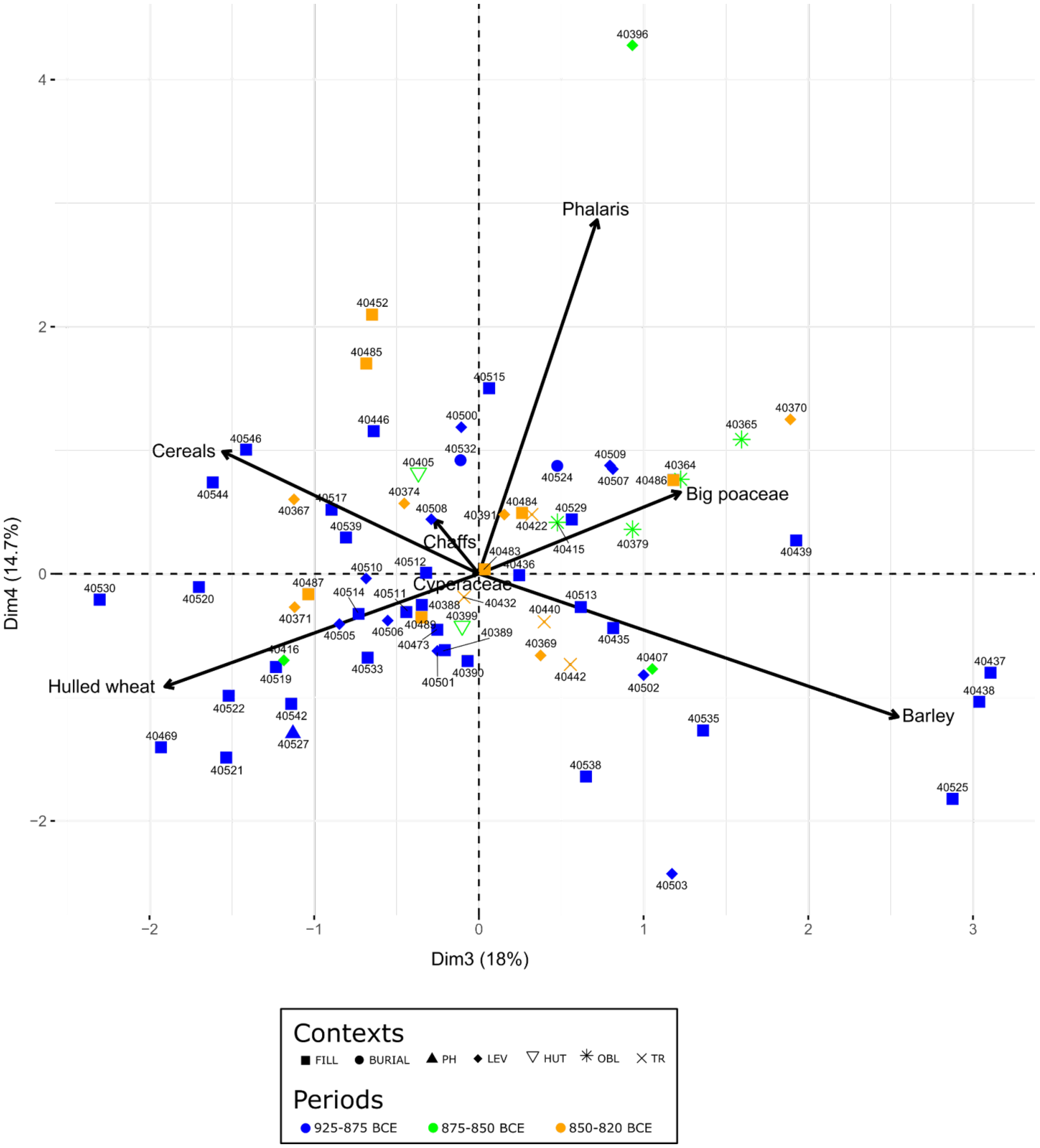

Figure 4.7: Palatine hill**.** PCA showing the dimensions 3 (18%) and 4 (14.7%) and. taking into account barley, hulled wheat, cereals, big Poaceae, *Phalaris* sp. and chaff. FILL: pit fills; BURIAL: burial; PH: Post Hole; LEV: leveling level; HUT: life of the hut; OBL: hut obliteration; TR: terracing (**Tab. 4.2**).

Figures 4.6 and **4.7** show that the samples belonging to the same archeological context are not necessarily grouped together on the biplots which suggests that most SUs are distinct actions with a specific archaeobotanical composition. It is clear that the pit fills are scattered on the graph which indicate that they were formed by distinct material depositions. In the same manner, no clear patterns stand out regarding the periods except the samples from period 875-850 BCE (green) on **figure 4.6** (Dim1 and 2) which are almost exclusively on the right part of the graph. This indicates that the majority of the samples were poor in chaffs except SU 40399. While belonging to the same archaeological context (hut), SU 40405 does not share this particularity. The samples dated from 875-850 BCE seemed more characterized by the presence of Cyperaceae and big Poaceae compared to the other periods. This pattern could be explained by the nature of the archeological contexts, they are all linked to hut activities (life of the hut, leveling levels, obliteration of the hut). Particular activities or manufactures could explain these observations.

When looking at the graph showing the dimensions 1 and 2 (**Fig. 4.6**), SU 40533 and SU 40407 stand out drastically from the others with a composition that is particularly correlated to the Cyperaceae. The first one was identified as a pit fill and could be linked to a specific deposition of Cyperaceae remains. The second sample is coming from a leveling level and could be linked to the crop processing or a specific activity carried out outside at the hut's proximity and then this soil would have been remobilized for the leveling. Other samples, to a lesser extent, are correlated to the Cyperaceae (SUs 40364, 40435 and 40405). In conclusion, the samples richer in Cyperaceae are not necessarily linked to a specific period or one type of context.

Still, looking at **figure 4.6** where chaffs are particularly well correlated to dimension 1, it is possible to identify samples that seem mainly composed of chaffs. The archaeological contexts they are from are mainly pit fills (SUs 40489, 40473, 40388, 40511, 40514) and one hut (SU 40399). These samples are thus representing the debris from grain cleaning that were probably thrown away in pits. Regarding SU 40399, the sample could have been taken from an area of the hut where crop processing activities took place.

On the **figure 4.7** showing the dimensions 3 and 4, a sample (SU 40396) belonging to a context of leveling is highly correlated to *Phalaris* sp. Other samples composed this archaeological context (SUs 40416, 40407) but they are not characterized by the presence of *Phalaris* sp.

Overall, when taking into consideration all the dimensions, the samples are dispersed everywhere on the biplots. Some seem richer in hulled wheat, cereals or barley but most of them are in the middle of the graph suggesting that the samples have a mixed and heterogeneous composition. The PCA showed that there is no correlation between the contexts defined by archaeology and their composition. They rather seemed to be the results of multiple deposition of material for different purposes rather than consistent units.

Stable isotope analysis

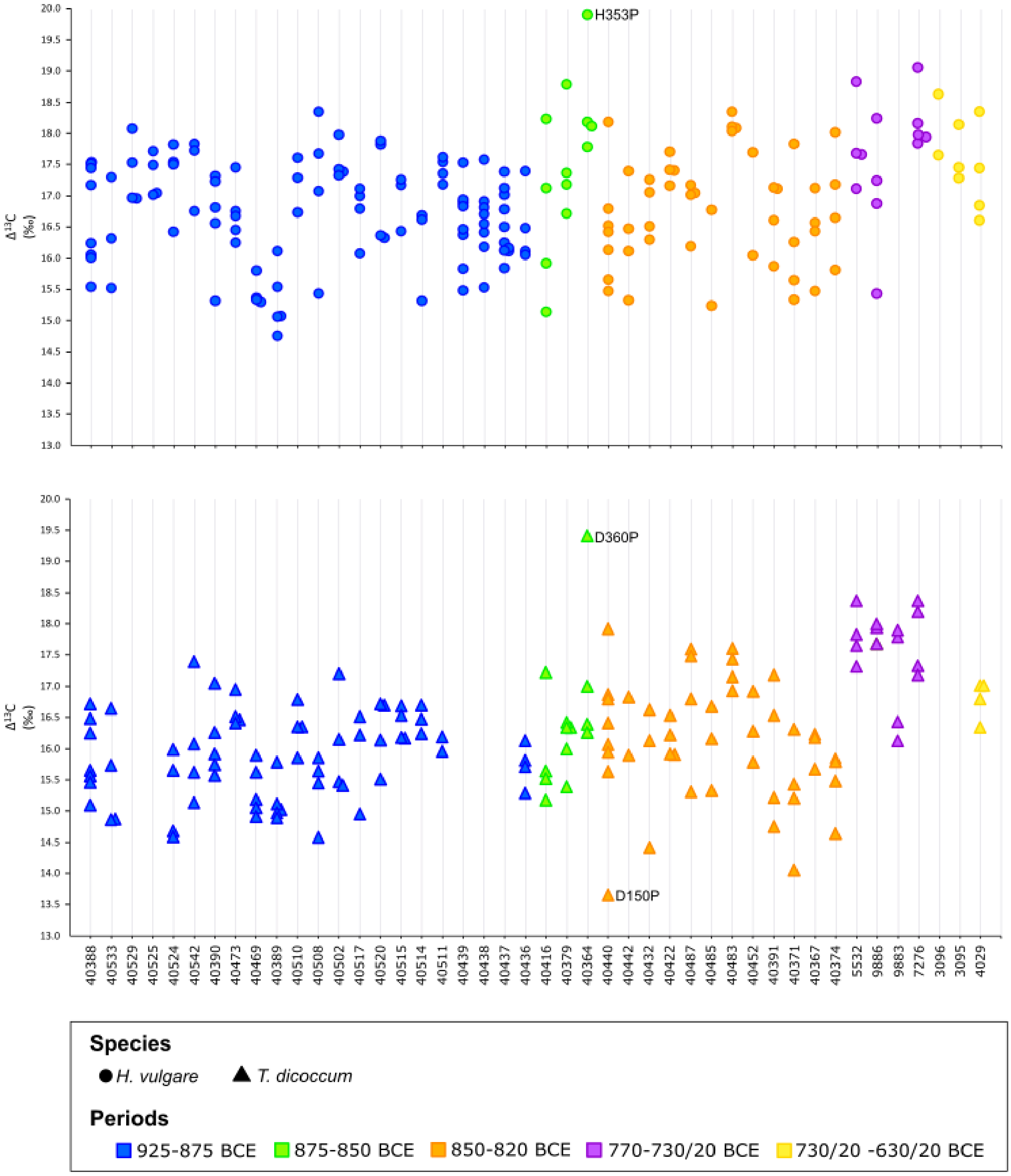

Figure 4.8: NE slope of the Palatine. Results for $\Delta^{13}C$ values grains by grains.

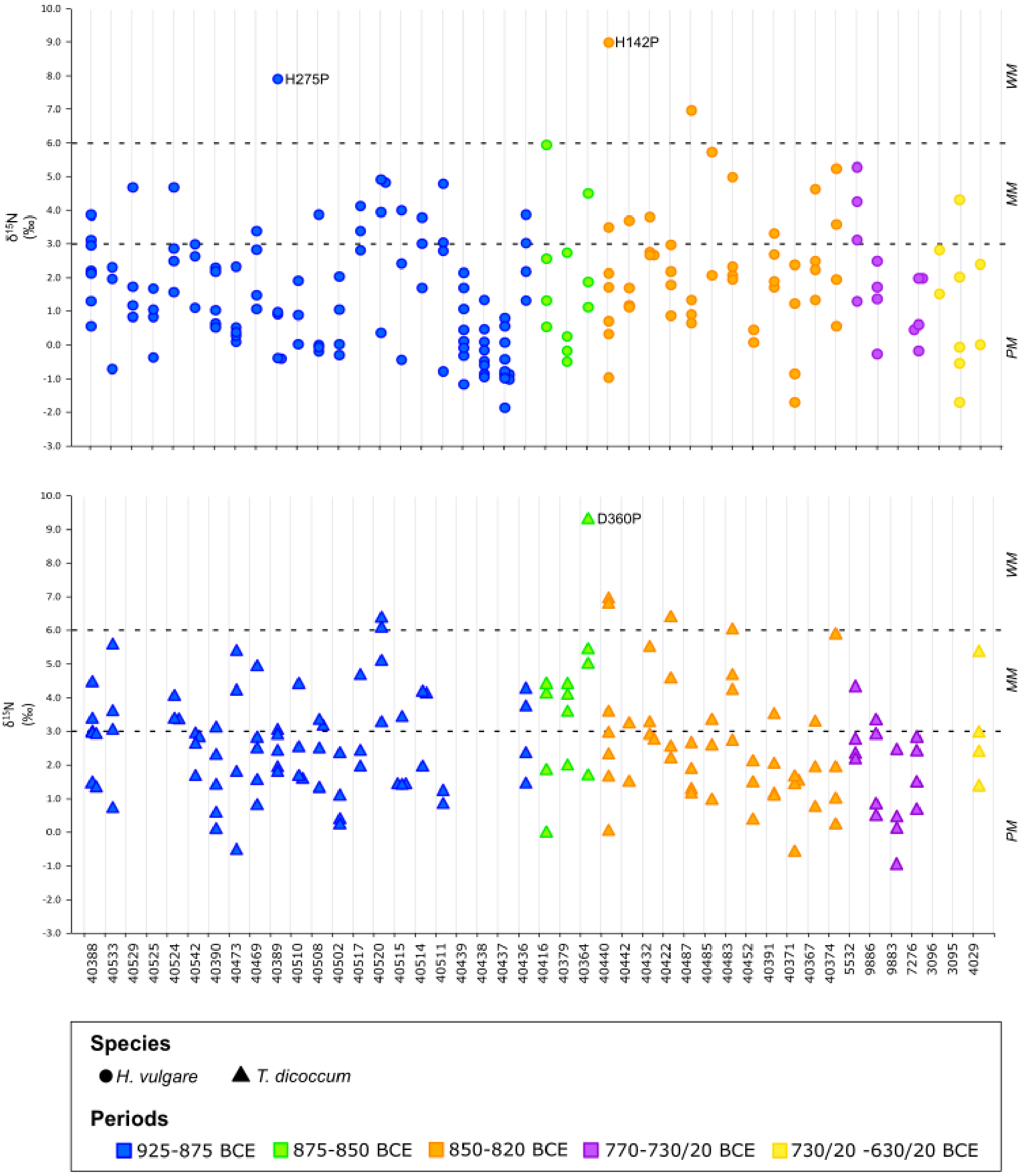

Figure 4.9: NE slope of the Palatine. Results for $\delta^{15}N$ values grains by grains. Dashed lines represent the thresholds for manuring: PM, poorly manured; MM, moderately manured, WM; well manured (Bogaard et al. 2007).

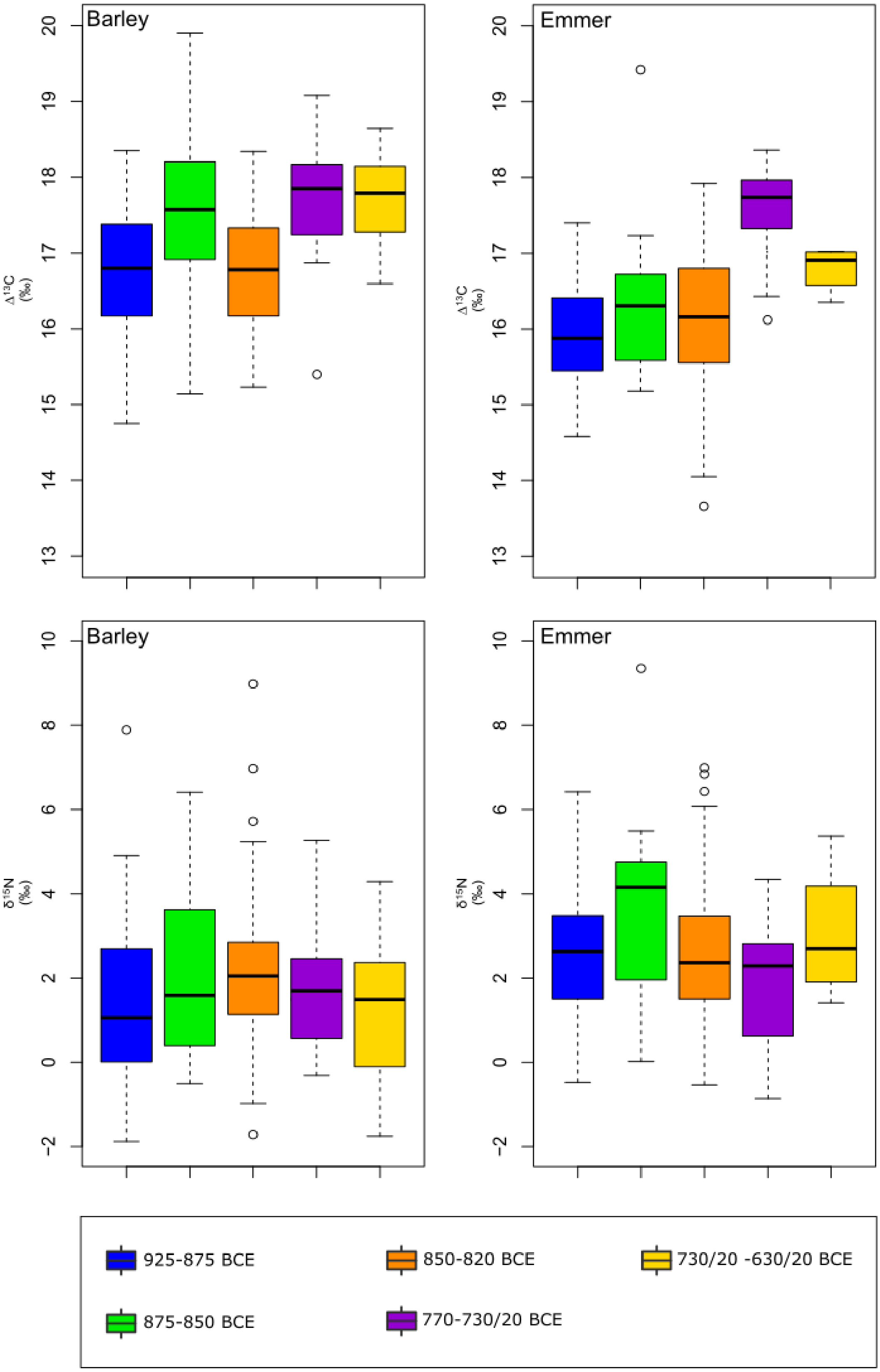

Figure 4.10: NE slope of the Palatine. Carbon and nitrogen stable isotope result for each investigated period of time.

The carbon and nitrogen stable isotope analysis provided results covering a time span from the 10th to the 7th c. BCE. The $\Delta^{13}C$ values of all the analyzed caryopses are between 14.7 and 19.9‰ for barley and 13.7 to 19.4‰ for emmer (**Fig. 4.8**). The $\delta^{15}N$ values range from -1.9 to 9‰ for barley grains and from -0.9 to 9.3‰ for emmer ones (**Fig. 4.9**). Looking at the grain-by-grain figures helps assess the dispersion of the dataset. A variability exists not only within SU but also between them. Some of the values stand out from the general range of the results but also from the results observed in their respective SU. Since no anomalies linked to the methodological and analytical process or to the grains themselves were found, those values were kept as part of the study. In **figure 4.8**, D150P has a particularly low $\Delta^{13}C$ value for emmer (13.7‰) while H353P has a higher value (19.9‰) of $\Delta^{13}C$ compared to the rest of the results. The caryopsis H142P (9.0‰) and H275P (7.9‰) also have higher values than what is commonly observed for their $\delta^{15}N$ (**Fig. 4.9**). Finally, D360P is particularly interesting because both its $\delta^{15}N$ (9.4‰) and its $\Delta^{13}C$ (19.4‰) are outside of the general range (**Fig. 4.8** and **4.9**). The grain D630P is particularly interesting as it stands out both from its $\Delta^{13}C$ and $\delta^{15}N$ values. Nonetheless, it is difficult to determine if it can be considered as a normal and expected variability resulting from natural variability or if it could be an indication of mixed origin of the archaeobotanical grains.

In order to look at possible changes through time, results of all the SU referred to each investigated period of time were grouped (**Fig. 4.10**). Looking at $\Delta^{13}C$ mean, barley grains present the same mean for period 925-875 BCE (mean: 16.8‰ ± 0.5) and 850-820 BCE (mean:16.8‰ ± 0.9). Emmer as well has similar means for these two periods (mean 925-875 BCE: 15.9‰ ± 0.2 and mean 850-820 BCE: 16.1‰ ± 0.9). The results of the in-between period (875-850 BCE) show similar values for emmer (mean: 16.4‰ ± 1.1), whereas the values of barley (mean: 17.5‰ ± 1.3) are significatively higher than 925-875 BCE (p-value$_{\text{periods1-4}}$ = 0.0167) and 850-820 BCE (p-value$_{\text{periods4-5}}$ = 0.0447) despite the high variability observed. An increase in $\Delta^{13}C$ values occurs for both crops at 770-730/20 BCE (mean barley: 17.7‰ ± 0.9; mean emmer: 17.6‰ ± 0.6), the means are statistically higher than all the other periods. This increasing trend is confirmed by the statistics except at 875-850 BCE for barley due to a higher variability (barley: p-value$_{\text{periods1-7}}$ = 0.00118, p-value$_{\text{periods5-7}}$ = 0.00502; emmer: p-value$_{\text{periods1-7}}$ = 1.33e^{-11}, p-value$_{\text{periods4-7}}$ = 1.16e^{-3}, p-value$_{\text{periods5-7}}$ = 1.43e^{-8}). Interestingly, unlike all the other periods, there is no significant difference between the means of emmer and barley as it would be expected in this latest period (p-value$_{\text{period7}}$ = 0.7513). In the following period (730/20-630/20 BCE) barley means stayed similar to the previous period (mean: 17.6‰ ± 0.7). However, statistically there is only a difference with 925/875 BCE (p-value$_{\text{periods1-8}}$ = 0.0261). Emmer grains have a lower mean than the previous period but still stay higher than the rest of the periods but are statistically not different from the other periods.

In other words, the carbon isotope signal remains stable until 850-820 BCE for both crops. Afterwards, a clear change in water status occurs with an increase in barley $\Delta^{13}C$ mean. The situation is a little different for emmer, although its $\Delta^{13}C$ mean increase at first, probably linked to an improvement of its water status, it decreases again in the last period. The difference of behavior between emmer and barley in the last period of time could find its origin in the scarce availability of emmer grains (4 grains of emmer coming from one SU were analyzed).

Therefore, it is possible that, in fact, emmer followed the same pattern as barley and that even after 770-730/20 BCE, it benefited from better conditions of water availability.

Since the stable carbon isotope composition of both crops increases at the end of the record (770-730/20 BCE) suggesting an improvement of the water status, it could point toward an influence of a climate event during this period. The available data for the studied region about paleoclimate fluctuations is mainly based on lake level reconstruction. When taking into consideration the lakes that are as close as possible to Rome, such as lakes Lungo, Fucino, Mezzano and Accesa, there are some consistencies in their level oscillations during the investigated periods. They all registered a rise of their water level between 3000 and 2600 cal. BP (1050 and 650 BCE) (Giraudi et al 2004; 2011; Magny et al 2007; Mensing et al 2015). These high lake levels were associated as well with the Calderone glacier expansion and periglacial soil found in the Apennines which would suggest a rather cool climate in Central Italy (Giraudi et al. 2011; Magny et al 2007; Mensing et al. 2015). Moreover, Peyron et al. (2011) mentioned that the current Mediterranean climate with its marked seasonality would have begun between 2500 and 2000 cal. BP (550-50 BCE). While this paleoclimate data is crucial to have an overview of the climate in the region during this period, the time-scale covered by these studies is usually longer and has a lower resolution than the archeological ones. Therefore, it remains challenging to synchronize data obtained from archeological records with observed climate changes (Berglund 2003; Mensing et al 2015). Overall, the regional paleoclimate data is in agreement with what is observed from the Δ^{13}C values, they both suggest an improvement of the atmospheric humidity during this period of time. As for the event happening at the 8th c. BCE, it is a brief and rapid change that, even if due to a climate oscillation, would not be detectable with the resolution of the lakes level studies. A change in rainfall pattern due to a change of seasonality could also be at the root of the change occurring during the 8th c. BCE. Indeed, seasonality is a crucial aspect to take into consideration when it comes to the growth of the plant (Heinrich & Hansen 2021). However, this kind of event is not always registered depending on the proxies used, different aspects of the climate can be assessed, some will be more sensitive to seasonal changes or will inform on local trends, while others will give more global results (Finné et al. 2019; Magny et al. 2013). As of today, in the region of interest there is no other kind of paleoclimate data that could be used to have a useful comparison with the Δ^{13}C record to prove or disprove a role of the climate whether it would have been global or seasonal.

Anthropic behaviors cannot be discarded while explaining the increase of the stable carbon isotope composition of the two crops during the 8th and 7th c. BCE. As mentioned before, material from the NE slope covering the 8th and 7th c. BCE was added for the stable isotope analysis. However, with the actual knowledge, it is not possible to know if the huts coming from the NE Palatine and the ones from the N slope were occupied by inhabitants of a single community, cultivating the same fields or if there were two different communities. Even if their precise location is not known, the similar environmental setting of the two areas suggests that the fields were probably under analogous conditions (**Fig. 4.11**). In this case, the changes occurring in the Δ^{13}C values would point toward a man or climate induced hypothesis. Nonetheless, nothing excludes the possibility that the fields of one of the settlements could have grown its cereals down a slope taking advantage of the water accumulation and leading to higher Δ^{13}C values (N slope) while the other could have cultivated them at higher elevations in better drained ground (NE slope). Whether the two excavations were part of the same community or not, the changes in the Δ^{13}C record could be linked to an advancement in the practices and selection of the fields across time due to an improvement of the farmer's knowledge. Above all, the 8th c. BCE. is a crucial moment in the development of the settlement. There is a reorganization of the space with the movement of the necropolis from the Forum area to the Esquiline. Furthermore, massive structures surrounding the Palatine were excavated, they were interpreted as fortification walls that, according to some scholars, would be linked to the mythical foundation of Rome (Benedetti et al. 2019). There is a long-standing debate on the exact nature of these changes and the social processes associated with this archeological evidence. However, even if it would be challenging to explain the causal link between social and political developments with the increase of Δ^{13}C values, there is a strong indication that a relationship exists between these different aspects.

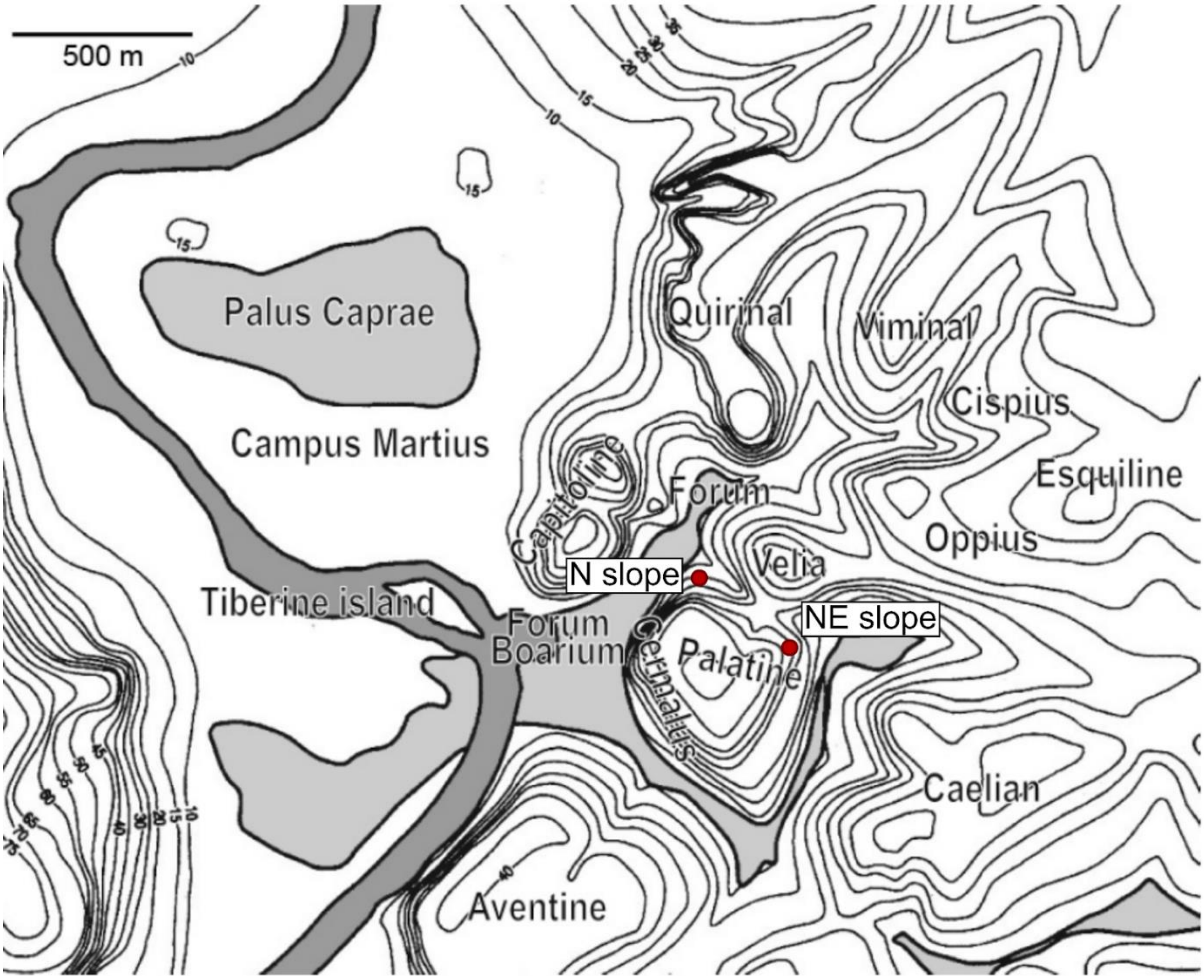

Figure 4.11: NE slope of the Palatine. Location of the two areas where the huts were excavated. Modified from Motta (2011).

Another significant observation is that in 770/730-20 BCE period barley and emmer have similar $\Delta^{13}C$ mean, although barley is expected to have a higher $\Delta^{13}C$ than emmer under the same environmental conditions. This is due to the fact that barley is more stress tolerant than emmer (Riehl 2009). Such a difference in the isotopic composition of the two crops is the one observed in all the studied periods except for the latest one. Considering this evidence, a climate event is still plausible to justify the increasing $\Delta^{13}C$ values but it would have had to be associated with a change, intentionally or not, in the management of emmer in particular, which would have been favored by better water conditions. Emmer is seen in literature as a very important and symbolic plant for Romans (rituals, diet…), therefore, they could have decided to put more effort in the cultivation of this crop.

Looking at the mean $\delta^{15}N$ values, results displayed in **figure 4.10** do not show differences across time for barley as confirmed by the ANOVA tests. On the contrary, periods 875-850 BCE seem to be different from the others in the case of emmer with higher a higher mean (mean: 3.9‰ ± 2.4). However, due to the high variability existing in the stable nitrogen isotope composition of both crops, no difference was statistically identified.

The large majority of the $\delta^{15}N$ values from the Palatine are below the 6‰ threshold calculated by Bogaard et al. (2013) on modern north European crops. According to these thresholds no animal manure was applied in large quantities and for a long period of time on these crops. The few grains above this threshold are, for the most part, standing out of the general pattern of their respective SU. Looking at the results of all the analyzed caryopses (**Fig. 4.9**), the $\delta^{15}N$ values of the two crops are distributed between 3 and 6‰ which show a medium application of manure during a long period of time or a large quantity of manure but in a short period of time and below the 3‰ that indicates no application of manure. However, a difference between emmer and barley was identified for all periods except for 925-875 BCE with emmer having higher values than barley. The difference observed does not seem to be linked to physiological differences between the crops. Experiments conducted on modern harvests of different crops (hulled barley, bread wheat, naked wheat, emmer and spelt) showed that they have the same answer to the addition of manuring (Bol et al. 2005; Fraser et al. 2011). Therefore, it suggests that manure (intentional or linked to pasture) could have been present in larger quantities for emmer than for barley. It is also possible that the emmer and barley fields were in different locations which did not have the same nitrogen composition.

Conclusion

The excavation of the NE slope of the Palatine Hill uncovered the most ancient layers ever found at Palatine Hill, they provided unique archaeobotanical material dating from the 10th and the 9th c. BCE. It constitutes a precious source of information to better understand these first populations living in the heart of ancient Rome. When associated with previous results coming from the N slope of the Palatine (Motta 2011), a chronological range spanning from the 10th to the 6th c. BCE is covered for the stable isotope analysis.

This multi-proxy analysis helps to understand the agriculture and environment surrounding the first settlements present at Palatine hill as well as their evolution across time. Regarding the type of environments in which the crop could have been grown, the recurrent presence of Cyperaceae in association with crops in the different archaeological contexts could point toward a cultivation in often flooded areas such as damp ground, ditches or marshes as suggested by Motta (2002). However, the PCA results showed that the Cyperaceae are present in the form of high concentrations in specific SUs. Even if the ubiquity of the taxa confirms its presence in the nearby environment, it would suggest mixt deposits with certain SUs linked with activities or crafting linked to the Cyperaceae.

When considered together, the archaeobotanical results and the stable isotope analysis suggest that, around the 9th c. BCE, emmer could slowly have started to gain importance over barley. The archaeobotanical study suggested a decrease in the presence of barley over time while carbon stable isotope analysis indicates that during the 8th and maybe the 7th c. BCE, emmer could have benefited from more favorable water conditions than barley. The 8th c. BCE, considered as a turning point, is marked by an increase in the water availability, without knowing the exact relationship existing between a potential climate event, the reorganization of the settlements and the potential social and political changes during this period. Further investigations are needed, with, for instance, the addition of data from other contemporary sites to better discriminate between these different factors.

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Chapter 5

A Regional perspective

In this chapter I will place the local data obtained at Gabii and at Rome in a broader regional perspective, integrating them with the results from a third site, Tarquinia. The archaeobotanical material from this site is currently under study by Fridja Smith as part of her PhD research at University of Cambridge, UK. A subset of 43 samples was selected to be included in this PhD project and, among them, eight samples provided caryopses suitable for isotopic analysis (see **Chapter 2: Material and methods** for issues of preservation and densities of charred remains). The archaeobotanical remains from this subset will be discussed in detail and contextualized with published data from the same site. Importantly, the chronology of the samples from Tarquinia (800-450 BCE) partially overlaps with samples from the Palatine Hill and with the ones from Gabii. This allows for a comparative assessment and a preliminary regional discussion.

The Etruscan settlement at Tarquinia

Description of the archaeological context

Tarquinia was one of the biggest and most important Etruscan centres of southern Etruria, flourishing since the 8th c. BCE **(Fig. 5.1)**. The ancient city is famous for its painted elite burials and only a few areas of the settlement have been excavated. The first trace of permanent occupation is an oval hut on the Pian della Civita plateau, dated from the second half of the 10th c. BCE onwards. The hut is situated near a natural bedrock cavity which had a possible sacral function. This natural feature was filled with offerings and periodically cleaned, evidence of its particular importance. This area, known as the Area Sacra, will become later a crucial and central place for the community. Indeed, it was continually occupied and the evidence of communal ritual action will persist and develop in the following centuries. During the 8th c. BCE, a stone building was built near the cavity (Area Alpha) while the rest of the settlement continued to expand. At the beginning of 7th c. BCE, the settlement was reorganized and a two-roomed rectangular structure was built next to the previous one (Building Beta). A large enclosure was then constructed around the building to create a defined monumental complex **(Fig. 5.2)**. During the first half of the 6th c. BCE, the monumental complex was extended and developed to continue to fulfil its public function. The 5th c. BCE is marked by a repurpose of the complex and a transformation of the urban layout (Bonghi Jovino 2010). The city was included in the Roman territory at the very end of the 3rd c. BCE and not so much is known about Tarquinia in Imperial time.

Figure 5.1: Tarquinia**.** The excavation of the Area Sacra/Monumental complex at Piana della Civita.

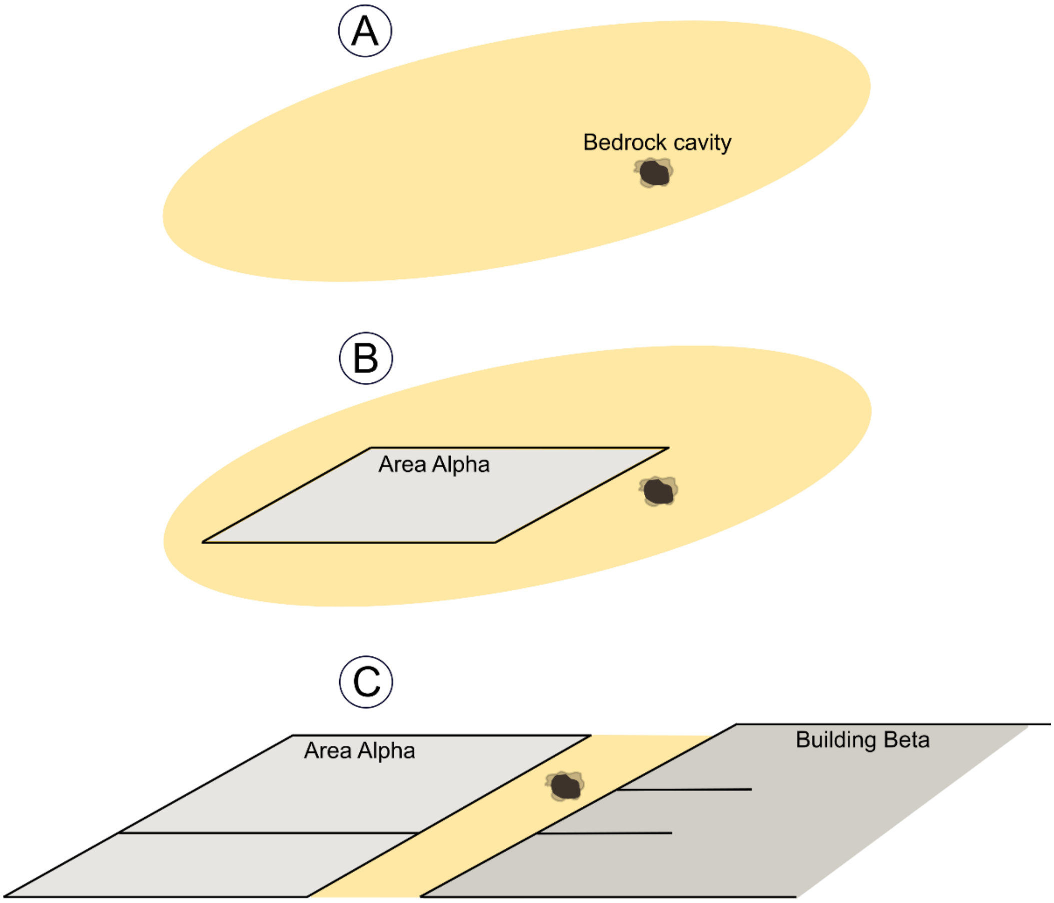

Figure 5.2: Tarquinia. Schematic representation of the Area Sacra/Monumental complex and its evolution at Tarquinia from the 10th to the 7th c. BCE. Modified from Bonghi Jovino (2010). A: 10th – 9th c. BCE. B: 8th c. BCE. C: 7th – 6th c. BCE.

Archaeobotany at Tarquinia

Two previous studies offer an analysis of archaeobotanical material retrieved during the excavation at Pian della Civita and allow us to have an overview of the taxa present at Tarquinia (Chiesa 2005; Rottoli 2005). These reports are rather limited in scope since they present the analysis of sediments filling various possible ritual vessels. No systematic sampling was in place and only contexts with visible and high concentration of material or ritual assemblages were analysed. It is possible anyway to make some general qualitative observations. Cereals are very abundant in the different samples, they are represented by *H. vulgare* (barley), *T. dicoccum* (emmer), *T. aestivum/durum* (naked wheat), *T. monococcum* (einkorn), *T. spelta* (spelt) and a single grain of *P. millaceum/setaria* (millet). Pulses such as *Lens culinaris* (lentil) and *Vicia faba* (faba beans) were also identified. Among the fruits are some remains of *Ficus carica* (fig) achenes, *Vitis vinifera* (grape) and *Sambucus* sp. (elder) seeds were found. A few weeds were also retrieved, *Avena sativa* (common oat), some seeds belonging to the Polygonaceae family, *Silene* species, and other ruderal weeds. Rottoli (2005) also described numerous mineralized remains of *Papaver somniferum* (poppy), *F. carica*, *Cucumis melo/sativus* (melon/cucumber), cfr. *Apium graveolens* (celery), *Petroselinum sativum* (persil), *V. vinifera*, *Prunus spinosa/domestica* (plum), *Prunus* type *avium* (wild cherry), *Malus* sp. and *Camelina sativa* (camelina) seeds.

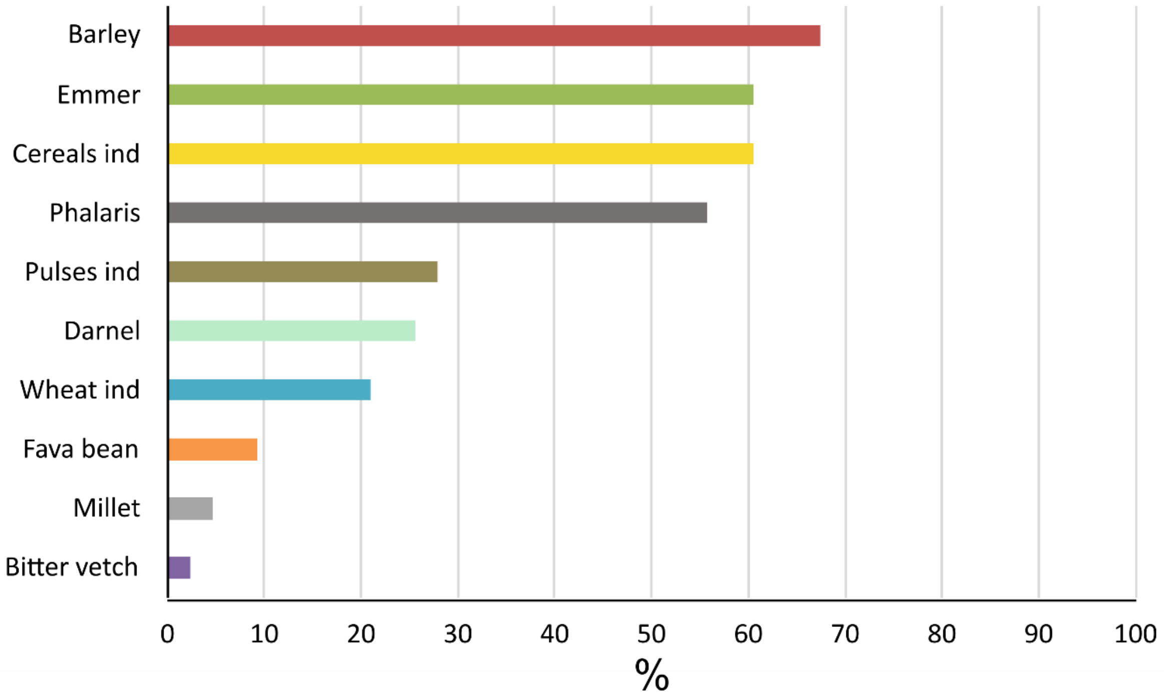

Figure 5.3: Tarquinia. Ubiquity of the main staple crops and weeds present from the 10th to the 5th c. BCE.

The archaeobotanical material presented in this study is the results of a blanket sediment sampling strategy. The implementation of a more systematic approach for the sampling is quite recent at Tarquinia and allow us to identified a total of 1330 specimens coming from 43 samples dated between the 10th and the 5th c. BCE. This new data gives the opportunity to look at plant use, crop production and consumption at Tarquinia from a new angle as well as gather more information about the everyday life of its inhabitants. The number of samples is not homogeneously distributed among the different periods and for some of them their chronology is still under study. For this reason, it was decided to not group the samples by periods. Cereals are the most present crop in the assemblage, they are represented mainly by *H. vulgare* followed by *T. dicoccum* **(Fig. 5.3)**. Few possible caryopses of *T. aestivum/durum* were found in 5 contexts dispersed over time. A handful of *P. miliaceum/Setaria* was found in some of the samples **(Fig. 5.3)**. *V. Faba* and *V. ervillia* were identified, however just a small quantity of remains in a few samples were retrieved. Weeds are a non-negligible part of the material found; they are mainly represented *Phalaris* sp. which are in about half of the SUs and by *Lolium temulentum* which was retrieved in several SUs **(Fig. 5.3)**. Some *F. carica* achenes, *Sambucus nigra* and *V. vinifera* seeds were present. The new data obtained are congruent with what was previously found and permits a better understanding of plant use at Tarquinia from the 9th c. BCE to the 5th c. BCE.

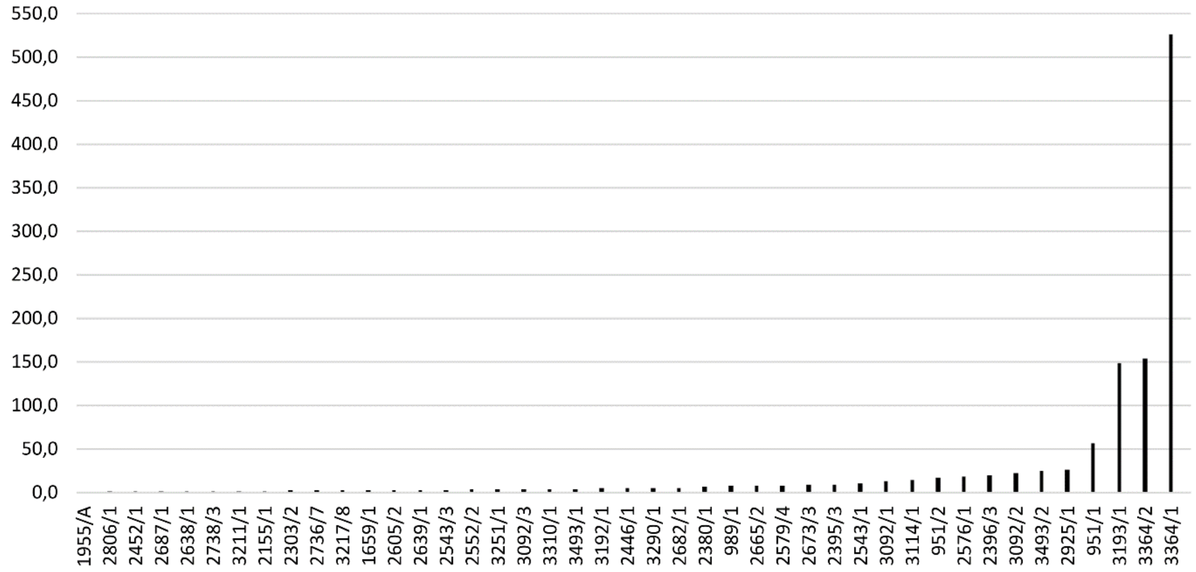

Figure 5.4: Tarquinia. Density of the different samples.

The density of the material is low **(Fig. 5.4)** and the diversity of taxa is poor, most of them are cereal and weed grains. This suggest that these few remains were probably mixed accidently with the sediment. Only three samples, SU 3364/2, SU 951/1 and SU 3193/2, have a higher density of material and one SU 3364/1 stands out from the other with an extremely high density **(Fig. 5.4)**. These samples belong to particular structures, SUs 3364/1, 3364/2 and 3193/2 were identified as a firepit which probably had a short lifespan. This could explain why the density of material was so high, especially for SU 3364/1 which was the hearth of the firepit.

Figure 5.5 which shows the percentage of barley, emmer and weeds (comprising *L. temulentum*, *L. multiflorum*, *Lolium* sp. *Phalaris* sp. and big Poaceae *Lolium* like) for the 4 samples having a higher density, tells us that SUs 3364/1 and 3364/2 are composed mainly of a mix of barley, emmer, weeds. There are in in rather equal proportion for 3364/2 while SU 3364/1 presents less emmer. SU 3193/1, which is external area of the firepit, is mainly composed of weeds, which are *Phalaris* sp. in this case. The large quantity of *Phalaris* sp. could suggest that they were used to feed or light the fire. SU 951/1 represents the sediment that was directly on top of two *olle* which were found at the base of a wall in area alpha. SU 951/1 presents a majority of barley and also some emmer, weeds and a handful of wheat chaff. The sediment inside the two *olle* was analysed by Rottoli (2005). He found numerous archaeobotanical remains including cereals, pulses, weeds and a few seeds coming from arboreal fruits such as grapevines or elder threes. The findings of SU 951/1 are similar with the one found inside the *olle*, but in absence of information about the density of material in the *olle* and the exact counting of remains, it is hard to know if the sediment could have the same origins.

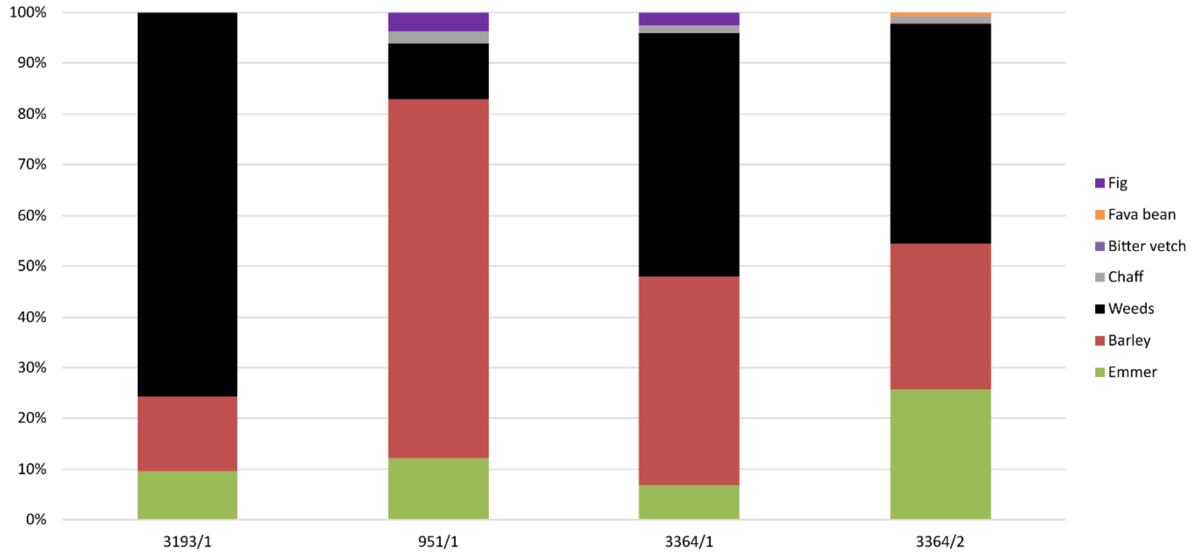

Figure 5.5: Tarquinia. Proportion of the most present crops and species.

Stable isotopes analyses

The samples

The samples for the stable isotope analyses were selected among the ones already studied for the archaeobotanical study. Due to the low density of the material, it was hard to find suitable contexts for the selection of cereal grains for the stable isotope analysis. Eight samples belonging to 6 SUs and grouped in 4 different periods were selected **(Tab. 5.1)**. Three of them (3364/1, 3364/2 and 3193/1) are coming from the firepit where a higher density of material was found. Moreover, this firepit had probably a short lifespan which allow us to avoid as much as possible the mixing of material coming from too different time periods. Two others (951/1 and 952/2) are coming from the *olle* but represent two different actions. The archaeological contexts of the other SUs were not always interpreted and they were selected because their density of material was a little higher than the rest of the samples. The age of the samples is determined according to the ceramic chronology of the SU.

Years BCE	SU/Subsample	Crops
800-730	3493/2	*T. dicoccum*
750-650	3364/1	*H. vulgare* & *T. dicoccum*
	3364/2	
	3193/1	*H. vulgare* & *T. dicoccum*
550-500	951/1	*H. vulgare* & *T. dicoccum*
	951/2	
500-450	2376/1	*H. vulgare* & *T. dicoccum*
	2579/4	*H. vulgare* & *T. dicoccum*

Table 5.1: Tarquinia**.** Samples selected for isotope analysis, their chronology and SUs**.**

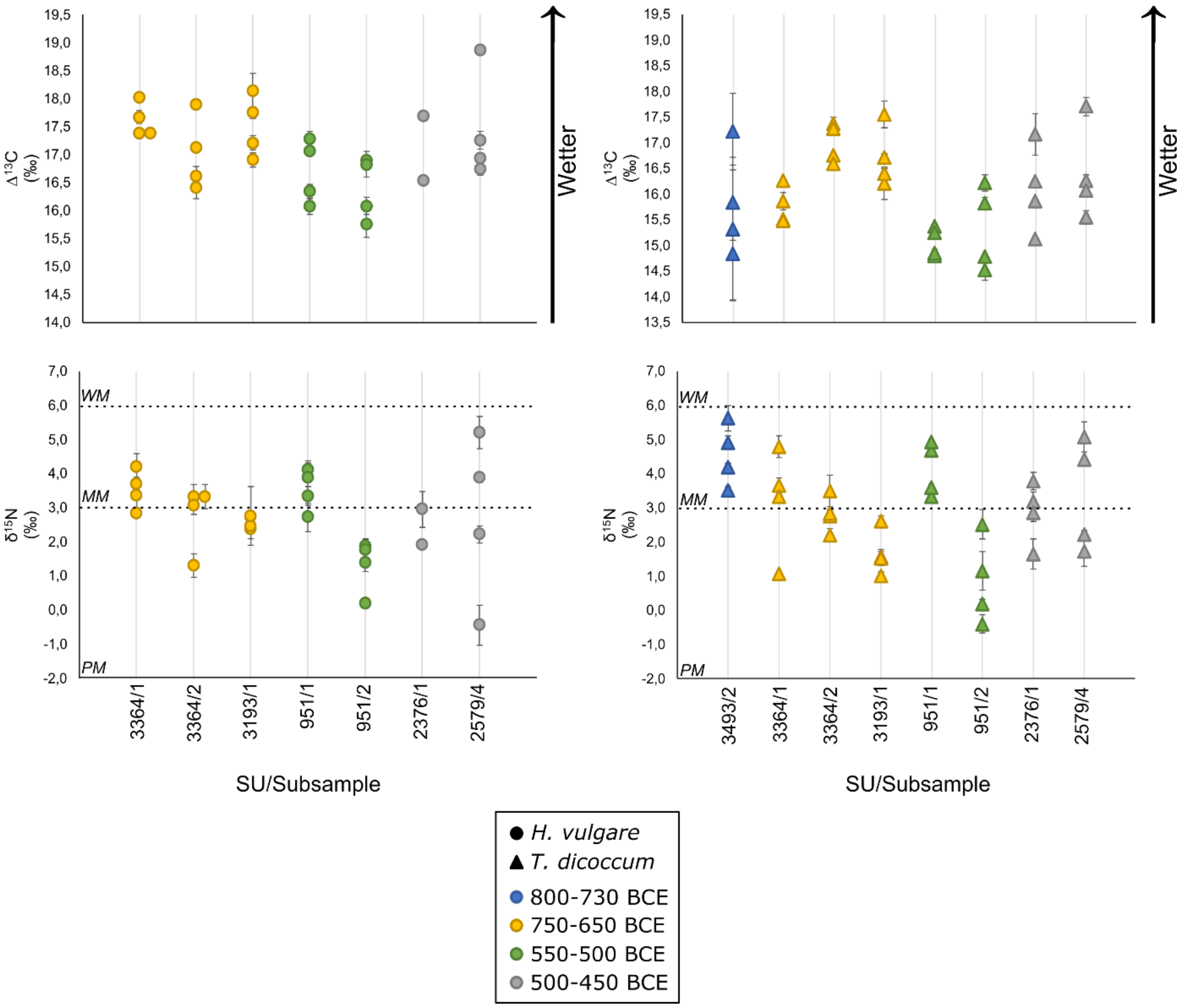

Figure 5.6: Tarquinia**.** Results of the stable isotope analysis. PM: poorly manured, MM: moderately manured, WM: well manured. Thresholds calculated according to Bogaard et al. (2013).

The **figure 5.6** shows the results of the $\Delta^{13}C$ and $\delta^{15}N$ measurements. Emmer grains cover a chronological range longer than barley for which no grains were available for the period 800-720 BCE. The $\Delta^{13}C$ values are between 15.8 and 18.9‰ for barley and between 14.5 and 17.7‰ for emmer. Barley values, as expected, are higher than the ones of emmer (Wallace et al. 2013). The $\delta^{15}N$ values are very similar in barley and emmer, they range from -0.4 to 5.2‰ for barley and from -0.4 to 5.6‰ for emmer.

The results obtained from the samples 3364/1 and 3364/2, while coming from the same SU, are not necessarily similar. Looking at emmer, the $\Delta^{13}C$ values of 3364/1 look lower than the ones of 3364/2, this not the case for barley where the trend seems opposite. For $\delta^{15}N$ results, 3364/1 has higher values than 3364/2 in the case of emmer. Disparities between the two subsamples of SU 951 were also detected. $\Delta^{13}C$ values are similar between 951/1 and 951/2, while they are different for the $\delta^{15}N$. Indeed, 951/1 has significantly higher values than 951/2 for both crops. This is an interesting find as the two subsamples do not have exactly the same origin.

951/1 corresponds to the sediments which directly covered and partially infiltrated the two vases mentioned above in the Rottoli (2005) study, while 951/2 is the sediment collected from the layer on top and around the vases when they were extracted. The difference in $\delta^{15}N$ could suggest a different origin of the two subsamples.

Looking at a more general view, from 800-730 BCE to 750-650 BCE, an increasing trend in $\Delta^{13}C$ can be observed for emmer. Between these same periods, the $\delta^{15}N$ values decrease, the thresholds for manuring even suggest the passage from a moderate application of manure to no application of manure. Interestingly, the higher $\Delta^{13}C$ seems to be linked with the lower $\delta^{15}N$. This trend is more visible for emmer than for barley, but that could be due to the lack of data for barley in the 800-730 BCE. What is particularly visible is the gap in values for $\Delta^{13}C$ between 750-650 BCE and 550-500 BCE. A drop is clearly identifiable, probably linked to a decrease in water availability for the plants, in the data for both subsamples. SU 2376 and 2579 seem to show a slight increase in $\Delta^{13}C$ compared to the previous period for both crops. The variability in $\delta^{15}N$ values for SU 2579 is rather large for barley which makes it difficult to draw any hypothesis. Emmer grains for the period 500-450 BCE show values in the same range as most of the other periods.

First stable isotopes result at all sites

Each of the sample sets coming from the three considered sites has its own chronological span but when considered together, an interval of time going from the 10th to the 5th c. BCE is covered. Figure 5.4 presents the $\Delta^{13}C$ and $\delta^{15}N$ values obtained from all sites and periods. Each dot represents the mean calculated with all the grains belonging to a period. At Palatine Hill, the division in the chronology is very detailed, in an attempt to homogenize the division of the chronology some periods were regrouped. The period from 925-875 BCE was put together with 875-850 BCE which led to a time span of 925-850 BCE.

Results

The results are presented in **figure 5.7**, as expected, (Wallace 2013), the $\Delta^{13}C$ values of barley are overall significatively higher (mean: 17.3‰) than emmer (mean: 16.6‰). The $\delta^{15}N$ results of emmer are, on the whole, higher (mean: 2.8‰) than the ones of barley (mean: 2‰). Figure 4 shows that the $\delta^{15}N$ values for both crops seem to be lower at Palatine hill and Tarquinia than at Gabii.

$\Delta^{13}C$ results for barley

From the 10th to the 9th centuries BCE, results are available only from Palatine Hill. There are no visible changes during this period of time, the mean value for the period between 925-875 BCE is equal to 17‰ while the one between 875-820 BCE is 16.7‰. There is, then, an increase of the values at Palatine Hill (mean: 17.7‰) during the 8th c. BCE (775-700 BCE) which is consistent with the value calculated at Gabii (mean:17.7‰). The following periods (700-550 BCE), including values from all the sites, are in the same range than the previous one and little intra-sites variation is observed. From 550 to 500 BCE, a significant drop is identified at Tarquinia (mean: 16.5‰) and at Gabii (mean:16.8‰). Finally, from 500 to 450 BCE where data are available only for Tarquinia, $\Delta^{13}C$ values are higher compared to the ones observed from 550 to 500 BCE (mean:17.3‰), they reach the values observed in the previous period at Tarquinia (17.4‰). However, since data is available only at Tarquinia, it is not possible to know if this is due to a specificity of the site or if changes in the environmental conditions could exist.

$\Delta^{13}C$ results for emmer

From the 10th to the 9th c. BCE the trend is the same for emmer and barley, there is no visible change during this time, both centuries show data with a mean of 16.1‰. Looking at data from Palatine hill, there is an increase in the values in the 8th cent. BCE, reaching the value at Gabii. This is consistent with what was observed for barley but the trend seems even more pronounced. The data obtained for Tarquinia at 800-725 BCE (available only for emmer; mean: 15.8‰) shows lower values than those at Gabii (mean: 17.6‰) and at Palatine Hill (mean: 17.6‰) for this period (790-700 BCE). This could be interpreted in two ways. Firstly, Tarquinia could be closer in time to the 10th and 9th c. BCE where low values were also observed at Palatine Hill. The results at Tarquinia would be, thus, linked to what happens during this period of time. However, it is also possible that these lower values are a specificity of the site of Tarquinia as, overall, it seems to present lower results compared to the two other sites. Between 700 and 600 BCE, more data is provided for Palatine Hill (mean:16.8‰) and Gabii (17.3‰); they show a slight decreasing trend compared to the previous period. At Tarquinia, the period 750-650 BCE covers both a part of the period 800-700 BCE and the period 700-600 BCE. The values are rather low (mean:16.5‰), more similar to the ones observed in the period 700-600 BCE at Gabii and Palatine Hill. This might suggest that these two periods could be closer in time. The period 600 to 550 BCE includes results coming only from Gabii. It is consistent with the results obtained from the previous periods at Gabii with a mean of 17.5‰. The values at Gabii are overall rather stable, except for 550-500 BCE where the values drop significantly (mean: 16.7‰). This decrease is also visible at Tarquinia at the same period (550-500 BCE) with a mean of 15.2‰. Even if they follow the same trends over time, the values for emmer at Tarquinia are overall lower than the ones of the other sites.

$\delta^{15}N$ results for barley

The variability for $\delta^{15}N$ is higher than for $\Delta^{13}C$ which makes it difficult to draw conclusions about possible differences or trends between periods and sites. In **figure 5.4**, there is an increase of the values during 750-650 BCE both at Gabii and Tarquinia, they decrease again at all sites in the following periods.

$\delta^{15}N$ results for emmer

As for barley no trends can be identified between sites or periods. It seems that the values are higher for the earliest periods. Moreover, one value from Tarquinia dated 800-730 BCE stands out from the other, but it is represented only by one SU which could affect the data.

Discussion

The dataset obtained is not only a story of agrarian practices at the dawn of urban centres, but it also tells us about the complex interplay between climate and human factors and can help disentangling them. This represents one of the main challenges of this work.

As explained in the introduction of this thesis, linking data obtained from archaeological material with climate studies is challenging mainly because of the difference in chronological scale and dating precisions. Moreover, pollen studies, which are routinely used to reconstruct climate conditions in the past, indicate that anthropogenic taxa (cultivated plants and weeds) have high values in the investigated period in Central Italy (Drescher-Schneider et al. 2007, Magri and Sadori 1999, Mercuri et al. 2002, Sadori 2018). This means that pollen records of last millennia cannot be used alone to assess past climate changes because the landscape was deeply influenced by humans. A clear example comes from the Lago di Pergusa sediment record, where, comparing stable isotope data and pollen data it is clear that vegetation is not only influenced by climate, but also by human activities (Sadori et al. 2016).

Even if it is not possible to exclude that the different societies we are dealing with, (from Tarquinia, Rome and Gabii), could have had local practices or preferences, looking at the trends obtain at the three archaeological sites should allow to distinguish the common trends, probably linked to climatic events from local variability most likely due to the site and its inhabitants. With these premises it is possible to look at the composite record keeping in mind the intrinsic limitations of the method.

The increasing trend observed between the 9th and the 8th c. BCE at Palatine Hill and possibly at Tarquinia (data available only for emmer) could be explained either by an anthropic factor or by a climatic event. Even if the comparison is challenging, some climatic and lake level studies from the region could help us draw some hypotheses. It was observed at lakes Accesa, Mezzano, and Fucino a phase of high stand at 2700 cal BP (ca. 750 BCE) (Magny et al. 2007). This might suggest that a global increase in water could have occurred during this period. In the present record a clear drop occurs at 550-500 BCE, it is very clear for both crops at Tarquinia but only for barley at Gabii. This drop is most likely associated with a decrease of water availability for the plants during this period. Given its synchronicity at both sites, this event was most likely driven by a climate/environmental factor which would have occurred at least at a regional scale. Nonetheless, it is not possible to totally exclude that this decrease in the values is independent at each site and would be linked to a more local anthropic factor.

Looking at the available paleoclimate data, little is known in the Mediterranean for the period, speleothem records could be quite helpful, but unfortunately, no data is available for the region of interest. At a larger scale, a phase of low solar activity, known as Great Solar Minimum (or as Homeric climatic Oscillation or Homeric minimum) occurred between 850 and 600 BCE. According to some authors it seems to have triggered a climatic change, which might have been global (e.g. Van Geel et al. 1996, 1999; Martin-Puertas et al. 2012). One of the hypotheses that would be worth investigating with more data in the future, is if such changes in sun activity could have caused climate changes as well in Central Tyrrhenian Italy and be linked with the increase observed at the Palatine in the 8th c. BCE but also, when it ends, to the decrease observed in the values at 6th c. BCE.

No important differences or clear trends can be identified between sites nor periods in terms of δ^{15}N values. Thresholds allowing to assess manuring levels were experimentally calculated in modern fields in northern Europe to create a baseline for past fields (Bogaard et al. 2013). Above 6‰ the plant can be considered as coming from a highly manured field and below 3‰, it is most likely a non manured field. Even if these values were obtained in northern Europe and no local values for reference are available, it is possible to see that almost all of the results are under 3‰ which indicate no manuring or very little animal manure for all sites and over time.

The first point to address is why looking at the use of animal manure? A demographic growth was postulated between the 10th and the 6th c. BCE and scholars hypothesized for this period an intensification of the production in order to feed the urban inhabitants. The issue of the definition of intensification was already addressed by Lodwick et al. (2021). They explained that the term intensification can refer either to an increase of the production, which can be achieved thanks to a panel of different practices which are usually not specified by scholars, or to a greater work input per unit of land. Different studies showed that from the 6th c. BCE and maybe earlier urban centres such as Rome would not be able to sustain their population anymore because of the lack of arable lands (Fulminante 2014). This could suggest that farmers would have needed to find solutions to enhance the yield of their fields instead of expanding them.

Even if the processes that led to the emergence of the urban centres were already in place, most of the chronology considered in this study still represents settlements with clusters of huts. This could explain why no use of animal manure was detected at all sites and that there is no evolution for most of the chronological sequence. However, during the latest period (since the 6th c. BCE), the settlements are almost unanimously considered as city states and yet the δ^{15}N values obtained for this time span do not suggest an application of manure. Different hypotheses can be drawn: 1) manure was never used for the investigated period; 2) manure was used, however due to the lack of local environmental reference for the δ^{15}N it was not possible to detect it 3) manure was used too occasionally to be detectable by nitrogen stable isotope analysis. Moreover, it is important to keep in mind that no application of animal manure does not mean no improvement of fertility (Heinrich et al. 2021).

It is challenging to compare the $\delta^{15}N$ values of the two crops due to the high variability observed. However, looking at the calculated means, it seems that the mean of emmer seems to be higher than barley from 925-825 BCE at Palatine Hill, this is also the case from 700-600 BCE but in that case, it could be observed both at Palatine Hill and Gabii. Around 700 BCE, an opposite trend can be identified with the mean of barley being higher than emmer's one at Gabii and Tarquinia. Whatever the differences, according to the thresholds, they still remain in the conditions of manuring which does not indicate a difference in management of the two crops.

Conclusion

The process of urbanization described in Central Tyrrhenian Italy during the first half of the 1st millennium BCE took its roots in the Bronze Age. However, most scholars focus their research on the transition between the 7th and the 6th c. BCE, when a phase of monumentalization and construction of public spaces is particularly visible in the archaeological records. This is considered to be the period marking the establishment of the first cities in Central Tyrrhenian Italy. The archaeological surveys pointed out, as well, a transformation of the agricultural exploitation both in Etruria and *Latium vetus* during this period (Cifani 2002). The carbon and nitrogen stable isotopes analyses covering this period show, for the major part, a stability in their values which do not suggest a drastic change in the agricultural practices. No application of manure is detected in continuity with what was previously observed. At the transition between the 7th and the 6th no changes in the water availability were detected. However, a very clear drop occurred at the 6th c. BCE in the $\Delta^{13}C$ values at Tarquinia and Gabii, in correspondence to a more urbanized context. Given the synchronicity of the event, the reduction of water availability was most likely driven by a climate/environmental factor which would have occurred at least at a regional scale.

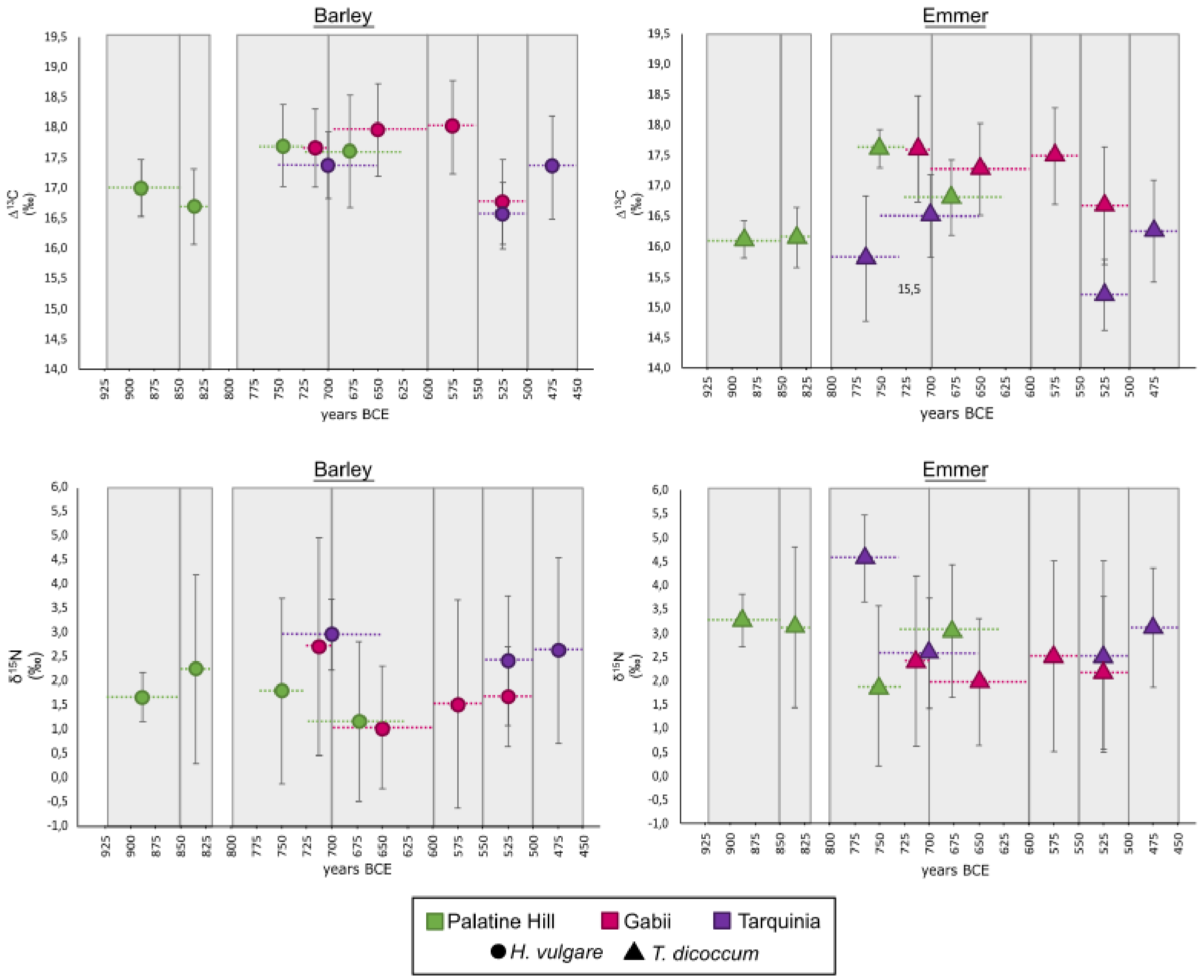

Figure 5.7: Carbon and nitrogen stable isotope results coming from the three investigated archaeological sites. Each dot represents the mean for all the grains composing this period and is the middle value of the chronological range given by the dating given by the ceramic. The dot lines represent this range.

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Chapter 6

Charcoals as environmental proxies

Wood had a central role in the life of ancient communities, it was used to make artifacts, build structures and was also one of the major fuel resources (Smart and Hoffman 1988). It has been recognized that the study of charred wood from archaeological contexts is a precious source of information to reconstruct the past vegetation surrounding a settlement (Chabal 1994; Figueiral and Mosbrugger 2000). Yet, it is essential to keep in mind that the charcoals retrieved in such contexts are subject to an anthropic filter. The different taxa found on a site are the result of a human selection according to diverse criteria among which the most common ones are the ease of the collection of the trees, and the type and characteristics of the wood sought by humans. Finally, cultural choices and preferences of each community are also important criteria for the selection of woods (Smart and Hoffman 1988). Therefore, a long repetitive accumulation of charcoal provides information about the uses and exploitation of the woodlands (Asouti and Austin 2005).

Beside the vegetation and its exploitation, more environmental information can be obtained from wood charcoal. As explained in **Chapter 2: Material and methods**, their carbon stable isotope ratio ($\delta^{13}C$) provides information about the natural water availability in which they developed (Ferrio et al. 2006; Fiorentino et al. 2008; review in Ferrio et al. 2020). This complementary set of analyses was never done till now in Peninsular Italy for this period and represents, thus, a pilot study.

This chapter presents the first results of the taxonomic identification, as well as the ^{14}C ages and carbon stable isotope analysis of wood charcoal from the Latin city of Gabii **(Chapter 1)**.

Anthracological study

The anthracological material comes from domestic and contexts excavated in area C and D. A total of 270 charcoal fragments from 48 different SUs were sampled, processed and identified for this study (see **Chapter 2: Material and methods** for a detailed explanation of the adopted methodology). While the results are still preliminary, they provide a first insight on the presence and use of certain taxa in the region between the 8th and the 6th c. BCE.

Ubiquity

In this study the ubiquity method was used to quantify and understand the importance of each taxon in the assemblage. This method can inform us on which taxa are the most frequent within the site but can hide patterns in terms of abundance (Asouti 2005). The assemblage includes 14 identified taxa and a 25% of indeterminate **(Fig. 6.1)**. The most ubiquitous taxon is, by far *Quercus deciduous*, it is also the most abundant. However, this abundance could be explained by the fragility of deciduous oak charcoals which tend to break easily. Some fragments of *Quercus ilex* (evergreen oak) type were also retrieved in several SUs. Both taxa were found at other sites like at Rome between the 7th and the 5th c. BCE (van Kampen et al. 2005). Also, from the Fagaceae family some fragments of *Fagus* sp. (beech) were identified in 10 of the 48 contexts. The Corylaceae are represented by *Carpinus* sp., however, some fragments were more problematic and were classified as *Carpinus/Ostrya*. Charcoals of *Ulmus* sp., are not very ubiquitous, they were retrieved in just two SUs but there are a lot of fragments. The Maloideae family is present in several SUs but it is always represented by only one fragment. The Prunoideae family and *Acer* sp. were rarely found among SUs and just a few fragments were present. The Cornus/Viburnum opulus category is principally concentrated in one SU. *Vitis* sp. (grapevine) as well as *Olea europaea* (olive tree) charcoals were retrieved in just a few contexts. The grape seeds found in the area C and D at Gabii are rather sparse and it was not possible to determine if they were coming from wild or domesticated grapevines. A handful of olive stones were found in contemporary levels in area A but for now nothing in areas C and D.

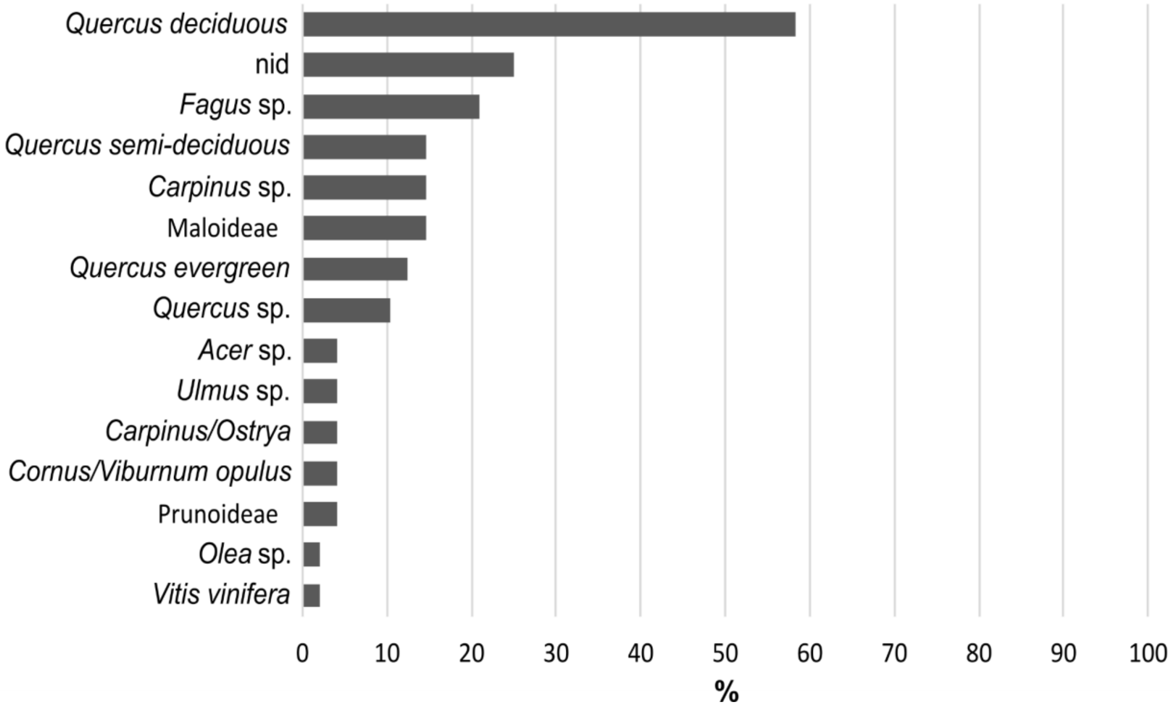

Figure 6.1: Gabii. Ubiquity of the tree taxa.

Discussion

The wood charcoal identified in this preliminary study originates from fuel debris accumulated in long-term mixed deposits. This kind of contexts offer the best potential for paleoenvironmental reconstruction as well as reflect more accurately the woodland management strategies around the settlement (Asouti 2005; Chabal 1997; Théry-Parisot et al. 2010). Their analysis showed us a predominance of deciduous oaks which can suggest a dominance and an easy accessibility of this taxa in the nearby settlement. Moreover, it constitutes a great fuel and construction material. For all these reasons, it is not surprising that a lot of fragments were found in most of the SUs at Gabii.

It is, instead, more unexpected to find fragments of *Fagus* sp., which is also the second most ubiquitous taxa, in low altitude environments such as Gabii. Indeed, the palynological and paleoenvironmental studies suggest that the environment was not suitable for beech anymore during this period. Beech develops in cool conditions on weakly acid soil (Pignatti 1998). Nowadays, they can be found at lower altitudes in the cold climate of northern Europe but in Central Italy it is restricted to mountain areas between 800 and 1000 m of altitude (Pignatti 1998). Its presence at Gabii can be explained by two main hypotheses; the first one is that beech would have survived in the form of relic areas in an ecological sanctuary and its presence would have been preserved and facilitated by the local populations for cultural purposes. The second option is that beech trees occupied higher altitudes where the climate was cooler. Nowadays, at about 20 km from the archaeological site of Gabii, beech patches were identified **(Fig. 6.2)**. They grow in soils on calcareous substrate that is favourable for beech trees. It is thus possible to postulate that also in the Iron Age some patches of beech were present and exploited and moved down to the plains by the nearby population. This possibility was considered by Veal (2014) to explain the big proportions of beech found at the archaeological site of Pompei during the 2nd c. BCE and the 1st c. AD where it should not be present as well.

Evergreen oaks were retrieved in a few SUs and only a handful of fragments. Olive trees were found in only one SU for now. Unlike the other taxa which are more characteristic of temperate climate, evergreen oaks and olive trees are found in a Mediterranean climate.

The same range of taxa were identified in several pollen studies done in the different volcanic lakes present in the region (Magri and Sadori 1999; Sadori et al. 2018; 2011). The findings in this study are consistent with the palynological reconstruction of the past vegetation dominated by mixed deciduous oak forests, associated with other temperate species, while, on the more arid and exposed areas, Mediterranean vegetation would have preferentially developed.

This study is preliminary; other charcoals already available will be studied in the near future to have a more complete understanding of woodland management and the environmental settings around the settlement.

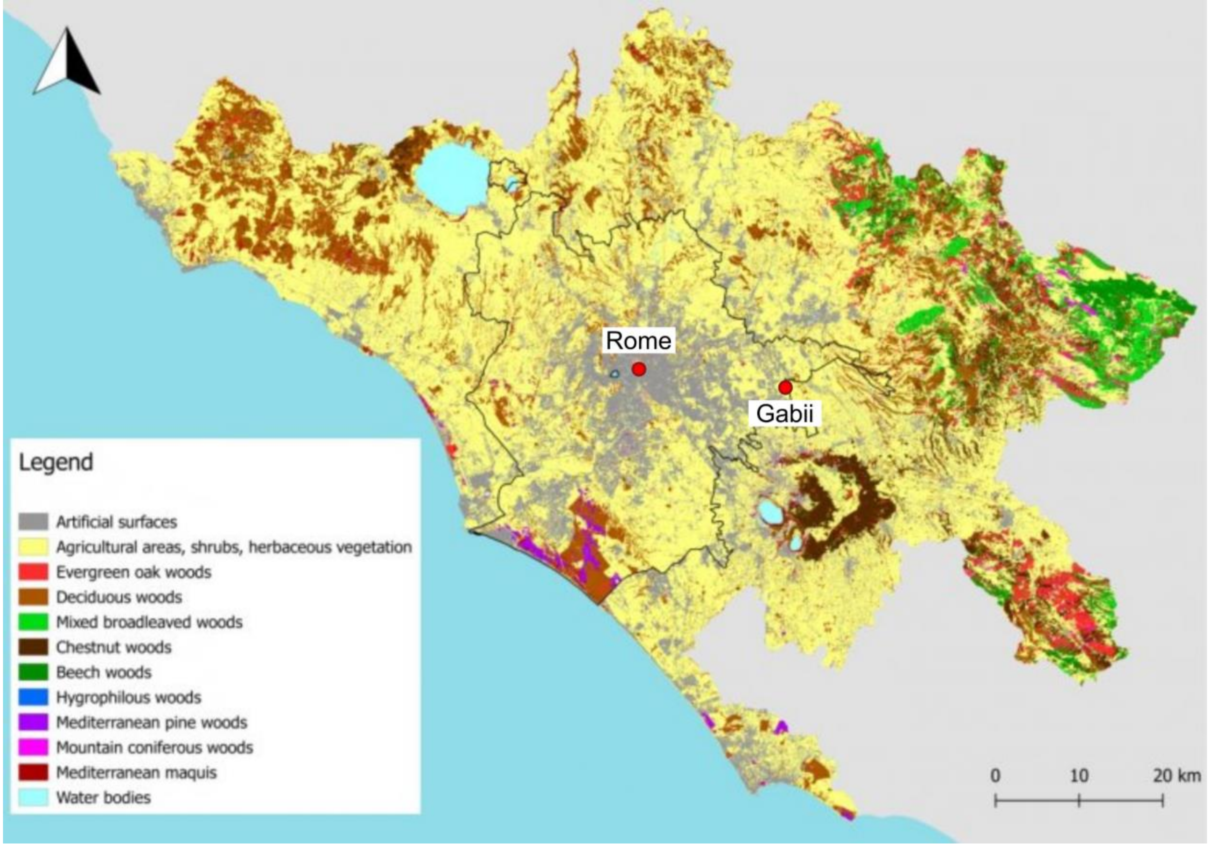

Figure 6.2: Actual distribution of beech woods in the studied region. Modified from Fusaro et al. (2017).

Stable isotope results

Trees register in their tissue's precious information about the environment they grew in such as water availability. This information is preserved even after its carbonization and carbon stable isotope analyses allow us to assess it. By comparing these results of the trends obtained for cereals, it is possible to discriminate human activities from environmental and climate changes. In order to apply this method to this study, 10 fragments identified as *Q. deciduous* (deciduous oak) were selected, treated and analysed (**Chapter 2: Material and methods)**. The preliminary results of this analysis are available and will be presented in this chapter.

The stable isotopic results range between -27.6 and 25‰ which is coherent with the values usually obtained for C_3 plants **(Tab. 6.1)**. As for cereal grains it was necessary to calculate $\Delta^{13}C$ in order to take into consideration the possible changes in the atmospheric CO_2 isotopic values. After correction thanks to the AIRCO2_LOESS system the values are between 19.0 and 21.7‰.

Sample Name	$\delta^{13}C$	$\Delta^{13}C$	%C	^{14}C BP	Relative probability within 2 σ	Median probability
UB 45661.1	-25,0	19,0	61,30	2563 ± 24	803 - 572	-778
UB 45661.2	-25,0	19,0	61,44			
Average	**-25,0**	**19,0**	**61,37**			
sd	*0,0*	*0,0*	*0,1*			
UB 45662.1	-25,5	19,5	60,52	2558 ± 29	804 - 565	-765
UB 45662.2	-25,5	19,5	61,37			
Average	**-25,5**	**19,5**	**60,95**			
sd	*0,0*	*0,0*	*0,6*			
UB 45663.1	-26,0	20,0	59,23	2578 ± 22	805 - 673	-785
UB 45663.2	-25,9	19,9	58,59			
Average	**-26,0**	**20,0**	**58,91**			
sd	*0,1*	*0,1*	*0,5*			
UB 45664.1	-25,4	19,4	59,71	2501 ± 23	773 - 544	-634
UB 45664.2	-25,5	19,4	61,79			
Average	**-25,4**	**19,4**	**60,75**			
sd	*0,0*	*0,0*	*1,5*			
UB 45665.1	-27,0	21,1	59,48	2510 ± 41	792 - 483	-639
UB 45665.2	-27,0	21,1	60,54			
Average	**-27,0**	**21,1**	**60,01**			
sd	*0,0*	*0,0*	*0,7*			
UB 45666.1	-25,4	19,4	59,48	2562 ± 43	809 - 544	-692
UB 45666.2	-25,4	19,4	60,41			
Average	**-25,4**	**19,4**	**59,95**			
sd	*0,0*	*0,0*	*0,7*			
UB 45667.1	-25,6	19,5	57,62	2579 ± 45	822 - 545	-766
UB 45667.2	-25,5	19,5	57,10			

Average	**-25,5**	**19,5**	**57,36**			
sd	*0,1*	*0,1*	*0,4*			
UB 45668.1	-27,6	21,7	60,58	2574 ± 41	812 - 547	-766
UB 45668.2	-27,6	21,7	61,01			
Average	**-27,6**	**21,7**	**60,80**			
sd	*0,0*	*0,0*	*0,3*			
UB 45669.1	-26,7	20,8	60,70	2758 ± 41	1002 - 819	-900
UB 45669.2	-26,8	20,8	61,26			
Average	**-26,8**	**20,8**	**60,98**			
sd	*0,0*	*0,0*	*0,4*			
UB 45670.1	-26,8	20,9	62,43	2589 ± 39	822 - 565	-783
UB 45670.2	-26,8	20,9	62,43			
Average	**-26,8**	**20,9**	**62,43**			
sd	*0,0*	*0,0*	*0,0*			

Table 6.1: Gabii. ^{14}C, δ^{13}C and the calculated Δ^{13}C results for the deciduous oak fragments. ^{14}C BP: non calibrated data; Relative probability within 2 σ and median probability: calibrated data.

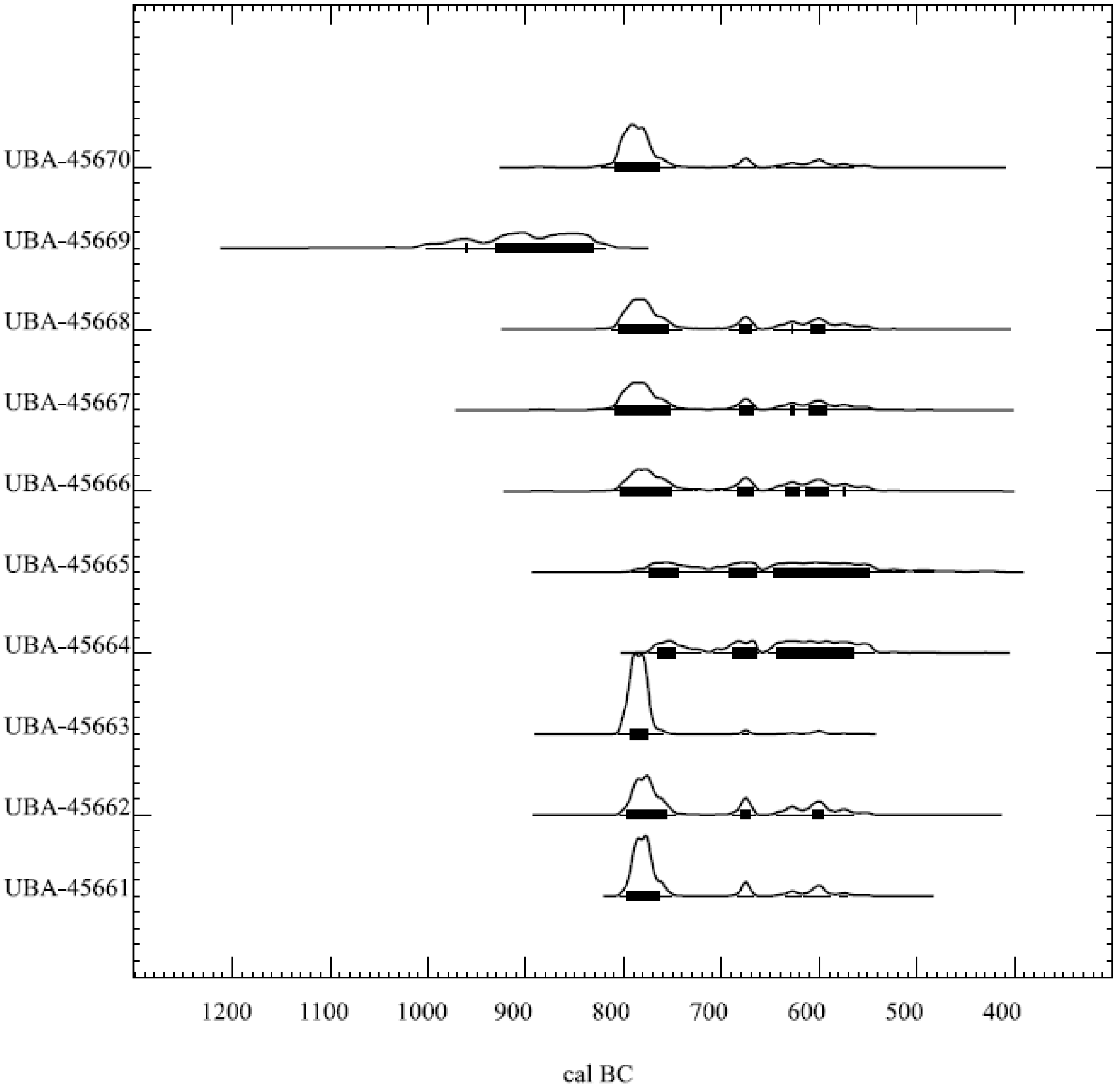

Figure 6.3: Gabii. Probability distribution for the 10 deciduous oak samples selected.

Figure 6.3 presents the posterior probability distribution for the 10 charcoal fragments analysed. Due to the Hallstatt plateau, which represents a flat area between the 9th and the 5th c. BCE on the reference curve used for calibration, the radiocarbon dates show a wide calibration interval for this period (Trias et al. 2020). For this reason, the calibrated ages obtained have poor precision and it was not easy to put the samples in a chronological order.

The median probability plotted with the 2-sigma uncertainty is shown in **figure 6.4**. Most of the samples overlapped at 820-540 BCE as expected, they have $\Delta^{13}C$ values that are between 19 and 20‰. They vary in a range of 1‰ which can be considered as small. Three points also in this period are higher compared to the two other ones. Finally, the oldest value, less problematic, is also in the higher range of $\Delta^{13}C$.

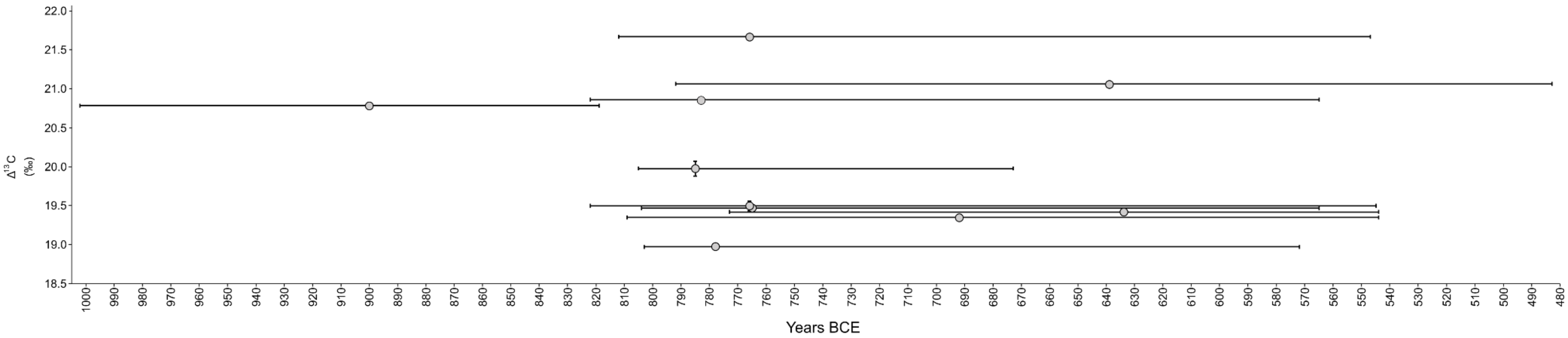

Figure 6.4: Gabii. Median probability with an uncertainty of 2 sigma.

When trying to put in sequence the charcoals it is clear that, UBA-45669 coming from SU 3529, is the oldest one. The other samples are trickier to put in sequence. One of the solutions considered was to use the median probability, keeping in mind that the range of uncertainty is big **(Fig. 6.5)**. The results show a variability more or less significant in the $\Delta^{13}C$ values between samples that does not seem linked to the chronology. Indeed, charcoal fragments, which have similar median probability, can have very different values, for instance UB 45668 (median probability: -766; $\Delta^{13}C$: 21.7‰) and UB 45667 (median probability: -766; $\Delta^{13}C$: 19.5‰) or UB 45665 (median probability: -639; $\Delta^{13}C$: 21.1‰) and UB 45664 (median probability: -634; $\Delta^{13}C$: 19.5‰). The most likely explanation is that this is due to the wide uncertainty in the dating. However, different environments of growth (e.g. top or bottom of a slope, proximity to a watering place) could also explain this variation.

In an attempt to have a more global view of the data, the $\Delta^{13}C$ mean for each century was calculated. For the samples dated from the 10th c. BCE a mean of 20.8‰ was obtained, 20.1‰ for the 8th c. BCE and 19.9‰ for the 7th c. BCE. Overall, values are stable across centuries.

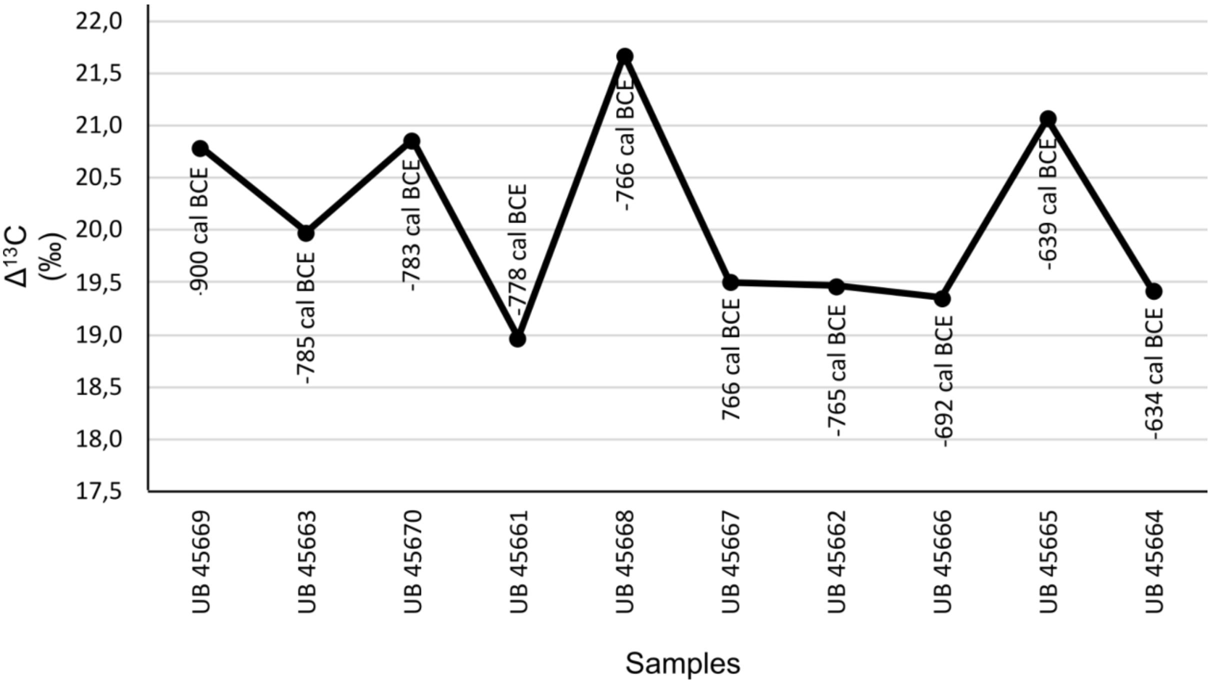

Figure 6.5: Gabii. Median probability and carbon stable isotope values.

The analysis of the first 10 charcoals allows only a partial comparison with the cereals. The period 550-500 BCE, where a drop was identified both at Tarquinia and Gabii, is not present in the charcoal record. Nonetheless, these results are promising and it is essential to continue to develop a method allowing the analysis of charcoals coming from urban contexts where the stratigraphy is complex and the charcoals are mainly in mixed deposits.

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Conclusion and perspectives

Conclusion

This is the first archaeobotanical study that involves three important sites, “kernels” of a complex societal change. The transformations observed during the 1st millennium BCE in Central Tyrrhenian Italy are part of the larger urbanization process happening in the Western Mediterranean. In Central Tyrrhenian Italy these changes found their origin during the Bronze Age and continued during the Iron Age (Pacciarelli 2017). Scholars tend to focus on the transition between the 7th and the 6th c. BCE, when a phase of monumentalization and construction of public spaces is particularly visible in the archaeological records (Fulminante 2014). This is considered to be the period marking the establishment of the first cities in Central Tyrrhenian Italy. During this period, the archaeological records and surveys pointed out, as well, a transformation of land exploitation and agricultural systems both in Etruria and *Latium vetus* (Cifani 2002). The exact nature and extent of these changes are still unknown, mainly due to a lack of data and studies focusing on this subject. Moreover, the relationships existing between urbanization process, demographic growth, agricultural changes and the climate instability occurring during this period are difficult to understand and disentangled.

The archaeobotanical studies can reflect changes in the agricultural practices by identifying changes in proportions or introduction/decline in use of crops. Overall, during the whole chronological sequence covered, barley and emmer stay the main cereals produced along with pulses represented by fava beans. However, local specificities among sites seem to exist, at Gabii a noteworthy presence of bitter vetch was identified from the 8th to the 6th c. BCE while this crop is, for the same period and in general, quasi absent from the archaeobotanical assemblages of Palatine Hill and Tarquinia. Millet, at Gabii, while absent during the 8th c. BCE seems to grow in importance in the following centuries, this trend is not visible for the other sites where, overall, millet stays very occasional. Other differences, such as the presence of spelt only at Palatine Hill, suggest that each site could have their own particularities. They could be linked either to an adaptation of the populations to their surrounding environment or to socio-economic preferences.

Another aspect of these agricultural transformations is field management and environment. The carbon and stable isotope analysis can help us to investigate this angle as well as understand the factors that could influence it. In terms of water availability, an increased trend might exist in the 8th c. BCE, followed by a more stable period. Further investigations need to be undertaken to confirm this increasing trend as only data from Palatine Hill are available for now. In the course of the 6th c. BCE, a drop was observed in concomitance at two sites suggesting a regional environmental/climatic event. All these changes in water availability could have affected plant development and therefore might have impacted the production. However, a direct correlation between an increase in the water availability and an increase in yield cannot necessarily be drawn. Indeed, plants can be not affected by the change of water availability. Even if the water availability keeps increasing, it will not be necessarily linked with an improve of the productivity as, when the plant reaches its need in water, it will stop up taking more water (water saturation). Too much water can also impact the plant in a negative way when too much water comes at once or in the wrong season. The discrimination between climate and anthropic factors, even if challenging, can be possible. One of the methods proposed here was to look at regional patterns in order to identify possible common trends which indicate a climatic event.

The application of animal manure is generally linked with an increase of the production in order to feed a growing population. This practice could have been used, among others, during this period of demographic growth. In the region of interest, the results do not suggest a constant and large use of animal manure in the fields. It is particularly interesting that even from the 6th c. BCE, when, according to some estimations calculated for Rome (Fulminante et al. 2014), the population exploded and when a large reorganization of the agricultural system was hypothesized, the situation remained stable. There is no doubt that the past populations needed to increase their production but it seems that they could have employed other methods. Even if the soil of Etruria and *Latium vetus* are very fertile, the availability of arable lands decreases over time, practices allowing an increase of the yield per field were probably used and could consist in fallows, green manure or intercropping non detectable with the nitrogen stable isotope analysis. This investigation about the manuring practices needs, in any case, to be continued with the creation of a local baseline for $\delta^{15}N$ in order to prove or disprove it.

The status of emmer and barley in human diet in this region still raises some debates, the way they were managed by humans could give us some indications about that matter. Overall, across the whole chronological sequence and among all sites no difference seemed to exist between emmer and barley. More attention could have been given to emmer in terms of water availability at the Palatine during the 8th c. BCE, without knowing for sure if it was a deliberate choice done by past inhabitants.

No clear and abrupt shift in terms of crop production and field management seem to occur during the 6th c. BCE, it is probable that the changes in the agricultural practices was a slow and gradual process.

The pilot study of wood charcoal represents another opportunity to understand in more details than environment and the climatic fluctuations as well as disentangle anthropic and climatic factors. Even if the method still needs more elaboration and the dataset must be enlarged, the results already obtained are promising to answer the question at hand.

Perspectives

The urbanization process, as well as the factors which could have influenced it, are a topic that has been debated for quite a long time and new angles need to be considered to bring new perspectives. The methods proposed in this thesis have never been used in this region and for this period of time before. They brought new data to the debate and helped understand some of its aspects better. For these reasons, more work needs to be done to continue to explore these research questions.

The environmental reference

As it was mentioned several times in this thesis, one of the limitations for the interpretation of the stable isotope analysis is the lack of a baseline representing the $\delta^{15}N$ value for plants growing in non-cultivated soil. This would help us to understand better if the crops could have been manured or not. In order to build a local baseline two main ideas, have to be explored. The first solution, already proposed in other studies, consists of running stable isotope analysis on modern cereal grains grown in the region of interest under different regimes of manuring. The other possibility would be to do stable isotope analysis on cereal grains that were planted by Prof. Laura Motta in the paleo soil exposed in area D during an excavation season and that are still available. The results could reflect the $\delta^{15}N$ of the plant grown in the non-cultivated archaeological soil. Moreover, no agriculture was practiced after the abandonment of the site and therefore, fertilizers were never used which removes the problem of modern contamination.

Charcoals and environment

The anthracological study has to be developed with the addition of more charcoal fragments already retrieved from the site of Gabii. This has the potential to give us a much more accurate picture of the wooded vegetation surrounding the settlement as well as its management by past populations. More charcoal fragments were found at Palatine Hill, and it is planned to do a comparable study which will give us a more general view of wood uses in the wider *Latium vetus*. Moreover, it is essential to continue the carbon stable isotope analysis to complete our records and chronological sequence in order to compare the trends obtained on cereals and understand if the $\Delta^{13}C$ values are impacted by environmental or cultural local specificities or by a more regional pattern linked to climate changes.

The regional perspective

In order to complete, improve and fill the gaps in the chronological sequence that we obtain for the cereal grains it would be necessary to obtain more data from the archaeological sites of Gabii, Palatine hill and Tarquinia. The results at Tarquinia are still preliminary, because so far, the context studies for this study were rather poor, but more contexts are under study by

Fridga Smith at the University of Cambridge, UK. Her archaeobotanical study will provide more material on stable isotope analysis and will, therefore, allow us to develop the study of this site. At Palatine Hill, for the centuries studied, it will be interesting to add data to confirm the different trends observed but it would be crucial to obtain more values for the 6th and 5th c. BCE in order to improve the chronological sequence already built in this study and confirm the drop in the values observed during the 6th c. BCE. Looking at Gabii, it would be necessary to add data for the 10th and 9th c. BCE if future archaeological excavations will make the material available.

Development of the project

Finally, it will be essential to take into consideration more archaeological sites that represent emerging urban centres in the two different regions (Etruria and *Latium vetus*) as well as to add other taxa (pulses) in order to confirm or disprove the patterns observed. This will also allow to detect possible local details in the crop management and in the production and consumption of staples.

Other uses of the stable isotope results

The stable isotope results will also be included in other studies linked to the different projects actually running at the three archaeological sites. One of the applications is the integration of the results in the palaeodietary models at Tarquinia and Gabii. Indeed, stable isotope analyses were run on animal and human bones dated from the same periods as the cereal grains at these two sites. The addition of cereal grains will improve the alimentary models as they constitute the first link in the food chain.

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APPENDIXES

	C 2821		C 2901		D 3540		C 2936		D 3709		D 3544		C 2935		C 2941		C 2860		C 2934		C 2845		C 2699		C 2676		C 2872		C 2742		C 2663		C 2732		C 2740	
Volume (ml)	16.6		45		10		20		22.5		25		17.5		12		11		15		40		16		23		26.5		47.5		8		17		25	
Weight (g)	7.7		15.0		3.7		8.1		6.9		9.3		7.1		5.0		4.2		5.9		26.7		6.4		7.1		12.8		14		3.7		7.1		8.9	
	Whole	Fg	Whole	Fg	Whole	Fg	Whole	Fg	Whole	Fg	Whole	Fg	Whole	Fg	Whole	Fg	Whole	Fg	Whole	Fg	Whole	Fg	Whole	Fg	Whole	Fg	Whole	Fg	Whole	Fg	Whole	Fg	Whole	Fg	Whole	Fg
Cereals nid	24	47	24	56	33	96			25	35	38	144	8	9	5	7	10	14	5	6	18	20	25	31	5	1	18	37	28	80	3		14	27	25	38
H. vulgare	25	4	67	16	108	13	65	12	33	6	238	26	5		3		9		6		106	34	24	5	1		28		64	9			8	2	33	2
T. dicoccum	7		27		7		24	1	24		18		7		14		5		3		13		13	2			7		11		3		8		10	
Triticum sp.	1		14		5		4		9	2	6		3		2		2				6		6		5		9		9	3			7		4	
T. mono cf			2																1																	
T. aestivum/durum cf			2						1																											
Panicum/Setaria											5																									
Setaria italica																																	1			
Vicia faba				9	2							2											1										1			
Vicia ervilia			4				11																						4							
Medicago sp.			3																																	
Trifolium sp. cf																											1									
Fabaceae nid													2	16					1	2				4				2		4			2	8		17
Lolium sp.		3		1	4		1				8	1									1	2	2						5				2		4	
Lolium temulentum	7		6		6		7		10		9		2		2						7		8						7		2		1		7	6
Lolium multiflorum/temulentum	1		1		3				6		3				1						3								1							
Lolium multiflorum			1						4		5																									
Phalaris sp.																					3							1							3	
Big poaceae					5								6		6					15											2				5	17
Vitis vinifera	1		1		1		1		1												1	1	1													
Ficus carica																																			1	
Silene gallica			1				1		8												1															
Malvaceae																					1														2	
Portulaca oleraceae																											1									
Brassicaceae																											1									

Appendix A: Gabii. Taxonomical identifications of the carpological remains.

Appendix B: Gaveriaux & al. (Submitted), supplementary material

Period	SU	Crops	Seed code	Lost after chemical treatment	δ^{15}N mean (‰)	sd	δ^{13}C mean (‰)	sd	Δ^{13}C mean (‰)	sd	C:N
1	3301	*H. vulgare*	H83		2.7	0.2	-22.6	0.2	16.4	0.2	31.5
1	3301	*H. vulgare*	H84		-0.5	0.2	-23.8	0,0	17.7	0,0	34.3
1	3301	*H. vulgare*	H85		-0.8	0.4	-24.5	0.1	18.5	0.1	49.6
1	3301	*H. vulgare*	H86		1.9	0.1	-23.7	0.2	17.6	0.2	29.4
1	3301	*T. dicoccum*	D87		1,0	0.3	-23.8	0,0	17.8	0,0	28.5
1	3301	*T. dicoccum*	D88		1.2	0.3	-22.8	0,0	16.7	0,0	29.8
1	3301	*T. dicoccum*	D105		1.4	0.1	-23.3	0.1	17.1	0.1	24.9
1	3301	*T. dicoccum*	D106		0.2	0.1	-23.6	0.1	17.4	0.1	29.1
1	2903	*H. vulgare*	H33		4.5	0.1	-24.7	0,0	18.6	0,0	31.9
1	2903	*H. vulgare*	H34		4.8	0,0	-23.5	0,0	17.4	0.1	19.7
1	2903	*H. vulgare*	H35		5.3	0.1	-23,0	0.3	16.8	0.3	19.2
1	2903	*H. vulgare*	H36		2.8	0,0	-24,0	0,0	17.9	0.1	27.9
1	2903	*T. dicoccum*	D37		1.5		-25.4		19.4		26.
1	2903	*T. dicoccum*	D38	Yes							
1	2903	*T. dicoccum*	D39		4.3	0.1	-24.1	0.2	18,0	0.2	28.6
1	2903	*T. dicoccum*	D40		2.7	0.1	-24.9	0.1	18.9	0.1	29.0
1	2907	*H. vulgare*	H1	Yes							
1	2907	*H. vulgare*	H2		5.9	0.2	-23.9	0,0	17.8	0,0	28.9
1	2907	*H. vulgare*	H3		1.6	0.1	-24.1	0.1	18,0	0.1	42.0
1	2907	*H. vulgare*	H4		1.6	0.1	-23.6	0.1	17.5	0.1	32.9
1	2907	*T. dicoccum*	D5		0.9	0.1	-23.5	0,0	17.4	0,0	28.2
1	2907	*T. dicoccum*	D6		5.8	0,0	-23.4	0,0	17.2	0,0	22.3
1	2907	*T. dicoccum*	D7		4.1	4.1	-23.3		17.1		30.6
1	2907	*T. dicoccum*	D8		3.5	0.1	-22.7	0.1	16.5	0.1	31.7
2	2868	*H. vulgare*	H25		0.7	0.1	-22.4	0.2	16.3	0.2	33.8
2	2868	*H. vulgare*	H26		-0.3	0.3	-23.5	0.1	17.4	0.1	41.7
2	2868	*H. vulgare*	H27		-0.9	0.1	-23.8	0,0	17.7	0,0	45.1
2	2868	*H. vulgare*	H28		1.6	0,0	-24.3	0.6	18.3	0.6	39.2
2	2868	*T. dicoccum*	D29		0.5	0.4	-23.6	0.2	17.5	0.2	30.5
2	2868	*T. dicoccum*	D30		2.8	0.2	-22.6	0.2	16.4	0.2	19.8
2	2868	*T. dicoccum*	D31		2,0	0.3	-21.9	0.2	15.7	0.2	
2	2901	*H. vulgare*	H43		0.2	0.2	-23.9		17.8		34.3
2	2901	*H. vulgare*	H44		2.6	0.2	-23,0	0.1	16.9	0.1	35.0
2	2901	*H. vulgare*	H45		2.2	0,0	-23.8	0,0	17.7	0,0	32.8
2	2901	*H. vulgare*	H46		0.9	0.2	-24.3	0,0	18.2	0,0	39.8
2	2901	*T. dicoccum*	D47		1.4	0.2	-23.6	0,0	17.5	0,0	34.3
2	2901	*T. dicoccum*	D48		1.4	0.1	-23.4	0.3	17.2	0.3	28.2
2	2901	*T. dicoccum*	D49		0.9	0.1	-23.8	0.1	17.8	0.1	33.2
2	2901	*T. dicoccum*	D50	Yes							
2	2881	*H. vulgare*	H17		2.6	0.1	-24.4	0,0	18.3	0,0	33.9
2	2881	*H. vulgare*	H18		1.3	0.1	-24,0	0,0	17.9	0,0	43.8
2	2881	*H. vulgare*	H19		1.3	0.1	-25.2	0.4	19.1	0.4	31.1
2	2881	*H. vulgare*	H20		2.9	0.2	-22.9	0.1	16.8	0.1	32.5

2	2881	*T. dicoccum*	D21		3.4	0.3	-23.1	0,0	17,0	0,0	25.5
2	2881	*T. dicoccum*	D22		2.3	0,0	-24.5	0.1	18.4	0.1	31.9
2	2881	*T. dicoccum*	D23		1.7	0.1	-24,0	0,0	17.9	0,0	37.5
2	2881	*T. dicoccum*	D24		3.2	0.1	-23.6	0.2	17.5	0.2	33.1
2	3544	*H. vulgare*	H89		2.5	0.2	-24.9	0.2	18.9	0.2	42.0
2	3544	*H. vulgare*	H90		0.4	0.4	-23.5	0,0	17.4	0,0	28.2
2	3544	*H. vulgare*	H91		-0.4	0.2	-24.7	0.3	18.6	0.3	33.6
2	3544	*H. vulgare*	H92		-0.8	0.2	-24.2	0.2	18.1	0.2	35.5
2	3544	*T. dicoccum*	D93		1.8	0.2	-22.8	0.1	16.6	0.1	28.9
2	3544	*T. dicoccum*	D94		0.4	0.2	-22.7	0,0	16.6	0,0	28.5
2	3544	*T. dicoccum*	D96		-0.3	0.3	-22.8		16.7		27.1
2	3544	*T. dicoccum*	D95	Yes							
2	3540	*H. vulgare*	H75		-1	0.3	-24.7	0.3	18.7	0.4	31.8
2	3540	*H. vulgare*	H76		1,0	0.5	-24.5	0.2	18.5	0.2	30.6
2	3540	*H. vulgare*	H77		0.9	0.2	-25.5	0.2	19.5	0.2	30.9
2	3540	*H. vulgare*	H78		-0.9	0.3	-24.3	0.1	18.2	0.1	37.1
2	3540	*T. dicoccum*	D79		0.8	0.3	-24.2	0.2	18.1	0.2	34.6
2	3540	*T. dicoccum*	D80		0.6	0,0	-23.2	0.1	17.1	0.1	27.0
2	3540	*T. dicoccum*	D81		1.8	0.3	-24.3	0.2	18.2	0.3	32.4
2	3540	*T. dicoccum*	D82		1,0	0,0	-24.4	0.3	18.4	0.3	27.7
2	3496	*H. vulgare*	H162G		0.5	0.0	-24.3	0.2	18.2	0.3	27,5
2	3496	*H. vulgare*	H163G		-0.3	0.4	-24.0	0.3	17.9	0.3	28,7
2	3496	*H. vulgare*	H164G		1.3	0.2	-24.2	0.1	18.1	0.1	25,2
2	3496	*H. vulgare*	H165G		0.5	0.1	-23.7	0.2	17.6	0.2	32,9
2	3496	*H. vulgare*	H166G		-0.3	0.6	-24.2	0.1	18.1	0.2	27,2
2	3763	*H. vulgare*	H97		1.9	0.2	-24.2	0.1	18.2	0.1	27.4
2	3763	*H. vulgare*	H98		0.7	0,0	-24.6	0.2	18.5	0.2	36.5
2	3763	*H. vulgare*	H99		1.1	0.4	-23.2	0.2	17,0	0.2	24.0
2	3763	*H. vulgare*	H100		1.1	0.2	-23.6	0,0	17.5	0,0	31.7
2	3763	*T. dicoccum*	D101		4.5	4.5	-23.7		17.7		33.2
2	3763	*T. dicoccum*	D102		4.8	0.3	-23,0	0.2	16.9	0.2	26.7
2	3763	*T. dicoccum*	D103		2.6	0.1	-23.9	0.1	17.8	0.1	24.9
2	3763	*T. dicoccum*	D104		3.3	0.4	-23.1	0,0	16.9	0,0	26.7
2	3763	*T. dicoccum*	D108		2.5	0,0	-22.1	0,0	15.9	0,0	20.8
2	3008	*H. vulgare*	H156G		1.6	0.3	-24.2	0.2	18.1	0.2	28,3
2	3008	*H. vulgare*	H157G		0.0	0.7	-25.6		19.6		28,3
2	3008	*H. vulgare*	H158G		3.9	0.2	-22.4		16.3		20,0
2	3008	*H. vulgare*	H159G		2.5	0.1	-23.8	0.0	17.7	0.0	24,7
2	3008	*H. vulgare*	H160G		2.7	0.4	-23.5	0.2	17.4	0.2	25,0
2	3008	*H. vulgare*	H161G		2.4	0.1	-24.1	0.1	18.0	0.1	22,1
3	3709	*H. vulgare*	H51		3.4	0.1	-23.5	0.2	17.4	0.2	28.9
3	3709	*H. vulgare*	H52		1.4	0.3	-24.5	0,0	18.5	0,0	38,4
3	3709	*H. vulgare*	H53		-0.5	0.5	-25,0	0.1	19,0	0.1	47.0
3	3709	*H. vulgare*	H54		4.3	0.5	-23.5	0,0	17.4	0,0	28.7
3	3709	*T. dicoccum*	D55		-0.4	0.3	-23.9	0,0	17.8	0,0	32.3
3	3709	*T. dicoccum*	D56		1.3	0.1	-24,0	0.1	17.9	0.2	29.5
3	3709	*T. dicoccum*	D57		4.3	0,0	-22.6	0.1	16.4	0.1	25.7
3	3709	*T. dicoccum*	D58		-1	0.1	-22,0	0.2	15.9	0.2	26.3
3	3706	*H. vulgare*	H67		3,0	0.4	-24,0	0.1	17.9	0.1	30.7
3	3706	*H. vulgare*	H68		0.4	0.2	-24.6	0.1	18.5	0.1	37.9

3	3706	*H. vulgare*	H69		4.3	0.1	-24.7	0.1	18.6	0.1	32.2
3	3706	*H. vulgare*	H70		-3.9	0.4	-24.8	0.1	18.7	0.1	24.9
3	3706	*T. dicoccum*	D71		3.6	0.4	-23.4	0,0	17.4	0,0	28.9
3	3706	*T. dicoccum*	D72		-0.3	0.1	-23.3	0,0	17.2	0,0	25.9
3	3706	*T. dicoccum*	D73		3.4	0.5	-23.6	0.1	17.5	0.1	34.2
3	3706	*T. dicoccum*	D74		1.4	0,0	-24,0	0.2	17.9	0.2	29.4
3	3305	*H. vulgare*	H59		0.9	0.2	-24.4		18.4		32.8
3	3305	*H. vulgare*	H60		-0.6	0.1	-24.8	0.1	18.8	0.1	40.7
3	3305	*H. vulgare*	H61		3.5	0.1	-24.7	0.2	18.7	0.2	28.4
3	3305	*H. vulgare*	H62		5.9	0.2	-23.7	0,0	17.6	0,0	33.7
3	3305	*T. dicoccum*	D63		4.4	0.2	-23.2	0.1	17,0	0.1	27.1
3	3305	*T. dicoccum*	D64		8.2	0.3	-23.8	0.1	17.7	0.1	30.0
3	3305	*T. dicoccum*	D65		2.3	0,0	-23,0	0.1	16.9	0.1	26.1
3	3305	*T. dicoccum*	D66		4.2	0.1	-24,0	0,0	17.9	0,0	33.0
3	3077	*H. vulgare*	H177G		0.5	0.5	-23.6	0.3	17.5	0.3	25,5
3	3077	*H. vulgare*	H178G		3.9	0.4	-23.9	0.0	17.9	0.0	29,4
3	3077	*H. vulgare*	H179G		2.0	0.1	-23.8	0.1	17.7	0.1	33,8
3	3077	*H. vulgare*	H180G		0.2	0.1	-23.2	0.1	17.1	0.1	34,4
3	3077	*T. dicoccum*	D181G		2.8	0.6	-23.6	0.1	17.5	0.1	21,2
3	3077	*T. dicoccum*	D182G		1.4	0.1	-22.3	0.1	16.2	0.1	16,2
3	3077	*T. dicoccum*	D183G		-1.1	0.4	-24.0	0.1	17.9	0.1	22,8
3	3077	*T. dicoccum*	D184G		3.0	0.3	-23.8	0.1	17.7	0.1	20,6
3	3057	*H. vulgare*	H148G		-0.5	0.1	-25.4	0.1	19.4	0.1	32,7
3	3057	*H. vulgare*	H149G		-1.1	0.5	-24.5	0.0	18.4	0.0	30,9
3	3057	*H. vulgare*	H150G		0.8	0.1	-25.1	0.0	19.1	0.0	29,5
3	3057	*H. vulgare*	H151G		0.1	0.3	-22.8	0.2	16.7	0.2	29,1
3	3057	*T. dicoccum*	D152G		2.9	0.8	-25.2	0.1	19.1	0.1	25,6
3	3057	*T. dicoccum*	D153G		3.0	0.5	-24.9	0.1	18.9	0.1	27,8
3	3057	*T. dicoccum*	D154G		3.8	0.1	-23.9	0.1	17.8	0.1	23,3
3	3057	*T. dicoccum*	D155G		0.7	0.3	-24.4	0,0	18.3	0,0	25,6
3	3047	*H. vulgare*	H167G		2.9	0.0	-24.0	0.1	18.0	0.1	27,3
3	3047	*H. vulgare*	H168G		1.5	0.2	-23.3	0.1	17.2		22,6
3	3047	*H. vulgare*	H169G		1.3	0.1	-23.4	0.1	17.3	0.1	29,6
3	3047	*H. vulgare*	H170G		1.1	0.2	-22.6	0.1	16.4	0.1	33,7
3	3047	*H. vulgare*	H171G		3.1	0.3	-24.1	0.2	18.0	0.2	27,8
3	3047	*T. dicoccum*	D172G		2.9	0.1	-22.6	0.0	16.5	0.0	27,6
3	3047	*T. dicoccum*	D173G		3.2		-23.7		17.6		30,3
3	3047	*T. dicoccum*	D174G		3,3	0,3	-23,9	0,1	17,9	0,2	28,4
3	3047	*T. dicoccum*	D175G		2.9	0.0	-22.5	0.1	16.4	0.1	26,5
3	3047	*T. dicoccum*	D176G		2.5	0.1	-23.7	0.0	17.7	0.0	25,1
4	2821	*H. vulgare*	H9	Yes							
4	2821	*H. vulgare*	H10		1.7	0.4	-23.2	0.1	17.2	0.1	35.9
4	2821	*H. vulgare*	H11		1.1	0.1	-23.3	0,0	17.2	0,0	34.7
4	2821	*H. vulgare*	H12		1.9	0.1	-23.2	0.1	17.1	0.1	38.2
4	2821	*T. dicoccum*	D13		0,0	0.2	-23.9	0.9	17.9	0.9	33.7
4	2821	*T. dicoccum*	D14		1.3	0.1	-24.6	0.4	18.5	0.4	26.5
4	2821	*T. dicoccum*	D15		2.2	2.2	-22.7		16.6		33.2
4	2821	*T. dicoccum*	D16		2.2	0.4	-24.4	0.1	18.4	0.1	30.0
4	3074	*H. vulgare*	H9bis		3.2	0.2	-22.5	0.7	16.4	0.7	36.9
4	3074	*H. vulgare*	H10bis		-0.2	0.5	-24.1	0,0	18,0	0,0	34.1

4	3074	*H. vulgare*	H11bis	0,0	0.1	-23.5	0.6	17.4	0.6	28.8
4	3074	*H. vulgare*	H12bis	3.3	0.2	-22.5	0.8	16.4	0.8	23.5
4	3074	*T. dicoccum*	D13bis	6,0	0.1	-22.4	0.1	16.3	0.1	23.8
4	3074	*T. dicoccum*	D14bis	3,0	0.2	-22.1	0.1	16,0	0.1	26.9
4	3074	*T. dicoccum*	D15bis	2.9	0.1	-22,0	0.1	15.8	0.1	24.2
4	3074	*T. dicoccum*	D16bis	1.7	0.1	-23.1	0.1	17,0	0.1	33.6
4	3060 A	*H. vulgare*	H17bis	2.7	0.1	-24,0	0.1	17.9	0.1	37.7
4	3060 A	*H. vulgare*	H18bis	2.6	0.2	-22.7	0.1	16.6	0.2	36.1
4	3060 A	*H. vulgare*	H19bis	0.7	0.4	-23.1	0.2	17,0	0.3	29.0
4	3060 A	*H. vulgare*	H20bis	1.8	0.3	-22.1	0.3	15.9	0.3	31.2
4	3060 A	*T. dicoccum*	D21bis	1.9	0.3	-23,0	0.1	16.9	0.1	30.3
4	3060 A	*T. dicoccum*	D22bis	3,0	0.2	-23.2	0.1	17.1	0.1	35.6
4	3060 A	*T. dicoccum*	D23bis	2.8	0.2	-21.7	0.1	15.5	0.1	28.7
4	3060 A	*T. dicoccum*	D24bis	1.2	0,0	-22.3	0,0	16.2	0,0	32.6
4	3044	*H. vulgare*	H1bis	1.1	0.1	-22.9	0.5	16.8	0.5	
4	3044	*H. vulgare*	H2bis	0.9	0.1	-22.4	0.1	16.3	0.1	
4	3044	*H. vulgare*	H3bis	2,0	0.3	-21.2	0.3	15,0	0.3	38.6
4	3044	*H. vulgare*	H4bis	0.9	0.1	-22.9	0.1	16.8	0.1	34.2
4	3044	*T. dicoccum*	D5bis	-0.8	0.4	-23.7	0.1	17.6	0.1	32.7
4	3044	*T. dicoccum*	D6bis	3.1	0.4	-22.8	0.2	16.7	0.2	25.4
4	3044	*T. dicoccum*	D7bis	0.4	0.1	-21.1	0.3	15,0	0.3	28.2
4	3183	*H. vulgare*	H26bis	2.6	0.2	-22.4	0.1	16.3	0.1	31.1
4	3183	*H. vulgare*	H27bis	2.7	0.3	-22.9	0.1	16.8	0.1	45.5
4	3183	*H. vulgare*	H28bis	1.1	0.1	-22.8	0,0	16.7	0,0	34.5
4	3183	*T. dicoccum*	D29bis	0.5	0.2	-21.5	0,0	15.4	0,0	28.1
4	3183	*T. dicoccum*	D30bis	2.3	0.3	-23,0	0.1	16.9	0.1	37.9
4	3183	*T. dicoccum*	D31bis	2.9	0.2	-22.4	0.3	16.3	0.4	31.8
4	3183	*T. dicoccum*	D32bis	4.6	4.6	-22.9		16.8		25.8

Table 3.1 supplementary material. Gabii. N and C isotope analysis results: means and standard deviations for each cereal grain.

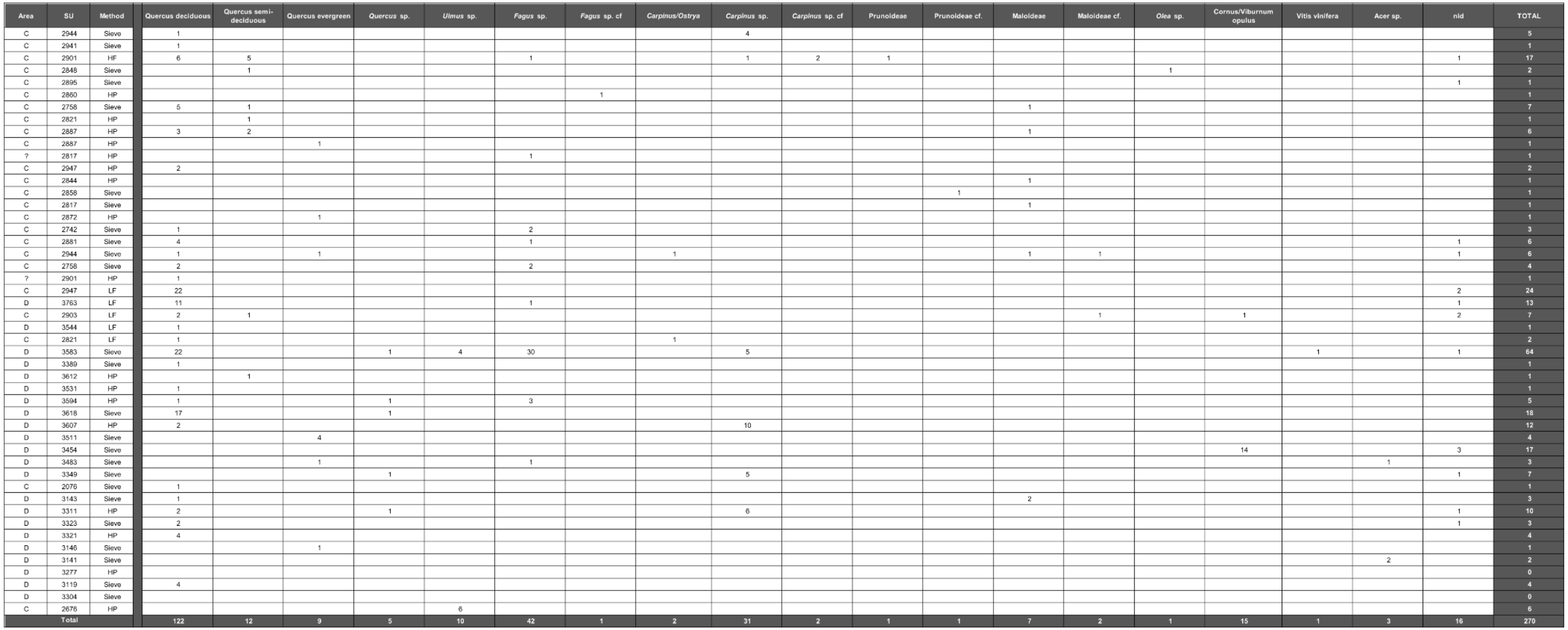
Periods	SU	Crops	δ^{15}N mean (‰)	sd	δ^{13}C mean (‰)	sd	Δ^{13}C mean (‰)	sd	C:N
1	3301	*H. vulgare*	0.8	1.7	-23.5	0.8	17.5	0.9	34,8
		T. dicoccum	0.9	0.5	-23.4	0.4	17.2	0.5	28,0
	2903	*H. vulgare*	4.4	1.1	-23.8	0.7	17.7	0.8	23,6
		T. dicoccum	2.8	1.4	-24.7	0.6	18.7	0.6	28,0
	2907	*H. vulgare*	3.0	2.5	-23.9	0.2	17.8	0.2	33,9
		T. dicoccum	3.6	2.0	-23.2	0.4	17.1	0.4	27,7
	Mean	***H. vulgare***	**2.7**	**1.8**	**-23.7**	**0.3**	**17.7**	**0.1**	**30,8**
	Mean	***T. dicoccum***	**2.4**	**1.4**	**-23.8**	**0.1**	**17.7**	**0.9**	**27,9**
2	2868	*H. vulgare*	0.3	1.1	-23.5	0.7	17.4	0.8	39,5
		T. dicoccum	1.8	1.1	-22.7	0.8	16.5	0.9	24,9
	2901	*H. vulgare*	1.5	1.1	-23.7	0.5	17.7	0.5	35,2
		T. dicoccum	1.2	0.3	-23.6	0.3	17.5	0.3	31,6
	2881	*H. vulgare*	2.0	0.8	-24.1	0.9	18.0	1.0	34,7
		T. dicoccum	2.7	0.8	-23.8	0.6	17.7	0.6	31,4
	3544	*H. vulgare*	0.4	1.5	-24.2	0.6	18.2	0.7	34,2
		T. dicoccum	0.6	1.1	-22.8	0.0	16.6	0.0	28,1
	3540	*H. vulgare*	0.0	1.1	-24.8	0.5	18.7	0.6	32,4
		T. dicoccum	1.0	0.5	-24.1	0.5	18.0	0.6	29,9
	3496	*H. vulgare*	0.3	0.7	-24.1	0.3	18.0	0.3	28,1
	3763	*H. vulgare*	1.2	0.5	-23.9	0.6	17.8	0.7	29,2
		T. dicoccum	3.5	1.1	-23.2	0.7	17.0	0.8	25,3
	3308	*H. vulgare*	2.2	1.3	-23.9	1.0	17.9	1.1	24,5
	Mean	***H. vulgare***	**0.9**	**0.8**	**-24.0**	**0.4**	**18.0**	**0.5**	**32,2**
	Mean	***T. dicoccum***	**1.8**	**1.1**	**-23.4**	**0.3**	**17.2**	**0.6**	**28,6**
3	3709	*H. vulgare*	2.2	2.1	-24.1	0.7	18.1	0.8	34,3
		T. dicoccum	1.1	2.4	-23.1	1.0	17.0	1.0	28,2
	3706	*H. vulgare*	1.0	3.6	-24.4	0.4	18.5	0.4	30,7
		T. dicoccum	2.0	1.8	-23.6	0.3	17.5	0.3	29,3
	3305	*H. vulgare*	2.4	2.8	-24.5	0.5	18.4	0.5	33,4
		T. dicoccum	4.8	2.5	-23.5	0.4	17.4	0.5	28,8
	3077	*H. vulgare*	1.7	1.7	-23.6	0.3	17.5	0.3	30,4
		T. dicoccum	1.5	1.9	-23.4	0.8	17.3	0.8	19,6
	3057	*H. vulgare*	-0.2	0.8	-24.4	1.2	18.4	1.2	30,4
		T. dicoccum	2.6	1.4	-24.6	0.6	18.5	0.6	25,5
	3047	*H. vulgare*	2.0	1.0	-23.5	0.6	17.4	0.6	27,8
		T. dicoccum	3.0	0.3	-23.3	0.7	17.2	0.7	27,4
	Mean	***H. vulgare***	**1.8**	**0.8**	**-24.1**	**0.4**	**18.3**	**0.2**	**31,2**
	Mean	***T. dicoccum***	**2.6**	**1.9**	**-23.6**	**0.5**	**17.3**	**0.3**	**26,5**
4	2821	*H. vulgare*	1.5	0.4	-23.2	0.1	17.1	0.1	36,1
		T. dicoccum	1.4	1.1	-24.1	0.8	17.9	0.4	30,5
	3074	*H. vulgare*	1.6	1.9	-23.1	0.8	17.1	0.8	30,0
		T. dicoccum	3.4	1.8	-22.4	0.5	16.3	0.5	26,6

3060A	*H. vulgare*	2.0	0.9	-23.0	0.7	16.9	0.8	33,2
	T. dicoccum	2.2	0.9	-22.6	0.6	16.4	0.7	31,7
3044	*H. vulgare*	1.2	0.5	-22.5	0.7	16.2	0.8	35,4
	T. dicoccum	0.9	2.0	-22.3	1.2	16.4	1.3	28,5
3183	*H. vulgare*	2.1	0.9	-22.7	0.2	16.6	0.3	36,3
	T. dicoccum	2.6	1.7	-22.4	0.7	16.3	0.8	30,3
Mean	***H. vulgare***	**1.7**	**0.4**	**-22.9**	**0.3**	**16.8**	**0.4**	**34,2**
Mean	***T. dicoccum***	**2.1**	**1.0**	**-22.8**	**0.8**	**16.7**	**0.7**	**29,5**

Table 3.2 supplementary material. Gabii. N and C isotope analysis results: means and standard deviations by stratigraphic units and by phase.

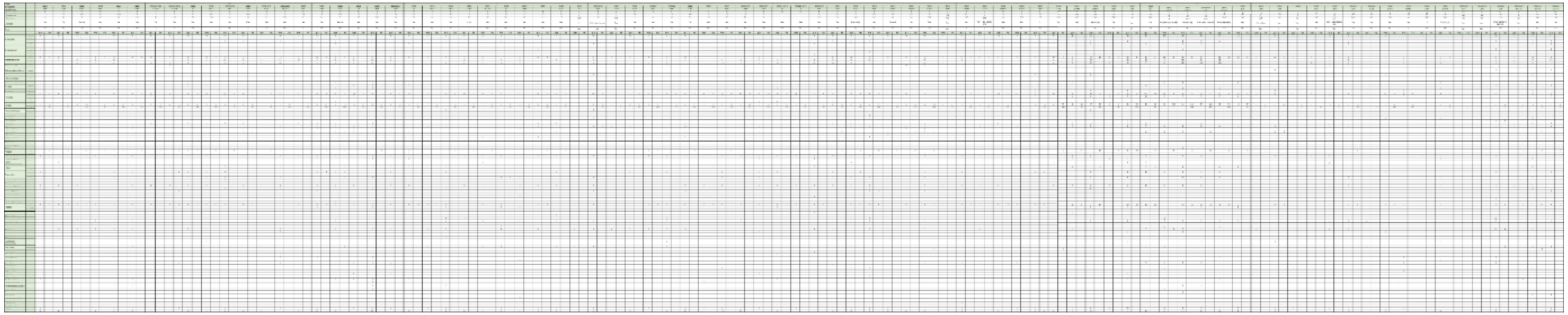
Pearson	**Data 1**	**Data 2**		**p-value**
Barley	$\delta^{15}N$	$\delta^{13}C$		0.3
Emmer	$\delta^{15}N$	$\delta^{13}C$		0
Barley	$\delta^{15}N$	N%		0.4
Emmer	$\delta^{15}N$	N%		0.1
Barley	$\delta^{13}C$	C%		0
Emmer	$\delta^{13}C$	C%		-0.1
Barley	C%	N%		0.2
Emmer	C%	N%		0.2
Student-t test	**Group 1**	**Group 2**	**Tested data**	**p-value**
General difference beween emmer and barley	Barley	Emmer	$\Delta^{13}C$	0.001909
	Barley	Emmer	$\delta^{15}N$	0.04544
Difference between emmer and barley phase 1	Barley	Emmer	$\Delta^{13}C$	0.8441
	Barley	Emmer	$\delta^{15}N$	0.737
Difference between emmer and barley phase 2	Barley	Emmer	$\Delta^{13}C$	0.002964
	Barley	Emmer	$\delta^{15}N$	0.006263
Difference between emmer and barley phase 3	Barley	Emmer	$\Delta^{13}C$	0.0005777
	Barley	Emmer	$\delta^{15}N$	0.4872
Difference between emmer and barley phase 4	Barley	Emmer	$\Delta^{13}C$	0.7456
	Barley	Emmer	$\delta^{15}N$	0.2707
ANOVA	**Data**	**Factor**		**p-value**
Barley	$\Delta^{13}C$	Periods		2.077e-07
Emmer	$\delta^{15}N$	Periods		0.02249
Barley	$\Delta^{13}C$	Periods		0.04316
Emmer	$\delta^{15}N$	Periods		0.7649

Table 3.3 supplementary material. Gabii. N and C isotope analysis: statistical tests and results.



Area	SU	Method	Quercus deciduous	Quercus semi-deciduous	Quercus evergreen	*Quercus* sp.	*Ulmus* sp.	*Fagus* sp.	*Fagus* sp. cf	*Carpinus/Ostrya*	*Carpinus* sp.	*Carpinus* sp. cf	Prunoideae	Prunoideae cf.	Maloideae	Maloideae cf.	*Olea* sp.	Cornus/Viburnum opulus	Vitis vinifera	Acer sp.	nid	TOTAL
C	2944	Sieve	1								4											5
C	2941	Sieve	1																			1
C	2901	HF	6	5				1			1	2	1								1	17
C	2848	Sieve		1													1					2
C	2895	Sieve																			1	1
C	2860	HP							1													1
C	2758	Sieve	5	1											1							7
C	2821	HP		1																		1
C	2887	HP	3	2											1							6
C	2887	HP			1																	1
?	2817	HP						1														1
C	2947	HP	2																			2
C	2844	HP													1							1
C	2858	Sieve												1								1
C	2817	Sieve													1							1
C	2872	HP			1																	1
C	2742	Sieve	1					2														3
C	2881	Sieve	4					1													1	6
C	2944	Sieve	1		1					1					1	1					1	6
C	2758	Sieve	2					2														4
?	2901	HP	1																			1
C	2947	LF	22																		2	24
D	3763	LF	11					1													1	13
C	2903	LF	2	1												1		1			2	7
D	3544	LF	1																			1
C	2821	LF	1							1												2
D	3583	Sieve	22			1	4	30			5								1		1	64
D	3389	Sieve	1																			1
D	3612	HP		1																		1
D	3531	HP	1																			1
D	3594	HP	1			1		3														5
D	3618	Sieve	17			1																18
D	3607	HP	2								10											12
D	3511	Sieve			4																	4
D	3454	Sieve																14			3	17
D	3483	Sieve			1			1												1		3
D	3349	Sieve				1					5										1	7
C	2076	Sieve	1																			1
D	3143	Sieve	1												2							3
D	3311	HP	2			1					6										1	10
D	3323	Sieve	2																		1	3
D	3321	HP	4																			4
D	3146	Sieve			1																	1
D	3141	Sieve																		2		2
D	3277	HP																				0
D	3119	Sieve	4																			4
D	3304	Sieve																				0
C	2676	HP					6															6
	Total		122	12	9	5	10	42	1	2	31	2	1	1	7	2	1	15	1	3	16	270

Appendix C: Gabii: Taxonomical identifications of the charcoal fragments. Collection method: HP, Hand-picked; HF, Heavy fraction; LT, Light fraction; Sieved: the totality of the sediment of each SU was dry sieved.



Appendix D: NE slope of the Palatine Hill: Taxonomical identifications of the carpological remains.

Periods	Contexts	SU	Square	Crops	Lost after chemical treatment	Code	δ^{15}N mean (‰)	sd	δ^{13}C mean (‰)	sd	Δ^{13}C mean (‰)	sd
925-875 BCE	FILL P1	40388	QCD3	*H. vulgare*		H12P	3,1	0,3	-22,2	0,1	16,0	0,1
925-875 BCE	FILL P1	40388	QCD3	*H. vulgare*		H13P	1,3	0,2	-23,6	0,0	17,5	0,0
925-875 BCE	FILL P1	40388	QCD3	*H. vulgare*		H14P	0,6	0,6	-21,7	0,1	15,5	0,1
925-875 BCE	FILL P1	40388	QCD3	*H. vulgare*		H15P	2,2	0,0	-23,3	0,2	17,2	0,2
925-875 BCE	FILL P1	40388	QCD3	*H. vulgare*		H1P	2,9		-22,2		16,1	
925-875 BCE	FILL P1	40388	QCD3	*H. vulgare*		H2P	3,8	0,1	-23,6	0,0	17,4	0,0
925-875 BCE	FILL P1	40388	QCD3	*H. vulgare*		H3P	2,1	0,1	-22,4	0,2	16,2	0,2
925-875 BCE	FILL P1	40388	QCD3	*H. vulgare*		H4P	3,9	0,3	-23,6	0,1	17,5	0,1
925-875 BCE	FILL P1	40388	QCD3	*T. dicoccum*		D17P	1,4	0,2	-21,6	0,0	15,5	0,0
925-875 BCE	FILL P1	40388	QCD3	*T. dicoccum*		D18P	1,5	0,1	-22,4	0,1	16,3	0,1
925-875 BCE	FILL P1	40388	QCD3	*T. dicoccum*		D19P	3,0	0,3	-21,3	0,0	15,1	0,0
925-875 BCE	FILL P1	40388	QCD3	*T. dicoccum*		D20P	3,0	0,5	-21,8	0,0	15,7	0,0
925-875 BCE	FILL P1	40388	QCD3	*T. dicoccum*	Yes	D7P						
925-875 BCE	FILL P1	40388	QCD3	*T. dicoccum*		D8P	3,4	0,0	-22,9	0,1	16,7	0,1
925-875 BCE	FILL P1	40388	QCD3	*T. dicoccum*		D9P	3,0	0,1	-22,6	0,1	16,5	0,1
925-875 BCE	FILL P1	40388	QCD3	*T. dicoccum*		D10P	4,5	0,2	-21,7	0,2	15,6	0,2
925-875 BCE	FILL P3	40533	QD2	*H. vulgare*	Yes	H21P						
925-875 BCE	FILL P3	40533	QD2	*H. vulgare*		H22P	-0,7	0,3	-21,7	0,1	15,5	0,1
925-875 BCE	FILL P3	40533	QD2	*H. vulgare*		H23P	1,9		-23,4		17,3	
925-875 BCE	FILL P3	40533	QD2	*H. vulgare*		H24P	2,3	0,1	-22,5	0,2	16,3	0,2
925-875 BCE	FILL P3	40533	QD2	*T. dicoccum*		D25P	3,1	0,1	-21,1	0,1	14,9	0,1
925-875 BCE	FILL P3	40533	QD2	*T. dicoccum*		D26P	5,6	0,1	-21,9	0,1	15,7	0,1
925-875 BCE	FILL P3	40533	QD2	*T. dicoccum*		D27P	3,6	0,2	-22,8	0,1	16,6	0,1
925-875 BCE	FILL P3	40533	QD2	*T. dicoccum*		D28P	0,8	0,2	-21,1	0,0	14,9	0,0
925-875 BCE	FILL P5	40529	Q. B-C1	*H. vulgare*		H361P	1,2	0,4	-23,1	0,1	17,0	0,1
925-875 BCE	FILL P5	40529	Q. B-C1	*H. vulgare*		H362P	0,8	0,5	-23,1	0,3	17,0	0,3
925-875 BCE	FILL P5	40529	Q. B-C1	*H. vulgare*		H363P	1,7	0,2	-23,6	0,2	17,5	0,2

925-875 BCE	FILL P5	40529	Q. B-C1	*H. vulgare*		H364P	4,7	0,2	-24,2	0,1	18,1	0,1
925-875 BCE	FILL P6	40525	Q. A1-2	*H. vulgare*		H293P	-0,4	0,5	-23,2	0,0	17,0	0,0
925-875 BCE	FILL P6	40525	Q. A1-2	*H. vulgare*		H294P	1,7	0,5	-23,1	0,1	17,0	0,1
925-875 BCE	FILL P6	40525	Q. A1-2	*H. vulgare*		H295P	0,8	0,1	-23,8	0,0	17,7	0,0
925-875 BCE	FILL P6	40525	Q. A1-2	*H. vulgare*		H296P	1,0	0,5	-23,6	0,2	17,5	0,2
925-875 BCE	Burial	40524	Q. D2	*H. vulgare*		H365P	4,7	0,1	-23,6	0,2	17,5	0,2
925-875 BCE	Burial	40524	Q. D2	*H. vulgare*		H366P	2,5	0,1	-23,9	0,0	17,8	0,0
925-875 BCE	Burial	40524	Q. D2	*H. vulgare*		H367P	1,5	0,5	-23,6	0,3	17,5	0,3
925-875 BCE	Burial	40524	Q. D2	*H. vulgare*		H368P	2,9	0,3	-22,6	0,0	16,4	0,0
925-875 BCE	Burial	40524	Q. D2	*T. dicoccum*		D369P	3,4	0,0	-20,9	0,1	14,7	0,1
925-875 BCE	Burial	40524	Q. D2	*T. dicoccum*		D370P	3,4	0,5	-20,8	0,0	14,6	0,0
925-875 BCE	Burial	40524	Q. D2	*T. dicoccum*		D371P	4,1	0,5	-22,2	0,0	16,0	0,0
925-875 BCE	Burial	40524	Q. D2	*T. dicoccum*		D372P	16,3	0,2	-21,8	0,0	15,7	0,0
925-875 BCE	FILL P8	40542	Q. A3	*H. vulgare*		H297P	3,0	0,2	-23,9	0,1	17,8	0,1
925-875 BCE	FILL P8	40542	Q. A3	*H. vulgare*		H298P	2,6	0,3	-23,8	0,1	17,7	0,1
925-875 BCE	FILL P8	40542	Q. A3	*H. vulgare*		H299P	1,1	1,1	-22,9	0,1	16,8	0,1
925-875 BCE	FILL P8	40542	Q. A3	*H. vulgare*	Yes	H300P						
925-875 BCE	FILL P8	40542	Q. A3	*T. dicoccum*		D301P	1,7	0,1	-21,8	0,1	15,6	0,1
925-875 BCE	FILL P8	40542	Q. A3	*T. dicoccum*		D302P	2,9	0,6	-23,5	0,1	17,4	0,1
925-875 BCE	FILL P8	40542	Q. A3	*T. dicoccum*		D303P	3,0	0,2	-22,2	0,1	16,1	0,1
925-875 BCE	FILL P8	40542	Q. A3	*T. dicoccum*		D304P	2,7	0,2	-21,3	0,0	15,1	0,0
925-875 BCE	FILL P9	40390	Q. B-C3	*H. vulgare*		H253P	2,3		-21,5	0,4	15,3	0,4
925-875 BCE	FILL P9	40390	Q. B-C3	*H. vulgare*		H254P	2,2	0,1	-23,4	0,0	17,3	0,0
925-875 BCE	FILL P9	40390	Q. B-C3	*H. vulgare*		H255P	0,6	0,4	-22,9	0,0	16,8	0,0
925-875 BCE	FILL P9	40390	Q. B-C3	*H. vulgare*		H256P	0,5	0,2	-23,3	0,0	17,2	0,0
925-875 BCE	FILL P9	40390	Q. B-C3	*H. vulgare*		H257P	1,0	0,1	-22,7	0,2	16,6	0,2
925-875 BCE	FILL P9	40390	Q. B-C3	*T. dicoccum*		D258P	0,6	0,1	-22,4	0,1	16,3	0,1
925-875 BCE	FILL P9	40390	Q. B-C3	*T. dicoccum*		D259P	2,3	0,1	-22,1	0,1	15,9	0,2
925-875 BCE	FILL P9	40390	Q. B-C3	*T. dicoccum*		D260P	3,1	0,4	-21,9	0,1	15,7	0,1
925-875 BCE	FILL P9	40390	Q. B-C3	*T. dicoccum*		D261P	1,4	0,1	-21,8	0,1	15,6	0,1

925-875 BCE	FILL P9	40390	Q. B-C3	*T. dicoccum*		D262P	0,1	0,1	-23,2	0,1	17,1	0,1
925-875 BCE	FILL P9	40473	Q. B-C3	*H. vulgare*		H263P	0,1	0,0	-22,8	0,0	16,7	0,0
925-875 BCE	FILL P9	40473	Q. B-C3	*H. vulgare*		H264P	0,5	0,6	-22,6	0,0	16,5	0,0
925-875 BCE	FILL P9	40473	Q. B-C3	*H. vulgare*		H265P	2,3	0,1	-22,9	0,3	16,7	0,3
925-875 BCE	FILL P9	40473	Q. B-C3	*H. vulgare*		H266P	0,3	0,7	-22,4	0,2	16,2	0,2
925-875 BCE	FILL P9	40473	Q. B-C3	*H. vulgare*		H267P	0,4	0,5	-23,6	0,2	17,5	0,2
925-875 BCE	FILL P9	40473	Q. B-C3	*T. dicoccum*		D268P	5,4	0,0	-22,6	0,3	16,5	0,3
925-875 BCE	FILL P9	40473	Q. B-C3	*T. dicoccum*		D269P	1,8	0,2	-22,7	0,1	16,5	0,1
925-875 BCE	FILL P9	40473	Q. B-C3	*T. dicoccum*	Yes	D270P						
925-875 BCE	FILL P9	40473	Q. B-C3	*T. dicoccum*		D271P	4,3	0,2	-22,6	0,1	16,4	0,1
925-875 BCE	FILL P9	40473	Q. B-C3	*T. dicoccum*		D272P	-0,5	0,7	-23,1	0,1	17,0	0,1
925-875 BCE	FILL P9	40469	Q. C-D3	*H. vulgare*		H283P	1,5	0,7	-22,0	0,1	15,8	0,1
925-875 BCE	FILL P9	40469	Q. C-D3	*H. vulgare*		H284P	2,8	0,2	-21,5	0,2	15,3	0,2
925-875 BCE	FILL P9	40469	Q. C-D3	*H. vulgare*		H286P	3,4	0,1	-21,5	0,3	15,3	0,3
925-875 BCE	FILL P9	40469	Q. C-D3	*H. vulgare*		H287P	1,1	0,1	-21,6	0,2	15,4	0,2
925-875 BCE	FILL P9	40469	Q. C-D3	*T. dicoccum*		D288P	5,0	0,0	-21,3	0,1	15,1	0,1
925-875 BCE	FILL P9	40469	Q. C-D3	*T. dicoccum*		D289P	2,8	0,2	-21,4	0,1	15,2	0,1
925-875 BCE	FILL P9	40469	Q. C-D3	*T. dicoccum*		D290P	2,5	0,2	-21,1	0,5	14,9	0,5
925-875 BCE	FILL P9	40469	Q. C-D3	*T. dicoccum*		D291P	0,9	0,1	-21,8	0,1	15,6	0,1
925-875 BCE	FILL P9	40469	Q. C-D3	*T. dicoccum*		D292P	1,6	0,0	-22,1	0,0	15,9	0,0
925-875 BCE	FILL P9	40389	Q.	*H. vulgare*		H273P	-0,4	1,0	-21,0		14,7	
925-875 BCE	FILL P9	40389	Q.	*H. vulgare*		H274P	-0,4	0,5	-21,7	0,1	15,5	0,1
925-875 BCE	FILL P9	40389	Q.	*H. vulgare*		H275P	7,9	0,6	-21,3	0,1	15,1	0,1
925-875 BCE	FILL P9	40389	Q.	*H. vulgare*		H276P	0,9		-22,3	0,1	16,1	0,1
925-875 BCE	FILL P9	40389	Q.	*H. vulgare*		H277P	1,0	1,3	-21,3	0,4	15,1	0,4
925-875 BCE	FILL P9	40389	Q.	*T. dicoccum*		D278P	2,0	0,2	-21,2	0,2	15,0	0,2
925-875 BCE	FILL P9	40389	Q.	*T. dicoccum*		D279P	2,5	0,1	-21,3	0,0	15,1	0,0
925-875 BCE	FILL P9	40389	Q.	*T. dicoccum*		D280P	1,8	0,2	-21,1	0,0	14,9	0,0
925-875 BCE	FILL P9	40389	Q.	*T. dicoccum*		D281P	3,1	0,1	-22,0	0,2	15,8	0,2
925-875 BCE	FILL P9	40389	Q.	*T. dicoccum*		D282P	2,9	0,0	-21,2	0,2	15,0	0,2
925-875 BCE	FILL LEV1	40510	Q. B2	*H. vulgare*		H305P	1,9	0,2	-22,9	0,2	16,7	0,2

925-875 BCE	FILL LEV1	40510	Q. B2	*H. vulgare*		H306P	0,9	1,0	-23,7	0,1	17,6	0,1
925-875 BCE	FILL LEV1	40510	Q. B2	*H. vulgare*		H307P	0,0	0,2	-23,4	0,0	17,3	0,0
925-875 BCE	FILL LEV1	40510	Q. B2	*H. vulgare*	Yes	H308P						
925-875 BCE	FILL LEV1	40510	Q. B2	*T. dicoccum*		D309P	4,4	0,2	-22,5	0,1	16,4	0,1
925-875 BCE	FILL LEV1	40510	Q. B2	*T. dicoccum*		D310P	1,6	0,2	-22,9	0,1	16,8	0,1
925-875 BCE	FILL LEV1	40510	Q. B2	*T. dicoccum*		D311P	2,6	0,1	-22,5	0,1	16,4	0,1
925-875 BCE	FILL LEV1	40510	Q. B2	*T. dicoccum*		D312P	1,7	0,4	-22,0	0,2	15,9	0,3
925-875 BCE	FILL LEV1	40508	Q. A-B2	*H. vulgare*		H313P	-0,2	0,0	-23,8	0,0	17,7	0,0
925-875 BCE	FILL LEV1	40508	Q. A-B2	*H. vulgare*		H314P	0,0	0,9	-23,2	0,1	17,1	0,1
925-875 BCE	FILL LEV1	40508	Q. A-B2	*H. vulgare*		H315P	3,9	0,2	-21,6	0,2	15,4	0,2
925-875 BCE	FILL LEV1	40508	Q. A-B2	*H. vulgare*		H316P	-0,1	0,7	-24,4	0,1	18,3	0,1
925-875 BCE	FILL LEV1	40508	Q. A-B2	*T. dicoccum*		D317P	3,2	0,4	-20,8	0,1	14,6	0,1
925-875 BCE	FILL LEV1	40508	Q. A-B2	*T. dicoccum*		D318P	3,4	0,0	-22,0	0,1	15,9	0,1
925-875 BCE	FILL LEV1	40508	Q. A-B2	*T. dicoccum*		D319P	1,4	0,3	-21,6	0,1	15,4	0,1
925-875 BCE	FILL LEV1	40508	Q. A-B2	*T. dicoccum*		D320P	2,5	0,7	-21,8	0,0	15,6	0,0
925-875 BCE	FILL LEV1	40502	Q. A-B1	*H. vulgare*		H321P	-0,3	0,1	-23,4	0,2	17,3	0,2
925-875 BCE	FILL LEV1	40502	Q. A-B1	*H. vulgare*		H322P	2,0	0,1	-23,5	0,0	17,4	0,0
925-875 BCE	FILL LEV1	40502	Q. A-B1	*H. vulgare*		H323P	1,0	1,3	-23,5	0,0	17,4	0,0
925-875 BCE	FILL LEV1	40502	Q. A-B1	*H. vulgare*		H324P	0,0	0,7	-24,1	0,3	18,0	0,3
925-875 BCE	FILL LEV1	40502	Q. A-B1	*T. dicoccum*		D325P	2,4	0,0	-21,6	0,1	15,4	0,1
925-875 BCE	FILL LEV1	40502	Q. A-B1	*T. dicoccum*		D326P	0,4	0,5	-21,7	0,1	15,5	0,1
925-875 BCE	FILL LEV1	40502	Q. A-B1	*T. dicoccum*		D327P	1,1	1,2	-22,3	0,1	16,1	0,1
925-875 BCE	FILL LEV1	40502	Q. A-B1	*T. dicoccum*		D328P	0,3	0,3	-23,3	0,1	17,2	0,1
925-875 BCE	FILL P10	40517	QA1-2	*H. vulgare*		H53P	3,4	0,1	-23,1	0,1	17,0	0,1
925-875 BCE	FILL P10	40517	QA1-2	*H. vulgare*		H54P			-23,2	0,1	17,1	0,1
925-875 BCE	FILL P10	40517	QA1-2	*H. vulgare*		H55P	2,8		-22,9		16,8	
925-875 BCE	FILL P10	40517	QA1-2	*H. vulgare*		H56P	4,1	0,3	-22,2	0,1	16,1	0,1
925-875 BCE	FILL P10	40517	QA1-2	*T. dicoccum*		D57P	2,5	0,0	-22,4	0,1	16,2	0,1
925-875 BCE	FILL P10	40517	QA1-2	*T. dicoccum*		D58P	4,7	0,9	-21,2	0,0	15,0	0,0
925-875 BCE	FILL P10	40517	QA1-2	*T. dicoccum*		D60P	2,0	0,4	-22,7	0,0	16,5	0,0
925-875 BCE	FILL P10	40520	QA1-2	*H. vulgare*		H45P	4,8	0,2	-22,5	0,4	16,3	0,4

925-875 BCE	FILL P10	40520	QA1-2	*H. vulgare*		H46P	3,9	0,1	-23,9	0,1	17,8	0,1
925-875 BCE	FILL P10	40520	QA1-2	*H. vulgare*		H47P	0,4	0,2	-24,0	0,0	17,9	0,0
925-875 BCE	FILL P10	40520	QA1-2	*H. vulgare*		H48P	4,9	0,3	-22,5	0,1	16,4	0,1
925-875 BCE	FILL P10	40520	QA1-2	*T. dicoccum*		D49P	5,1	0,2	-22,3	0,4	16,1	0,4
925-875 BCE	FILL P10	40520	QA1-2	*T. dicoccum*		D50P	6,1	0,2	-22,8	0,0	16,7	0,0
925-875 BCE	FILL P10	40520	QA1-2	*T. dicoccum*		D51P	6,4	0,4	-21,7	0,0	15,5	0,1
925-875 BCE	FILL P10	40520	QA1-2	*T. dicoccum*		D52P	3,3	0,1	-22,9	0,1	16,7	0,1
925-875 BCE	FILL P10	40515	QB2	*H. vulgare*		H61P	-0,5		-22,6		16,4	
925-875 BCE	FILL P10	40515	QB2	*H. vulgare*		H62P	2,4	0,0	-23,3	0,1	17,2	0,1
925-875 BCE	FILL P10	40515	QB2	*H. vulgare*		H63P	4,0	0,2	-23,4	0,1	17,3	0,1
925-875 BCE	FILL P10	40515	QB2	*T. dicoccum*		D65P	3,5	0,3	-22,7	0,1	16,5	0,1
925-875 BCE	FILL P10	40515	QB2	*T. dicoccum*		D66P	1,5	0,5	-22,3	0,0	16,2	0,0
925-875 BCE	FILL P10	40515	QB2	*T. dicoccum*		D67P	1,5	0,1	-22,8	0,2	16,7	0,2
925-875 BCE	FILL P10	40515	QB2	*T. dicoccum*		D68P	1,4	0,2	-22,3	0,0	16,2	0,0
925-875 BCE	FILL P10	40514	QC2	*H. vulgare*	Yes	H37P						
925-875 BCE	FILL P10	40514	QC2	*H. vulgare*		H38P	3,0	0,1	-22,8	0,0	16,7	0,0
925-875 BCE	FILL P10	40514	QC2	*H. vulgare*		H39P	1,7	0,1	-21,5	0,0	15,3	0,0
925-875 BCE	FILL P10	40514	QC2	*H. vulgare*		H40P	3,8	0,1	-22,8	0,0	16,6	0,0
925-875 BCE	FILL P10	40514	QC2	*T. dicoccum*		D41P	2,0	0,1	-22,8	0,0	16,7	0,0
925-875 BCE	FILL P10	40514	QC2	*T. dicoccum*	Yes	D42P						
925-875 BCE	FILL P10	40514	QC2	*T. dicoccum*		D43P	4,2	0,1	-22,6	0,0	16,5	0,0
925-875 BCE	FILL P10	40514	QC2	*T. dicoccum*		D44P	4,2	0,2	-22,4	0,1	16,2	0,1
925-875 BCE	FILL P10	40511	QB2	*H. vulgare*		H29P	-0,8		-23,6	0,0	17,5	0,0
925-875 BCE	FILL P10	40511	QB2	*H. vulgare*		H30P	3,0	0,1	-23,3	0,0	17,2	0,0
925-875 BCE	FILL P10	40511	QB2	*H. vulgare*		H31P	2,8	0,1	-23,5	0,3	17,4	0,3
925-875 BCE	FILL P10	40511	QB2	*H. vulgare*		H32P	4,8	0,2	-23,7	0,1	17,6	0,1
925-875 BCE	FILL P10	40511	QB2	*T. dicoccum*		D33P	0,9	0,1	-22,1	0,2	16,0	0,2
925-875 BCE	FILL P10	40511	QB2	*T. dicoccum*	Yes	D34P						
925-875 BCE	FILL P10	40511	QB2	*T. dicoccum*	Yes	D35P						
925-875 BCE	FILL P10	40511	QB2	*T. dicoccum*		D36P	1,3	0,2	-22,3	0,1	16,2	0,1
925-875 BCE	FILL P11	40439	QA1	*H. vulgare*		H98P	-0,3		-23,1		16,9	

925-875 BCE	FILL P11	40439	QA1	*H. vulgare*		H99P	0,4	0,3	-23,6	0,1	17,5	0,1
925-875 BCE	FILL P11	40439	QA1	*H. vulgare*		H100P	1,7	0,1	-22,6	0,1	16,5	0,1
925-875 BCE	FILL P11	40439	QA1	*H. vulgare*		H101P	-0,1	0,3	-23,0	0,1	16,8	0,1
925-875 BCE	FILL P11	40439	Q	*H. vulgare*		H102P	-1,2	0,3	-23,0	0,2	16,9	0,2
925-875 BCE	FILL P11	40439	Q	*H. vulgare*		H103P	2,1	0,2	-21,7	0,2	15,5	0,2
925-875 BCE	FILL P11	40439	Q	*H. vulgare*		H104P	1,1	0,4	-22,5	0,2	16,4	0,2
925-875 BCE	FILL P11	40439	Q	*H. vulgare*		H105P	0,1	0,1	-22,0	0,2	15,8	0,2
925-875 BCE	FILL P11	40438	QA1	*H. vulgare*		H89P	0,1	0,2	-22,8	0,2	16,7	0,2
925-875 BCE	FILL P11	40438	QA1	*H. vulgare*		H90P	-1,0	0,1	-22,3	0,1	16,2	0,1
925-875 BCE	FILL P11	40438	QA1	*H. vulgare*	Yes	H91P						
925-875 BCE	FILL P11	40438	QA1	*H. vulgare*		H92P	-0,2	0,1	-22,6	0,0	16,4	0,0
925-875 BCE	FILL P11	40438	QA1	*H. vulgare*		H93P	-0,6	0,3	-22,7	0,0	16,5	0,1
925-875 BCE	FILL P11	40438	QA1	*H. vulgare*		H94P	-0,5	0,5	-23,0	0,1	16,9	0,1
925-875 BCE	FILL P11	40438	QA1	*H. vulgare*		H95P	0,5	0,4	-22,9	0,0	16,8	0,0
925-875 BCE	FILL P11	40438	QA1	*H. vulgare*		H96P	-0,9	0,0	-23,7	0,1	17,6	0,1
925-875 BCE	FILL P11	40438	QA1	*H. vulgare*		H97P	1,3	0,1	-21,7	0,0	15,5	0,0
925-875 BCE	FILL P11	40437	Q	*H. vulgare*		H78P	0,1	0,3	-22,3	0,2	16,1	0,2
925-875 BCE	FILL P11	40437	Q	*H. vulgare*		H79P	-0,4	0,6	-23,1	0,0	17,0	0,0
925-875 BCE	FILL P11	40437	Q	*H. vulgare*		H80P	-1,0	0,5	-23,2	0,0	17,1	0,0
925-875 BCE	FILL P11	40437	Q	*H. vulgare*		H81P	0,6	0,2	-22,3	0,3	16,2	0,3
925-875 BCE	FILL P11	40437	Q	*H. vulgare*		H82P	-0,8	0,7	-22,3	0,2	16,1	0,2
925-875 BCE	FILL P11	40437	Q	*H. vulgare*		H83P	-1,0	0,3	-22,6	0,1	16,5	0,1
925-875 BCE	FILL P11	40437	QA1	*H. vulgare*		H85P	-0,9	0,3	-22,9	0,3	16,8	0,3
925-875 BCE	FILL P11	40437	QA1	*H. vulgare*		H86P	0,8		-22,0		15,8	
925-875 BCE	FILL P11	40437	QA1	*H. vulgare*		H87P	-0,9	0,5	-22,4	0,2	16,2	0,2
925-875 BCE	FILL P11	40437	QA1	*H. vulgare*		H88P	-1,9	0,0	-23,5	0,3	17,4	0,4
925-875 BCE	FILL P11	40436	QA1	*H. vulgare*		H69P	3,9	0,2	-22,6	0,0	16,5	0,0
925-875 BCE	FILL P11	40436	QA1	*H. vulgare*		H70P	2,2	0,3	-22,2	0,1	16,1	0,1
925-875 BCE	FILL P11	40436	QA1	*H. vulgare*		H71P	1,3	0,5	-23,5	0,1	17,4	0,1
925-875 BCE	FILL P11	40436	QA1	*H. vulgare*		H72P	3,0	0,0	-22,3	0,0	16,1	0,0
925-875 BCE	FILL P11	40436	QA1	*T. dicoccum*		D73P	1,5		-21,5		15,3	

925-875 BCE	FILL P11	40436	QA1	*T. dicoccum*	D74P	2,4	0,4	-22,3	0,2	16,1	0,2
925-875 BCE	FILL P11	40436	QA1	*T. dicoccum*	D75P	3,8	0,0	-22,0	0,0	15,8	0,0
925-875 BCE	FILL P11	40436	QA1	*T. dicoccum*	D76P	4,3	0,5	-21,9	0,1	15,7	0,1
875-850 BCE	FILL LEV2	40416	Q.	*H. vulgare*	H337P	0,5	1,2	-24,3	0,1	18,2	0,1
875-850 BCE	FILL LEV2	40416	Q.	*H. vulgare*	H338P	1,3	0,0	-22,1	0,0	15,9	0,0
875-850 BCE	FILL LEV2	40416	Q.	*H. vulgare*	H339P	5,9	0,1	-23,2	0,1	17,1	0,1
875-850 BCE	FILL LEV2	40416	Q.	*H. vulgare*	H340P	2,5	0,7	-21,3	0,2	15,1	0,2
875-850 BCE	FILL LEV2	40416	Q.	*T. dicoccum*	D341P	0,0	0,1	-21,4	0,1	15,2	0,1
875-850 BCE	FILL LEV2	40416	Q.	*T. dicoccum*	D342P	4,2	0,3	-23,3	0,1	17,2	0,1
875-850 BCE	FILL LEV2	40416	Q.	*T. dicoccum*	D343P	4,4	0,2	-21,7	0,2	15,5	0,2
875-850 BCE	FILL LEV2	40416	Q.	*T. dicoccum*	D344P	1,9	0,1	-21,8	0,1	15,6	0,1
875-850 BCE	OBL	40379	Q. C-D3	*H. vulgare*	H329P	2,7	0,6	-22,8	0,1	16,7	0,1
875-850 BCE	OBL	40379	Q. C-D3	*H. vulgare*	H330P	-0,2	0,0	-24,8	0,1	18,8	0,1
875-850 BCE	OBL	40379	Q. C-D3	*H. vulgare*	H331P	0,3	0,3	-23,3	0,1	17,2	0,1
875-850 BCE	OBL	40379	Q. C-D3	*H. vulgare*	H332P	-0,5	1,1	-23,5	0,1	17,4	0,1
875-850 BCE	OBL	40379	Q. C-D3	*T. dicoccum*	D333P	3,6	0,6	-21,6	0,0	15,4	0,0
875-850 BCE	OBL	40379	Q. C-D3	*T. dicoccum*	D334P	4,1	0,1	-22,5	0,2	16,3	0,2
875-850 BCE	OBL	40379	Q. C-D3	*T. dicoccum*	D335P	4,5	0,3	-22,6	0,3	16,4	0,3
875-850 BCE	OBL	40379	Q. C-D3	*T. dicoccum*	D336P	2,0	0,6	-22,2	0,3	16,0	0,3
875-850 BCE	OBL	40364	Q. C3	*H. vulgare*	H353P	1,9	0,3	-25,9	0,0	19,9	0,0
875-850 BCE	OBL	40364	Q. C3	*H. vulgare*	H354P	1,1	0,7	-24,2	0,5	18,1	0,5
875-850 BCE	OBL	40364	Q. C3	*H. vulgare*	H355P	4,5	0,1	-24,3	0,2	18,2	0,2
875-850 BCE	OBL	40364	Q. C3	*H. vulgare*	H356P	6,4	0,5	-23,9	0,0	17,8	0,0
875-850 BCE	OBL	40364	Q. C3	*T. dicoccum*	D357P	1,7	0,2	-22,5	0,1	16,4	0,1
875-850 BCE	OBL	40364	Q. C3	*T. dicoccum*	D358P	5,1	0,2	-22,4	0,1	16,3	0,1
875-850 BCE	OBL	40364	Q. C3	*T. dicoccum*	D359P	5,5	0,6	-23,1	0,3	17,0	0,3
875-850 BCE	OBL	40364	Q. C3	*T. dicoccum*	D360P	9,3	0,5	-25,4	0,2	19,4	0,2
850-820 BCE	TR	40440	QA3	*H. vulgare*	H142P	9,0	0,4	-21,8	0,1	15,7	0,1
850-820 BCE	TR	40440	QA3	*H. vulgare*	H143P	-1,0	0,3	-22,6	0,1	16,4	0,1
850-820 BCE	TR	40440	QA3	*H. vulgare*	H144P	0,3	0,1	-21,7	0,0	15,5	0,0

850-820 BCE	TR	40440	QA3	*H. vulgare*		H145P	0,7	0,4	-22,3	0,0	16,1	0,0
850-820 BCE	TR	40440	QA2	*H. vulgare*	Yes	H132P						
850-820 BCE	TR	40440	QA2	*H. vulgare*		H133P	2,1	0,4	-22,9	0,1	16,8	0,1
850-820 BCE	TR	40440	QA2	*H. vulgare*		H134P	1,7	0,1	-24,3	0,0	18,2	0,0
850-820 BCE	TR	40440	QA2	*H. vulgare*		H135P	3,5	0,1	-22,7	0,0	16,5	0,0
850-820 BCE	TR	40440	QA3	*T. dicoccum*		D148P	3,6	0,2	-22,2	0,1	16,1	0,1
850-820 BCE	TR	40440	QA3	*T. dicoccum*		D149P	3,0	0,3	-21,8	0,1	15,6	0,1
850-820 BCE	TR	40440	QA3	*T. dicoccum*		D150P	3,6	0,3	-19,9	0,1	13,7	0,1
850-820 BCE	TR	40440	QA3	*T. dicoccum*		D151P	2,4	0,0	-22,6	0,0	16,4	0,0
850-820 BCE	TR	40440	QA2	*T. dicoccum*		D138P	7,0	0,2	-22,1	0,0	16,0	0,1
850-820 BCE	TR	40440	QA2	*T. dicoccum*		D139P	6,8	0,1	-23,0	0,2	16,9	0,2
850-820 BCE	TR	40440	QA2	*T. dicoccum*		D140P	1,7	0,2	-24,0	0,5	17,9	0,5
850-820 BCE	TR	40440	QA2	*T. dicoccum*		D141P	0,1	0,2	-22,9	0,1	16,8	0,2
850-820 BCE	TR	40442	Q	*H. vulgare*		H113P	3,7	0,3	-22,6	0,1	16,5	0,1
850-820 BCE	TR	40442	Q	*H. vulgare*		H114P	1,2	0,4	-22,3	0,1	16,1	0,1
850-820 BCE	TR	40442	Q	*H. vulgare*		H115P	1,1	0,2	-21,5	0,0	15,3	0,0
850-820 BCE	TR	40442	Q	*H. vulgare*		H116P	1,7	0,4	-23,5	0,1	17,4	0,1
850-820 BCE	TR	40442	Q	*T. dicoccum*		D118P	1,5	0,3	-22,1	0,1	15,9	0,1
850-820 BCE	TR	40442	Q	*T. dicoccum*		D119P	3,3	0,1	-23,0	0,1	16,8	0,1
850-820 BCE	TR	40432	QA2	*H. vulgare*		H120P	4	0,1	-22,4	0,0	16,3	0,0
850-820 BCE	TR	40432	QA2	*H. vulgare*		H121P	2,7	0,3	-22,7	0,0	16,5	0,0
850-820 BCE	TR	40432	QA2	*H. vulgare*		H122P	2,7	0,3	-23,2	0,1	17,1	0,1
850-820 BCE	TR	40432	QA2	*H. vulgare*		H123P	2,7	0,1	-23,4	0,0	17,3	0,0
850-820 BCE	TR	40432	QA2	*T. dicoccum*		D126P	2,8	0,1	-22,3	0,1	16,1	0,1
850-820 BCE	TR	40432	QA2	*T. dicoccum*		D127P	2,9	0,1	-20,6	0,0	14,4	0,0
850-820 BCE	TR	40432	QA2	*T. dicoccum*		D128P	3,3		-21,5		15,3	
850-820 BCE	TR	40432	QA2	*T. dicoccum*		D129P	5,6	0,3	-22,8	0,2	16,6	0,2
850-820 BCE	TR	40422	Q. A2	*H. vulgare*		H223P	2,2	1,2	-23,3	0,1	17,2	0,1
850-820 BCE	TR	40422	Q. A2	*H. vulgare*		H224P	0,9	0,6	-23,8	0,0	17,7	0,0
850-820 BCE	TR	40422	Q. A2	*H. vulgare*		H225P	1,8	0,4	-23,5	0,1	17,4	0,1
850-820 BCE	TR	40422	Q. A2	*H. vulgare*		H226P	3,0	0,0	-23,5	0,1	17,4	0,1

850-820 BCE	TR	40422	Q. A2	*T. dicoccum*		D227P	2,6	0,2	-22,1	0,1	15,9	0,1
850-820 BCE	TR	40422	Q. A2	*T. dicoccum*		D228P	4,6	0,5	-22,1	0,0	15,9	0,0
850-820 BCE	TR	40422	Q. A2	*T. dicoccum*		D229P	2,2	0,0	-22,4	0,1	16,2	0,1
850-820 BCE	TR	40422	Q. A2	*T. dicoccum*		D230P	6,4	0,3	-22,7	0,0	16,5	0,0
850-820 BCE	FILL P13	40487	QCD3	*H. vulgare*		H106P	0,6	0,7	-23,3	0,3	17,2	0,3
850-820 BCE	FILL P13	40487	QCD3	*H. vulgare*		H107P	7,0	0,5	-22,3	0,1	16,2	0,1
850-820 BCE	FILL P13	40487	QCD3	*H. vulgare*		H108P	1,3	0,2	-23,2	0,3	17,0	0,3
850-820 BCE	FILL P13	40487	QCD3	*H. vulgare*		H84P	0,9	0,1	-23,1	0,0	17,0	0,1
850-820 BCE	FILL P13	40487	QCD3	*T. dicoccum*		D109P	2,7	0,2	-22,9	0,6	16,8	0,6
850-820 BCE	FILL P13	40487	QCD3	*T. dicoccum*		D110P	1,3	0,4	-23,7	0,0	17,6	0,0
850-820 BCE	FILL P13	40487	QCD3	*T. dicoccum*		D111P	1,2	0,1	-21,5	0,1	15,3	0,1
850-820 BCE	FILL P13	40487	QCD3	*T. dicoccum*		D112P	1,9	0,2	-23,6	0,1	17,5	0,1
850-820 BCE	FILL P13	40485	QD1	*H. vulgare*		H153P	5,7	0,4	-22,9	0,2	16,8	0,2
850-820 BCE	FILL P13	40485	QD1	*H. vulgare*	Yes	H154P						
850-820 BCE	FILL P13	40485	QD1	*H. vulgare*		H155P	2,1	0,5	-21,4	0,3	15,2	0,4
850-820 BCE	FILL P13	40485	QD1	*H. vulgare*	Yes	H156P						
850-820 BCE	FILL P13	40485	QD1	*T. dicoccum*		D157P	3,4	0,1	-22,8	0,1	16,7	0,1
850-820 BCE	FILL P13	40485	QD1	*T. dicoccum*		D158P	1,0	0,5	-22,3	0,3	16,2	0,3
850-820 BCE	FILL P13	40485	QD1	*T. dicoccum*	Yes	D159P						
850-820 BCE	FILL P13	40485	QD1	*T. dicoccum*		D160P	2,6	0,3	-21,5	0,0	15,3	0,0
850-820 BCE	FILL P13	40483	Q.D1	*H. vulgare*		H345P	2,1	0,6	-24,4	0,3	18,3	0,3
850-820 BCE	FILL P13	40483	Q.D1	*H. vulgare*		H346P	2,3	0,1	-24,2	0,1	18,1	0,1
850-820 BCE	FILL P13	40483	Q.D1	*H. vulgare*		H347P	5,0	0,3	-24,1	0,0	18,0	0,0
850-820 BCE	FILL P13	40483	Q.D1	*H. vulgare*		H348P	1,9	0,4	-24,2	0,0	18,1	0,0
850-820 BCE	FILL P13	40483	Q.D1	*T. dicoccum*		D349P	4,7	0,0	-23,7	0,2	17,6	0,2
850-820 BCE	FILL P13	40483	Q.D1	*T. dicoccum*		D350P	6,1	0,0	-23,3	0,1	17,2	0,1
850-820 BCE	FILL P13	40483	Q.D1	*T. dicoccum*		D351P	4,3	0,1	-23,6	0,0	17,4	0,0
850-820 BCE	FILL P13	40483	Q.D1	*T. dicoccum*		D352P	2,8	0,1	-23,1	0,0	16,9	0,0
850-820 BCE	FILL P13	40452	Q	*H. vulgare*	Yes	H161P						
850-820 BCE	FILL P13	40452	Q	*H. vulgare*		H162P	0,1	0,4	-23,8	0,1	17,7	0,1
850-820 BCE	FILL P13	40452	Q	*H. vulgare*	Yes	H163P						

850-820 BCE	FILL P13	40452	Q	*H. vulgare*		H164P	0,4	0,5	-22,2	0,3	16,0	0,3
850-820 BCE	FILL P13	40452	Q	*T. dicoccum*	Yes	D165P						
850-820 BCE	FILL P13	40452	Q	*T. dicoccum*		D166P	0,4	0,2	-23,0	0,0	16,9	0,0
850-820 BCE	FILL P13	40452	Q	*T. dicoccum*		D167P	1,5	0,7	-22,0	0,0	15,8	0,2
850-820 BCE	FILL P13	40452	Q	*T. dicoccum*		D168P	2,2	0,0	-22,4	0,2	16,3	0,2
850-820 BCE	FILL LEV3	40391	QA2	*H. vulgare*		H170P	3,3	0,2	-22,0	0,2	15,9	0,3
850-820 BCE	FILL LEV3	40391	QA2	*H. vulgare*		H171P	1,7	0,3	-23,2	0,1	17,1	0,1
850-820 BCE	FILL LEV3	40391	QA2	*H. vulgare*		H172P	1,9	0,6	-23,3	0,0	17,1	0,0
850-820 BCE	FILL LEV3	40391	QA2	*H. vulgare*		H173P	2,7	0,1	-22,7	0,0	16,6	0,0
850-820 BCE	FILL LEV3	40391	QA2	*T. dicoccum*		D174P	3,6	0,2	-21,0	0,0	14,8	0,0
850-820 BCE	FILL LEV3	40391	QA2	*T. dicoccum*		D175P	1,2	0,3	-21,4	0,0	15,2	0,0
850-820 BCE	FILL LEV3	40391	QA2	*T. dicoccum*		D176P	2,1	0,1	-22,7	0,1	16,5	0,1
850-820 BCE	FILL LEV3	40391	QA2	*T. dicoccum*		D177P	1,1	0,3	-23,3	0,1	17,2	0,1
850-820 BCE	FILL LEV3	40371	Q	*H. vulgare*		H186P	-1,7	0,1	-23,9	0,1	17,8	0,1
850-820 BCE	FILL LEV3	40371	Q	*H. vulgare*		H187P	1,2	0,4	-21,5	0,1	15,3	0,1
850-820 BCE	FILL LEV3	40371	Q	*H. vulgare*		H188P	2,4	0,2	-21,8	0,0	15,6	0,0
850-820 BCE	FILL LEV3	40371	Q	*H. vulgare*		H189P	-0,9		-22,4		16,3	
850-820 BCE	FILL LEV3	40371	Q	*T. dicoccum*		D190P	1,6	0,3	-22,5	0,8	16,3	0,8
850-820 BCE	FILL LEV3	40371	Q	*T. dicoccum*		D191P	-0,5	0,7	-21,4	0,3	15,2	0,3
850-820 BCE	FILL LEV3	40371	Q	*T. dicoccum*		D192P	1,5	0,0	-20,3	0,0	14,1	0,0
850-820 BCE	FILL LEV3	40371	Q	*T. dicoccum*		D193P	1,7	0,0	-21,6	0,0	15,4	0,0
850-820 BCE	FILL LEV3	40367	QA3	*H. vulgare*		H194P	1,3	0,2	-22,7	0,3	16,6	0,3
850-820 BCE	FILL LEV3	40367	QA3	*H. vulgare*		H195P	2,5	0,1	-22,6	0,2	16,4	0,2
850-820 BCE	FILL LEV3	40367	QA3	*H. vulgare*		H196P	4,6	0,3	-23,2	0,2	17,1	0,3
850-820 BCE	FILL LEV3	40367	QA3	*H. vulgare*		H197P	2,2	0,0	-21,7	0,2	15,5	0,2
850-820 BCE	FILL LEV3	40367	QA3	*T. dicoccum*		D198P	3,3	0,2	-21,8	0,2	15,7	0,2
850-820 BCE	FILL LEV3	40367	QA3	*T. dicoccum*		D199P	0,8	0,3	-22,4	0,3	16,2	0,3
850-820 BCE	FILL LEV3	40367	QA3	*T. dicoccum*		D200P	2,0	0,4	-22,3	0,0	16,2	0,0
850-820 BCE	FILL LEV3	40367	QA3	*T. dicoccum*	Yes	D201P						
850-820 BCE	FILL LEV3	40374	QA2	*H. vulgare*		H178P	1,9	0,1	-24,1	0,4	18,0	0,4
850-820 BCE	FILL LEV3	40374	QA2	*H. vulgare*		H179P	0,6	0,0	-22,8	0,0	16,6	0,0

850-820 BCE	FILL LEV3	40374	QA2	*H. vulgare*		H180P	5,2	0,1	-22,0	0,1	15,8	0,1
850-820 BCE	FILL LEV3	40374	QA2	*H. vulgare*		H181P	3,6	0,1	-23,3	0,1	17,2	0,1
850-820 BCE	FILL LEV3	40374	QA2	*T. dicoccum*		D182P	2,0	0,1	-22,0	0,0	15,9	0,0
850-820 BCE	FILL LEV3	40374	QA2	*T. dicoccum*		D183P	1,0	0,1	-22,0	0,0	15,8	0,0
850-820 BCE	FILL LEV3	40374	QA2	*T. dicoccum*		D184P	5,9	0,3	-21,7	0,0	15,5	0,0
850-820 BCE	FILL LEV3	40374	QA2	*T. dicoccum*		D185P	0,3		-20,9		14,6	
770-730/20 BCE	*	4029		*H. vulgare*		H235P	4,3	0,0	-23,5	0,0	17,4	0,0
770-730/20 BCE	*	4029		*H. vulgare*		H236P	2,0	0,2	-24,4	0,1	18,4	0,1
770-730/20 BCE	*	4029		*H. vulgare*		H237P	2,4	0,0	-22,9	0,1	16,8	0,2
770-730/20 BCE	*	4029		*H. vulgare*		H238P	0,0	0,7	-22,7	0,0	16,6	0,0
770-730/20 BCE	*	4029		*T. dicoccum*		D239P	1,4	0,3	-23,1	0,2	17,0	0,2
770-730/20 BCE	*	4029		*T. dicoccum*		D240P	3,0	0,0	-23,1	0,1	17,0	0,1
770-730/20 BCE	*	4029		*T. dicoccum*		D241P	5,4	0,2	-22,9	0,2	16,8	0,2
770-730/20 BCE	*	4029		*T. dicoccum*		D242P	2,4	0,6	-22,5	0,0	16,3	0,0
770-730/20 BCE	*	3095		*H. vulgare*		H231P	-1,8	0,2	-24,2	0,1	18,1	0,1
770-730/20 BCE	*	3095		*H. vulgare*		H232P	-0,6	0,5	-23,4	0,1	17,3	0,1
770-730/20 BCE	*	3095		*H. vulgare*	Yes	H233P						
770-730/20 BCE	*	3095		*H. vulgare*		H234P	-0,1	0,2	-23,5	0,1	17,5	0,1
770-730/20 BCE	*	3096		*H. vulgare*		H251P	1,5	0,4	-24,7	0,1	18,6	0,1
770-730/20 BCE	*	3096		*H. vulgare*		H252P	2,8	0,1	-23,7	0,1	17,7	0,1
730/20-630/20 BCE	*	7276	NS	*H. vulgare*		H214P	-0,2	0,8	-23,9	0,1	17,9	0,1
730/20-630/20 BCE	*	7276	NS	*H. vulgare*		H215P	1,9	0,3	-24,1	0,0	18,0	0,0
730/20-630/20 BCE	*	7276	NS	*H. vulgare*		H216P	1,9	0,1	-24,0	0,2	17,9	0,2
730/20-630/20 BCE	*	7276	NS	*H. vulgare*		H217P	0,4	0,3	-25,1	0,0	19,1	0,0
730/20-630/20 BCE	*	7276	NS	*H. vulgare*		H218P	0,6	0,1	-24,2	0,1	18,2	0,1
730/20-630/20 BCE	*	7276	NS	*T. dicoccum*		D219P	1,5	0,6	-23,4	0,0	17,3	0,0
730/20-630/20 BCE	*	7276	NS	*T. dicoccum*		D220P	0,7	0,2	-24,2	0,1	18,2	0,1
730/20-630/20 BCE	*	7276	NS	*T. dicoccum*		D221P	2,4	0,1	-23,3	0,1	17,2	0,1
730/20-630/20 BCE	*	7276	NS	*T. dicoccum*		D222P	2,8	0,1	-24,4	0,2	18,4	0,2
730/20-630/20 BCE	*	9883	NS	*T. dicoccum*		D210P	0,1	0,2	-22,3	0,1	16,1	0,1

730/20-630/20 BCE	*	9883	NS	*T. dicoccum*	D211P	0,5	0,4	-23,9	0,1	17,8	0,1
730/20-630/20 BCE	*	9883	NS	*T. dicoccum*	D212P	2,5	0,4	-22,6	0,1	16,4	0,1
730/20-630/20 BCE	*	9883	NS	*T. dicoccum*	D213P	-0,9	0,1	-24,0	0,1	17,9	0,1
730/20-630/20 BCE	*	9886	NS	*H. vulgare*	H202P	1,7	0,1	-23,0	0,1	16,9	0,1
730/20-630/20 BCE	*	9886	NS	*H. vulgare*	H203P	1,3	0,2	-21,6	0,2	15,4	0,2
730/20-630/20 BCE	*	9886	NS	*H. vulgare*	H204P	-0,3	0,0	-23,3	0,2	17,2	0,2
730/20-630/20 BCE	*	9886	NS	*H. vulgare*	H205P	2,5	0,3	-24,3	0,2	18,3	0,1
730/20-630/20 BCE	*	9886	NS	*T. dicoccum*	D206P	3,3	0,2	-24,0	0,4	17,9	0,4
730/20-630/20 BCE	*	9886	NS	*T. dicoccum*	D207P	2,9	0,1	-23,7	0,4	17,7	0,4
730/20-630/20 BCE	*	9886	NS	*T. dicoccum*	D208P	0,9	0,1	-23,7	0,2	17,7	0,2
730/20-630/20 BCE	*	9886	NS	*T. dicoccum*	D209P	0,5	0,2	-24,1	0,1	18,0	0,1
730/20-630/20 BCE	*	5532		*H. vulgare*	H243P	4,2	0,4	-23,2	0,1	17,1	0,1
730/20-630/20 BCE	*	5532		*H. vulgare*	H244P	3,1	0,7	-24,9	0,2	18,8	0,3
730/20-630/20 BCE	*	5532		*H. vulgare*	H245P	5,3	0,1	-23,7	0,1	17,7	0,1
730/20-630/20 BCE	*	5532		*H. vulgare*	H246P	1,3	0,1	-23,8	0,0	17,7	0,0
730/20-630/20 BCE	*	5532		*T. dicoccum*	D247P	4,3	0,1	-24,4	0,0	18,4	0,0
730/20-630/20 BCE	*	5532		*T. dicoccum*	D248P	2,8	0,2	-23,4	0,0	17,3	0,0
730/20-630/20 BCE	*	5532		*T. dicoccum*	D249P	2,4		-23,9	0,1	17,8	0,1
730/20-630/20 BCE	*	5532		*T. dicoccum*	D250P	2,2	0,2	-23,7	0,1	17,6	0,1

Appendix E: NE slope of the Palatine Hill. Δ^{13}C and δ^{15}N mean and standard deviations for each grain.

Periods	**Contexts**	**SU**	**Crops**	**δ^{15}N mean (‰)**	**sd**	**δ^{13}C mean (‰)**	**sd**	**Δ^{13}C mean (‰)**	**sd**
925-875 BCE	FILL P1	40388	*H. vulgare*	2.5	1.2	-22.8	0.8	16.7	0.8
			T. dicoccum	2.8	1.1	-22.1	0.6	15.9	0.6
	FILL P3	40533	*H. vulgare*	1.2	1.7	-22.5	0.9	16.4	0.9
			T. dicoccum	3.3	2.0	-21.7	0.8	15.5	0.8
	FILL P5	40529	*H. vulgare*	2.1	1.8	-23.5	0.5	17.4	0.5
	FILL P6	40525	*H. vulgare*	0.8	0.9	-23.4	0.3	17.3	0.3
	Burial	40524	*H. vulgare*	2.9	1.3	-23.4	0.6	17.3	0.6
			T. dicoccum	3.6	0.4	-21.4	0.7	15.2	0.7
	FILL P8	40542	*H. vulgare*	2.2	1.0	-23.5	0.6	17.4	0.6
			T. dicoccum	2.6	0.6	-22.2	0.9	16.1	1.0
	FILL P9	40390	*H. vulgare*	1.3	0.8	-22.8	0.8	16.6	0.8
			T. dicoccum	1.5	1.2	-22.3	0.6	16.1	0.6
		40473	*H. vulgare*	0.7	0.9	-22.9	0.4	16.7	0.5
			T. dicoccum	2.8	2.6	-22.7	0.2	16.6	0.2
		40469	*H. vulgare*	2.2	1.1	-21.6	0.2	15.4	0.2
			T. dicoccum	2.6	1.6	-21.5	0.4	15.3	0.4
		40389	*H. vulgare*	1.8	3.5	-21.5	0.5	15.3	0.5
			T. dicoccum	2.5	0.6	-21.4	0.3	15.2	0.4
	FILL LEV1	40510	*H. vulgare*	0.9	0.9	-23.3	0.4	17.2	0.4
			T. dicoccum	2.6	1.3	-22.5	0.4	16.3	0.4
		40508	*H. vulgare*	0.9	2.0	-23.3	1.2	17.1	1.2
			T. dicoccum	2.6	0.9	-21.6	0.5	15.4	0.6
		40502	*H. vulgare*	0.7	1.1	-23.6	0.3	17.5	0.3
			T. dicoccum	1.1	1.0	-22.2	0.8	16.1	0.8
	FILL P10	40517	*H. vulgare*	3.4	0.7	-22.9	0.4	16.7	0.5
			T. dicoccum	3.1	1.5	-22.1	0.8	15.9	0.8
		40520	*H. vulgare*	3.5	2.1	-23.2	0.8	17.1	0.9
			T. dicoccum	5.2	1.4	-22.4	0.5	16.3	0.6
		40515	*H. vulgare*	2.0	2.3	-23.1	0.4	17.0	0.5
			T. dicoccum	2.0	1.0	-22.5	0.3	16.4	0.3
		40514	*H. vulgare*	2.8	1.1	-22.4	0.7	16.2	0.8
			T. dicoccum	3.5	1.3	-22.6	0.2	16.5	0.2
		40511	*H. vulgare*	2.4	2.3	-23.5	0.2	17.4	0.2
			T. dicoccum	1.1	0.3	-22.2	0.2	16.1	0.2
	FILL P11	40439	*H. vulgare*	0.5	1.1	-22.7	0.6	16.5	0.7
		40438	*H. vulgare*	-0.2	0.8	-22.7	0.6	16.6	0.6
		40437	*H. vulgare*	-0.6	0.8	-22.7	0.5	16.5	0.5
		40436	*H. vulgare*	2.6	1.1	-22.7	0.6	16.5	0.6
			T. dicoccum	3.0	1.3	-21.9	0.3	15.7	0.3
		Mean	*H. vulgare*	1.9	1.1	-22.9	0.6	16.8	0.6
		Mean	*T. dicoccum*	2.7	1.0	-22.1	0.4	15.9	0.5

875-850 BCE	FILL LEV 2	40416	*H. vulgare*	2.6	2.4	-22.7	1.3	16.6	1.4
			T. dicoccum	2.6	2.1	-22.1	0.9	15.9	0.9
	OBL	40379	*H. vulgare*	0.6	1.5	-23.6	0.9	17.5	0.9
			T. dicoccum	3.6	1.1	-22.2	0.5	16.0	0.5
		40364	*H. vulgare*	3.5	2.4	-24.6	0.9	18.5	1.0
			T. dicoccum	5.4	3.1	-23.4	1.4	17.3	1.5
		Mean	*H. vulgare*	2.2	1.5	-23.6	0.9	17.5	1.0
		Mean	*T. dicoccum*	3.9	1.4	-22.6	0.7	16.4	0.8
850-820 BCE	TR	40440	*H. vulgare*	2.3	3.3	-22.6	0.9	16.5	0.9
			T. dicoccum	3.5	2.4	-22.3	1.2	16.2	1.2
		40442	*H. vulgare*	1.9	1.2	-22.5	0.8	16.3	0.9
			T. dicoccum	2.4	1.2	-22.5	0.6	16.4	0.7
		40432	*H. vulgare*	3.0	0.6	-22.9	0.4	16.8	0.5
			T. dicoccum	3.7	1.3	-21.8	0.9	15.6	1.0
		40422	*H. vulgare*	1.9	0.9	-23.5	0.2	17.4	0.2
			T. dicoccum	4.0	1.9	-22.3	0.3	16.1	0.3
	FILL P13	40487	*H. vulgare*	2.5	3.0	-23.0	0.4	16.9	0.5
			T. dicoccum	1.8	0.7	-22.9	1.0	16.8	1.1
		40485	*H. vulgare*	3.9	2.6	-22.2	1.0	16.0	1.1
			T. dicoccum	2.3	1.2	-22.2	0.7	16.1	0.7
		40483	*H. vulgare*	2.8	1.5	-24.2	0.1	18.1	0.1
			T. dicoccum	4.5	1.4	-23.4	0.3	17.3	0.3
		40452	*H. vulgare*	0.2	0.3	-23.0	1.1	16.9	1.2
			T. dicoccum	1.4	0.9	-22.5	0.5	16.3	0.6
	FILL LEV3	40391	*H. vulgare*	2.4	0.7	-22.8	0.6	16.7	0.6
			T. dicoccum	2.0	1.1	-22.1	1.1	15.9	1.1
		40371	*H. vulgare*	0.2	1.9	-22.4	1.1	16.3	1.1
			T. dicoccum	1.1	1.1	-21.4	0.9	15.3	0.9
		40367	*H. vulgare*	2.7	1.4	-22.5	0.7	16.4	0.7
			T. dicoccum	2.0	1.3	-22.2	0.3	16.0	0.3
		40374	*H. vulgare*	2.8	2.0	-23.0	0.9	16.9	0.9
			T. dicoccum	2.3	2.5	-21.6	0.5	15.4	0.6
		Mean	*H. vulgare*	2.2	1.1	-22.9	0.6	16.8	0.6
		Mean	*T. dicoccum*	2.6	1.1	-22.3	0.5	16.1	0.6
770-730/20 BCE	*	4029	*H. vulgare*	2.2	1.8	-23.4	0.8	17.3	0.8
			T. dicoccum	3.0	1.7	-22.9	0.3	16.8	0.3
	*	3095	*H. vulgare*	-0.8	0.8	-23.7	0.4	17.6	0.5
	*	3096	*H. vulgare*	2.1	0.9	-24.2	0.7	18.2	0.7
		Mean	*H. vulgare*	2.2	1.2	-23.8	0.4	17.7	0.5
		Mean	*T. dicoccum*	3.0		-22.9		16.8	
730/20-630/20 BCE	*	7276	*H. vulgare*	0.9	1.0	-24.3	0.5	18.2	0.5
			T. dicoccum	1.9	1.0	-23.8	0.6	17.8	0.6
	*	9883	*T. dicoccum*	0.6	1.4	-23.2	0.9	17.1	0.9
	*	9886	*H. vulgare*	1.3	1.2	-23.0	1.1	16.9	1.2

			T. dicoccum	1.9	1.4	-23.9	0.2	17.8	0.2
	*	5532	*H. vulgare*	3.5	1.7	-23.9	0.7	17.8	0.7
			T. dicoccum	2.9	1.0	-23.9	0.4	17.8	0.4
		Mean	*H. vulgare*	1.9	1.4	-23.7	0.6	17.6	0.7
		Mean	*T. dicoccum*	1.8	0.9	-23.7	0.4	17.6	0.4

Appendix F: NE slope of the Palatine Hill. $\Delta^{13}C$ and $\delta^{15}N$ means and standard deviations by stratigraphic units, archaeological contexts and by periods.

Appendix G: Tarquinia: Taxonomical identifications of the carpological remains.

Period	**Sett**	**SU**	**C**	**Sample n°**	**Crops**	**Seed code**	**Lost after chemical treatment**	**δ^{15}N mean (‰)**	**sd**	**δ^{13}C mean (‰)**	**sd**	**Δ^{13}C mean (‰)**	**sd**
800-730	Q	3493	2126	2	*T. dicoccum*	D33T		5.0	0.2	-21.0	0.9	14.8	0.9
800-730	Q	3493	2126	2	*T. dicoccum*	D34T		3.5	0.1	-22.0	0.7	15.8	0.7
800-730	Q	3493	2126	2	*T. dicoccum*	D35T		4.2	0.1	-23.3	0.7	17.2	0.7
800-730	Q	3493	2126	2	*T. dicoccum*	D36T		5.6	0.4	-21.5	1.3	15.3	1.4
750-650	Q	3364	2015	1	*H. vulgare*	H17T		3.7	0.1	-23.5	0.0	17.4	0.0
750-650	Q	3364	2015	1	*H. vulgare*	H18T		2.8	0.1	-24.1	0.0	18.0	0.0
750-650	Q	3364	2015	1	*H. vulgare*	H19T		4.2	0.4	-23.8	0.1	17.7	0.1
750-650	Q	3364	2015	1	*H. vulgare*	H20T		3.4	0.5	-23.5	0.1	17.4	0.1
750-650	Q	3364	2015	1	*T. dicoccum*	D21T		3.7	0.2	-21.7	0.1	15.5	0.1
750-650	Q	3364	2015	1	*T. dicoccum*	D22T		4.8	0.3	-22.0	0.2	15.9	0.2
750-650	Q	3364	2015	1	*T. dicoccum*	D23T		3.3	0.1	-21.7	0.1	15.5	0.1
750-650	Q	3364	2015	1	*T. dicoccum*	D24T		1.1	0.0	-22.4	0.0	16.3	0.0
750-650	Q	3364	2015	2	*H. vulgare*	H25T		3.3	0.4	-22.6	0.2	16.4	0.2
750-650	Q	3364	2015	2	*H. vulgare*	H26T		1.3	0.4	-24.0	0.1	17.9	0.1
750-650	Q	3364	2015	2	*H. vulgare*	H27T		3.3	0.4	-22.8	0.2	16.6	0.2
750-650	Q	3364	2015	2	*H. vulgare*	H28T		3.1	0.3	-23.2	0.0	17.1	0.0
750-650	Q	3364	2015	2	*T. dicoccum*	D29T		2.2	0.2	-23.5	0.1	17.4	0.1
750-650	Q	3364	2015	2	*T. dicoccum*	D30T		2.8	0.2	-22.9	0.0	16.8	0.0
750-650	Q	3364	2015	2	*T. dicoccum*	D31T		2.8	0.1	-22.7	0.4	16.6	0.1
750-650	Q	3364	2015	2	*T. dicoccum*	D32T		3.5	0.5	-23.4	0.1	17.3	0.1
750-650	Q	3193	1890	1	*H. vulgare*	H37T		2.8	0.9	-23.3	0.1	17.2	0.1
750-650	Q	3193	1890	1	*H. vulgare*	H38T		2.7		-24.2	0.3	18.1	0.3
750-650	Q	3193	1890	1	*H. vulgare*	H39T		2.4	0.0	-23.0	0.1	16.9	0.1
750-650	Q	3193	1890	1	*H. vulgare*	H40T		2.5	0.4	-23.8	0.1	17.8	0.1
750-650	Q	3193	1890	1	*T. dicoccum*	D41T		1.6	0.4	-22.4	0.3	16.2	0.3
750-650	Q	3193	1890	1	*T. dicoccum*	D42T		1.0	0.1	-22.6	0.1	16.4	0.1
750-650	Q	3193	1890	1	*T. dicoccum*	D43T		1.5	0.2	-22.9	0.1	16.7	0.1

750-650	Q	3193	1890	1	*T. dicoccum*	D44T	2.6	0.2	-23.7	0.3	17.6	0.3
550-500	M	951	558	1	*H. vulgare*	H1T	3.3	0.3	-23.4	0.1	17.3	0.1
550-500	M	951	558	1	*H. vulgare*	H2T	4.1	0.3	-23.2	0.0	17.1	0.0
550-500	M	951	558	1	*H. vulgare*	H3T	2.7	0.4	-22.2	0.1	16.1	0.1
550-500	M	951	558	1	*H. vulgare*	H4T	3.9	0.4	-22.5	0.1	16.3	0.1
550-500	M	951	558	1	*T. dicoccum*	D5T	3.3	0.1	-21.5	0.0	15.4	0.0
550-500	M	951	558	1	*T. dicoccum*	D6T	3.6	0.1	-21.0	0.1	14.8	0.1
550-500	M	951	558	1	*T. dicoccum*	D7T	4.7	0.1	-21.0	0.1	14.9	0.1
550-500	M	951	558	1	*T. dicoccum*	D8T	5.0	0.0	-21.4	0.0	15.2	0.0
550-500	M	951	558	2	*H. vulgare*	H9T	0.2	0.1	-21.9	0.2	15.8	0.2
550-500	M	951	558	2	*H. vulgare*	H10T	1.9	0.2	-23.0	0.1	16.9	0.1
550-500	M	951	558	2	*H. vulgare*	H11T	1.8	0.3	-22.2	0.1	16.1	0.2
550-500	M	951	558	2	*H. vulgare*	H12T	1.4	0.3	-22.9	0.2	16.8	0.2
550-500	M	951	558	2	*T. dicoccum*	D13T	0.2	0.1	-21.0	0.0	14.8	0.0
550-500	M	951	558	2	*T. dicoccum*	D14T	-0.4	0.3	-22.0	0.1	16.0	0.1
550-500	M	951	558	2	*T. dicoccum*	D15T	1.2	0.6	-22,3	0.2	16.2	0.2
550-500	M	951	558	2	*T. dicoccum*	D16T	2.5	0.4	-21.0	0.2	15.0	0.2
500-450	HM	2576	1471	1	*H. vulgare*	H45T	3.0	0.5	-22.6	0.0	16.5	0.0
500-450	HM	2576	1471	1	*H. vulgare*	H46T	1.9		-23.8		17.7	
500-450	HM	2576	1471	1	*T. dicoccum*	D48T	3.2	0.3	-21.3	0.0	15.1	0.0
500-450	HM	2576	1471	1	*T. dicoccum*	D49T	3.0	0.3	-22.4	0.1	16.2	0.1
500-450	HM	2576	1471	1	*T. dicoccum*	D50T	3.9	0.3	-22.0	0.0	15.9	0.0
500-450	HM	2576	1471	1	*T. dicoccum*	D51T	1.7	0.4	-23.2	0.4	17.2	0.4
500-450	HM	2579	1475	4	*H. vulgare*	H52T	2.2	0.3	-22.8	0.1	16.7	0.1
500-450	HM	2579	1475	4	*H. vulgare*	H53T	-0.4	0.6	-24.9	0.1	18.9	0.1
500-450	HM	2579	1475	4	*H. vulgare*	H54T	5.2	0.5	-23.3	0.2	17.3	0.2
500-450	HM	2579	1475	4	*H. vulgare*	H55T	3.9	0.1	-23.0	0.0	16.9	0.0
500-450	HM	2579	1475	4	*T. dicoccum*	D56T	2.2	0.1	-22.4	0.1	16.3	0.1
500-450	HM	2579	1475	4	*T. dicoccum*	D57T	4.4	0.0	-23.8	0.2	17.7	0.2
500-450	HM	2579	1475	4	*T. dicoccum*	D58T	1.7	0.4	-22.2	0.0	16.1	0.0

500-450	HM	2579	1475	4	*T. dicoccum*	D59T	5.1	0.4	-21.7	0.1	15.6	0.1

Appendix H: Tarquinia. Δ^{13}C and δ^{15}N means and standard deviations for each grain.

Period	Sett	SU	C	Sample n°	Crops	δ^{15}N mean (‰)	sd	δ^{13}C mean (‰)	sd	Δ^{13}C mean (‰)	sd
800-730	Q	3493	2126	2	*T. dicoccum*	4,6	0,9	-22,0	1,0	15,8	1,0
750-650	Q	3364	2015	1	*H. vulgare*	3,5	0,6	-23,7	0,3	17,6	0,3
750-650	Q	3364	2015	1	*T. dicoccum*	3,2	1,6	-22,0	0,3	15,8	0,4
750-650	Q	3364	2015	2	*H. vulgare*	2,8	1,0	-23,2	0,6	17,0	0,7
750-650	Q	3364	2015	2	*T. dicoccum*	2,8	0,5	-23,1	0,4	17,0	0,1
750-650	Q	3193	1890	1	*H. vulgare*	2,6	0,2	-23,6	0,5	17,5	0,1
750-650	Q	3193	1890	1	*T. dicoccum*	1,7	0,7	-22,9	0,6	16,7	0,6
		Mean			***H. vulgare***	**3,0**	**0,5**	**-23,5**	**0,3**	**17,4**	**0,3**
		Mean			***T. dicoccum***	**2,6**	**0,8**	**-22,7**	**0,6**	**16,5**	**0,6**
550-500	M	951	558	1	*H. vulgare*	3,5	0,6	-22,8	0,6	16,7	0,6
550-500	M	951	558	1	*T. dicoccum*	4,2	0,8	-21,2	0,3	15,1	0,3
550-500	M	951	558	2	*H. vulgare*	1,3	0,8	-22,5	0,5	16,4	0,5
550-500	M	951	558	2	*T. dicoccum*	1,3	1,1	-21,6	0,7	15,5	0,7
		Mean			***H. vulgare***	2,4	1,5	-22,7	0,2	16,6	0,2
		Mean			***T. dicoccum***	2,7	2,0	-21,4	0,2	15,3	0,3
500-450	HM	2576	1471	1	*H. vulgare*	2,5	0,8	-23,2	0,8	17,1	0,8
500-450	HM	2576	1471	1	*T. dicoccum*	3,0	0,9	-22,2	0,8	16,1	0,9
500-450	HM	2579	1475	4	*H. vulgare*	3,8	2,2	-23,5	1,0	17,5	1,0
500-450	HM	2579	1475	4	*T. dicoccum*	3,4	1,7	-22,5	0,9	16,4	0,9
		Mean			***H. vulgare***	3,1	0,9	-23,4	0,2	17,3	0,2
		Mean			***T. dicoccum***	3,2	0,3	-22,4	0,2	16,3	0,2

Appendix I: Tarquinia. Δ^{13}C and δ^{15}N means and standard deviations by stratigraphic units, and by periods.

Other products

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L'alimentation des premières sociétés agropastorales du Sud de la France : premières données isotopiques sur des graines et fruits carbonisés néolithiques et essais de modélisation

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Résumé

L'analyse isotopique ($\delta^{13}C$ et $\delta^{15}N$) d'ossements humains a permis de franchir un pas décisif dans la connaissance de l'alimentation des sociétés du Néolithique. Cependant, les données isotopiques des ressources végétales cultivées ou sauvages n'étaient pas jusqu'à présent intégrées dans la reconstitution du régime alimentaire des Hommes. Cette étude propose d'explorer les variations isotopiques enregistrées dans des carporestes provenant de sept sites archéologiques néolithiques du sud de la France, afin de comprendre les facteurs environnementaux et/ou anthropiques qui peuvent les influencer. Ces données sont ensuite incluses dans les modèles alimentaires de sujets retrouvés dans les mêmes sites ou à proximité. Les analyses isotopiques des carporestes indiquent que des environnements similaires n'engendrent pas des valeurs homogènes. Au niveau de certains sites, les résultats suggèrent des pratiques de cultures différentes entre espèces. Les modèles alimentaires confirment certaines interprétations proposées précédemment, notamment l'existence de groupes humains au sein d'un même site ne consommant pas les mêmes ressources. Ils montrent également que certains aspects de leur alimentation notamment les ressources sauvages auraient pu être sous-estimées.

Mots-clés : paleodiète, isotopes stables, carpologie, Méditerranée, Néolithique

Abstract

Stable isotope analyses (δ^{13}C and δ^{15}N) of human bones have been crucial for understanding the diets of Neolithic societies. However, isotopic measurements of wild and cultivated vegetal resources have not as yet been integrated into reconstructions of human diets. This study explores the isotopic variations in seed and fruit remains from seven Neolithic sites in Southern France. It aims to understand environmental and/or anthropic factors that could influence the isotopic ratios. These data are then included in a dietary model for individuals found at the same sites or nearby. Analysis of botanical remains indicate that similar environments do not provide homogeneous values. For some sites, results suggest different cultivation practices according to species. The dietary models confirm some interpretations previously proposed, including a diversity in the dietary habits at one site. However, some aspects of the diet could have been under-estimated, such as the consumption of wild food plants.

Key-words: paleodiet, stable isotopes, archaeobotany, Mediterranean, Neolithic

Abridged version

The use of carbon (δ^{13}C) and nitrogen (δ^{15}N) stable isotope analyses on human and animal bones is a relevant tool for studying the diet of the first agropastoral societies of the Neolithic (Bocherens et Drucker, 2003; Schoeninger et DeNiro, 1984). According to previous analyses of adult human bones from the Mediterranean region, the diet of Early and Middle Neolithic people was based mostly on terrestrial mammals, including domestic ones (Goude, 2007; Goude et al., 2011; 2013; Le Bras-Goude et al., 2006a; Le Bras-Goude et al., 2006b; Le Bras-Goude et al., 2010; Müller et al., 2009). Botanical resources seem to have played a secondary role (Gleize et al., 2019; Goude et Herrscher, 2018; Le Bras-Goude., 2009). Nonetheless, their presence is attested in archaeological sites in southern France by charred fruit and seed remains, occasionally in large quantities. In addition to cereals, which were the most common discovery, and legumes, which were found occasionally, wild fruits such as acorns have been regularly found, sometimes in large quantities, indicating that they may have been commonly collected and eaten. The importance of vegetal resources could therefore have been underestimated in previous dietary studies. In fact, no botanical isotopic data have up to now been available in Southern France and consequently could not be taken into consideration in the interpretation of Neolithic diets. Moreover, when assessing vegetal proteins, former studies assumed that humans and animals ate plants with similar isotopic values. However, isotopic ratios in plants are influenced by anthropologic (Bogaard et al., 2007; Bol et al., 2005; Fraser et al., 2011), environmental (Ferrio et al., 2007; Flohr et al., 2011; Amundson et al., 2003) and physiological factors (Flohr et al., 2011; Virginia et Delwiche, 1982). In this context, and considering the lack of isotopic data in the Mediterranean region for vegetal resources, this study tests the possibility of reconsidering paleodietary studies by adding stable isotopic data from botanical material. Our objectives are 1) to produce the first stable isotopic data (δ^{13}C and δ^{15}N) from charred fruits and seeds of six taxa (*Hordeum vulgare* ; *Triticum aestivum/turgidum* ; *T. dicoccum* ; *T. monococcum* ; *Vicia sativa;* and acorns of *Quercus* sp.) from seven Neolithic archaeological sites of southern France, and 2) to integrate these results into a Bayesian dietary model based on stable isotope measurements already available from human and other animal bones from five archaeological sites in the region.

The results of isotopic analyses of botanical remains do not allow the identification of meaningful differences among species of cereals regarding the Δ^{13}C values (δ^{13}C corrected to take into account δ^{13}C fluctuation of the atmospheric CO_2 through time) (*H.vulgare* : 17,0 ±1 (n=10); *T. aestivum/turgidum* : 16.7 ±0.7 (n=7) ; *T. dicoccum* : 16.7 ±1 (n=10)) nor nitrogen values (*H.vulgare* : 6.9 ±2.7 (n=10); *T. aestivum/turgidum* : 4.7 ±1.8 (n=7) ; *T. dicoccum* : 5.0 ±1.4 (n=10). Acorns have low δ^{15}N values (0.8 and 1.7‰), close to those of legumes which have a mean of 1± 0.2‰ (n=4). The similarities among the values for different plant taxa could create a misinterpretation of the resources consumed, stressing the importance of analyzing a wide range of taxa at the site when possible. Isotopic values of cereals do not show homogeneity in sites located in the same broad area or in those with similar environmental characteristics. Variation in isotopic values for one species is very likely due to the influence of local environmental conditions as well as, possibly, climatic changes that occurred during the time lapse covered at the sites. The variation for a given species at a single site can also be explained by human cultivation practices. Naked wheat and barley seem to have been managed in different ways at La Font-aux-Pigeons. The carbon values are higher for naked wheat than barley, indicating better water availability. Water availability is significantly higher in Claparouse for common vetch than cereals (18.7 ±0.9 (n=4) and 16.4 ±0.1 (n=3)). Incidentally, this could support the hypothesis of the cultivation of common vetch rather than gathering of seeds in wild stands (Bouby et Léa 2006).

Isotopic values from carpological remains are integrated into Bayesian dietary models for humans from the sites of Pendimoun, le Rastel, Fontbrégoua, in Provence, and the sites of le Crès and le Pirou in l'Hérault. The elements from specific sites have been sorted into distinct groups based on archaeological data and prior paleo-alimentary studies. At Pendimoun, wild resources, both vegetal and animal, probably had an important role in the diets of adult individuals. Cultivated cereals found at the site were also part of their diet. The woman F2, found in a particular funerary context, seems to have benefited from a more balanced diet with an equal contribution from vegetal and animal resources. The model shows a more important consumption of wild animals at the site of Fontbrégoua compared to other resources. It is consistent with the nature of the site, which is a seasonally occupied cave where a lot of wild animal bones have been found. For the sites situated in l'Hérault, le Crès and le Pirou, three groups were analyzed. The first one shows a large consumption of plants with low δ^{15}N, such as legumes and acorns, as well as wild animals. The second one may have had a more balanced diet. The last group, represented by dog remains, has intermediate values: plants such as legumes and wild animals played a larger part in the diet than for the second human group. The Bayesian models stress the importance of the consumption of vegetal resources which could

have been underestimated in previous paleodietary studies. The role of wild plants such as acorns seems more important than previously thought. Finally, different diets at the same site could reflect different social statures, giving insights into the organization of the first agropastoral societies.

This exploratory work should be complemented by additional isotopic analyses of botanical remains in order to refine our paleodietary interpretations and to improve our understanding of the environmental and anthropological factors influencing isotopic values. Nonetheless, these first results show that this method allows deeper insights into the resources consumed by Neolithic individuals, shining a new light on the place and diversity of vegetal resources in human diets.

1. Introduction

En France, l'utilisation, depuis plus d'une décennie, des marqueurs isotopiques pour étudier l'alimentation humaine durant la Préhistoire, et particulièrement au Néolithique, a permis de documenter les modes de subsistance et d'inférer sur des choix culturels, économiques et environnementaux. A partir des valeurs des isotopes stables du carbone ($\delta^{13}C$) et de l'azote ($\delta^{15}N$) mesurées dans le collagène osseux de restes humains et d'animaux qui leur sont associés sur les sites archéologiques, il est possible de discuter l'importance relative des protéines animales dans la diète (Bocherens et Drucker, 2003) au cours des dernières années de la vie de l'individu (Hedges et al., 2007 ; Valentin, 2002) ainsi que l'origine environnementale des ressources (ex. marine vs. terrestre) (Schoeninger et DeNiro, 1984). De récentes synthèses sur des sites localisés du nord au sud de la France soulignent notamment l'impact des paramètres environnementaux locaux sur les compositions isotopiques des ressources, la variabilité entre les différents groupes humains en termes de consommation de protéines animales (Goude et Fontugne, 2016) et des différences entre sujets masculins et féminins selon les sites (Goude et al., 2013 ; Rey et al., 2017). Toutefois, jusqu'à présent, ces études utilisaient des référentiels isotopiques locaux, uniquement établis à partir de vestiges osseux d'animaux domestiques et sauvages, et ne prenaient pas en compte tout le pan de l'alimentation que constituaient les ressources végétales. De plus, les études relatives à l'alimentation reposaient sur l'hypothèse que la faune et les Hommes consommaient des plantes dont les valeurs isotopiques étaient identiques. Ainsi, une augmentation du $\delta^{13}C$ et du $\delta^{15}N$ entre des taxons distincts était interprétée comme témoignant d'une position plus élevée dans la chaine alimentaire (Styring et al., 2015). Cependant, il a été montré que les valeurs isotopiques du carbone et de l'azote des plantes variaient en fonction des espèces (Flohr et al., 2011; Virginia et Delwiche, 1982) et étaient influencées par des paramètres environnementaux et climatiques (Ferrio et al., 2007; Flohr et al., 2011; Amundson et al., 2003). Certaines pratiques agricoles comme l'ajout de fumure ou l'amélioration de la disponibilité en eau au sein des cultures impactent également le $\delta^{13}C$ et le $\delta^{15}N$ mesurés sur des carporestes carbonisés (Bogaard et al., 2007; Bol et al., 2005; Fraser et al,. 2011). Les ressources végétales exploitées par l'Homme sont représentées dans les sites archéologiques par des restes, dont les plus communs, ceux qui peuvent être identifiés avec la plus grande précision, sont les graines et fruits carbonisés. Ces derniers sont d'ailleurs habituellement considérés comme majoritairement constitués de déchets de l'alimentation de l'Homme ou des animaux vivant dans son entourage. Ils sont carbonisés accidentellement ou volontairement au cours de leur traitement. Il reste cependant toujours difficile de connaître les usages précis de chaque plante. Il est également difficile de déterminer dans quelle mesure la représentation d'une plante dans le registre archéobotanique est fidèle à son importance économique pour les populations passées, sachant que la conservation par carbonisation impose un filtre taphonomique majeur, au bénéfice des graines et fruits les plus résistants et de ceux les plus communément traités par la chaleur (séchage, grillage, cuisson, usage comme combustible) (e.g. Lebreton et al. 2017).

De nombreuses études paléoalimentaires ont déjà été conduites en Méditerranée occidentale sur des restes osseux de sujets humains adultes de sites du Néolithique ancien et moyen (sud de la France et Ligurie). Celles-ci ont montré que les mammifères terrestres, notamment domestiques, constituaient la majorité des apports protéiques (Goude, 2007; Goude et al., 2011; 2013; Le Bras-Goude et al., 2006a; Le Bras-Goude et al., 2006b; Le Bras-Goude et al., 2010; Müller et al., 2009). La part végétale semblait secondaire, excepté dans certains cas comme en Languedoc, où une contribution significative de céréales et/ou légumineuses a été suggérée (Gleize et al., 2019; Goude et Herrscher, 2018; Le Bras-Goude et al., 2009). Pour ce qui est des études carpologiques, bien qu'encore trop limitées, elles permettent d'esquisser les grands traits des ressources alimentaires végétales consommées par les populations néolithiques dans le Sud-Est de la France (Marinval, 1993; 2008; Martin et al., 2016; Bouby et al., 2018; 2019; 2020). Les vestiges les plus fréquents renvoient au corpus des céréales, globalement dominé par le blé nu (*Triticum aestivum/turgidum*) et l'orge nue (*Hordeum vulgare* var. *nudum*). Les blés vêtus, amidonnier (*Triticum dicoccum*) et engrain (*Triticum monococcum*), fournissent une contribution majeure à certaines périodes, au tout début du Néolithique ancien, et à partir de la seconde moitié du Chasséen (après 4000 BC). Les autres plantes cultivées sont beaucoup plus rares, la conservation par carbonisation ne favorise pas leur enregistrement. Les légumineuses, en particulier lentille (*Lens culinaris*), gesse (*Lathyrys cicera/sativus*) et pois (*Pisum sativum*), sont occasionnellement enregistrées. Quelques découvertes sporadiques de graines de lin (*Linum usitatissimum*) et de pavot (*Papaver somniferum*) rappellent que l'alimentation végétale devait intégrer des produits oléagineux. La présence récurrente de multiples fruits sauvages constitue la partie émergée d'un pan de l'alimentation constitué de ressources sauvages cueillies dont l'importance réelle demeure bien difficile à évaluer pour des raisons taphonomiques. Effectivement, les restes fruitiers sont plus abondants et diversifiés dans les sites néolithiques où ils pourront être conservés dans l'eau que dans les sites de milieu sec, où seuls les restes carbonisés se conservent (e.g. : Colledge et Conolly, 2014). Des concentrations de glands (*Quercus* sp.) carbonisés trouvées dans plusieurs sites montrent que ces fruits sauvages ne constituaient pas que des grappillages opportunistes, mais pouvaient être collectés en masse pour faire l'objet d'un traitement spécifique et être éventuellement stockés pour un usage décalé.

La diversité de l'alimentation végétale des sociétés agropastorales du Néolithique est difficile à évaluer uniquement au travers des études carpologiques et des mesures isotopiques réalisées sur les ossements. De plus, compte tenu des découvertes sur la variabilité isotopique des plantes, liée notamment à l'environnement et aux pratiques humaines, il semble nécessaire de reconsidérer les études paléoalimentaires à la lumière de données isotopiques paléobotaniques. Les objectifs de cet article sont donc 1) de produire des valeurs isotopiques à partir de graines et fruits néolithiques du sud de la France où, à la différence du nord de l'Europe

(Aguilera et al., 2018 ; Bogaard et al., 2013 ; Styring et al., 2017), du sud du bassin Méditerranéen (Araus et al., 1997 ; Ferrio et al., 2005) et du Proche-Orient (Fiorentino et al., 2012 ; Masi et al., 2014), les études isotopiques sur des échantillons carpologiques sont presque inexistantes (Alagich et al., 2018) et 2) de prendre en compte ces résultats dans une modélisation, intégrant différentes ressources alimentaires végétales, réalisée à partir de résultats isotopiques sur ossements humains préalablement disponibles dans la région.

2. Matériel et méthode

2.1 Nature et provenance du matériel carpologique

Les analyses isotopiques ont été réalisées sur des restes carpologiques provenant de sept sites archéologiques localisés dans le sud de la France, datés entre le Néolithique ancien et final (5750-5700 BC jusqu'à 2000 BC) (Fig. 1). Les sites sont des occupations de plein air et des abris sous roche (Tab 1). Les carporestes analysés correspondent principalement à des caryopses de céréales : orge commune (*Hordeum vulgare* L.), blé nu (*Triticum aestivum/turgidum* L.), amidonnier (*Triticum dicoccum* Schubl.) et engrain (*Triticum monococcum* L.). Les légumineuses sont représentées par la vesce commune (*Vicia sativa* L.). Quelques glands de chêne (*Quercus* sp) ont également été étudiés. Pour notre sélection d'échantillons nous avons privilégié les espèces pour lesquelles des données isotopiques sont disponibles sur des semences actuelles et celles qui étaient les plus abondantes dans les contextes archéologiques. Selon le site d'étude, les carporestes ont été retrouvés dans des assemblages de nature différente (Tab 1). Certains constituent des concentrations, présentant une forte densité carpologique ainsi que la domination d'une seule, ou d'un petit nombre d'espèces : il s'agit généralement de produits homogènes, représentant un évènement particulier. Les autres sont des ensembles ouverts qui représentent des accumulations plus diffuses, souvent constitués de déchets multiples (Bouby, 2014). L'ensemble du matériel est conservé par carbonisation.

Sites	**Communes**	**Départements**	**Périodes**	**Nature du site**	**Références**	**Matériel analyses isotopiques**	
						Graines/Fruits	**Ossements humains**
Pendimoun	Castellar	Alpes-Maritimes	Néolithique ancien	Abri sous roche	Binder et al. 1993 ; 2020	X	X
La Font aux pigeons	Châteauneuf-les-Martigues	Bouche-du-Rhône	Néolithique ancien	Abri sous roche	Courtin et al. 1985 ; Binder et al. 2017	X	X
Claparouse	Lagnes	Vaucluse	Néolithique moyen	Plein air	Léa et al. 2004 ; Bouby & Léa 2006	X	
Fontbrégoua	Salernes	Var	Néolithique moyen	Abri sous roche	Binder 1987 ; Le Bras-Goude et al 2010	X	
Le Pirou	Valros	Hérault	Néolithique moyen	Plein air	Gleize et al. 2019		X
Le Crès	Béziers	Hérault	Néolithique moyen	Plein air	Loison et al. 2004 ; Le Bras-Goude et al. 2009		X
Jardins de Vert Parc	Castelneau-le-Lez	Hérault	Néolithique moyen	Plein air	Vignaud 1999	X	
Burlière	Trets	Bouche-du-Rhône	Néolithique moyen	Plein air		X	
La Perte du Cros	Saillac	Lot	Néolithique moyen Néolithique final	Abri sous roche	Galan 1967 ; Gernigon et al. 2008	X X	

Tab 1 : Informations concernant les sites archéologiques
Tab 1 : Information on archaeological sites

2.2 Échantillonnage

Les échantillons isolés pour analyses isotopiques sont systématiquement composés des carporestes d'une seule espèce, issus d'un prélèvement unique. Ils contiennent deux à trois spécimens. La quantité de restes carpologiques étant restreinte pour la majorité des sites, nous avons choisi de minimiser la taille des échantillons afin de privilégier la réalisation de réplicas et ainsi pouvoir évaluer la variabilité interne au prélèvement archéologique. Selon les sites, le nombre de réplicas par espèce a varié selon la quantité de matériel carpologique disponible ainsi qu'en fonction de leur réaction au traitement chimique.

2.3 Traitement chimique et analyses isotopiques

Le traitement chimique utilisé est celui de Fraser et al. (2013), confirmé par Vaiglova et al. (2014). Il repose sur un traitement acide-base-acide (ABA). Il permet de retirer les contaminants tels que les carbonates et les acides humiques, qui impactent le δ^{13}C, ainsi que les nitrates qui influencent le δ^{15}N. Dans un premier temps, les carporestes sont plongés dans le HCl concentré à 0.5M et placés dans une étuve à 70° C pendant 30 minutes. Cette étape permet d'éliminer les carbonates. Ils sont ensuite rincés 5 fois à l'eau distillée jusqu'à ce que la solution redevienne claire et que le pH soit neutre. La deuxième étape consiste à ajouter du NaOH à 0.1M, puis à chauffer la solution à l'étuve à 70° C pendant 60 minutes avant de rincer 5 à 9 fois à l'eau distillée selon les échantillons. Le traitement au NaOH permet de retirer les acides humiques. Pour finir, les carporestes sont à nouveau traités au HCl à 0.5M, chauffés à 70° C pendant 30 minutes et rincés 5 fois à l'eau distillée afin de libérer le CO_2 qui aurait pu être piégé durant l'étape précédente. L'eau distillée permet d'éliminer les nitrates.

Les carporestes traités sont ensuite séchés à l'étuve pendant 18h à 65°C, puis réduits en une fine poudre homogène, dont 1.5 à 2 mg sont incorporés dans les capsules d'étain. Toute cette phase de préparation des échantillons a été réalisée dans la plateforme de biochimie du LAMPEA, Aix-en-Provence, France. Les analyses élémentaires et isotopiques ont été réalisées par EA-IRMS (analyseur élémentaire couplé à un spectromètre de masse isotopique ; Iso-Analytical Ltd.; Crewe, Royaume-Uni). L'erreur sur la mesure est calculée à partir de réplicas de standards internes qui sont la farine de blé (IA-R001), un mélange de sulfate d'ammonium et de sucre de betterave (IA-R045/IA-R005) et un mélange de sulfate d'ammonium et de sucre de canne (IA-R046/IA-R006). Elle est au maximum de 0.14 ‰ pour le δ^{15}N et de 0.1 ‰ pour le δ^{13}C, en prenant 2 erreurs standards.

2.4 Effet de la carbonisation sur le δ^{15}N et le δ^{13}C et calcul de Δ^{13}C

La plupart des études menées montrant que les valeurs du δ^{13}C ne sont pas ou très peu affectées par les conditions de carbonisation (Fraser et al., 2013 ; Styring et al., 2013), aucune correction n'est appliquée à nos données pour le δ^{13}C. En revanche, il semble que le δ^{15}N subisse un changement directionnel systématique lors de la carbonisation (Fraser et al., 2013 ; Nitsch et al., 2015). D'après Nitsch et al. (2015), l'ampleur de ce changement est liée à la durée et plus particulièrement à la température de carbonisation. Les conditions exactes de carbonisation (T° et durée) des graines utilisées n'étant pas connues, la correction de 0.31‰ proposée par Nitsch et al. (2015) est appliquée.

Les variations de δ^{13}C du CO_2 de l'atmosphère au cours de l'Holocène doivent être prises en compte pour pouvoir comparer les résultats de différentes périodes (Ferrio et al., 2005 ; Ferrio et al., 2007 ; Heaton, 1999). Le calcul utilisé est celui proposé par Farquhar et al. (1982).

$$\Delta^{13}C = \frac{\delta^{13}C_{air} - \delta^{13}C_{sample}}{\left(1 + \frac{\delta^{13}C_{sample}}{1000}\right)}$$

Le $\delta^{13}C_{air}$ correspond à la valeur isotopique du CO_2 atmosphérique pour une période de temps spécifique, estimée à partir de données provenant de carottes de glace couvrant l'intégralité de l'Holocène (Eyer et al., 2004 ; Francey et al., 1999 ; Indermühle et al., 1999 ; Leuenberger et al., 1992), et $\delta^{13}C_{sample}$ à la valeur isotopique de l'échantillon.

2.5 Modélisation

Trois modélisations chrono-géographiques sont proposées à partir du package SIAR (Stable Isotope Analysis in R; Inger et al., sans date ; Parnell et Jackson, 2013) implémenté dans l'environnement R (R Development Core Team 2011). Les boîtes-à-moustaches proposées par cette application représentent une estimation des proportions de ressources consommées avec des intervalles de probabilité de 25, 75 et 95%. Les fractionnements isotopiques pris en compte pour l'établissement des modèles sont ceux entre l'aliment (plantes, muscles animaux) et le collagène osseux humain (1$\Delta^{13}C$ de ca. +5‰ et $\Delta^{15}N$ de ca. +4‰) (DeNiro et Epstein, 1978; DeNiro et Epstein, 1981). Les modèles ont donc été générés en prenant compte ces offsets entre les tissus, les concentrations élémentaires, les données isotopiques avec leurs écart-types et pas *d'a priori*.

3. Résultats & discussion

Les plantes étant à la base de la chaine alimentaire, leurs valeurs de $\Delta^{13}C$ et de $\delta^{15}N$ ont un impact sur l'ensemble des niveaux trophiques. Il est donc important de prendre en compte, non seulement les valeurs isotopiques spécifiques de la plante, mais également les facteurs naturels ou anthropiques qui peuvent les influencer afin de les intégrer à l'interprétation des données pour la paléoalimentation.

3.1 Variabilité interspécifique des valeurs isotopiques

Les résultats confirment que les plantes ayant des voies d'assimilation de l'azote différentes possèdent des valeurs isotopiques spécifiques, toujours visibles dans les carporestes carbonisés (Tab 2). Les plantes fixatrices d'azote, représentées ici par des graines de *V. sativa* provenant d'une fosse du site chasséen de Claparouse, ont une moyenne de $\delta^{15}N$ de 1 ± 0.2‰ (n=4). Cette valeur est bien plus basse que celle des plantes non fixatrices d'azote, qui malgré une certaine variabilité, sont autour de 5.6 ± 2.2 ‰ (n= 29).

Les mesures isotopiques des glands de *Quercus* sp. sont essentielles à prendre en compte, car ces derniers semblent constituer une source de nourriture importante dans certains

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1 $\Delta^{13}C$ correspond ici à une différence liée au fractionnement isotopique entre l'alimentation et le collagène osseux analysé et non à la prise en compte des variations de $\delta^{13}C$ du CO2 de l'atmosphère au cours de l'Holocène pour comparer les ratios isotopiques du carbone des carporestes.

sites pré et protohistoriques (Ruas et Marinval, 1991 ; Marinval, 2008). Les glands de l'abri de Pendimoun ont des $\Delta^{13}C$ semblables à ceux des céréales en C_3. Leurs valeurs de $\delta^{15}N$ sont relativement basses par rapport aux autres taxons, se rapprochant de celles des légumineuses (Tab 2). La différence de 0.8‰ qui existe entre les deux mesures du $\delta^{15}N$ peut être expliquée notamment par le fait que les glands ne peuvent être identifiés que jusqu'au niveau du genre. Il est ainsi possible qu'ils appartiennent à plusieurs espèces possédant des physiologies et des compositions chimiques légèrement différentes, pouvant induire un fractionnement différent. Les espèces présentes en région méditerranéenne, en particulier dans l'environnement contrasté du site de Pendimoun, sur la frange méridionale des Alpes, peuvent pousser dans des conditions écologiques très diverses. Une étude anthracologique a notamment mis en évidence la présence de la chênaie caducifoliée qui dominerait le paysage durant l'Impressa (Battentier et al., 2015), le chêne sempervirent serait également présent bien que plus discret (Battentier et al., 2015). Il est intéressant de noter que des valeurs isotopiques de $\delta^{15}N$ mesurées sur des glands modernes provenant de différentes espèces : sempervirentes, persistantes ou caduques ont donné des résultats se situant dans la même fourchette (-2 à 7‰) que nos données, confirmant ainsi les mesures effectuées (Alegria et al., 2020; Koenig et al.,2008).

De manière générale, les données obtenues ne permettent pas d'observer de différences de $\Delta^{13}C$ entre les céréales étudiées (*H.vulgare* : 17,0 ±1 (n=10); *T. aestivum/turgidum* : 16.7 ±0.7 (n=7) ; *T. dicoccum* : 16.7 ±0.1 (n=10)). Ceci se vérifie au niveau des sites dans lesquels deux espèces de céréales ont pu être étudiées permettant de comparer directement les résultats, comme *T. dicoccum* et *T. monococcum* à la Burlière, ou *H. vulgare* et *T. aestivum/turgidum* à la Font-aux-Pigeons. Diverses études, basées aussi bien sur du matériel actuel qu'archéologique, ont cependant mis en évidence des différences interspécifiques même si elles restent discrètes. Les caryopses d'orge présentent généralement des valeurs de $\Delta^{13}C$ plus hautes que celles du blé nu (Ferrio et al., 2005; Flohr et al., 2011; Riehl et al., 2008) et de l'amidonnier (Riehl, 2008; Riehl, 2009; Masi et al., 2014). Ceci est expliqué par une demande en eau moins forte chez l'orge que le blé et par un cycle de croissance plus court, lui permettant d'éviter davantage la sécheresse estivale et le stress hydrique, conduisant à une baisse du $\Delta^{13}C$. Les carporestes étudiés venant de périodes et d'environnements bien distincts, cela pourrait expliquer la grande hétérogénéité des valeurs du $\Delta^{13}C$ et donc masquer de telles différences interspécifiques au sein des céréales en C_3. En ce qui concerne le $\delta^{15}N$, les résultats sont très variables et il ne semble pas y avoir de différence marquée et directionnelle entre les céréales (*H. vulgare* : 6.9 ±2.7 (n=10) ; *T. aestivum/turgidum* : 4.7 ±1.8 (n=7) ; *T. dicoccum* :5.0 ±1.4 (n=10)).

Le tableau 2 montre dans quel type d'assemblages les carporestes ont été trouvés, il ne semble pas que les valeurs entre les graines provenant de concentrations soient plus homogènes que celles provenant d'assemblages ouverts.

3.2 Variabilité intraspécifique des valeurs isotopiques

Les données ne permettent pas de détecter une influence de la situation géographique ou environnementale des sites dans la variabilité du signal isotopique pour une même espèce. Si l'on se réfère aux valeurs isotopiques des céréales (les seules qui permettent une comparaison entre plusieurs sites) on ne perçoit pas, par exemple, une homogénéité particulière des valeurs des $\Delta^{13}C$ et $\delta^{15}N$ pour le site de la Burlière et de la Font-aux-Pigeons, localisés dans des conditions environnementales proches, tous les deux dans le bassin de l'Etang de Berre à proximité de la Méditerranée (Fig. 2 et 3). A l'opposé, les valeurs isotopiques de la Perte du Cros, site le plus occidental, localisé dans l'ambiance plus humide et plus fraîche des causses du Quercy, ne se détachent pas de celles des sites de milieu méditerranéen. Les paramètres influençant le plus fortement les valeurs isotopiques semblent être des facteurs plus strictement locaux tels que la topographie, les caractéristiques édaphiques, l'altitude ou encore la densité de la canopée (Amundson et al., 2003 ; Heaton, 1999 ; Flohr et al., 2011) que notre échantillonnage ne permet pas de détecter. Les sites ne couvrant pas toujours les mêmes périodes et étant échelonnés sur une durée de 3500 ans environ, l'hétérogénéité des valeurs dans une même région géographique pourrait également être expliquée par les variations climatiques ayant eu lieu au cours du temps. (Jalut et al., 2000, Mauri et al., 2015; Peyron et al., 2011).

3.3 Conditions et pratiques de culture

La comparaison des données obtenues à des valeurs seuils pour la disponibilité en eau et la fertilisation, calculées sur des cultures actuelles, permet de mieux cerner les conditions dans lesquelles les plantes étudiées ont pu être cultivées au Néolithique. Les référentiels actuels sont incontournables pour l'interprétation des mesures isotopiques effectuées sur des carporestes archéologiques. Il faut cependant se garder d'un comparatisme strict, car les conditions climatiques et socio-environnementales dans lesquelles ils ont été réalisés ne sont pas toujours directement transférables au passé, a fortiori si les études modernes n'ont pas été effectuées à proximité des sites archéologiques. Les seuils de disponibilité en eau ont été déterminés grâce à des mesures réalisées sur des cultures expérimentales de *H. vulgare* et *T. aestivum* localisées en région méditerranéenne et en Asie du sud-est (Wallace et al., 2013). Globalement, les carporestes néolithiques du Sud de la France semblent provenir de plantes ayant été dans des conditions environnementales variables sans que l'on puisse identifier une tendance au niveau des espèces ou des périodes (Fig. 2). Des indices de fertilité ont de même été calculés pour le $\delta^{15}N$ sur des cultures actuelles situées en zone tempérée d'Europe du Nord (Boogard et al., 2013). Confrontés à ces valeurs (Fig. 3), presque aucun carporestes ne se trouve dans la zone PM (*poorly manured*). Il est alors vraisemblable que les niveaux enregistrés signent une fertilisation des sols par l'Homme. C'est tout particulièrement le cas pour les valeurs situées dans la zone WM (*well manured*), considérée comme témoignant de parcelles ayant reçu une quantité importante de fumure sur le long terme (Boogard et al., 2013), comme pour les orges et certains échantillons d'amidonnier de la Perte du Cros, l'amidonnier et l'engrain de la Burlière ou encore certaines orges ou blés nus de la Font-aux-Pigeons. Selon les mesures actuelles, la zone MM (*moderately manured*) peut correspondre à un amendement en faible quantité sur le long terme, à un effet résiduel passé ou encore aux toutes premières années d'amendement (Fraser et al., 2011).

Sites	Contextes archéologiques	Références	Codes	Nature de l'assemblage	Phases chrono culturelles	Taxons	Azote	Carbone	$\delta^{15}N$	$\delta^{13}C$	$\delta^{15}N$ cor.	$\Delta^{13}C$
							(%)	(%)	(‰)	(‰)	(‰)	(‰)
Pendimoun	Couche	AP 43870	PE_43870	Ouvert	Impressa	*Quercus* sp.	1,6	65,3	1,1	-24,3	0,8	18,1
Pendimoun	Couche	AP 46819	PE_46819	Ouvert	Impressa	*Quercus* sp.	**0,9**	66,1	**2,0**	-25,0	1,7	18,8
Font aux pigeons	Fosse	17-fosse	FP_17	Indéterminé	Cardial	*H. vulgare*	2,9	59,6	5,3	-23,1	4,9	16,9
Font aux pigeons	Fosse	17-fosse	FP_17	Indéterminé	Cardial	*H. vulgare*	2,5	65,0	5,2	-23,5	4,9	17,2
Font aux pigeons	Fosse	17-fosse	FP_17	Indéterminé	Cardial	*H. vulgare*	3,5	63,5	10,7	-23,4	10,4	17,1
Font aux pigeons	Fosse	17-fosse	FP_17	Indéterminé	Cardial	*H. vulgare*	2,3	62,9	12,0	-23,7	11,7	17,5
Font aux pigeons	Fosse	17-fosse	FP_17	Indéterminé	Cardial	*T. aestivum/turgidum*	2,9	61,6	6,1	-23,6	5,8	17,4
Font aux pigeons	Fosse	17-fosse	FP_17	Indéterminé	Cardial	*T. aestivum/turgidum*	2,6	62,5	6,1	-23,9	5,8	17,7
Font aux pigeons	Couche	C11	FP_C11	Indéterminé	Cardial	*H. vulgare*	2,8	65,1	3,7	-22,2	3,4	16,1
Font aux pigeons	Couche	C11	FP_C11	Indéterminé	Cardial	*H. vulgare*	2,4	59,5	4,6	-23,1	4,3	17,1
Font aux pigeons	Couche	C11	FP_C11	Indéterminé	Cardial	*H. vulgare*	2,1	62,4	6,5	-23,4	6,2	17,4
Font aux pigeons	Couche	C11	FP_C11	Indéterminé	Cardial	*H. vulgare*	2,9	64,3	6,6	-23,0	6,3	17,0

Font aux pigeons	Couche	C11	FP_C11	Indéterminé	Cardial	*T. aestivum/turgidum*	3,7	62,4	8,2	-21,9	7,9	15,8
Claparouse	Fosse	Z 130-140 S I-d5	CL_130	Concentration	Chasséen récent	*V. sativa*	5,0	49,0	1,2	-24,1	0,9	18,1
Claparouse	Fosse	Z 130-140 S I-d5	CL_130	Concentration	Chasséen récent)	*V. sativa*	4,7	46,8	1,4	-23,9	1,1	17,9
Claparouse	Fosse	Z 150-155 S I-d5	CL_150	Concentration	Chasséen récent	*V. sativa*	5,5	48,3	1,1	-25,7	0,8	19,8
Claparouse	Fosse	Z 150-155 S I-d5	CL_150	Concentration	Chasséen récent	*V. sativa*	5,2	48,2	1,5	-24,8	1,2	18,9
Claparouse	Fosse	Z 120-130 S I-d5	CL_120	Concentration	Chasséen récent	*T. dicoccum*	3,3	49,1	4,6	-22,5	4,2	16,5
Claparouse	Fosse	Z 140-145 S I-d5	CL_140	Concentration	Chasséen récent	*T. aestivum/turgidum*	3,6	49,9	3,8	-22,3	3,5	16,3
Claparouse	Fosse	Z 140-145 S I-d5	CL_140	Concentration	Chasséen récent	*T. aestivum/turgidum*	3,3	50,0	4,3	-22,4	4,0	16,4
Fontbrégoua	Couche	Carrés IJ-13/14 - Couche 21 P140	FO_21	Ouvert	Chasséen récent	*T. dicoccum*	3,9	64,3	3,0	-22,1	2,7	16,1
Fontbrégoua	Couche	Carrés IN-12/15 - Couche 22 P140	FO_22	Ouvert	Chasséen récent	*T. dicoccum*	3,6	65,0	6,3	-23,2	6,0	17,2
Jardins de Vert Parc	Fosse-silo	SI 1085		Ouvert	Chasséen récent	*T. aestivum/turgidum*	2,4	49,9	3,4	-23,1	3,1	17,1
Jardins de Vert Parc	Fosse-silo	SI 1085		Ouvert	Chasséen récent	*T. aestivum/turgidum*	2,3	49,3	3,2	-22,0	2,9	16,0
Burlière	Fosse-silo	FS3333		Concentration	Chassée récent / final	*T. monococcum*	4,2	63,6	6,7	-21,7	6,4	15,7

Burlière	Fosse-silo	FS3333		Concentration	Chassée récent / final	*T. monococcum*	3,7	62,0	3,5	-22,0	3,1	16,0
Burlière	Fosse-silo	FS3333		Concentration	Chassée récent / final	*T. dicoccum*	3,5	61,6	5,0	-22,1	4,6	16,1
Burlière	Fosse-silo	FS3333		Concentration	Chassée récent / final	*T. dicoccum*	3,8	58,5	6,7	-21,0	6,4	15,0
La Perte du Cros	Couche	US1102 W2 P230	PC_1102	Concentration	Chasséen récent	*T. dicoccum*	3,2	59,8	6,4	-24,0	6,1	18,1
La Perte du Cros	Couche	US1102 W2 P230	PC_1102	Concentration	Chasséen récent	*T. dicoccum*	3,8	60,9	6,8	-24,1	6,5	18,2
La Perte du Cros	Couche	US1102 W2 P230	PC_1102	Concentration	Chasséen récent	*T. dicoccum*	3,8	61,0	6,7	-22,9	6,4	17,0
La Perte du Cros	Couche	US1118 W3 P250	PC_1118	Concentration	Chasséen récent	*H. vulgare*	3,3	59,9	8,5	-20,9	8,2	14,8
La Perte du Cros	Couche	US1118 W3 P250	PC_1118	Concentration	Chasséen récent	*H. vulgare*	3,4	48,7	9,2	-24,4	8,9	18,5
La Perte du Cros	Couche	US1088 B5 P201	PC_1088	Concentration	Néolithique final	*T. dicoccum*	4,1	61,7	3,6	-22,2	3,3	16,2
La Perte du Cros	Couche	US1088 B5 P201	PC_1088	Concentration	Néolithique final	*T. dicoccum*	3,7	62,4	4,4	-22,2	4,1	16,2

Tab 2 : Résultats des analyses isotopiques réalisées sur les carporestes
Tab 2: Stable isotope analysis results performed on archaeobotanical remains

Le site de la Font aux Pigeons permet une confrontation des ratios isotopiques des orges et des blés nus laissant entrevoir une possible différence en termes de gestion des deux espèces. Les mesures de $\Delta^{13}C$ des carporestes du blé nu du contexte FP_17, sont dans la zone WW (*well watered*), indiquant une bonne disponibilité en eau, contrairement aux orges qui sont dans la zone PW (*poorly watered*) (Fig. 2). Au niveau du contexte FP_C11 qui représente une phase d'occupation plus récente, les orges se trouvent encore dans la zone PW, en revanche les grains de blé nu passent dans la zone PW (Fig 2). Il faut cependant rester prudent face à l'identification d'une différence de gestion par rapport à la phase précédente en raison de la faible quantité de mesures pour ce contexte. Les mesures du $\delta^{15}N$ de l'orge sont très variables pour les deux contextes, témoignant à la fois d'un ajout de fumure moyen et important (Fig. 3). Cette variabilité peut révéler l'exploitation de parcelles aux propriétés contrastées, ou faisant l'objet de pratiques de gestion différenciées. Elle pourrait également être expliquée par le fait qu'il s'agit de récoltes de différentes années.

A la Perte du Cros, les grains d'amidonnier du Néolithique moyen (PC_1102 et PC_1118) se situent dans la zone WM pour le $\delta^{15}N$ (Fig. 3). Les valeurs du $\Delta^{13}C$ indiquent également une très bonne disponibilité en eau (Fig 2). Les conditions environnementales dans lesquelles les amidonniers de la Perte du Cros se sont développés au Néolithique moyen semblent donc particulièrement favorables. Les orges quant à eux, bien qu'étant également dans la zone WM (Fig 3), présentent des résultats plus contrastés pour le $\Delta^{13}C$ avec une valeur indiquant des plantes s'étant développées avec suffisamment d'eau et une valeur se situant dans la zone PW (Fig. 2). Par rapport à la période précédente les grains d'amidonnier du Néolithique final (PC_1088) témoignent d'un apport en eau et d'une fertilité plus limités (Fig 2 et 3), sans que l'on puisse en l'état savoir s'il existe une tendance chronologique qui pourrait refléter l'érosion des terres au cours du Néolithique avec l'aridification du climat pour la baisse du $\Delta^{13}C$ et l'appauvrissement des terres cultivées pour le $\delta^{15}N$. Il se peut également que la gestion de l'amidonnier est changée au fil du temps et que moins d'attention lui soit apporté au profit d'autres céréales. La réalisation de mesures additionnelles pourrait aider à lever cette dernière hypothèse.

Les graines de *V. sativa* provenant de Claparouse, ont un $\Delta^{13}C$ élevé (18.7 ±0.9 (n=4)) par rapport aux céréales retrouvées sur le même site (16.4 ±0.1 (n=3)) (Fig. 2). Ferrio et al. (2005) expliquent ces hautes valeurs par le fait que les légumineuses produisent leurs fruits sur une longue durée, durant laquelle l'apport hydrique reste généralement bon (mars, jusqu'à juin). Néanmoins, il n'est pas possible d'écarter l'hypothèse selon laquelle les céréales et la vesce n'auraient pas été traitées de la même manière par les cultivateurs. D'après les mesures réalisées par Wallace et al. (2013) sur une légumineuse, *Lens culinaris*, les valeurs observées à Claparouse correspondent à des plantes s'étant développées dans d'excellentes conditions de disponibilité en eau.

La présence de la vesce commune à Claparouse soulève une question relative à l'origine des graines. L'espèce est rarement attestée dans le Néolithique du nord-ouest méditerranéen et était inconnue jusque-là, à cette époque, dans le Midi de la France. La plante possédant des formes spontanées localement, il est difficile de savoir si les graines proviennent de vesces cultivées ou de cueillettes réalisées dans les populations sauvages. La concentration de graines de *V. sativa*, fortement majoritaires dans l'assemblage de Claparouse (98%), Bouby et Léa (2006) supposent qu'elles proviennent de cultures plutôt que de cueillettes. Le bon apport hydrique enregistré par le signal isotopique s'accorde bien avec cette hypothèse, puisque la mise en culture suppose le choix d'un terrain et la réalisation, par les pratiques de cultures, de conditions favorables à la croissance de la plante.

3.4. Modélisation de la paléodiète au Néolithique dans le sud de la France

Les premières données isotopiques sur les vestiges carpologiques du Néolithique dans le sud de la France offrent l'opportunité de proposer de nouvelles interprétations paléoalimentaires à partir des données humaines et animales acquises jusqu'alors, ainsi que de réévaluer les différents rôles que pourraient avoir les ressources végétales et animales dans l'apport protéique des sujets humains. Nous proposons d'apporter de nouvelles connaissances sur l'alimentation humaine en remobilisant les données isotopiques précédemment publiées. Pour ce, nous utilisons un modèle bayésien qui prend en compte, d'une part, la part relative des animaux et des végétaux analysés des sites ou les plus proches géographiquement et chronologiquement des sites (modèle A) et, d'autre part, la part relative de toutes les différentes espèces de végétaux néolithiques du sud de la France (modèle B).

Un premier groupe de modèles est effectué à partir des données humaines des sites du Néolithique ancien et moyen de Pendimoun (Cardial) et du Rastel (Culture des Vases à Bouche Carrée ou Pré-Chasséen) (Le Bras-Goude et al., 2006b), en séparant l'individu féminin F2 de Pendimoun des autres sujets adultes, étant données ses caractéristiques isotopiques (Le Bras-Goude et al., 2006a) et son traitement funéraire particulier (Binder et al., 1993) (Fig. 4). Le résultat montre que, pour le groupe de sujets adultes, les herbivores sauvages (cerf, chevreuil), suivi par les bovins domestiques ainsi que les glands, retrouvés en grande quantité sur le site de Pendimoun (Binder et al., 2020) pouvaient représenter une part importante de l'alimentation. Ils seraient complétés par diverses autres ressources carnées (Fig. 4, modèle A). On peut également soupçonner une consommation de céréales, qui sont attestées par la carpologie dans le Néolithique ancien de Pendimoun, i.e. l'orge nue, l'amidonnier et l'engrain (Binder et al., 1993, 2020). Pour le sujet féminin F2, les différentes ressources considérées dans le modèle, qu'elles soient animales ou végétales, seraient consommées à part égale (Fig. 4, modèle A). Ces résultats confirment la part importante des protéines animales dans l'alimentation des premiers agropasteurs de Provence, mais indiquent que les ressources sauvages, animales comme végétales, ont pu avoir un rôle significatif contrairement à ce qui était suggéré dans les premières interprétations isotopiques et archéozoologiques (Binder et al., 1993; Le Bras-Goude et al., 2006a). Le choix d'inclure les glands dans les modèles alimentaires a été motivé par les résultats de plusieurs études carpologiques qui ont montré la grande récurrence des fruits sauvages dans les habitats néolithiques et de l'âge du Bronze de l'arrière-pays, notamment dans les occupations en grottes et abris-sous roche, par rapport aux grands habitats de la zone littorale (Antolín et Jacomet, 2015; Alonso et al., 2016; Bouby et al., 2020). La question d'une plus grande contribution des fruits à l'alimentation des habitants reste posée dans ces études, mise en balance avec une sur-représentation d'origine taphonomique ou un lien avec le fourrage des animaux domestiques. Les résultats des modèles calculés à Pendimoun peuvent constituer des arguments pour une consommation significative des fruits dans ces habitats. Lorsque l'ensemble des végétaux est considéré dans le modèle (Fig. 4, modèle B), on remarque que les deux groupes présentent des résultats équilibrés entre les différents végétaux sauvages ou cultivés. Les restes carpologiques du site de Pendimoun indiquent une diversité des apports végétaux domestiques et sauvages (Binder et al., 1993, Binder et al., 2020) et donc une variété d'environnements exploités par les sujets humains. Ce constat a également été fait sur la base de l'identification de microrestes végétaux retrouvés dans le tartre dentaire de sujets néolithiques méditerranéens de la fin du VI^{e} et début du V^{e} mill. avant notre ère (Power in Goude et al. 2020), et à partir des travaux carpologiques d'Antolin (2016) réalisés sur des sites néolithiques du nord-est de la péninsule Ibérique.

Un second groupe de modèles est réalisé à partir des données humaines du site Néolithique ancien et moyen de Fontbrégoua, où les individus sont considérés ensemble en raison de l'homogénéité des données biochimiques mesurées (Le Bras-Goude et al., 2010) (Fig. 5). La comparaison entre les différentes sources souligne la part importante des protéines animales et en particulier des animaux sauvages, comme le cerf et le chevreuil, par rapport aux ressources végétales, tel l'amidonnier (Fig. 5, modèle A). Ce résultat conforte les premières interprétations isotopiques et les études archéozoologiques proposées sur ce site, qui indiquent une occupation saisonnière de la grotte et l'exploitation importante des ressources animales, notamment sauvages, attestée par les rejets de boucherie (Helmer, 1979; Villa et al., 1986). La comparaison ciblée sur l'ensemble des végétaux suggère que les plantes préférentiellement consommées pourraient être des céréales diverses et pas nécessairement l'amidonnier qui est pourtant attesté sur le site (Fig. 5, modèle B). D'ailleurs au Cardial, les céréales sont bien représentées dans le spectre carpologique de Fontbrégoua, avec l'orge nue, le blé nu, l'amidonnier et l'engrain. Elles sont accompagnées par plusieurs légumineuses (gesse, lentille, vesce) et par une diversité de fruitiers sauvages parmi lesquels se détachent *Pinus* sp., *Quercus* sp. et *Vitis vinifera* (Savard, 2000).

Enfin, un troisième groupe de modèles intègre les sujets humains du Néolithique moyen (Chasséen) des sites du Crès et du Pirou, dans l'Hérault. Ici également, plusieurs groupes sont étudiés séparément (2 groupes humains et les chiens), en fonction des données précédemment acquises qui indiquaient de possibles différences alimentaires et mobilités différentielles entre les sujets (Gleize et al., 2019; Goude et al., 2012; Le Bras-Goude et al., 2009) (Fig. 6). Le premier groupe correspond à des sujets humains pour lesquels il a été proposé, sur la base des données isotopiques du collagène osseux, une alimentation protéique incluant une part significative de végétaux. La modélisation propose que les légumineuses (telles que les vesces) aient constitué une part importante, voire très importante, des protéines de l'alimentation. En revanche, la contribution potentielle d'animaux sauvages (ici des cervidés) proposée par le modèle n'avait pas été précédemment évoquée (Gleize et al., 2019; Le Bras-Goude et al., 2009) (Fig. 6, modèle A). Le second groupe comprend des individus pour lesquels il a été initialement proposé, sur la base des données isotopiques du collagène osseux, une alimentation protéique plus mixte, incluant une part significative de protéines animales. Les résultats actuels confirment une contribution plus équitable et diversifiée, à la fois des ressources animales et végétales, confortant les premières interprétations isotopiques (Fig. 6, modèle A). Le modèle établi à partir des chiens suggère quant à lui un rôle plus important des légumineuses et des animaux sauvages dans leur alimentation (Fig. 6, modèle A). Les résultats sur les chiens sont importants à prendre en considération sachant que certains auteurs (e.g. Cannon et al., 1999) ont proposé d'utiliser leurs données isotopiques pour discuter l'alimentation humaine, lorsque peu, voire aucun reste anthropologique n'est disponible. Comme observé par cette proposition de modélisation et synthétisé dans d'autres articles (e.g. Goude et Fontugne, 2016), l'alimentation canine, du moins pour le Néolithique moyen du sud de la France, n'est pas un indicateur très précis de l'alimentation humaine, mais peut indiquer de grandes tendances (e.g. marin vs. terrestre). Pour l'ensemble des trois groupes les céréales semblent avoir une contribution moins importante par rapport aux légumineuses et aux ressources animales. Lorsque l'ensemble des végétaux est pris en compte, le première groupe auraient pu avoir consommé plus particulièrement des ressources végétales sauvages telles que le gland alors que les modèles pour les deux autres groupes indiquent un apport plus ou moins équivalent des différentes plantes cultivées ou sauvages (Fig. 6, modèle B). Ces nouvelles données renforcent les hypothèses précédemment émises : (1) sur la particularité de quelques individus du Crès et du Pirou (dont les $\delta^{15}N$ mesurés dans le collagène osseux sont parmi les plus bas enregistrés dans les sites néolithiques en France ; Goude et Fontugne, 2016), qui pourraient être plus impliqués dans des activités spécialisées en lien avec le traitement des végétaux (*sensus lato*), comme en témoigne le mobilier de mouture présent dans certaines des sépultures du Crès (Loison et al., 2004) ; (2) sur les ressources consommées par les chiens domestiques retrouvés dans les fosses sépulcrales, qui pourraient principalement provenir des refus alimentaires humains.

Conclusion

Les résultats de cette étude exploratoire montrent que les données isotopiques issues des restes carpologiques permettent de revoir les interprétations paléoalimentaires relatives aux premiers agropasteurs du Néolithique dans le sud de la France, en réévaluant la contribution des végétaux dans l'apport protéique. Les données permettent notamment de discuter de la place de certaines ressources sauvages dans l'alimentation, en particulier les glands, dont le signal isotopique peut parfois se confondre avec celui des plantes fixatrices d'azote, comme les légumineuses.

Il est toutefois nécessaire de considérer que les interprétations proposées sur la base de ces modèles sont uniquement relatives aux ressources que nous avons pu intégrer dans ces derniers et ne doivent pas minimiser le rôle d'autres aliments non pris en compte, comme les ressources aquatiques ou d'autres ressources sauvages, végétales ou animales, non identifiées sur les sites archéologiques. De plus, l'utilisation des données archéobotaniques reste exploratoire et l'interprétation des résultats obtenus est soumise à plusieurs biais. En effet, les analyses isotopiques ont été réalisées sur une sélection parmi les restes carpologiques disponibles, qui est probablement encore loin de fournir une image complète de la variabilité des signaux isotopiques pour l'ensemble des plantes consommées par les néolithiques du sud de la France. Les études carpologiques sur le Néolithique sont encore déficitaires dans la région et peu de grandes séries carpologiques sont disponibles. Certaines, issues de fouilles anciennes, sont difficilement exploitables. Les valeurs isotopiques sur les graines et les fruits dont nous disposons à l'issue de ce travail ne couvrent pas la totalité des plantes alimentaires attestées sur les sites. Elles sont issues de phases chrono culturelles, de situations géographiques et de conditions écologiques et paléo-climatiques variées et l'influence de ces divers paramètres doit encore être mieux appréhendée. En outre, en un site donné, les pratiques agricoles (e.g. choix des terres cultivées, fertilisation) influent sur le signal isotopique pour les espèces cultivées. Il est donc nécessaire d'aborder en amont les divers facteurs (e.g. apport en eau, fertilisation) pouvant influencer les signaux isotopiques mesurés sur les restes carpologiques pour approfondir l'interprétation des données sur l'alimentation humaine émises par la modélisation. Cette étude souligne également le besoin d'augmenter le corpus, en termes de nombre d'échantillons et de travailler à l'échelle locale. Cette approche est difficile à l'heure actuelle, car plusieurs des sites sur lesquels ont été découverts les restes humains n'ont pas fait l'objet d'étude carpologique, ou n'ont pas livré de graines et fruits. Il faut alors rechercher des carporestes provenant de contextes contemporains à ceux des ossements humains ou animaux afin de limiter l'impact environnemental, mais également de prendre en compte les pratiques humaines pouvant exister au niveau du site.

Enfin, cette étude propose, pour la première fois en Méditerranée occidentale, un corpus de données isotopiques sur des végétaux issus des récoltes et des cueillettes des premiers agropasteurs installés dans la région. Ces données isotopiques ouvrent la perspective d'une nouvelle approche permettant de mieux caractériser les pratiques agricoles néolithiques, par ailleurs fort mal connues dans cette zone géographique. Les premiers résultats laissent penser que les cultures étaient régulièrement fertilisées, ce qui confirme des résultats isotopiques et carpologiques obtenus ailleurs en Europe (Aguilera et al., 2018; Alagich et al., 2018; Bogaard et al., 2013; Styring et al., 2017). Dans un second temps, ces données isotopiques sur le végétal permettent de rééquilibrer les contributions relatives entre plantes et animaux dans l'alimentation humaine. Cette nouvelle documentation prend un intérêt particulier pour les premières sociétés agropastorales, pour lesquelles beaucoup de questions restent encore en suspens en Méditerranée. La diversité des ressources consommées et l'apport des ressources marines fait partie de ces questions. Ces dernières ont été mises en évidence sur plusieurs sites côtiers du sud de la France et en Ligurie grâce à des études ichtyologiques et malacologiques (e.g. Desse et Desse-Berset), ou encore grâce à l'analyse des résidus de poterie (Craig et al., 2013). Il est également, possible de retrouver des témoignages de consommation de poisson par l'étude des micro-restes du tarte dentaire (Cristiani et al., 2018). Toutefois, les premières investigations menées dans le sud-est de la France à partir de ces deux approches n'ont pas encore révélées de consommation claire de ressources aquatiques (marine ou d'eau douce). Si le développement de nouvelles méthodes, comme l'analyse des microrestes contenus dans le tartre dentaire (R. Power dans Goude et al. 2019; 2020) ou encore l'analyse des phytolithes des couches archéologiques (Delhon et al., 2019), contribuent à mettre en lumière la diversité des plantes ayant pu être consommées, les données isotopiques des carporestes peuvent offrir des informations de tout premier ordre sur les conditions environnementales et techniques dans lesquelles ces plantes ont été produites, informations indispensables pour interpréter les données isotopiques humaines.

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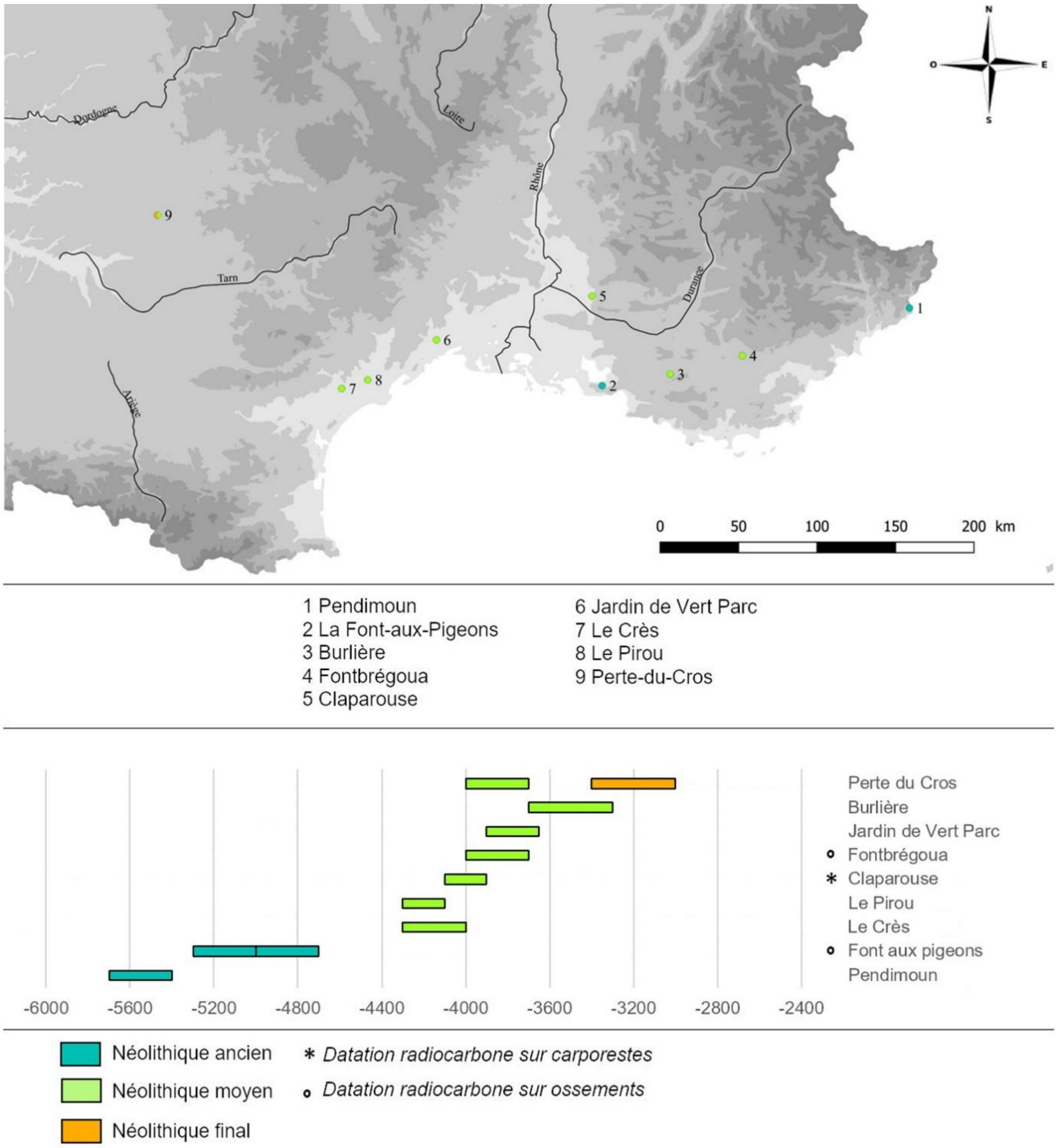


Figure 1 : Localisation et datation des sites archéologiques
Figure 1: Localisation and dating of archaeological sites

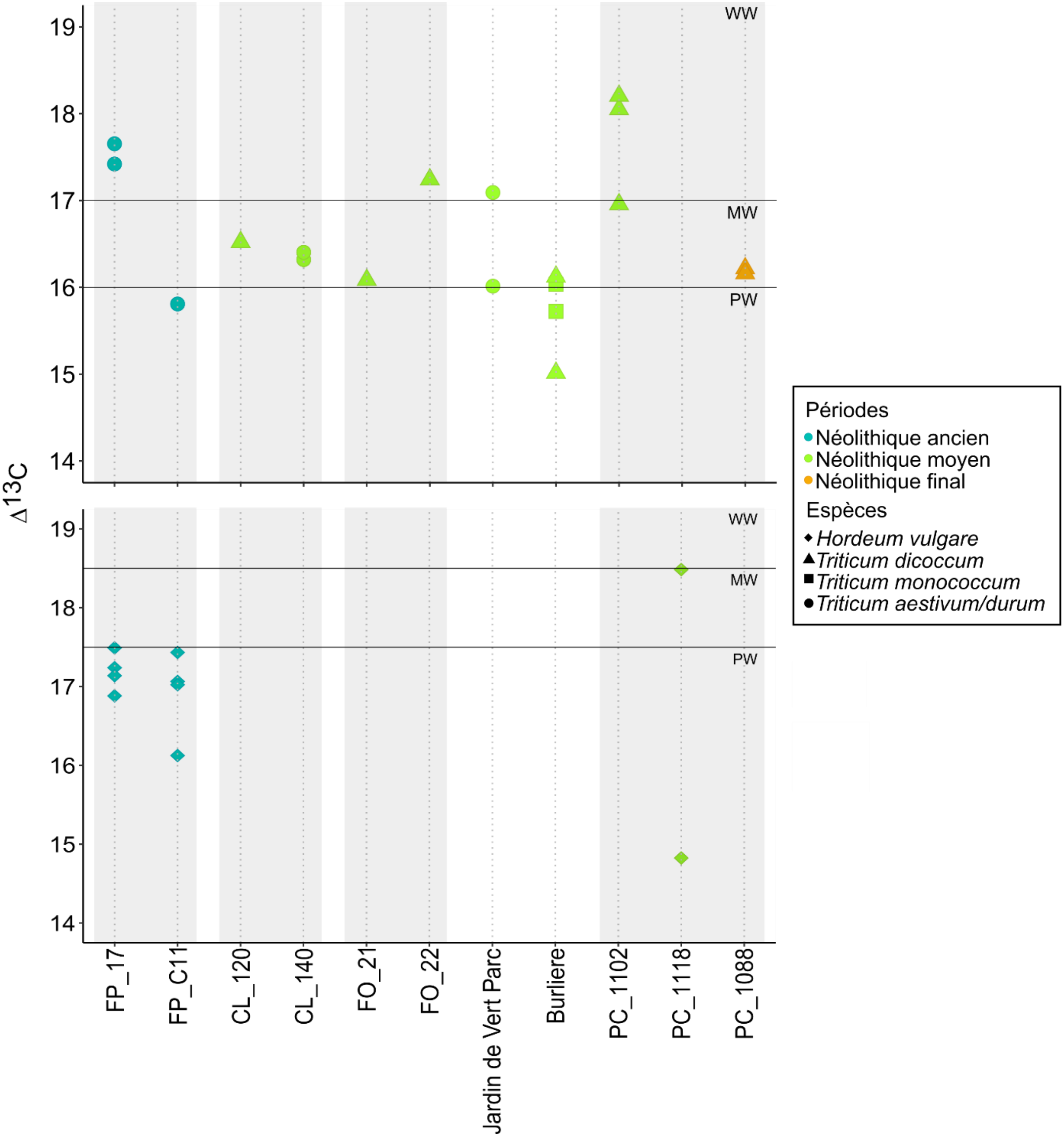


Figure 2 : Valeurs isotopiques de $\Delta^{13}C$ et disponibilité en eau. (WW): Bon apport en eau. (MW): apport en eau modéré. (PW): apport en eau insuffisant ou faible. 1: La Font aux Pigeons; 2: Claparouse; 3: Fontbrégoua; 4: La Perte du Cros.

Figure 2: Isotopic values of $\Delta^{13}C$ and water availability. (WW): well-watered. (MW): moderately watered. (PW): poorly watered. 1: La Font aux Pigeons; 2: Claparouse; 3: Fontbrégoua; 4: La Perte du Cros.

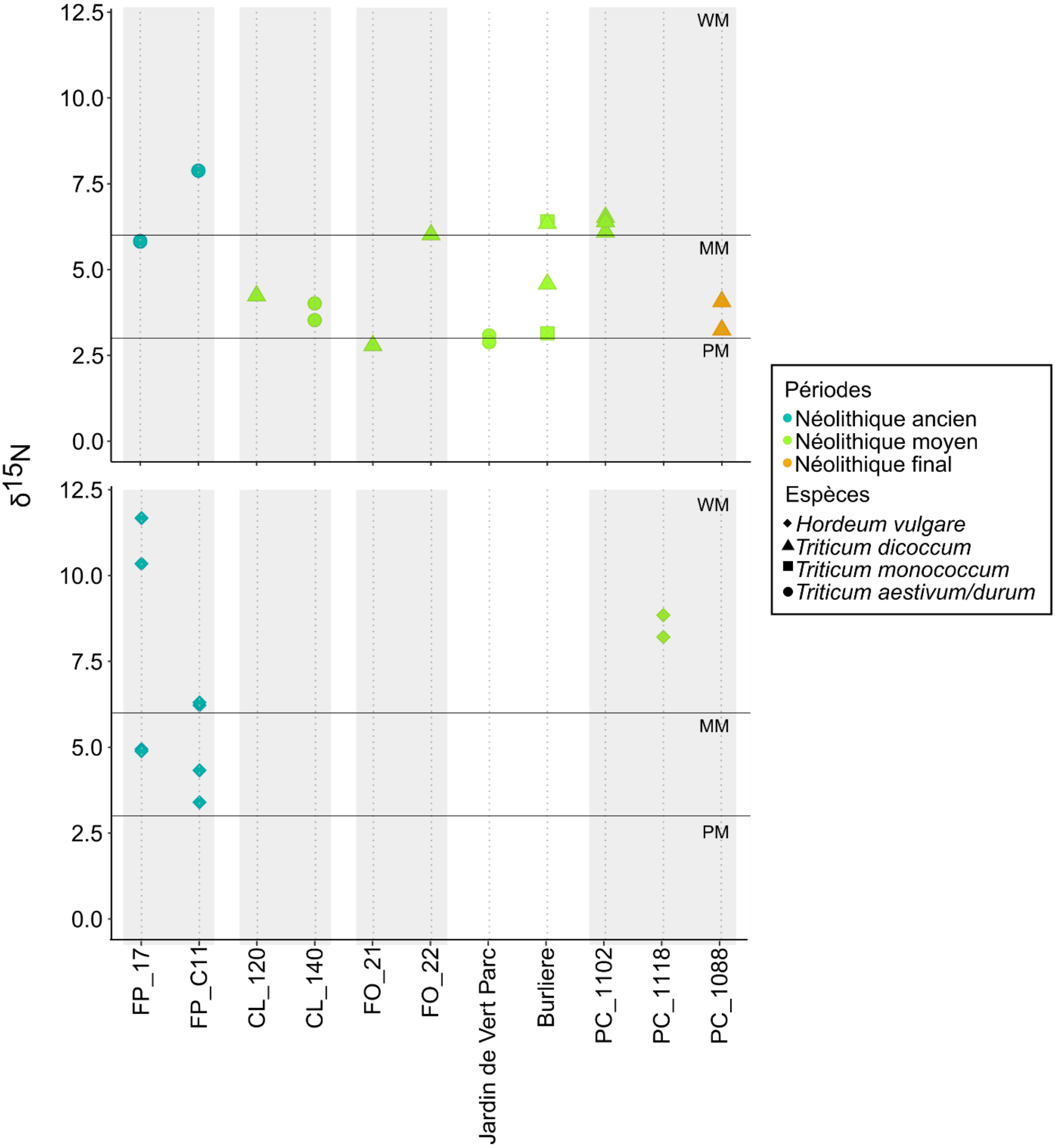


Figure 3 : Valeurs isotopiques de $\delta^{15}N$ et seuils de fertilité. (WM): fertilisation importante. (MM): fertilisation modérée. (PM): faible fertilisation. 1: La Font aux Pigeons; 2: Claparouse; 3: Fontbrégoua; 4: La Perte du Cros.

Figure 3: Isotopic values of $\delta^{15}N$ and manuring. (WM): well manured. (MM): moderately manured. (PM): poorly manured. 1: La Font aux Pigeons; 2: Claparouse; 3: Fontbrégoua; 4: La Perte du Cros.

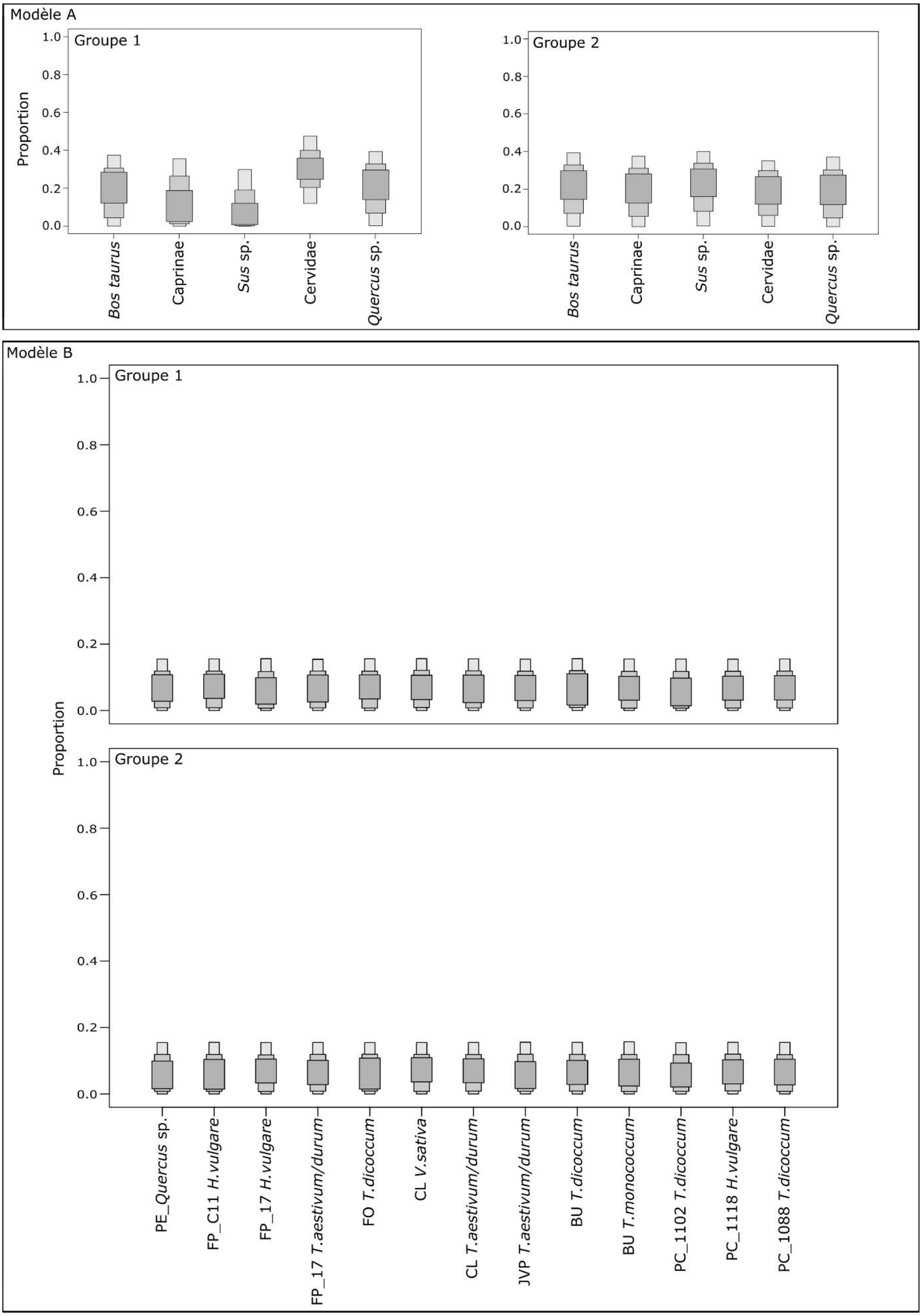

Modèle A
Groupe 1
Proportion
1.0
0.8
0.6
0.4
0.2
0.0
Bos taurus
Caprinae
Sus sp.
Cervidae
Quercus sp.
Groupe 2
1.0
0.8
0.6
0.4
0.2
0.0
Bos taurus
Caprinae
Sus sp.
Cervidae
Quercus sp.
Modèle B
Groupe 1
Proportion
1.0
0.8
0.6
0.4
0.2
0.0
Groupe 2
1.0
0.8
0.6
0.4
0.2
0.0
PE_Quercus sp.
FP_C11 H.vulgare
FP_17 H.vulgare
FP_17 T.aestivum/durum
FO T.dicoccum
CL V.sativa
CL T.aestivum/durum
JVP T.aestivum/durum
BU T.dicoccum
BU T.monococcum
PC_1102 T.dicoccum
PC_1118 H.vulgare
PC_1088 T.dicoccum

Figure 4: Modélisation alimentaire pour les individus de Pendimoun et du Rastel (Cardial-VBQ). Modèle A : valeurs pour la viande et les végétaux locaux. Modèle B : valeurs pour les végétaux du Néolithique (ancien et moyen) du sud de la France. Groupe 1 : femme F1 et 3 hommes (Le Bras-Goude., 2006a et b) ; Groupe 2 : femme F2 de Pendimoun.
Figure 4: A: Food modelling for the individuals of Pendimoun and of the Rastel (Cardial-VBQ). Model A: values for local meat and botanical remains. Model B: values for botanical remains from Neolithic (Early and Middle) of southern France. Group 1: women F1 and 3 men (Le Bras-Goude., 2006a et b); Group 2: woman F2 from Pendimoun.

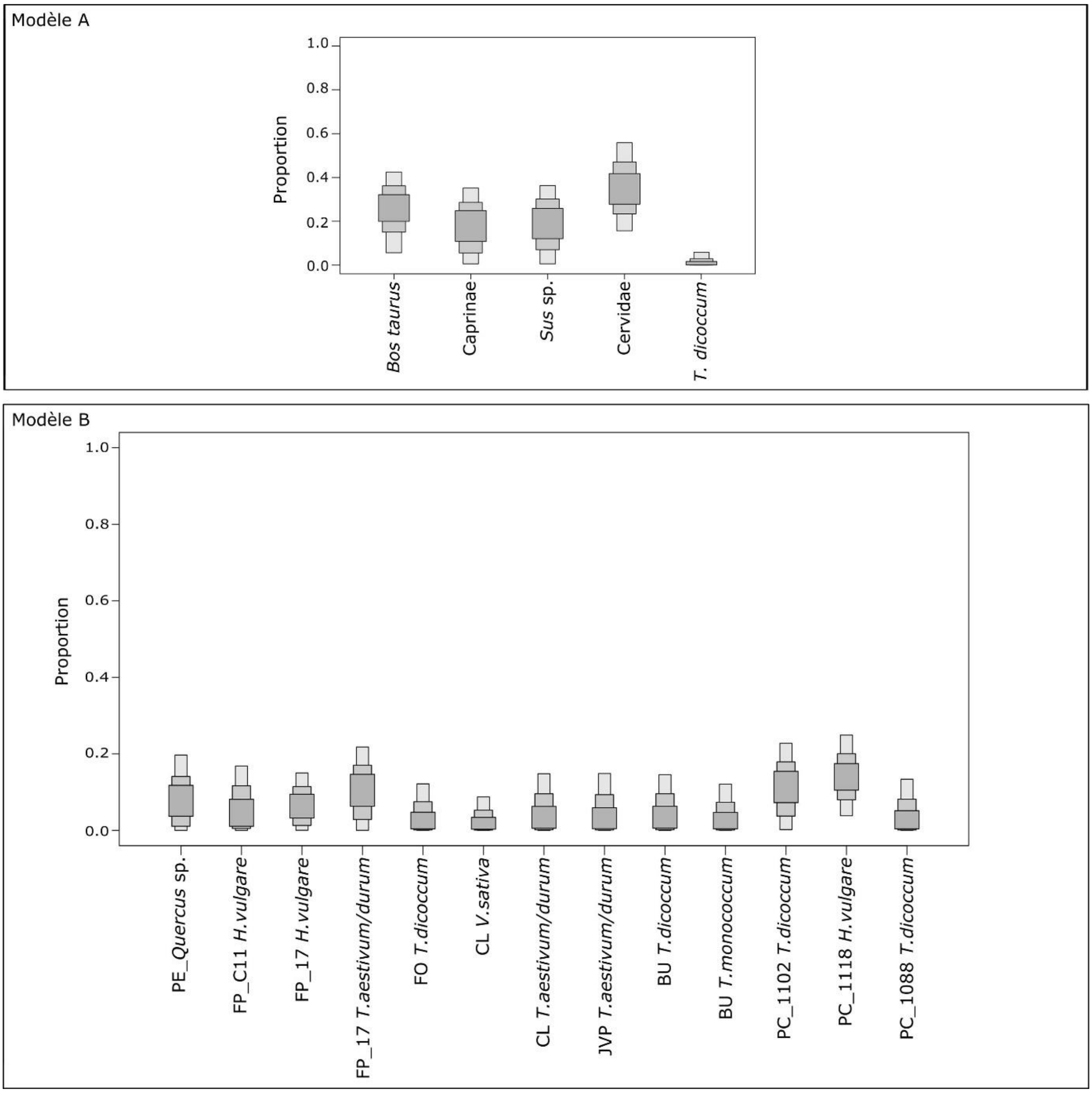
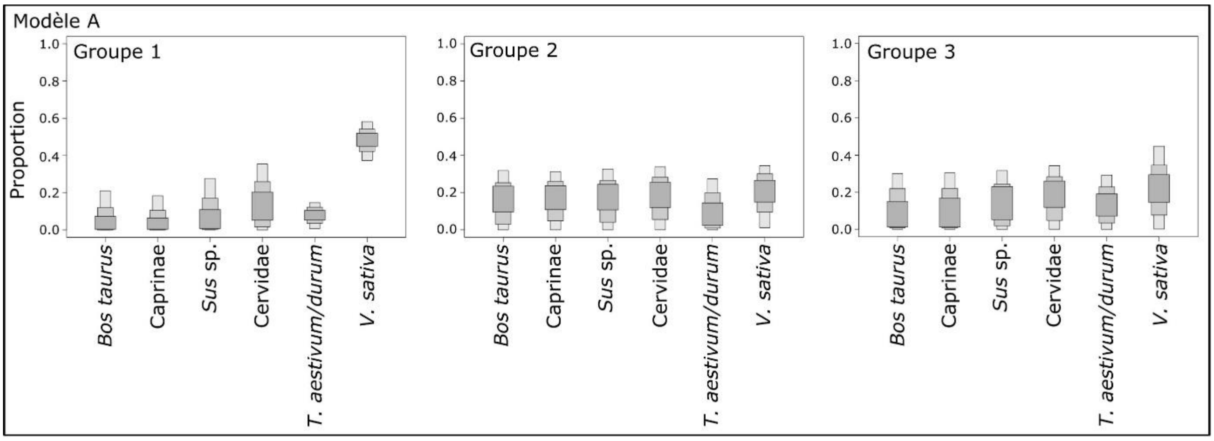


Figure 5 : Modélisation alimentaire pour les individus de Fontbrégoua (transition Néolithique ancien et moyen). Modèle A : valeurs pour la viande et les végétaux locaux. Modèle B : valeurs pour les végétaux du Néolithique (ancien et moyen) du sud de la France ; Groupe 1 : tous les sujets humains (Goude et al., 2010).

Figure 5: A: Food modelling for the individuals of Fontbrégoua (transition between the Early and the middle Neolithic). Model A: values for local meat and botanical remains. Model B: values for botanical remains from Neolithic (Early and Middle) of southern France. Group 1 : all humans (Goude et al., 2010).


Modèle A
Groupe 1
Groupe 2
Groupe 3
Proportion
1.0
0.8
0.6
0.4
0.2
0.0
Bos taurus
Caprinae
Sus sp.
Cervidae
T. aestivum/durum
V. sativa

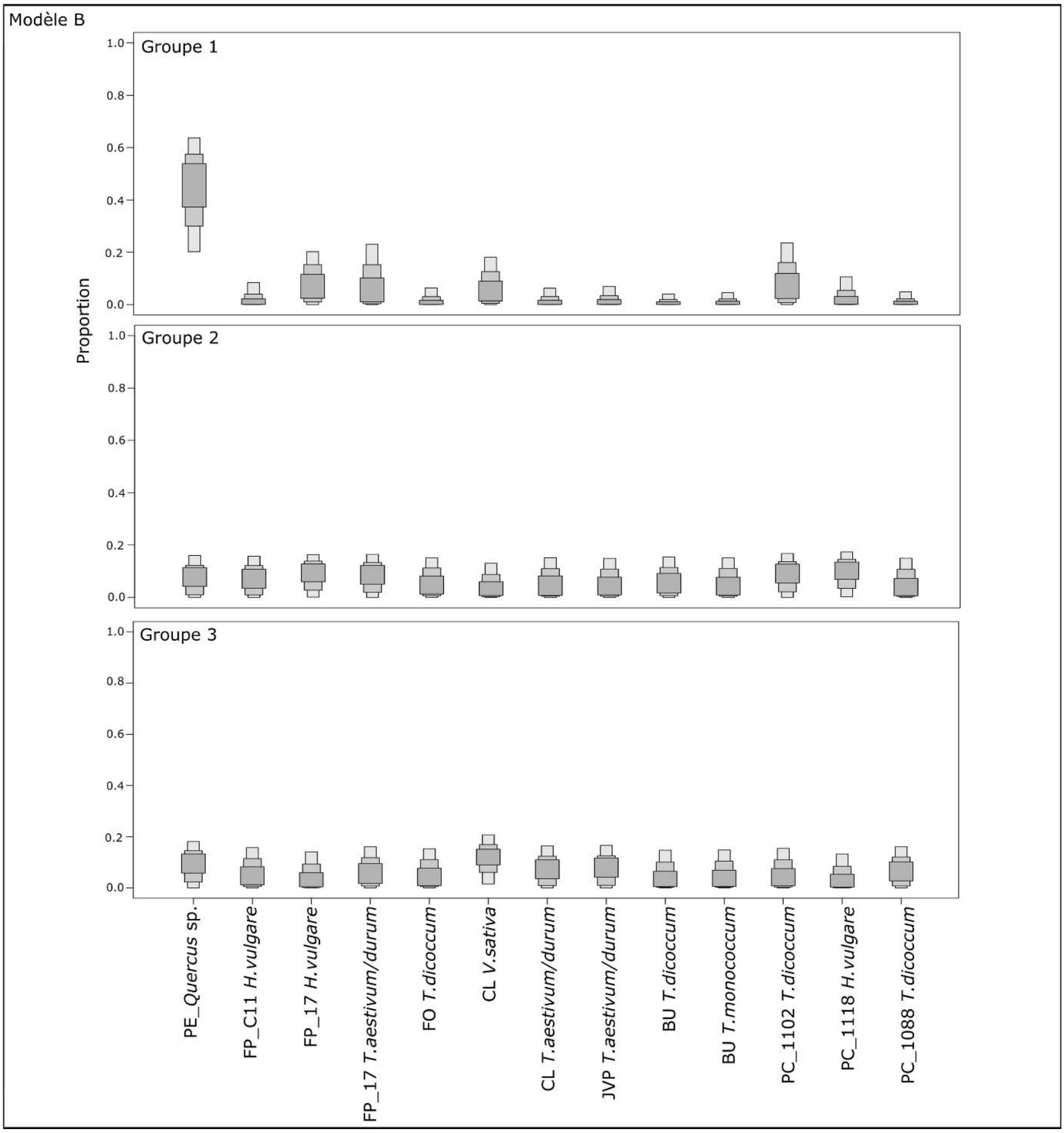

Modèle B
Groupe 1
Groupe 2
Groupe 3
Proportion
1.0
0.8
0.6
0.4
0.2
0.0
PE_*Quercus* sp.
FP_C11 *H.vulgare*
FP_17 *H.vulgare*
FP_17 *T.aestivum/durum*
FO *T.dicoccum*
CL *V.sativa*
CL *T.aestivum/durum*
JVP *T.aestivum/durum*
BU *T.dicoccum*
BU *T.monococcum*
PC_1102 *T.dicoccum*
PC_1118 *H.vulgare*
PC_1088 *T.dicoccum*

Figure 6: Modélisation alimentaire pour les individus du Crès et du Pirou (Chasséen). Modèle A : valeurs pour la viande et les végétaux locaux, incluant les données sur la vesce de Claparouse suite contenues des hypothèses formulaient par Le Bras-Goude et al., 2019. Modèle B : valeurs pour les végétaux du Néolithique (ancien et moyen) du sud de la France. Groupe 1 : autres sujets du Crès et groupe B du Pirou ; Groupe 2 : sépulture 10b du Crès et sujets groupe A du Pirou (Gleize et al., 2019). Groupe 3 : chiens du Pirou.
Figure 6: Food modelling for the individuals of Le Crès and Le Pirou (Chassean). Model A: values for local meat and botanical remains including legumes from Claparouse considering initial hypothesis proposed by Le Bras-Goude et al., 2019. Model B: values for botanical remains from Neolithic (Early and Middle) of southern France. Group 1: others humans from Le Crès and from Le Pirou group; Group 2: burial 10b from Le Crès and humans from the group A of Le Pirou (Gleize et al., 2019). Group 3: dogs from Le Pirou.