Feeding the City: A comparative study of agricultural production in Bronze Age systems of Western Asia

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Abstract

The development of large urban societies in Western Asia during the Bronze Age has often been viewed as a pivotal transition in human history. As part of this narrative, however, agriculture and the nature of food production have frequently been relegated to the rural hinterland and divorced from daily life in the city. This research aims to explore the relationship between established early cities and the specific systems of agricultural production needed to sustain them, by assessing the nature of farming practice at two key Bronze Age sites. These two sites, Hattusha in Central Anatolia and Tell Brak in north-eastern Syria, were both major urban centres with large socially stratified populations and control of widespread hinterlands. Additionally, they provide data from two climatic and environmental zones, as well as two different cultural settings, providing the opportunity to investigate the nature of agriculture under a range of variable conditions.

The archaeobotanical analysis of stored charred macro-remains assemblages from both sites has provided the opportunity to explore the relationship between crop choice, farming regime and urban society. Compositional, spatial and crop processing analysis has provided information regarding the origins of the material, as well as allowing the assessment of activities and depositional processes that may have formed the assemblages. Furthermore, the analysis of crop stable carbon and nitrogen isotopes combined with the functional ecology of arable weeds has allowed the identification of multiple crop management systems designed by each society. These results have

revealed that both cities were reliant on low-input, low variance farming systems, but that within these systems a high level of agricultural variation was present. At Hattusha, correspondence analysis and crop stable isotope analysis have indicated that stored cereals were grown under a range of crop husbandry regimes. This included low-intensity systems characterized by low inputs of water and medium-low inputs of manure, and higher-intensity systems characterized by medium inputs of water and high inputs of manure. The existence of stored cereals grown under multiple regimes may suggest that the inhabitants of Hattusha were pooling resources from different areas within the wider rural hinterland. By contrast, crop stable isotope analysis and functional ecology analysis from Tell Brak have suggested that different species of cultivar were likely to have been grown in different areas of the landscape to maximise the potential arable yield of marginal environmental conditions. Overall, farming within both of these societies appears to have been a dynamic system that was adapted to overcome specific environmental and social challenges whilst also performing a key role in sustaining and supporting the urban population.

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Chapter 1

Introduction

1.1 Bronze Age urbanism in western Asia and the state of research

The development of large, socially stratified 'urban' settlements in Central Anatolia and the Near East during the Bronze Age (c. 3000-1000 cal. BC) has often been seen as a pivotal transition in human history. This period saw major changes in terms of social organization, the construction of monumental architecture and the formation of new urban landscapes, signalling a decisive break with earlier periods (Postgate, 1992; Smith, 2003; Yoffee, 2004; Taylor, 2012). As part of this view, much archaeological research has fallen within "standard narratives of elite control" (Gallagher & McIntosh, 2015) concerned only with material culture, building construction, settlement organization and the power derived from controlling the agricultural economy and associated produce (e.g. Childe, 1950; Wittfogel, 1957). Within these archaeological narratives, agriculture is rarely described as a dynamic, flexible system. Rather, the rise of the city has been used to signify the end of the 'agricultural origins' story, as farming was finally divorced from city life and relegated to the rural hinterland (Smith, 2003). This division between 'urban' and 'rural' or the city and its hinterland was informed by a new, modernist understanding of urban life that saw the city as an essentialist reality, separate from smaller farming communities living in the countryside (Barthel & Isendahl, 2013). This view had developed within the Chicago School of urban sociology in the 1920s-30s (Wirth, 1938) and led to the

creation of narrow expectations of what should be found historically within each of these separate zones. This view also delineated the anticipated social interactions between city dwellers, farmers and agricultural land, dividing these relationships along lines of social and economic power (McIntosh, 1999).

This disconnect between agriculture and the city and between agricultural producers and specialist non-producers has, however, failed to address how large urban areas were able to supply the large quantities of produce needed to feed highly nucleated populations, including specialist and bureaucratic non-producers. Similarly, this view also fails to explain how cities were able to maintain their urban populations, in some cases for thousands of years, through periods of shifting climatic change, periodic harvest failure and episodes of inter-society conflict (e.g. Childe, 1950; Bryce, 2002; Hamblin, 2006; Kaniewski *et al*. 2010). Recent studies, however, have sought to redress the division between rural versus urban life (Sinclair, 2010; Gallagher & McIntosh, 2015) by arguing that the 'hinterland' is a key part of the definition of the city. Certainly, it was the exploitation of the land surrounding the urban area that allowed the city to function as a sustainable entity (Fischer & Herschend, 2010). Moreover, the potential flow of organic nutrients and waste produced by a concentrated population may also have increased the productivity of that land if it was used as a manure source (Ljungkvist *et al.* 2010).

1.2 The development of agricultural systems

This research project seeks to clarify the relationship between established early cities, the specific systems of agricultural production needed to sustain them and the relationship between the city and the rural hinterland. This will be achieved by

assessing the nature of farming practice at two major Bronze Age cities, Boğazköy-Hattusha (hereafter Hattusha) in Central Anatolia and Tell Brak in northern Mesopotamia. Recent archaeobotanical research into Neolithic farming has shown that village communities throughout Europe and western Asia were often established around the small-scale, intensive management of domesticated crops and livestock (e.g. Halstead, 1989; Bogaard, 2005). Intensive agricultural management here refers to the use of farming methods that required high labour inputs to increase crop yields per unit of land under cultivation. These methods may have included hand-weeding, hoeing, the application of manure to increase soil fertility and the use of artificial watering systems (Bogaard, 2004; 2005). Additionally, these mixed systems were arranged around the domestic mode of production (DMP) and would have involved the cultivation of a wide range of domesticated crops alongside the use of strategic wild plant sources (e.g. Bakels, 1991; Hansen, 1992; Valamoti, 2004; Bakels & Zeiler, 2005). A range of domesticated animals would also have been kept as a multi-purpose source of meat, wool, milk and low-level traction (e.g. Halstead, 1995a; 1996; Evershed *et al.* 2008; Isaakidou, 2008).

By contrast the development and maintenance of Bronze Age cities may have involved varying degrees of 'extensification' alongside the mobilization of surplus from small-scale domestic farmers in order to generate the amount of food necessary to feed a large urban population of non-producers. Certainly during the periods covered by this thesis, the cities of Hattusha and Tell Brak enclosed areas in excess of 70 hectares (Seeher, 2000a; Bryce, 2002: 12; Ur, 2010) with large populations of c. 20,000-25,000 inhabitants requiring the generation and mobilization of significant quantities of food. In this respect, land-intensive or 'extensive' agriculture is thought to have seen a dramatic increase in the amount of land that was being farmed, involving the large-scale

cultivation of arable estates using labour-saving techniques such as broadcast sowing, the use of specialist plough oxen to prepare the soil for planting, and the use of fallowing as a form of weed control (e.g. Postgate, 1992; Halstead, 1995a; Yakar, 2000; Styring *et al*. 2017). Unlike intensive, mixed systems, 'extensive' farming would also have specialised in the cultivation of cereal crops, as these species can produce regular yields under marginal conditions and with relatively small labour inputs (Halstead, 1999). The relationship and transition between intensive and less intensive ('extensive') farming, however, is not fully understood. Different accounts highlight the relative importance of small-scale surpluses produced by the domestic household, sharecropping arrangements between farmers and land-owners and large-scale production on wide-ranging estates (e.g. Sherratt, 1981; Halstead, 1989; Yakar, 2000). This project will investigate the nature of urban agricultural regimes and the extent to which Bronze Age cities relied on a combination of more intensive 'infield' crop production located near the city and more extensive 'outfield' production within the sites environs, for their sustainability and development.

1.3 Urban resilience and coping with risk

Key to the understanding of these established urban agricultural regimes are the dual themes of risk and 'urban resilience' (e.g. Holling, 1973; 1986; Adams, 1978; Barthel & Isendahl, 2003; Redman & Kinzig, 2003). Risk is here defined as a probabilistic variance (Bedford & Cooke, 2001) reflecting the chance that the real return on a specific investment might in reality be very different from the predicted return. Closely linked to this is the concept of 'uncertainty' referring to unplanned possibilities or situations where not all the information is known and the range of outcomes cannot

be predicted (Marston, 2011). In terms of agricultural production, risk is associated primarily with food loss or total subsistence failure. This risk can become even more pronounced in an urban environment due to the number of people who do not contribute directly to the agricultural economy. This means that the ability of the city and its population to survive ecological and subsistence-based disasters must necessarily be higher than that of the rural village. The inhabitants of many Bronze Age cities, especially those located in marginal environments reliant on rain-fed agricultural systems may have been under constant ecological stress to produce enough food yearly, whilst maintaining a stored surplus in case of drought or poor harvests. In these cases the relationship between risk management and adequate provisions may have been delicately balanced. These farming regimes, therefore, would be expected to favour low variance returns that aim to minimize subsistence failure but also tend to operate at a fraction of the system's total agricultural potential (Smith, 2011). This may include the use of 'extensive' farming regimes involved in the large-scale cultivation of arable land but with low labour inputs per hectare cultivated.

Closely related to risk, the concept of resilience refers to the capacity of a socio-ecological system to absorb shocks whilst maintaining the same state and then to continue developing afterwards (e.g. Carpenter & Gunderson, 2001; Holling & Gunderson, 2002; Walker *et al*. 2004; Barthel & Isendahl, 2013). As part of this concept, it is understood that variability, disturbance and unpredictability are not the exceptions to the ecosystem but are rather underlying rules that must be overcome (Cote, 2011). In terms of agricultural production, urban resilience refers to the ability of the urban population to cope with multiple mass harvest failures without completely collapsing. Strategies such as agricultural diversification are adopted, therefore, to combat the threat of poor harvests and total subsistence disintegration. Marston (2011)

has identified three categories of agricultural diversification which could have been incorporated into an urban farming system: crop diversification, spatial diversification and temporal diversification. Crop diversification involves the cultivation of multiple domesticated crop species possibly within the same field, crop rotation and the supplementation of crops with managed horticultural products, gathered wild foods and animal products. Spatial diversification includes the dispersion of fields within a wide agricultural zone as a means of utilizing a range of microenvironments, field fragmentation amongst a community of farmers, sharecropping and the long-distance trade of food items between climatically distinct regions. Finally, temporal diversification consists of multiple planting and/or harvesting times, as well as the use of long-term and short-term storage systems. In this capacity storage is thought of as a buffering mechanism which can be considered alongside food sharing as a risk-reduction strategy (Winterhalder, 1990). Together, all of these diversification strategies may reduce the overall efficiency of agricultural production, but will minimize the risk of total subsistence failure ensuring the survival of the urban population through periods of crisis. The concept of urban resilience, however, also relies on the development of socio-ecological memory (Barthel *et al.* 2010). Within a city, the impact of the local climate and environment combined with the memory of past subsistence failures will have led to the development of specific agricultural strategies as a means of coping with 'food shocks'. It is expected, therefore, that the degree to which agriculture appears 'extensive' and/or the extent to which farming regimes are diversified, will be different for each specific Bronze Age society and/or Bronze Age city.

1.4 Spheres of Production

The concept of urban resilience can manifest itself in multiple ways as each urban area is likely to develop its own diversification mechanisms to avoid and/or overcome subsistence failure. One commonly shared mechanism, however, is the creation of different, diverse spheres of production which can operate independently of each other (cf. Polanyi, 1957; Urry, 1981; Smith, 2004). Each individual sphere of production can be controlled by a different portion of society and can also be separated from each other geographically as well as administratively. In this respect, one sphere of production could be the domestic household cultivating relatively small portions of land either within a rural village or surrounding the city itself. A second sphere could be the cultivation of crown-owned lands or large arable estates owned by the temple. This land may have been worked primarily by slaves or serfs and the produce used for rations. Both of these spheres of production would have been able to operate independently of each other and on different scales, yet could also overlap when produce from both is stored collectively for the benefit of the state. For example, in ancient Mayan cities small plots of domestic farmland would often be integrated throughout the city, alongside the cultivation of larger agricultural areas outside of the city walls (Sanders *et al.* 2003). At the Classic period city of Xuch in the Puuc region on the Yucatan peninsula (c. 250 – 900 AD), city inhabitants produced food in urban farmstead gardens, managed orchards, and cultivated crops in large-scale infield and outfield areas. In this system, urban farmsteads were managed solely by urban farmers and were used to grow a variety of foods primarily for the individual household. By contrast, outfield cultivation was controlled by city elites and managed by a bureaucracy as part of the taxation system (Barthel & Isendahl, 2013). After the collapse of some portions of Mayan society in the 9th century AD, outfield cultivation was abandoned due to its

unsustainability and a reduction in the agricultural labour force, but small-scale farming did continue in the urban farmsteads, and it was this domestic sphere of production that proved the resilient key to subsistence security within this society.

In a similar manner, Medieval Constantinople (c. 565 – 1025 AD) relied both on the importation of staple foods and the local cultivation of crops. Early on in the history of the city, large amounts of cereal grain were imported from the Nile valley to feed its inhabitants. Only some of this grain was distributed for immediate consumption, however, and much was stored in large granaries as a buffer against years of poor harvest (Ljungkvist *et al.* 2010; Barthel & Isendahl, 2013). Crops were also grown locally, in a production zone thought to have been 2km in diameter outside of the city walls of Constantinople. Documentary evidence shows that monasteries and city elites were the owners of most of this land, but in practice it was rented out to and farmed by urban smallholders. By diversifying the origins of their staple foods, the inhabitants of Constantinople were able to protect themselves against the harvest failures that had plagued Anatolia and Egypt, as well as storing a surplus for times of complete subsistence crisis. Both of these examples of the ancient Maya and Constantinople suggest that the most effective means of combating risk and maintaining a high level of urban resilience is through the use of agricultural diversification mechanisms. Archaeologically these mechanisms have been identified through physical evidence such as architecture, documentary evidence and also through the use of ethnographic analogy. In each of these cases, however, direct evidence of what was being grown, how it was being grown and the social context in which farming was being practiced, is severely lacking. By investigating each of these themes this project hopes to shed light on the relationship between the city, agricultural production and why certain farming regimes were implemented in these urban areas.

1.5 Research hypothesis, aims and objectives

The central hypothesis to be investigated in this project is that large urban areas were reliant on a range of agricultural regimes, involving varying degrees of 'extensification' and diversification, for their sustainability. These regimes are likely to have been highly diverse and may have involved the production of certain stress-tolerant crops within 'outfield' areas, combined with the 'infield' cultivation of a wide range of domesticated cultivars. The assessment of this hypothesis will involve a number of aims:

- To investigate the nature of crop production at two well-established Bronze Age cities in Central Anatolia and northern Mesopotamia
- To assess how diverse management practices may have affected social organization within both the city and smaller rural communities
- To use the dual themes of risk and urban resilience as approaches to agricultural regime choice
- To use innovative methods to interpret key archaeobotanical assemblages

These aims will be achieved by carrying out a comparative analysis of the ecological and social implications of farming practice at the Bronze Age sites of Hattusha in Central Turkey and Tell Brak in north-eastern Syria (see **Figures 1.1** and **2**)[1] The choice of these two sites was based on a number of factors including: the spectacular nature of their archaeobotanical assemblages, their locations within marginal or challenging environments for arable farming and their status as large urban centres. During the period covered by this project, these cities had fully emerged as major urban centres

[1] Access to archaeobotanical material from these sites has been made available through the ERC-funded AGRICURB project led by Amy Bogaard at the University of Oxford and the kind assistance of Reinder Neef and Jürgen Seeher from the Deutsches Archäologisches Institut (Hattusha) and from Michael Charles at the University of Oxford and Geoff Emberling at the University of Michigan (Tell Brak).

Figure 1.1 – Map showing the locations of Hattusha and Tell Brak in Western Asia.

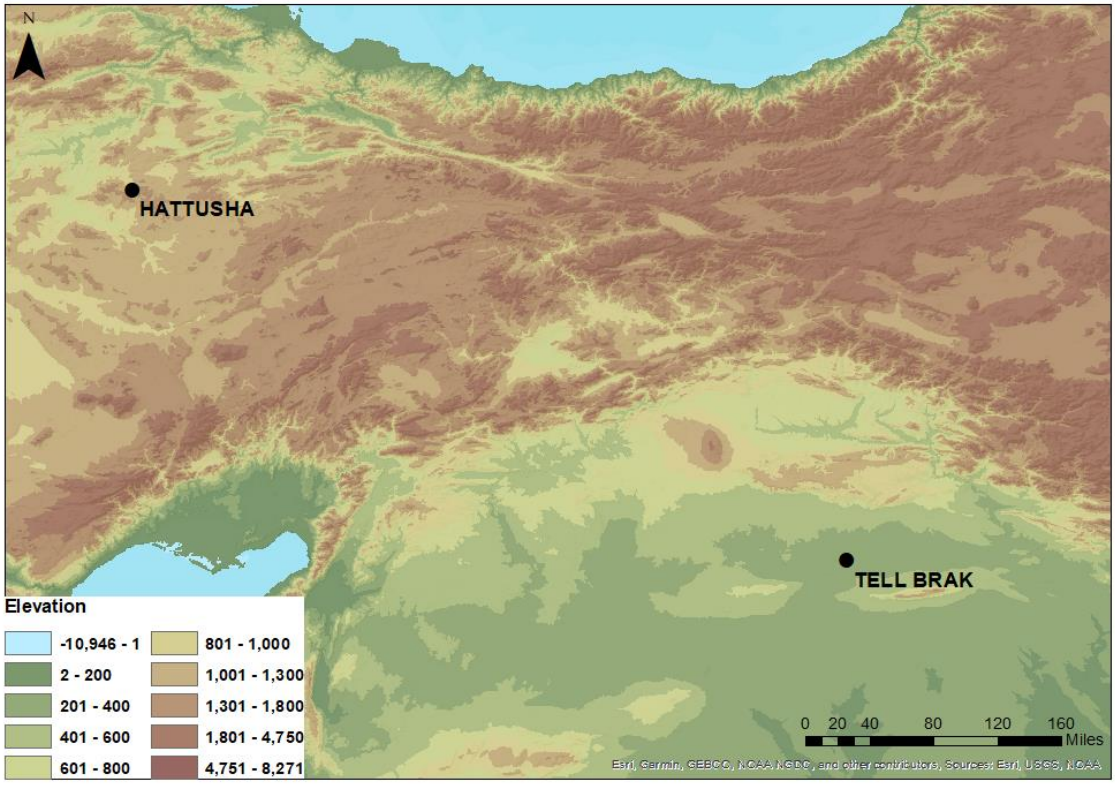


Figure 1.2 – Topographical map showing the elevation and terrain of Hattusha and Tell Brak in Western Asia

defined by large socially stratified populations, an appreciable division of labour between food producers, artisans and bureaucrats (Scott, 2017), well established urban architecture and control over a widespread hinterland. This project will, therefore, focus on the maintenance of the city within these different regions, rather than the initial emergence and development of these urban areas (see **Chapter 2** for detailed chronologies of these sites). Additionally, these sites provide data from a range of climate and environmental zones, as well as different cultural settings within western Asia. The archaeobotanical material that will be analysed as part of this project has been recovered from one specific area and/or context of the city (these areas will be discussed in detail in **Chapter 2**). This will allow a focus on one particular chronological phase of each city which can then be compared with results from other periods, other areas of the same site and other sites from the same geographical region. Direct comparisons between the two sites, however, will be limited due to the fundamental differences between the periods and societies they represent. Instead, it is intended that these two case studies will be used to comment on the nature of Bronze Age farming by addressing issues that would have been faced by urban populations regardless of location or societal structure. At each site some preliminary archaeobotanical work has already been undertaken (Neef, 2001; Charles & Bogaard, 2001; Hald & Charles in Emberling & McDonald, 2001; College, 2003; Hald, 2005). This thesis will seek to build on these initial results by using them as a basis for future archaeobotanical identifications as well as combining them with recently developed archaeobotanical techniques.

Throughout the project three key objectives will be used to help structure the research and the final presentation of the results. These key objectives are to investigate:

- The formation of the archaeological record and the context of deposition.

- The range of crop husbandry schemes and agricultural management systems used.
- The implications that agricultural regime choice and the range of farming management systems employed has for the nature of urban society, and the sustainability of the city.

The formation of the archaeological record includes all activities that may have led to the final deposition of archaeological and archaeobotanical material. This includes actions that would have taken place before deposition such as crop processing techniques and the burning of animal dung, as well as the method by which the archaeobotanical material was eventually preserved. Each of these activities would have fundamentally changed the nature of the archaeobotanical material that was eventually recovered by introducing significant sources of bias. It is, therefore, essential to understand these processes and what effects they may have had on the archaeobotanical material, before accurate interpretations of plant use and crop husbandry can be made. Similarly, archaeological context must also be taken into account, as the location of deposition may indicate the eventual intended use of the material as well as providing information regarding produce ownership. The archaeobotanical assemblages from each site have been recovered primarily from storage contexts, yet the type of storage was different in each case. Full analysis of each storage context may help to explain the intended use of the produce, but also may indicate the initial origins of the plant material and how it was grown.

Crop husbandry schemes are here defined as the specific techniques and processes used to cultivate domesticated crop species. These can include tillage, the application of manure, the exploitation of water resources and the use of a crop rotation system. An understanding of the nature of crop husbandry will lead to an exploration of

the wider social implications of farming in specific areas and why certain agricultural strategies may have been used in different zones within a larger region. At both Hattusha and Tell Brak agricultural production was likely to have encompassed a spectrum of practices including the use of several distinctive 'spheres of production' owned and managed by separate segments of society. It is also likely that each of these spheres would have operated on a different scale (i.e. small-scale household production, large-scale arable estate production) and that distinct crop husbandry methods would have been used in each.

Lastly, the data gathered from the first two objectives will be combined to assess the role that Bronze Age urban agriculture had on both the organization of each society but also on the development and maintenance of the city. Key to this will be the understanding of *why* farming was practiced in particular ways both temporally and spatially and *how* these methods were linked to the dual themes of risk and urban resilience. Finally, it is hoped that this synthesis will form the basis of a new discussion regarding the social and ecological consequences of farming practice under conditions of lasting social differentiation in Bronze Age urban centres of western Asia.

1.6 Thesis structure

The layout of this thesis is as follows; **Chapter 2** provides the environmental and geographic settings for Hattusha and Tell Brak. It also details a brief historical background for the development of each city and an account of the excavation of the area where archaeobotanical samples have been recovered from. This chapter finishes with a short explanation of the current state of research regarding Bronze Age agriculture in each region, including a synthesis of documentary and archaeological

evidence. **Chapter 3** explains the methodological background of the methods and techniques used in this thesis. This includes a discussion of the literature surrounding the development of crop processing analysis and the use of functional weed ecology as well as the scientific context for crop stable isotope analysis. **Chapter 4** details the specific methods used in this thesis to select, recover, identify and analyse archaeobotanical samples from Hattusha and Tell Brak. This chapter will explain why certain material was chosen for analysis, how it was identified and quantified and the statistical techniques used for analysis. It will also include a detailed methodology regarding the application of functional weed ecology and crop stable carbon and nitrogen isotope analysis as complementary approaches to the understanding of crop husbandry.

The results of this thesis have been split into four chapters; at each stage of analysis samples from Hattusha and Tell Brak have been investigated and reported on separately. This is due to the fact that both of these sites are fundamentally different in terms of the period and society they represent. Direct comparisons between the two sites are, therefore, problematic and will not be attempted until the discussion chapter of this thesis. **Chapter 5** provides an overview of the archaeobotanical results from Hattusha and explores the compositional variability of samples using correspondence analysis and percentage stacked bar charts. It also assesses the potential role of crop processing as a taphonomic process to the formation of the assemblage. **Chapter 6** details the results of crop husbandry analysis at Hattusha. This includes the results from crop stable carbon and nitrogen isotope analysis and an exploration of the weed flora assemblage through the use of functional weed ecology. It will finish with the amalgamation of these results and the statistical examination of this combined dataset. **Chapter 7** provides an overview of the archaeobotanical results from Tell Brak. Additionally, it

will investigate compositional and spatial variability throughout the assemblage using correspondence analysis and located compositional pie charts. Finally, this chapter will also detail the results of crop processing analysis on the Tell Brak archaeobotanical material. **Chapter 8** reports the results of crop stable isotope analysis and functional weed ecological analysis at Tell Brak as well as the amalgamation and statistical analysis of these results. **Chapter 9** provides a detailed discussion of the results presented in the previous four chapters as well as integrating these results with evidence from other archaeological and documentary sources. It will finish with an examination of the original hypothesis and an examination of the nature of Bronze Age agriculture. **Chapter 10** will conclude this thesis by addressing the research aims laid out above (**Section 1.5**) before finally suggesting some directions for future work into this area of research.

Chapter 2

The sites under study – environment and history

This chapter provides the environmental and historical background pertinent to the sites of Hattusha and Tell Brak. The first section will cover the topography, climate and vegetation history of the region surrounding each site. The second section will provide a historical overview and details of the excavation of each structure relevant to this thesis. Finally, this chapter will discuss the current state of knowledge regarding urban agriculture in each area as well as providing information on preliminary archaeobotanical work completed at both Hattusha and Tell Brak.

2.1 Hattusha – environmental background

2.1.1 Location and topographic features

The Central Anatolian plateau, also called the central massif zone, is located in modern Turkey (see **Figure 2.1**) and is delimited by the mountainous north and south folded zones that run nearly the length of the country (Yakar, 2000: 226). The region is not a uniform area, but is comprised of high-altitude, gently sloping plains separated by various mountain ranges c. 1500-1700m above sea level (Bottema & Woldring, 1990). The area also includes the central and upper reaches of the Kızılırmak River which flows for c. 700km through the Central Anatolian plateau before reaching the Pontic reaches in the north of Turkey (European Environment Agency, 2002). The site of

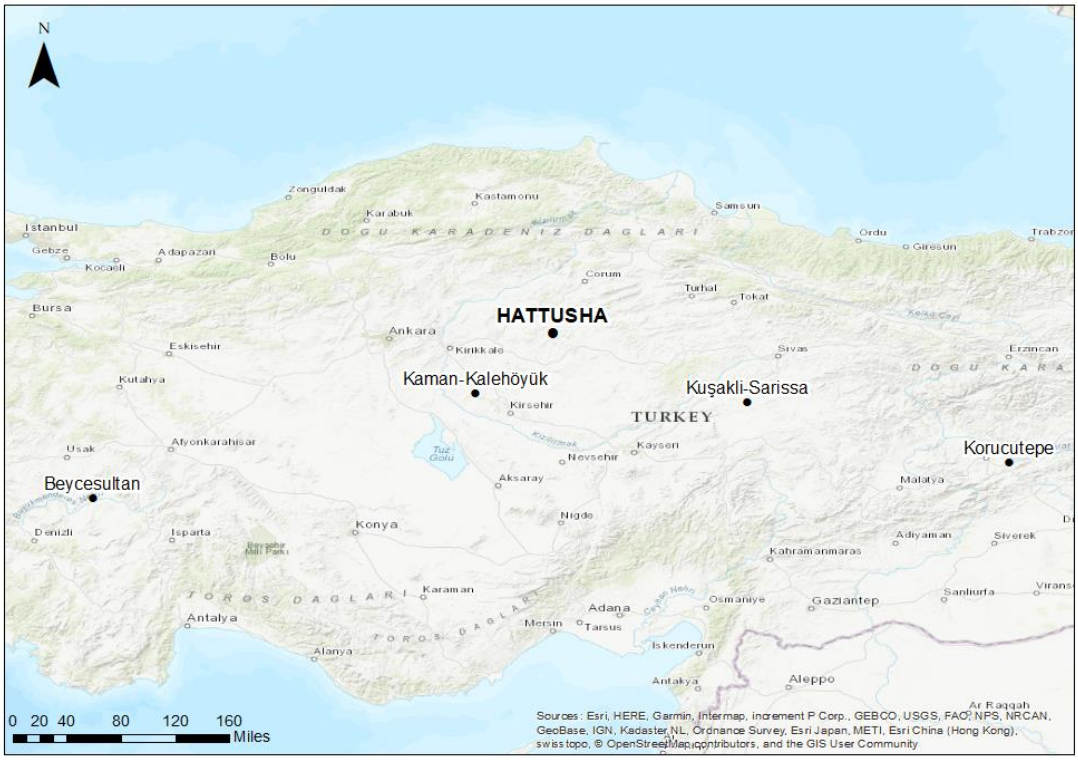


Figure 2.1 – Map showing the location of Hattusha and other Hittite sites with archaeobotanical remains mentioned in this thesis.

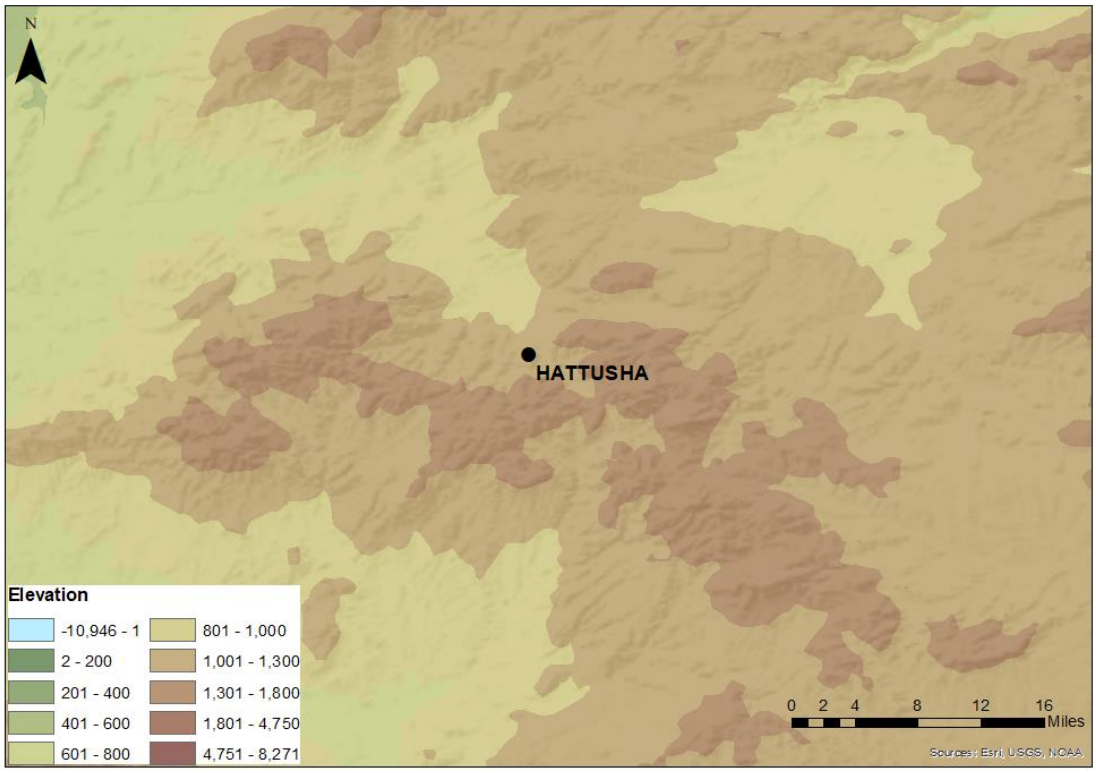


Figure 2.2 – Topographical map showing the elevation and terrain of the land immediately surrounding Hattusha.

Hattusha is situated in the north-central plateau area, surrounded by the Bithynia, Paphlagonia and Pontus mountains in the north and the Lycian, Pamphylia and Cilician Taurus Mountains in the south (Yakar, 2000: 227; Schachner, 2011: 22). The site is located near the town of Boğazkale in Çorum province[2] c. 210km east of Ankara, Turkey's modern capital city. The province is characterized by a number of small and fertile intermontane plains and river valleys within the central massif zone capable of supporting dry arable farming (Branting, 1996).

The city of Hattusha lies at an altitude of c. 900m above sea level in the northern section of the site, but this gradually rises to c.1250m in the south (https://www.geoplaner.com/ - see **Figure 2.2**) The location would have had a number of natural advantages including a guaranteed water supply in the form of seven springs, nearby woodlands for timber and surrounding valleys for arable land (Bryce, 2002: 12). This physical environment would have provided the wider region with a unified subsistence base and control of this base would have allowed the concentration of power to be held within the city itself (Gorny, 1989).

In terms of underlying geology and soil types, Hattusha is located in a complex Triassic geological area (Dündar, 2009) comprised of sedimentary rocks ranging from the Palaeozoic to Quaternary eras (see **Figure 2.3**) Furthermore there are extensive areas of volcanic material, although there are no active volcanoes present in the region (European Environment Agency, 2002). The soils of this area are also complicated but are characterized generally as moisture-retaining brown and reddish-brown loam soils (Yakar, 2000: 227- see **Figure 2.4**). These soils are calcareous (Sillanpää, 1982) but are considered to be reasonably fertile and can produce a good crop even after a dry winter when fallowing rotation is practiced.

[2] The Yozgat province border is located only 3km south of Hattusha.

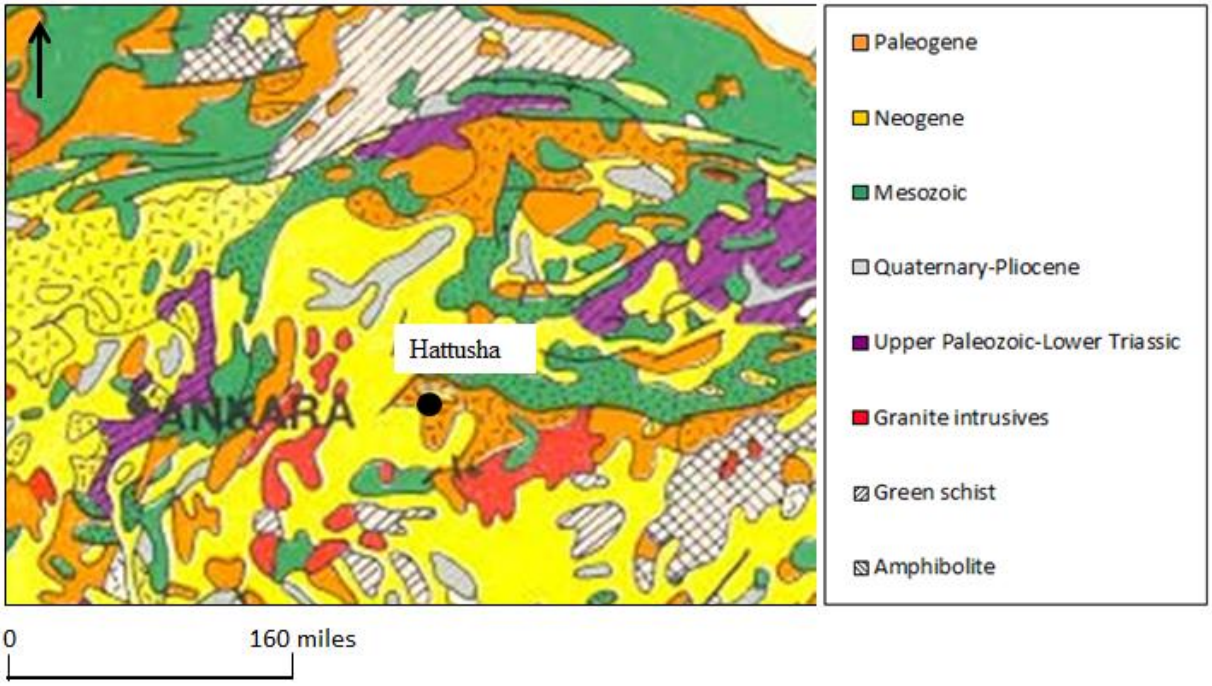
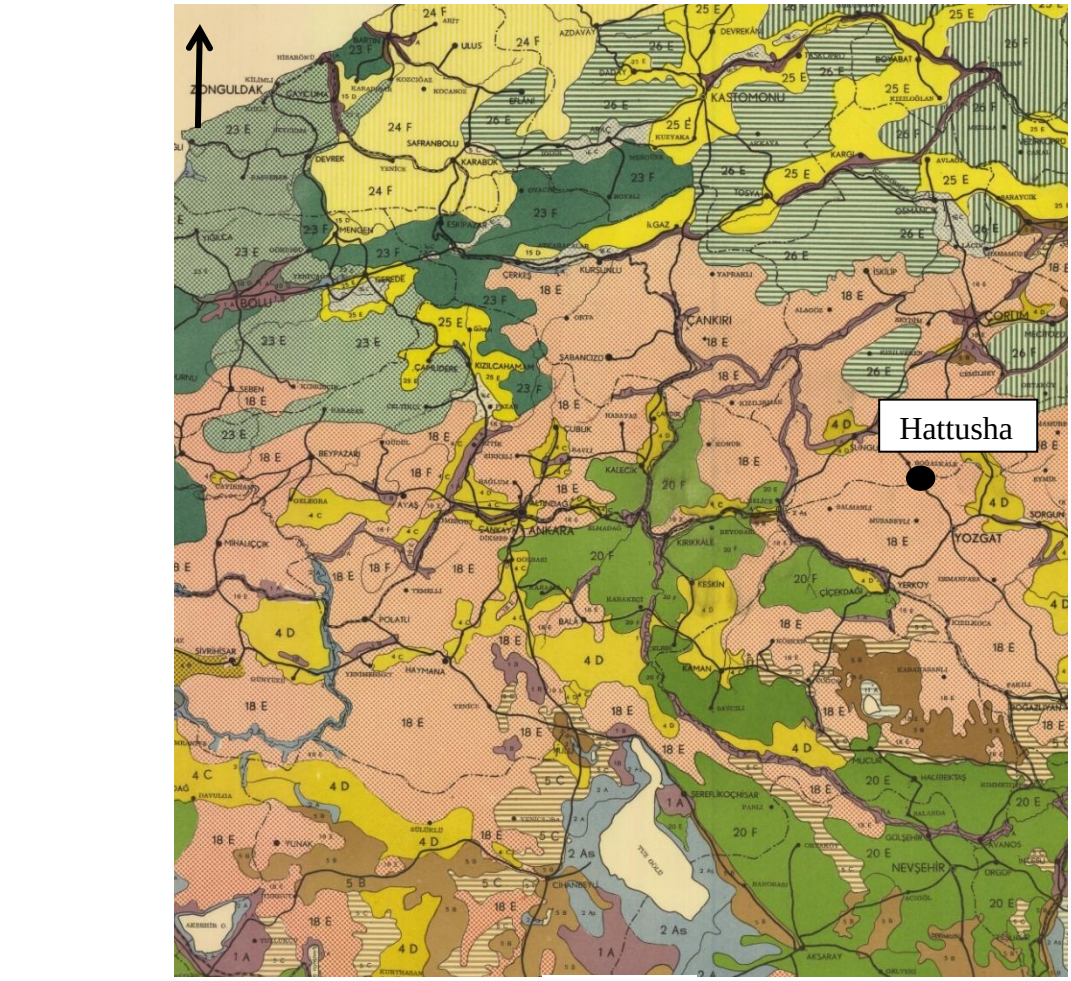


Figure 2.3 – Geological map of the region surrounding Hattusha (https://www.turkishmaps.com)

2.1.2 Climate

The Central Anatolian plateau currently experiences a continental climate with warm, dry summers and cold, wet winters (DSa – humid continental climate, Koppen-Geiger classification). Conditions vary significantly at the regional level, however, and can often be unpredictable leading to intense periods of drought and occasional famines (Seeher, 2006: 16). Temperatures generally range from about c. 28-30°C in the summer months and can drop to -5°C in winter. Average temperatures in January are -1°C and in August reach c. 20.4°C[3]. Rainfall averages c. 451mm a year, with the majority of precipitation falling between March - June and also November - January. These averages, however, can fluctuate dramatically from year to year. With regard to the agricultural calendar, dry conditions in the summer months often lead to very high

[3] Modern climate data is taken from https://en.climate-data.org/.



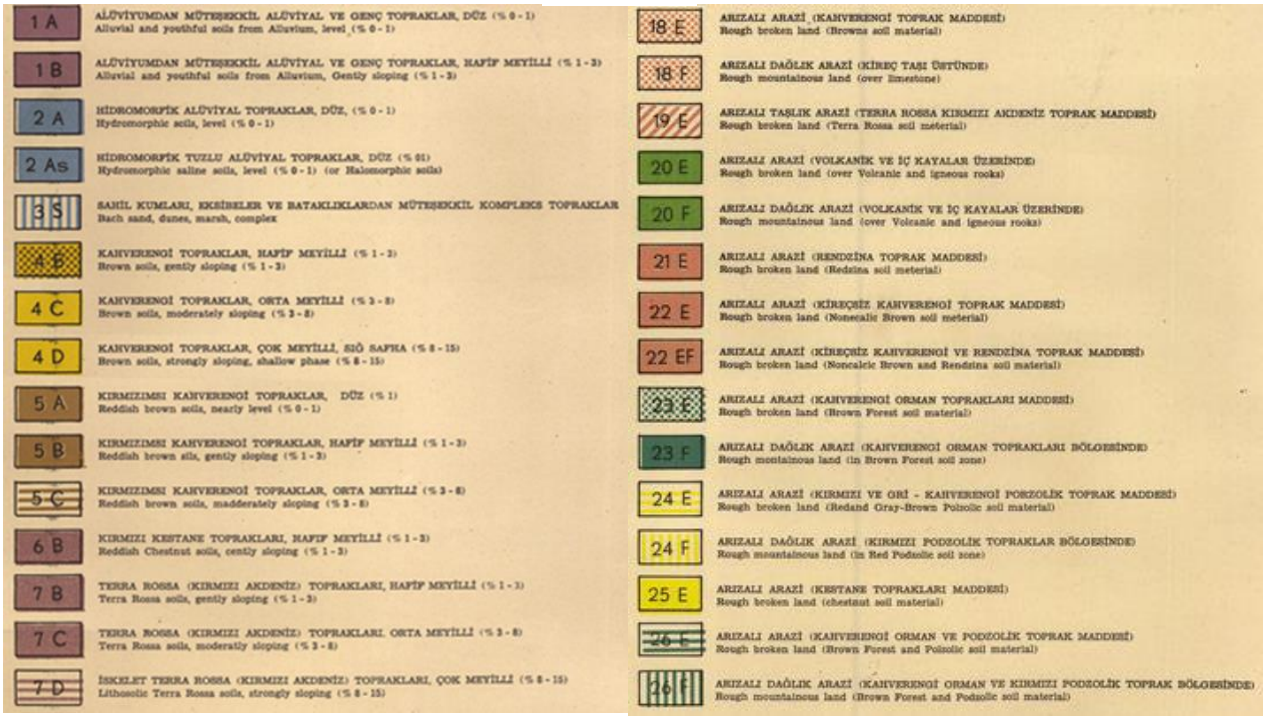


Figure 2.4 – Soil map of the region around Hattusha (European soil data centre).

evaporation rates (c. 6mm/day) so autumn rains are necessary to start the cultivation season as they soften the land for ploughing (Yakar, 2000: 277). A delay to these rains can often lead to a reduction in annual cereal yields and without the spring rains, crop failure is common. Additionally, late frosts in April and May can also cause significant damage to the arable harvest and this also seems to have been an issue in the Bronze Age as referenced within the Hittite texts (Ünal, 1977).

Palaeoclimate reconstructions of the Central Anatolian plateau have indicated that, with the exception of the Aceramic Neolithic, the historical climatic conditions in this region were fairly similar to those experienced today (Yakar, 2000: 227; Wick *et al.* 2003; Dörfler *et al.* 2011; Schachner, 2011: 36). The early Holocene appears to have been fairly wet, but from c. 4500 BC lake isotope records indicate that conditions became gradually drier (Mayewski *et al.* 2004; Roberts *et al.* 2011a). During the 3rd millennium BC the climate continued to become more arid and pollen records analysed from cores taken from Lakes Yenicağa and Abant, located north-east of Hattusha, imply that there may have been a small shift to lower winter and higher summer temperatures (Yakar, 2000: 10). These conditions also caused a reduction in lake water and humidity levels causing a slight decrease in precipitation rates to those seen in the region today. This period was, however, interspersed with periods of increased humidity that allowed the expansion of cereal agriculture and horticulture in the Central Anatolian region (Wick *et al.* 2003). Overall, climate conditions during the Hittite period are thought to have resembled conditions seen in modern Turkey, including unpredictable episodes of drought and phases of climatic stability. Overall, these conditions would have been capable of supporting rainfed farming without the need for large-scale agricultural irrigation.

2.1.3 Vegetation

The modern vegetation of the Central Anatolian plateau encompasses the westernmost part of the Irano-Turanian phytogeographical region (European Environment Agency, 2002). In reality, however, the local environs of Hattusha exhibit characteristics of a highly modified, anthropogenic landscape. Much of the region is primarily 'true' steppe grassland (Davis, 1965-88) and is used for both arable and pastoral agriculture (Condé *et al*. 2002). Stands of trees are infrequent and located mostly in areas of high altitude or in riverine environments. In these areas the steppe-forest is characterized by *Quercus*, *Juniperus*, *Pistacia* and *Crataegus* species, whilst *Pinus* stands dominate the mountain slopes and *Salix*/*Populus* and *Ulnus* the river banks (Zohary, 1973). Heavily forested areas, however, are rare throughout the plateau region today and most of this area is visibly bare and steppic.

The environmental history of the Central Anatolian plateau during the Neolithic and Bronze Age has not been intensively studied, especially in comparison to other regions within the Near East. This is due to a lack of detailed local pollen records and identified macrobotanical remains. Regional pollen records indicate the establishment of *Quercus* woodland in the early Holocene throughout Turkey (Roberts *et al*. 2011b). Forested areas of both deciduous and coniferous trees then dominated the landscape, reaching a maximum extent at c. 3000 BC before beginning a dramatic decline (Woldring & Cappers, 2001). This decline in woodland during the Bronze Age is thought to have been due to massive deforestation by the Hittites for the creation of arable land (Wright *et al*. 2015). Certainly in the environs of Hattusha, pollen cores taken from a lake in the immediate vicinity of the city have shown that the surrounding forest was decimated during this period (Schachner, 2011: 31). Similarly, at the contemporary site of Kuşakli-Sarissa, located to the east of Hattusha (see **Figure 2.1**),

an increase in pollen from the mugwort (Asteraceae) and goosefoot (Chenopodiaceae) families indicates a growing amount of steppe-like vegetation (Dörfler *et al*. 2011). Finally, recent anthrocological work by Asouti (2013) and Wright *et al*. (2015) has shown that there was a significant reduction in forest taxa richness during the Hittite Old Kingdom period (c. 1680-1360 BC). Wright *et al*. (2015) suggests that this was due to an expansion of agricultural and grazing land during this period and that Hittite farmers were modifying their production systems in response to state demands for greater quantities of produce.

2.2 Hattusha – historical background

The Hittite empire first emerged in Central Anatolia during the 17th century BC and encompassed a kingdom, called the 'Land of Hatti' which extended throughout Central Anatolia to northern Syria (Bryce, 2002: 12). During the period covered by this thesis the kingdom is thought to have reached from near Gordium in the west, to Malatya at the eastern extent, and from c. 100km south of the Black Sea coast to Aleppo in northern Syria to the south (Liverani, 2014:259). This kingdom was ruled by a royal dynasty based at the site of Hattusha, a large city located near the modern town of Boğazkale in central Turkey, c. 200km east of Ankara, which acted as the administrative, religious and cultural capital of the Hittites. Evidence for human occupation in this region begins during the 6th millennium BC and by the 19th century BC the settlement of Hattusha had been established as a trading post by Assyrian merchants (Hamblin, 2006). This settlement was destroyed by King Anitta during his expansion into Central Anatolia during the Assyrian Colony Period c. 1750 BC (Liverani, 2014: 303), and the area was not re-occupied until c. 1650 BC when King

Hattusili I established his capital at the site (see **Table 2.1** for a summary of Hittite phasing).

Table 2.1 - Summary of Hittite phasing, key events at Hattusha and previous archaeobotanical work completed at the site. The chronological period focused on in this thesis is highlighted in red.

Hittite Phasing and Ruler	Absolute dates	Key Events at Hattusha	Previous Archaeobotanical Work at Hattusha
Old Kingdom			
Labarna I	1680-1650 BC	Reunification of Central and Eastern Anatolia	
Hattusili I	1650-1620 BC	Foundation of Hattusha	
		Construction of the silo complex	Hopf, 1992
Mursili I	1620-1590 BC	Destruction of the silo complex	Neef, 2001
New Kingdom			
Suppiluliuma	1360-1322 BC	Construction of silos on Büyükkaya	Seeher, 2000b
Tudhaliya IV	1239-1220 BC	Expansion of Hattusha into the Upper City	
	1190 BC	Sacking of Hattusha and collapse of the Hittite empire	

The city itself was situated in a naturally defensible position, on an outcrop of rock providing lines of sight in all directions (Bryce, 2002: 13) and was further protected from the elements by the precipice of Büyükkale (Seeher, 2000a). It was also well positioned to dominate both the east-west and the north-south trade routes within Anatolia. During the Old Kingdom period (c. 1700-1400 BC) Hattusha remained relatively small for a Near Eastern city, encompassing only 1.25km by 0.5km in the northern section known today as the Lower City (see **Figure 2.5**). This area was dominated by the Büyükkale acropolis in the south-east sector and the mountain ridge of Büyükkaya to the north (Seeher, 2000a). The acropolis itself was reserved for the

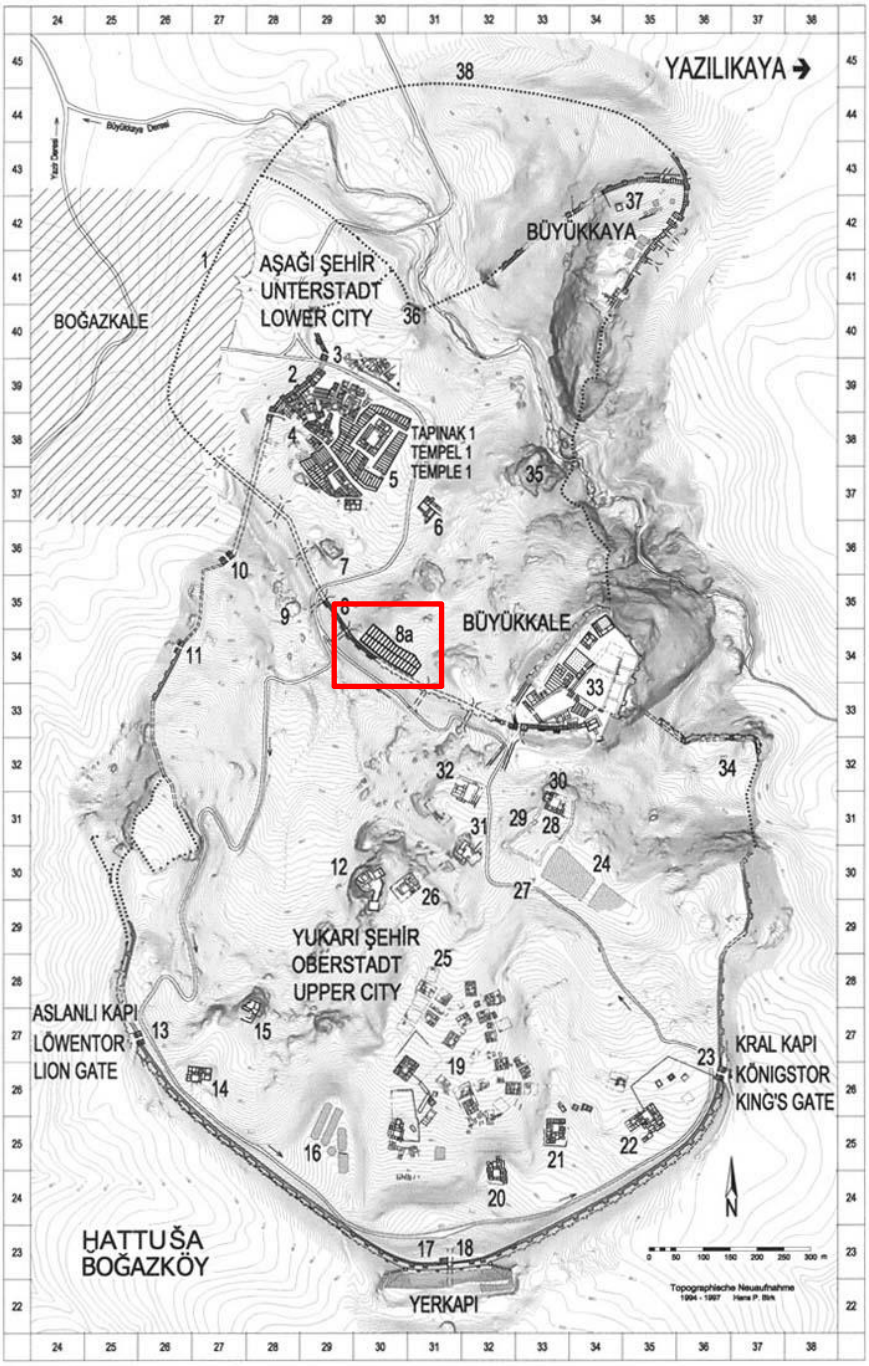


Figure 2.5 – An aerial plan of the city of Hattusha with the location of the silo complex marked in red (Seeher *pers. comm*.).

royal court and contained both the administrative buildings and the palace complex, where the king was kept separate from members of the general populace (Bryce, 2002: 12). Hattusha underwent huge expansion after the city had been sacked by an army from

the northern Kaska region c. 1400 BC. During the reign of Tudhaliya IV the Upper City was constructed to the south of the Lower City, effectively doubling the size of the urban area. At its peak the city would have covered an area of 1.8km^2 with a c. 8km long defensive boundary wall (Bryce, 2002: 13) and contained as many as 30 temples. The layout of the Upper City led early excavators to interpret Hattusha as a symbol of Hittite cosmology, with the acropolis in the north symbolizing the earthly world, the temple-city as the godly world, and the district in the middle providing transition between the two (Neve, 1993). Estimated populations during the Old Kingdom period are c. 20,000 inhabitants and this is thought to have reached to c. 40,000-50,000 during the reign of Suppiluliuma I (Bryce, 2002; Hamblin, 2006). Seeher (2006), however, has questioned the extent to which this population, with the exception of the king and court, actually resided within the city itself. Instead, he has suggested that the population majority were more likely to have been based in smaller rural towns within Hattusha's hinterland. Hattusha was finally abandoned during the 12th century BC after much of the city was destroyed by fire. Linked to this abandonment, however, was the outbreak of widespread famine throughout Central Anatolia, and documentary evidence provides records of the Hittites appealing to the Egyptians to send grain to Hattusha over multiple years (Bryce, 2002). Worsening climactic conditions are often cited as the cause of this famine as harvests failed for consecutive years (Weiss, 1982; Kaniewski *et al.* 2010) eventually leading to the collapse of the Hittite empire.

2.2.1 Excavation of the Silo Complex

Hattusha was rediscovered during the late 19th century AD, with large-scale excavation beginning in the 1960s under the direction of the Deutsches Archäologisches

Institut (Seeher, 1995). The main area of focus for this thesis, however, is a large underground silo complex (see **Figure 2.6**), initially discovered as part of the Iron Age and Byzantine excavations in the Lower City (1960-3). Although initial investigation was brief, the remains of a large Hittite building were uncovered and were thought to have been used as a storage magazine. The excavation of large structures also thought to have been used as cereal grain storage facilities on the mountain ridge of Büyükkaya, north of the Lower City, later led to a re-evaluation of the function of this building, and the silo was re-excavated during the 1998 - 2000 field seasons under the direction of Jürgen Seeher (Seeher, 2006: 46). As part of this excavation a large quantity of charred cereal grain was discovered alongside a silo wall and this led to the establishment of a much larger excavation of the whole silo complex area. Overall, several hundred tonnes of charred plant remains were found preserved underground in layers up 1.2m thick (see **Figure 2.7**), with excavation removing over four tonnes of material from five individual storage chambers. Sub-samples of this material were sent to the University of Oxford in September 2014 and have been analysed as part of this project[4].

The silo complex is located underground on the north-western slope in the Lower City between Kizlar Kaya and the Büyükkale acropolis, and behind the defensive postern wall (Seeher, 2000a). Radiocarbon dating of wood taken from the architectural structure of the silo has shown that construction likely took place during the late 17th century – early 16th century BC (Seeher, 2006: 56), probably during the reign of Hattusili I. The silo seems to have been carefully planned to take advantage of a natural depression where the bedrock is not so close to the present-day surface (Seeher, 2006: 49). The silo complex is about 118m long and between 33 - 40m wide and was divided

[4] This was part of a collaborative arrangement between Reinder Neef at the Deutsches Archäologisches Institut in Berlin and Amy Bogaard at the University of Oxford after Hattusha was initially selected as a case study for the Agricultural Origins of Urban Civilization ERC-funded project (AGRICURB).

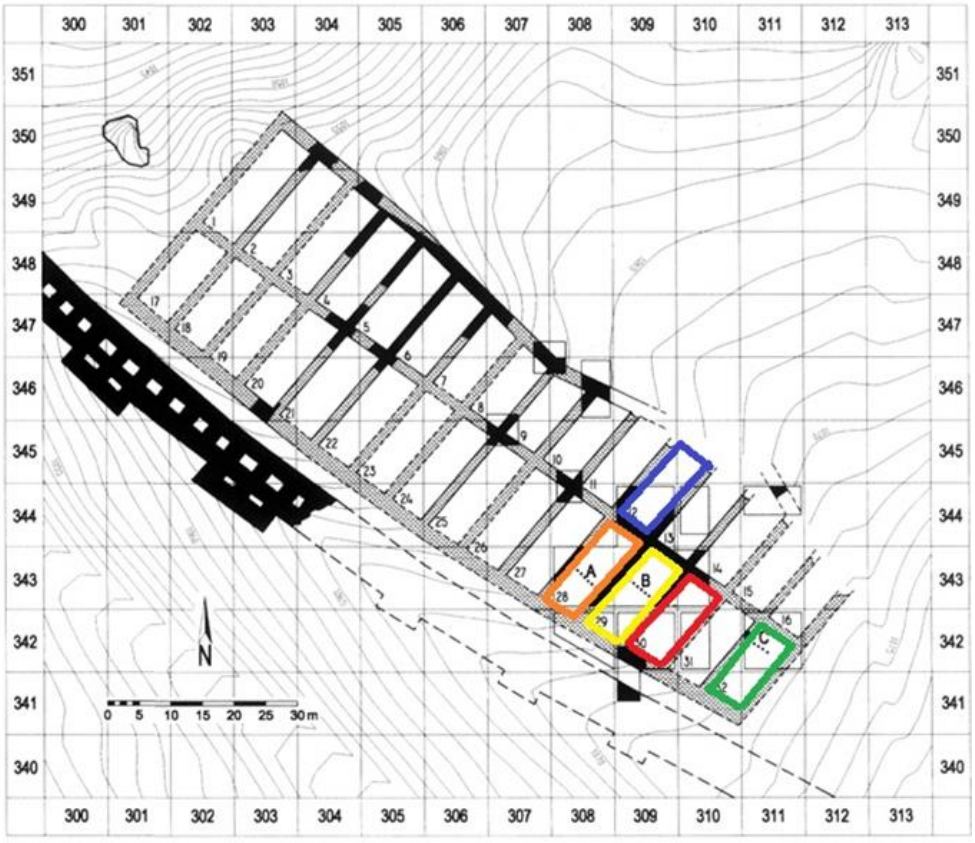


Figure 2.6 – Plan of the silo complex at Hattusha (Seeher, 2006) with the five chambers studied marked in colour, Chamber 12 – blue, Chamber 28 – orange, Chamber 29 – yellow, Chamber 30 – red, Chamber 32 – green.

Figure 2.7 – Photo of the excavation of Chamber 30 showing the mass of charred plant remains and the paved stone floor (Neef *pers. comm.*).

into 32 individual chambers that were arranged in two rows of 16 chambers each (see **Figure 2.6**). The chambers themselves were constructed from large mudbrick walls about 1.5m thick, and each chamber measured roughly 13 - 16m x 6m (Seeher, 2000a). Chamber depth, however, varied due to the chamber's position on the slope and the height of the underlying bedrock which seems to have varied by roughly 15m between one end of the silo and the other (Seeher, 2006: 50). Internally, the mud brick walls were coated with mud plaster and each chamber also had a paved stone floor to reduce the contact between the stored grains and the soil. Some chambers also seem to have had timber beams inserted as a means of stabilising the mud-brick walls; these were probably only added as maintenance, however, in cases where walls were slumping after the silo had been in use for some time (Seeher, 2000a). The stored cereals would have been covered with straw and other insulating material to protect the grain, before being capped with an earthen 'lid' which would have extended over the outer edge of the mudbrick walls as a means of directing rainwater away from the silo (Seeher, 2006: 50).

This method of construction would have meant that each chamber could have functioned as an independent 'unit' of storage, able to be accessed, filled and emptied separately from the others (Seeher, 2000b). Before the grain was emptied into the chambers, however, a thick packing of straw and reeds was used to line the walls; this insulation material is directly attested through charred remains in burned chambers and as silicified material in unburned ones (Seeher, 2006: 48). This packing layer would have acted as a buffer against ground humidity and also would have reduced contact between the grain and the mudbrick walls. Each chamber would then have been filled to capacity before being capped with the earthen 'lid', creating an airtight seal. This

hermetic method of storage would have allowed agricultural produce to be kept underground for c. 5-7 years and within modern ethnographic studies, hermetically stored food has been recorded as lasting for multiple decades (Seeher, 2006: 50). Once the seal was breached, however, the grain would have had to have been taken out within a day to reduce the chances of grain germination and attack by insects (Seeher, 2006: 50). When filled to capacity, it has been estimated that the silo complex would have held around 7000-9000m^3 of cereal grain, enough food to have fed 20,000-30,000 people for a year (Seeher, 2006: 81). By dividing the silo into 32 separate chambers, however, the whole complex would not have had to be in use at the same time, as some chambers could have been filled whilst others were left empty. This seems to have been the case particularly after part of the complex was destroyed by fire, as Seeher (2006: 46) has suggested that the unburned north-western end of the structure was in use for a number of years afterwards.

The burning event itself is thought to have occurred not long into the use-life of the silo and radiocarbon dating of the cereal grains indicates that the destruction took place during the early 16th century BC. There are no archaeological indications of how the fire started, although spontaneous combustion has been ruled out (Seeher, 2006: 49). Instead, it is likely that the fire ignited above the silo complex, before spreading to the mud-brick walls, timber beams and finally to the stored crops. In total, the fire destroyed 12 of the 32 storage chambers, and of these 12, five were totally excavated to reveal the charred remains of stored cereals in layer of 0.8 - 1.2m thick (Dörfler *et al.* 2011). Due to the hermetic nature of the silo, however, it seems likely that the fire burned at a relatively low temperature (200 - 380°C) charring much of the grain rather than reducing it to ash. In general, much of the material recovered from the silo was very well-preserved and included chaff and weed seeds alongside complete wheat and

barley grains (Neef, 2001). In areas where the material was less well preserved there is evidence that the collapse of the burnt mudbrick walls increased the amount of oxygen available, thereby allowing the fire to burn at much higher temperatures. Overall, it seems likely that the fire continued to smoulder for a number of weeks as it would have been very difficult to extinguish from above the ground. Although, as noted, parts of the silo remained unburned and possibly continued to be used, there is no evidence that the silo was repaired or rebuilt, and complete abandonment of the complex had clearly occurred by the time the Iron Age settlement was established c. 900 B.C. (Seeher, 2006: 50).

2.2.2. Text-based evidence for Late Bronze Age agriculture at Hattusha

During the Late Bronze Age, famine was an ever-present danger to the inhabitants of Hattusha due to the variable nature of the Central Anatolian environment (Bryce, 2002: 72). Climatically, the region around Hattusha is typical of a continental region, suffering from very cold winters and hot, dry summers. Rainfall, although averaging c. 400mm/year, can be very sporadic and often leads to intense periods of drought. The instigation of a sustainable and resilient agricultural system would, therefore, have been paramount to the survival of the Hittite capital. Information regarding this system, however, is severely lacking. To date in this region, archaeobotanical work has been focused on five Hittite sites including Hattusha (see **Figure 2.1** and **Table 2.2**). With the small amount of quantitative data available, therefore, archaeobotanists have been limited mainly to discussing crop choice and the use of different crop species. Current knowledge regarding Hittite agricultural regimes has been based primarily on documentary evidence, in conjunction with the limited

archaeobotanical remains. The excavation of the royal archives at Hattusha recovered c. 30,000 clay tablets dealing with legal contracts, literature and royal correspondence (Bryce, 2002: 15). Unfortunately these tablets rarely record Hittite daily life and scholars are often forced to rely on ethnographic analogies, or comparisons with the contemporary Old Babylonian Empire (Yakar, 2000: 259). Documents that do deal directly with agricultural production are limited to the Hittite Law Code and several cadastral documents and these only cover factors such as the division of farmland, agricultural taxation and labour obligations to the Hittite crown (Hoffner, 1974: 48-49). Nominally, all arable land in the Hittite Empire was directly owned and worked for the king; however, in practice the system was much more fluid and complex. Instead, Hittite farming seems to have been based on relatively small-scale independent households, especially in rural village communities, and large estates that had been allocated to high-ranking individuals and worked by serfs and/or slaves in a 'feudal-type' system. Additionally, crown land not assigned for military production or to specific individuals, would often be managed by independent farmers under a sharecropping system (Yakar, 2000: 259). Overall, Hittite agriculture seems to have been a highly variable system comprised of multiple production sectors both in rural and urban contexts.

The Law Code also records that all Hittite subjects (excluding the elite and those with special dispensation from the king) were required to perform compulsory *luzzi* service on crown lands (Yakar, 2000: 267). Each individual household was obliged to send several adults and plough oxen to cultivate crown lands on average twice a week, and this number was determined by both the size of the family and the number of draught animals they owned. This system of *luzzi* service was controlled by district governors who would have lived locally, and any resultant produce was owned directly

Table 2.2 - Summary of Hittite sites in Central Anatolia with identified archaeobotanical remains.

Site	Region of Turkey	Crops Identified	Reference
Beycesultan	South-west	Hulled barley, naked barley, emmer, lentil,	Helbaek, 1961
Korucutepe	South-east	Hulled barley, emmer, lentil	van Zeist & Bakker-Heeres, 1975
Kuşakli-Sarissa	Central-east	Hulled barley, emmer, free-threshing wheat, lentil	Pasternak, 1998
Kaman-Kalehöyük	Central	Hulled barley (2-row & 6-row), free-threshing wheat, einkorn, chickpea, lentil, pea, bitter vetch, flax	Fairbairn & Omura, 2005

by the king. Agricultural goods produced by independent households were also subject to taxation by the Hittite state. In the Hittite Law Code, Article 56 details the *sahhan*, a tax that required a portion of all food products, livestock, secondary products such as wool, and manufactured goods, to be paid to the crown (Yakar, 2000: 267). Cereals were particularly suited to collection as taxed produce because grain fields were visible and easily assessable by administrators (Scott, 2017: 131). Additionally, cereals have one determined harvest, unlike pulses that can be continually harvested over a longer period, allowing tax collectors an annual fixed point in the agricultural year to assess and collect taxed produce (Scott, 2017: 129). Grain gathered through this taxation system, as well as tribute from vassal states and crops that had been harvested from the crown lands were then stored in large grain depots throughout the empire. An example of one of these depots may be the large underground silo complex at Hattusha (Bryce, 2002: 77). These storage facilities would have been vitally important to the Hittites as they provided the rations needed to feed workers and administrators not directly involved in food production, as well as providing a source of relief in times of harvest failure (Seeher, 2006: 81). The construction of large storage facilities and the

implementation of a complex taxation system were, therefore, essential to the maintenance of the city of Hattusha.

Hittite texts also record some information regarding the variety of crops being grown, referring to four terms for wheat and two terms for barley (Hoffner, 1974: 37; Yakar, 2000: 278). Evidence for this range of cereal cultivars (see **Table 2.2**) has been supported by the limited range of archaeobotanical material from Hattusha (Neef, 2001; Pasternak in Schachner, 2012), Kuşakli-Sarissa (Pasternak, 1998; Dörfler *et al.* 2011) and Kaman-Kalehöyük (Fairbairn & Omura, 2005). From these sites six cereal cultivars have been identified (Dörfler *et al*. 2011) including: two glume (hulled) wheat species, einkorn (*Triticum monococcum* L.) and emmer (*Triticum dicoccum* Schübl), two free-threshing wheat species, bread wheat and club wheat (*Triticum aestivum* L./*durum* Desf.), as well as two-row and six-row hulled barley (*Hordeum vulgare* L.). Of these species, hulled barley, referred to as *halkiš* in Hittite texts, is the most frequently identified archaeobotanically, and is thought to have been the primary crop due to its present-day tolerance of dry growing conditions.

Barley had multiple purposes in Hittite life as it could be used both for human consumption and as fodder for livestock (mentioned in the text as *ša.gal*). Archaeobotanical evidence from Kuşakli-Sarissa has indicated that barley grain would have been used to make a type of flat bread as well as groats, and both of these foods have been found in carbonised form. Alternatively, hulled barley may also have been used to brew beer, as the grains do not need to be de-husked (Brouwer, 1972) and beer is mentioned in the Hittite texts (Ünal, 1983). Barley by-products were also utilized, with barley straw and chaff being identified as a tempering agent in mudbrick (Seeher, 2000a). Wheat was also an important cultivar for the Hittites and may have been used primarily for human consumption (Dörfler *et al.* 2011). The archaeobotanical

identification of at least four different species may indicate that different wheat varieties were grown for different purposes, although evidence for this theory is lacking. Pulses by contrast are rarely mentioned in Hittite texts, and archaeobotanical finds are very infrequent. This would suggest that pulses did not play a major role in the taxed and centrally administered sector of the Hittite agricultural economy, and that instead they were grown on a small-scale predominantly by independent households for their own subsistence.

2.3 Preliminary archaeobotanical work at Hattusha

The aim of archaeobotanical work undertaken as part of this thesis, is to contribute a significant body of data towards the understanding of Late Bronze Age agriculture at Hattusha and more widely within the Hittite empire. Preliminary identification of this material was undertaken by Reinder Neef at the Deutsches Archäologisches Institut, and was published in 2000 (Neef, 2001). In total, Neef studied 36 samples from five different burnt chambers in the silo (see **Table 2.3**). Selected samples derived from a number of different arbitrary spits taken throughout the fills of each chamber, as a means of exploring the internal stratigraphy of each individual storage unit. Due to differing levels of grain preservation in each chamber, however, the number of samples analysed per chamber varied significantly. All of the plant remains were preserved through charring, with the only exception being the seeds of *Buglossoides* (Boraginaeceae), which are naturally calcareous and can survive without charring (Pustovoytov *et al.* 2004).

Table 2.3 – The samples studied by Neef (2001) by chamber number.

Chamber	No. of Samples
12	5
28	1
29	4
30	21
32	5
Total	**36**

In terms of the crops recovered from the silo, Neef (2001) observed that hulled barley was by far the most abundant both in terms of the sum of grains identified and their presence in each sample. This would suggest that hulled barley was the primary crop being stored in the silo. Several species of glume wheat were also present in all five chambers, although in much lower abundances than hulled barley. The only exception to this was Chamber 32, which was thought to have been primarily used for the storage of glume wheat. Glume wheat was often found still in spikelet form, with the glumes still attached to the grain. This method of storing glume wheat is commonly seen as a means of protecting the grain from weevils and fungus (Seeher, 2006: 78-9), and/or, because glume wheat can be planted in spikelet form as suggested by Neef (2001). Sowing glume wheat in the spikelet would certainly remove the requirement for labour intensive de-husking that is normally only carried out before human consumption. Similarly hulled barley grains were also found associated with 'light' chaff, with the majority still enclosed within the lemma and palea. This would suggest that both wheat and barley crops had been through some initial processing stages, but that final de-husking and chaff removal would only have happened before human consumption (Hillman, 1984; Jones, 1984a).

Pulse cultivars were also identified in a number of samples, including grass pea (*Lathyrus sativus* L.), lentil (*Lens culinaris* L.) and bitter vetch (*Vicia ervilia* L.). These species only occurred in very small quantities in comparison to quantities of cereal grain and were present in only 36% samples overall (14 samples), suggesting that these taxa may have been contaminants of the primary cereal crops. One exception to this, however, was a pulse type identified as a miniature Celtic bean, *Vicia faba* var. *minuta* L. (Neef *et al.* 2012: 214), which was at least as abundant as the cereal grains in some samples. The high numbers of this species perhaps indicates that this pulse was cultivated alongside glume wheat and hulled barley as a secondary crop.

In agro-ecological terms, however, the most interesting feature of the archaeobotanical material recovered from the silo complex was the large quantity of wild/weed taxa that were present in every sample. As part of Neef's (2001) preliminary work over 70 different species were identified, and most show a preference for calcareous, loamy soils, similar to the conditions found in the area of Hattusha (Dörfler *et al.* 2011). All weed taxa that had been identified by Neef were also indigenous to Anatolia, consistent with the hypothesis that this grain was locally produced. Finally, the high densities of weed/wild seeds identified per sample would seem to indicate that the cereal fields were not being intensively weeded, and perhaps were poorly tended in general.

2.4 Tell Brak – environmental background

2.4.1 Location and topographic features

The geographic region of Ancient Mesopotamia roughly covers the modern countries of Iraq and north-eastern Syria, with areas of south-western Iran and south-eastern Turkey as neighbouring regions with varying degrees of contact (see **Figure 2.8**). The region is dominated by the Tigris and Euphrates river systems which flow from the Taurus Mountains in eastern Turkey to the Persian Gulf in southern Iraq (Akkermans & Schwartz, 2003). The site of Tell Brak itself is located within northern Mesopotamia[5], an area that includes south-eastern Turkey, north-eastern Syria and northern Iraq and is bordered on the east and west sides by the Tigris and Euphrates rivers (Oates *et al*. 2001). Northern Mesopotamia is separated geographically from southern Mesopotamia by the abuttal of the southern alluvial plains to the Jezira limestone plateau (Lloyd, 1984). The name Jezira translates as 'island', referring to the fact that this area of Mesopotamia is sandwiched between the Tigris and Euphrates rivers. The principle settlements within this area are Raqqa in Syria, Diyarbakir in Turkey and Mosul in Iraq. Tell Brak itself is located about 40km north-east of the city of Al-Hasakah on the Upper Khabur plain.

The main mound at Tell Brak lies at an altitude of 357m above sea level (https://www.geoplaner.com/) on a large expanse of flat, rolling plain (Weiss, 1986 – see **Figure 2.9**). The city was established on one of the major routes from the Tigris Valley to south-eastern Anatolia and western Syria. This road would have left the Tigris River in northern Iraq and passed through the gap created by the Jebel Sinjar and Jebel Jeribe mountains to Tell Brak (Oates *et al*. 2001). The site is also situated close to the

[5] Northern Mesopotamia and southern Mesopotamia are sometimes referred to as Upper and Lower Mesopotamia respectively.

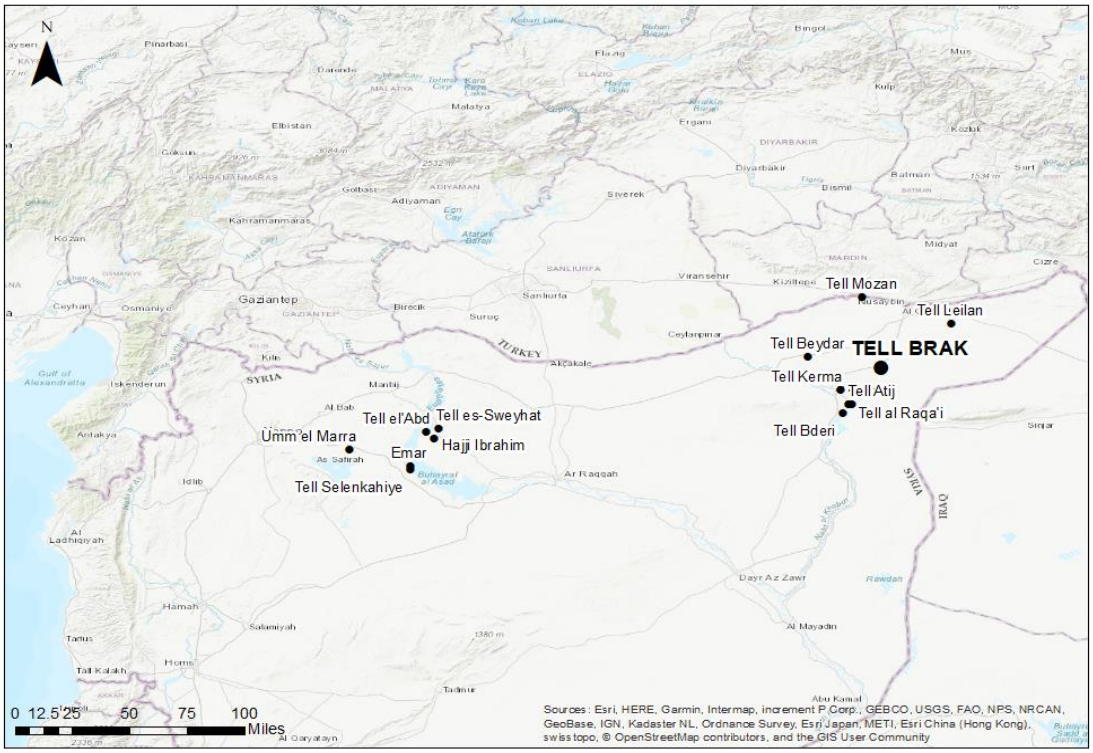


Figure 2.8 – Map showing the location of Tell Brak and other northern Mesopotamian sites with archaeobotanical remains mentioned in this thesis.

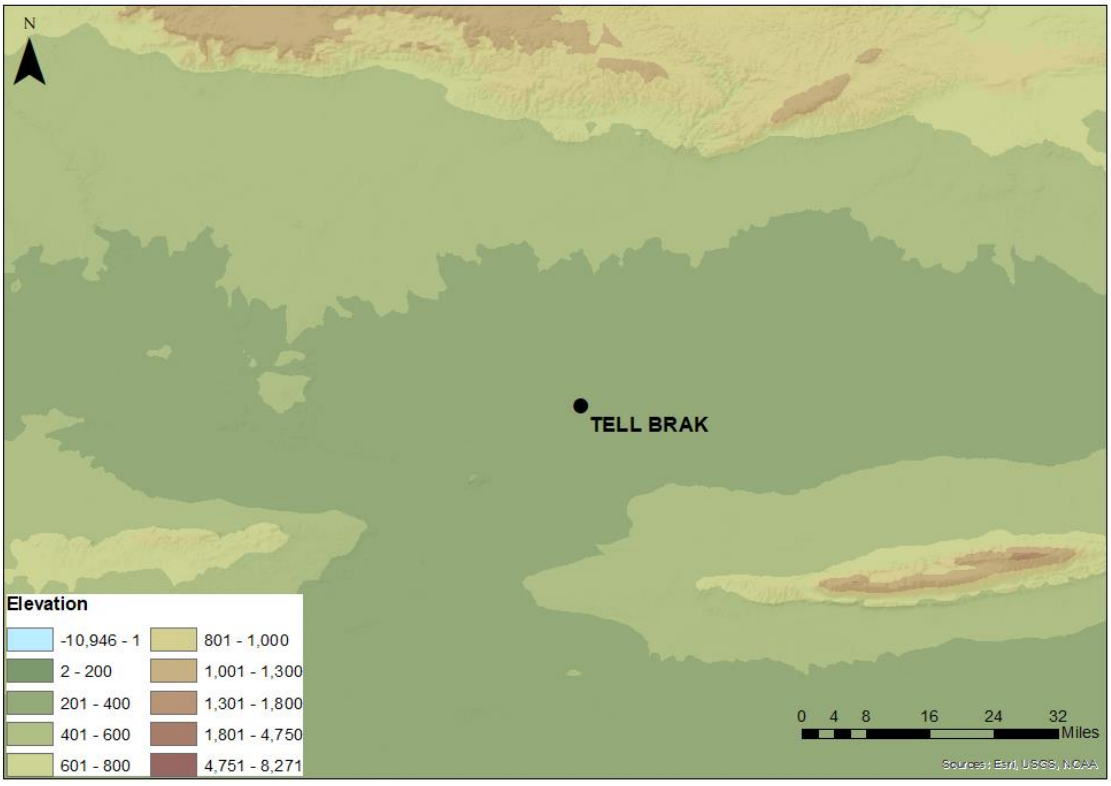


Figure 2.9 – Topographical map showing the elevation and terrain of the land immediately surrounding Tell Brak.

confluence of the nearby wadis of Radd and Jaghjagh. Today these water courses are quite small and farmers must rely on diesel powered irrigation systems to provide enough water for crop growth (Charles *et al*. 2010). During the Bronze Age, however, these wadis must have been extremely important as can be seen from the number of tell sites (e.g. Tell Barri and ancient Nisibis) constructed on their banks, and control of these water sources would have been vital (Oates, 1990).

Geologically, Tell Brak is located in a region of Cretaceous and Tertiary sedimentary rocks (Gruchy *et al*. 2016 – see **Figure 2.10**) overlaid by an area of extensive alluvial and colluvial Quaternary silts (Courty, 1994; Wilkinson *et al*. 2001). The soils themselves are mainly calcic xerosols (Wilkinson, 2003), a semi-arid soil with weak horizon development regarded as reasonably fertile (see **Figure 2.11**). Alluvial soils located on the banks of the wadis Jaghjagh and Radd would have been even further enriched with nutrients potentially providing prime arable land (French, 2003). Since the Bronze Age, however, there has been a certain amount of soil erosion and leaching caused by continuous farming activity and a reduction in annual rainfall. It has been suggested, therefore, that modern soils may be slightly less fertile than Bronze Age soils, although this issue has yet to be fully assessed.

2.4.2 Climate

The current climate of northern Mesopotamia is typically continental with hot, dry summers and cool winters (BSh semi-arid steppe, Koppen-Geiger classification). Temperatures generally range from about 25 - 35°C in July and August but can increase to highs of around 44°C. Winter temperatures can drop to below freezing but tend to

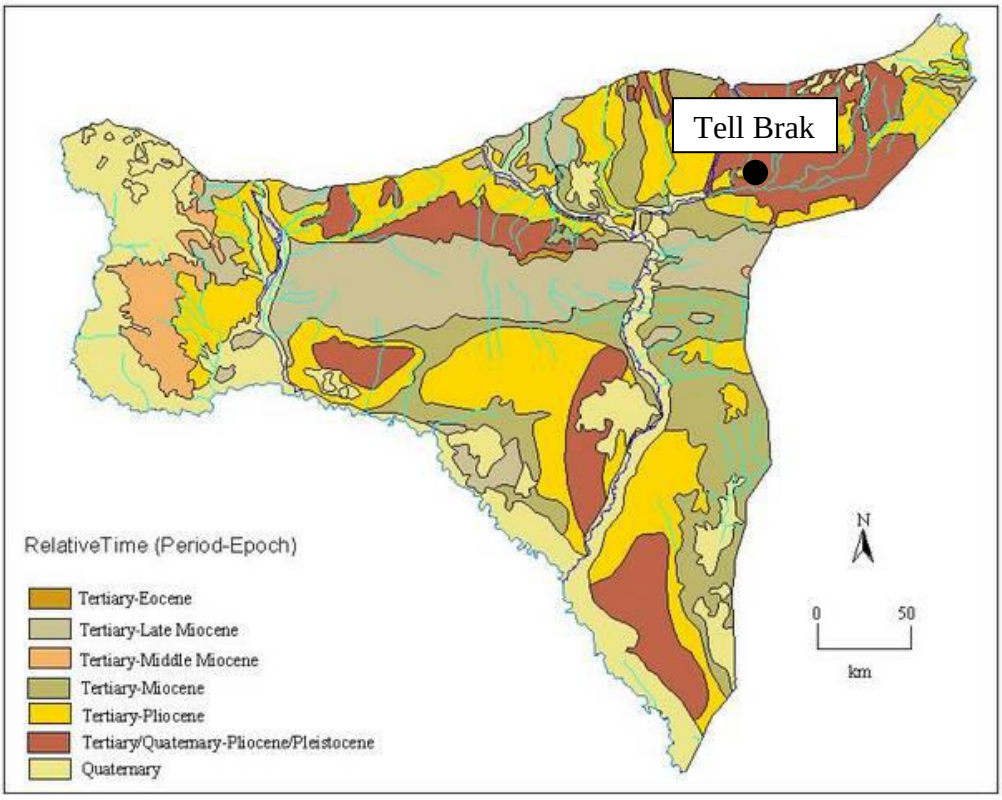


Figure 2.10 – Geology map of the Jezira region and Tell Brak (Mathys, 2001).

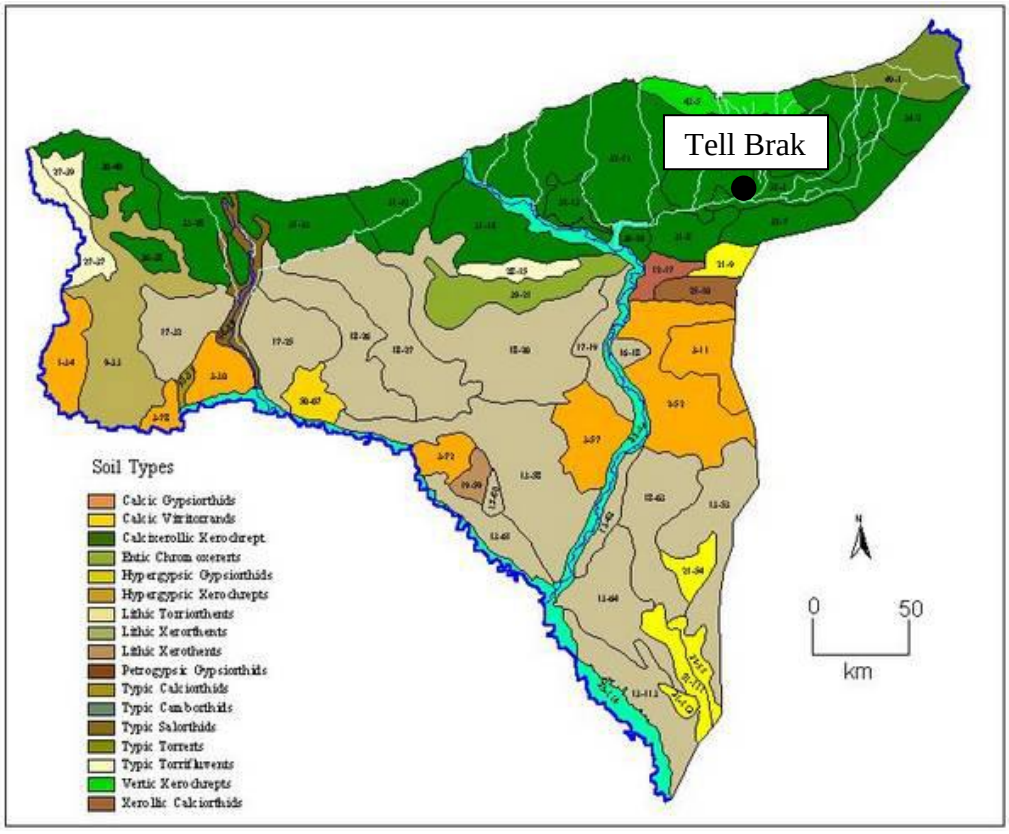


Figure 2.11 – Soil map of the Jezira region and Tell Brak (Mathys, 2001)

average around 5°C[6]. In terms of rainfall Tell Brak is located in a marginal area for rain-fed agriculture, lying between the 250 - 300mm annual rainfall isohyets (Charles *et al*. 2010). Modern average rainfall at the site is 363mm/year (Hijmans *et al*. 2005). The majority of precipitation falls between the months of November - January and again in March - May, and there is occasional snowfall in the winter months. During the last decade, however, the region seems to have become even drier, with recorded rainfall levels in Al-Hasakah barely topping 100mm/year.

Past climate reconstructions of the northern Mesopotamian region have been hampered by a lack of local paleoclimate indicators. This is due to the fact that in areas where rainfall is less than 300mm/year, pollen records are only poorly preserved (Gruchy *et al*. 2016). Lake cores have, however, been recovered from Lake Ghab in north-western Syria (Bottema, 1986) and Lake Van in Turkey (Wick *et al*. 2003). Similarly, relevant speleothems have been recovered from Jeita Cave (Lebanon), Peqiin Cave and Soreq Cave (Israel) but these records can only be used to describe climatic trends at the regional rather than the local level. These lines of evidence suggest that the climate in Mesopotamia from c. 12,000 BC until the 4th millennium BC was warmer and wetter than the present day, allowing the exploitation of a greater arable farming area. During this period, however, there undoubtedly would have been many minor climate fluctuations causing phases of drought and crop failure (Wilkinson, 1994). Certainly one such climate event occurred c. 3200 BC (5.2kyr BP), causing widespread aridification and potentially contributing to the Uruk collapse. Evidence for this event has come from eastern Mediterranean ocean cores (Robinson *et al*. 2006) and speleothems (Bar-Matthews *et al*. 2003) both of which suggest increases in aridity and decreases in rainfall during this period (Charles *et al*. 2010). Similarly, charcoal analysis

[6]Modern climate data is taken from https://www.worldweatheronline.com/.

at Tell Brak has indicated an increase in the more drought-tolerant *Pistacia* at this time over *Quercus* species suggesting a decrease in annual precipitation (Deckers & Pessin, 2010). These vegetation changes, however, are not thought to have been long-term enough to lead to the creation of an independent pollen zone. Instead it is likely that this relatively short-lived period of aridification was potentially catastrophic for the respective arable economy due to a c. 27% reduction in rainfall in an already marginal region (Weiss, 2002; Charles *et al.* 2010).

From the Late Chalcolithic period and throughout the Bronze Age (c.4000-1200 BC) local proxy climate data is available from archaeobotanical macro-remains (e.g. Miller, 1997; McCorriston, 1995; McCorriston & Weisberg, 2002, Charles *et al*. 2010), anthrocological material (e.g. Deckers & Riehl, 2007; Deckers & Pessin, 2011) and stable isotope analysis (e.g. Riehl, 2009; Styring *et al*. 2017). These lines of evidence suggest that after the 5.2kyr BP event precipitation levels did recover slightly but that general conditions remained fairly dry. Using speleothem $\delta^{18}O$ values from Soreq Cave in Israel (Bar-Matthews & Ayalon, 2011), and the present-day calibration relationship between these values and rainfall, has led to the estimation that rainfall was 313mm/year during the Early Dynastic III period (Styring *et al*. 2017). During the Early Bronze Age (2900-2000 BC) these dry conditions, due in part to the 4.2kyr BP event (c. 2200), led to an increase in dry shrub steppe plants in the Upper Khabur basin (Gruchy *et al*. 2016) and an accelerated rate of desertification in the south of the region which continued throughout the Middle Bronze Age (2000-1600 BC). Correspondingly, charcoal analysis suggests an increase in riverine forest during the Early Bronze Age but a reduction in the amount of woodland overall (Deckers & Riehl, 2007). Stable carbon isotope analysis from a number of sites also indicates a decrease in soil moisture values during this period (Riehl *et al.* 2014). These combined sources of evidence

suggest that during the Early Bronze Age (c. 2900-2500 BC) the inhabitants of Tell Brak would have faced a period of high water stress that would have undoubtedly have impacted their ability to engage in arable farming. Later in the Middle Bronze Age aridity levels may have increased even further due to the effects of the 4.2kyr BP event, long-term human occupation and land exploitation (Gruchy *et al*. 2016) and it was not until the Late Bronze Age (1600-1200 BC) that a reduction in anthropogenic pressure allowed the region to recover.

Overall, it would appear that climactic conditions during the Early Bronze Age were drier than those seen in the region today. This has led to a debate about whether Tell Brak farmers would have required large-scale irrigation for crop cultivation or whether they would have been dependant on rainfed agriculture (McCorriston & Weiss, 2002). As was mentioned above, modern farmers in the region rely on diesel-powered irrigation systems to produce reliable yields, but to date no definite archaeological evidence of Bronze Age irrigation systems have been discovered (Wilkinson, 1990). This would suggest that Tell Brak farmers were heavily reliant on the winter rains and the nearby wadis for the water needed for cereal cultivation and any changes to these water sources may have been devastating (Riehl, 2009). Furthermore, work completed on 20th century yields/hectare of irrigated crops in Massayib, southern Mesopotamia vs. rainfed crops from Mosul, Iraq (average annual rainfall of 385mm) has shown that irrigated crops can produce over twice the amount of rainfed crops (Oates & Oates, 1976). Tell Brak farmers would, therefore, have needed to cultivate much larger stretches of agricultural land than farmers in the south to produce the quantities of food needed to feed the city. Additionally, it has been suggested that Tell Brak was importing grain from cities (e.g. Tell Leilan) to the north that were situated in more favourable locations for rainfed agriculture, to bolster their own harvests (Weiss e*t al*. 2002).

2.4.3 Vegetation

The modern vegetation of northern Mesopotamia is principally steppic and is bordered by forests to the north in southern Turkey and desert to the south in Iraq. The site of Tell Brak is located in the modern vegetation zone categorized as Moist Steppe (although Dry Steppe could also be applicable in the south of the region due to the low average rainfall) and is dominated by grass steppe and land predominantly under cultivation. Trees and woodland are mainly absent, although there are small pockets of *Pistacia* - *Amygdalus* forest located near the rivers and wadis (Guest, 1966). Zohary (1950) has said that steppic environments consist of open plant communities that are limited primarily by climatic conditions and lack of rainfall. Certainly the local environs of Tell Brak are almost barren and desert-like in the dry summer months, but covered with diverse grassland species after the arrival of the winter rains (Charles *pers comm.*).

Past vegetation reconstructions of this region have indicated the existence of much more extensive *Quercus* woodland areas, particularly in the period leading up to the Late Chalcolithic (e.g. Bottema & Cappers, 2000; Deckers, 2011). Certainly during the Late Neolithic (c. 6000 BC) spatial reconstructions based on pollen evidence show that the northern Jezira was covered by dwarf shrubland with cold-deciduous montane woodland on the hills (van Zeist & Bottema, 1991). As mentioned above, however, during the Late Chalcolithic period and the Early Bronze Age, fluctuations in climate and increasing aridity led to a reduction in woodland and an expansion of grass/shrub steppe. This process escalated throughout the Middle Bronze Age due to the effects of continuous human exploitation until a slight recovery in woodland during the Late Bronze Age (Deckers, 2011).

2.5 Tell Brak – historical background

The area of northern Mesopotamia is located in a semi-arid steppic environment, although the area is generally fertile, and is often referred to as the 'granary of Syria' (Weiss, 1985; Hald, 2008). One of the major settlements of northern Mesopotamia, the site of Tell Brak (see **Figure 2.12**) is located in north-eastern Syria on the Upper Khabur plain, and is thought to have acted as a 'gateway city', controlling the crossing points at the nearby wadis of Radd and Jaghjagh and the major roads between Assyria, the northern Levant and the Euphrates Valley (Oates *et al.* 2001). The earliest occupation at the site is dated to the Ubaid period c. 5th millennium BC, although the excavation of Halafian ceramics and Pre-pottery Neolithic B chipped stone may indicate that settlement in the area extends back into the 8th millennium BC.

The site continued to grow throughout the Late Chalcolithic period (see **Table 2.4** for a summary of Tell Brak phasing) and is likely to have developed into a complex settlement before the Uruk expansion for southern Mesopotamia, with monumental architecture, numerical tablets and a population of up to 20,000 inhabitants (e.g. Hald, 2008). This has led to some debate among archaeologists as to whether Tell Brak was simply influenced by contact with southern Mesopotamian migrants (Akkermans & Schwartz, 2003), or was taken over by them entirely (Emberling, 2002). Certainly the construction of the Eye Temple during the northern Middle Uruk Period seems to showcase a considerable number of design elements also featured on southern Mesopotamian buildings, such as the use of stone rosettes (Emberling, 2002). The excavation of northern chaff-tempered ceramics in Area TW, however, would suggest that northern Mesopotamian culture was also still flourishing (Oates & Oates, 1993) during this period.

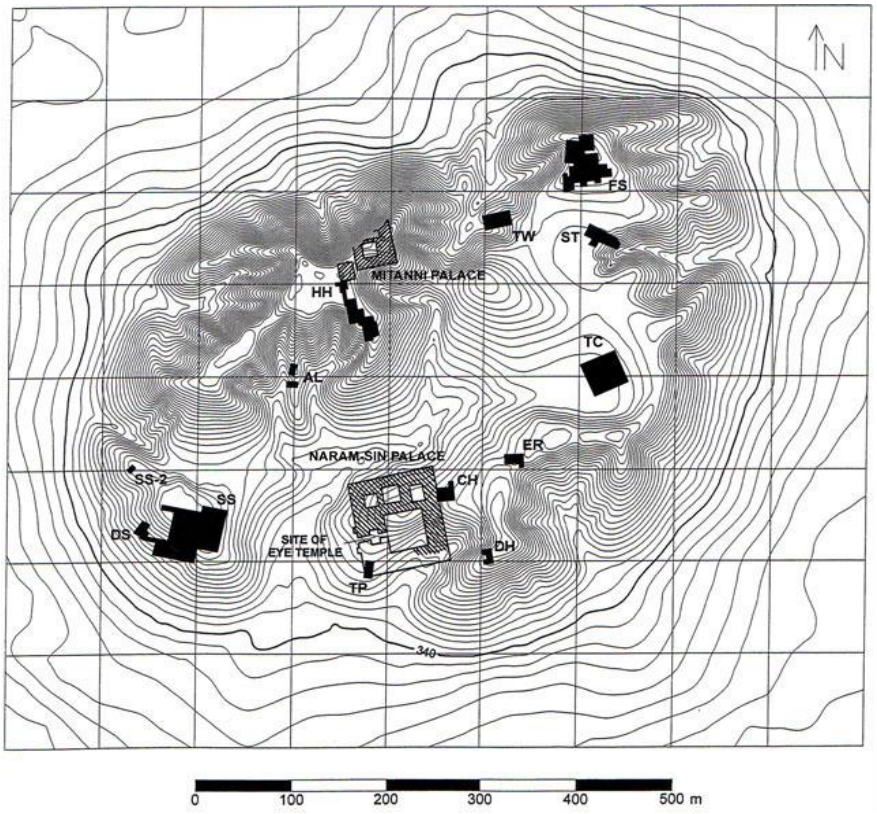


Figure 2.12 – Plan of the main mound at Tell Brak showing Area TC and other excavation areas (Emberling *et al.* 1999)

Table 2.4 – Summary of Tell Brak phasing, climatic shifts and previous archaeobotanical work completed at the site. The chronological period focused on in this thesis is highlighted in red.

Chronology	Tell Brak phase	C14 dates	Southern Mesopotamian phasing	Northern Mesopotamian phasing	Climatic Shifts	Previous archaeobotanical work at Tell Brak
Late Chalcolithic	F	4000-3200	Middle Uruk	Northern Middle Uruk	Moist/humid	Hald, 2008
	G	3200-3000	Late Uruk	Late Uruk	Arid	
Early Bronze Age	H	3000-2900	Jemdet Nasr	Post-Uruk	Moist/humid	
	J	2900-2600	Early Dynastic I-III	Ninevite 5	Moist/humid	Colledge, 2003
	K	2600-2400	Early Dynastic IIIa	Ninevite 5	Moist/humid	Charles & Bogaard, 2001, Emberling & McDonald, 2001
	L	2400-2300	Early Dynastic IIIb	Post-Ninevite 5	Moist/humid	
	M	2300-2100	Akkadian	Akkadian	Moist/humid Arid	
	N	2100-2000	Ur III	Post-Akkadian	Moist/humid	
Middle Bronze Age		2000-1850	Isin-Larsa	Middle Bronze I	Moist/humid	
	P	1850-1500	Old Babylonian	Middle Bronze II	Moist/humid	

At the end of the 4th millennium, however, northern Mesopotamia entered a period of 'devolution' (Schwartz, 1994) and southern Uruk influences disappear from the archaeological record. At Tell Brak, the lower town was abandoned (Wilkinson, 2000) and there is evidence for increased regionalization in small rural villages (Ur, 2010). The reasons for this collapse have been linked to a period of drought (discussed above) which may well have led to widespread poor harvests and subsistence failure (Charles *et al.* 2010). This may have encouraged people to move away from urban centres and back to more sustainable rural communities. The city at Tell Brak, however, did not completely collapse, and improving climatic conditions during the first half of the 3rd millennium BC saw a surge of re-urbanization. By c. 2600 BC the greater urban area (including the agricultural hinterland) at Tell Brak had reached c. 65-70 hectares (Emberling *et al.* 1999) and documentary evidence from Ebla identifies the city as Nagar, thought to have been the most important settlement in this area during the second half of the 3rd millennium BC (Oates & Oates, 2001). Nagar was ruled by one individual with the title of 'EN', and although no royal palace has yet been discovered, the construction of the 'Naramsin palace', a large fortified building with a number of small storage rooms, may point to the existence of a complex bureaucracy and administrative system being directed from the city.

2.5.1 Excavation of Area TC

Today the main mound of the site is 800 x 600m in area, c. 40m high, and surrounded by clusters of smaller tells of a slightly later date. In total the actual city would have covered an area of <130 hectares at its zenith (Wilkinson *et al.* 2001). Excavation work began at the site under the direction of Max Mallowan in 1937 and

focused on the 'Eye Temple' and other deposits from the later 3rd millennium BC. Work was then resumed in 1976 by David and Joan Oates and continued until 2004 under the direction of Geoff Emberling and Helen MacDonald. More recent investigations into Tell Brak have focused on the earlier 4th and 5th millennium levels uncovered in Area TW as well as large-scale intensive surveys of the wider urban landscape using satellite imagery (Ur, 2003). The area of interest to this project, however, was excavated during the 1999 field season directed by Emberling (*et al.* 1999) during which a large oval building, dating to the late Early Dynastic III period, was discovered in Area TC (see **Figure 2.13**). This area had been previously excavated by Mallowan in the 1930s; however, no architecture was uncovered due to a 3m deep overburden of soil wash (Mallowan, 1947: 79). The building revealed covered an area of 45 x 50m and is known as the 'Temple Oval' due its resemblance of the temple oval at Khafajah (Delougaz, 1940). Structurally this building was organized around two central courtyards with an outer enclosure wall which had been constructed in segments (Emberling & MacDonald, 2001).

Internally the building was divided into a number of different rooms, many of which contained objects associated with storage and food processing. Around the outer courtyard were rooms thought to have been used for the production of bread. This included Rooms 7 and 8, measuring 2 x 2m each, which were used for grain storage and the larger Room 2 (c. 2 x 6m in area) which contained seven small bread ovens along the east and south walls (Emberling e*t al.* 1999). The inner courtyard by contrast seems to have been more domestic in character and contained a small kitchen (Room 14), a reception room with benches built into the outer walls (Room 16) and another small store room (Room 15). Also found in the building were 250 door and package sealings indicating bureaucratic control over the produce being stored and manufactured.

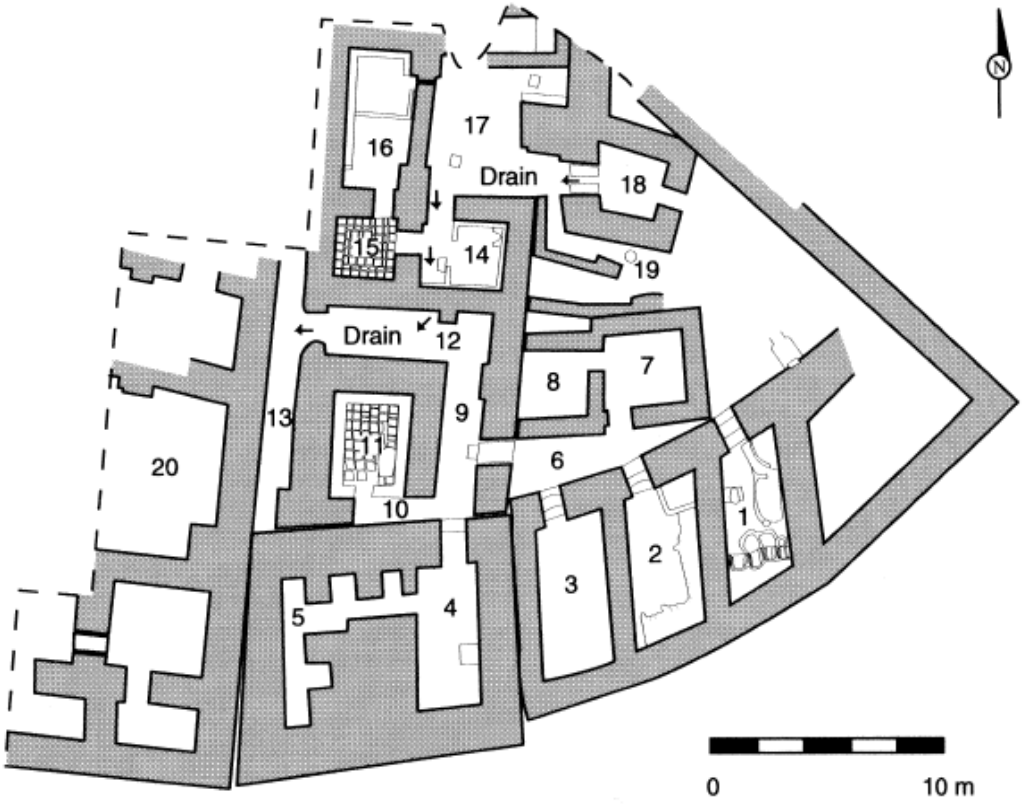


Figure 2.13 – Plan of the excavation of Area TC and the Temple Oval building (Emberling & McDonald, 2001).

This has led to the interpretation that the oval was a public building associated with the administration of grain and bread rations to a segment of the wider population of Tell Brak (Emberling & MacDonald, 2003). The building itself seems to have gone through three phases of construction and may, in some parts, have had an upper storey. The Temple Oval building was almost entirely destroyed by fire at the beginning of the Akkadian period, possibly by invading Akkadian armies (Emberling & MacDonald, 2003). At the time of destruction the building was still in use and contained large stores of crops. During the excavation of this area, therefore, high concentrations of charred cereal grains were found in many of the rooms. In particular, Room 16 contained piles of pure grain alongside mixed piles of grain and chaff, suggesting that inhabitants were doing final grain cleaning at the time of the fire.

2.5.2 Current evidence for Bronze Age agriculture in northern Mesopotamia

Unlike the Late Bronze Age in Central Anatolia, the Early Bronze Age (EBA) in northern Mesopotamia has benefited from a number of archaeobotanical studies which have focused on a range of different sized settlements (see **Table 2.5**). These studies have produced information regarding crop selection and agricultural management which have been combined with evidence from textual sources and landscape survey data to provide a much fuller picture of agriculture during the Late Chalcolithic and Early Bronze Age periods. This section will give a brief overview of these different strands of evidence for farming in northern Mesopotamia and particularly at Tell Brak.

To date many archaeobotanical studies have concentrated on the expansion of Late Chalcolithic settlements throughout northern Mesopotamia (e.g. McCorriston & Weisberg; Hald, 2008) followed by the transition to the Early Bronze Age (c. 3200-2500 BC), and the agricultural changes associated with a period of regional urban 'devolution' (Emberling *et al.* 1999; Wilkinson, 2000) and subsequent re-urbanization and settlement growth (Ur, 2010). These changes in settlement patterns may have been linked to the period of dramatic climate change and environmental degradation thought to have occurred c. 3200 BC (Robinson *et al*. 2006). Unlike southern Mesopotamian agriculture in the Early Bronze Age which could remain relatively well buffered against climactic changes by using [large-scale] irrigation mechanisms (Liverani, 2014), northern Mesopotamian agriculture was very sensitive to even small changes in annual rainfall (Riehl, 2009). As mentioned above, therefore, the control of water and access to well-watered soils was of central importance to farming management at all northern Mesopotamian sites and particularly at Tell Brak where even slight fluctuations could have led to subsistence failure.

Table 2.5 - Summary of northern Mesopotamian sites in Syria with identified archaeobotanical remains.

Site	Region of Syria	C14 dates (if known)	Crops Identified	Reference
Emar	West-central		Cereal indet.	Riehl, 1999
Hajji Ibrahim	West-central		Barley indet., Emmer/Einkorn, Lentil	Miller, 1997
Tell al-Raqa'i	East	2900-2600 BC	Hulled barley (2-row), Emmer, Einkorn, Free-threshing wheat, Lentil, Pea	van Zeist, 1999/2000
Tell Atij	West		Hulled barley (2-row & 6-row), Emmer, Einkorn, Free-threshing wheat, Grass pea, Lentil, Pea	McCorriston, 1995
Tell Bderi	East	3000-2300 BC	Hulled barley (2-row), Emmer, Einkorn, Grass pea, Lentil	van Zeist, 1999/2000
Tell el'Abd	West		Hulled barley (2-row & 6-row), Emmer/Einkorn, Lentil	Riehl, 2012
Tell es-Sweyhat	East	2400 BC	Barley indet., Emmer, Einkorn, Free-threshing wheat, Grass pea, Lentil	van Zeist & Bakker-Heeres, 1985; Miller, 1997
Tell Kerma	West		Hulled barley (2-row), Emmer, Einkorn, Free-threshing wheat, Grass pea, Flax	McCorriston, 1995
Tell Mozan	East		Hulled barley (2-row), Emmer, Einkorn, Free-threshing wheat, Grass pea, Lentil, Pea	Riehl, 2000
Tell Selenkahiye	West/central	2400 BC	Hulled barley (2-row), Emmer, Einkorn, Grass pea, Lentil, Flax, Pea	van Zeist & Bakker-Heeres, 1985
Umm el-Marra	West	2500 BC	Barley indet., Emmer/Einkorn, Free-threshing wheat, Grass pea, Lentil	Miller,1997; Schwartz *et al.* 2000

Archaeobotanical evidence from all northern Mesopotamian sites indicates that the primary crops were hulled barley and the glume wheats (see **Table 2.5**). In general, large-scale Mesopotamian cereal cultivation is thought to have been controlled primarily by the temple and the palace, and these large institutions were capable of mobilizing considerable portions of the population for help with the planting and the harvest (Postgate, 1992). Cereals were then likely used to provide rations for temple and palace employees as indicated by an Old Akkadian tablet from Tell Brak that records the payment of barley flour rations to workmen (Eidem *et al.* 2001). The relative proportions of wheat and barley, however, do seem to have changed throughout the Late Chalcolithic and Early Bronze Age periods. Archaeobotanical evidence from the

Khabur Basin Project (McCorriston & Weisberg, 2002) has suggested that barley emerged as the predominant crop during the early 3rd millennium BC, after an initial phase when other crops, including wheat, had larger roles in the production of food. This evidence has been supported by similar archaeobotanical finds from Tell es-Sweyhat dated to slightly later in the 3rd millennium BC (Miller, 1997), and from previous work at Tell Brak (Colledge, 2003).

The reasons for this change in cereal production have been closely linked to the period of aridity at the end of the 4th millennium BC (see **Table 2.4**) as barley copes better than wheat in drier conditions (Riehl, 2009). It could be connected, however, with an expansion in animal herding and an increased need for fodder (McCorriston & Weisberg, 2002). Certainly, texts from Tell Beydar in the 3rd millennium BC indicate that barley was the major source of animal fodder (Van Lerberghe, 1996) and evidence from faunal remains assemblages throughout northern Mesopotamia indicate an expansion of cattle herding during this period (Zeder, 2003).

At Tell Brak, archaeobotanical evidence supports the theory that the cultivation of the glume wheats and hulled barley were likely to have been a mainstay of the agricultural economy (Charles & Bogaard, 2001; Hald, 2008). By contrast, archaeobotanical evidence for pulse consumption during the Early Bronze Age at Tell Brak is very limited, existing mainly in the form of low density finds from domestic contexts (Charles & Bogaard, 2001). This again seems to be part of a regional trend in northern Mesopotamia, as pulse remains have only been identified in small quantities from other sites (e.g. Tell al Raqa'i; van Zeist, 1999 and Tell Kerma; McCorriston, 1995) and only appear textually in the lexical lists from south Mesopotamian palace archives (Postgate, 1992: 170). This lack of pulses has again been linked to the period of increased aridification (c. 3200 BC) and problems with water control (Riehl, 2009),

as pulse husbandry does require an ample water supply. Another explanation, however, would suggest that pulse cultivation was simply not that important to the temple and palace economies, and that pulses were possibly only grown by independent households on a small scale.

In terms of land organization and possession during the Early Bronze Age, the number of cuneiform tablets that cover the control of agricultural land and the sale of land would seem to indicate that a high value was placed on cultivable areas, and that owning land involved a number of complexities (Liverani, 2014). Documentary evidence from southern Mesopotamia suggests that by far the largest landowners within Mesopotamian society were the palace and the temple, both of which would have possessed sizeable tracts of land around the city. Firstly there would be the 'property of the En' which was cultivated directly by temple staff for the benefit of the temple. Secondly 'subsistence fields' would be given to workers to provide for their own maintenance, and lastly land that was excess to temple requirements would be rented out to individuals in return for a portion of their crops (Postgate, 1992). By contrast, private land seems a lot harder to define due to the lack of documents recovered that mention it. Certainly private landownership would have existed especially in rural villages, but it seems likely that these areas were relatively small and used primarily for household subsistence (Postgate, 1992). In northern Mesopotamia, evidence for land ownership and organization during the Early Bronze Age is much sparser, and instead archaeologists have relied on evidence from large-scale land surveys (Wilkinson, 2000; 2003). At Tell Brak, CORONA satellite photos have been used to map ancient road systems thought to lead to and from agricultural production areas (Ur, 2003 – see **Figure 2.14**). Termed 'hollow ways', these road systems are composed of broad, shallow linear depressions in the landscape, thought to be formed by the continuous

passage of human and animal traffic. Forty-eight of these 'hollow ways' have been identified so far radiating out from the main tell c. 3-5km (Wilkinson *et al*. 2014) and can be used to infer potential radial field divisions and the limits of agricultural land at the site.

Figure 2.14 – CORONA satellite photo showing the 'hollow ways' radiating out from the central mound of Tell Brak (Ur, 2003).

2.6 Previous archaeobotanical work at Tell Brak

There have been a number of previous archaeobotanical studies carried out on material recovered from Tell Brak (e.g. Hald, 2005: 2008; Colledge, 2003). Two of these studies (Charles & Bogaard, 2001; Held & Charles in Emberling & McDonald,

2001) also focus on the period analysed as part of this project, and these earlier studies have been integrated alongside the new results from this thesis to form a more comprehensive picture of agricultural production at Tell Brak during the Early Bronze Age. The first of these previous studies was completed on archaeobotanical material recovered from earlier excavations (1978-84 seasons). This work has indicated that the principal cultivars at Tell Brak during the 3rd millennium BC were 2-row hulled barley and the glume wheats, einkorn wheat and emmer wheat. Of these cereal crops, hulled barley was by far the most ubiquitous, being found in 94% of samples (Charles & Bogaard, 2001), whilst einkorn wheat was more common than emmer wheat (present in 40% and 10% of samples respectively). The large amount of material that was identified as 'einkorn/emmer', however, precludes any conclusion as to the predominance of one species. By contrast, pulse species were much less frequently identified, with lentil, pea and grass pea present in only 28%, 17% and 11% of samples respectively. Other potentially cultivated plants may have been safflower (*Carthamus tinctorius* L.) and flax (*Linum usitatissimum* L.), although the number of seeds identified to these species was relatively low.

Spatial variation in sample composition indicates that there may have been a contrast between domestic and public production of agricultural goods (Charles & Bogaard, 2001). For example, in Level 3 of Area FS, an Akkadian public building (see **Figure 2.12**), only hulled barley was found. Pulse species by contrast are entirely absent. By comparison samples taken from domestic contexts in areas CH and ER do include pulses as well as cereal grains. This may indicate two separate, yet complementary, scales of production in existence during the 3rd millennium BC at Tell Brak. Firstly a 'specialized institutional agriculture' administered by the temple administration which focused on hulled barley and wheat production as a means of

providing bread rations for workers and fodder for palace livestock. Secondly, a 'household-scale agriculture' which included the private cultivation of a much wider range of crops including pulses, cereals and other species such as flax.

The second study was completed by Mette Marie Hald during the excavation of Area TC and involved the preliminary analysis of 25 samples taken from five different areas in the Temple Oval building.[7] These samples were chosen for analysis due to the variety and abundance of charred seeds present within them, and due to their location in different areas of the building. Preliminary analysis was carried out on only the coarse fraction (material >1mm) of each sample, and especially rich samples were randomly split into fractions until a count of 300 cereal grains had been reached. Throughout the assemblage a number of different cereal cultivars were identified. Of these species, 2-row hulled barley (the only barley species identified) was the most prominent and was present in relatively high concentrations in all 25 samples with the exception of one taken from Room 12. By contrast, at least four different species of wheat were identified including the glume wheats; einkorn wheat, emmer wheat and spelt wheat along with free-threshing wheat. Unlike 2-row barley, however, all wheat species were found in relatively low concentrations, again with the exception of samples from Room 12 which were dominated by emmer wheat (Emberling & McDonald, 2001).

Other cultivars encompassed a number of pulse taxa such as lentil and pea. The number of pulse seeds identified, however, was very low and would suggest that these species were contaminants of the cereal crop rather than being independently cultivated. Unlike the charred material from the Hattusha silo complex, the material from the Temple Oval building was very clean, with only minor occurrences of cereal chaff and small weed seeds. In total, only nine weed species were identified and this may indicate

[7] These samples have been re-examined and re-identified as part of this thesis.

that harvested plants had been fine sieved before being stored (Hillman, 1984; Jones, 1984a). Identified weed/wild taxa were primarily large wild grasses, such as wild barley (*Hordeum spontaneum* K. Koch) and a number of *Aegilops* species. These weeds are of a similar size to that of the cereal grains so would not have been removed either during the winnowing process or during sieving. The lack of chaff remains and weed seeds present within the cereal deposits has led to suggestions that these stores were destined for use in brewing (Emberling & McDonald, 2001). Other excavated artefacts associated with the cereal stores from the Temple Oval, however, indicate that this building was involved in the mass production of bread rations for Tell Brak workers. Related to this, the lack of other cultivars like the pulses, found in the Temple oval building would seem to support the theory (mentioned above) by Charles & Bogaard (2001) that 3rd millennium BC agriculture at Tell Brak was segmented into domestic vs. public production.

Chapter 3

Relevant approaches to archaeobotanical analysis

This chapter provides an overview of the methods and theories that have been incorporated into this study to investigate and analyse archaeobotanical remains. The first section will cover the origins and formation of the archaeobotanical record at each of the sites studied, including preservation methods and taphonomic processes. The second section will examine a variety of approaches to the study of charred plant material, providing both a review of current archaeobotanical research and an outline of how each approach works. These approaches have been selected for use in this thesis due to their relevance for answering the specific research aims and objectives set out in **Section 1.5**, **Chapter 1**. Methodologies to be discussed as part of this study include crop processing analysis, functional weed ecological analysis and crop stable isotope analysis.

3.1 Formation of the archaeobotanical record

The recovery of plant remains from the archaeological record is the last step in a long sequence of pre-depositional activities and post-depositional processes. Both of these sets of activities will have necessarily manipulated and distorted both the composition of plant remains that can be recovered and the creation of archaeological knowledge from their subsequent analysis. It is, therefore, essential that each potential

source of bias is identified and understood in terms of how it may affect archaeobotanical interpretations. This in turn will affect to what extent other investigative methodologies, such as crop stable isotope analysis and functional weed ecological analysis; can be applied to the raw data.

3.1.1 Sources of archaeobotanical material

There are multiple ways that plant material may have been transported to and deposited on a particular site, including both human activities and natural processes. The extent to which these sources can be disentangled from one another will have important consequences for the type of questions that can be addressed on the basis of the material recovered. For example, when considering the nature of crop husbandry at a particular site it is necessary to ascertain that the archaeobotanical remains identified originate from crops or crop-related material (i.e. arable weeds), rather than naturally occurring plants from the local environment that have arrived on site by some other means. To this end, the archaeological context from which samples have been taken must also be identified and analysed. Crops and their associated by-products are the most common source of plant material on an archaeological site and can be identified as stored produce, the remains of food (e.g. Dennell, 1976), fodder for livestock (e.g. Jones, 1998; Halstead & Jones, 1989) or as a fuel supply (e.g. Ntinou & Badal, 2000). Other sources of plant remains include the collection of wild plants for food, building materials, the burning of animal dung which can often contain the remains of plants that have been consumed by livestock (Miller, 1984; Charles, 1998), and plant material from the surrounding environment which may have been transported onto the site by accident.

With regards to the archaeobotanical material analysed as part of this study it is likely that the majority of plant remains were derived from crops or crop-related by-products. This assumption is based not only on the identification of the plant material itself, but also on the archaeological contexts that this material was recovered from. For example, archaeobotanical samples from Hattusha were taken from a large underground silo building, a hermetic long-term storage facility used particularly for the storage of agricultural produce (Sigaut, 1988; Seeher, 2000a: 2000b; Weinburg *et al.* 2007). Similarly, physical evidence for direct crop storage was also identified from the TC oval building at Tell Brak. It is possible, however, that non-crop related plant remains may also have found their way into storage facilities, and alternative sources of material must also be considered as part of this analysis.

3.1.2 Preservation of plant material by charring

Plant remains can be preserved archaeologically by waterlogging, desiccation, mineralisation and/or charring (e.g. Green, 1982; Addyman & Black, 1984; Maier, 1999). The preservation of plant material by charring is the most frequent way for archaeobotanical remains to survive within the archaeological record in the Near East and Central Anatolia. This can occur in a number of ways, either on purpose (e.g. the burning of fuel, waste disposal, ritualistic burning) or accidentally (e.g. during food preparation and cooking, during periods of conflict) and leads to the preservation of *in situ* plant remains, such as crop stores (Valamoti, 2004; van der Veen, 2007). Preservation by charring, however, imposes biases to a greater extent than other preservation processes (Green, 1982; van der Veen, 2007; College & Connolly, 2014). Type of plant, the intended use of the plant, the temperature of the fire and the amount

of time that the plant is exposed to the heat will all impact on exactly what plants and plant parts survive. For example, leafy vegetables and oil-rich seeds are rarely found in the archaeobotanical record as they are comparatively less likely to survive the charring process than cereal grains (Dennell, 1976; Wilson, 1984), or are less likely to come into contact with sources of heat/fire to begin with. Moreover, with regards to cereals, the parts that are most likely to survive burning are the grains and straw/culm nodes, whilst light chaff and rachis is destroyed (van der Veen, 2007). Experiments by Boardman & Jones (1990) have shown that a lack of oxygen will generally provide a broader band of survival conditions allowing for some chaff preservation, but that higher charring temperatures (over c.240°C) would cause a bias towards the preservation of grains only. Additionally, seeds that have been charred at these higher temperatures and for longer durations (more than 3 hours) are likely to become distorted or cracked and are, therefore, much more difficult to identify positively (Braadbaart, 2008; Charles *et al*. 2015). The charred plant remains recovered from any site, therefore, potentially represent only a small proportion of the stored crops and associated arable weeds in use by that society (Green, 1982), and this must be considered in any further analysis.

3.2 Crop processing

Crop processing is carried out on harvested crops as a means of cleaning the grain and removing impurities such as weed seeds, straw remains and chaff. Generally, there are several stages of crop processing, and at each stage a different combination of crop components and unwanted by-products is produced. The processing of crops can have a dramatic effect on the type and range of plant material preserved within the archaeobotanical record, as the removal of various plant parts and weed seeds

systematically biases the assemblage. Furthermore, the failure to identify a particular crop processing stage can lead to the misinterpretation of crop husbandry practices (Jones, 1992) and the intended final use of various plant parts. Within archaeobotany the analysis of crop processing stages can be used to identify cultivation practices (Dennell, 1976) as well as areas of the site which have been used for crop processing activities (Hillman, 1981; van der Veen, 1992).

Crop processing activities have been fairly well studied ethnobotanically, with much research taking place on the island of Amorgos in Greece and in Aşvan, Turkey (Jones, 1983a; 1984a; Hillman, 1981; 1984; 1985). These studies have focused on the different stages of crop processing; winnowing, coarse sieving and fine sieving, as well as on two different categories of cereal that behave differently when processed; free-threshing cereals (Jones, 1984a) and hulled (glume) wheats (Hillman, 1981). Free-threshing cereals include *Triticum aestivum/durum* as well as *Hordeum vulgare* whilst glume wheats include primarily *Triticum monococcum* and *Triticum dicoccum*. These two cereal categories are initially processed in the same way: firstly the crop is threshed and straw is removed from the harvested cereal ears. Secondly, the crop is winnowed to remove small, light plant items such as rachis, awns and some small weed seeds from the cereal grain. Coarse-sieving may then be used to remove remaining heavy straw and larger weed seeds, pods and culm nodes. After this stage, free-threshing cereals and glume wheats require different methods of processing due to the physiology of each species' grain and chaff. After coarse-sieving, free-threshing cereals are fine-sieved to remove weed seeds that are smaller than the grain. The crop may then be hand sorted to remove any final impurities, although this stage is often completed immediately prior to consumption and free-threshing grain is commonly stored after the fine-sieving stage. By contrast, glume wheats require an extra stage of processing to remove the grain from

its enclosing glumes. After coarse-sieving, glume wheats are dehusked by pounding or grinding (Hillman 1981; Küster, 1984; Peña-Chocarro & Zapata, 2003) and then winnowed again to remove glume bases and spikelet forks. A final sieving stage is then performed to remove any remaining spikelets and larger weed seeds. Dehusking can also take place piecemeal before consumption and glume wheats can be stored as complete spikelets. Retention of the spikelet can help to preserve the grain in long-term storage and ethnographic evidence has indicated that glume wheats can also be planted in spikelet form (Neef, 2001; Halstead, 2014: 158).

At each stage of crop processing weed seeds, chaff and other impurities are removed systematically due to each items' underlying properties. These properties include factors such as size, weight and seed shape aerodynamics. Ethnographic research has then sought to detect crop processing stage due to the identification of these underlying properties and by understanding exactly when items are removed from the assemblage during the crop processing sequence (Jones, 1983b; Hillman, 1981; 1984). This has been done by comparing the ratios of grain and chaff present in an archaeobotanical assemblage, with the known ratio of grain and chaff that occurs in a cereal ear (e.g. Hillman, 1984; Jones, 1990; van der Veen, 1992). Discrepancies between the two ratios that cannot be due to a charring bias can, therefore, be interpreted as due to the effects of crop processing. For example, high ratios of free-threshing chaff in comparison to grain are indicative of early crop processing stages such as winnowing and coarse-sieving. By contrast, large quantities of grain in comparison to chaff suggest that the crop has been through the fine-sieving stage (Hillman, 1984; Jones, 1990). This method has been further refined by the inclusion of weed seed ratios alongside grain and chaff. Ethnographic work by Jones (1990) identified that each crop processing stage also produced specific ratios of weed seeds:

grain: chaff, and that by quantifying this data it was possible to compare archaeobotanical assemblages directly with ethnographic case studies. This method has since been used in multiple archaeobotanical studies as a means of identifying crop processing products and by-products (e.g. Charles & Bogaard, 2001; Valamoti, 2004; Hald, 2008; Bogaard, 2011, Stroud, 2016).

One of the primary limitations to using the ratios of grain to chaff to identify crop processing stages, however, is the differential preservation rates of light and heavy chaff (as discussed above in **Section 3.1.2**, Boardman & Jones, 1990). Jones (1987, 1990), therefore, used quantitative ethnographic data to classify weed seeds by their aerodynamic properties, size and 'headedness' as a means of determining crop processing stage. The six categories are: 'big, heavy, headed' (BHH), 'big, free, heavy' (BFH), 'small, headed, heavy' (SHH), 'small, headed, light' (SHL), 'small, free, heavy' (SFH) and 'small, free, light' (SFL). With regards to individual crop processing stage, weeds removed during winnowing are generally 'small, free and light' whilst weeds removed by hand sorting are 'big, free and heavy'. Jones (1987) then used discriminant analysis to classify ethnographic crop samples on the basis of weed seed composition and aerodynamic categorization. Finally, this same discriminant analysis was then applied to archaeobotanical samples as a means of classifying them as; winnowing by-product, coarse-sieving by-product, fine-sieving by-product or fine-sieving product.

Other limitations to the application of ethnographic crop processing studies to archaeological material is that these studies are representative of crop processing activities in a particular area during the 20th century AD. Care must be taken, therefore, when applying these methods to archaeobotanical assemblages as husbandry and harvesting methods may have varied radically through time, potentially changing the ratios of grain: chaff: weeds present during crop processing. Similarly, the tools used to

accomplish crop processing and in particular the sieve sizes, are likely to have varied by region and chronological period. This will have an impact on the size of plant items retained or discarded during the sieving stages and must be taken into consideration when analysing crop processing activities. Additionally, these ethnographic case studies have been focused primarily on free-threshing cereals. This reduces the applicability of these results to glume wheat dominated assemblages due to these species' different processing requirements and prevents a direct comparison between the ethnographic data (Hillman, 1984; Jones, 1983a: 1983b; 1990) and archaeobotanical results. Attempts have been made to overcome this limitation by the calculation of weed seeds to glume base proportions within the fine-sieving by-products of glume wheats (Bogaard, 2011: 75). Without further detailed quantification of glume wheat ethnobotanical samples and the physical types of associated arable weed seeds (D'Andrea & Mitiku, 2002), however, any application of these techniques for crop processing analysis must be treated with caution.

3.3 Approaches to crop husbandry

Crop husbandry methods are of particular interest to archaeobotanists as they reflect not only how a society manages the agricultural economy for subsistence and longer term storage, but are also closely related to other factors such as socio-economic organization and social inequality (Kohler *et al*. 2017; Bogaard *et al*. 2018). In this study the term crop husbandry will refer to the specific methods used by the farmer to cultivate crops, including the use of manure, tillage, artificial watering, sowing and harvesting times. Many of these techniques rely on high inputs of labour and are, therefore, related to each community's latent social structure and the ownership of

agricultural land. Crop husbandry is also closely related to the size of an individual society and the scale of plant cultivation (Styring *et al*. 2017).

Methods of crop husbandry are integral to an overall understanding of the nature of farming regimes implemented by each society. Recent archaeobotanical research into Neolithic farming has shown that village communities throughout Europe and western Asia were often established around the small-scale, intensive management of domesticated crops and livestock (e.g. Halstead, 1989; Bogaard, 2004; 2005). These intensive, mixed systems were arranged around the domestic mode of production (DMP) and would have involved the cultivation of a wide range of crops using labour demanding techniques such as weeding, watering and manuring (Bogaard, 2004). By contrast, Bronze Age societies were utilizing far more 'extensive' forms of agriculture (e.g. Halstead, 1995a: 1999; Styring *et al*. 2017). These regimes would have been capable of generating large quantities of produce, for both daily consumption and storage, by cultivating large areas of arable land with comparatively low labour inputs. Labour-saving techniques such as broadcast sowing and the ox-drawn ard would have been employed alongside the use of fallowing as a form of weed control. Moreover, these regimes would have specialised in the cultivation of stress-tolerant cereal crops with reliable annual yields under low-input conditions, rather than the broader-spectrum systems implemented by Neolithic communities (Halstead, 1999).

Two methods of analysing crop husbandry methods are the stable isotope analysis of cereal grains and the use of functional weed ecology. These approaches provide data on different yet complementary aspects of crop husbandry and cultivation. The stable isotopic analysis of carbon and nitrogen ratios in cereal grains provides inferences into the watering and manuring status of these crops (e.g. Bogaard *et al*. 2007; Wallace *et al*. 2013). The functional weed ecology of arable weeds presents

evidence regarding the intensity and permanence of cultivation (e.g. Jones, 2002; Bogaard, 2004; Bogaard *et al*. 2016a; 2016b). Both of these approaches will be discussed in greater detail below.

3.3.1 Crop stable isotope analysis

Within archaeology, stable isotope analysis has been primarily used to infer information about human palaeodiets by measuring the ratio of heavier to lighter isotopes of carbon and nitrogen in human and animal bone collagen (e.g. Schoeninger *et al*. 1983; Clutton-Brock & Noe-Nygaard, 1990). More recently, however, the stable isotopic analysis of carbon and nitrogen in charred plant remains has been used to infer both water availability and the manuring status of cultivated crops (e.g. Bogaard *et al*. 2007; Fraser *et al*. 2011; Vaiglova *et al*. 2014a). Isotopes are variants of a chemical element which have the same number of protons within each atom, but a different number of neutrons and consequently a different atomic weight. Isotope fractionation takes place during a phase transition process, when the ratio of light to heavy isotopes within the individual molecules is either depleted or elevated. For example, water availability is linked to the fractionation of carbon during photosynthesis and similarly manuring status can be inferred from the volatilisation of the lighter nitrogen isotope after enrichment. The relative stable isotope ratios of carbon and nitrogen can then be measured to infer the extent of human crop management systems and the use of varying husbandry techniques. Both of these approaches will be discussed in further detail below with reference to cereal crops only, as stable isotope analysis of charred pulse remains has not been completed as part of this study.

3.3.1.1 Carbon stable isotope analysis

There are two stable isotopes of carbon, ^{12}C and ^{13}C occurring in a natural proportion of approximately 99:1 with atmospheric carbon dioxide. C_3 plants, such as cereals and pulses, differentially assimilate these stable carbon isotopes from atmospheric carbon dioxide during the photosynthetic process, by converting carbon dioxide and ribulose bisphosphate into 3-phosphoglycerate (Bassham *et al*. 1950). During this process the heavier ^{13}C isotope is discriminated against so that plant structural carbon is depleted of ^{13}C relative to atmospheric carbon dioxide (Farquhar & Richards, 1984). This ratio of ^{13}C to ^{12}C is expressed as a $\delta^{13}C$ value, reflecting the ^{13}C discrimination during photosynthesis and the $\delta^{13}C$ value of carbon dioxide assimilated by the plant (Farquhar *et al.* 1982). The concentration of atmospheric carbon dioxide has, however, fluctuated throughout history and this must be taken into account during stable isotope analysis. For this reason $\delta^{13}C$ values are converted into $\Delta^{13}C$, which reflect the carbon isotope discrimination independent of atmospheric carbon dioxide concentrations (Farquhar *et al*. 1982; 1989; Wallace *et al*. 2013). This is calculated following Farquhar *et al*. (1982):

$$\Delta‰ = \frac{\delta^{13}C_{air} - \delta^{13}C_{plant}}{1 + \delta^{13}C_{plant}/1000}$$

The degree to which ^{13}C is discriminated against during photosynthesis is closely related to plant water stress. During periods of adequate water availability the stomata on plant leaves will be open, allowing both the release of water through transpiration and the maximum assimilation of carbon dioxide. Thus, when water is easily obtainable the discrimination of ^{13}C is at its highest and when measured, isotope ratios of ^{13}C appear depleted (Wallace *et al*. 2013). By contrast, during periods of water

stress, the stomata will respond to chemical signals produced by dehydrating roots and close to prevent water loss (Chaves *et al*. 2002). This will additionally decrease carbon dioxide assimilation rates in photosynthetic leaves due to reduced photosynthetic metabolites and enzymes activity (Lisar *et al*. 2012). Instead, plants rely on intracellular carbon dioxide for a greatly diminished photosynthetic rate. In periods of drought stomata can be closed for long periods of time, ^{13}C discrimination will not occur and measured isotope ratios appear less depleted. It is this particular response to water stress and the resultant variable ^{12}C: ^{13}C ratios that allow carbon stable isotope analysis to be used as a proxy for crop water availability during plant growth. Similarly, when considered alongside climatological factors such as rainfall, carbon stable isotope ratios can be used to indicate the use of artificial watering techniques and irrigation within the archaeological record.

To date there have been a number of studies on the relationship between stable carbon isotope ratios and water availability using both modern crop remains and archaeobotanical plant remains (e.g. Araus & Buxó, 1993; Araus *et al*. 1997; 1999; Ferrio *et al.* 2005; Aguilera *et al*. 2008 Fiorentino *et al.* 2008; Riehl *et al*. 2008; Wallace *et al.* 2013; 2015). Some of these studies have focused on using stable carbon isotope ratios to identify palaeoenvironmental conditions for plant growth in the Near East and Mediterranean regions (e.g. Ferrio *et al.* 2005; Riehl *et al.* 2008; Fiorentino *et al*. 2008; Caracuta *et al.* 2012), and to distinguish seasonal climatic instabilities and drought. More applicable for this study, however, has been the work completed on past agrarian practices and the use of artificial watering by Wallace *et al*. (2013; 2015). These modern experimental studies were performed on crops grown in locations throughout the Mediterranean and Near East and in a range of both rainfed and irrigated conditions. The results of this study have shown that stable carbon isotope analysis can be used to

infer watering conditions directly from the remains of ancient cereal grains and pulses. This work has, however, also shown that the use of artificial water inputs and the resultant elevation of $\Delta^{13}C$ values are variable depending on the crop species and between individual years. Experimental research on present-day crops has shown that hulled barley has a $\Delta^{13}C$ of c. 1-2‰ higher than wheat grown in the same watering conditions, due to its greater use of reserve carbohydrates during the grain filling period (Anyia *et al*. 2007; Wallace *et al*. 2013). Barley is thought to finish photosynthesis earlier in the growing year, therefore avoiding the driest parts of the summer (Araus *et al*. 1997). This differs by variety, however, as two-row barley has $\Delta^{13}C$ of c. 1‰ higher, whilst six-row barley has an even greater offset of c. 2‰ higher relative to wheat $\Delta^{13}C$ values (Flohr *et al*. 2011; Stokes *et al*. 2011). The effects of artificial watering on glume wheat $\Delta^{13}C$ values are less well reported on, as the experimental work needed has not yet been completed (Wallace *et al.* 2015). There have been a number of studies comparing $\Delta^{13}C$ values for the grain of glume wheat and free-threshing wheats grown in the same watering conditions (Heaton *et al*. 2009; Khazaei *et al.* 2009; Konvalina *et al*. 2013), but these studies have reported a range of discrepancies between the species (between 0.3‰-2‰) and were completed in different climatic regions. Due to the narrow discrepancy margin, however, and the fact that many recent stable isotopic studies have analysed glume wheat and free-threshing wheat material, it has been assumed that both wheat species will have similar isotopic values (Bogaard *et al.* 2013; Vaiglova *et al.* 2014a; Wallace *et al*. 2015; Styring *et al*. 2017).

From these determinations Wallace *et al*. (2013) have proposed a set of watering bands as a means of inferring the relationship between watering status and $\Delta^{13}C$ values (see **Figure 3.1**). These bands divide $\Delta^{13}C$ values into three broad categories: well-watered, moderately watered and poorly watered, but also include the offset between

wheat and barley discussed above. Well-watered crops are those grown in conditions where water is not a limitation on plant growth. By contrast poorly watered crops are those grown in conditions which pose major restrictions on plant development. One of the major limitations to these watering bands and to the analysis of carbon stable isotope values in general, however, is the inability to factor topographic features into the model unless the specific location of the fields are known. Work by Bogaard *et al*. (2016a) has shown that slope gradient and proximity to the base of a slope can have an impact on cereal $\Delta^{13}C$ values. In this study of modern fields in Provence, southern France, it was shown that steeply sloping fields were generally associated with lower $\Delta^{13}C$ values, indicating 'drier' conditions, suggesting that these fields were subject to greater levels of water run-off. This consideration must, therefore, be taken into account when interpreting the use of artificial watering from carbon stable isotope values.

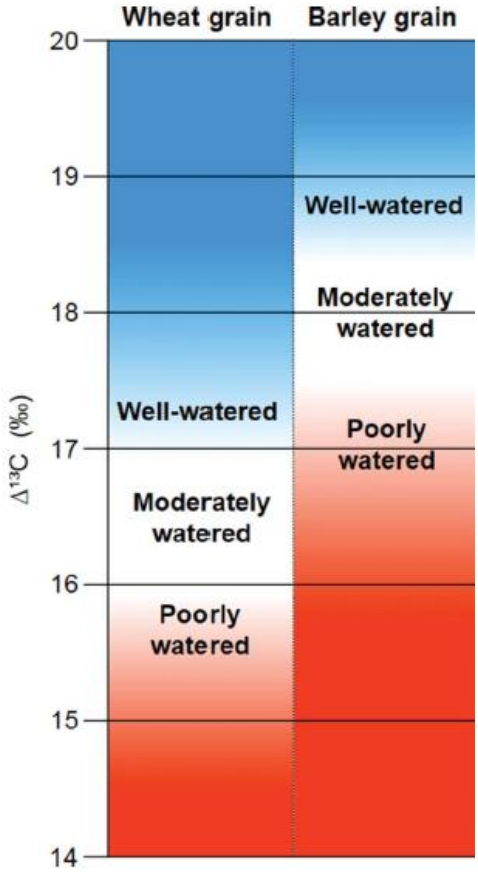


Figure 3.1 - Diagrammatic representation of the watering bands hypothesized by Wallace *et al*. (2013) showing water availability against $\Delta^{13}C$.

3.3.1.2 Nitrogen stable isotope analysis

There are two stable isotopes of nitrogen: ^{14}N and ^{15}N. Of the two, ^{14}N is the most common, making up 99.634% of all the nitrogen on earth, whilst the heavier isotope, ^{15}N, comprises the remaining 0.366%. Nitrogen is of vital importance to plant growth and development because it is a major component of chlorophyll, the compound which allows plants to photosynthesize. It is also a key part of amino acids which form a significant element of plant protein. In this respect, plant growth can be greatly enhanced or limited due to the amount of nitrogen present in the soil during early development. Soil nitrogen quantities are very variable, however, due to the number of biogeochemical processes taking place in the nitrogen cycle as nitrogen circulates from atmospheric to terrestrial ecosystems.

In order for plants to use atmospheric nitrogen (N_2) it must first be fixed into the usable form of ammonium (NH_4^+). This is mostly achieved by diazotroph bacteria (Moir, 2011) using the nitrogenase enzyme to combine N_2 with hydrogen (H) to produce ammonia (NH_3). Ammonium ions can then be formed in low pH conditions by the protonation of ammonia. Plants, such as the cereal crops, rely on nitrifying bacteria (e.g. *Nitrosomonas*) in the soil to convert ammonia and ammonium into nitrites (NO_2^-) and nitrates (NO_3^-) in a process known as nitrification. Cereals are then able to absorb nitrogen in these forms from the soil. Nitrogen can also be lost from the soil through denitrification (Knowles, 1982). During this process nitrites and nitrates are converted back into nitrogen gas by denitrifying bacteria (e.g. *Pseudomonas*). This is particularly common in waterlogged soils, due to the anaerobic conditions present in these environments. By contrast, some species of bacteria (e.g. *Rhizobium*) are commonly involved in a symbiotic relationship with plants from the *Leguminosae* family, producing ammonia in exchange for carbohydrates (Raven *et al*. 2005). Legumes are,

therefore, referred to as 'nitrogen-fixing' as they are capable of producing their own usable nitrogen as well as increasing the nitrogen content of deficient soils.

With regard to the study of stable isotopes, the ratio of ^{14}N:^{15}N ($\delta^{15}N$) in cereals is measured to infer potential levels of enrichment within the soil. Although the $\delta^{15}N$ of soil can be affected by a number of different factors (e.g. denitrification, waterlogging), other crop husbandry activities, such as manuring, have also been shown to change $\delta^{15}N$ values (Bogaard *et al*. 2007; Fraser *et al*. 2011; 2013). This is because the application of manure leads to the enrichment of the soil with the heavier nitrogen isotope (^{15}N), as much of the lighter element (^{14}N) is volatised into the air as ammonia (Bogaard *et al*. 2007). The ammonium still present within the soil is then converted into nitrates, as described above, which are used by the crops, enriching them in ^{15}N also (Heaton, 1987). The measurement of the $\delta^{15}N$ values of charred plant remains, therefore, can indicate the presence of artificially enriched soils, and the potential use of manuring within a farming system (Fraser *et al*. 2011).

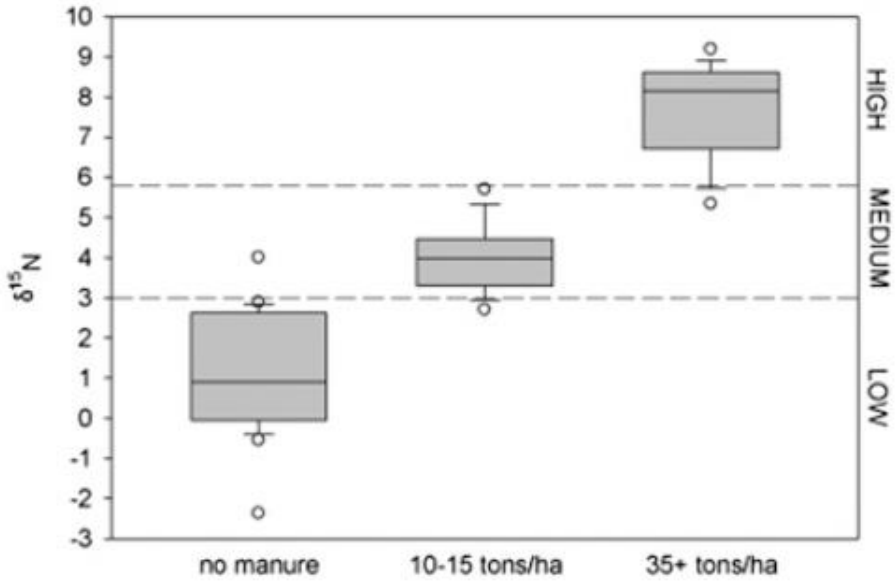


Figure 3.2 - Graphical representation of manuring bands from Bogaard *et al* (2013) showing manuring rates against $\delta^{15}N$.

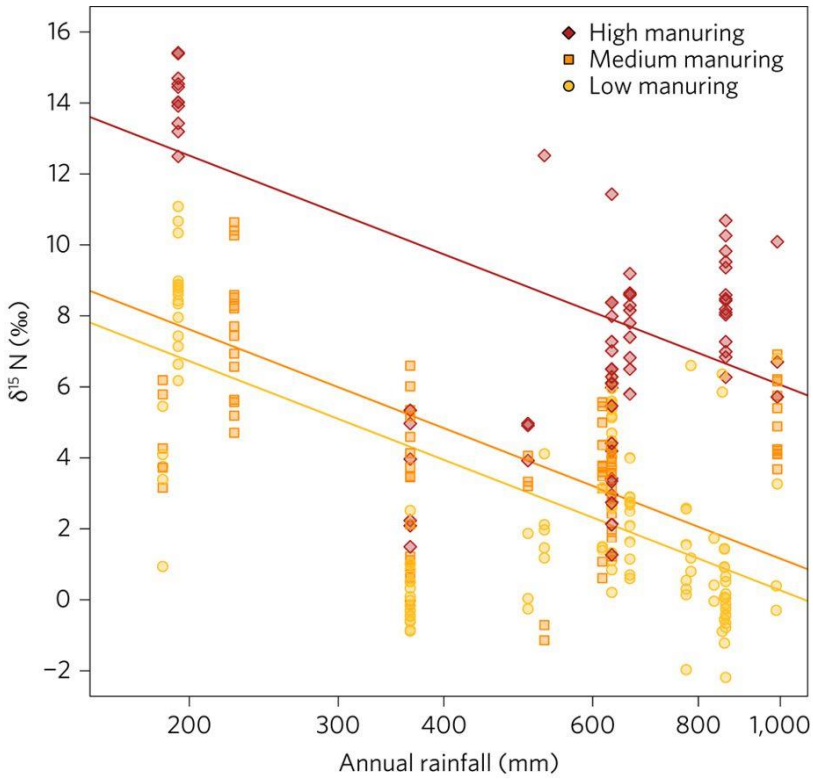


Figure 3.3 – Modern cereal grain $\delta^{15}N$ values plotted against the natural log of past mean annual rainfall from Styring *et al.* (2017), colour coded by manuring level.

A series of modern studies, conducted in temperate Europe and Morocco, have ascertained that the application of manure can raise the $\delta^{15}N$ values of soils and cereal crops by as much as 10‰ (Fraser *et al.* 2011; Styring *et al.* 2016a). These enrichment levels are closely linked to the frequency and quantity of manuring as well as what type of manure is being applied (i.e. animal manure, midden material). Bogaard *et al.* (2013) have also developed a set of manuring bands (based on modern studies) to indicate the intensity of manuring on cereal crops (see **Figure 3.2**).Within this model $\delta^{15}N$ values below 2‰ would indicate that no manure had been applied to the field within the last three agricultural cycles. Values between 2-6‰ suggest medium manuring (<20 tonnes/ha) and values above 6‰ signify intense manuring (c. 30+ tonnes manure/ha). Plant $\delta^{15}N$ values can, however, be elevated further by aridity and it is important to take

this into account when inferring relative manuring intensity (Handley *et al*. 1999; Hartman & Danin, 2010). As a means of countering the impact of aridity Styring *et al*. (2016; 2017) used the work completed by Hartman & Danin (2010) on modern plant $\delta^{15}N$ values and estimates of past rainfall to adjust the manuring bands (see **Figure 3.3**). These altered bands allow more accurate estimates of manuring intensity in semi-arid regions and particularly in northern Mesopotamia (Styring *et al*. 2017).

3.3.2 Functional weed ecology and the functional interpretation of botanical surveys (FIBS)

The analysis of the weed material from an archaeobotanical assemblage can be used to make a number of inferences associated with crop husbandry such as sowing and harvesting times, the use of weeding, hoeing and crop rotation. Weed species have different ecological requirements and preferences, with the prominence of certain weed species at a particular time and place reflecting the nature of the crop husbandry regime under which they grew (Jones, 2002). Thus, the ecology of weeds identified from archaeological samples can be used to reconstruct ancient crop husbandry regimes. A key assumption to this approach, however, is that present-day arable weeds have the same ecology as arable weeds from the distant past. This is probably not the case in every circumstance as some habitats and ecological preferences may have changed over time (Hillman, 1981). These problems can be reduced, however, by using groups of weed species as the unit of analysis as it is unlikely that all weed species will have been through the same changes (Jones, 1992). There have been a number of approaches to weed ecology including phytosociology, Ellenberg numbers and the Functional Interpretation of Botanical Surveys (FIBS), each of which will be discussed below.

Phytosociology seeks to classify stands of vegetation into plant communities based on the occurrence of 'character species' (Westhoff & van der Maarel, 1973; Jones, 1992). These species occur either exclusively or primarily within a specific habitat allowing the classification of the vegetation stand into this particular environment. This approach is of limited use within archaeobotanical analysis, however, as it relies on the assumption that these phytosociological plant communities have not changed throughout history, a fact that appears unlikely (Hillman, 1991; Jones, 1992). Moreover, as mentioned above, the formation of the archaeobotanical record often incorporates multiple harvesting and processing events, implying that individual samples cannot be used to represent one single plant community or environmental condition. Instances where phytosociology has been used in archaeobotanical analysis tend to be far more generalized, using 'character species' as indicators of much broader ecological conditions. For example, Jones (1992) uses the phytosociological classes of Secalinetea and Chenopodietea to indicate 'field-type' and 'garden-type' weeds. In both of these classes, the wide range of weed species represented encompass a much larger geographic range and are, therefore, less likely to be affected by singular environmental changes over time. Even within these more generalized analytical classes, however, some issues of equifinality still arise due to the reliance placed on data gathered through field observation. Denoted plant classes can only be used to address the location of where a weed species is found, rather than analysing aspects of the environment which caused it to grow there in the first place (Jones, 1992; Charles *et al*. 1997). For example, when analysing arable weeds it can be impossible to tell whether a phytosociological class is present because of underlying habitat conditions or because of a specific crop husbandry technique such as manuring or artificial watering (Jones, 1992).

Another approach to weed ecology is the use of Ellenberg numbers (Ellenberg, 1950; 1979) which use a series of scales for environmental variables (i.e. light, temperature etc.) to infer soil fertility and moisture levels. Unlike phytosociology, Ellenberg numbers are based on the ecological preferences of individual species, rather than groups of plants, assigning each species with 'indicator values' that relate to a specific aspect of the environment (Jones, 1992; van der Veen, 1992). It also reduces the problem posed by the potential mixing of weeds from varying habitats within the archaeobotanical record. In this respect, samples containing weeds with very different 'indicator values' would suggest the integration of remains from multiple habitat sources or environmental conditions. The use of Ellenberg numbers within archaeobotanical analysis has, however, been limited due to the fact that the data used to construct the environmental scales was gathered primarily from Central Europe, limiting the extent to which they can be used in other climatic areas of the world (Bogaard, 2002). Additionally, like phytosociology, Ellenberg numbers were based on data from field observations, preventing the assessment of which ecological factor has determined the existence of weed species in that specific location (Charles *et al*. 1997).

In order to use weed remains to identify ancient environmental conditions or precise crop husbandry practices, therefore, Jones (2002) points out that it is necessary to consider the ecological principles underlying weed species distribution and to identify relevant characteristics that enable species to thrive under particular conditions. The use of functional plant ecology[8] consequently, is based on the measurement of the 'functional attributes' of weeds, allowing distinct ecological factors to be monitored independently (Charles *et al.* 1997; Bogaard *et al.* 1999; 2001; 2016a; 2016b; Jones *et al.* 2000; Jones, 2002; Bogaard, 2004). This technique was developed at the Unit of

[8] This used to be referred to as the 'Functional Interpretation of Botanical Surveys' (FIBS).

Comparative Plant Ecology at the University of Sheffield as a means of investigating the impact of ecological processes on species' distribution (Hodgson, 1989; 1990; Hodgson & Grime, 1990; Hodgson *et al*. 1999; 2017), but has since been used and developed further as part of the ERC-funded AGRICURB project at the University of Oxford (Bogaard *et al*. 2016a; 2016b). As part of this technique information from modern field surveys as well as behavioural and morphological plant traits such as specific leaf area, stomatal density and canopy height are measured and then correlated with environmental conditions such as; moisture content, soil disturbance and fertility. For example, the density and size of stomata on an individual plant leaf reflects that species' tolerance for dry conditions. Similarly, mean specific leaf area, leaf thickness and canopy height, are related to the growth rate of the plant and may indicate the fertility of the soil it is growing in (e.g. Bogaard *et al.* 2001; Jones, 2002). In this respect, it is the functional characteristics of each plant rather than the plant itself which are associated with a particular crop husbandry technique.

This is the major advantage of using functional ecology in archaeobotany over phytosociology or Ellenberg numbers, as it is not reliant on species preferences or plant groupings within the field, but rather on the functional attributes of individual weeds. By understanding the relationship between functional attribute and plant growth this technique can be applied to archaeobotanical weed assemblages regardless of whether modern weed surveys have been undertaken in the region (Charles *et al.* 1997). This factor is essential to the study of ancient crop husbandry as it allows the use of modern weed data from different climatic regions[9] to classify ancient weed data on the basis of functional traits. Archaeobotanical weed remains can then be categorized using

[9] Modern weed surveys were undertaken by the University of Sheffield and the University of Oxford in areas which still utilize traditional farming techniques and husbandry methods. These areas included Asturias in northern Spain, Evvia in Greece, Provence in southern France and a variety of agricultural regions in Morocco (Jones *et al.*1999; 2000; Bogaard *et al*. 2016a; 2016b).

discriminant analysis as characteristic of either high or low intensity farming regimes (Bogaard *et al*. 2016a; 2016b, Styring *et al*. 2017).

The application of functional ecology to arable weed taxa has also been used to estimate crop sowing times (Bogaard *et al*. 2001). Previous studies have used the germination time of weed species to infer the initial crop sowing period, for example spring-sown crops are generally dominated by spring-germinating weed species (Ellenberg, 1950). The use of techniques such as hoeing and hand-weeding, however, can bias arable weed assemblages as they systematically remove germinated weed species and confuse overall weed signals. The incorporation of other functional attributes such as flowering onset and flowering duration can help to distinguish crop sowing times within intensive agricultural systems. In an ethnobotanical study of modern weed survey datasets from Germany, Bogaard *et al*. (2001) found that autumn-sown crops were associated with weed species which had a short flowering period (>3 months), whilst spring-sown crops were associated with long-flowering species (>5 months) and/or species with a late flowering onset (e.g. from July onwards). These attributes could then be applied to archaeobotanical assemblages as a means of assessing the potential crop sowing period. This method, however, has one major limitation due to the fact that the original ethnographic research was undertaken in temperate Europe. In order to apply this methodology to archaeobotanical assemblages from the Near East, therefore, the categories for flowering onset must be adapted to reflect the fact that the harvest period falls earlier in the year within these areas.

Despite its advantages over other approaches functional ecology is, however, subject to several limitations and these must be taken into account when using it as an interpretative tool. Firstly, weed functional attributes are mainly based on locally collected attribute data, meaning that weeds represented in more than one study do not

necessarily have exactly the same values in each area (Jones *et al*. 2010). Furthermore, there are limits to the amount of modern survey data that can realistically be collected within each study area and consequently the interpretations that can be made with this data.

Chapter 4

Methods

This chapter will detail the specific methods followed when recovering, selecting and analysing archaeobotanical assemblages. Firstly, it will explain the protocol used for the onsite recovery of material at both Hattusha and Tell Brak. Secondly, it will specify how archaeobotanical samples were chosen for further study before describing identification and quantification techniques used for primary analysis. Finally, it will detail the analytical methods used, crop stable isotope analysis and functional ecological analysis, as a means of assessing the use of various crop husbandry methods.

4.1 Sample recovery

The archaeobotanical samples analysed as part of this research come from two unique archaeological sites that have been subject to diverse excavation methodologies. This is partly due to the nature and location of each site and also due to the time period when the sites were excavated. Recent excavations have benefited from innovations in archaeological practice and technique and this is reflected in the methods used for sample recovery. Procedures for environmental sampling have, therefore, been reported on an individual basis as a means of fully identifying potential sources of recovery bias.

4.1.1 Hattusha

Bulk archaeobotanical samples from the Hattusha underground silo were initially taken from each of the five excavated chambers. Each chamber was divided up using a grid system (Seeher, *pers comm*) and samples were taken from each gridded square as a means of establishing compositional heterogeneity across each chamber. Additionally, each chamber was excavated using a number of arbitrary spits (c. 20cm in depth), and samples were taken from all of these levels to explore any variation by depth within each chamber (Diffey *et al.* 2017). Due to the unique nature of preservation and the sheer quantity of material discovered in the underground silo at Hattusha, charred plant remains were recovered directly and without the need for flotation. A total of four tonnes of charred archaeobotanical material was removed from the five chambers. This included the charred grain itself and straw insulation material found as both phytoliths and charred macrobotanical remains. From these four tonnes of material, about 50kg of the most well-preserved samples were eventually selected for export to the Deutsches Archäologisches Institut in Berlin (Diffey *et al.* 2017). This material provided both a vertical and horizontal cross-section of all five chambers. The remaining material was then re-buried or kept at the Hattusha dig-house in Turkey (Seeher, 2006: 46-47).

Table 4.1 - The number of samples studied from Hattusha, by chamber.

Chamber	No. of Samples
12	12
28	1
29	7
30	19
32	6
Total	**45**

4.1.1.1 Hattusha sub-sampling and scanning

Initial sub-sampling, scanning and preliminary identification of some Hattusha material was undertaken in 2000 by Reinder Neef from the Deutsches Archäologisches Institut in Berlin. In total Neef (2001) studied 35 samples from four different burnt chambers in the silo (see **Table 2.3**). Neef first randomly sub-sampled down each sample to c. one litre of charred material using a riffle box (cf. van der Veen and Fieller 1982). This was then split further into 1mm and 0.5mm fractions using geological sieves before scanning and identification. As part of this project at the University of Oxford a further 10 samples were selected for analysis and were chosen primarily from chambers that were underrepresented within the assemblage. Again these samples were first sub-sampled, riffled and split into 2mm, 1mm and 0.5mm fractions using geological sieves. Based on the preliminary identification and quantification work done by Neef, the target of >600 identifiable items (500 crop items and 100 seeds of potential arable weeds) from each sample was set. This number of crop and weed items should provide sufficient evidence for sample richness and represent the range of items present within both components of the total sample (cf. van der Veen and Fieller, 1982).

It quickly became apparent that with the exception of two samples, this target would be easily achievable and that further sub-sampling would be needed. Samples were, therefore, first separated into 4mm, 2mm, 1mm and 0.3mm fractions using sieves, and depending on the size of the sample, were randomly sub-sampled using a riffle box. This resulted in fractions estimated to contain c. 600 identifiable items (500 crop items and 100 seeds of potential arable weeds), prior to sorting by microscope. In total, 45 samples from Hattusha were incorporated into this study. These samples came from five burnt chambers within the underground silo and from a range of excavated arbitrary spits within each chamber (see **Table 4.1**).

4.1.2 Tell Brak

Soil samples were taken systematically from every undisturbed archaeological unit from Area TC, resulting in 85 fully processed archaeobotanical samples. Areas with a high concentration of botanical remains were systematically sampled at small intervals to aid the analysis of spatial variation within the assemblage (Emberling & McDonald, 2001). Additionally, visible concentrations of charred plant material were collected without the need for flotation. With regards to the flotation samples, however, an initial 60 litres of soil was taken from each unit or the entire unit if it was smaller than this. Soils were sampled and dry-sieved on site using a mesh with a 1cm aperture. This generally resulted in a flotation sample of 30-40 litres which was processed using a flotation machine based on the French design (French, 1971). All floating material (flot) was collected using 1mm and 0.3mm sieves and the heavy residue was retained using a 1mm mesh.

After flotation half of the heavy residue was discarded unless it was observed to contain visible concentrations of fishbone or charred plant material. The remaining heavy residue was then dried and split into random eighths using a large riffle box. One eighth of the residue was then further split by being sieved though 5mm and 1mm sieves. These fractions were entirely sorted on site for charred plant remains, pottery, bone, chipped stone and other archaeological objects. All remaining residue was stored for future study. Correspondingly, after the flots had been dried, they were bagged for export. All standard size flots were exported wholesale, and large flots (3-4 litres) were split down to c. 1-2 litres for export to the UK for further study.

4.1.2.1 Tell Brak sub-sampling and scanning

After export, all samples were briefly scanned to assess sample richness and the diversity of plant remains (Emberling & McDonald, 2001). From this evaluation 25 samples were chosen for part of a preliminary study undertaken by Mette Marie Hald at the University of Sheffield (Charles & Hald in Emberling & McDonald, 2001). These samples were determined by the abundance of charred remains in each sample and the range of species represented. A target of 300 identified cereal grains was set and due to the richness of the assemblage most samples had to be split down into smaller fractions using a riffle box. This fraction was then sieved through a 1mm and 0.3mm sieve, although only the 1mm fraction was looked at as part of this initial study. As part of this project at the University of Oxford, a further 33 samples were chosen for full identification and analysis. These samples were selected due to their apparent archaeobotanical richness and also because of their contextual provenance within Area TC.

The initial 25 samples studied by Hald were mainly taken from two rooms within the Temple Oval, Room 16 and Room 17 (Emberling & McDonald, 2001). The additional 33 samples, therefore, were also chosen as they encompassed a greater number of rooms, providing evidence for different activities and depositional events with Area TC. As with the previously analysed samples from Tell Brak, a target of c. 300 cereal grains was set, the lack of weed seeds in this assemblage meant that a target number of potential arable weeds was not set. Samples were first sieved through a 4mm, 2mm, 1mm and 0.3mm stack of sieves and then riffled to extract an appropriate sub-sample. In addition to this, the 0.3mm fractions from the 25 samples analysed by Hald were also riffled and scanned. In total, 58 samples from Area TC were examined for this study. These samples were taken from 10 different rooms within the Temple Oval

building with the majority of samples originating from Room 12 and Room 16 (see **Table 4.2**).

Table 4.2 – The number of samples studied from Tell Brak, by room.

Room No.	No. of Samples
4	1
6	1
8	5
9	2
12	12
13	1
16	27
17	4
18	1
Ncy	3
Unknown	1
Total	**58**

4.2 Sorting and identification

All samples from Hattusha and Tell Brak were sorted and identified at the University of Oxford using a Nikon stereomicroscope (x7-80). This included the re-analysis of plant remains from all of the samples from these sites that had previously been worked on by other scholars so that a formal identification criterion could be standardised and corrected across all sites. Plant items were identified using comparative modern material from the reference collection in the School of Archaeology and relevant published sources. This included a number of seed atlases

(Berggren, 1969; 1981, Cappers *et al.* 2009; 2012, Neef *et al*. 2012), archaeobotanical publications (e.g. Jacomet, 1987; 2006, Nesbitt, 1993; 2006, Jones *et al.* 2000) as well as seed descriptions in the Flora of Turkey (Davis *et al*. 1965-88), the Flora of Iraq (Guest, 1966, Townsend & Guest, 1966; 1968; 1974; 1985) and the Novelle Flore du Liban et de la Syrie (Mouterde, 1966). The Latin nomenclature for all crops follows Zohary *et al*. (2012) and for wild species: Davis *et al*. (1965-88) and Guest (1966-1985). Plant authorities will be stated on the first mention of each species within the text.

At both sites, most of the plant remains were preserved through charring, with the exception of *Buglossoides* sp. (Boraginaceae) which are naturally calcareous and can survive without charring (Pustovoytov *et al*. 2004). It is, therefore, difficult to ascertain whether seeds of this species were ancient or modern, although the presence of charred *Buglossoides* sp. in the Hattusha assemblage would seem to confirm that they were contemporary with the rest of the material.

The crops from both the Tell Brak and Hattusha assemblages were in general, common species of cereals and pulses with well-defined identification criteria (e.g. Jacomet, 2006; Zohary & Hopf, 2012). There were two main exceptions to this rule; firstly, at Tell Brak small-grained varieties of hulled barley and glume wheat were identified from a number of samples within the assemblage. The categorization of these small-grained cereals as either tail grains of the main hulled barley and emmer wheat crops or as a unique variety of these crop species will be explored further with reference to crop processing (see **Section 7.10**, **Chapter 7**) and crop stable isotope analysis (see **Sections 8.2** and **8.3**, **Chapter 8**). The second exception was the identification of 1-grain *Triticum dicoccum* (emmer wheat) within the Hattusha silo assemblage, as both complete spikelets and loose grains. The presence of this type of emmer wheat became

apparent after the identification of intact emmer wheat spikelets that contained only one grain, rather than the usual two grains. In modern wheat specimens 1-grain spikelets occur at the terminal end of the ear, and consequently are referred to as the terminal spikelet (Nesbitt, 1993). In terms of identification, the rachis of these terminal spikelets is rotated 90° relative to the glume base, there is no ventral scar on the spikelet form and only one grain develops within the glumes due to the lack of growing space. Morphologically the actual grain is very similar to the 2-grain examples, although 1-grain grains tend to have a more convex ventral face (due to the absence of lateral pressure from another developing grain) and are often slightly longer than 2-grain grains (Martinoli & Nesbitt, 2003).

Archaeologically, examples of 1-grain emmer have been identified – based on the convexity of the ventral face of the grain – on a number of sites in Turkey, such as Neolithic Höyücek in south-west Turkey and Kaman-Kalehöyük in central Turkey (Nesbitt, 1993; Martinoli & Nesbitt, 2003). The number of actual 1-grain grains identified, however, has been very low and accordingly made up around only 2% of each assemblage (Martinoli & Nesbitt, 2003), leading to the assumption that these grains originated from the terminal spikelets of emmer wheat ears. By contrast, the number of 1-grain emmer spikelets identified from within the Hattusha silo complex was relatively high, outweighing the number of 2-grain spikelets in a 3:1 ratio. This factor coupled with the presence of a ventral scar on the spikelet fork led to the conclusion that these spikelets could not all be terminal spikelets, but instead must represent emmer wheat spikelets in which only one grain had developed, perhaps due to specific growing conditions. Upon disarticulation, it was observed that the 1-grain grains from these spikelets complied generally with identification criteria suggested by Nesbitt (1993), although a number of examples also appeared very thin and slightly

shrivelled. From these grains, and from a number of disarticulated 2-grain spikelets, a series of criteria were created to aid in the identification of 1-grain and 2-grain emmer wheat grains where these were not preserved within the spikelet. In many cases, however, variable charring effects within each chamber and particularly between chambers meant that the observable differences between the grains were so subtle that a large number of emmer wheat grains had to be categorized as indeterminate. Finally, due to the lack of concrete morphological difference between 2-grain and 1-grain emmer wheat grains these categories have been merged together for the purposes of analysis.

In terms of the identification of weed/wild taxa, the plant remains from the Hattusha and Tell Brak assemblages were first divided into family types and where possible genus. Further identification to the species level was then attempted on types which occurred in over 10% of all samples within each assemblage. Specific identification criteria for the weed/wild taxa used in later analyses is presented in the weed catalogue.

4.3 Quantification

The quantification of plant items was achieved using a specific set of criteria to ensure that individual plant parts were not counted more than once and that the total number of represented species was not over-estimated. The minimum number of individuals (MNI), a standardised count of plant fragments, was used initially to record the amount of identified charred plant remains for all samples in each assemblage. MNI was calculated in each case by counting easily identifiable diagnostic plant item areas (Jones, 1991) to make sure that broken or distorted seeds were not counted more than

once. With regard to cereal grains, both embryo and apical ends were recorded separately but only the most abundant category was used to determine the final grain total. Similarly, for glume wheat chaff each glume base was scored individually, and spikelet forks were recorded as two glume bases. The Hattusha silo assemblage also contained fully intact glume wheat spikelets. In order to make these values comparable both within the Hattusha assemblage and with other archaeobotanical assemblages all glume wheat spikelets were 'deconstructed' into their constituent parts. In this respect, each 2-grain emmer wheat spikelet was counted as two emmer wheat glume bases and two emmer wheat grains, whilst each 1-grain emmer wheat or einkorn wheat spikelet was counted as two glume bases and one grain each. Barley and free-threshing wheat rachis internodes were counted individually based on the presence of the top of the internode. Correspondingly, culm nodes from cereal straw were also counted individually.

The quantification of pulse species proved more problematic than that of the cereals. In most cases, the simplest means of assessing the total number of pulse seeds would be to score two separated cotyledons as one whole seed, and this was accomplished wherever possible. A large number of the pulse remains from Hattusha, however, had been damaged during the recovery process. This meant that many samples contained large quantities of tiny pulse fragments and the establishment of an MNI was very difficult. Ultimately, the total number of pulses was calculated by estimating the number of pulse fragments that would be required to make up one whole pulse seed. Similarly, with regard to fruit and nut species identified in both assemblages, where seeds/nuts had completely fragmented and the embryo was not visible (e.g. *Vitis* sp., *Pistacia* sp. and *Prunus* sp.) an MNI was estimated.

Seeds from wild or weed taxa were largely scored individually even when fragmented, except for when it was clear that broken fragments belonged to the same seed (cf. van der Veen, 1992). With regard to wild grass seeds and chaff the same criteria applied to the quantification of cereal grains and chaff was used to calculate an MNI. In some wild taxa, such as *Polygonum* sp., *Bunias orientalis* L., *Boreava aptera* Boiss. & Heldr., *Caucalis platycarpos* L. and *Turgenia latifolia* L., the inner core/seed was often identified separately from its outer shell. In each case, the inner core/seed was scored separately from the outer shell to avoid the duplication of these specific species.

Finally, although rare in both the Tell Brak and Hattusha assemblages, all wood charcoal found in the 4mm and 2mm sieve fractions was quantified by volume (ml). This approach was selected for consistency with earlier archaeobotanical studies at Tell Brak that had used this quantification method (Charles & Bogaard, 2001; Charles & Hald in Emberling & McDonald, 2001; Colledge, 2003).

After the initial quantification stage was completed data were standardized so that all samples from each site were comparable with each other. Firstly, the total number of plant items was calculated for each sample by adding up scores from each sieved fraction and from heavy residues (where these were present). In cases where flots had been sub-sampled, the scores for the sample fraction were multiplied to 100%, or to their highest sorted fraction. Exceptions to this rule were sub-samples that would have had to have been multiplied by more than eight to reach 100%. In these cases, the highest sieve fractions were divided down so that all sample fractions were comparable. Also, where the volume of floated soil was known, the density of plant remains per litre was calculated. This was not possible for the Hattusha assemblage as no soil was recovered from the silo and plant remains density was 100%.

4.4 Amalgamation and reassignment of taxa

In order to allow for comparisons between samples from each assemblage and the use of further statistical analytic techniques, some categories of identified taxa were amalgamated where it was thought likely that categories concerned all came from the same taxon. This was done to prevent preservational differences between samples, rather than differences in species composition, being picked up during the analysis (Valamoti, 2004). Firstly, all cf. categories containing items that could not be fully identified due to preservation conditions, but that strongly resembled one particular taxon, were amalgamated with remains from that taxon that had been positively identified within the same sample. If no items of a cf. category had been fully identified, these items would remain as a cf. classification. All amalgamated cf. wild taxa are listed in **Table 4.3**.

With regards to the identification of crops, there was a portion of material from all sites that could not be identified to the species or variety level due in part to the effects of charring, but also to poor preservation conditions. These remains were, therefore, categorized in broad indeterminate classes, such as glume wheat indeterminate and pulse indeterminate. So that these items could be included in further statistical analysis, they were proportionally re-assigned using information from positively identified crops within the same sample. For this re-assignment process it was assumed that these indeterminate taxa would have the same proportions as fully identified crops. For example, indeterminate barley grains from the Hattusha silo assemblage were proportionally re-assigned as either 6-row type or 2-row type based on the proportions of each species in the relevant sample. Additionally, it was necessary to proportionally re-assign glume wheat grain and chaff from nine individual samples from the Hattusha silo assemblage, again based on the proportions of each species in the

Table 4.3 – Amalgamated categories of cf. weed/wild taxa

Species category	Amalgamated category
Boreava cf.	*Bunias/Boreava cf.*
Bunias cf.	
Brassica cf.	*Brassica cf. nigra*
Brassica cf. nigra	
Caucalis cf.	*Caucalis platycarpos*
Caucalis platycarpos	
Chenopodium cf.	*Chenopodium cf. album*
Chenopodium cf. album	
Conringia cf.	*Conringia orientalis*
Conringia orientalis	
Gypsophila cf.	*Gypsophila cf. pilosa*
Gypsophila cf. pilosa	
Lolium cf.	*Lolium persicum*
Lolium persicum	
Neslia cf.	*Neslia paniculata*
Neslia paniculata	
Ranunculus cf.	*Ranunculus arvensis*
Ranunculus arvensis	
Sinapis cf.	*Sinapis cf. arvensis*
Sinapis cf. arvensis	
Thlaspi cf.	*Thlaspi arvense*
Thlaspi arvense	
Turgenia cf.	*Turgenia latifolia*
Turgenia latifolia	
Vaccaria cf.	*Vaccaria pyramidata*
Vaccaria pyramidata	

relevant chamber. This was required due to the fact that these plant items had been retained by Reinder Neef (*pers comm.*) at the Deutsches Archäologisches Institut for use in future editions of the *Digital Atlas of Economic Plants in Archaeology* (Neef *et al.* 2012). In each case, the total number of grains or glume bases was known and this allowed the reassignment of each plant item based on the relative proportions of fully identified wheat items within the same sample. Where this was not possible, re-assignment was based on fully identified wheat items from samples originating from the same stratigraphical level/arbitrary spit. It should be noted that while taxa were

amalgamated, amalgamation of samples was not necessary for this study as all samples, from both Hattusha and Tell Brak, came from separate excavated spits and grid squares.

4.5 Analytical methods

The analyses undertaken during the course of this research included the use of a number of techniques as a means of answering the research aims laid out in the introduction. These include various methods of compositional analysis including the use of percentage stacked bar charts, alongside other techniques used to explore taphonomic processes such as crop processing.

4.5.1 Correspondence analysis

Correspondence analysis (CA) is an ordination technique used primarily to explore similarities and differences among individual samples by arranging these samples along a set of axes based on species composition (e.g. Jones, 1984a; 1991, Jones *et al.* 1995). By producing two/three-dimensional scatter plots, positive or negative associations between samples or species can be used to identify patterns within the data, some of which are not immediately obvious from the raw data itself. Within this analysis these plots show only the first two axes which generally account for the greater part of inter-sample variability. The centre of each plot, where the two axes cross, is referred to as the origin, and associations between samples are shown by the direction and distance in which each sample diverges from this central point. Samples that cluster together, therefore, have a relatively similar composition whereas samples that diverge in opposing directions from the origin are compositionally distinct from

each other. CA can, however, unduly emphasize the importance of rare taxa, or samples that contain only a small number of items. This produces scatter plots that are skewed by these rare species and unusual samples (Lange, 1990; Jones, 1991). To avoid this problem, samples from the Tell Brak and Hattusha assemblages that contained less than 100 crops items were excluded from CA (cf. van der Veen & Fieller, 1982). Additionally, all significant outlier species were also removed from the analysis in both assemblages, so that variation amongst the most well represented species could be examined.

Within this research four different types of plot have been used as a means of exploring underlying trends in species and sample variation. These include scatter plots of samples and/or species, scatter plots that display the number of taxa contained in each sample and finally, plots in which species have been categorized into groups of taxa, allowing each sample to be represented by a pie-chart. Samples have also been coded by other relevant variables, for example, chamber number and stratigraphic level. Correspondence analysis was carried out using the CANOCO 5 software for Windows 8 (Ter Braak & Šmilauer, 2012). In all diagrams, axis 1 (which accounts for the most variation) was plotted horizontally and axis 2 vertically.

4.5.2 Crop processing analysis

Crop processing analysis was undertaken using three different analytical methods: crop-based analysis, crop and weed-based analysis and weed only analysis. These techniques are all grounded in comparisons made with ethnobotanical research conducted by Jones (1983a; 1883b; 1987; 1990) on the Greek island of Amorgos. Crop processing analysis was initially performed on crop only components of both the

Hattusha and Tell Brak assemblages. Ratios of free-threshing grain species (hulled barley and free-threshing wheat) to rachis components were then calculated and compared with ethnographic data from Jones (1983a; 1987; 1990). The ratios of glume wheat grains to chaff were also calculated but could not be compared with ethnographic data due to the lack of research completed on the processing of these species. Instead, these samples were compared with the expected potential grain to chaff ratio of samples containing complete spikelets. This potential ratio ranges from 0.3-1.5 (Bogaard, 2011) due to the presence of 1- and 2-grain glume wheat species. It also takes into account the charring bias against the survival of glume bases (Boardman & Jones, 1990; Charles *et al*. 2015). Use of this potential ratio, therefore, allows for the identification of glume wheat grain dominated samples, glume wheat chaff dominated samples and samples that may originally have contained intact spikelets but that were destroyed due to the charring process.

Crop and weed-based analysis was completed using triangular plots to compare the relative proportions of grain to chaff to weed seeds of the dominant crop species in each sample (Jones, 1990). This method is based on the assumption that weed seeds present in each sample derive from the arable fields of the dominant crop. In order to establish the dominant crop species, samples were initially classified into groups based on the total number of grain and chaff items present. At Tell Brak, samples were split into four groups: Group 1. Samples containing at least 80% hulled barley remains, Group 2. Samples with less than 80% hulled barley remains but at least 80% hulled barley and free-threshing wheat remains, Group 3. Samples containing at least 80% glume wheat remains, Group 4. Samples with mixed compositions containing remains from all three cereal species. At Hattusha, samples were only split into three groups (Group 2 was removed) due to the lack of free-threshing wheat remains and the

threshold for these groups was lowered to 70% cereal species dominance due to the mixed nature of the underground silo samples. Crop and weed ratios were then calculated for Groups 1 and 2 and these results were compared with ethnographic work by Jones, (1990). Again, however, the comparison of glume wheat dominated samples with the ethnographic research is problematic and must be treated with caution as this work was based on free-threshing cereals. The majority of Group 3 samples from both sites, however, contained only small amounts of glume base material indicating that all samples have been through the fine-sieving processing stage when most glume wheat chaff is removed (Bogaard, 2011).

Analysis based on weed content only was performed on samples from both sites that contained 10 or more weed seeds. This analysis was again based on ethnobotanical research conducted by Jones (1983a; 1983b; 1984a; 1987) to assess the use of weed physiological properties for determining crop processing stage. Weed items were first classified into groups based on size (big or small), aerodynamic qualities (light or heavy) and the propensity for seeds to remain in the head (free or headed). The weed 'size' category was centred on the predicted sieve size aperture used for processing at each site. Ethnographic research has indicated that fine sieve sizes range between 1.5mm-2mm (Jones, 1984a: 1990; Charles & Bogaard, 2001). Weeds were initially classified as big or small using both 1.5mm and 2mm sieve sizes and then compared to understand which taxa would change size class. In the vast majority of cases the use of varying sieve sizes did not change the weed size category for weed/wild taxa, so a sieve size of 2mm was chosen for both assemblages. Weed size was categorised as either big or small, therefore, by determining whether a seed would or would not fit through a sieve with a 2mm mesh size. This was based on visual judgements made whilst examining material in the laboratory and from previous studies of archaeobotanical

material (Jones, 1983b; Charles & Bogaard, 2001; Stroud, 2016). Aerodynamic qualities and 'headedness' were also assessed using visual and morphological research from past studies and from the examination of weed reference material at the University of Oxford. Weed items that had only been identified to family and indeterminate weed categories were excluded due to the lack of morphological information available about these items and the fact that each plant family contains species with overlapping categories. Additionally, *Vicia faba* var. *minuta* and the other pulse species were also removed due to their potential presence as cultivated crops. Discriminant analysis was performed on the resultant weed dataset using SPSS version 24. Discriminant functions were extracted to re-classify the archaeological samples on the basis of Jones' (1983a; 1983b) original ethnographic data. Within this dataset Jones (1983a; 1983b) used the proportions of weed seeds of different physical types to classify each sample as the product of one of the four main crop processing stages: winnowing by-product, coarse-sieving by-product, fine-sieving by-product and fine sieving product. This classification has then been used to re-classify the archaeological samples into these same four categories.

4.6 Crop husbandry analysis

A number of different methods were used to analyse the use of potential crop husbandry techniques at each site. These methods included strategic use of crop stable isotope analysis and the analysis of specific arable weed ecological characteristics, such as functional traits and the broader ecology of specific species.

4.6.1 Carbon and nitrogen crop stable isotope analysis

The analysis of stable isotope values requires a lot of individual steps, each with its own detailed methodology. Each of these stages will be explained fully below and include sample selection, the use of Fourier Transform Infrared Spectroscopy (FTIR) to identify potential sources of contamination, sample pre-treatment, sample analysis and finally the statistical analysis of the raw stable isotopic values.

4.6.1.1 Sample selection – Hattusha

Stable isotope samples were initially chosen from the underground silo at Hattusha as a means of answering a set of questions formulated before the stable isotope laboratory work began:

- Were the cereal crops at Hattusha subject to artificial watering, as inferred from carbon stable isotope ratios ($\delta^{13}C$)?
- Were the cereal crops at Hattusha grown in soils with enriched ^{15}N values, inferred from nitrogen stable isotope ratios ($\delta^{15}N$), suggesting the use of manuring?
- Are there significant differences in the results from the two cereal species analysed indicating the preferential treatment of one over the other?
- Are there significant differences in the results among chambers?
- Can these results be used to support patterns identified independently from the archaeobotanical material and weed functional ecology to infer the use of growing conditions and their range of variation at Hattusha?

This led to the creation of a number of primary criteria used to select samples for stable isotope analysis from the Hattusha assemblage. Firstly, samples were selected from all five chambers as a means of assessing variation in stable isotope values between the chambers. Secondly, from inside each chamber, samples were selected from each arbitrarily excavated spit, to assess potential variation within the chambers themselves. Finally, samples of both wheat and barley were selected to evaluate the differences in growing conditions between the two cereal crops. The species chosen were 6-row hulled barley and 2-grain emmer wheat, as these cereals were the most securely identified at the time.

It was then essential to further refine this sample selection by the number of seeds available in each sample and the overall seed charring condition. Experimental work on plant stable isotope ratios has shown that inter-grain variability within the same cereal ear can range up to 2.0‰ in $\delta^{15}N$ (Bogaard *et al.* 2007) and up to 0.7‰ in $\delta^{13}C$ (Heaton *et al.* 2009). Work by Kanstrup *et al*. (2012) and Nitsch *et al.* (2015) has shown that the homogenization of 10 cereal grains adequately characterised the mean isotopic value, smoothing out inter-grain variability, whilst also destroying the lowest possible number of charred seeds. Samples included in this study, therefore, all contained at least 10 grains of emmer wheat and/or hulled barley. Similarly the temperature at which a seed has been charred and the duration of time at which it has been exposed to heat can cause physical distortions to the seeds (Charles *et al*. 2015), as well has having a significant effect on the stable isotope ratios of both nitrogen and carbon (Braadbaart *et al.* 2004; Fraser *et al*. 2013; Styring *et al.* 2013; Nitsch *et al.* 2015). Experiments carried out on modern cereal grains have shown that within an optimal charring window, temperatures of 215 - 260°C can lead to an increase in $\delta^{15}N$ by 0.05 - 0.57‰ and that charring periods of over 4 hours led to slight increases in both $\delta^{15}N$ and $\delta^{13}C$ (Nitsch *et*

al. 2015). As a means of limiting the effects of charring temperature and duration it was, therefore, crucial to select cereal grains that showed the least amount of physical distortion. In total, 64 samples containing 10 cereal grains each, were selected from the Hattusha silo assemblage for both carbon and nitrogen stable isotope analysis (see **Table 4.4**).

Table 4.4 – The number of samples from the Hattusha assemblage selected for crop stable isotope analysis, by crop species and chamber number.

Chamber	Species	No. of Samples
12	Hulled barley	8
12	Emmer wheat	10
28	Hulled barley	1
28	Emmer wheat	1
29	Hulled barley	4
29	Emmer wheat	5
30	Hulled barley	9
30	Emmer wheat	18
32	Hulled barley	2
32	Emmer wheat	6
Total		**64**

4.6.1.2 Sample selection – Tell Brak

The selection of Tell Brak samples for stable isotope analysis essentially followed the same principles laid out above for the Hattusha assemblage and sought to answer a similar set of research questions, albeit ones formulated specifically for Tell Brak:

- Were the cereal crops at Tell Brak subject to artificial watering, as inferred from carbon stable isotope ratios ($\delta^{13}C$)?
- Were the cereal crops at Tell Brak grown in soils with enriched ^{15}N values, inferred from nitrogen stable isotope ratios ($\delta^{15}N$), suggesting the use of manuring?
- Are there significant differences in the results from the four cereal species analysed indicating the preferential treatment of one over the other? In particular, do the results from the small grain cereal varieties look distinctly different from the results of hulled barley and emmer wheat indicating the separate treatment of these crops?
- Can these results be used to infer specific crop husbandry regimes/growing conditions and/or contrasting land-use patterns at Tell Brak?

Samples were selected from all excavated rooms within the TC oval area, and from rooms that had been excavated using a grid system (i.e. Room 16), samples were chosen from a number of different grid squares across the room. Again, emmer wheat and hulled barley were selected to assess variation in growing conditions amongst the cereals. Additionally, samples of the small hulled barley and small glume wheat were also chosen for stable isotope analysis as a means of assessing the impact of potential growing conditions on grain size and the development of these smaller varieties of cereal. As with the samples selected from the Hattusha assemblage, the Tell Brak selected samples were further refined by charring condition, resulting in the rejection of one sample from Room 18 in which all cereal grains were too distorted. With regard to the smaller varieties of wheat and barley, 20 seeds were selected so that after crushing and pre-treatment there would still be enough material available for both nitrogen and

carbon analysis. In total, 41 samples from the Tell Brak TC oval assemblage were selected for stable isotope analysis (see **Table 4.5**).

Table 4.5 – The number of samples from the Tell Brak assemblage selected for crop stable isotope analysis, by crop species and room number.

Room	Species	No. of Samples
6	Hulled barley	1
8	Hulled barley	2
8	Small barley	1
9	Hulled barley	2
9	Small barley	1
9	Emmer wheat	1
9	Small wheat	1
12	Hulled barley	5
12	Small barley	2
12	Emmer wheat	5
12	Small wheat	2
13	Hulled barley	1
16	Hulled barley	10
16	Small barley	5
17	Hulled barley	1
17	Emmer wheat	1
Total		**41**

4.6.1.3 Pre-Treatment

The nature of charred archaeobotanical material is such that plant remains are susceptible to a variety of different kinds of contamination during deposition and subsequent long-term burial (Vaiglova *et al*. 2014b). There are three major contaminants that may affect the ratios of stable isotopes in charred grain. Carbonates,

nitrates and humic acid are all present naturally within the soil and can often be absorbed by buried material including charred plant remains (Kuwatsuka *et al.* 1978; Schnitzer & Khan, 1975). Pre-treatment of the plant material is sometimes necessary, therefore, to remove any contamination that would potentially distort the results of isotopic analysis. Vaiglova *et al*. (2014b) has also shown, however, that the pre-treatment process itself can also interfere with stable isotope ratios, and that consequently pre-treatment should only be carried out on archaeobotanical material if contamination can be proven to be present.

To identify possible contamination Fourier Transform Infrared Spectroscopy (FTIR) was used to screen samples from the Hattusha assemblage and prevent the pre-treatment of uncontaminated cereal grains. This technique was completed on 10 samples from Hattusha, from a range of chambers and arbitrary spits, (see **Table 4.6**) using the methodology established by Vaiglova *et al.* (2014b). The samples were first crushed using a pestle and mortar and then analysed using a Fourier Transform Infrared Spectrometer with Attenuate Total Reflectance (FTIR-ATR). The background was then subtracted and a baseline correction was carried out using Agilent Resolution Pro. These spectra were normalised and then compared with the spectra produced by artificially contaminated modern and ancient seeds (Vaiglova *et al*. 2014b). This evaluation, however, produced no evidence of any form of contamination within the Hattusha seeds comparable with the experimental data (see **Figure 4.1**). It was, therefore, decided that pre-treatment of these cereal grains was not necessary but that the grains should be gently scraped to remove surface contamination before stable isotope analysis. It was also necessary to remove the lemma and palea from a number of 6-row hulled barley grains from Chamber 30 using a scalpel. Experimental work by Nitsch *et al*. (2015) has shown that the stable isotope ratios of charred hulled and

pearled barley are similar, but it was decided that where preserved, the lemma and palea should be removed to ensure uniformity in barley grain composition across the entire assemblage.

Table 4.6 - Samples from the Hattusha assemblage selected for FTIR, by species and chamber number.

Chamber	Species	No. of samples chosen for FTIR
12	Hulled barley	1
12	Emmer wheat	1
28	Hulled barley	1
29	Hulled barley	1
29	Emmer wheat	1
30	Hulled barley	1
30	Emmer wheat	2
32	Hulled barley	1
32	Emmer wheat	1
Total		**10**

The cereal grains selected for stable isotope analysis from the Tell Brak assemblage were not assessed for contamination using FTIR because a previous FTIR investigation on seeds from the same excavation area had already been carried out by Styring *et al*. (2017). As part of this study, three samples of cereal grains from Tell Brak had been analysed and peaks characteristic of carbonate contamination (870 and 720 cm^{-1}) were observed in each of the spectra (Styring *et al.* 2017). It was, therefore, decided to acid pre-treat all cereal grains from Tell Brak following the protocol established by Vaiglova *et al*. (2014b) to dissolve any carbonate traces. Cereal grains were first examined using a low power binocular microscope (x7-57) for any visible

surface contaminants, such as soil, and these were removed by gentle scraping with a scalpel. Grains were then weighed, placed in glass test tubes and treated with 10ml of 0.5M hydrochloric acid at 70°C for 30-60 minutes, or until all acid effervescence had finished. The acid was then removed using a plastic pipette and the grains were rinsed three times using distilled water, or until the remaining liquid had reached a neutral pH. Excess water was then removed from the test tubes and the samples were freeze-dried for 24 hours. Finally, both the pre-treated Tell Brak samples and the untreated Hattusha samples were (re-)weighed and crushed using an agate mortar and pestle.

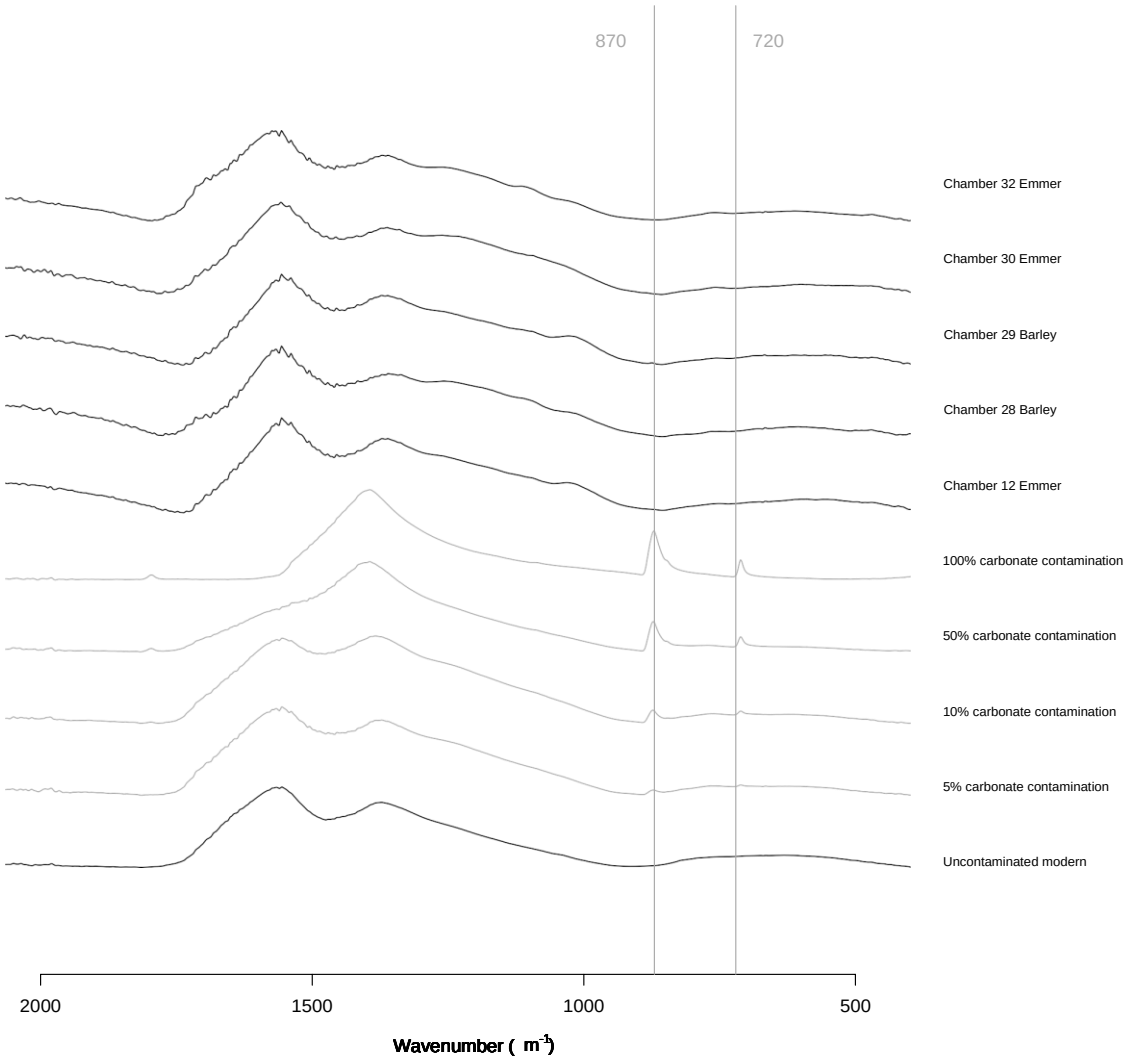


Figure 4.1 - FTIR spectra for five Hattusha samples compared to modern grain artificially contaminated with carbonate.

4.6.1.4 Stable carbon and nitrogen isotope measurement

The crushed and homogenized samples were weighed into tin capsules for stable carbon and nitrogen isotope analysis on a Sercon EA-GSL mass spectrometer. The values for $\delta^{13}C$ and $\delta^{15}N$ were measured in separate runs due to the low %N in the samples. For each run, values were measured with reference to a number of international standards and were calibrated using an internal alanine standard. For the $\delta^{13}C$ determinations, isotope ratios were normalized to the Vienna Peedee Belemnite scale (VPDB) using four replicate standards of IAEA-C6 and IAEA-C7. Similarly, the determination $\delta^{15}N$ values were calculated again the atmospheric composition of $N_{2,}$ using caffeine and IAEA-N2 as the standards. Measurement uncertainties for $\delta^{13}C$ and $\delta^{15}N$ values were calculated using the with-run variability of the raw measurements and the known uncertainty of the two reference standards using the approximation method (Kragten, 1994). All calculations were performed using the statistical programming language R (3.2.3). Finally, the C:N ration was calculated using the %C and %N values taken from the raw data:

$$\mathrm{C{:}\,N} = \binom{C\%}{N\%}\ x\ \binom{14}{12}$$

4.6.1.5 Testing data reliability

To test the level of confidence in stable isotope data, recent plant isotope studies (e.g. Bogaard *et al*. 2013; Fraser *et al*. 2013) have utilized a number of different methods to assess data reliability. This is because archaeobotanical plant isotope scholarship is still a relatively recent field of study and the chemical composition of ancient charred plants is still not fully understood, particularly in comparison with

collagen stable isotope studies. One of the most commonly used methods has been to compare the mean and standard deviation of the C:N ratio of archaeological material against that of modern charred cereals (Fraser *et al.* 2013; Vaiglova *et al*. 2014a; Styring *et al*. 2015). There are some inherent problems with this technique, however, due to the process of plant stable isotope analysis. Firstly, carbon and nitrogen samples are run on the mass spectrometer independently of each other in separate batches so there may be machine inconsistencies between the two runs. Secondly, sample weights for the nitrogen run are greater than those of the carbon run to ensure that a positive nitrogen measurement is made. Finally, both stable isotope runs are subject to human error in terms of weighing procedures and the use of multiple balances when preparing the samples. All of these small sources of error can combine to distort the C:N ratio of each archaeobotanical assemblage.

Figure 4.2 shows the mean and standard deviations (see **Table 4.7**) of C:N ratios of both Tell Brak and Hattusha stable isotope samples alongside modern charred hulled barley and emmer C:N ratios from Fraser *et al*. (2013). From this graph it is clear that the archaeological material is far more variable than the modern results. Additionally, with regard to the Tell Brak results, the ratio of carbon to nitrogen is heavily skewed resulting in a much lower ratio than is seen in the modern material. A Kruskal-Wallis test ($H(2)=3.60$, $p=<0.001$) and subsequent post-hoc analysis[10] show that there is a significant difference between all three assemblages (see **Table 4.8**). If the C:N ratio is accepted as an indicator of data reliability, therefore, all stable isotope results from both Tell Brak and Hattusha would have to be treated with caution as they differ from the results of modern charred cereals.

[10] The results of a Levene Test revealed that the C:N ratio results had an unequal variance and required the use of a non-parametric robust ANOVA method. Additionally, a robust Dunn Test post-hoc analysis was performed on the results of the Kruskal-Wallis test.

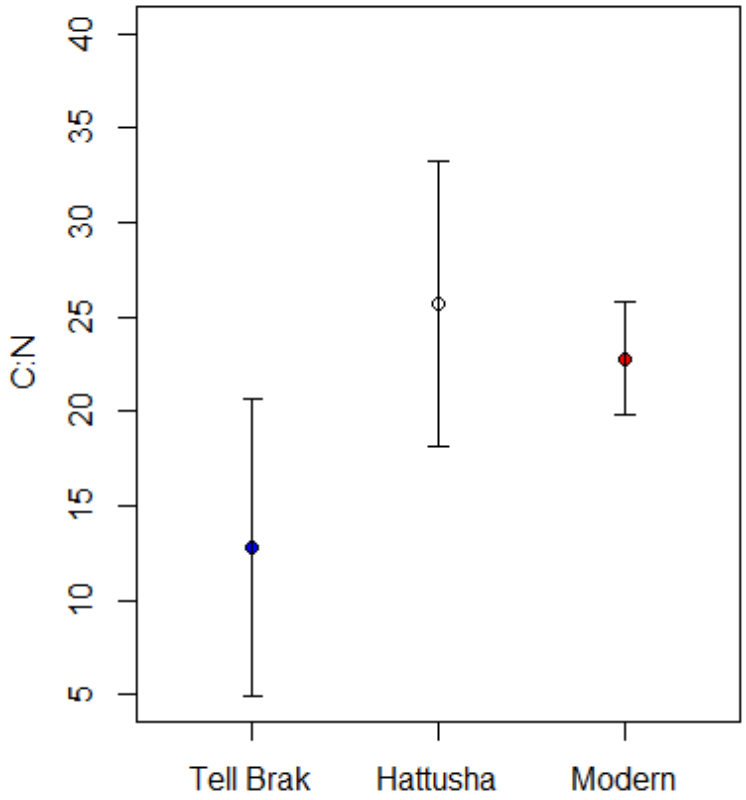


Figure 4.2 – Plot of the mean and standard deviations of C:N ratios of stable isotope samples from Hattusha, Tell Brak and modern charred material.

Table 4.7 – The mean and standard deviations of C:N ratios of stable isotope values from Hattusha, Tell Brak and modern charred material.

Source of material	Number of Samples	Mean	Standard Deviation
Tell Brak	41	12.80	7.83
Hattusha	64	25.67	7.59
Modern	9	22.79	2.99

Table 4.8 – The results of a Kruskal-Wallis test and post-hoc analysis on the C:N ratios of stable isotope values from Hattusha, Tell Brak and modern charred material.

Statistical Test	Sources of material	Result
Kruskal-Wallis test	All	H(2)=36.60, p=<0.001
Post-hoc Dunn test	Hattusha-Modern	<0.001
Post-hoc Dunn test	Hattusha-Tell Brak	<0.001
Post-hoc Dunn test	Tell Brak-Modern	<0.001

Another method of assessing data reliability has been to compare the percent carbon (%C) and the percent nitrogen (%N) from archaeological samples again with modern charred examples (Fraser *et al*. 2013). This allows the identification of outlier samples and provides information regarding the individual species on a sample-by-sample basis rather than only the mean result from all samples. To minimise some of these sources of error the percentage carbon and nitrogen have both been taken from the carbon run and the nitrogen run respectively (Ditchfield *pers comm*.). **Figure 4.3** is a scatterplot showing %C and %N values from Tell Brak, Hattusha and the modern experimental data, coded by cereal taxa. Again, it is clear that the archaeological samples are far more variable, in both %C and %N, than the modern samples. Kruskal-Wallis tests and post-hoc analyses were performed on both %C and %N individually by site (see **Table 4.9**). Firstly, with regard to the %C these tests indicate that there is no significant difference between Tell Brak samples and the modern samples and Hattusha samples and the modern samples, but that there is a statistical difference between the Tell Brak samples and the Hattusha samples. Additionally, the range of %C results from the Hattusha samples is much wider than the equivalent ranges from the Tell Brak and modern samples. It has been suggested, however, that this could be a result of sample weighing errors and because when exposed to air during the weighing process both stable isotope standards and samples absorb water from the air potentially increasing %C (Ditchfield *pers comm*.).

The results of statistical tests on the %N of samples from all sites, indicate that these results are all significantly different from each other ($H(2)=44.45$, $p=<0.001$). Similarly, from **Figure 4.3** it is obvious that the Tell Brak samples contain a much higher concentration of %N than the samples from Hattusha and the modern samples. Furthermore, it would appear that the small varieties of cereal have particularly high

%N values, whereas the values for large-seeded hulled barley are much more in line with the modern values. High %N can be an indication of nitrate contamination, but no indication of this was observed in the results of FTIR carried out on the Tell Brak seeds (Styring *pers comm.*; Bogaard *et al.* 2016b). Moreover, research by Vaiglova *et al.* (2014a) has shown that nitrate contamination is removed during the pre-treatment process and all samples from Tell Brak were pre-treated with a low concentrate acid wash. Another explanation for these elevated %N values could be the link between crop yield and N utilization. Triboi *et al.* (2006) have shown through modern experiments that there is a strong negative relationship between grain yield and N concentration. This may suggest that the Tell Brak cereals, particularly the small varieties, were much lower yielding than the modern samples due to genetic factors but also environmental conditions. Certainly, crop yields have been heavily influenced by humans within recent history by the manipulation of starchy endosperm as a storage tissue and a subsequent increase in grain sizes (e.g. Khush, 1999; Tilman *et al*. 2002; Evenson & Gollin, 2003). This may considerably affect the efficacy of comparing ancient cereal grains with modern grains, even those grown under carefully controlled experimental conditions.

To conclude, the calculation of data reliability by comparing archaeological data with modern experimental data is subject to various sources of error and bias that may affect the overall results. With regard to the results from Hattusha and Tell Brak, these comparisons would require all stable isotope values to be treated with caution and some of the Hattusha values would need to be disregarded. These sources of error have been minimised wherever possible through the use of FTIR and pre-treatment to remove contaminants. Consequently, although the %C and %N composition of samples from Hattusha and Tell Brak are significantly different from those measured in modern

material, these values have been accepted as reliable representations of the isotopic ratio present in cereal grains at both sites.

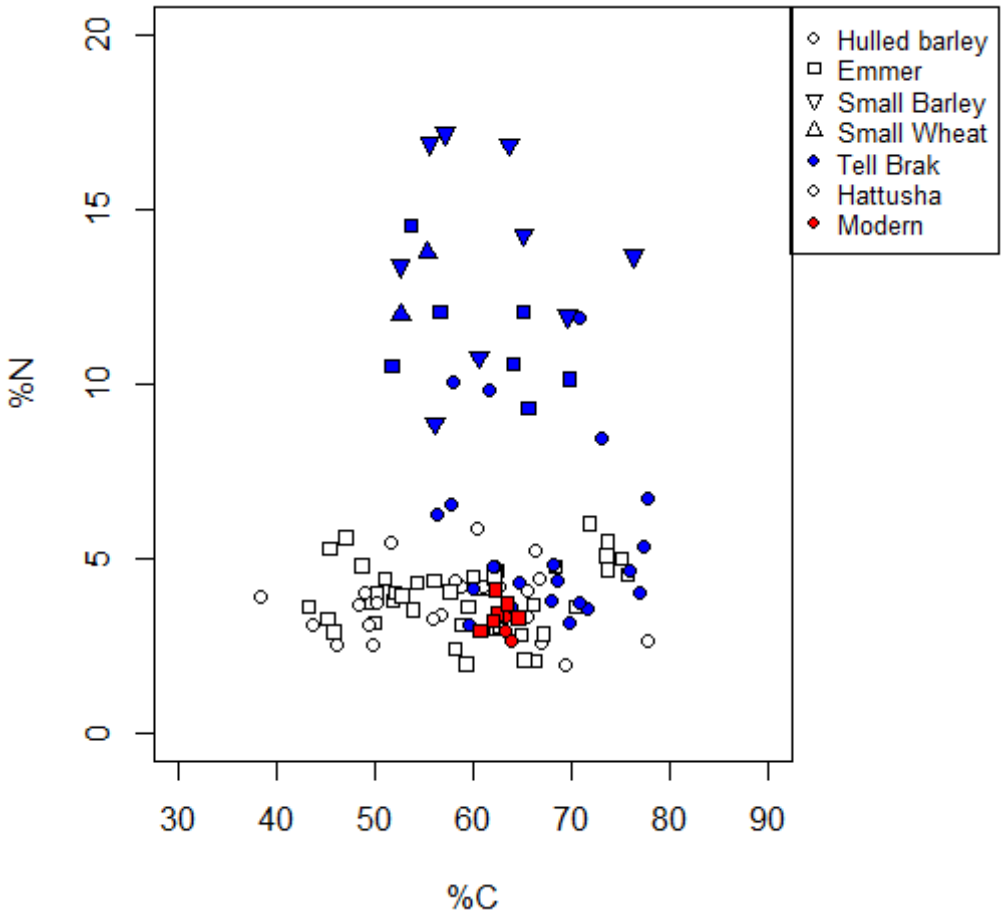


Figure 4.3 – Scatterplot showing %C and %N values from Hattusha, Tell Brak and modern cereal samples.

Table 4.9 - The results of a Kruskal-Wallis test and post-hoc analysis on the %C and %N values of stable isotope values from Hattusha, Tell Brak and modern charred material.

Statistical Test	%C - %N	Sources of material	Result
Kruskal-Wallis test	%C	All	H(2)=7.63, p=0.022
Post-hoc Dunn test	%C	Hattusha-Modern	p=0.36970225
Post-hoc Dunn test	%C	Hattusha-Tell Brak	p=0.02374323
Post-hoc Dunn test	%C	Tell Brak-Modern	p=0.87223835
Kruskal-Wallis test	%N	All	H(2)=44.45, p=<0.001
Post-hoc Dunn test	%N	Hattusha-Modern	p=<0.001
Post-hoc Dunn test	%N	Hattusha-Tell Brak	p=<0.001
Post-hoc Dunn test	%N	Tell Brak-Modern	p=<0.001

4.6.1.6 Re-running samples

A number of samples at both Hattusha and Tell Brak were classified as statistical outliers. These samples were classed as outliers if the stable isotopic value was higher than the third quartile or smaller than the first quartile by 1.5 times the interquartile range of data from that sample's species. These outlying samples were all re-measured twice and compared with the original result. In every case the re-analysis of these outlying samples returned similar results with very low standard deviations between the re-runs and the original samples (see **Table 4.10**). This therefore led to the acceptance of the originally measured values as true representations of the isotopic ratio.

Table 4.10 – The results of re-runs completed on outlier stable isotope values from Hattusha and Tell Brak.

Site	Sample ID	Isotope	Species	Original Value(‰)	1st Re-run (‰)	2nd Re-run (‰)	Average (‰)	SD (‰)
Hattusha	HAT36	δ^{15}N (‰)	Emmer wheat	8.41	9.59	9.63	9.21	0.69
Hattusha	HAT58	δ^{15}N (‰)	Hulled barley	9.11	9.05	8.88	9.01	0.12
Tell Brak	TB04	δ^{15}N (‰)	Small barley	9.63	9.61	9.77	9.67	0.09
Tell Brak	TB22	δ^{15}N (‰)	Small barley	8.79	9.5	9.61	9.30	0.45
Tell Brak	TB25	δ^{15}N (‰)	Hulled barley	7.49	7.54	7.64	7.56	0.08
Tell Brak	TB28	δ^{15}N (‰)	Small barley	8.62	8.61	8.66	8.63	0.03
Tell Brak	TB35	δ^{15}N (‰)	Hulled barley	9.55	9.31	9.43	9.43	0.12
Tell Brak	TB38	δ^{15}N (‰)	Emmer wheat	3.02	2.83	3.09	2.98	0.13

4.6.1.7 Charring correction

As mentioned above, experiments carried out on the effects of charring on the stable isotopic values of seeds have shown that both δ^{15}N and δ^{13}C experience an

increase, even within the optimal charring window (Nitsch e*t al.* 2015). All stable isotope values ($\delta^{15}N$ and $\delta^{13}C$) from Tell Brak and Hattusha samples were, therefore, corrected for the effect of charring by subtracting 0.31‰ and 0.11‰, respectively, to allow comparisons with modern stable isotopic studies.

4.6.1.8 Conversion of $\delta^{13}C$ values to $\Delta^{13}C$ values

All $\delta^{13}C$ were converted to $\Delta^{13}C$ so that comparisons could be made both between Tell Brak and Hattusha and with modern stable isotopic studies. This conversion allows the representation of $\Delta^{13}C$ independent of it CO_2 source and changes the negative values of $\delta^{13}C$ into the positive values of $\Delta^{13}C$. These calculations were made from the determined $\delta^{13}C$ ($\delta^{13}C_{plant}$) and a $\delta^{13}C_{air}$ past air value using the AIRCO2_LOESS system (Ferrio *et al.* 2005). The equation follows studies made by Farquhar *et al*. (1989).

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

4.6.2 Functional weed ecology and discriminant analysis

The permanence of cultivation and crop sowing times were assessed using arable weed species ecological information collected from the *Flora of Turkey* (Davis, 1965 - 1989) and the *Flora of Iraq* (Guest, 1966). This included information regarding the flowering onset and duration of each weed species, the expected life cycle of the plant and general habitat preferences. All results were then classified by flowering onset and flowering duration as early/short-flowering (early onset and short-flowering

periods), late-flowering, long-flowering or indeterminate. Where weed remains had only been identified to the genus level, all weed species from the appropriate environmental and geographic region around each site were merged to create a single combined result. This meant that many taxa could be classified only as indeterminate due to different potential onset dates within the genus or a medium flowering period which fell outside of the short/long categories. Results were then compared with modern ethnobotanical research in Germany by Bogaard *et al*. (2001) as a means of ascertaining the potential harvest time and consequently the crop sowing period.

Another aspect of crop husbandry that was examined was the intensity of crop cultivation and the level of labour input related to plant disturbance and general fertility. To this end discriminant analysis was used to make direct comparisons between archaeobotanical weed data and modern weed floras grown under known conditions. This statistical technique combined functional ecological attributes (the discriminating variables) in a linear equation, as a means of differentiating between pre-defined modern agrosystems (i.e. low-intensity and high-intensity agriculture). This equation can then be used to classify unknown cases, such as archaeobotanical samples, into the same groups. This method was applied to the archaeological data as part of the 'Functional Interpretation of Botanical Surveys' (FIBS), (Jones *et al.* 1995; 1999; 2000; Bogaard *et al*. 1999; Charles *et al*. 2002) as a means of distinguishing between agricultural regimes (see **Section 3.3.2**, **Chapter 3**). This approach to archaeobotanical weed assemblages was initially adapted from the FIBS method, developed at the Unit of Comparative Plant Ecology at the University of Sheffield (Hodgson, 1989; 1990; 1991; Hodgson *et al*. 1999) and has been further developed in 'The Agricultural Origins of Urban Civilization' (AGRICURB) at the University of Oxford (Bogaard *et al.* 2016a;

2016b). The analysis is undertaken using semi-quantitative data (presence/absence) as this is more directly comparable with archaeobotanical datasets.

Firstly, a discriminant analysis model was created based on field data from four modern field studies in northern Spain, Greece, southern France and Morocco (Jones *et al.* 1999; 2000; Bogaard *et al*. 2016a; 2016b). These modern studies were undertaken in regions within a variety of climate zones as well as a range of high- and low-intensity agricultural regimes to provide a broad spectrum of examples with which to compare archaeological data. In each study area, a number of weed field surveys[11] were completed, collecting data on the range and variety of arable weed species growing within each specific agricultural regime. Functional data on the attributes of these particular arable weeds (i.e. canopy height, canopy diameter, specific leaf area and leaf area per node: thickness) were also provided from the FIBS database at the University of Sheffield. **Figure 4.4** displays the relative importance of each measured functional attribute to successfully classify the samples. The percentage of fields correctly classified into the pre-defined categories defines the success of the analysis, together with the ecological 'logic' of the functional attributes used as relevant discriminating variables. This created **Figure 4.5** which shows the individual field data for these modern studies, with each field represented by one data point. These points have been classified into two groups: high-intensity agricultural regimes in black (e.g. manured, weeded and sometimes watered garden plots, with high labour inputs) and low-intensity agricultural regimes in white (e.g. rain-fed fields with less manuring and weeding and hence lower labour inputs). These points have also been used to create weighted averages for each type of regime, as illustrated by the large group centroid points (Bogaard *et al*. 2016a; 2016b).

[11] Modern field data was collected from individual quadrats measured along transects within each field under study.

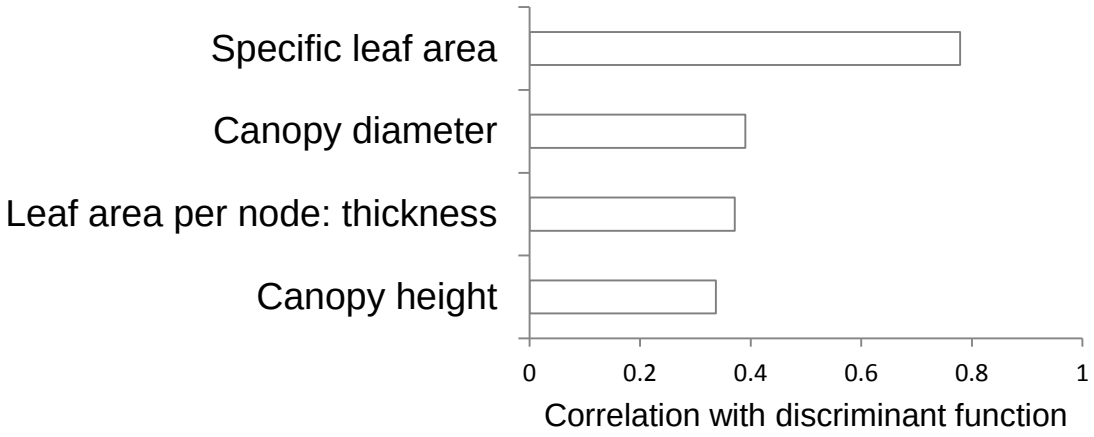


Figure 4.4 – Bar chart displaying the relative importance of each measured functional attribute to the classification of weed samples.

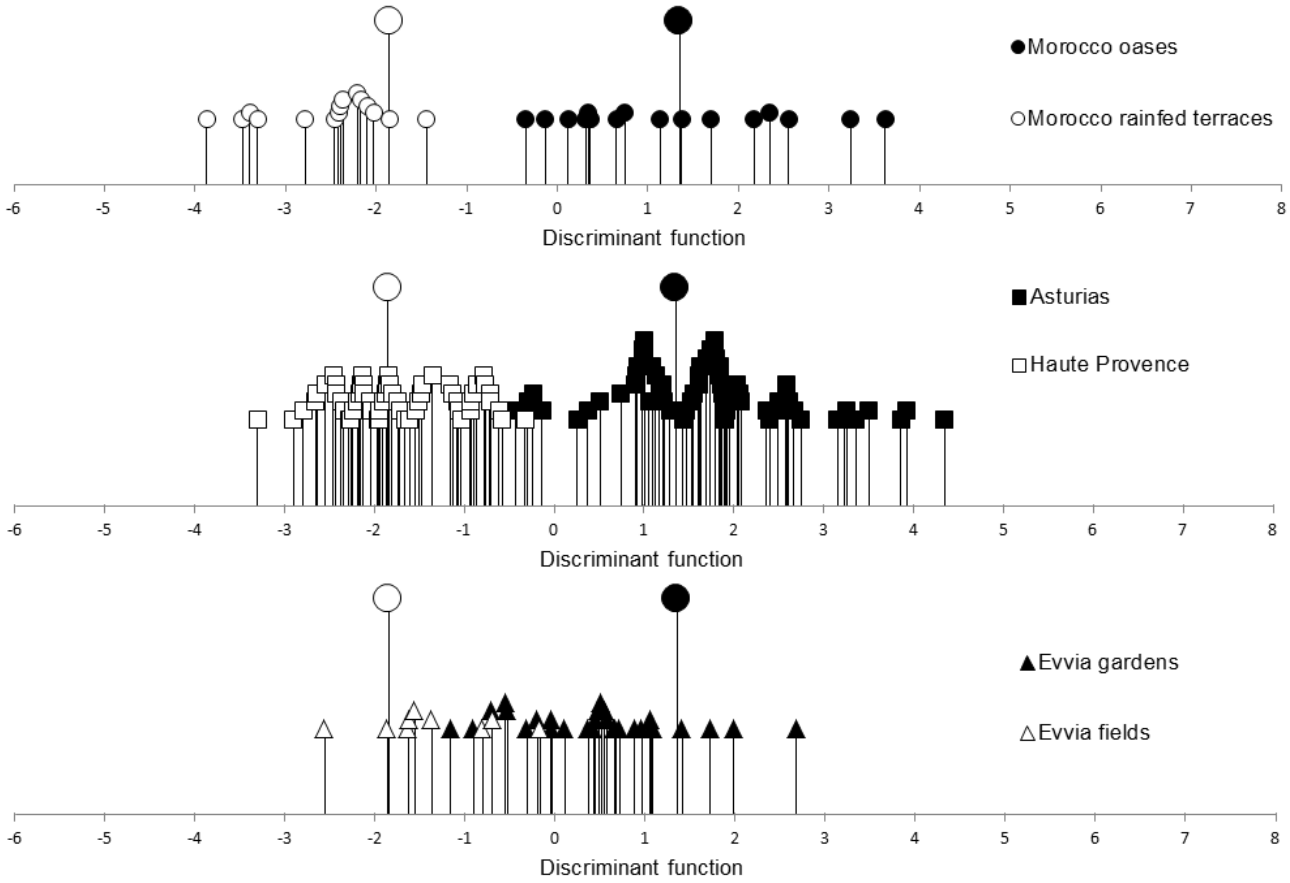


Figure 4.5 - The distribution of modern field survey samples in relation to the discriminant function extracted to distinguish between high (black) and low (white) intensity crop husbandry regimes.

Archaeobotanical data are then classified using the same discriminant function. Only arable weeds that had been identified to the species level were included in this analysis, and also only samples that contained 10 or more of these identified weed species. This data was converted into presence/absence scores, so that it was directly comparable with the values from the modern field surveys, and then classified by how closely the archaeobotanical data fitted with the modern models. The statistical software used to perform these analyses was IBM SPSS Statistics 22 and discriminant scores were plotted using Microsoft Excel.

Chapter 5

Archaeobotanical results from Hattusha

5.1 Overview of samples

The Hattusha assemblage is comprised of 45 samples taken from five separate chambers within the underground silo complex (**Table 4.1**). These chambers were located at the eastern end of the silo complex towards the Büyükkale acropolis building (**Figure 2.3**). Each chamber was excavated by arbitrary spit, usually measuring 15-20 cm in depth, and archaeobotanical samples were taken from each layer (see **Section 4.1.1**, **Chapter 4**). The number of spits excavated per chamber, however, varied by chamber depth and by the preservation of the charred plant material inside. Chamber 30 is the best represented with 19 samples originating from 6 arbitrary spits. The chamber was excavated on a grid system which contained 13 roughly sized 2 x $1m^2$ squares arranged in rows of five from left to right (see **Figure 5.1**). The majority of archaeobotanical samples (13 samples) were taken from squares in the middle of the grid system and particularly squares 8, 11 and 13. By contrast, there was only one sample taken from the outer edge of the grid system, square 7. Chamber 29, located to the west of chamber 30, (see **Figure 2.3**) was also excavated on a linear grid system of seven equal grid squares (see **Figure 5.2**). Unlike Chamber 30, however, samples from Chamber 29 were only taken from two arbitrary stratigraphic layers. Chamber 32, situated at the eastern extreme of the silo, (see **Figure 2.3**) was not excavated on a grid system as only a small sondage was dug on the western side of the chamber. Single

samples from this chamber were recovered from each arbitrary layer, without horizontal grid sampling across the chamber. There was no surviving stratigraphic information for Chamber 12, the most westerly of the chambers, due to internal destruction by mice and moles (Seeher *pers. comm*). Samples, therefore, were taken from a variety of depths, and several actually originate from Iron Age levels above the burnt silo. Due to the large concentration of charred plant remains in these samples, however, it was thought that this material was still primarily Hittite and had been brought up from the silo below by rodents. Finally, Chamber 28 is only represented by one sample due to the limited nature of excavation in this area of the silo.

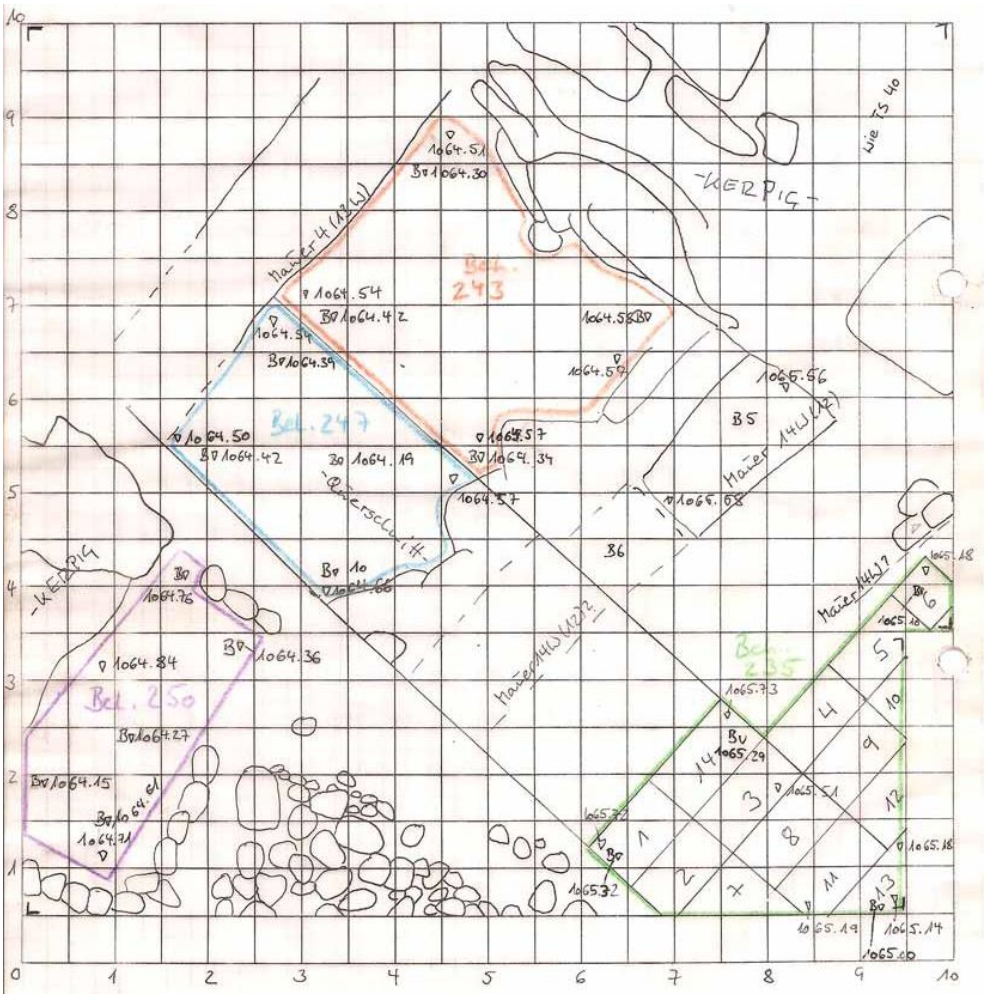


Figure 5.1 – Sketch plan of Chamber 30 showing the grid system (outlined in green) used for excavation (Seeher *pers. comm.*).

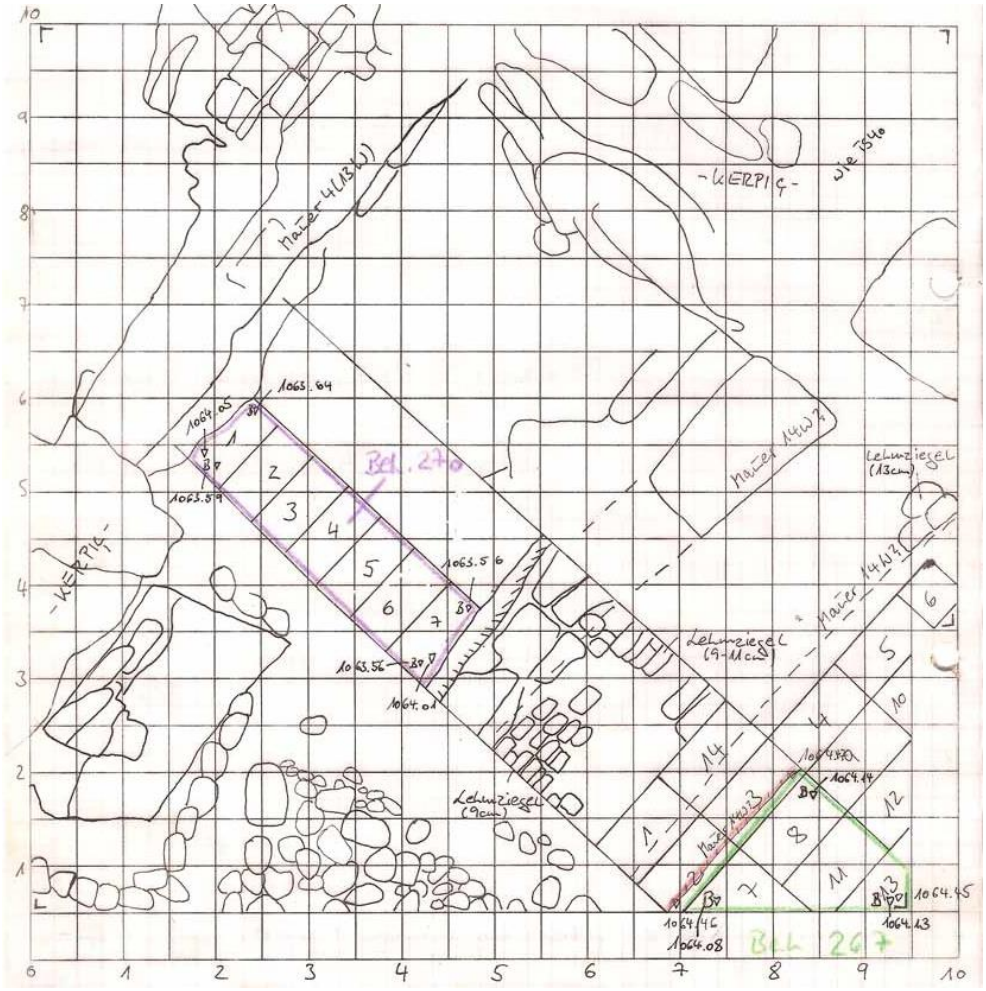


Figure 5.2 – Sketch plan of Chamber 29 showing the linear grid system (outlined in purple) used for excavation (Seeher *pers. comm.*).

5.2 Overview of the assemblage

Figure 5.3 summarizes the major proportions of all major archaeobotanical categories identified within the underground silo complex. All samples contain a mixture of cereal grains, cereal chaff, pulses and weed/wild taxa; the data have been sorted to emphasize the contrast between those samples dominated by cereal grains, on the one hand, and those dominated by weed/wild taxa, on the other. Cereal grains are the most dominant component of the assemblage with over 50% of the samples (26

samples) containing over 50% cereal grain. Weed/wild taxa also comprise a large proportion of the assemblage, with five samples containing over 40% weed/wild items. There are also three samples containing over 40% pulse species and the role of this category will be discussed in greater detail below.

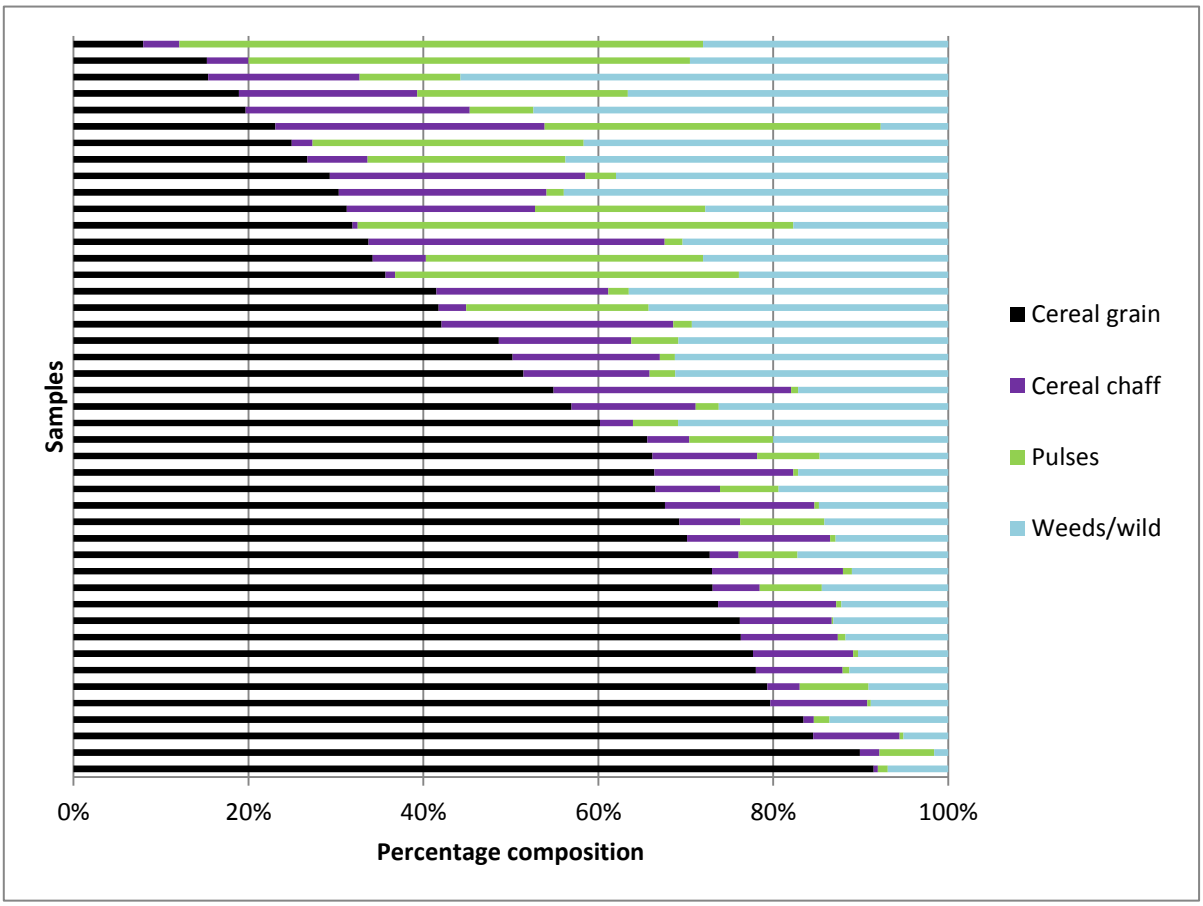


Figure 5.3 – Percentage stacked bar chart of all samples from Hattusha showing the proportions of the four major categories of plant remains.

The cereal chaff category, by contrast encompasses a much smaller proportion of the assemblage. The maximum cereal chaff contained in any one sample was 34%, but in general the percentage of cereal chaff ranged from between 10-20% of each individual sample. The predominance of cereal grain throughout the silo complex is what would be expected from a large storage facility, the contents of which were likely

destined for human and/or animal consumption. More surprising, however, is the high percentage of weed/wild taxa. The sealed nature of this crop storage would suggest that in most cases these taxa represent arable weeds of cereal cultivation and their inclusion in the silo could point to a low level of cereal processing before storage, possibly combined with the presence of very weedy fields due to a lack of weeding during crop growth. Further exploration of sample composition, however, will be needed before definitive conclusions regarding crop processing or crop husbandry can be reached, and these factors will be discussed in much greater detail in **Sections 5.7** and **5.8** below.

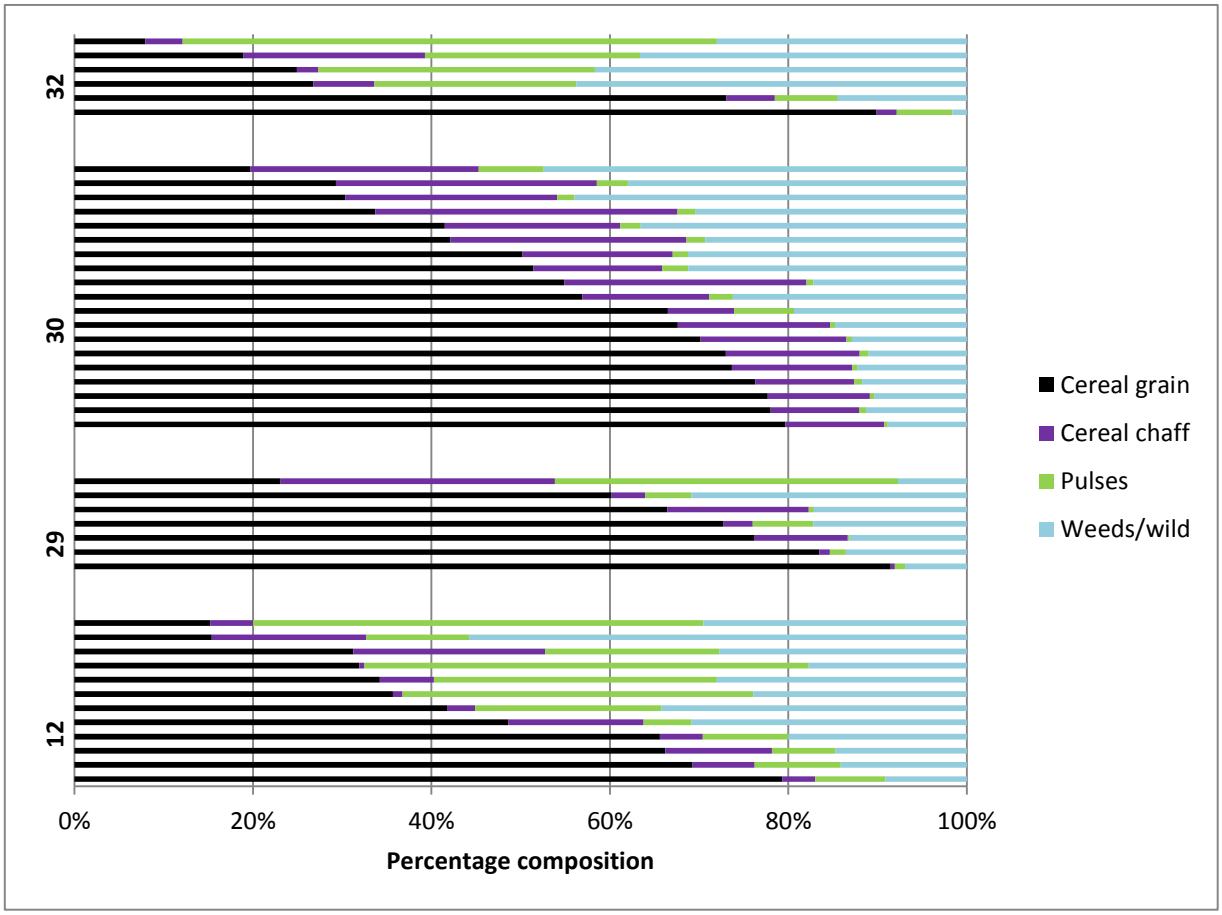


Figure 5.4 – Percentage stacked bar chart of all samples, classified by major plant remains and arranged by chamber number.

Figure 5.4 shows the same analysis as used above in **Figure 5.3**, but with the samples arranged by chamber number. Again, the data has been ordered to emphasize the contrast between cereal grain-dominated samples and weed/wild-dominated samples. Chamber 28 has been left out of this analysis as it was only represented by one sample. By arranging the samples by chamber number, it becomes clear that each chamber has a distinctive composition. In general it would seem that Chambers 12 and 32 contain the highest proportions of pulses and weed/wild taxa compared to cereal grains, with one sample from Chamber 32 containing 60% pulse taxa and 28% weed/wild items, compared with only 12% cereal grain. It would also appear that Chamber 32 has the most variable composition within the chamber itself, with one sample containing 90% cereal grain and one sample containing 8% cereal grain. By contrast, samples from Chamber 29 have significantly lower pulse taxa and weed/wild percentages. Instead these samples are primarily composed of cereal grain, with one sample (29_191_503) containing over 90% of this category.

The chamber with the most distinctively different composition, however, is Chamber 30 which appears to contain an average of 20% cereal chaff per sample. By comparison the percentage composition of cereal chaff within the other chambers is much more variable with one sample from Chamber 12 and one sample from Chamber 32 containing less than 5%. This may indicate that the samples from Chamber 30 had undergone a different stage of crop processing before storage than samples from the other chambers. Alternatively, it may indicate that the charring temperatures reached in this chamber were lower than the rest of the silo, thus favouring the preservation of light chaff which would have been destroyed in higher temperatures (Boardman & Jones, 1990; Charles *et al*. 2015). These possibilities will be explored further below as a means of assessing whether the presence of chaff in Chamber 30 is a ‘real’ difference or a

matter of taphonomy. Finally, sample bars were also arranged by arbitrary excavation spit to assess variation by depth within each chamber. The resulting bar chart (**Figure 5.5**) shows no patterning by arbitrary spit. Intra-chamber variability will be explored below in much greater detail using correspondence analysis (see **Section 5.7** below).

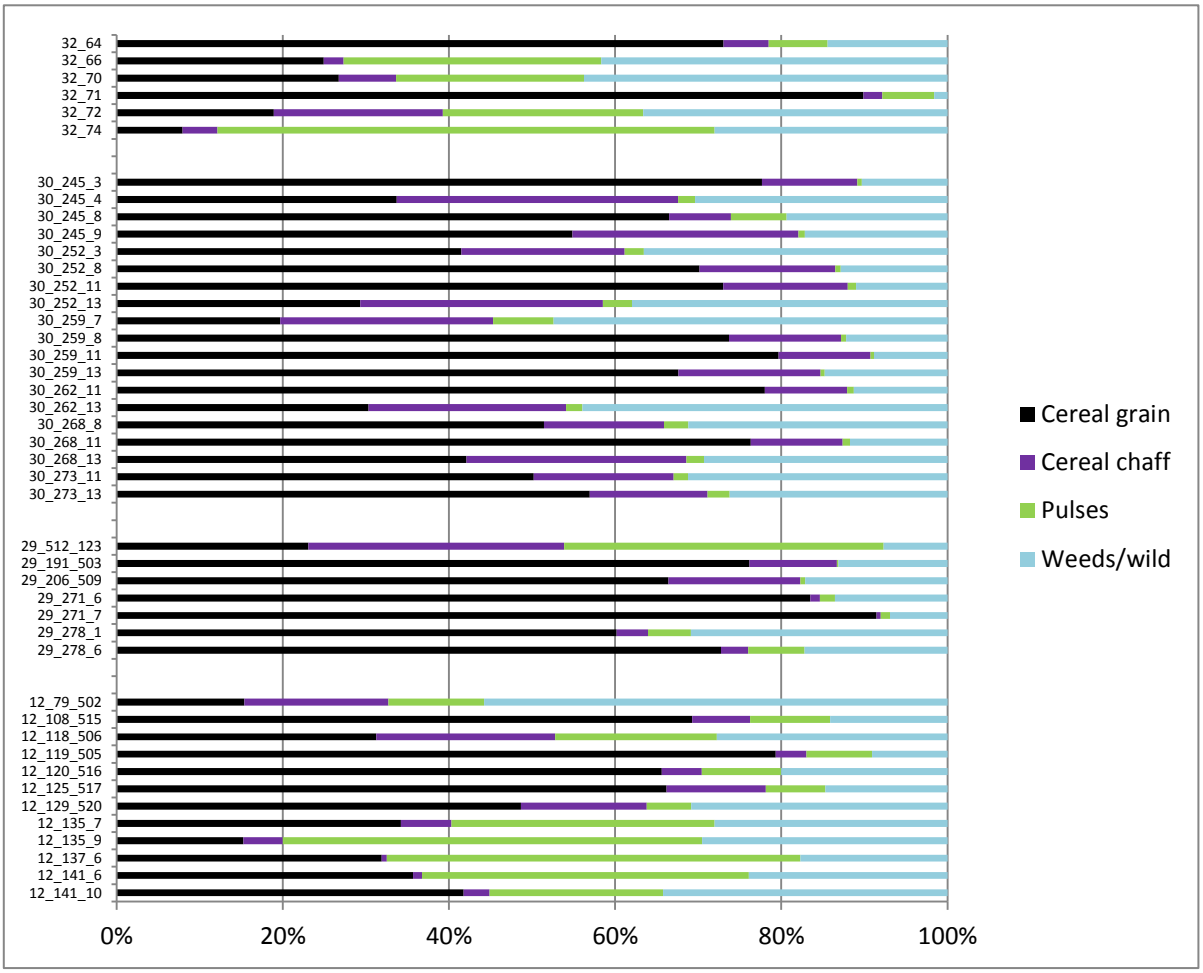


Figure 5.5 – Percentage stacked bar chart of all samples classified by major plant remains, arranged by chamber number and by arbitrary excavation spit.

5.3 Major crops

The major crops identified from the underground silo complex are hulled barley (*Hordeum vulgare*) which occurred in 44/45 (98%) of samples and the glume wheats

(*Triticum monococcum /dicoccum*) which also occurred in 98% of samples (see **Table 5.1**). Both crops have a similar predominance throughout the assemblage, with 22/45 (49%) of samples containing over 70% hulled barley grain and 23/45 (51%) of samples containing over 70% glume wheat grain (see **Figure 5.6**). In terms of the total number of grains per species, however, hulled barley appears in the greatest quantities; whilst the number of glume wheat grains was significantly lower (see **Table 5.1**).

Table 5.1 – Summary of the frequency and abundance of major plant taxa.

Plant item	Presence	Ubiquity (%)	Max/sample	Sum
Cereal grains				
Hulled barley Total	44	98	8694	74165
Straight Hulled barley	27	60	340	2020
Twisted Hulled barley	36	80	672	5576
Indet. Hulled barley	44	98	8022	66569
Naked barley	10	22	8	26
Glume wheat Total	44	98	5536	32617
Emmer wheat Total	44	98	5536	27931
2-grain Emmer wheat	41	91	976	6728
1-grain Emmer wheat	33	73	437	3224
Indet. Emmer wheat	44	98	4560	17979
Einkorn wheat	32	71	557	4686
Free-threshing wheat	13	29	16	77
Chaff				
2-grain Emmer wheat spikelet	18	40	122	653
1-grain Emmer wheat spikelet	20	44	285	1728
Einkorn wheat spikelet	19	42	121	546
Emmer wheat glume base	44	98	1072	9144
Einkorn wheat glume base	30	67	285	2534
Emmer wheat terminal glume base	15	33	18	131
Free-threshing wheat rachis	18	40	30	125
Hulled barley rachis Total	27	60	76	542
6-row Hulled barley rachis	17	38	27	130
2-row Hulled barley rachis	20	44	49	320
Indet. Hulled barley rachis	4	9	54	92
Pulses				
Lathyrus sativus	8	18	4	13
Lens culinaris	16	36	10	55
Vicia ervilia	34	76	144	452
Vicia faba var. minuta	45	100	1237	8898
Weed/Wild Total	45	100	2411	26611

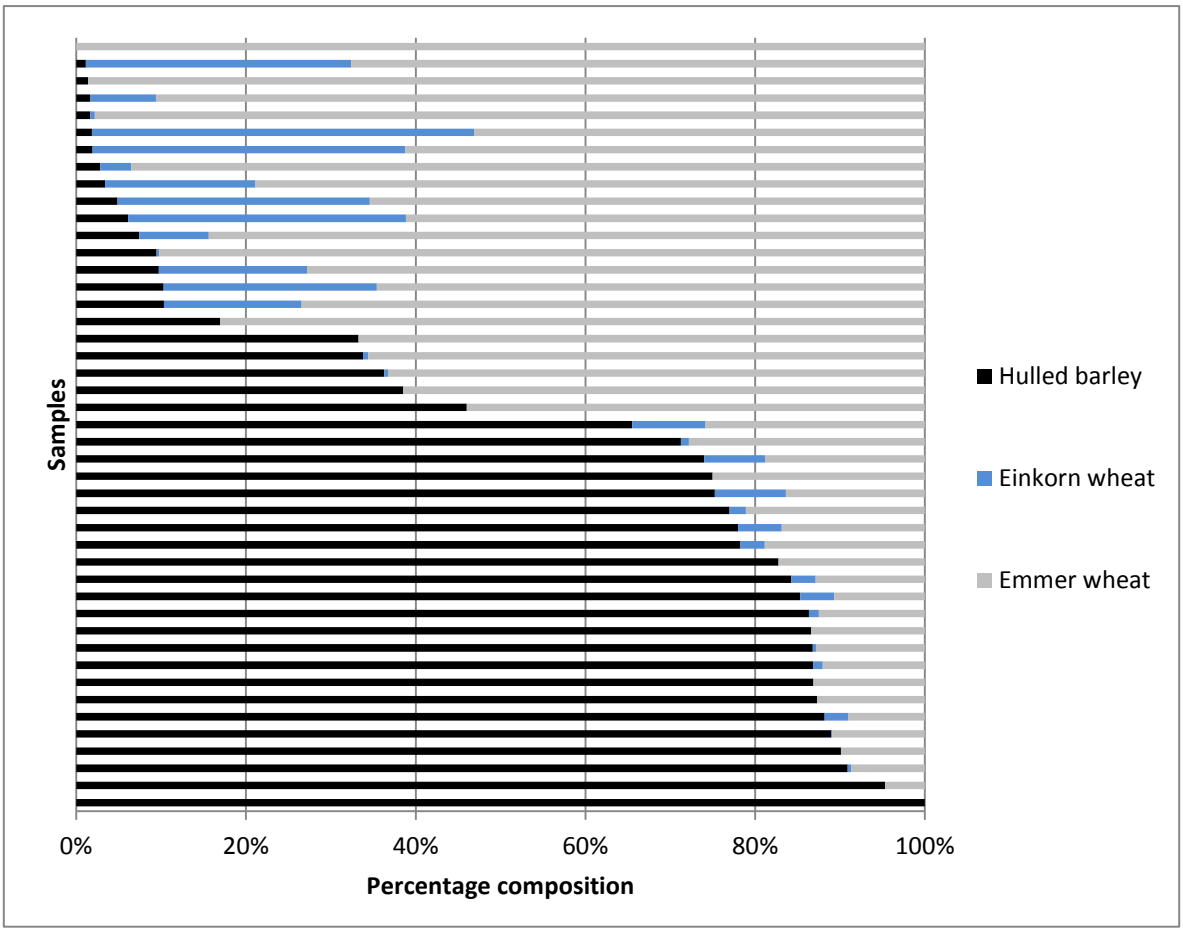


Figure 5.6 – Percentage stacked bar chart showing major crop proportions for all samples.

5.3.1 Hulled barley

Hulled barley was represented by a mixture of morphologically straight grains from the central spikelet of the barley ear and twisted grains from one of the lateral spikelets of a 6-row barley ear. Overall, there was a slightly higher ubiquity of twisted grains, present in 36/45 (80%) of samples, than straight grains which were present in 27/45 (60%) of samples. Similarly, within the entire silo there was a higher total sum of twisted grains vs. straight grains, roughly corresponding with a 2:1 ratio (see **Table 5.1**). This would suggest that the hulled barley stored in the silo was primarily of the 6-row variety (*Hordeum vulgare vulgare*). In terms of barley chaff, however, there was a significant amount of 2-row hulled barley rachis identified in 20/45 (44%) of samples

suggesting that this variety of barley was also present within the silo (see **Table 5.1** for the ubiquity of both barley chaff species). Differing preservation levels throughout the silo and within each chamber also resulted in a large number of unidentifiable hulled barley grains which cannot be identified as straight or twisted. With this in mind, therefore, it appears that the silo was used to store mainly 6-row hulled barley, but that 2-row hulled barley was also present in smaller quantities.

5.3.2 Glume wheats

Glume wheats[12] at Hattusha are represented by two different species, emmer wheat (*Triticum dicoccum*) and einkorn wheat (*Triticum monococcum*). Unlike hulled barley, however, these species appear in widely differing proportions within the silo. Emmer wheat grain is the most commonly identified species, occurring in 44/45 (98%) of samples whilst einkorn wheat grain was present in 32/45 (71%) of samples (see **Figure 5.6**). This relationship was also closely mirrored in terms of glume wheat chaff, with emmer wheat chaff appearing in 44/45 (98%) of samples and einkorn wheat in 30/45 (66%) of samples. The differences between the two glume wheat types become even more apparent, however, when looking at the total amount of grain identified to each species (see **Table 5.1** for the total numbers of each species). These stark differences in terms of grain quantity when compared with grain ubiquity between the glume wheat species, therefore, indicate that even though einkorn wheat was present in

[12]In order to calculate the true quantities of emmer wheat and einkorn wheat it was necessary to proportionally re-assign 17 unidentified amounts of glume wheat grain and chaff from nine individual samples. This was required due to the fact that these plant items had been retained by Reinder Neef (*pers comm.*) at the Deutsches Archäologisches Institut for use in future editions of the *Digital Atlas of Economic Plants in Archaeology* (Neef *et al.* 2012). In each case the total number of grains or glume bases was known and this allowed the reassignment of each plant item based on the relative proportions of fully identified wheat items within the same sample. Where this was not possible, re-assignment was based on fully identified wheat items from samples originating from the same stratigraphical level/arbitrary spit.

over half of all samples analysed, emmer wheat was by far the predominant glume wheat crop. Further examination of the differences between glume wheat species will be carried out below as part of the sample composition analysis.

Emmer wheat and einkorn wheat were well represented throughout the assemblage as a mixture of both grains and spikelet forks/glume bases. Additionally, in 20/45 (44%) of samples (see **Table 5.1**) entire, intact glume wheat spikelets were also preserved. These were identified primarily in every excavated arbitrary layer of Chamber 30, and also in the uppermost spit in Chamber 32. The presence of glume wheat spikelets within the assemblage indicated, without doubt, that a fraction of the glume wheat crop was being stored within the spikelet, and would have required further processing for human consumption. Additional processing stages would not be needed, however, if the cereals in the silo complex were designated as seed crop for the following year (Neef, 2001), or if it was to be used as animal fodder (Jones, 1998). The disarticulation of a number of these glume wheat spikelets revealed that grains charred within the spikelet looked significantly different from grains charred outside of the spikelet, due to the differing impressions of the glumes on the grain. From this it became possible to identify grains that had potentially been charred within the spikelet from other chambers where spikelets had not survived. Similarly, the ratio of glume bases to grain was analysed to reconstruct the presence of spikelets in other samples. Both of these methods, however, are potentially problematic, due in part to the differing survival rates of grain and chaff within the archaeological record (Boardman & Jones, 1990; Charles *et al*. 2015). It was unclear, however, whether the presence of spikelets in these specific layers was a result of differing primary deposition or of archaeological preservation. This issue will be re-considered with reference to crop processing stages (see **Section 5.8**) at a later phase of the analysis.

Another factor that became apparent after the identification of complete glume wheat spikelets was the frequent presence of emmer wheat spikelets that only contained one grain, rather than the usual two grains. In 'normal' 2-grain emmer wheat, the terminal spikelet of each cereal ear only contains one grain. The large number of 1-grain emmer wheat spikelets identified from within the Hattusha silo, however, would suggest that this may have been a separate variety of emmer wheat, rather than simply just terminal grains (this will be discussed in further detail in **Section 9.1.2.1**, **Chapter 9**). Archaeologically examples of 1-grain emmer wheat have been identified on a number of sites in Turkey by Mark Nesbitt (Nesbitt, 1993; Martinoli & Nesbitt, 2003) due to the convexity of the ventral face of the grain. By contrast, the number of 1-grain emmer wheat spikelets identified from within the Hattusha silo complex was relatively high, with a total of 1728 spikelets counted from 20/45 (44%) of samples. Correspondingly, in the majority of these samples the number of 1-grain spikelets far outweighed the number of 2-grain spikelets in a 3:1 ratio (see **Table 5.1**).

In many cases, however, variable charring effects within each chamber and particularly between chambers meant that the observable differences between the grains were so subtle that a large number of emmer wheat grains had to be categorized as indeterminate. In fact, in a reverse situation to that observed with the spikelets, the number of identified 2-grain emmer wheat grains was higher than 1-grain grains. This is thought to be because emmer wheat grains from two-grained spikelets were easier to identify by their flattened ventral faces whereas emmer wheat grains from one-grained spikelets look very like emmer wheat grains charred out of the spikelet and were, therefore, often assigned to an indeterminate category. Due to the lack of concrete morphological differences between emmer wheat grains from one- versus two-grained spikelets, these categories have been merged together for the purposes of this analysis

(see **Section 4.2**, **Chapter 4** for further details on the identification of 1-grain emmer wheat).

5.4 Crop contaminants

Aside from the primary crops of hulled barley, emmer wheat and einkorn wheat shown in **Figure 5.6**, samples from the Hattusha silo complex also contained several other potential crop taxa, including both cereals and pulses. Although these taxa may well have been being cultivated within Hittite agricultural regimes at the time, the small quantities of plant items identified, combined with low overall ubiquities (see **Table 5.1**), suggest that these taxa were not purposefully being stored in the silo and instead are present as crop contaminants.

Free-threshing wheat (*Triticum aestivum/durum*) was identified in every chamber of the silo, with the grain present in 13/45 (29%) of samples and free-threshing wheat rachis in 18/45 (40%) of samples. The total sum of free-threshing wheat plant parts identified, however, was significantly lower than the comparative totals for hulled barley and glume wheat, with only 77 grains and 125 rachis internodes that could not be identified to species. This pattern suggests that free-threshing wheat may have been a common crop contaminant throughout the agricultural regime(s) represented within the silo.

Other potential crop contaminants included naked barley (*Hordeum* L. var. *nudum*), which was present in 10/45 (22%) of samples, and a number of domesticated pulse species: bitter vetch (*Vicia ervilia*), lentil (*Lens culinaris*) and grass pea (*Lathyrus sativus*). Of these species, lentil and grass pea were both identified only in a minority of

samples – 16/45 (35%) and 8/45 (18%) of samples, respectively (see **Table 5.1**) and were, therefore, discounted as cultivated crops. By contrast, bitter vetch was identified in a much larger proportion of the assemblage: 34/45 (76%) of samples. In a similar manner to free-threshing wheat, however, the total number of bitter vetch remains counted was considerably lower than those of the cereal crops (see **Table 5.2**), and for this reason it was discounted as a primary cultivar. Previous work on the silo assemblage had also identified another pulse species, a variety of small broad bean or Celtic bean (*Vicia faba* var. *minuta*, Neef *et al.* 2012). Significantly, in contrast with the other domesticated pulse taxa, this species was present in large quantities throughout the silo, particularly within Chamber 32, and was identified in 45/45 (100%) of samples from the silo. This high number of *Vicia faba* var. *minuta* remains would suggest that this species may have been cultivated nearby within the Hattusha landscape and as a result had encroached on the cereal fields. Furthermore, when comparing the quantity of *Vicia faba* var. *minuta* with the quantity of cereal grain it is clear that the amount of cereal grain within each chamber still far outweighs that of this pulse species. It is unlikely, therefore, that this species was purposefully stored within the underground silo and instead suggests this was incorporated alongside the cereal grain as a contaminant.

5.5 Weed/wild taxa

As **Figure 5.3** made clear, a large proportion of the Hattusha silo assemblage is comprised of weed/wild taxa, and indeed every sample studied was found to contain a large number of weed/wild plant items. In total 100 identified taxa, from type- to species level, were identified within the underground silo assemblage. This number of taxa is not uncommon for an archaeobotanical assemblage, but what was unusual was

the sheer quantity of weed/wild items in every sample (see **Table 5.1**). Of the 100 taxa identified, 17 were found in over 50% (23/45) of the samples and seven were found in over 80% (37/45) of the samples. These common weed species included: *Bifora radians* M. Bieb., *Polygonum aviculare* L., *Ranunculus arvensis* L., *Galium tricornutum* Dandy, *Galium spurium* L., and *Vaccaria pyramidata* Medik. (see **Table 5.2**). The interpretation of these weed/wild taxa will be considered in greater detail later in this chapter with reference to crop processing and in **Chapter 6** through the use of functional ecology (see **Section 5.8** and **Section 6.8**, **Chapter 6**).

Table 5.2 – Summary of the frequency and abundance of major weed/wild taxa.

Weed/wild taxa	Presence	Ubiquity (%)	Max/sample	Sum
Avena sterilis/fatua cf.	25	56	51	397
Bifora radians	42	93	180	2516
Boreava aptera cf.	23	51	38	165
Buglossoides arvensis	33	73	73	294
Bupleurum sp.	27	60	66	303
Caucalis platycarpos	31	69	33	341
Centaurea sp.	27	60	13	103
Cruciata laevipes	31	69	51	253
Galium spurium	39	87	150	698
Galium triconutum	45	100	1296	12001
Lolium persicum	26	58	94	565
Neslia paniculata	33	73	12	150
Polygonum aviculare	42	93	262	2068
Ranunculus arvensis	42	93	197	1900
Turgenia latifolia	34	76	62	635
Vaccaria pyramidata	41	91	200	1703
Veronica hederifolia	32	71	22	160

5.6 Other

A number of fruit and nut remains were also identified within the assemblage in very low quantities. These taxa included: *Pistacia* sp., *Pyrus/Malus* sp., *Prunus* sp., *Rubus* sp. and *Vitis vinifera* L. All of these species were only represented by one seed/nutshell fragment (each species has an assemblage ubiquity of 2%) and as such do not contribute to the overall composition of the assemblage in any significant way. It is likely that these remains became incorporated within the assemblage by accident, potentially during crop processing or during the initial filling of the silo. In addition, 51 specimens of grain weevil (*Sitophilus granarius*) were found in 11/45 (24%) of samples. There was no detectable correlation between the number of grain weevils present and the dominant species of crop present in the sample. There were also trace amounts of charcoal (>2mm fragments of charcoal identified per sample) although this would be expected within a large crop storage facility, and it is thought that this charcoal may derive from wood fragments from timber beams used to support the mud brick walls of the chambers (Seeher, 2006).

5.7 Exploratory analysis of sample composition

5.7.1 Correspondence analysis

Correspondence analysis (CA) was used to explore similarities and differences in the archaeobotanical composition of individual samples, following the principles and methods laid out in **Chapter 4** (see **Section 4.5.1**). The following sets of analyses include those based on crops only, crop and weed/wild taxa and weed/wild taxa only.

To avoid analyses being skewed by the occurrence of rare taxa or small unrepresentative samples, samples containing less than 100 crop items (three samples in total) were excluded from all analyses (cf. van der Veen & Fieller 1982), along with all taxa present in less than 25% of samples (53 taxa in total). The 25% threshold was chosen, not only to remove outlier taxa that would have skewed the analysis, but also to reduce the imbalance between the number of taxa and number of samples in the analyses and to ensure greater statistical reliability (Ter Braak & Smilauer, 2012). Similarly, for analyses based on weed/wild taxa only, samples containing less than 100 weed/wild items (five samples in total) were excluded. For CA carried out only on the assemblage from Chamber 30 (**Section 5.7.2.1**), the number of taxa present in 25% of samples was re-calculated using the number of samples from the chamber. All taxon codes for correspondence analysis are explained in **Table 12.1**, **Appendix.**

5.7.1.1 Variation in crop composition

Initial correspondence analyses based on crop composition included intact emmer and einkorn wheat spikelets as separate categories to emmer and einkorn wheat grain and glume bases. The scatterplots produced, however, showed that these items were extreme outliers and skewed the analysis accordingly (plot not shown). For this reason, the 'deconstructed' totals calculated for emmer and einkorn wheat spikelets (see **Section 5.3.2**) have been used in all subsequent compositional analyses, so that the presence of whole spikelets within only a small number of samples, and primarily one chamber (Chamber 30), does not unduly affect the analyses. In this respect, each 2-grain emmer wheat spikelet was counted as two emmer wheat glume bases and two emmer

wheat grains, while each 1-grain emmer or einkorn wheat spikelet was counted as two glume bases and one grain each.

CA based on crop items only was carried out on the resulting crop dataset including all samples containing over 100 crop items, after glume wheat grains had been proportionally re-assigned (see **Section 5.3.2)** and whole spikelets 'deconstructed'. **Figure 5.7** is a biplot showing 42 samples, coded by chamber number, and the six major cereal crop categories. The most notable trend is that all cereal species are clustered near the origin of the plot indicating their ubiquity throughout the assemblage. Einkorn wheat is the only species located slightly further away towards the positive (right) end of axis 1 in accord with its presence primarily within one chamber (Chamber 30). By contrast, sample points show some clear patterning when coded by chamber. The most notable pattern is the dense clustering of samples from Chamber 30 towards the negative (bottom) end of axis 2, indicating their association with einkorn wheat and hulled barley rachis and grain. All other samples from the remaining four chambers appear to have a wider distribution, reflecting their varied cereal species composition and their lack of association with einkorn wheat. Unlike Chamber 30, however, samples from the other chambers are still clustered together but there is considerable overlap between the different chambers. Samples from both Chamber 12 and Chamber 29 appear to have two distinct compositions; samples located towards the negative end of axis 2 associated with hulled barley remains, and samples located towards the positive end of both axes associated with emmer wheat grain. Chamber 32 meanwhile, appears to have a slightly more uniform composition with four samples located towards the positive end of both axes associated with emmer wheat grain and only two outlier samples with more varied cereal compositions. The single sample from Chamber 28 is located within the cluster of samples from Chambers 12 and 30 towards the negative

end of axis 1. This is consistent with a principally hulled barley based sample composition.

Figure 5.8 presents the plot for this analysis with species categorised into groups of taxa allowing each sample to be represented by a pie chart. This further illustrates the contrast among dominant crop species, with einkorn-containing samples towards the positive (right) end of axis 1, barley-dominated samples towards the negative (left) end of axis 1 and emmer-rich samples towards the positive ends of both axes. Though all Chamber 30 samples were clustered together towards the negative end of axis 2, this chamber actually contains samples with two very distinct compositions: samples located towards the negative end of axis 1, dominated by hulled barley grains, and samples positioned toward the positive end of axis 1 with a more mixed composition of emmer wheat grain and chaff, einkorn wheat and chaff and a very small proportion of hulled barley grains. In fact, this second grouping of samples from Chamber 30 seems to be the most compositionally diverse in crop terms across the entire Hattusha assemblage. Samples from the other chambers fall into one of three categories. Samples dominated by hulled barley are located toward the negative end of axis 1 and on either side of axis 2. Samples dominated by emmer wheat grain are located towards the positive end of both axes. Samples containing a mixture of both hulled barley and emmer wheat grain are concentrated towards the positive end of axis 1 but closer to the origin than samples dominated by emmer wheat grain. These two plots (**Figures 5.7** and **5.8**), therefore, demonstrate that each chamber was used to store a mixture of wheat and barley crops, but that within and between each chamber there is significant variation in terms of crop composition.

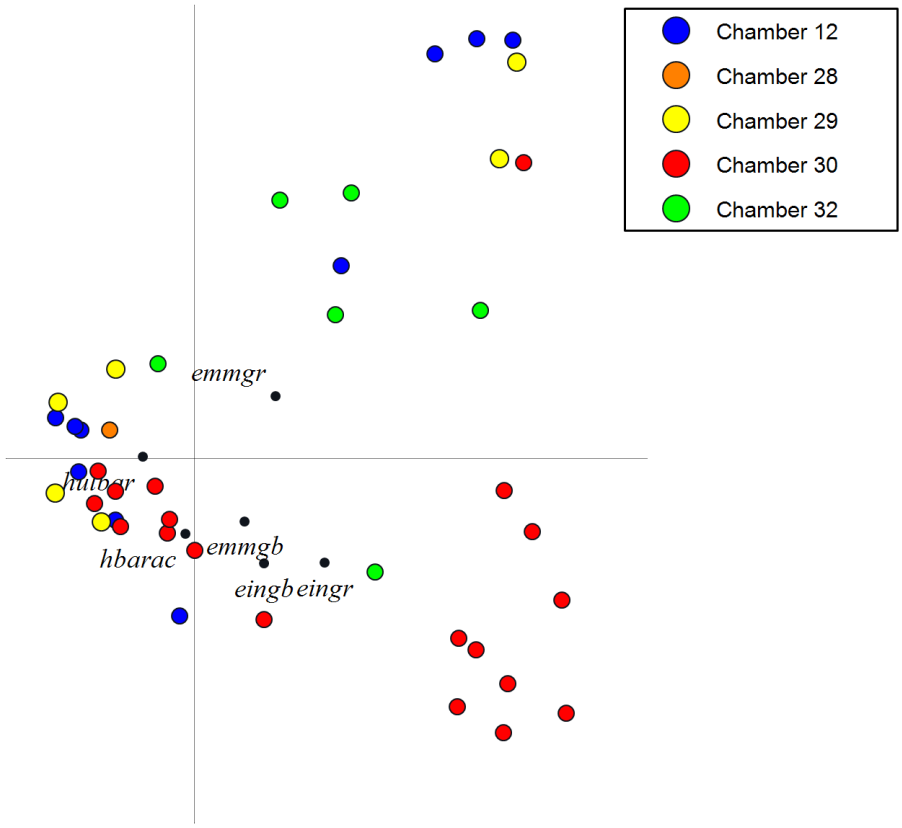


Figure 5.7 – CA biplot of 42 samples and major cereal crop categories, coded by chamber number.

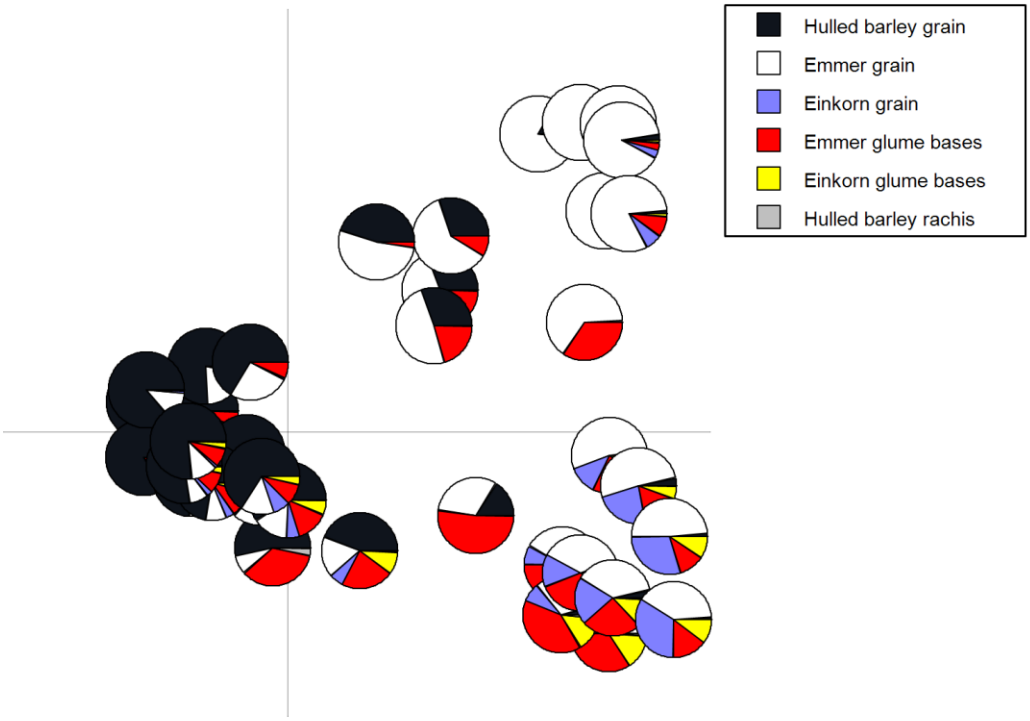


Figure 5.8 – CA plot of 42 samples with samples represented as pie charts showing proportions of major crop categories.

5.7.1.2 Variation in crop and weed/wild taxa composition

In this correspondence analysis, the relationships among cereal crops and weed/wild taxa were explored. This analysis incorporated amalgamated categories of weed/wild taxa (see **Table 4.3**, **Chapter 4)** to avoid unnecessary overlaps between items from the same taxon. This correspondence analysis was carried out on all samples containing over 100 crop items (42 samples) and all plant species present in over 25% of samples (50 taxa). **Figure 5.9** presents the scatterplot of species and shows that the cloud of species at the origin includes the primary cereal crops, hulled barley and emmer wheat alongside the most common weeds species (e.g. *Polygonum aviculare*, *Bifora radians* etc. as mentioned above in **Section 5.5**), indicating their ubiquity throughout the assemblage. A group of weed/wild taxa are located towards the positive end of axis 1 and the negative end of axis 2, while another group is distributed along the positive end of axis 2 indicating their relative rarity across the assemblage (e.g. *Convolvulus arvensis* L. and *Adonis annua* L.).

Figure 5.10 shows the accompanying sample scatterplot for this analysis, coded by chamber number. Samples from Chambers 29 and 30 occur in two distinct clusters; one group located towards the negative end of axis 1 and one group located towards the positive end of axis 2. This suggests that samples from these chambers fall into two compositionally distinct groups. Samples from the Chambers 12 and 32 also now show clear clustering with respect to axis 1 and to some extent, axis 2. This trend points to the fact that these chambers contain samples that are compositionally unique to that chamber. This is particularly the case with samples from Chamber 32 which are situated toward the positive end of axis 1 and the negative end of axis 2 (i.e. the bottom right quadrant of the plot).

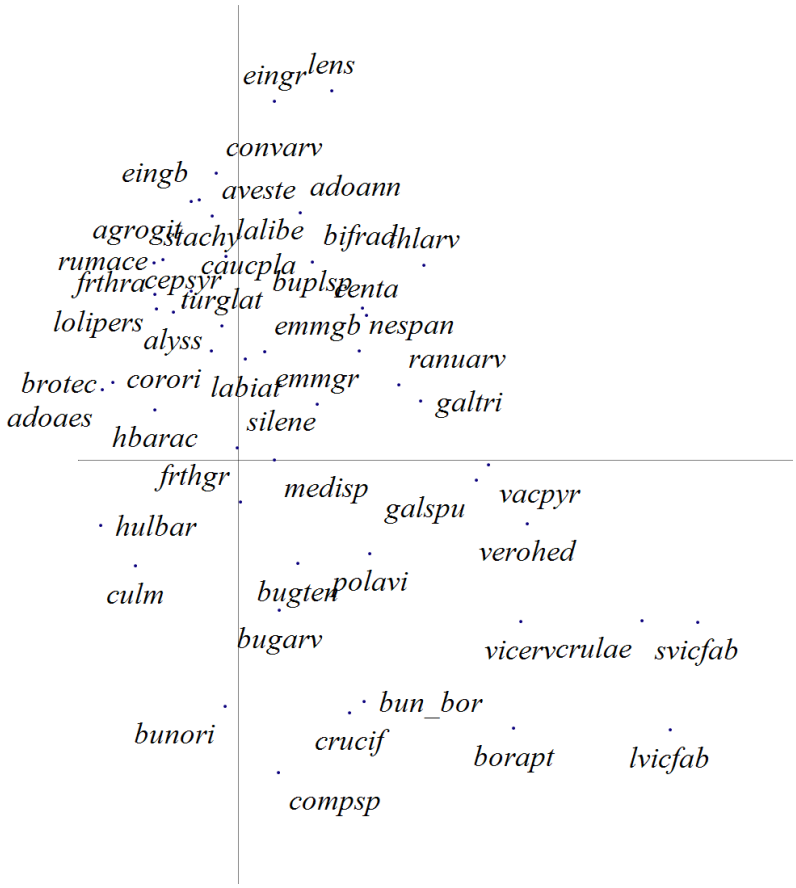


Figure 5.9 – CA scatterplot of 50 taxa.

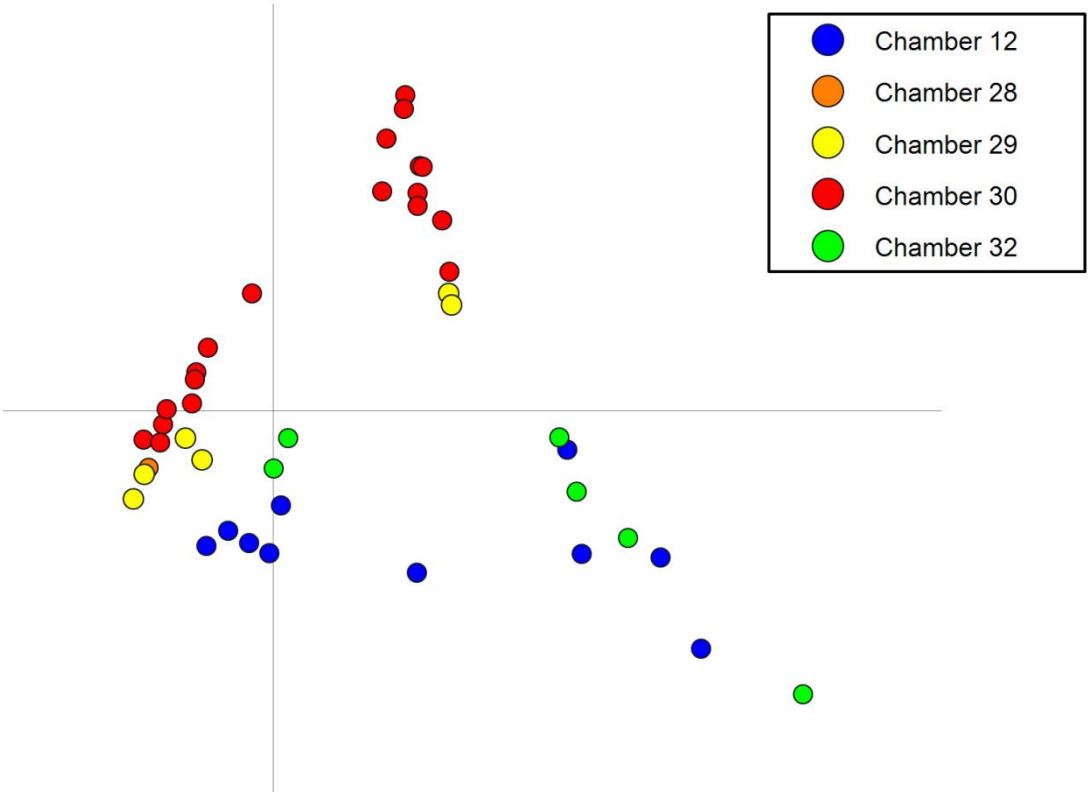


Figure 5.10 – CA plot of 42 samples and 50 taxa, coded by chamber number.

Figure 5.11 displays the number of taxa contained in each sample, of the 50 taxa incorporated into the analysis. This graph clearly demonstrates that samples from Chamber 30 had the widest range of identified species. By contrast, samples from Chambers 12 and 32 contain a smaller range of taxa. Chamber 12 in particular seems to contain a number of samples with less weed/wild taxa identified to the species level and is possibly indicative of poorer levels of preservation in this chamber. The grouping of samples in **Figures 5.10** and **5.11** suggests that each chamber contains a specific weed compositional 'type' that is a distinct signature within the wider Hattusha silo assemblage. This also indicates that the crops stored in each chamber may not have come from the same source and perhaps, critically, also not from the same agricultural regime. Finally, there is also a high level of intra-chamber variability and this will be further explored below.

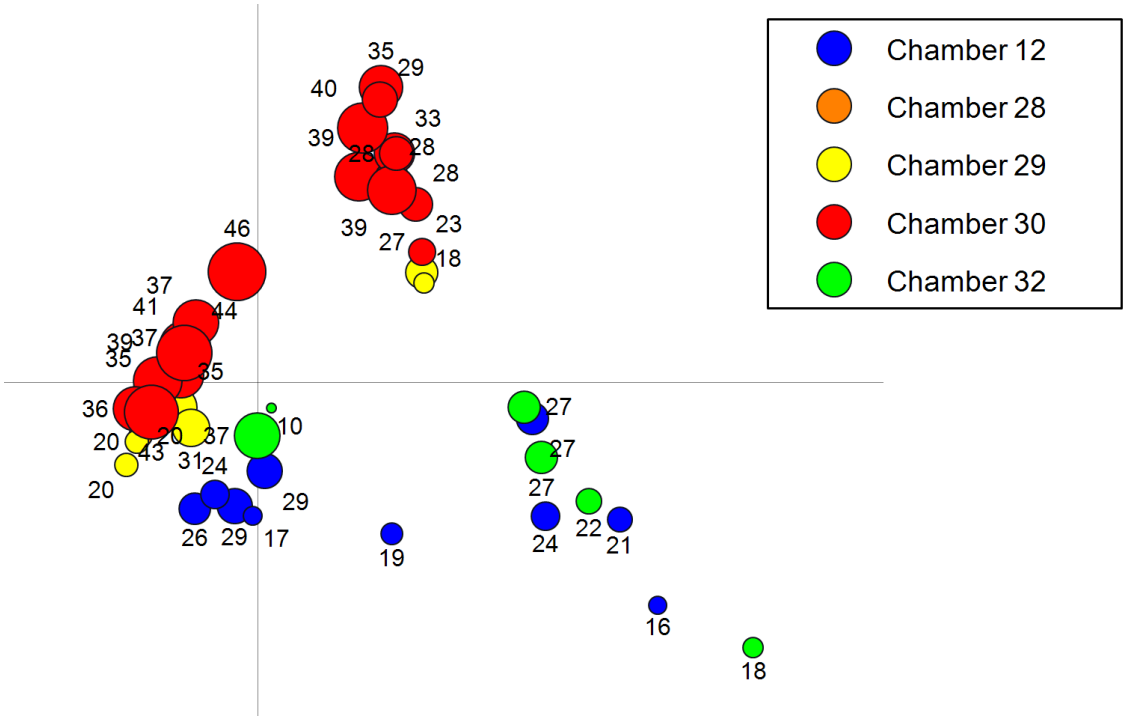


Figure 5.11 – CA plot of 42 samples and 50 taxa, coded by chamber number and displaying the number of taxa present in each sample.

5.7.1.3 Variation in weed/wild taxa composition

It has already been shown that the Hattusha silo assemblage contains a high proportion of weed/wild taxa in comparison to cultivated crops, and that samples tend to cluster together by individual chamber. It was, therefore, decided to perform a further analysis on the basis of weed/wild taxa only, as a means of exploring this aspect of variation among the samples separately from crop composition. This analysis included all samples which contained over 100 weed/wild items (39 samples) and taxa that were present in over 25% of the samples (37 taxa). **Figure 5.12** shows a scatter plot of the weed/wild taxa and, as in **Figure 5.9**, it is again clear that the majority of taxa are clustered towards the negative ends of both axes and towards the origin of the plot. There is also a small group of taxa (including *Cruciata laevipes* Opiz., *Galium spurium* and *Medicago* sp.) located towards the positive end of axis 2. The most noticeable grouping, however, is a grouping already identified in **Figure 5.9** at the positive end of axis 1 and the negative end of axis 2. This grouping is comprised of *Bunias orientalis, Boreava aptera, Compositae* sp., *Cruciferae* sp., *Buglossoides arvensis* L., *Buglossoides tenuiflora* L. and *Polygonum aviculare*.

Figure 5.13 shows the samples coded by chamber number, and again samples are clustered together by chamber. Chamber 12 has the most variable composition and appears the most distinct from the other chambers, located along the positive end of axis 1 and on both ends of axis 2. In terms of taxa, Chamber 12 appears to have contained large proportions of: *Bunias orientalis*, *Buglossoides* sp., *Cruciferae* sp. and *Polygonum aviculare*. Chamber 32 and 29 seem to have relatively similar weed/wild compositions, a fact that was not apparent from the crop-only analysis. All samples from these two chambers (with the exception of one sample from Chamber 29) are located towards the negative end of axis 1 and the positive end of axis 2. Samples from Chamber 29 are

located slightly closer to the origin of the plot, implying the presence of the most commonly identified weed/wild taxa, whereas samples from Chamber 32 are situated further towards the positive end of axis 2, reflecting a higher proportion of *Cruciata laevipes* and *Galium spurium*, which occupy this position in the corresponding taxa plot (**Figure 5.12**). Finally, samples from Chamber 30 are located near the origin and towards the negative end of both axes. In every correspondence analysis performed thus far, samples from Chamber 30 have been split into two groups slightly separate from the other chamber groupings. One of these groups was located near the origin of the plot and one located at the positive end of both axes. In earlier analyses (**Figure 5.7** and **Figure 5.10**) this patterning could have been explained due to the separation of samples into those dominated by hulled barley grain and those dominated by emmer wheat grain and also by the identification of einkorn wheat in some of these samples, a species barely present in other chambers. **Figure 5.13** however, shows that, while contrasting in crop composition, the weed/wild species composition of Chamber 30 appears to be uniform across *all* samples from that chamber. This indicates that regardless of crop type, all samples from Chamber 30 have a similar weed/wild composition that is unique from that of the other chambers.

Figure 5.14 shows the same analysis with the number of species identified in each sample. Again, as in **Figure 5.11**, samples from Chamber 30 contain the largest variety of taxa, with one sample containing 33 weed/wild taxa out of a possible 37. Comparatively, samples from Chambers 12 and 32 have a much smaller range of taxa, with a number of samples containing less than 20 taxa, and one sample from Chamber 32 only containing five taxa. This chamber patterning is particularly interesting when compared with **Figure 5.4** from the overview, as it is clear that Chambers 12 and 32 contained a large percentage of weed/wild taxa in comparison to crops, but only a small

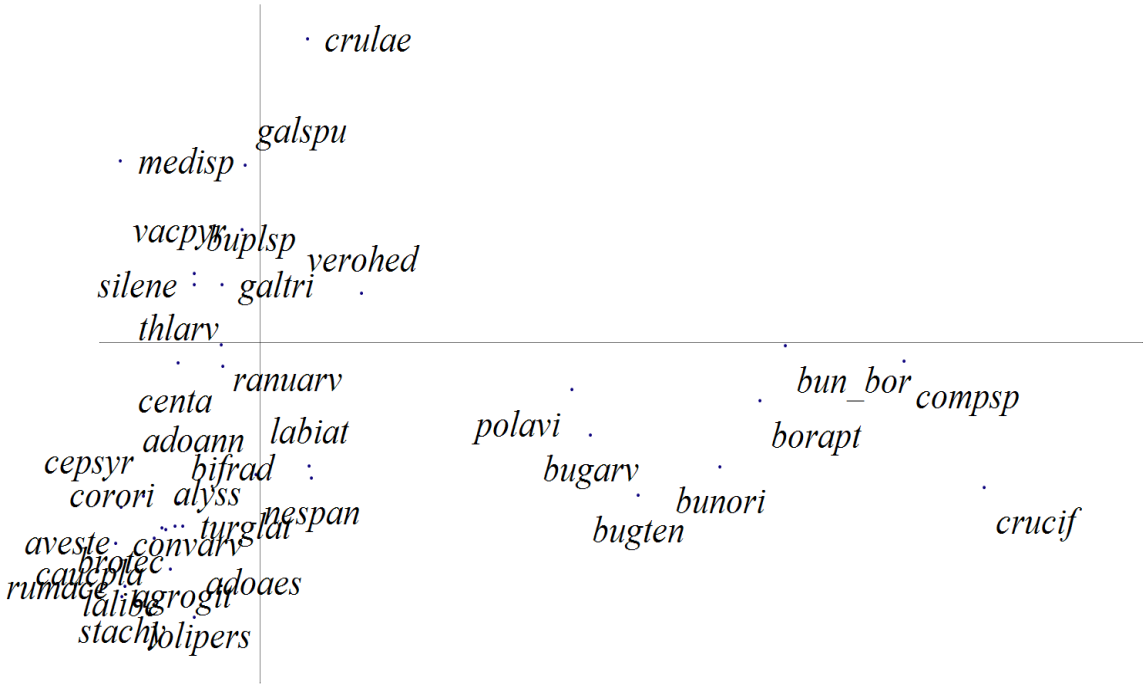


Figure 5.12 – CA scatterplot of 37 weed/wild taxa.

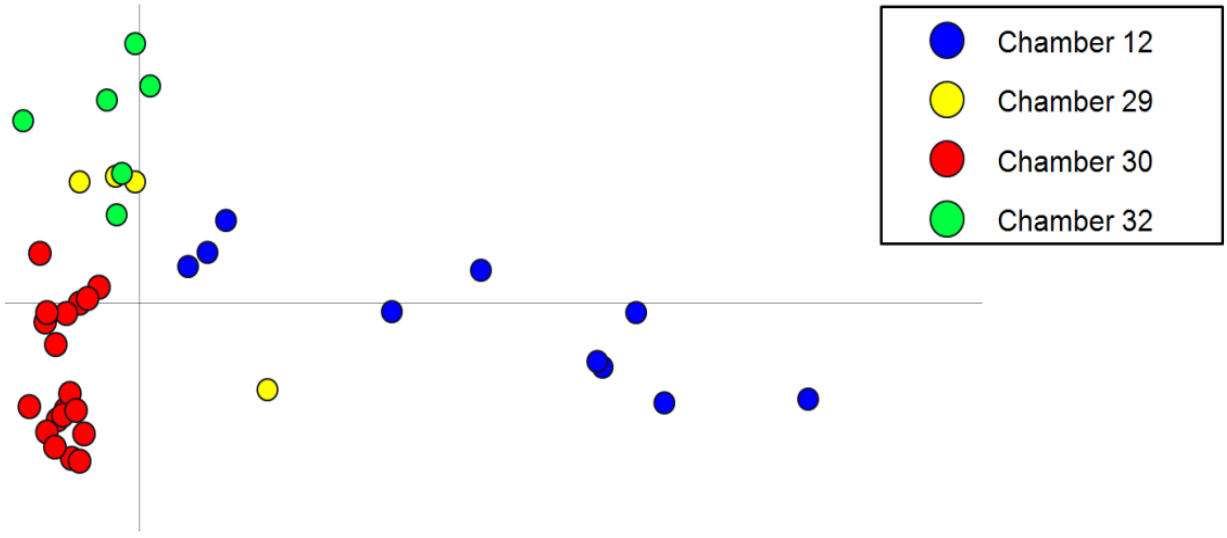


Figure 5.13 – CA plot of 39 samples and 37 weed/wild taxa, coded by chamber number.

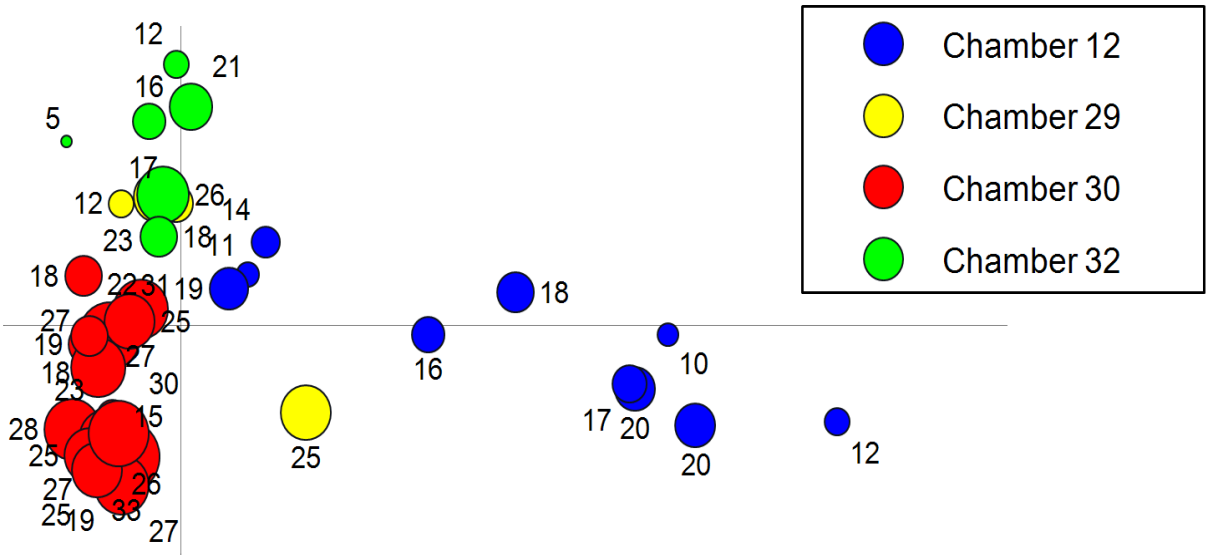


Figure 5.14 – CA plot of 39 samples and 37 weed/wild taxa, coded by chamber number and displaying the number of samples present in each sample.

range of species, whereas Chambers 29 and 30 contain a larger proportion of cereal crop grains, in comparison to weed/wild items, but a much wider variety of weed/wild species. The distinctive combinations of cultivated crops with weed/wild taxa in each chamber indicate that the crops stored in the silo complex were likely cultivated in multiple growing locations and potentially in multiple agricultural regimes. This will be explored further below through crop stable isotope analysis (see **Section 6.1**, **Chapter 6**, **Section**) and functional weed ecological analysis (see **Section 6.8**, **Chapter 6**, **Section**).

5.7.2 Variation within chambers

This next section will explore compositional variation within each chamber as a means of assessing the homogeneity of the charred material stored in the same location.

This analysis is also an opportunity to assess whether or not the arbitrary spits and grid sampling captured any vertical and/or horizontal stratigraphy within the chamber. Chamber 28 has been left out of this analysis as it is represented by only one sample.

5.7.2.1 Chamber 30

Correspondence analysis was carried out initially on samples from Chamber 30, as this chamber had the most samples, and contained the highest number of weed taxa identified to species. **Figure 5.15** is a crop-only plot of all 19 samples from Chamber 30. Samples are represented as pie charts showing the respective proportions of all crop grains and chaff. From this chart it is clear that samples from Chamber 30 fall into three categories: those dominated by hulled barley grain, located towards the origin and the negative end of axis 1, those dominated by emmer wheat grain, located towards the positive end of axis 1 and the negative end of axis 2, and those with a more mixed composition of glume wheat grains and glume wheat chaff toward the positive ends of both axes. This suggests the presence of two distinct crop compositions within the chamber: hulled barley, and a mixed glume wheat crop of predominantly emmer wheat alongside small quantities of einkorn wheat. In this case it is not surprising that many of the glume wheat dominated samples contain high proportions of chaff as it seems likely that this crop was stored within the spikelet in this chamber. Furthermore, it has been shown experimentally that charring under conditions of reduced oxygen can lead to the preservation of light chaff (Boardman & Jones, 1990).

A further correspondence analysis was carried out on all crops and weed/wild taxa which were present in over 25% of the samples in Chamber 30 (19 samples, 63 taxa) after the removal of *Boreava aptera*, a weed/wild species that behaved as an

outlier and highly skewed the initial plot (plot not shown). This correspondence analysis was conducted in order to assess whether the hulled barley dominated samples had a noticeably different associated weed/wild assemblage from the glume wheat dominated crops. **Figure 5.16** shows all taxa located within a large cluster around the origin of the plot. The only exceptions to this trend are *Bromus* sp. (located to the negative end of axis 2), *Medicago* sp. and *Cruciata laevipes* (located towards the positive end of axis 2). This would suggest that, even though samples from Chamber 30 contain primarily hulled barley or glume wheat, both crop types have extremely similar associated weed/wild assemblages and contain the same range of taxa. When this analysis is displayed as compositional pie charts (**Figure 5.17**), however, it becomes clear that the samples with larger proportions of glume wheat grain contain much higher proportions of weed/wild remains than hulled barley dominated samples. This indicates that even though both cereal species were accompanied by a similar *range* of weed/wild taxa, the glume wheat dominated samples contained much higher *quantities* of these taxa. This aspect of the Chamber 30 assemblage will be analysed and discussed in greater detail with reference to crop processing and functional ecology in **Section 5.8** and **Section 6.8**, **Chapter 6**.

Finally, both **Figures 5.15** and **5.16** were also coded by vertical excavation spit and horizontal grid number, but neither of these plots displayed any visible trends between sample composition and physical location within the chamber and, therefore, these plots are not shown in this thesis. This would suggest then that a certain amount of mixing had taken place either before or during crop storage, and was almost certainly exacerbated by the effects of the burning event.

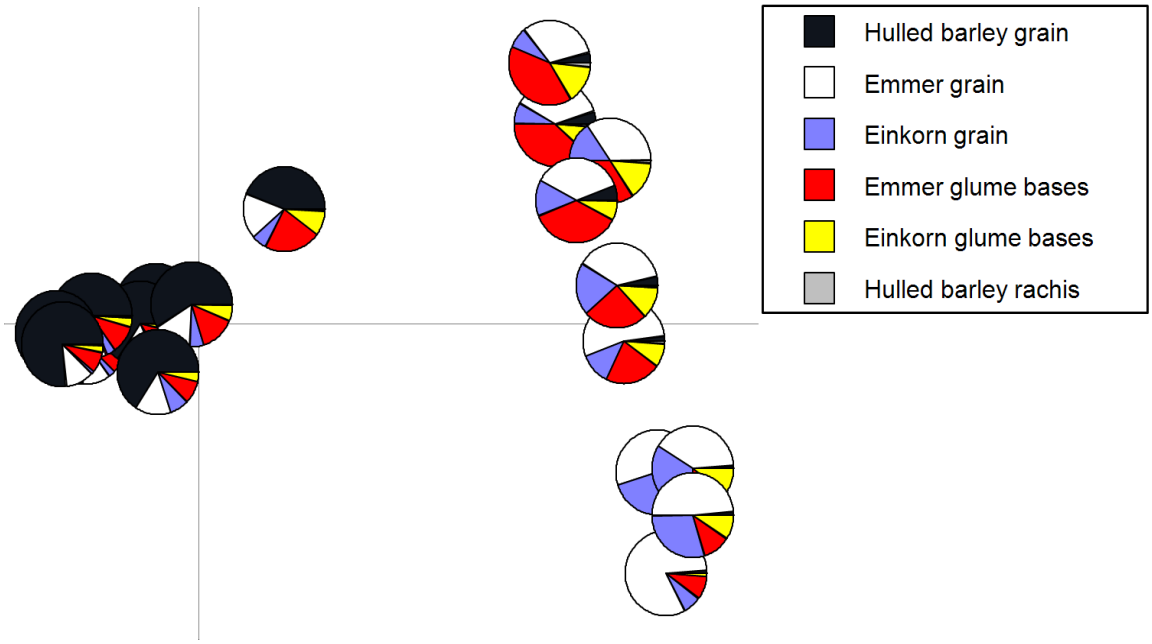


Figure 5.15 – CA plot of 19 samples from Chamber 30 with samples represented as pie charts showing proportions of major crop categories.

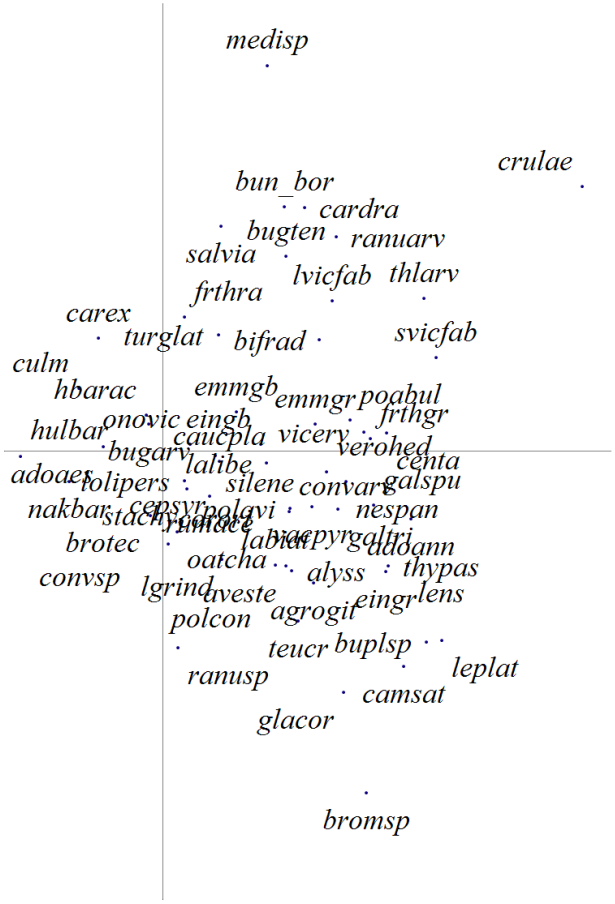


Figure 5.16 – CA scatterplot of 63 taxa from Chamber 30.

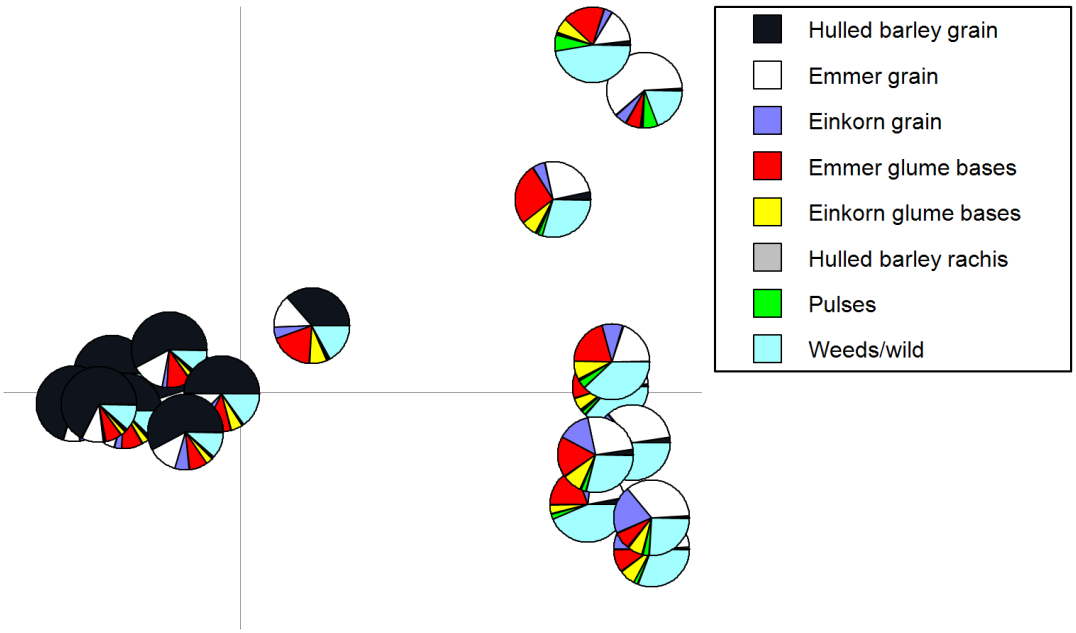


Figure 5.17 – CA plot of 19 samples and 63 taxa from Chamber 30 with samples represented as pie charts showing the proportions of major plant item categories.

5.7.2.2 Chamber 29

Due to the low number of samples recovered from the other chambers, correspondence analysis was not appropriate for exploring variation within these chambers. This is due to the discrepancy between the number of samples and the number of species/taxa included in the analysis. The archaeobotanical compositions of Chambers 12, 29, and 32 have, therefore, been analysed using percentage stacked bar charts.

It is clear from previous analyses (**Figures 5.10** and **5.13**) that samples from Chamber 29 are similar to samples from Chamber 30 in terms of their crop/weed proportions and wide ranging weed/wild assemblages. It might be expected, therefore, that samples from Chamber 29 would behave in a similar manner to those of Chamber 30. **Figure 5.18** shows a crop-only analysis carried out on all Chamber 29 samples containing over 100 crop items (six samples), with samples displayed as individual bars

stacked in stratigraphical order. As was the case in Chamber 30 it is evident that there is a clear divide between emmer wheat grain dominated samples, hulled barley grain dominated samples and samples containing a significant quantity of emmer wheat glume bases. Unlike Chamber 30, however, there also appears to be some slight stratigraphical patterning within the chamber. For example, the two samples dominated by emmer wheat grain both originate from the bottom of the chamber (level 278), whilst samples from higher in the sequence are all hulled barley grain dominated. Interestingly, it would also seem that the higher the stratigraphical level the less emmer wheat grain and the more emmer wheat glume bases are present in each sample (levels 206 and 191). There does not appear, however, to be any horizontal patterning within the assemblage, although the low number of samples taken from this chamber makes this difficult to truly assess.

A further crop and weed/wild analysis was carried out on all taxa present in 25% of Chamber 29 samples (35 taxa) as a means of assessing the relationship between crops and associated weed/wild assemblages. **Figure 5.19** is a stacked bar chart showing samples by classified plant groups again arranged in stratigraphical order. From this it would seem that there is a (weak) relationship between dominant crop species and the quantity of weed/wild taxa present within the sample. In general, emmer wheat grain dominated samples seem to contain a higher proportion of weed/wild taxa, whilst hulled barley dominated samples contain slightly lower proportions. Additionally, it would appear that emmer wheat samples also contain a larger proportion of pulse remains, suggesting an association between these species. The pulse category here is dominated by *Vicia faba* var. *minuta*. This relationship between emmer wheat grain and a higher

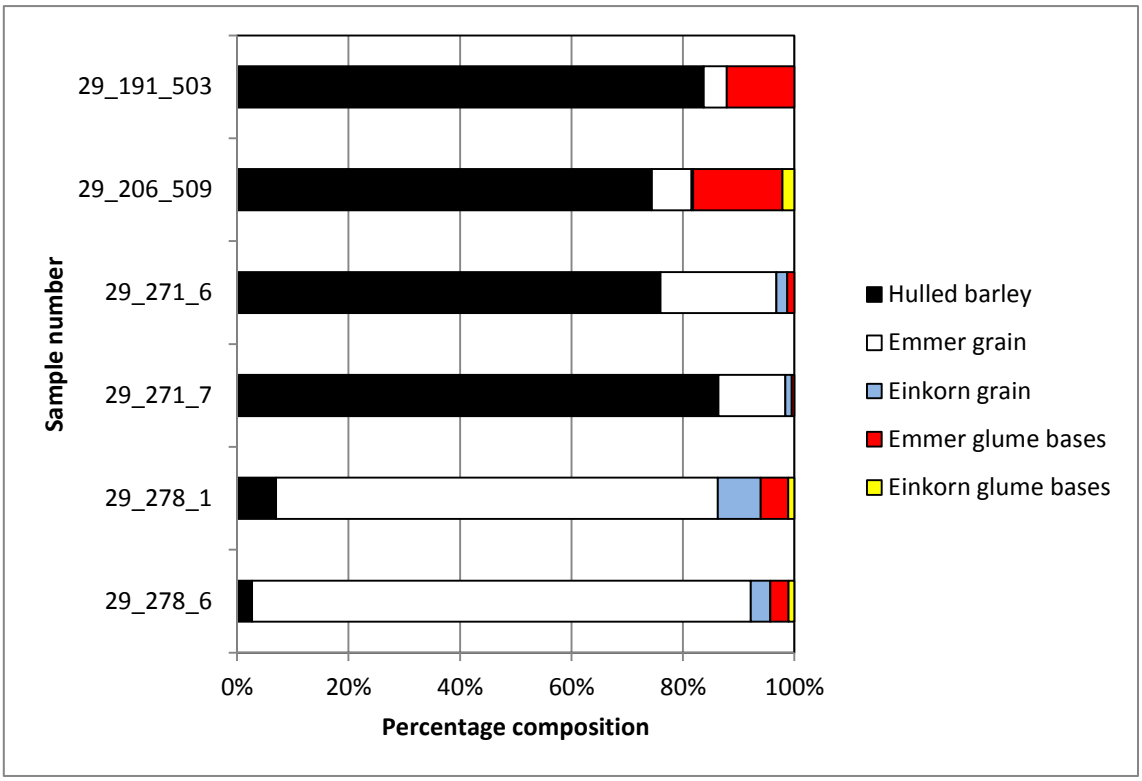


Figure 5.18 – Percentage stacked bar chart of six samples from Chamber 29 showing proportions of major crop categories.

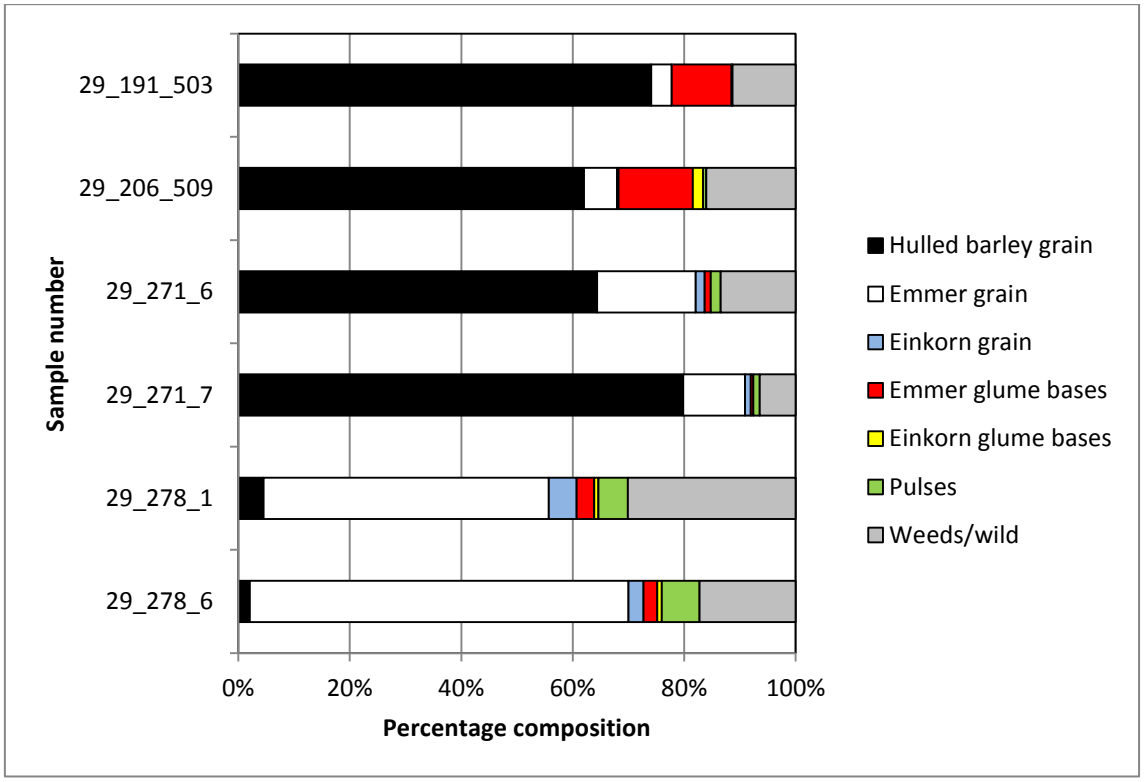


Figure 5.19 – Percentage stacked bar cart of six samples from Chamber 29 showing proportions of major crop categories, pulses and weed/wild taxa.

amount of weed/wild remains is similar to that identified above in Chamber 30 and again suggests that the majority of weed/wild remains entered the silo with the glume wheats. When looking at weed/wild taxa at the species level, however, the crops hulled barley and emmer wheat share a very similar range of weed species. This suggests, as was the case with Chamber 30, that both of these cereal crops were cultivated under similar growing conditions before being stored together within the chamber.

5.7.2.3 Chamber 32

Compositional analysis was carried out on all six samples from Chamber 32. **Figure 5.20** presents the crop-only percentage stacked bar chart arranged in stratigraphical order. Unlike the crop-only plots from Chambers 30 and 29, samples from Chamber 32, with the exception of sample 32_74, do not seem to have been dominated by a single crop species. Instead, all samples have a mixed composition of hulled barley grain, emmer wheat grain and emmer wheat glume bases. Overall, however, this chamber contains the greatest quantities of emmer wheat grain identified from the underground silo assemblage. There is also some degree of vertical stratigraphy; the amount of hulled barley grain decreases from the top of the chamber (level 64) to the bottom of the chamber (level 74), while the amount of emmer wheat glume bases increases with chamber depth, even though emmer wheat grain does not visibly increase with depth. Additionally, sample 32_64 from the top of the chamber is the only sample to contain a visible amount of einkorn wheat grain. When compared with the equivalent amounts of hulled barley and emmer wheat grain, however, einkorn wheat grain only comprises less than 1% of the total crop grains identified within this sample.

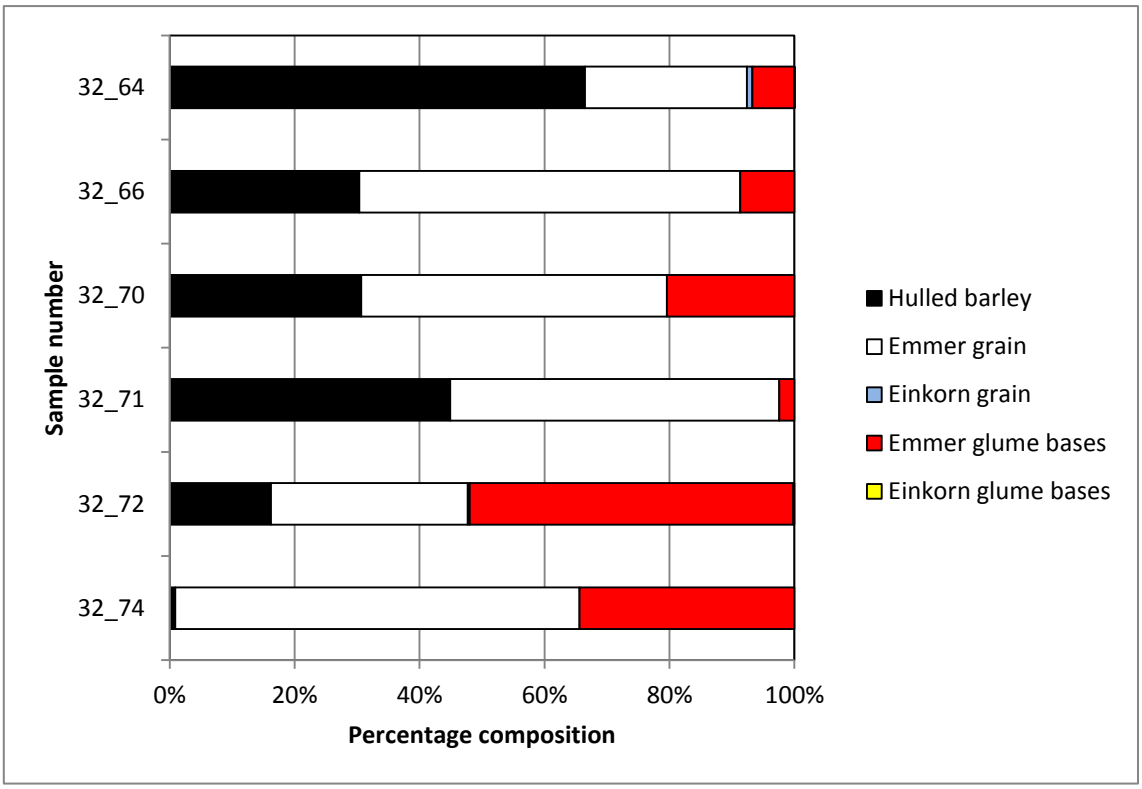


Figure 5.20 – Percentage stacked bar chart of all samples from Chamber 32 showing proportions of major crop categories.

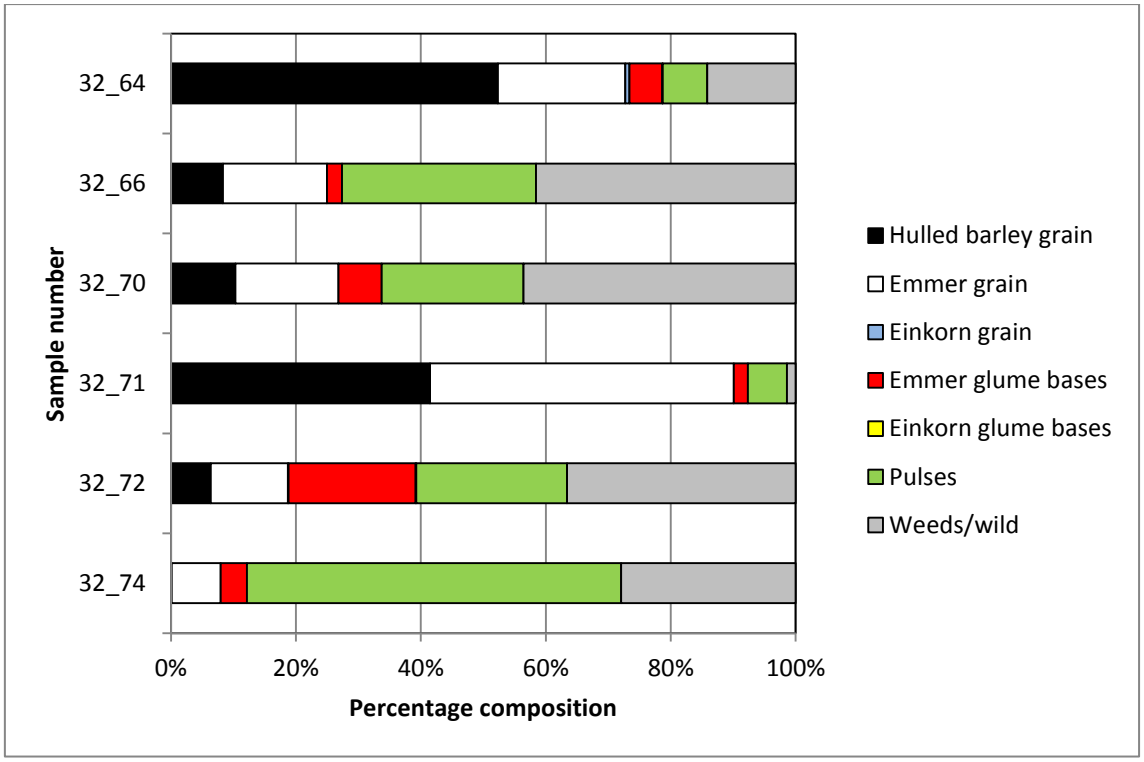


Figure 5.21 – Percentage stacked bar chart of all samples from Chamber 32 showing proportions of major crop categories, pulses and weed/wild taxa.

Figure 5.21 is a stacked bar chart showing the major crop species from Chamber 32 alongside a weed/wild taxa category and a pulse category. From this plot it is evident that there is an overall decrease in the amount of cereal grain within the lower levels of the chamber (levels 72 and 74) and a subsequent increase in weed/wild species and pulses. In particular, the lowest level of the chamber (level 74) contains only 8% cereal grain and 88% weed/wild taxa and pulses. The most obvious exception to this rule is the sample from level 71 which contains a much higher proportion of crop grains to weed/wild species and a low percentage of emmer wheat glume bases in comparison to the other samples. In fact, the composition of sample 32_71 is so different from the samples recovered from the stratigraphic levels above and below it, it appears likely that this sample was mislabelled and actually originates from a higher level of the chamber.

This chamber also contains the largest quantities of pulse remains identified from the silo assemblage. As was stated above with regards to Chamber 29, the pulse category in Chamber 32 is dominated by *Vicia faba* var. *minuta* and throughout the underground silo assemblage this species seems to be associated primarily with emmer wheat grain. Chamber 32 compositionally contains the largest amounts of emmer wheat grain identified from an individual chamber within the silo and consequently also contains the largest proportions of *Vicia faba* var. *minuta* further underlining their association. This would seem to indicate that this pulse species is a specific crop contaminant of emmer wheat and that its presence within hulled barley dominated samples is as a result of the post-processing mixing of crops prior to final storage.

5.7.2.4 Chamber 12

Crop-only compositional analysis (**Figure 5.22**) carried out on all samples containing over 100 crop items (10 samples) from Chamber 12 shows a decrease in hulled barley grain and corresponding increase in emmer wheat grain with increasing stratigraphical depth. This compositional separation between samples at the bottom and top of the chamber further supports the theory that hulled barley and the glume wheats were cultivated and processed separately before being stored together within the silo. Additionally, the higher levels of the silo also appear to contain higher proportions of emmer wheat glume bases.

Figure 5.23 plots all plant taxa identified in over 25% of samples (34 taxa) as classified groups arranged in stratigraphical order. As was seen in the previous correspondence analysis plot (**Figure 5.10** above) this graph indicates a high level of variety in terms of Chamber 12 sample composition. Some broad trends are visible, however, particularly with regards to the categories of weed/wild material and pulse remains. Again, as was seen in Chambers 29 and 32, higher percentages of pulse (primarily *Vicia faba* var. *minuta*) are present in samples containing more emmer wheat grain, lending further support to the identification of this pulse species as a specific contaminant of the glume wheat crops. Additionally, these samples also contain higher proportions of weed/wild taxa. By comparison, samples containing principally hulled barley grain contain larger percentages of hulled barley rachis and lower percentages of weed/wild taxa and pulses. Furthermore, samples taken from the very top layers of the chamber seem to have a more mixed composition, although this can perhaps be explained by the fact that this chamber had been heavily eroded by mice and moles which may have mixed up any discrete depositions.

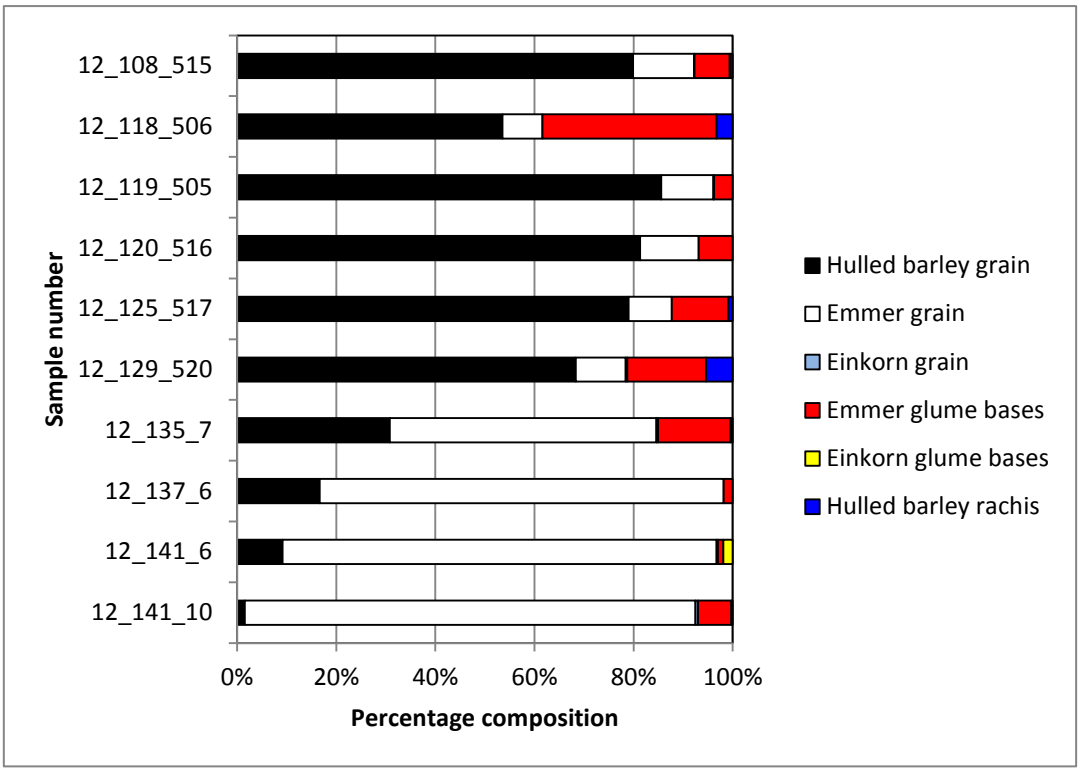


Figure 5.22 – Percentage stacked bar chart of 10 samples from Chamber 12 showing proportions of major crop categories.

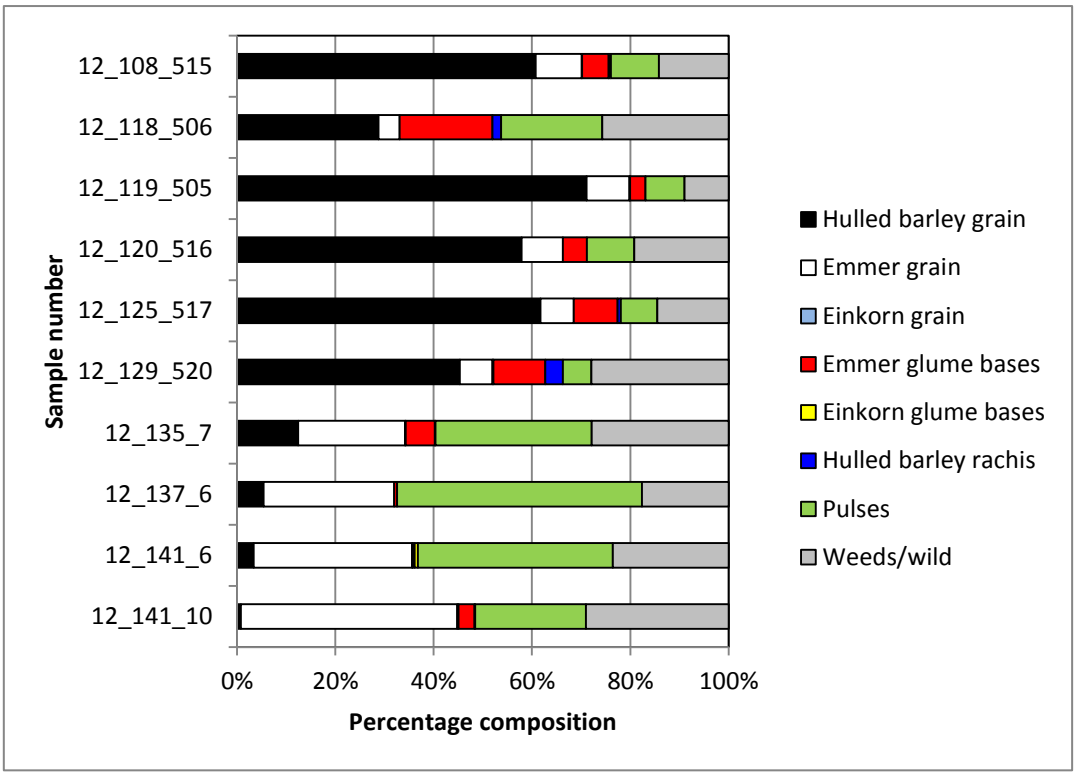


Figure 5.23 – Percentage stacked bar chart of 10 samples from Chamber 12 showing proportions of major crop categories, pulses and weed/wild taxa.

5.7.3 Summary of compositional analysis

This series of compositional analyses has demonstrated the high level of variation throughout the Hattusha silo and identified that each chamber has a unique combination of cultivated crops and associated weed/wild taxa. The unique 'signatures' identified for each chamber suggest that the stored crops derived from multiple growing locations with distinctive weed floras, which may reflect distinct growing conditions and land management regimes. These implications, which are significant for our understanding of the potential range of husbandry regimes in use at Hattusha, will be explored in greater detail below with reference to functional ecology and stable isotope analysis (see **Section 6.1** and **Section 6.8**, **Chapter 6**). Compositional analysis has also indicated a certain amount of intra-chamber variability and internal assemblage stratigraphy, suggesting that each chamber may contain crops from a certain range of agricultural locations and/or conditions. There also appears to be some broad assemblage-wide trends with regards to proportions of weed/wild tax and pulses.

Compositional evidence from all chambers indicates that samples dominated by emmer wheat grain also contain higher percentages of weed/wild taxa and *Vicia faba* var. *minuta* than the respective hulled barley grain-dominated samples. This would suggest that throughout the assemblage the majority of weed/wild remains originally derive from the glume wheat fields, and that *Vicia faba* var. *minuta* is a specific contaminant of emmer wheat. As mentioned above, however, it is clear from **Figure 5.13** that each chamber contains a unique weed/wild assemblage and that regardless of the dominant cereal species within a particular sample the range of weed/wild taxa remains the same on a chamber-by-chamber basis. This indicates that the hulled barley and glume wheat from each chamber were grown under similar husbandry conditions (although not together as a 'maslin' crop) and that differences in weed/wild taxa

proportions may be due to the use of differing crop processing techniques for each cereal crop.

Stratigraphical analysis of Chambers 29, 32 and 12 has also shown that there is some limited intra-chamber variability by depth. The hermetic nature of the chambers also means that in Chamber 29 and 12 it is possible to tell that the emmer wheat crop was poured into the chamber first before the hulled barley, an event that was likely to have occurred on the same day to reduce potential contamination by grain pests or fungi. Chamber 30, however, does not have any visible vertical or horizontal stratigraphy. These inferences will also be explored further in later sections of this thesis by analysing crop processing stages and the context of taphonomic processes affecting the assemblage (below) as well as with regard to crop stable isotope analysis and functional ecological analysis (see **Section 6.1** and **Section 6.8**, **Chapter 6**).

5.8 Crop processing analysis

As was discussed above in **Section 5.2** the Hattusha assemblage is comprised primarily of samples that contain varying proportions of cereal grain and weed/wild items. All samples also contain a mixture of glume wheat grain and hulled barley grain in varying concentrations throughout the different chambers. Furthermore, although there are greater numbers of hulled barley grain within the assemblage in general, overall there are more samples dominated by glume wheat grain. The assessment of crop processing stages has, therefore, been carried out separately on hulled barley-dominated samples and glume wheat-dominated samples to take into account post-processing mixing, as it is unlikely that these two species were grown as a maslin crop (see **Section 3.2**, **Chapter 3** for a more detailed explanation of this

process). With regards to the weed/wild species sources it is thought likely, given the storage context of the samples and compositional analysis, that all taxa derived from the arable fields rather than arriving on site as part of animal dung or by some other route. For the purposes of this analysis, therefore, no weed/weed species have been excluded unless clearly specified below. The only exception to this was *Vicia faba* var. *minuta*, which has been removed due to its status as a potential cultivated crop. Crop processing analysis has been carried out using three primary approaches on a sample-by-sample basis. First, samples were analysed on the basis of crop remains only. Secondly, crop remains and weed/wild remains were analysed together. Finally weed/wild remains were examined in isolation (see **Section 4.5.2**, **Chapter 4** for a more detailed methodology)

5.8.1 Crop-based analysis

Figure 5.24 shows the relative proportions of the three major cereal types (based on total counts of grain, chaff and rachis) in all 45 samples as a triangular plot (hereafter triplot), colour-coded by chamber number. From this triplot it is clear that free-threshing wheat does not play a major role within the Hattusha assemblage and that samples are instead composed of a mixture of hulled barley items and glume wheat items. These results mirror that of correspondence analysis (see **Section 5.7.1.1**) and further confirm the duality of samples from Chambers 29 and 30 as dominated by either hulled barley or glume wheat. Additionally, samples from Chamber 32 appear to have the most mixed composition in terms of the species of cereal remains.

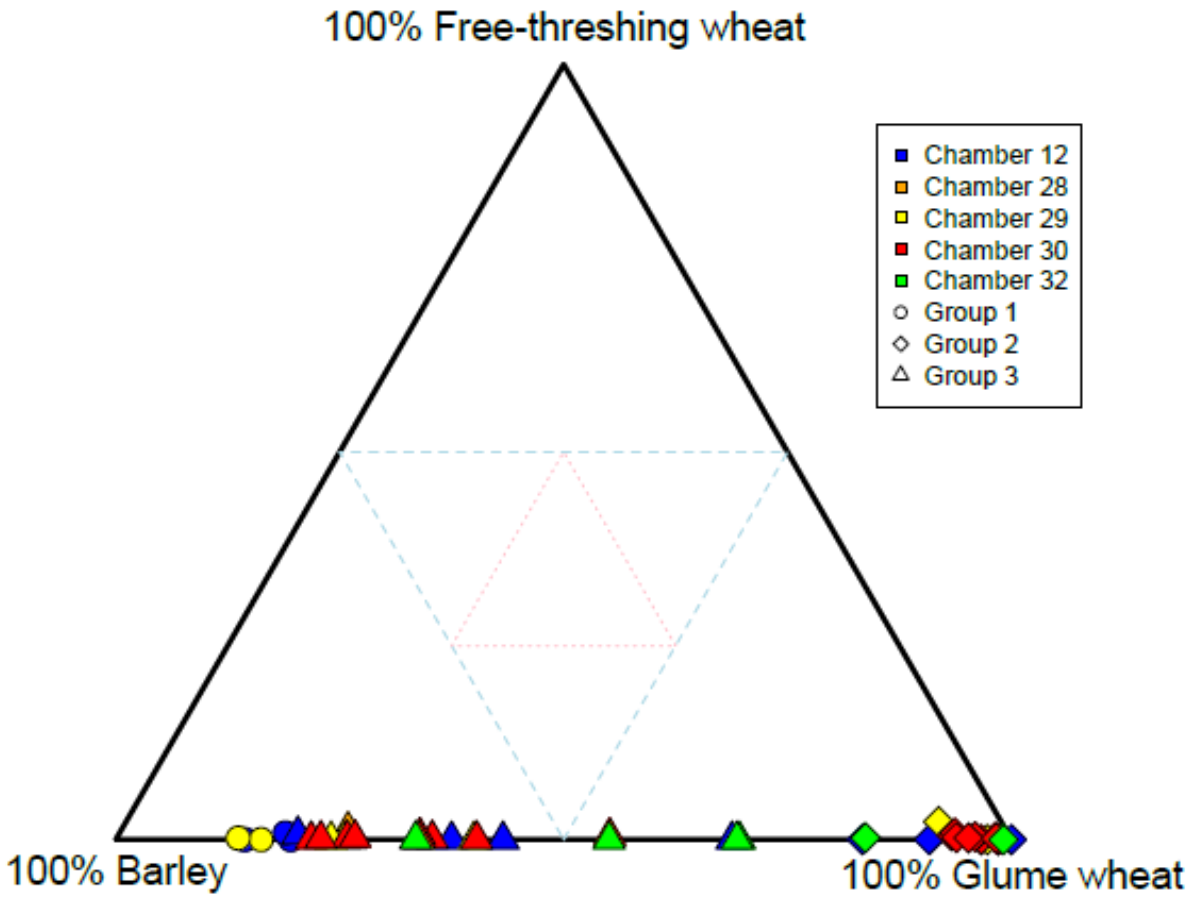


Figure 5.24 – Triplot showing the relative proportions of the three major cereal types in all 45 samples, coded by chamber number.

The next stage of the crop processing analysis focused on the ratio of grain to chaff within the Hattusha samples. As was shown in **Section 5.2** (above) cereal grain is far more prevalent than cereal chaff within every chamber of the silo. This is particularly evident when comparing ratios of six-row hulled barley grain to rachis in samples which contained over 100 hulled barley items (27 samples). The average ratio for these samples was 162.8 (very high) and ranged from 621 - 4 (see **Table 5.3**). Moreover, nine of these samples did not contain any hulled barley rachis, precluding the calculation of a ratio. The grain to chaff ratios from the silo suggests, therefore, that the majority of hulled barley had been through several stages of crop processing and was stored as fine sieve product. These ratios were also compared with Jones' (1990)

ethnographic study of the crop processing sequence on the Greek island of Amorgos. This study provided an approximate grain to chaff ratio for all crop processing stages from winnowing to fine sieving and shows that grain to chaff ratios increase with each subsequent processing step. With reference to this study, the hulled barley from Hattusha appears to be predominantly 'clean product' (19 samples). The remaining eight samples with over 100 hulled barley grains are classified as fine sieving by-product but are right at the top end of this category.

Table 5.3 – Summary of hulled barley grain to rachis ratio and product/by-product classification.

Chamber No.	Sample Code	Total Items	Total Grain	Total Rachis	Ratio	Product/By-product classification
12	12_108_515	2239	2224	15	148.3	Fine sieve product
12	12_118_506	281	265	16	16.6	Fine sieve by-product
12	12_119_505	1600	1600	0	n/a	Fine sieve product
12	12_120_516	758	758	0	n/a	Fine sieve product
12	12_125_517	1728	1710	18	95.0	Fine sieve by-product
12	12_129_520	738	684	54	12.7	Fine sieve by-product
12	12_135_7	170	168	2	84.0	Fine sieve by-product
28	28_2_100	946	941	5	188.2	Fine sieve product
29	29_191_503	386	386	0	n/a	Fine sieve product
29	29_206_509	1387	1382	5	276.4	Fine sieve product
29	29_271_6	2189	2189	0	n/a	Fine sieve product
29	29_271_7	3712	3712	0	n/a	Fine sieve product
30	30_245_3	4799	4785	14	341.8	Fine sieve product
30	30_245_9	1991	1960	31	63.2	Fine sieve by-product
30	30_252_8	4291	4219	72	58.6	Fine sieve by-product
30	30_252_11	4155	4140	15	276.0	Fine sieve product
30	30_259_8	5985	5909	76	77.8	Fine sieve by-product
30	30_259_11	7906	7846	60	130.8	Fine sieve product
30	30_259_13	3643	3612	31	116.5	Fine sieve product
30	30_262_11	6282	6257	25	250.3	Fine sieve product
30	30_268_11	4734	4717	17	277.5	Fine sieve product
30	30_268_13	130	104	26	4.0	Fine sieve by-product
32	32_64	8708	8694	14	621.0	Fine sieve product
32	32_66	164	164	0	n/a	Fine sieve product
32	32_70	288	288	0	n/a	Fine sieve product
32	32_71	4721	4721	0	n/a	Fine sieve product
32	32_72	336	336	0	n/a	Fine sieve product

The average ratio of glume wheat grains to glume bases, however, is much lower than that seen for hulled barley. This is perhaps to be expected when taking into account the differing processing needs of glume wheat and hulled barley and the survival rate of grain over chaff, particularly with regard to free-threshing cereals (Boardman & Jones, 1990; Charles *et al*. 2015). In total, 41 samples contained over 100 glume wheat items. Within these 41 samples the average ratio of grain to chaff was 1.9 and the range was 0.2 to 45.3 (see **Table 5.4**). Of these samples only one had a grain to chaff ratio of 0.3 or lower, indicating that this sample resembled crop processing waste derived from the de-husking of spikelets. Moreover, this sample was from Chamber 12 and had a very mixed composition with a high percentage of weed/wild items.

Eighteen samples contained a ratio of glume wheat grain to chaff of 0.3-1.5: the ratio range hypothesized to represent the presence of whole spikelets (see **Section 4.5.2**, **Chapter 4** for spikelet range methodology, Bogaard, 2011). In the case of the Hattusha assemblage, this hypothesis can be tested as whole spikelets do survive within the silo. When analysed, all 19 samples from Chamber 30 were found to contain intact emmer wheat and einkorn wheat spikelets, and of these samples 13 also contain a grain to chaff ratio of 0.3-1.5. The ratios of the remaining six samples are just over the spikelet threshold (see **Table 5.4**) and likely represent the presence of intact spikelets along with higher than usual proportions of grain due to post-processing mixing. None of the other chambers were found to contain intact spikelets (with the exception of six spikelets identified from Chamber 32), yet each chamber contained at least one sample with the spikelet ratio (two from Chamber 12, one from Chamber 28, one from Chamber 29 and one from Chamber 32). This observation suggests that glume wheat spikelets were stored in these chambers but that they possibly became disaggregated as a result of the fire itself. Furthermore, the preservation levels in these chambers were not as good as

Table 5.4 – Summary of glume wheat grain to chaff ratio and class classification.

Chamber No.	Sample Code	Total Items	Total Grain	Total Chaff	Ratio	Class Classification
12	12_108_515	544	344	200	1.7	Clean grain
12	12_118_506	214	40	174	0.2	Glume base
12	12_119_505	269	199	70	2.8	Clean grain
12	12_120_516	174	110	64	1.7	Clean grain
12	12_125_517	436	188	248	0.8	Spikelet
12	12_129_520	263	104	159	0.7	Spikelet
12	12_135_7	375	295	80	3.7	Clean grain
12	12_137_6	185	181	4	45.3	Clean grain
12	12_141_6	336	325	11	29.5	Clean grain
12	12_141_10	772	717	55	13.0	Clean grain
28	28_2_100	326	196	130	1.5	Spikelet
29	29_206_509	475	138	337	0.4	Spikelet
29	29_271_6	693	655	38	17.2	Clean grain
29	29_271_7	585	563	22	25.6	Clean grain
29	29_278_1	507	474	33	14.4	Clean grain
29	29_278_6	360	344	16	21.5	Clean grain
30	30_245_3	1671	893	778	1.1	Spikelet
30	30_245_4	1247	598	649	0.9	Spikelet
30	30_245_8	816	733	83	8.8	Clean grain
30	30_245_9	2450	1031	1419	0.7	Spikelet
30	30_252_3	715	485	230	2.1	Clean grain
30	30_252_8	2345	1191	1154	1.0	Spikelet
30	30_252_11	2130	1150	980	1.2	Spikelet
30	30_252_13	707	357	350	1.0	Spikelet
30	30_259_7	221	93	128	0.7	Spikelet
30	30_259_8	2175	1016	1159	0.9	Spikelet
30	30_259_11	2206	1050	1156	0.9	Spikelet
30	30_259_13	2462	1270	1192	1.1	Spikelet
30	30_262_11	1867	991	876	1.1	Spikelet
30	30_262_13	1090	585	505	1.2	Spikelet
30	30_268_8	1035	803	232	3.5	Clean grain
30	30_268_11	2423	1553	870	1.8	Clean grain
30	30_268_13	2635	1598	1037	1.5	Spikelet
30	30_273_11	1149	858	291	2.9	Clean grain
30	30_273_13	1028	820	208	3.9	Clean grain
32	32_64	4386	3506	880	4.0	Clean grain
32	32_66	376	329	47	7.0	Clean grain
32	32_70	652	460	192	2.4	Clean grain
32	32_71	5792	5536	256	21.6	Clean grain
32	32_72	1734	658	1076	0.6	Spikelet
32	32_74	219	143	76	1.9	Clean grain

those seen in Chamber 30, supporting the theory that intact spikelets may simply not have survived in these conditions. The final 22 samples containing over 100 glume wheat items all have ratios of above 1.5 and five samples have very high ratios of above

20. This would suggest that these samples are primarily composed of clean, processed grain that had been fine sieved to remove small chaff remains.

5.8.2 Crop- and weed-based analysis

The second stage of crop processing analysis involved the assessment of crop proportions alongside weed/wild remains. With regards to the Hattusha assemblage this was viewed as the most important aspect of crop processing analysis due to the high number of weed/wild items identified within the silo and following Jones (1990) these proportions are a means of ascertaining particular crop processing stages. As stated above, hulled barley and glume wheat remains were treated separately due to the singular processing needs of each species. Similarly, it was assumed that all weed/wild taxa had originated from the arable fields with the exception of *Vicia faba* var. *minuta* which was removed from this analysis. Samples were classified into groups based on the dominant crop species; Group 1. Samples containing at least 70% hulled barley remains, Group 2. Samples containing at least 70% glume wheat remains, Group 3. Samples containing a mixed composition of remains from both cereal species. For the following analyses, therefore, only samples from Groups 1 and 2 were analysed as samples from Group 3 were deemed to be too 'mixed' for further evaluation (see **Table 12.2**, **Appendix** for the group classification of each sample). The samples from each of these groups was then compared with ethnographic data analysed by Jones (1990) on percentages of cereal grain, chaff/rachis remains and weed/wild seeds recorded from varying stages of crop processing on the Greek island of Amorgos. This ethnographic work, however, was only carried out on free-threshing cereals so the proportional percentages for glume wheat processing are not known. Nevertheless, this approach can

still provide a general comparison between the cereals and a rough estimation of crop processing stage.

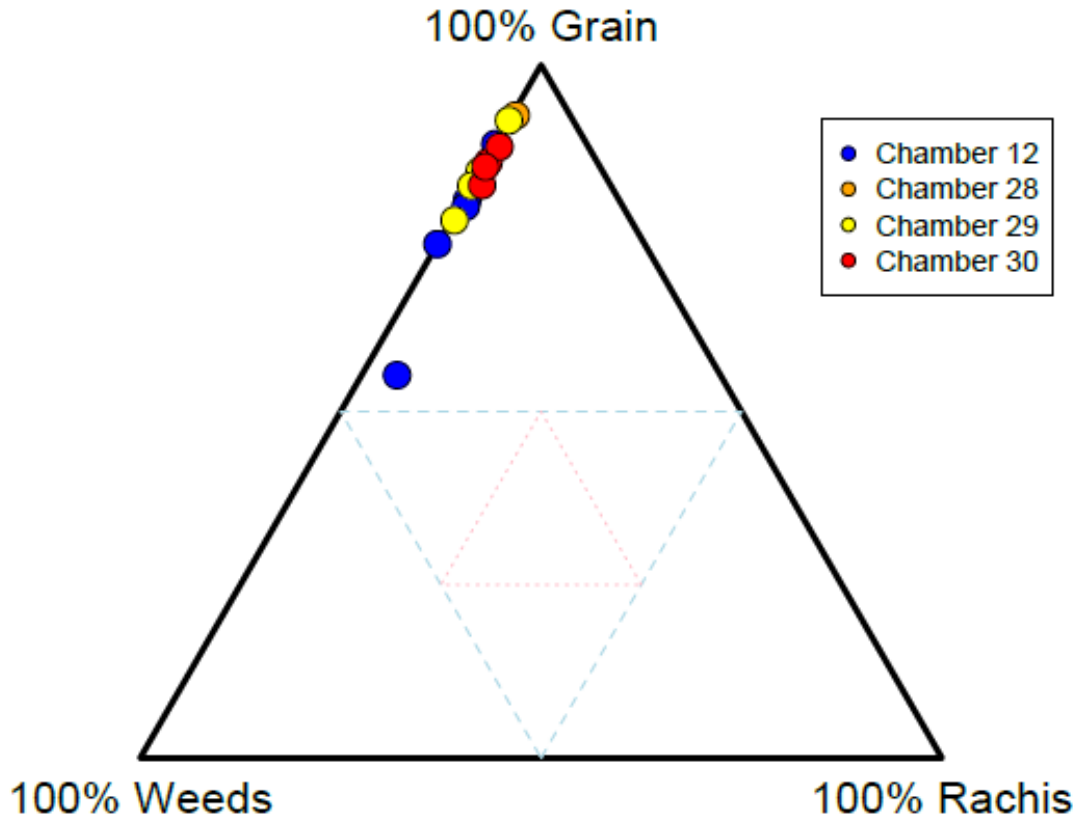


Figure 5.25 – Triplot showing the relative proportions of grain, rachis and weed/wild taxa for samples from Group 1.

Figure 5.25 shows the percentages of grain, rachis and weed/wild seeds for samples from Group 1, points are also colour coded by chamber number. There are no samples from Chamber 32 included in this analysis as none of them met the 70% hulled barley items threshold. The clustering of points towards the 100% hulled barley grain corner of the triplot indicates that samples with high proportions of hulled barley items are largely comprised of clean, processed grain. By contrast, rachis remains and weed/wild seeds barely register within this plot, with the exception of one sample from Chamber 12 (12_129_520) which has relatively equal amounts of grain and weed/wild

seeds. Samples from the other chambers appear fairly uniform and there is no overt patterning by chamber number. Comparison with the ethnographic values from Jones (1990) suggests that all of these samples fall within the percentages for fine sieve product. Additionally, the ethnographic Amorgos material derived from earlier stages of crop processing generally contained high numbers of culm nodes (Jones, 1990). These remains are generally removed during the winnowing and coarse sieving stages as they are light, relatively small and tend not to be found in fine sieve product or by-product. At Hattusha, identifiable culm nodes totalled less than 1% of the entire assemblage and corroborate the conclusion that these samples are representative of fine sieve product.

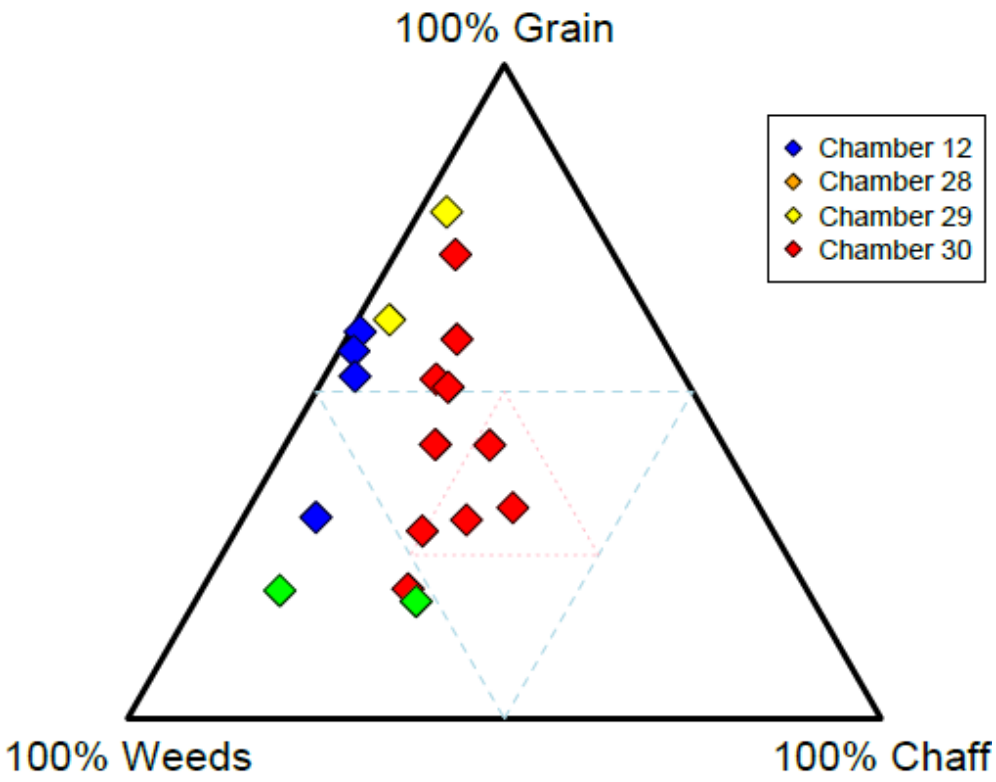


Figure 5.26 – Triplot showing the relative proportions of grain, chaff and weed/wild taxa for samples from Group 2.

Figure 5.26 shows the percentages of grain, chaff and weed/wild seeds for samples from Group 2; again points are colour coded by chamber number. By contrast with **Figure 5.25**, samples containing over 70% glume wheat items have a much more varied composition. In particular these samples have much higher percentages of weed/wild seeds and a few contain dominant proportions of these taxa. Additionally, these samples also contain larger numbers of chaff items, particularly samples from Chamber 30, which contained intact spikelets. This would, however, be expected due to the differing survival rates of hulled barley rachis and glume wheat chaff within the archaeobotanical record (Boardman & Jones, 1990). These samples cannot be directly compared with the Amorgos ethnographic data (Jones, 1990) due to the differing processing needs of glume wheats vs. free-threshing cereals (discussed in **Section 3.2**, **Chapter 3**). The high numbers of glume wheat grain and the ratio of grain to chaff (discussed above) within each of these samples, however, would suggest that these samples are likely to represent fine sieve product. The only possible exceptions to this may be the two samples from Chamber 32 which contained very high percentages of weed/wild seeds in comparison to cereal grain. Both of these samples, however, were located at the bottom of the chamber and it is conceivable that some of these weed/wild seeds may have trickled down through the assemblage post-deposition.

Comparison of **Figure 5.25** with **Figure 5.26** suggests that the majority of weed/wild seeds identified within the Hattusha silo originally came from the fields in which glume wheats were being cultivated, rather than from the hulled barley fields. This may also indicate that the hulled barley crop was subject to weeding within the field and/or had been more rigorously processed before being stored, whilst some of the glume wheats had not been dehusked and were stored within the spikelet. These

hypotheses will be further explored in **Section 6.8, Chapter 6** with regard to weed functional ecological analysis and crop stable isotope analysis.

5.8.3 Weed-based analysis

The final crop processing analysis was based solely on weed/wild data. This method used discriminant analysis of ethnographic data by Jones (1983b; 1984a) to classify the archaeobotanical data from Hattusha in terms of crop processing stages on the basis of physical weed seed types (see **Section 4.5.2**, **Chapter 4** for further details on this methodology). This analysis was only performed on samples that contained over 10 weed items that could be categorized to physical type, resulting in the exclusion of one sample (29_512_123). Additionally, it could also only be carried out on weeds that had been identified to the genus level and as such can be characterised to a specific physical type. This led to the exclusion of eight weed/wild groups identified only to the family level. Weed seeds from Hattusha were first classified by size (big or small), headedness (free or headed) and aerodynamic factors (light or heavy) to make this data independent of crop type and comparable with Jones' (1984a) ethnobotanical data (see **Table 12.3**, **Appendix** for full list of classified weed/wild items). As was demonstrated above, Jones' ethnographic work was only carried out on free-threshing cereals, making comparisons with glume wheat crops potentially difficult. The exclusion of crop items from this analysis, however, makes this comparison much less problematic as varying crop processing stages should have removed the same weed/wild seeds regardless of the cereal species being processed.

Figure 5.27 shows the results of the discriminant analysis, including Jones' (1983b; 1984a) ethnobotanical data and the Hattusha archaeobotanical data colour-

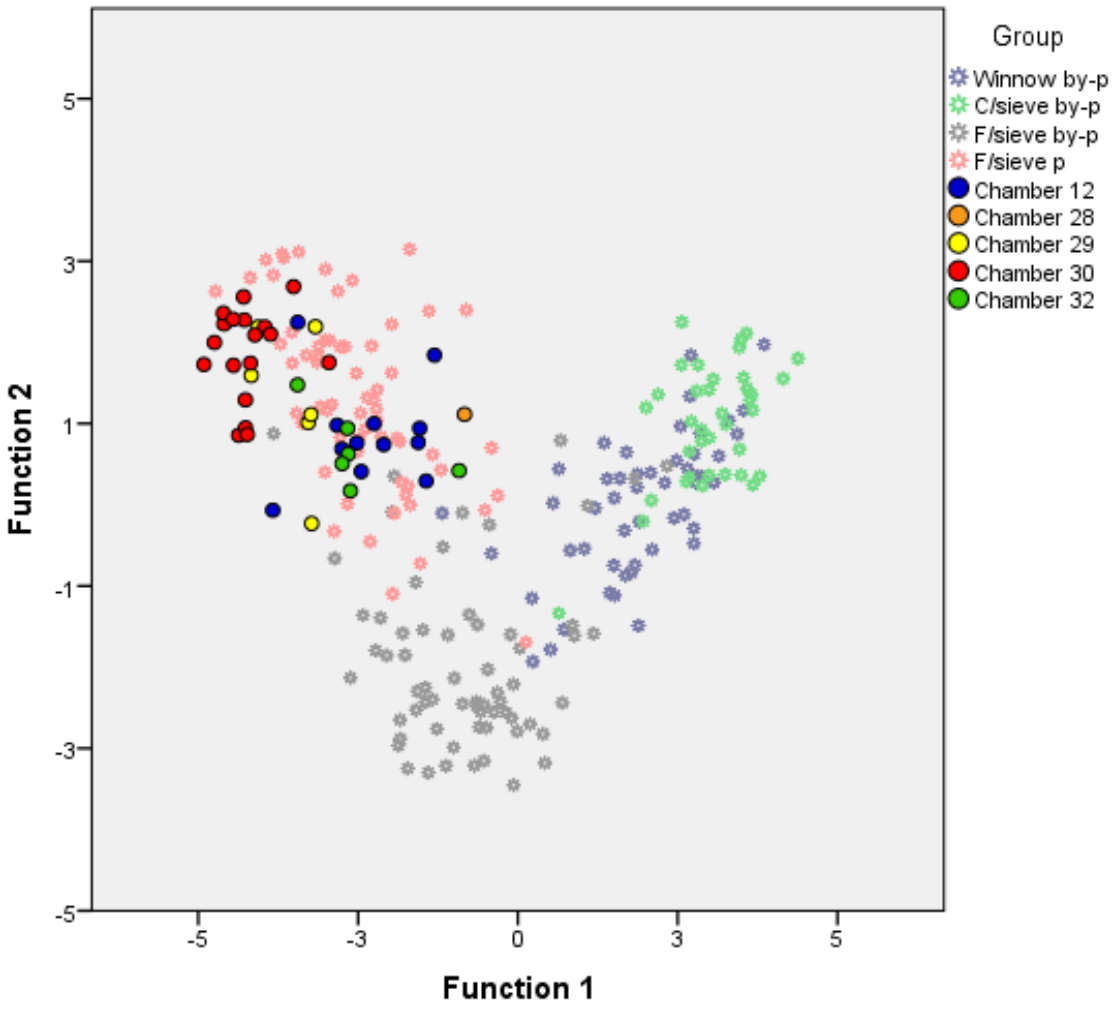


Figure 5.27 – Plot showing the results of the extracted discriminant function, including Jones' (1983b; 1984a) ethnobotanical data and the Hattusha archaeobotanical data, colour coded by chamber number.

coded by chamber. All samples, with the exception of one, have been classified with very high probabilities as fine sieve product (see **Table 5.5**). The one exception to this classification was the sample from Chamber 28 (orange) which has been classified as winnowing by-product, although with a low probability (0.65). This classification was most likely due to a high number of *Alyssum* sp. seeds present within the sample, which otherwise did not contain a large amount of weed/wild seeds. *Alyssum* sp. morphologically is categorised as small, headed and light, making it likely that it would be removed during the winnowing process. Within the crop only and crop and weed

Table 5.5 – Summary of discriminant analysis classification for weed-based crop processing analysis.

Chamber No.	Sample Code	Crop-processing classification	Probability (%)
12	12_108_515	Fine sieve product	0.993
12	12_118_506	Fine sieve product	0.982
12	12_119_505	Fine sieve product	0.845
12	12_120_516	Fine sieve product	0.996
12	12_125_517	Fine sieve product	0.968
12	12_129_520	Fine sieve product	1.000
12	12_135_7	Fine sieve product	0.996
12	12_135_9	Fine sieve product	0.998
12	12_137_6	Fine sieve product	0.986
12	12_141_10	Fine sieve product	0.977
12	12_141_6	Fine sieve product	0.994
12	12_79_502	Fine sieve product	0.990
28	28_2_100	Winnowing by-product	0.649
29	29_191_503	Fine sieve product	0.999
29	29_206_509	Fine sieve product	1.000
29	29_271_6	Fine sieve product	1.000
29	29_271_7	Fine sieve product	0.999
29	29_278_1	Fine sieve product	1.000
29	29_278_6	Fine sieve product	0.961
30	30_245_3	Fine sieve product	1.000
30	30_245_4	Fine sieve product	1.000
30	30_245_8	Fine sieve product	1.000
30	30_245_9	Fine sieve product	1.000
30	30_252_3	Fine sieve product	1.000
30	30_252_8	Fine sieve product	1.000
30	30_252_11	Fine sieve product	1.000
30	30_252_13	Fine sieve product	1.000
30	30_259_7	Fine sieve product	1.000
30	30_259_8	Fine sieve product	1.000
30	30_259_11	Fine sieve product	1.000
30	30_259_13	Fine sieve product	1.000
30	30_262_11	Fine sieve product	1.000
30	30_262_13	Fine sieve product	1.000
30	30_268_8	Fine sieve product	1.000
30	30_268_11	Fine sieve product	1.000
30	30_268_13	Fine sieve product	1.000
30	30_273_11	Fine sieve product	1.000
30	30_273_13	Fine sieve product	1.000
32	32_64	Fine sieve product	1.000
32	32_66	Fine sieve product	0.997
32	32_70	Fine sieve product	0.961
32	32_71	Fine sieve product	0.714
32	32_72	Fine sieve product	0.992
32	32_74	Fine sieve product	0.989

analysis discussed above this sample was firmly classified as fine sieve product with a dominant proportion of hulled barley grain. In this situation, therefore, it would seem likely that *Alyssum* sp. should be classified as an outlier. Unfortunately, however, Chamber 28 is comprised of only one sample meaning that the presence of *Alyssum* sp. within this sample may only have been a one off within the larger Chamber.

As was seen above in **Section 5.7.1.3** samples from the individual chambers generally cluster together, again reflecting the differing weed/wild compositions present within each chamber as seen in **Figure 5.13**. This supports the theory, therefore, that the crops stored within each chamber were grown under multiple conditions and/or multiple regions on the Central Anatolian plateau, rather than reflecting distinct processing events for each cereal taxa. Additionally, there does not seem to be any separation between the samples dominated by hulled barley or glume wheat, again highlighting the limitation of using free-threshing ethnobotanical data to classify glume wheat samples as seen in **Figure 5.26**.

5.8.4 Conclusions

The results from all three stages of crop processing analysis generally correspond with each other and indicate that the majority of samples from the Hattusha silo can be classified as fine sieve products (see summary **Table 5.6**). This is the expected classification given the predominance of cereal grain and large-sized weed/wild seeds throughout the assemblage. Crop processing analysis has also highlighted the fact that hulled barley and glume wheat crops may have been grown under differing conditions, that glume wheat fields were 'weedier' in general or that each cereal taxa was subject to different levels of crop processing post-harvest.

Certainly, in line with inferences made from CA in **Section 5.7**, it would seem that the majority of weed/wild items identified within the assemblage entered the silo as part of the glume wheat crop rather than with the hulled barley. This would also explain why Chamber 32 seems to contain a larger proportion of weed/wild seeds than the other chambers, as the lower levels of this chamber (see **Figure 5.20**) contain primarily glume wheat. Finally, the results of crop processing analysis suggest that the majority of samples from the silo contain a mixture of hulled barley and glume wheat crops that were grown separately rather than as a maslin crop. These crops were then amalgamated post-harvest and post-processing, potentially whilst they were being deposited into the individual chambers.

Table 5.6 – Summary of all crop-processing analysis for all samples from the Hattusha underground silo complex.

Chamber No.	Sample Code	Barley ratio classification	Glume wheat ratio classification	Composition	Group No.	Classification based on crop/weed analysis	Classification based on Jones' (1990) weed/wild analysis
12	12_79_502			Mixed	3		Fine sieve product
12	12_108_515	Fine sieve product	Clean grain	Hulled barley	1	Fine sieve product	Fine sieve product
12	12_118_506	Fine sieve by-product	Glume base	Mixed	3		Fine sieve product
12	12_119_505	Fine sieve product	Clean grain	Hulled barley	1	Fine sieve product	Fine sieve product
12	12_120_516	Fine sieve product	Clean grain	Hulled barley	1	Fine sieve product	Fine sieve product
12	12_125_517	Fine sieve by-product	Spikelet	Hulled barley	1	Fine sieve product	Fine sieve product
12	12_129_520	Fine sieve by-product	Spikelet	Hulled barley	1	Fine sieve product	Fine sieve product
12	12_135_7	Fine sieve by-product	Clean grain	Mixed	3		Fine sieve product
12	12_135_9			Glume wheat	2	Fine sieve by-product	Fine sieve product
12	12_137_6		Clean grain	Glume wheat	2	Fine sieve product	Fine sieve product
12	12_141_10		Clean grain	Glume wheat	2	Fine sieve product	Fine sieve product
12	12_141_6		Clean grain	Glume wheat	2	Fine sieve product	Fine sieve product
28	28_2_100	Fine sieve product	Spikelet	Hulled barley	1	Fine sieve product	Winnowing by-product
29	29_191_503	Fine sieve product		Hulled barley	1	Fine sieve product	Fine sieve product
29	29_206_509	Fine sieve product	Spikelet	Hulled barley	1	Fine sieve product	Fine sieve product
29	29_271_6	Fine sieve product	Clean grain	Hulled barley	1	Fine sieve product	Fine sieve product
29	29_271_7	Fine sieve product	Clean grain	Hulled barley	1	Fine sieve product	Fine sieve product
29	29_278_1		Clean grain	Glume wheat	2	Fine sieve product	Fine sieve product
29	29_278_6		Clean grain	Glume wheat	2	Fine sieve product	Fine sieve product
29	29_512_123			Mixed	3		
30	30_245_3	Fine sieve product	Spikelet	Hulled barley	1	Fine sieve product	Fine sieve product
30	30_245_4		Spikelet	Glume wheat	2	Fine sieve by-product	Fine sieve product
30	30_245_8		Clean grain	Glume wheat	2	Fine sieve product	Fine sieve product
30	30_245_9	Fine sieve by-product	Spikelet	Mixed	3		Fine sieve product
30	30_252_3		Clean grain	Glume wheat	2	Fine sieve by-product	Fine sieve product
30	30_252_8	Fine sieve by-product	Spikelet	Mixed	3		Fine sieve product
30	30_252_11	Fine sieve product	Spikelet	Mixed	3		Fine sieve product
30	30_252_13		Spikelet	Glume wheat	2	Fine sieve by-product	Fine sieve product

Chamber No.	Sample Code	Barley ratio classification	Glume wheat ratio classification	Composition	Group No.	Classification based on crop/weed analysis	Classification based on Jones (1990) weed/wild analysis
30	30_259_7		Spikelet	Glume wheat	2	Fine sieve by-product	Fine sieve product
30	30_259_8	Fine sieve by-product	Spikelet	Hulled barley	1	Fine sieve product	Fine sieve product
30	30_259_11	Fine sieve product	Spikelet	Hulled barley	1	Fine sieve product	Fine sieve product
30	30_259_13	Fine sieve product	Spikelet	Mixed	3		Fine sieve product
30	30_262_11	Fine sieve product	Spikelet	Hulled barley	1	Fine sieve product	Fine sieve product
30	30_262_13		Spikelet	Glume wheat	2	Fine sieve by-product	Fine sieve product
30	30_268_8		Clean grain	Glume wheat	2	Fine sieve product	Fine sieve product
30	30_268_11	Fine sieve product	Clean grain	Mixed	3		Fine sieve product
30	30_268_13	Fine sieve by-product	Spikelet	Glume wheat	2	Fine sieve by-product	Fine sieve product
30	30_273_11		Clean grain	Glume wheat	2	Fine sieve product	Fine sieve product
30	30_273_13		Clean grain	Glume wheat	2	Fine sieve product	Fine sieve product
32	32_64	Fine sieve product	Clean grain	Mixed	3		Fine sieve product
32	32_66	Fine sieve product	Clean grain	Mixed	3		Fine sieve product
32	32_70	Fine sieve product	Clean grain	Mixed	3		Fine sieve product
32	32_71	Fine sieve product	Clean grain	Mixed	3		Fine sieve product
32	32_72	Fine sieve product	Spikelet	Glume wheat	2	Fine sieve by-product	Fine sieve product
32	32_74	Fine sieve product	Clean grain	Glume wheat	2	Fine sieve by-product	Fine sieve product

Chapter 6

Approaches to crop husbandry at Hattusha

This chapter will explore approaches to crop husbandry at Hattusha through the use of crop stable isotope analysis and functional weed ecology. These two methods focus on different features of the Hattusha assemblage but produce complementary data that can be both compared and integrated to provide a detailed investigation into the use of different husbandry techniques and farming regimes. The first section will present the results from carbon and nitrogen crop stable isotope analysis, exploring both inter- and intra-chamber variability. The second section will present the results from functional ecological analysis. The final section will combine these two strands of evidence to compare variation *across* farming regime(s).

6.1 Crop stable isotope analysis

This section will present the results of carbon and nitrogen stable isotope analysis of two major cereals (six-row hulled barley grains and 2-grained emmer wheat grains) from the Hattusha silo assemblage (see **Section 4.6.1.4**, **Chapter 4** for the methods used for this analysis). Both cereal taxa were analysed from all five chambers and from each arbitrary excavation 'spit' wherever possible (see **Section 4.6.1.1**, **Chapter 4** for further information on sample selection). The results will focus first on the carbon stable isotope analysis followed by the nitrogen stable isotope analysis.

Additionally, differences between the two cereal taxa will be statistically analysed on an inter- and intra-chamber level. These results will be used to assess potential crop husbandry practices and cereal growing conditions reflected by the Hattusha assemblage and to answer research questions set out in **Section 1.5**, **Chapter 1**.

6.2 Carbon – overview

Figure 6.1 shows the $\Delta^{13}C$ values[13] from the Hattusha silo assemblage and **Figure 6.2** shows the means and standard deviations for each taxon. Overall, there is limited variation within each taxon, as indicated by the standard deviations (see **Figure 6.2**). These narrow standard deviations lie just above the ±0.5‰ value reported by Nitsch *et al*. (2015) for expected variation in $\Delta^{13}C$ values of cereals cultivated under the same growing conditions and indicate the relative homogeneity of results within each taxon. Comparing the two taxa, the mean value for emmer wheat (n=40) is 16.53±0.56‰ whilst the mean value for hulled barley (n=24) is slightly higher, at 17.03±0.53‰ (see **Table 6.1**). The values from Chamber 28 were excluded from all further statistical analysis due to the small number of samples analysed (see **Table 12.8**, **Appendix** for raw values). A Welch two-sample T-test indicates that the values from hulled barley are statistically different from the results of emmer wheat (T (50.454) = -3.55, p=0.0008). This statistical difference may be due to a physiological difference between wheat and barley, specifically earlier completion of photosynthesis and grain ripening in barley (Araus *et al*. 1997). This discrepancy in terms of plant growth plausibly accounts for an offset of typically 1-2‰ in $\delta^{13}C$ values between modern

[13] For calculation of the $\Delta^{13}C$ please see **Section 4.6.1.8**, **Chapter 4**.

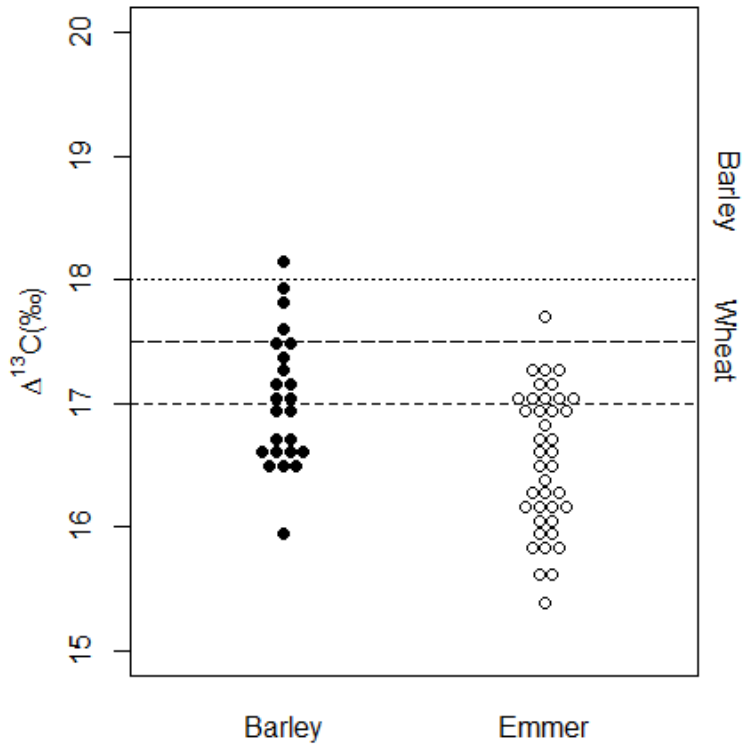


Figure 6.1 - $\Delta^{13}C$ values of the two major cereal species. The lower dashed line indicates the beginning of the 'well-watered' zone for emmer and the middle and upper dotted line, the beginning of the two potential 'well-watered' zones for barley (see below for full explanation).

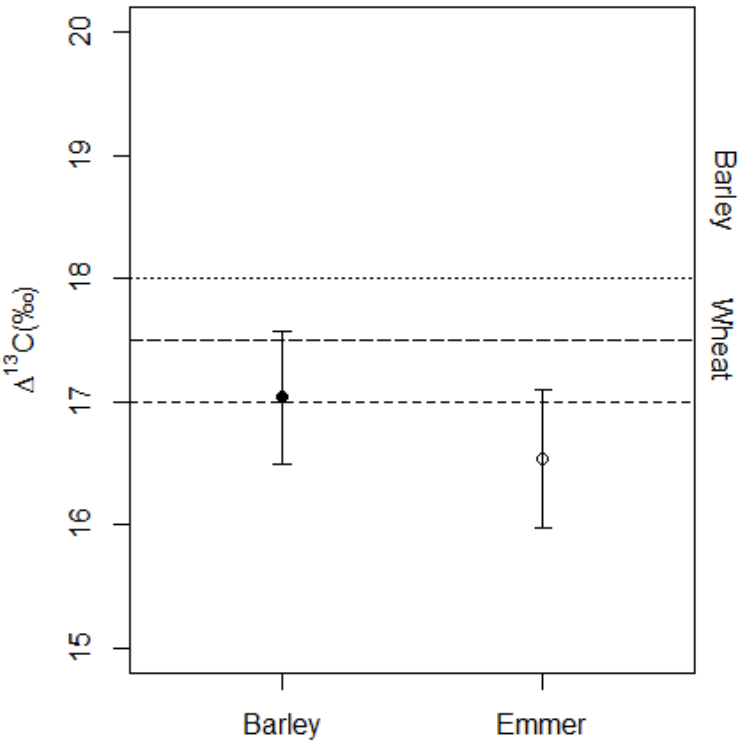


Figure 6.2 – The means and standard deviations of the $\Delta^{13}C$ values of barley and emmer.

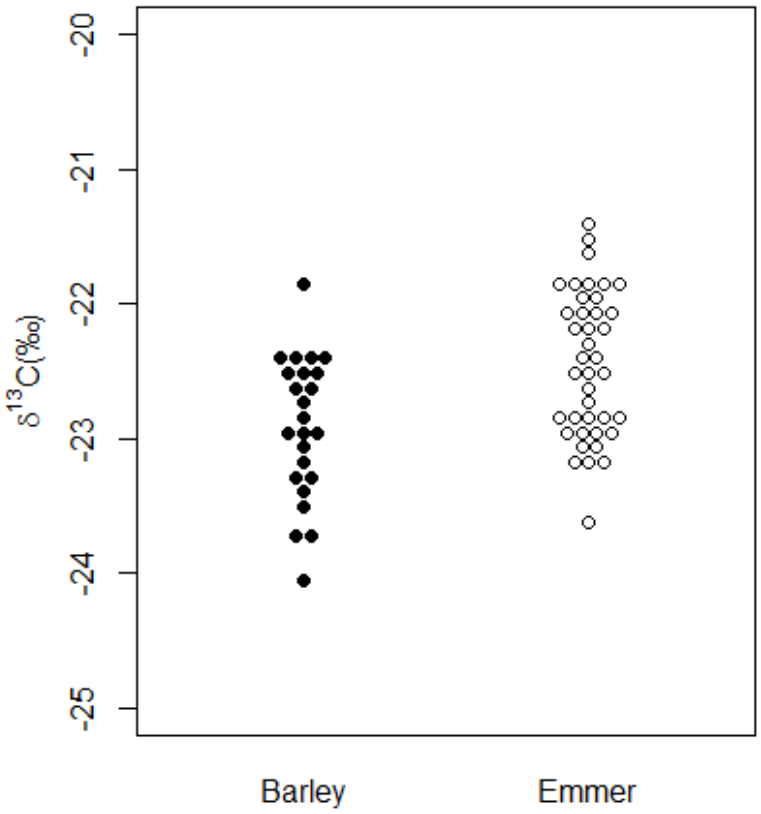


Figure 6.3 - $\delta^{13}C$ values of the two major cereal species.

Table 6.1 – The number of samples, means and standard deviations of $\delta^{13}C$ and $\Delta^{13}C$ values, by chamber number.

Chamber	Taxon	No. of samples	Mean ($\delta^{13}C$ ‰)	Standard deviation ($\delta^{13}C$ ‰)	Mean ($\Delta^{13}C$ ‰)	Standard deviation ($\Delta^{13}C$ ‰)
All	Barley	24	-23.03	0.51	17.03	0.54
	Emmer	40	-22.55	0.54	16.53	0.56
Twelve	Barley	8	-23.3	0.43	17.31	0.44
	Emmer	10	-22.91	0.36	16.91	0.37
Twenty-eight	Barley	1	n/a	n/a	n/a	n/a
	Emmer	1	n/a	n/a	n/a	n/a
Twenty-nine	Barley	4	-22.81	0.26	16.80	0.27
	Emmer	5	-22.46	0.36	16.43	0.38
Thirty	Barley	9	-22.73	0.35	16.72	0.37
	Emmer	18	-22.2	0.48	16.17	0.50
Thirty-two	Barley	2	n/a	n/a	n/a	n/a
	Emmer	6	-23.12	0.14	17.12	0.15

hulled barley and free-threshing wheat (Anyia *et al*. 2007; Wallace *et al*. 2013)[14]. This experimental work by Wallace *et al*. (2013), however, was completed on hulled barley and free-threshing wheat rather than emmer wheat, so the results cannot be compared directly. **Figure 6.3** shows the normalised $\delta^{13}C$ values before the conversion to $\Delta^{13}C$.

To assess whether or not the difference in values between the taxa was as a result of different husbandry practices or physiological differences, a range of offsets were applied to the hulled barley values. With an offset of 1‰ the hulled barley values still tested as significantly different to the emmer, and would indicate that hulled barley was grown in *better* watered conditions than emmer wheat. By contrast, with a lower offset of 0.5‰, there was no statistically significant difference between the two cereals (see **Table 6.2**). This would suggest that hulled barley and emmer wheat were grown under similar watering conditions. The question of whether hulled barley and emmer wheat were cultivated under the same or different growing conditions will be explored in further detail below with reference to the $\Delta^{13}C$ values from individual chambers and the $\delta^{15}N$ values. In comparison with the watering bands set out by Wallace *et al.* (2013) relatively few samples fall within the well-watered band. Assuming a 1‰ offset, only 11 emmer wheat samples (27.5% of all emmer wheat samples) fall within this range and only one barley sample (4% of all hulled barley samples). If the offset is reduced to 0.5‰, however, the results appear more similar, with six hulled barley values (6%) falling within the well-watered band. This discrepancy between the two taxa may be partly due to the fact that more emmer wheat samples were analysed overall than hulled barley samples.

[14] See **Section 3.3.1.1**, **Chapter 3** and **Section 4.6.1**, **Chapter 4** for a more detailed discussion of these physiological differences between wheat and barley.

Table 6.2 – Results of Welch's two sample T-test conducted on the $\Delta^{13}C$ values from both cereals when a 1‰ or 0.5‰ offset is applied to the barley.

Statistical Test	Chamber	Results	1‰ offset	0.5‰ offset
Welch's two-sample T-test	All	T(50.454)= -3.55, p=0.0008	T(50.454)= -3.56, p=0.0008	T(50.454)= -0.0036, p=0.9971
Welch's two-sample T-test	Twelve	T(13.763)= -2.06, p=0.0593	T(13.763)= 3.03, p=0.0091	T(13.763)= -0.49, p=0.6332
Welch's two-sample T-test	Twenty-nine	T(6.9665)= -1.71, p=0.1306	T(6.9665)= 2.93, p=0.2226	T(6.9665)= -0.61, p=0.5633
Welch's two-sample T-test	Thirty	T(21.315)= -3.25, p=0.0038	T(21.315)= 2.63, p=0.01563	T(21.315)= 0.31, p=0.7598
Welch's two-sample T-test	Thirty-two	T(1.2465)= -4.80, p=0.0940	T(1.2465)= 0.66, p=0.6084	T(1.2465)= 2.07, p=0.2457

6.2.1 Carbon – intra-chamber variation

As was seen in the overall results, the values from each chamber appear similar to each other, indicating a lack of variation within each taxon by chamber. Moreover, the standard deviations from each chamber are narrower than the overall standard deviation, indicating that the $\Delta^{13}C$ values from each chamber are fairly consistent with each other (see **Table 6.1**). Chamber 30 shows the greatest variation, with a mean value for emmer wheat (n=18) of 16.17±0.50‰ and a mean value for hulled barley (n=9) of 16.72±0.37‰. The difference between the values for both taxa is 0.55‰. By contrast, values from Chamber 29 have a smaller standard deviation, indicating less variability, with a mean value for emmer wheat (n=5) of 16.43±0.38‰, a mean value for hulled barley (n=4) of 16.80±0.27‰ and a difference of 0.37‰ between the taxa. The results from Welch's two-sample t-tests performed on the cereals within each chamber (see **Table 6.2**) show that Chamber 30 was the only chamber where hulled barley was statistically different from emmer wheat (T(21.315)= -3.25, p=0.0003). Offsets of 1‰ and 0.5‰ were also applied to the results from individual chambers and, as was seen in

the overall results, with an offset of 0.5‰ there was no significant difference between the taxa in any chamber.

To assess further the growing conditions of both taxa and the plausibility of a physiological/natural offset of around 0.5‰, the differences between the $\Delta^{13}C$ values of emmer wheat and hulled barley from each chamber were examined on a sample-by-sample level. This involved evaluating the difference between the $\Delta^{13}C$ values of each taxon from each archaeobotanical sample that had had both hulled barley grains and emmer wheat grains isotopically analysed from it (see **Table 6.3**). The mean difference between emmer wheat and hulled barley from all samples was 0.41±0.42‰. The small standard deviation indicates that there was little variation in the difference between emmer wheat and hulled barley on a sample-by-sample basis, and that in general all samples exhibited a similar difference between the two taxa. The mean difference was then calculated for each chamber and these values were compared using ANOVA. This produced a result of $F(2,17)= 0.613$, $p=0.553$, indicating that there was no significant variation in the differences between emmer and barley. Furthermore, the results of a Tukey post-hoc test showed that there were no significant differences among the chambers. These results, therefore, imply that the emmer wheat and hulled barley from each individual chamber were cultivated under conditions that produced a consistent offset between them. It is plausible, therefore, that a difference of *c.* 0.5‰ was the natural offset between the cereals when grown under the same set of conditions. Furthermore, if there had been preferential treatment of one cereal taxa over the other it would be expected that the results from the ANOVA would have shown statistical variation between the chambers. These results, however, indicate that, even though the mean $\Delta^{13}C$ values of emmer wheat and hulled barley from Chamber 12 were higher

than the mean values from Chamber 30, the differences between both taxa within each chamber were consistent across the assemblage.

Table 6.3 – List of samples that had both hulled barley and emmer wheat isotopically analysed from them, allowing the mean difference to be calculated between the two taxa.

Context No.	Chamber
12_108_515	12
12_118_506	12
12_119_505	12
12_120_514/516	12
12_125_517	12
12_129_520	12
12_135_7	12
12_141_6	12
29_206_509	29
29_271_6	29
29_271_7	29
30_245_3	30
30_245_9	30
30_252_8	30
30_252_11	30
30_259_8	30
30_259_11	30
30_259_13	30
30_262_11	30
30_262_13	30

6.2.2 Carbon – inter-chamber variation

As has been alluded to above, the $\Delta^{13}C$ values show some variation by chamber. **Figure 6.4** shows **Figure 6.1** coded by chamber. From this plot it is clear that that there is some visible clustering of $\Delta^{13}C$ values by chamber. The first group of values from Chambers 30 and 29 appear to group together and encompass the lower end of recorded

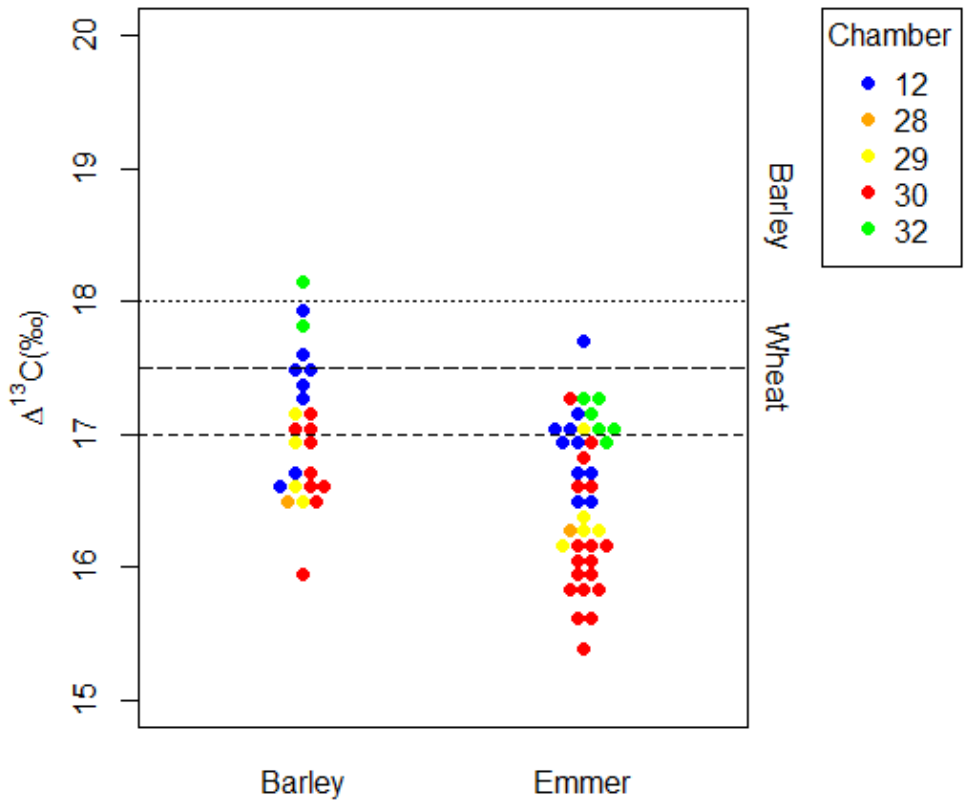


Figure 6.4 - $\Delta^{13}C$ values of the two major cereal species, coded by chamber number.

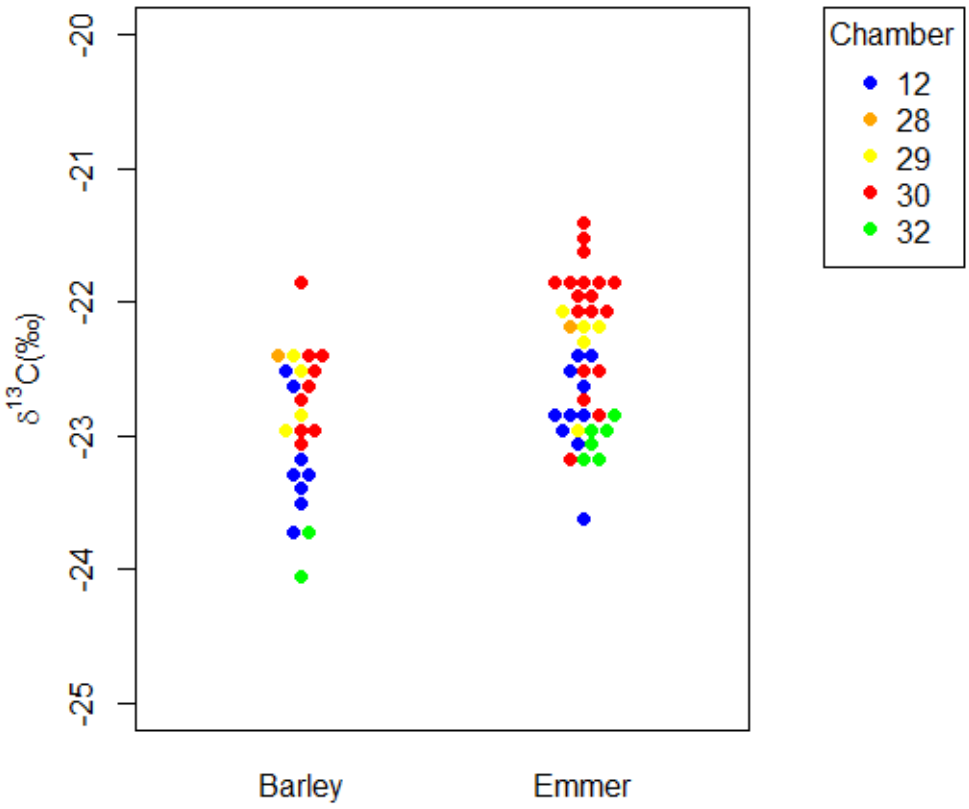


Figure 6.5 - $\delta^{13}C$ values of the two major cereal species, coded by chamber number.

$\Delta^{13}C$ values. This suggests that crops from these chambers were grown under relatively dry conditions. By contrast, the second group of values from Chamber 12 and 32 clusters towards the higher end of this range, and some values fall within the well-watered band. These results mirror the chamber groupings discussed in **Section 5.7.1**, **Chapter 5** with reference to correspondence analyses carried out on the Hattusha assemblage. In **Figure 5.10** it was apparent that Chambers 29 and 30 were compositionally similar to each other and dissimilar to Chambers 32 and 12, and these patterns also appear in the stable isotope results. . **Figure 6.5** shows the normalised $\delta^{13}C$ values coded by chamber, before the conversion to $\Delta^{13}C$.

The results of an ANOVA test, performed on all chambers with three or more samples, confirm that there are significant differences between the chambers with regard to the $\Delta^{13}C$ values of both emmer wheat and hulled barley (see **Table 6.4**). Additionally, the results of the post-hoc Tukey test prove that the groupings visible in **Figure 6.4** are statistically significant. The greatest statistical difference appears to occur between the results from Chambers 12 and 30 (hulled barley $p=0.0138$, emmer wheat $p<0.001$), and between Chambers 30 and 32 (emmer wheat $p<0.001$). By contrast, there are no statistically significant differences between the results from Chambers 29 and 30 (hulled barley $p=0.9344$, emmer wheat $p=0.6005$) and Chambers 12 and 32 (emmer wheat $p=0.757$). Perhaps more surprisingly, however, there is also no statistically significant difference between the results of Chambers 29 and 12 (hulled barley $p=0.1033$, emmer wheat $p=0.1821$) even though these chambers are compositionally distinct with regard to archaeobotanical results. These results suggest that the crops from each chamber were cultivated under growing locations unique to each chamber, but that each of set of conditions was not dramatically different from each other.

Table 6.4 – The results of an ANOVA test and post-hoc analysis on the $\Delta^{13}C$ values of barley and emmer wheat between chambers.

Statistical Test	Species	Chambers included	Results
ANOVA	Barley	All	F(2,18)= 5.431, p=0.0143
ANOVA	Emmer	All	F(3,35)= 11.12, p=<0.0001
Post-hoc Tukey Test	Barley	12, 30	0.0138
Post-hoc Tukey Test	Emmer	12, 30	<0.001
Post-hoc Tukey Test	Barley	29, 12	0.1033
Post-hoc Tukey Test	Emmer	29, 12	0.1821
Post-hoc Tukey Test	Barley	29, 30	0.9344
Post-hoc Tukey Test	Emmer	29, 30	0.6005
Post-hoc Tukey Test	Emmer	29, 32	0.0483
Post-hoc Tukey Test	Emmer	12, 32	0.757
Post-hoc Tukey Test	Emmer	32, 30	<0.001

Overall, the crops from Chambers 12 and 32 appear to have been grown under more favourable watering conditions, with some values indicative of well-watered conditions. By contrast, the results from Chambers 30 and 29 indicate that these crops were generally grown under poorer conditions. Further to these over-arching trends, however, the statistical tests have indicated that even though the results from Chambers 12 and 29 appear visibly discrete, these differences are not significant. When considering this result in conjunction with the visible chamber groupings, therefore, it would seem that the differences in watering status of crops from the Hattusha silo is unlikely to reflect radically different husbandry regimes. As stated in **Section 2.1.2**, **Chapter 2** the annual average rainfall (c. 451mm/year) on the Central Anatolian plateau is enough to support rainfed agriculture without the need for large-scale irrigation systems or artificial watering (Yakar, 2000: 273; Dörfler *et al*. 2011). It would seem likely, therefore, that the differences in the $\Delta^{13}C$ values from each chamber are the result of environmental considerations, such as moisture-retaining soil and/or proximity

to water sources or due to fluctuating rainfall levels between separate areas or years, rather than presence/absence of irrigation systems by Hittite farmers.

6.3 Nitrogen – overview

Figure 6.6 and **Figure 6.7** show the crop stable nitrogen isotope results alongside the means and standard deviations for each taxon. There is a significant amount of variation within both taxa, ranging from high values of 9.1‰ to low values of 3.0‰. Moreover, the standard deviations measured for both taxa (see **Table 6.5**) appear considerably wider than the expected variation of 1‰ reported by Nitsch *et al*. (2015) for crops cultivated within a single growing condition. The mean values for both taxa are very similar; the value for emmer wheat (n=40) is 5.60±1.41‰ whilst the value for hulled barley (n=24) is 5.64±1.45‰. These results suggest that, although there is considerable variability within the results of each taxon, overall the values measured for both cereals are analogous (see **Table 6.5**). Again at this stage of analysis the values from Chamber 28 were excluded from further statistical tests due to the lack of samples. A Welch two-sample t-test was performed on the results from the remaining four chambers and indicated there was no significant difference between the $\delta^{15}N$ values measured for hulled barley and emmer wheat ($T(47.541)= -0.11$, $p=0.915$).When comparing these results with the manuring bands first postulated by Bogaard *et al*. (2013) and refined by Styring *et al*. (2016; 2017) to take account of aridity effects, it would appear that the $\delta^{15}N$ values from the Hattusha silo fall into all three levels of manuring intensity. This suggests that these crops were subject to the application of manure although in highly variable amounts across the assemblage. In a similar manner

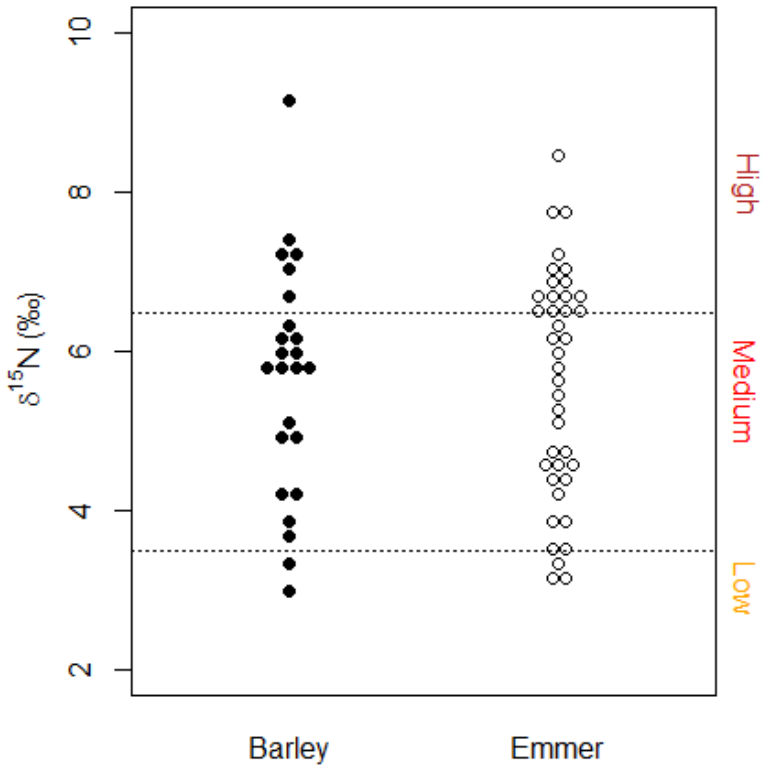


Figure 6.6 - $\delta^{15}N$ values of the two major cereal species, with manuring bands adjusted for aridity.

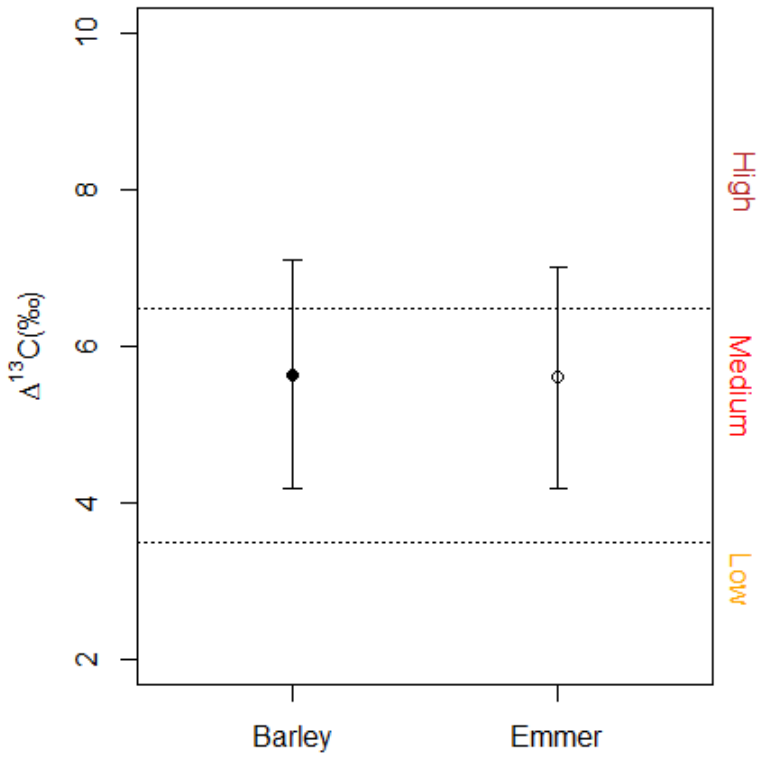


Figure 6.7 – The means and standard deviations of the $\delta^{15}N$ values of barley and emmer.

to the higher number of emmer samples that fell within the well-watered band with regard to $\Delta^{13}C$ values, more emmer wheat samples also fall within the high manuring bracket than hulled barley samples.

6.3.1 Nitrogen – intra-chamber variation

Chamber 29 shows the greatest intra-chamber variation, with a mean value for emmer wheat (n=5) of 5.52±1.16‰ and a mean value for hulled barley (n=4) of 4.80±1.50‰. By contrast, the results from Chamber 12 show very little variation, with a mean value for emmer wheat (n=10) of 6.57±0.33‰ and a mean value for hulled barley (n=8) of 6.70±0.57‰ (see **Table 6.5**). This suggests that there is some level of inter-chamber variation in $\delta^{15}N$ values, to be explored in greater detail in the section below. The results from Welch's two-sample t-tests performed on the cereals within each chamber (**Table 6.6**) indicate that there is no significant difference between the $\delta^{15}N$ values of both cereals within any chamber, confirming the overall results.

6.3.2 Nitrogen – inter-chamber variation

Figure 6.8 shows **Figure 6.6** coded by chamber. Again, as was seen from the $\Delta^{13}C$ values, there is visible clustering of samples by chamber in the same general pattern. Chambers 12 and 32 have generally higher $\delta^{15}N$ values for both taxa and these samples fall primarily within the high manuring bracket. Juxtaposed against this are the values from Chambers 29 and 30 which are grouped together within the medium and low manuring brackets. As noted above, these groupings echo patterns already observed within the correspondence analysis (see **Figure 5.10**).

Table 6.5 – The number of samples, means and standard deviations of $\delta^{15}N$ values, by chamber number.

Chamber	Taxon	No. of samples	Mean (‰)	Standard deviation (‰)
All	Barley	24	5.64	1.45
	Emmer	40	5.6	1.41
Twelve	Barley	8	6.7	0.57
	Emmer	10	6.57	0.33
Twenty-eight	Barley	1	n/a	n/a
	Emmer	1	n/a	n/a
Twenty-nine	Barley	4	4.80	1.51
	Emmer	5	5.52	1.16
Thirty	Barley	9	4.64	0.92
	Emmer	18	4.34	1.24
Thirty-two	Barley	2	n/a	n/a
	Emmer	6	6.97	0.69

Table 6.6 – Results of Welch's two sample T-test conducted on the $\delta^{15}N$ values from both cereals, by chamber number.

Statistical Test	Chamber	Results
Welch's two-sample T-test	All	T(47.541)= -0.11, p=0.915
Welch's two-sample T-test	Twelve	T(10.679)= -0.53, p=0.61
Welch's two-sample T-test	Twenty-nine	T(5.5911)= -0.79, p=0.4609
Welch's two-sample T-test	Thirty	T(20.907)= -0.25, p=0.8051
Welch's two-sample T-test	Thirty-two	T(1.0642)= -0.35, p=0.7854

The results of an ANOVA test on the $\delta^{15}N$ emmer wheat values and a Kruskal-Wallis test[15] on the $\delta^{15}N$ barley values from each chamber with three or more samples established that there are significant differences among the different chambers (see **Table 6.7**). Furthermore, the results of the post-hoc analyses proved that differences between chambers already observed with regard to the $\Delta^{13}C$ values are repeated in the

[15] The results of a Levene test revealed that the $\delta^{15}N$ barley results had an unequal variance and required the use of a non-parametric counterpart to the one-way ANOVA test used on the $\delta^{15}N$ emmer results. Additionally, a robust Dunn Test post-hoc analysis was performed on the results of the Kruskal-Wallis test.

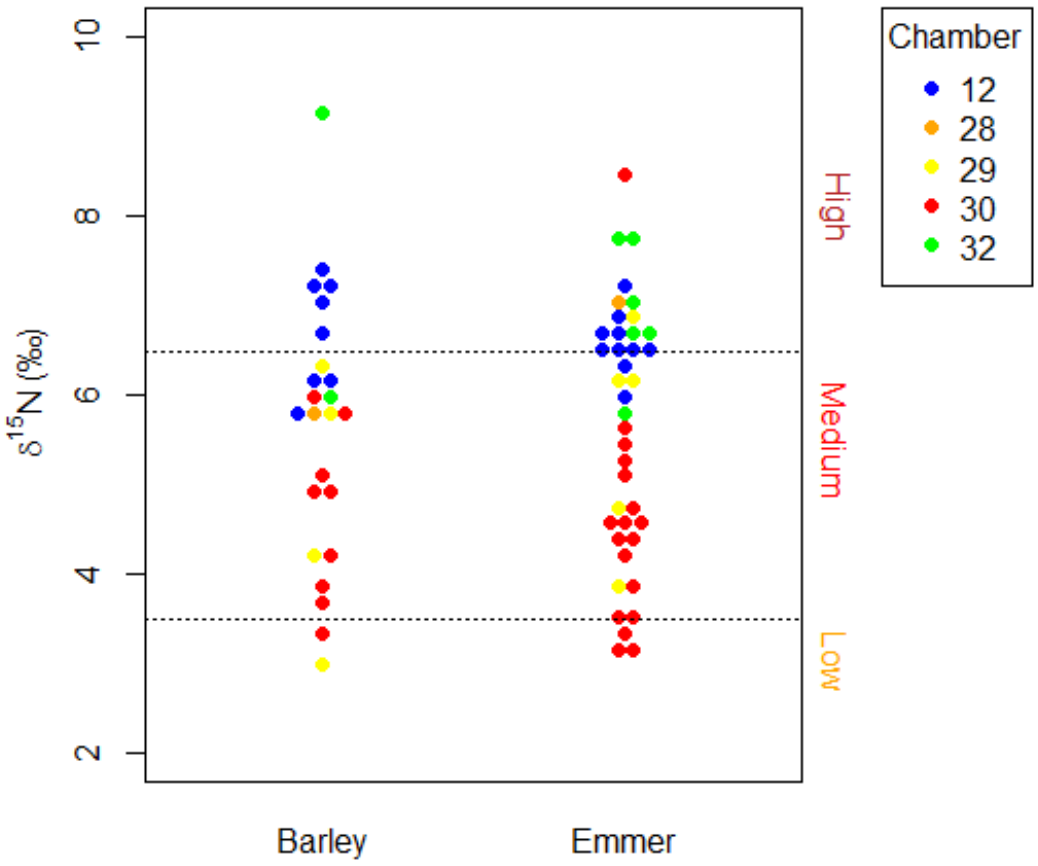


Figure 6.8 - $\delta^{15}N$ values of the two major cereal species, coded by chamber number and with manuring bands adjusted for aridity.

Table 6.7 – The results of an ANOVA test, a Kruskal-Wallis test and post-hoc analysis on the $\delta^{15}N$ values of barley and emmer wheat between chambers.

Statistical Test	Species	Chambers included	Results
Kruskal-Wallis	Barley	All	H(2)= 11.19, p=0.0037
ANOVA	Emmer	All	F(3,35)= 13.78, p=<0.0001
Post-hoc Dunn Test	Barley	12, 30	0.0042
Post-hoc Tukey Test	Emmer	12, 30	<0.001
Post-hoc Dunn Test	Barley	29, 12	0.0506
Post-hoc Tukey Test	Emmer	29, 12	0.2324
Post-hoc Dunn Test	Barley	29, 30	0.7600
Post-hoc Tukey Test	Emmer	29, 30	0.2194
Post-hoc Tukey Test	Emmer	29, 32	0.0928
Post-hoc Tukey Test	Emmer	12, 32	0.8614
Post-hoc Tukey Test	Emmer	32, 30	<0.001

$\delta^{15}N$ values. Again, as was reported above with reference to the $\Delta^{13}C$ values, the greatest statistical variation is between two pairs of chambers: Chambers 12 and 30, and Chambers 30 and 32. Additionally there are no significant differences between Chambers 29 and 30, Chambers 12 and 32 and Chambers 29 and 12. It would appear, therefore, that the crops from each chamber were grown under conditions of ^{15}N enrichment unique to each chamber, but that each of these conditions was not radically different from each other. Instead, these $\delta^{15}N$ results indicate a spectrum of manuring rather than individual, separate regimes. Furthermore, the average annual rainfall (c. 451mm/year) at Hattusha means that the natural ^{15}N enrichment of soils caused by aridity is not a major factor here (Styring *et al*. 2016a; 2017). The higher $\delta^{15}N$ values are plausibly, therefore, the result of artificial enrichment through manuring or middening, although other sources of 'natural' ^{15}N enrichment such as the seasonal wetting and drying of soils cannot be completely ruled out. Overall, the cereals from Chambers 12 and 32 received the highest levels of manuring whilst cereals from Chambers 29 and 30 received medium manuring levels and in some cases perhaps were not subject to artificial enrichment at all.

6.4 The relationship between carbon and nitrogen

Figure 6.9 shows a scatterplot of all crop stable isotope carbon and nitrogen values, coded by cereal taxon. As was discussed above, there is no significant clustering of values by taxon, but $\delta^{13}C$ values for hulled barley tend to be slightly lower than the values for emmer wheat. This discrepancy in $\delta^{13}C$ values is likely due to a physiological difference between wheat and barley discussed above. Also notable is a statistically significant negative correlation visible between $\delta^{15}N$ values and $\delta^{13}C$ values (Pearson's

product-moment correlation co-efficient = -0.46, p= 0.0001). **Figure 6.10** shows the same results coded by chamber number. It is clear that there is some clustering of values by chamber, as was seen from the separate carbon and nitrogen results discussed above. Overall, it would seem that the samples from Chambers 12 and 32 group together indicating relatively low $\delta^{13}C$ values and relatively high $\delta^{15}N$ values. By contrast, samples from Chamber 30 tend to have slightly higher $\delta^{13}C$ values and lower $\delta^{15}N$ values. Results from Chamber 29 appear to be the most variable of the entire assemblage.

6.5 Crop stable isotope analysis conclusions

The results of carbon and nitrogen stable isotope analysis of emmer wheat and hulled barley grains from the Hattusha silo support the hypothesis that the crops from each individual chamber were cultivated under different growing conditions involving the use of unique land management regimes and different agricultural locations. As mentioned above, however, these chamber-specific agricultural conditions were not radically different from each other, but rather represent a spectrum of crop husbandry regimes. Overall, the crops from Chambers 12 and 32 seem to have been grown under favourable watering conditions and with the highest levels of artificial enrichment, most likely caused by manuring. By contrast, crops from Chambers 29 and 30 were grown in generally drier conditions and with medium to low inputs of manure. As was noted above, average rainfall on the Central Anatolian plateau was enough to support rainfed agriculture during the Bronze Age, suggesting that the differences in $\Delta^{13}C$ values between chambers are unlikely to be due to artificial watering. When considering these differences alongside the $\delta^{15}N$ values, however, it may be possible to explain the higher

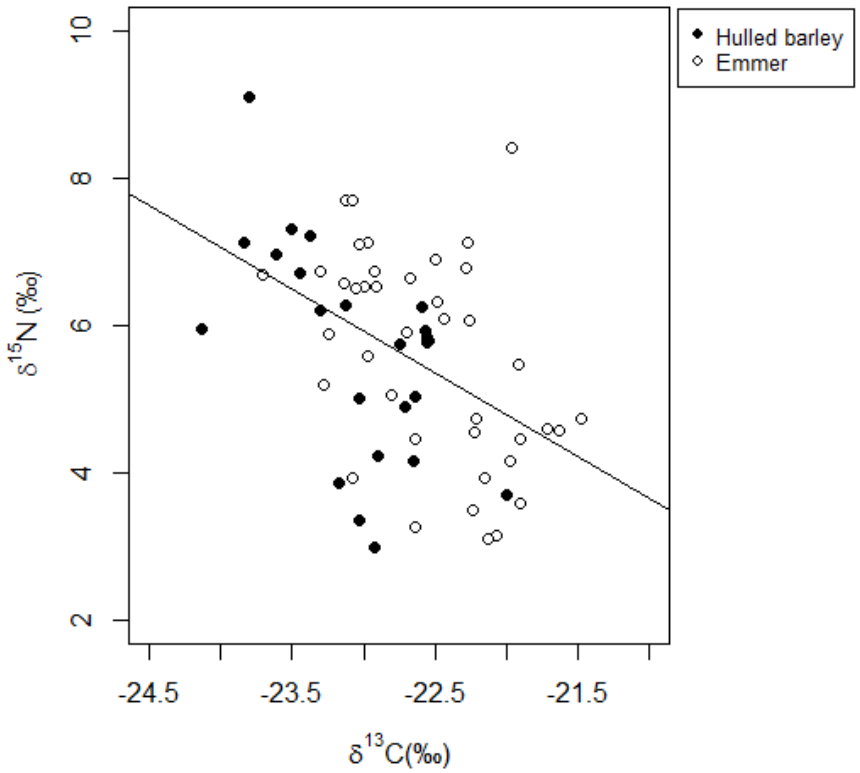


Figure 6.9 – Scatterplot of all crop stable isotope carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) values, coded by cereal taxon (line equation = y=-0.1879x-21.6752).

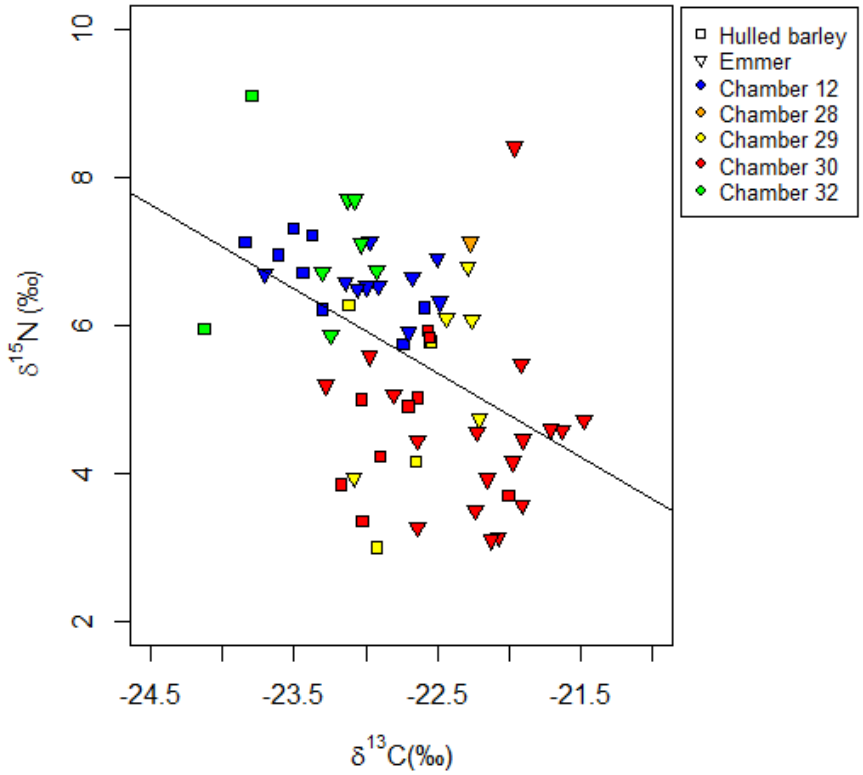


Figure 6.10 – Scatterplot of all crop stable isotope carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) values, coded by cereal taxon and chamber number.

$\Delta^{13}C$ values from Chambers 12 and 32 because these chambers also show the highest levels of soil enrichment. These better watered soils, caused by higher rainfall levels or locally wetter soils, may have made manuring more beneficial in these specific areas leading to the elevation of $\delta^{15}N$ values and in turn led to greater water retention within these soils. Similarly, the lower rates of manuring observed in Chambers 29 and 30 may have contributed to the lower $\Delta^{13}C$ values and generally drier growing conditions of crops from these chambers.

The results from the crop stable isotope analysis have also suggested that the emmer wheat and hulled barley from each chamber were grown under similar conditions and likely the same husbandry regimes. As was shown above from the $\Delta^{13}C$ values, there was no significant variation by chamber in the difference between $\Delta^{13}C$ values calculated for emmer wheat and hulled barley. This consistency across the assemblage indicated that there was no preferential treatment of one cereal over the other and, coupled with the similar $\delta^{15}N$ means and standard deviations measured from both taxa (see **Table 6.5**), signifies that both cereal taxa, from each chamber, were grown under the same conditions. Finally, the patterning by chamber observed in both carbon and nitrogen crop stable isotope values provides an independent line of evidence for the chamber-specific patterns identified from correspondence analysis carried out in **Section 5.7.1**. This not only supports the theory that each chamber is representative of a distinct set of growing conditions, but also underlines the reliability of the data gained from crop stable isotope analysis. The range of crop husbandry regimes as indicated by the results of crop stable isotope analysis will be considered in further detail below with reference to the results of the functional ecology of arable weed taxa.

6.6 Weed evidence and functional ecological analysis

This section will present the results of ecological analysis performed on the arable weed assemblage identified within the Hattusha underground silo samples. Methods used in this section include an assessment of crop sowing times and the use of functional weed ecology (e.g. Jones *et al*. 2005; Bogaard *et al*. 2016a: 2016b). The functional analysis of arable weed floras compares archaeobotanical data with evidence from modern weed floras grown under known husbandry conditions along a spectrum from low to high labour-intensity (see **Section 3.3.2**, **Chapter 3** and **Section 4.6.2**, **Chapter 4** for a more detailed methodology). These results will then be compared to the results of crop stable isotope analysis as a means of identifying potential crop husbandry practices and growing conditions used in the cultivation of the stored cereals.

As was discussed in **Chapter 5** the archaeobotanical assemblage from the underground silo at Hattusha is representative of the direct storage of processed crops alongside the remains of weed/wild taxa growing in the same locales. Additionally, the hermetic nature of the underground silo has preserved and protected these remains from contamination with other sources of archaeobotanical material. This specific storage context, therefore, has allowed the identification of most weed/wild taxa as having derived from the cultivated fields, rather than having entered the assemblage via other activities such as dung burning. Furthermore, ecological information taken from the *Flora of Turkey* (cf. Davis, 1965-1989) has indicated that the majority of these weed/wild taxa grow in cultivated fields and in open, ruderal habitats. It is very likely then that weed/wild taxa identified from the Hattusha assemblage are weeds of arable cultivation and grew alongside the barley and wheat crops in the fields. The functional ecological analysis of these species, therefore, can potentially provide direct evidence for specific growing conditions and land management systems employed by Hittite

farmers. For the purposes of the following analyses, the remains of *Vicia faba* var. *minuta* have been removed, as their identification as a potential crop would mean that they would not reflect cereal growing conditions in the same way.

The identification of weed species from open, cultivated habitats would also suggest that the cereals from the Hattusha silo were being grown in open, steppic habitats and permanently cultivated fields. Experimental research carried out in Germany has shown that newly created fields tend to have a high percentage of perennial weeds from woodland habitats (Bogaard, 2002). By comparison well-established fields tend to have high proportions of annual weeds from open and ruderal habitats. Clearly, the vegetation and climatic conditions of the Central Anatolian plateau cannot be compared directly with those in Germany; rather this study of temperate Europe can be used as an analogy to broadly assess the environmental conditions and permanence of cultivation at Hattusha. The preferred habitats of all potential arable weeds were investigated alongside available evidence for the vegetation history of this region. As stated above, the majority of weed/wild taxa grow in open habitats, on cultivated land and waste/fallow ground. Additionally, pollen cores taken from Lakes Yenicağa and Abant, located north-east of Hattusha, have shown that any surrounding forest was cleared during the Bronze Age for the creation of agricultural and grazing land (Schachner, 2011; 2012; Wright *et al*. 2015). These two strands of evidence support the hypothesis that the crops stored within the Hattusha silo were grown in well-established fields which had been cleared for the purposes of large-scale cereal cultivation.

6.7 Sowing time

Information from arable weeds can be used to estimate the period of the year in which the crops were initially sown (e.g. Behr & Jacomet, 1991; van der Veen, 1992, Bogaard *et al*. 2001). These inferences have generally been based on modern observational data (Bogaard *et al*. 2001) in temperate Europe (Germany) which found that the month of flowering onset and the length of the flowering period of weed/wild taxa can be used to predict the initial germination time of these plants and thus crop sowing time. From this work it was established that weed species which flower in the late spring/early summer are generally associated with autumn-sown crops. This is because a relatively early/short flowering time predicts an autumn germination period and suggests that these species began to germinate shortly after the crop was sown. Similarly, these species are unlikely to be associated with a spring-sown crop as they tend not to survive ploughing (Bogaard *et al*. 2001). Moreover, spring-germinating species that flower in the autumn are associated with spring-sown crops and not with an autumn sowing period for much the same reasons. Spring-germinating species can still grow amongst autumn-sown crops, however, if hand-weeding and/or disturbance is not intensive and competition from autumn-germinating species is not too high (Bogaard *et al*. 2001). In Europe, therefore, an autumn germination time is predicted by species with a short flowering period (1-3 months) and early flowering onset during the months of January to June and is generally associated with autumn-sown crops. By contrast, plants with long flowering periods (>5 months) and/or late flowering times (July onwards) are associated with spring-sown crops. There are, however, many species with a mixture of early/medium onset flowering periods and/or medium-flowering times and these species cannot be correlated with either autumn or spring sown crops.

Today the harvest time on the Central Anatolian plateau falls within the months of July and August (Yakar, 2000) and the cereal crops are generally sown during the autumn months to take advantage of seasonal rainfall (see **Section 2.1.2**, **Chapter 2**). Palaeoclimate reconstructions of the Late Bronze Age have shown that the climate resembled conditions seen in modern Turkey, so it is likely that the agricultural year followed the same patterns recorded today. This harvest time is roughly the same time as the German harvest time used in the Bogaard *et al*. (2001) study and allows the flowering categories created for that study to be applied here (see **Table 6.8**). All identified arable weeds species and remains identified to the genus level from the Hattusha assemblage with available flowering data from the Flora of Turkey (Davis, 1966-1989) were categorised by flowering onset and duration. These results were then compared with the modern ethnobotanical data from Germany (see **Section 4.6.2**, **Chapter 4** for a detailed methodology).

Table 6.8 – Summary of flowering categories used for the Hattusha weed/wild taxa based on flowering onset and flowering duration.

Flowering onset	Flowering Duration	Flowering classification
January-June	1-3 months	Short flowering/early-intermediate onset
July onwards	1-5 months	Late flowering
January-June	>5 months	Long flowering

Table 6.9 shows all flowering data for identified arable weed species. Of the 87 species for which information was available, 30 species fall within the early/short category and have been classified in the autumn sowing class. By contrast, only two species have late flowering onset, *Carthamus tinctorius* and *Polygonum aviculare*, and

have been classified in the spring-germinating class. It should be noted that *Polygonum aviculare* is very well represented throughout the assemblage, with a ubiquity of 93%. A further eight species (e.g. *Bifora radians*, *Veronica hederifolia* and *Convolvulus arvensis*) have a long flowering period and may be representative of a germination period during both the spring and autumn. All other species have been classified as indeterminate.

Due to the high number of indeterminate species **Figure 6.11** shows the number of weed species against the month of flowering onset, coded by flowering category. This shows that the majority of species begin flowering in April and May. This would suggest that these species began germinating during the autumn alongside the autumn-sown crops. These results, therefore, indicate that the cereal crops stored in the Hattusha silo were primarily sown during the autumn, but that spring-germinating taxa do also infrequently occur in the assemblage. Bogaard *et al*. (2005) have noted that crop processing can bias results against spring-germinating taxa as these species are commonly removed during fine sieving. As was shown in **Section 5.8**, **Chapter 5** all Hattusha samples have been classified as fine sieving products so it is possible that many more spring-germinating taxa may have been removed prior to storage. Generally, however, the results show that autumn-germinating weed species are prevalent within the Hattusha silo assemblage, consistent with autumn sowing.

Table 6.9 – All flowering data for identified arable weed species including overall sowing class.

Taxa	No. of species	Ubiquity (%)	Flowering onset	Flowering onset class	Flowering duration class	Combined classification	Sowing class
Brassica nigra	1	6.7	March	Early	Short	Early/Short	Autumn
Camelina sativa	1	20	March	Early	Short	Early/Short	Autumn
Conringia orientalis	1	37.8	March	Early	Short	Early/Short	Autumn
Medicago arabica/polymorpha	2	8.9	March	Early	Short	Early/Short	Autumn
Fumaria parviflora	1	6.7	March	Early	Short	Early/Short	Autumn
Camelina/conringia	2	4.4	March	Early	Short	Early/Short	Autumn
Asperugo procumbens	1	2.2	April	Early	Short	Early/Short	Autumn
Buglossoides tenuiflorum	1	44.4	April	Early	Short	Early/Short	Autumn
Cardaria draba	1	15.6	April	Early	Short	Early/Short	Autumn
Lallemantia iberica	1	33.3	April	Early	Short	Early/Short	Autumn
Ajuga chamaepitys	1	4.4	April	Early	Short	Early/Short	Autumn
Adonis annua	1	42.2	April	Early	Short	Early/Short	Autumn
Turgenia latifolia	1	75.6	April	Early	Short	Early/Short	Autumn
Adonis aestavalis	1	26.7	April	Early	Short	Early/Short	Autumn
Coronopus squamatus	1	2.2	April	Early	Short	Early/Short	Autumn
Scorpiurus sp.	1	2.2	April	Early	Short	Early/Short	Autumn
Bellevalia sp.	3	8.9	April, May	Early/intermediate	Short	Early/Short	Autumn
Boreava aptera	1	51.1	May	Early/intermediate	Short	Early/Short	Autumn
Boreava orientalis	1	15.6	May	Early/intermediate	Short	Early/Short	Autumn
Lepidium latifoliatum	1	22.2	May	Early/intermediate	Short	Early/Short	Autumn
Lepidium perfoliatum	1	4.4	May	Early/intermediate	Short	Early/Short	Autumn
Scirpus sp.	1	8.9	May	Early/intermediate	Short	Early/Short	Autumn
Cephalaria syriaca	1	44.4	May	Early/intermediate	Short	Early/Short	Autumn
Lolium persicum	1	57.8	May	Early/intermediate	Short	Early/Short	Autumn
Poa bulbosa	1	17.8	May	Early/intermediate	Short	Early/Short	Autumn
Onobrychis vicifolia	1	13.3	May	Early/intermediate	Short	Early/Short	Autumn
Papaver somniferum	1	2.2	May	Early/intermediate	Short	Early/Short	Autumn
Glaucium corniculatum	1	20	May	Early/intermediate	Short	Early/Short	Autumn

Taxa	No. of species.	Ubiquity (%)	Flowering onset	Flowering onset class	Flowering duration class	Combined classification	Sowing class
Delphinium staphisagria	1	4.4	May	Early/intermediate	Short	Early/Short	Autumn
Carthamus tinctorius	1	2.2	July	Late	Short	Late	Spring
Polygonum aviculare	1	93.3	July	Late	Long	Late	Spring
Veronica hederifolia	1	71.1	February	Early	Long	Long	(Spring)
Coronilla scorpiodes	1	6.7	March	Early	Long	Long	(Spring)
Convolulus arvensis	1	24.4	April	Early	Long	Long	(Spring)
Thymelaea passerina	1	20	April	Early	Long	Long	(Spring)
Bifora radians	1	93.3	April	Early	Long	Long	(Spring)
Calystegia sepium	1	4.4	May	Early/intermediate	Long	Long	(Spring)
Hordeum spontaneum	1	6.7	May	Early/intermediate	Long	Long	(Spring)
Polygonum convolvulus	1	15.6	May	Early/intermediate	Long	Long	(Spring)
Thlaspi arvense	1	24.4	February	Early	Medium	Indeterminate	Indeterminate
Alyssum sp.	33	26.7	February, March, April, May, June, July	Early/intermediate/late	Short/medium/long	Indeterminate	Indeterminate
Lamium sp.	11	4.4	February, March, April, June	Early/late	Short/medium/long	Indeterminate	Indeterminate
Ornithogalum sp.	13	6.7	February, March, April, May	Early/intermediate	Short/medium/long	Indeterminate	Indeterminate
Silene sp.	38	31.1	February, March, April, May, June, July, August	Early/intermediate/late	Short/medium	Indeterminate	Indeterminate
Bromus tectorum	1	24.4	March	Early	Medium	Indeterminate	Indeterminate
Medicago truncatula	1	22.2	March	Early	Medium	Indeterminate	Indeterminate
Ranunculus arvensis	1	93.3	March	Early	Medium	Indeterminate	Indeterminate
Galium spurium	1	86.7	March	Early	Medium	Indeterminate	Indeterminate
Stellaria sp.	2	2.2	March, April	Early	Short/medium	Indeterminate	Indeterminate
Galium sp.	2	2.2	March, April	Early	Medium	Indeterminate	Indeterminate
Medicago sp.	14	31.1	March, April, May	Early/intermediate	Short/medium/long	Indeterminate	Indeterminate
Bromus sp.	16	20	March, April, May, June	Early/intermediate	Short/medium/long	Indeterminate	Indeterminate
Potentilla sp.	14	2.2	March, April, May	Early/intermediate	Short/medium/long	Indeterminate	Indeterminate

Taxa	No. of species	Ubiquity (%)	Flowering onset	Flowering onset class	Flowering duration class	Combined classification	Sowing class
Vicia sp.	24	22.2	March, April, May, June	Early/intermediate	Short/medium/long	Indeterminate	Indeterminate
Geranium sp.	14	2.2	March, April, May, June	Early/intermediate	Short/medium	Indeterminate	Indeterminate
Helianthemum sp.	6	2.2	March, April, May, June	Early/intermediate	Short/medium/long	Indeterminate	Indeterminate
Salvia sp.	28	13.3	March, April, May, June, July,	Early/inter/late	Short/medium/long	Indeterminate	Indeterminate
Bromus sterilis	1	4.4	April	Early	Medium	Indeterminate	Indeterminate
Anchusa officinalis	1	2.2	April	Early	Medium	Indeterminate	Indeterminate
Buglossoides arvensis	1	73.3	April	Early	Medium	Indeterminate	Indeterminate
Buglossoides sp.	2	17.8	April	Early	Short/medium	Indeterminate	Indeterminate
Agrostemma githago	1	26.7	April	Early	Medium	Indeterminate	Indeterminate
Vaccaria pyramidata	1	91.1	April	Early	Medium	Indeterminate	Indeterminate
Neslia paniculata	1	73.3	April	Early	Medium	Indeterminate	Indeterminate
Cruciata laevipes	1	68.9	April	Early	Medium	Indeterminate	Indeterminate
Galium tricornutum	1	100	April	Early	Medium	Indeterminate	Indeterminate
Avena sterilis/fatua	2	55.6	April, June	Early/intermediate	Medium/Long	Indeterminate	Indeterminate
Ziziphora sp.	4	4.4	April, May	Early/intermediate	Short/medium/long	Indeterminate	Indeterminate
Phalaris sp.	3	6.7	April, May	Early/intermediate	Short/medium/long	Indeterminate	Indeterminate
Convolvulus sp.	10	20	April, May, June	Early/intermediate	Short/medium/long	Indeterminate	Indeterminate
Teucrium sp.	7	17.8	April, May, June	Early/intermediate	Short/medium	Indeterminate	Indeterminate
Melilotus sp.	4	4.4	April, May, June	Early/intermediate	Short/medium/long	Indeterminate	Indeterminate
Onobrychis sp.	17	8.9	April, May, June	Early/intermediate	Short/medium	Indeterminate	Indeterminate
Lepidium sp.	8	11.1	April, May, June	Early/intermediate	Short/medium	Indeterminate	Indeterminate
Bupleurum sp.	11	60	April, May, June, July, August	Early/intermediate/late	Short/medium	Indeterminate	Indeterminate
Chenopodium sp.	4	6.7	May	Early/intermediate	Short/medium	Indeterminate	Indeterminate
Boreava/Bunias sp.	3	42.2	May	Early/intermediate	Short/medium	Indeterminate	Indeterminate
Taeniatherum caput-medusae	1	2.2	May	Early/intermediate	Medium	Indeterminate	Indeterminate
Rumex acetosella	1	31.1	May	Early/intermediate	Medium	Indeterminate	Indeterminate

Taxa	No. of species	Ubiquity (%)	Flowering onset	Flowering onset class	Flowering duration class	Combined classification	Sowing class
Bunias orientalis	1	24.4	May	Early/intermediate	Medium	Indeterminate	Indeterminate
Caucalis platycarpos	1	68.9	May	Early/intermediate	Medium	Indeterminate	Indeterminate
Stachys sp.	13	26.7	May, June	Early/intermediate	Short/medium/long	Indeterminate	Indeterminate
Polygonum sp.	2	4.4	May, June, July	Early/intermediate/late	Short/long	Indeterminate	Indeterminate
Heliotropium sp.	7	2.2	May, June, July	Early/inter/late	Short/medium/long	Indeterminate	Indeterminate
Centaurea sp.	31	60	May, June, July, August	Early/inter/late	Short/medium	Indeterminate	Indeterminate
Onopordum acanthium	1	2.2	June	Intermediate	Short	Indeterminate	Indeterminate
Consolida regalis	1	6.7	June	Intermediate	Short	Indeterminate	Indeterminate

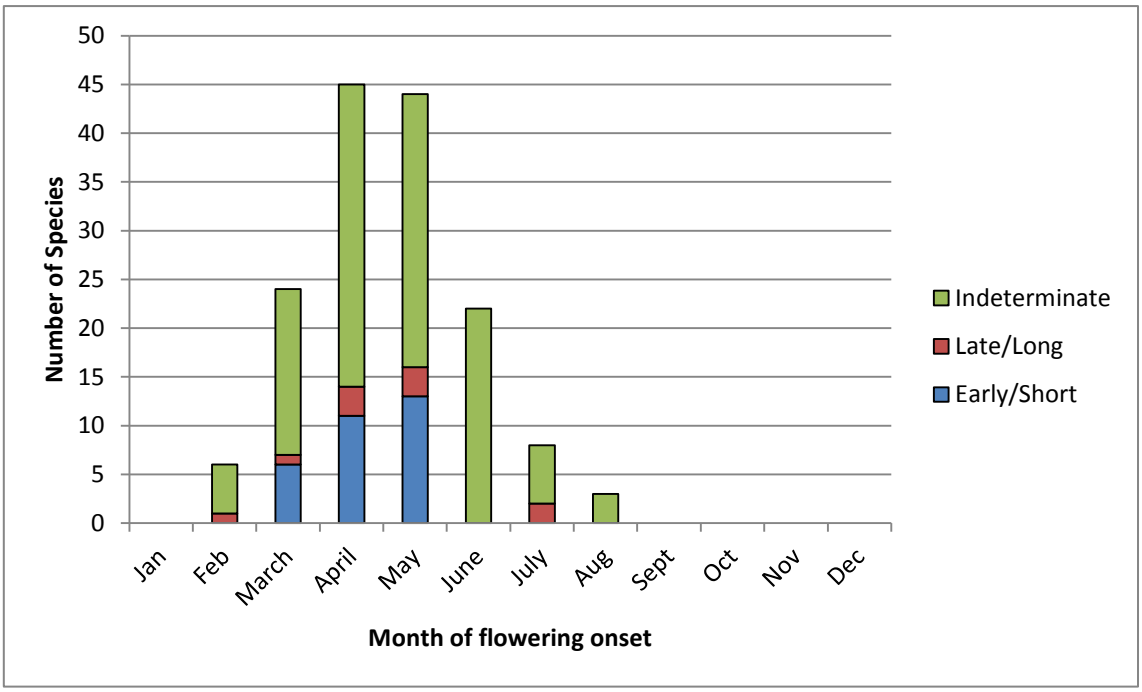


Figure 6.11 – Bar chart showing the number of weed species against the month of flowering onset, coded by flowering category.

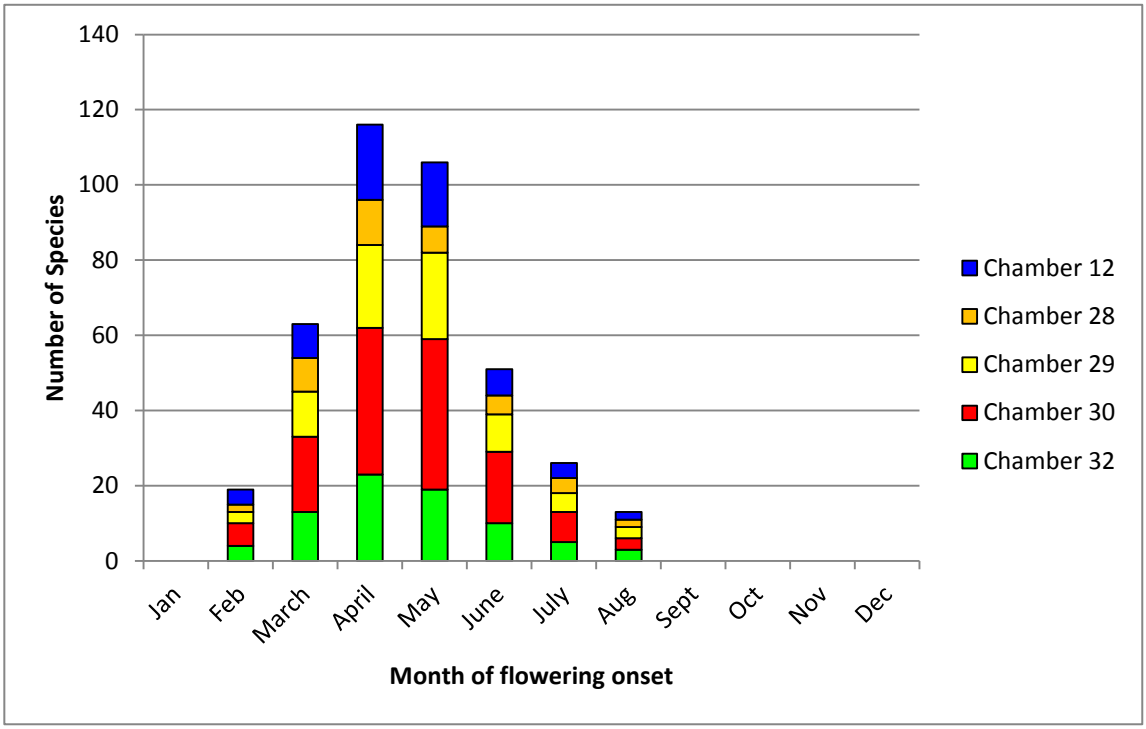


Figure 6.12 – Bar chart showing the number of weed species against the month of flowering onset, coded by chamber number.

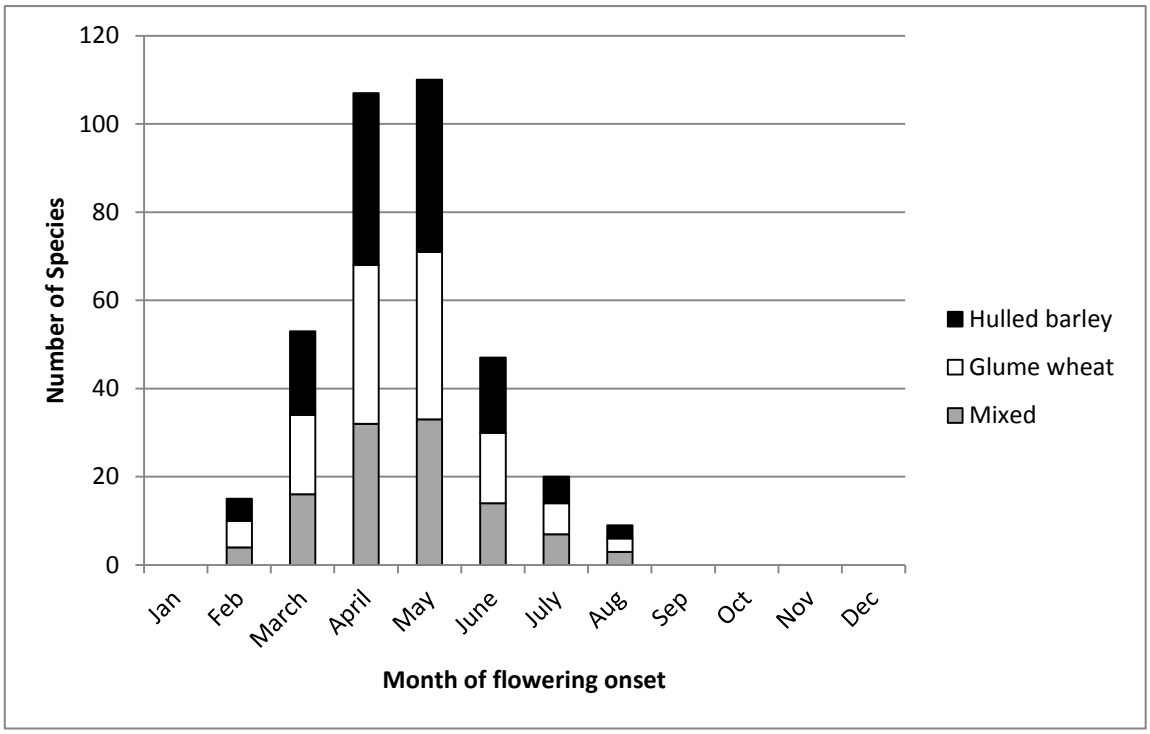


Figure 6.13 – Bar chart showing the number of weed species against the month of flowering onset, coded by dominant cereal taxa.

Figure 6.12 and **Figure 6.13** show species number and month of flowering onset coded by chamber number and dominant cereal taxa. This was done to examine whether sowing time may have varied by chamber or by cereal species. Both **Figure 6.12** and **Figure 6.13** show no discernible patterning with the majority of species again beginning to flower in April and May. From these results, therefore, it would seem that all cereal species from all chambers were likely to have been sown in the autumn period.

6.8 Intensity of cultivation

The intensity of cultivation was assessed by comparing semi-quantitative arable weed data from Hattusha with modern field weed data from a spectrum of management

intensities using discriminant analysis (see **Section 4.6.2**, **Chapter 4** for relevant methodology). Arable weed data from Hattusha included all remains identified to the species level, but excluded species that occurred in only one sample (see **Table 12.4**, **Appendix** for full list of species included). Additionally, only samples that contained 10 or more weed seeds were included, leading to the exclusion of one sample from Chamber 29 (29_512_123). One-off weed species and samples with very low quantities of weed seeds were removed from this analysis as their scores would have been unfairly weighted by one weed species.

Modern comparative arable weed data was based on amalgamated presence/absence field data from four modern weed survey studies in northern Spain, Greece, southern France and Morocco (Jones *et al.* 1999: 2000; Bogaard *et al*. 2016a; 2016b), as presented in Bogaard et al. (2016b). These modern studies were undertaken in regions with a variety of climate zones as well as a range of high- and low-intensity agricultural regimes to provide a broad spectrum of examples with which to compare archaeological data (see **Section 3.3.2**, **Chapter 3**). **Figure 6.14** shows the individual field data for these modern studies with each surveyed field represented by one data point. These points have been classified into two groups: high-intensity agricultural regimes in black (e.g. manured, weeded and sometimes watered garden plots, with high labour inputs) and low-intensity agricultural regimes in white (e.g. rain-fed fields with less manuring and weeding and hence lower labour inputs), with 94% of fields (179 out of 190 fields) correctly reclassified (Bogaard *et al*. 2016b). These points have also been used to calculate average scores for each type of regime, as illustrated by the larger group centroid points.

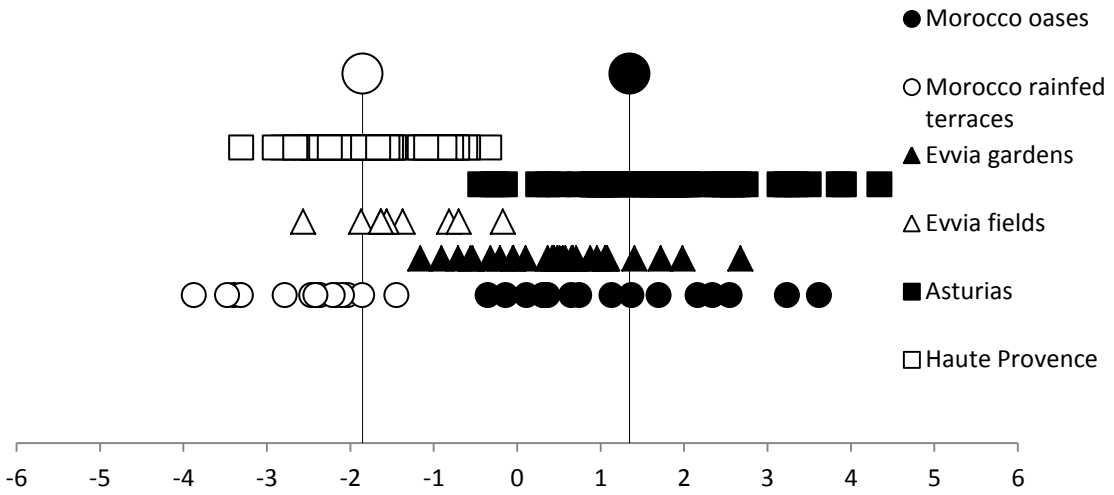


Figure 6.14 – Combined plot of modern field survey samples in relation to the discriminant function extracted to distinguish between high (black) and low (white) intensity crop husbandry regimes.

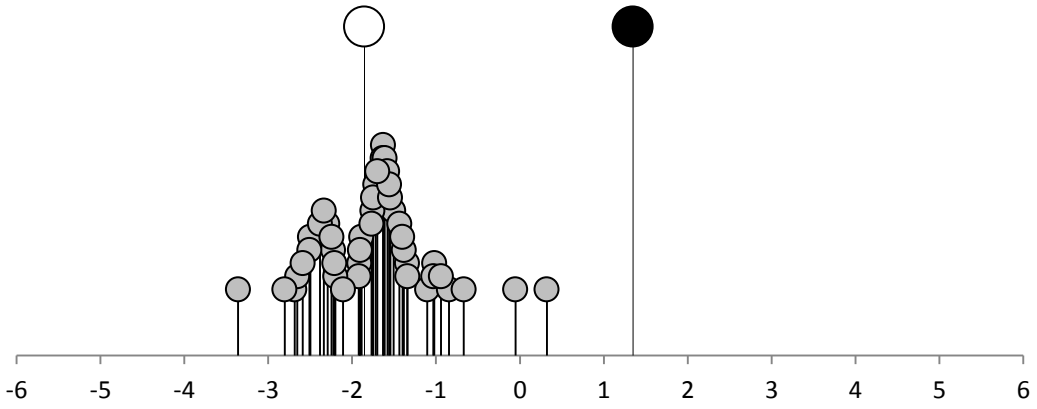


Figure 6.15 – Plot of Hattusha samples in relation to the discriminant function extracted to distinguish between high and low intensity crop husbandry regimes.

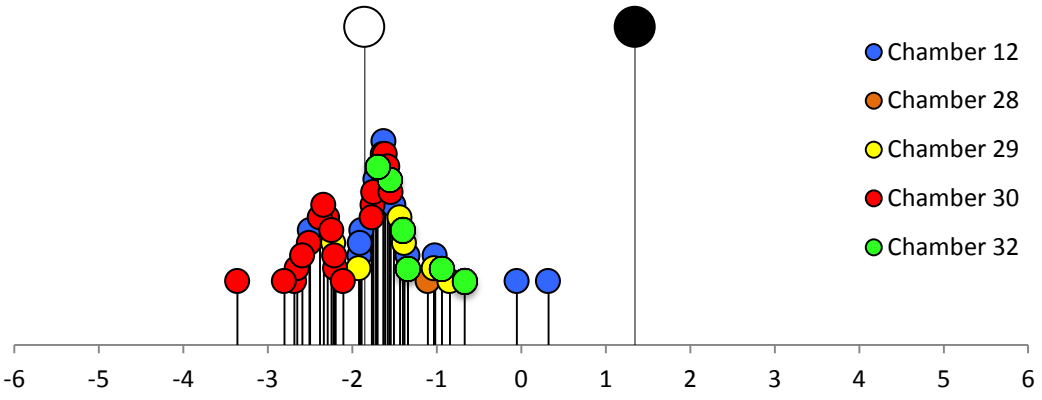


Figure 6.16 – Plot of Hattusha samples in relation to the discriminant function, coded by chamber.

The discriminant function extracted to distinguish the modern high- and low-intensity regimes was used to classify the Hattusha archaeobotanical samples as unknown cases (cf. Jones *et al.* 2000; Bogaard *et al.* 2016a; 2016b). A total of 44 samples from the Hattusha assemblage were classified after the removal of sample 29_512_123 from Chamber 29. The discriminant analysis function extracted to maximise separation of the modern groups was then used to classify the archaeobotanical samples (average probability of 0.97) as deriving from high- or low-intensity management. From **Figure 6.15** it is clear that the vast majority of Hattusha samples are located towards the low-intensity end of the axis, and are clustered to either side of the low-intensity centroid in two separate peaks. There are also two samples that had higher scores on the discriminant function and were classified as high-intensity.

The majority of samples were classified with a very high probability (0.90), while four samples were classified with lower probabilities, including both of the two 'high-intensity' samples (see **Table 6.10** for all probability results). The results for these four samples, therefore, and in particular the 'high-intensity' samples, should be treated with caution as the classification of these samples is less certain. When compared with the discriminant analysis performed on modern weed datasets (**Figure 6.14**), it appears that the Hattusha samples correlate most closely with the fields managed under low-intensity conditions in Haute Provence (southern France) and in rainfed terrace fields in Morocco. These agricultural regimes have been classified as low-intensity and were characterized by relatively low levels of disturbance (i.e. tillage and weeding) and moderate to low manuring rates (the relationship between low-intensity regimes and elevated $\delta^{15}N$ values will be discussed in detail below). It is posited, therefore, despite obvious geographical differences between the areas, that the agricultural regimes implemented by Hittite farmers were also characterised by the same low input levels.

Table 6.10 – The number of taxa per sample from the Hattusha assemblage used in the discriminant analysis as well as the results of the discriminant analysis showing the classification of each sample as high- or low-intensity, with high or low probability.

Sample code	No. of taxa	No. of items	Probability	Intensity Class
12_108_515	16	451	0.991	Low
12_118_506	7	172	0.995	Low
12_119_505	14	177	0.982	Low
12_120_516	7	217	0.995	Low
12_125_517	15	349	0.921	Low
12_129_520	19	409	0.999	Low
12_135_7	14	333	0.995	Low
12_135_9	9	28	0.988	Low
12_137_6	8	114	0.863	High
12_141_10	16	442	0.988	Low
12_141_6	11	232	0.97	Low
12_79_502	5	26	0.655	High
28_2_100	9	40	0.938	Low
29_191_503	13	58	0.998	Low
29_206_509	20	348	0.995	Low
29_271_6	18	440	0.974	Low
29_271_7	13	302	0.978	Low
29_278_1	17	248	0.869	Low
29_278_6	10	82	0.924	Low
30_245_3	22	720	0.992	Low
30_245_4	24	565	0.999	Low
30_245_8	12	209	0.987	Low
30_245_9	29	871	0.999	Low
30_252_11	24	766	0.992	Low
30_252_13	18	454	0.992	Low
30_252_3	19	417	0.984	Low
30_252_8	24	960	0.998	Low
30_259_11	26	927	1	Low
30_259_13	26	1012	0.999	Low
30_259_7	21	239	1	Low
30_259_8	28	1078	1	Low
30_262_11	28	988	1	Low
30_262_13	25	885	0.999	Low
30_268_11	28	882	0.998	Low
30_268_13	31	1106	0.998	Low
30_268_8	18	497	0.986	Low
30_273_11	24	504	0.997	Low
30_273_13	19	372	0.999	Low
32_64	21	2270	0.985	Low
32_66	13	799	0.9	Low
32_70	15	1188	0.99	Low
32_71	5	152	0.975	Low
32_72	15	1877	0.97	Low
32_74	12	507	0.791	Low

Figure 6.16 shows the same discriminant analysis plot of Hattusha samples, colour coded by chamber number. It is apparent that some of the chamber patterning evident in the correspondence analysis, on the basis of crop/weed taxon composition, can also be seen within the discriminant analysis, based on weed functional trait values. Sample points from Chamber 30 are generally clustered together (as they were in the CA) and have the most negative scores on the discriminant function. This suggests that, of the five chambers studied, the crops stored in Chamber 30 were subject to the lowest levels of intensity/input in comparison with the rest of the Hattusha assemblage. Samples from Chamber 29 and Chamber 32 are also closely clustered together on the discriminant function, although Chamber 29 samples are located closer to the negative end of the axis, while Chamber 32 samples have slightly higher values. By comparison, samples from Chamber 12 encompass a much greater range of values and include the only two samples classified as high-intensity (although with lower probabilities when compared with rest of the assemblage).

This greater variety was also observed in the correspondence analysis (see **Figure 5.10**, **Chapter 5**), and indicates that crops from this chamber are likely to have been cultivated within a particularly wide range of growing conditions. Certainly the two samples classified as 'high-intensity' would suggest that the crops from these samples were cultivated with greater levels of intensity/input than crops from Chamber 30 and from other crops being stored within the same chamber. It is, therefore, possible that the crops stored in Chamber 12 came from a particularly diverse set of growing conditions, and that across the entire silo complex there is both inter- and intra- chamber variability in terms of agricultural intensity.

6.9 Functional weed ecology conclusions

The above evidence from weed ecological analysis has indicated that the cereals stored in the Hattusha silo were grown in permanently cultivated fields in open, steppic environments. Crops were also most likely to have been sown during the autumn to take advantage of the winter and spring rains and were harvested during July and August. Spring sowing of crops cannot, however, be completely ruled out and it is possible that some farmers may have chosen to plant more crops in the spring if the previous winter months had been particularly harsh.

The results from functional ecology have shown that the majority of Hattusha silo samples, and particularly samples from Chamber 30, can be classified as low-intensity. This indicates that these crops were grown under low-input agricultural regimes, without intensive tillage, manuring or weeding. The Hattusha samples thus correlate closely with modern weed data from low-intensity regimes in the disparate regions of Haute Provence and Morocco. In all of these cases there are major differences both geographically and climatologically; for example the study area in Haute Provence has a greater annual rainfall (c. 700-900mm/year, Bogaard *et al*. 2016a) than the Central Anatolian plateau (c. 451mm/year), which has led to the development of very different weed floras, in terms of species, in each region. However, despite geographical differences, the evident similarities between discriminant values among similar present-day agricultural regimes shows that particular agricultural practices encourage the growth of weed species with similar functional ecological attribute values. The observation that the Hattusha crops generally align with low-intensity agrosystems suggests that they derive from extensive, large-scale production geared towards the generation of surplus produce.

6.10 Comparing the results of crop stable isotope analysis and functional weed ecological analysis

Direct comparison of stable isotope results with the results of functional weed ecology on a sample-by-sample basis has previously been limited in archaeobotanical research. This is because modern studies have shown that a close correlation should only be expected when comparing *across* multiple contrasting agricultural regimes rather than within a single agrosystem (Bogaard *et al*. 2016a; 2016b). Similarly, regimes identified as low-intensity through functional ecology can still include the use of manuring and artificial watering (Bogaard *et al*. 2016b). Additionally, it has often been difficult to guarantee that identified weed/wild taxa actually originate from the same fields as the cereal grains measured for stable isotope analysis, and that both are representative of the same field conditions. The abundance of weed seeds alongside crop remains from the Hattusha silo, however, has reduced the potential for sample contamination, and weed ecological information indicates that the majority of weed/wild taxa are arable weeds of cultivation. Furthermore, the results of stable isotope analysis (**Section 6.4**) have shown that the cereals grown within each chamber were cultivated under a distinct and separate set of husbandry conditions unique to that chamber. The results from functional ecology (**Figure 6.16**) mirrored these results and showed a similar clustering of samples by chamber. In this respect it would appear that each chamber of the Hattusha silo potentially represents a distinct set of conditions that was not dependent on the species of crop being cultivated.

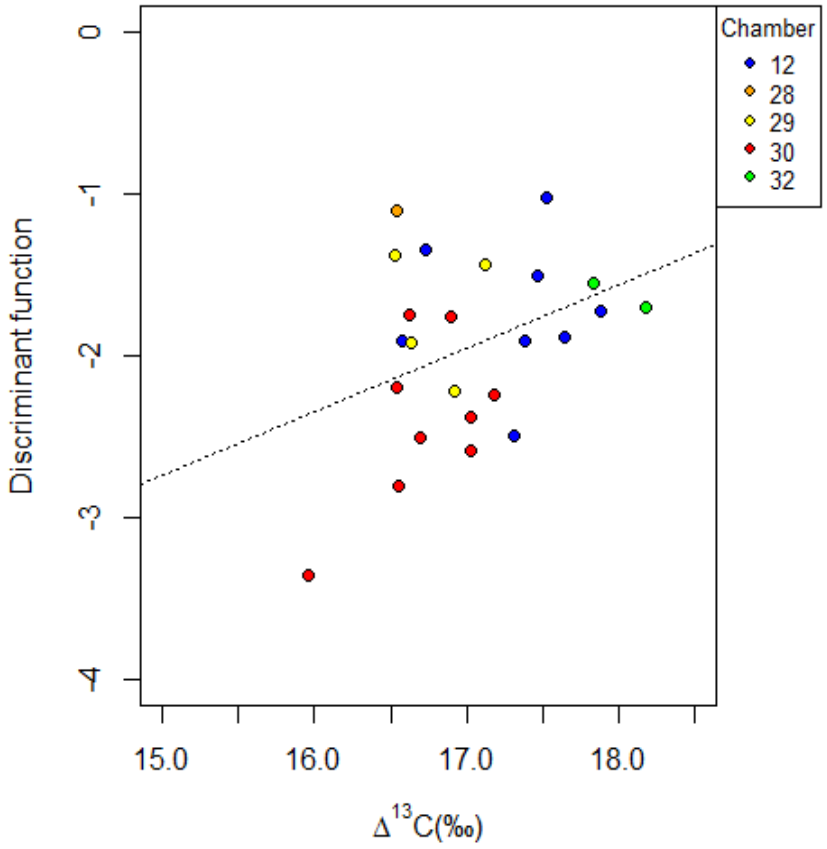
Figures 6.17a and **6.17b** and **Figures 6.18a** and **6.18b** plot the results from carbon and nitrogen stable isotope analysis against the discriminant score produced from functional ecological analysis. Results have also been separated by cereal species (hulled barley and emmer wheat) as a means of investigating possible differences

between the two crops. Plots were also coded by chamber number to assess variability on a chamber-by-chamber basis. All scatterplots show a positive correlation, indicating that samples with high stable isotope results also have high discriminant function scores. Simple linear regressions were carried out to examine this relationship between $\Delta^{13}C$, $\delta^{15}N$ and discriminant function score in more detail (see **Table 6.11**). All scatterplots, with the exception of **Figure 6.17a** (barley $\Delta^{13}C$ value and discriminant score), showed a significant relationship ($p=<0.05$ see **Table 6.11**) between stable isotope results and functional ecology discriminant score. The correlation p values between $\delta^{15}N$ values and discriminant score are statistically more significant than the equivalent correlation between $\Delta^{13}C$ values and discriminant score. This is consistent with the theory that the addition of manure to soil will improve fertility and overall productivity and that within Central Anatolia soil nutrients are likely to have been a more limiting factor than water availability for crop growth. Furthermore, the correlation between emmer stable isotope results and discriminant score appears to be stronger than the correlation between the respective barley results. This supports the theory, discussed initially with reference to crop processing (**Section 5.8**, **Chapter 5**), that the majority of identified weed species entered the Hattusha silo with the emmer wheat crop rather than with the barley.

Table 6.11 – Results of simple linear regressions carried out to examine the relationship between $\Delta^{13}C$, $\delta^{15}N$ and discriminant function.

Species	Stable isotope	Results
Barley	Carbon ($\Delta^{13}C$)	R^2=0.1008, p=0.0717
Barley	Nitrogen ($\delta^{15}N$)	R^2=0.1471, p=0.0363
Emmer	Carbon ($\Delta^{13}C$)	R^2=0.09677, p=0.0286
Emmer	Nitrogen ($\delta^{15}N$)	R^2=0.2297, p=0.0010

A



B

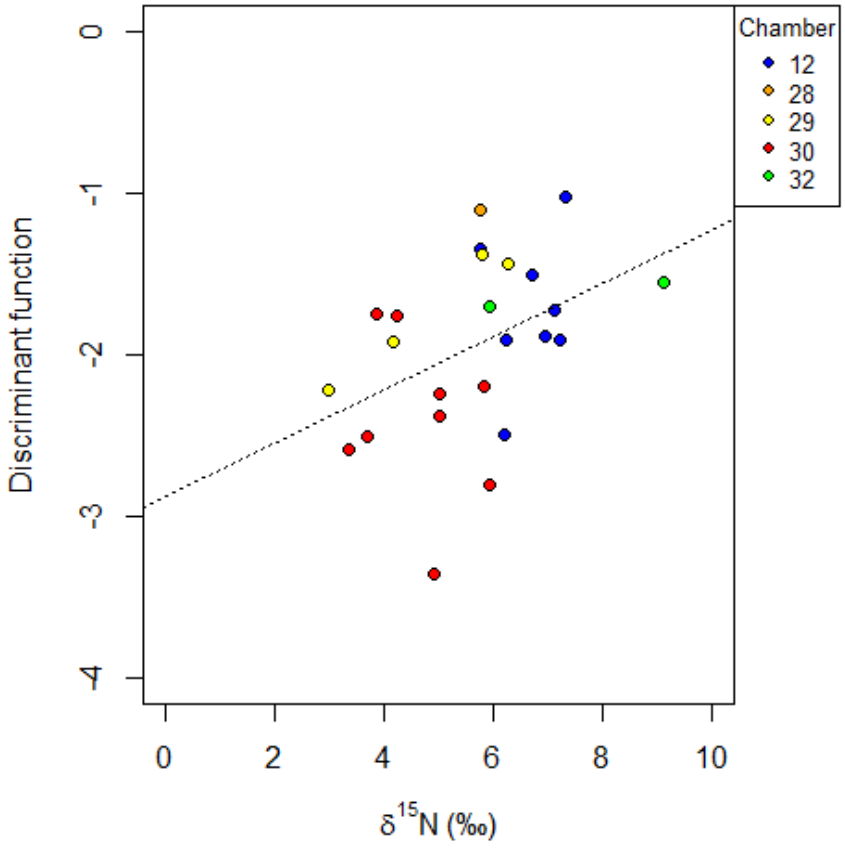
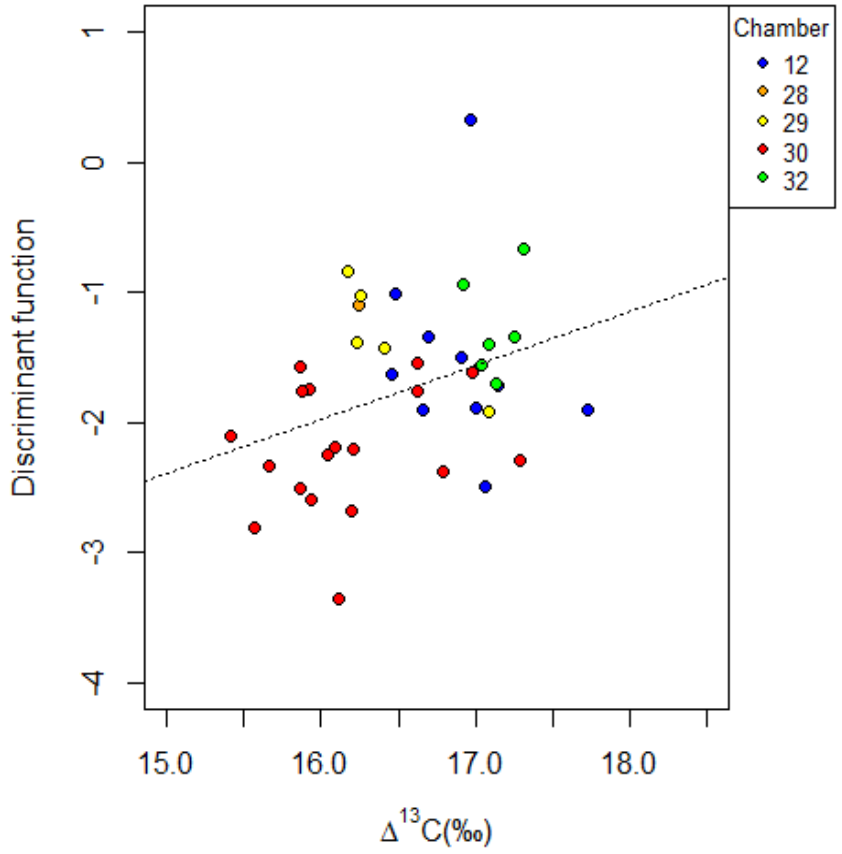


Figure 6.17a and b – Plots showing the relationship between weed discriminant function score and $\Delta^{13}C$ and $\delta^{15}N$ values for hulled barley.

A



B

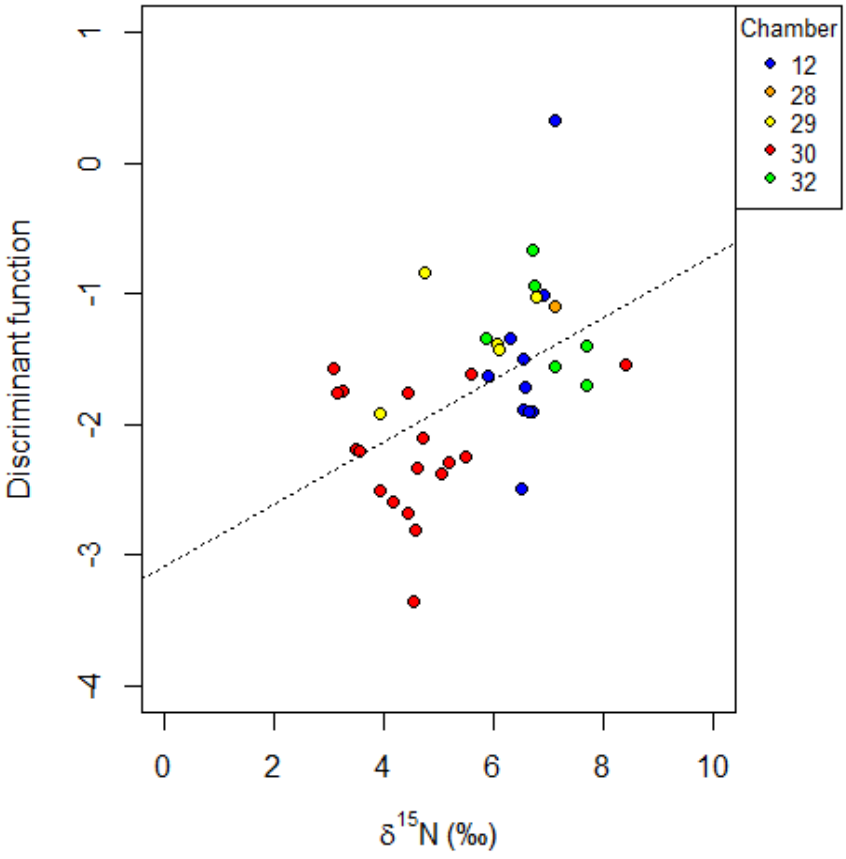


Figure 6.18a and b – Plots showing the relationship between weed discriminant function score and $\Delta^{13}C$ and $\delta^{15}N$ values for emmer wheat.

In both pairs of figures data points also cluster to some extent by chamber number. In each plot data points from Chamber 30 appear to be the most clearly separated from the others. This indicates that samples from this chamber have the lowest $\Delta^{13}C$ and $\delta^{15}N$ values and also the lowest discriminant function scores from the entire assemblage. These results reinforce the theory that cereals stored in Chamber 30 were grown under a distinctive, less intensive husbandry regime compared with the cereals stored in the other chambers. Samples from Chambers 12, 29 and 32 do also exhibit some slight clustering (most clearly in **Figures 6.18a** and **6.18b**) but not to the same extent as observed for Chamber 30. This would seem to indicate that crops stored in these chambers were cultivated under more variable growing conditions, and that the growing conditions indicated by these results were not radically different from each other. Instead, crops from each chamber were cultivated under different 'versions' of the same basic agricultural regime.

The relationship between chamber, discriminant function score and stable isotope values was investigated using multiple linear regression models with coefficients for discriminant function (DF), $\Delta^{13}C$ value, $\delta^{15}N$ value and chamber (see **Table 6.12**). These results show that chamber did not have a significant effect on discriminant function or stable isotope value. The only exception to this was the effect of chamber on the discriminant value of barley and $\delta^{15}N$ value ($p = 0.048$), which did return a significant result. This result was relatively marginal, however, so does not change the interpretation discussed above. Finally, there is no correlation between discriminant function score and crop stable isotope values *within* each chamber. This observation is reminiscent of results from modern studies completed in Morocco and Provence (Bogaard *et al*. 2016a; 2016b) where clear relationships between the two sets

of results were apparent only across contrasting regimes and not within one single agrosystem.

Table 6.12 – Results of multiple linear regression models with coefficients for discriminant function (DF), $\Delta^{13}C$ value, $\delta^{15}N$ value and chamber, by cereal taxa.

Barley	Formula		R^2	Beta	SE	t	p
	$\Delta^{13}C$ ~DF + Chamber	Constant	0.11	17.95	0.42	42.39	<0.001
		DF		0.29	0.2	1.48	0.155
		Chamber		-0.01	0.01	-1.16	0.261
	DF~$\Delta^{13}C$ + Chamber	Constant	0.1	-7.18	3.87	-1.85	0.0779
		$\Delta^{13}C$		0.33	0.22	1.48	0.1549
		Chamber		-0.01	0.01	-0.94	0.3606
	$\delta^{15}N$~DF + Chamber	Constant	0.26	9.8	1.05	8.37	<0.001
		DF		0.81	0.49	1.67	0.111
		Chamber		-0.07	0.03	-2.1	0.048
	DF~$\delta^{15}N$ + Chamber	Constant	0.12	-2.8	0.73	-3.52	0.0020
		$\delta^{15}N$		0.14	0.087	1.17	0.1114
		Chamber		-0.008	0.01	-0.52	0.6093
Emmer	$\Delta^{13}C$ ~DF + Chamber	Constant	0.15	17.47	0.32	54.11	<0.001
		DF		0.24	0.13	1.93	0.0609
		Chamber		-0.02	0.01	-1.89	0.0669
	DF~$\Delta^{13}C$ + Chamber	Constant	0.08	-7.82	3.38	-2.31	0.0262
		$\Delta^{13}C$		0.38	0.2	1.93	0.0609
		Chamber		-0.008	0.01	-0.55	0.5873
	$\delta^{15}N$~DF + Chamber	Constant	0.29	8.49	0.75	11.36	<0.001
		DF		0.94	0.29	3.23	0.0026
		Chamber		-0.05	0.02	-2.01	0.0522
	DF~$\delta^{15}N$ + Chamber	Constant	0.21	-3.03	0.62	-4.91	<0.001
		$\delta^{15}N$		0.23	0.07	3.23	0.0026
		Chamber		-0.001	0.01	-0.11	0.9099

6.11 Summary of the combined stable isotope and functional ecology results

The combined results from functional ecology and crop stable isotope analysis show that there is a significant correlation between weed ecological discriminant

function scores and cereal $\Delta^{13}C$ and $\delta^{15}N$ values. In this respect samples with the lowest discriminant scores, indicating low-intensity agriculture, also have the lowest $\Delta^{13}C$ and $\delta^{15}N$ values, indicating relatively low inputs of water and manure. This close correlation between samples, however, only occurs *among* the different chambers rather than within individual chambers. These results are analogous with modern results from Morocco and Provence where a correlation between weed ecological traits and stable isotope values was only found *across* contrasting regimes rather than within a homogenous agrosystem (Bogaard *et al*. 2016a; 2016b). In this perspective, it appears plausible that the crops within the different chambers from the Hattusha silo represent the produce of five distinct agricultural regimes, rather than the use of different agricultural locations or years within a homogeneous system. To this end, it is likely that the produce from each chamber was grown within a different location/agricultural community inside the rural hinterland of Hattusha (this will be discussed further in **Chapter 9**). The results of the multiple linear regressions, however, would suggest that chamber does not have a significant effect on discriminant score or stable isotope values. The crops from each chamber, therefore, were unlikely to have been grown under radically different conditions, but rather utilizing variations of the same basic agricultural approach.

Chapter 7

Archaeobotanical results from Tell Brak

7.1 Overview of samples

The Tell Brak assemblage is comprised of 58 samples taken from 11 different rooms or spaces from destruction level 11 within the TC oval building (**Table 4.2** and **Figure 2.7** for a plan of the TC oval building). These 58 samples were selected from the original 85 samples recovered from the TC oval building as they were representative of all excavated rooms and also due to their visible 'richness' in plant remains. The number of samples per room varies radically as additional samples were taken where charred plant material was visible within the archaeological matrix upon excavation. Rooms 12 and 16, therefore, are represented by multiple samples as these areas contained visibly dense concentrations of charred plant material. Room 16 in particular was found to contain large visible quantities of charred material and is the best represented room with 27 samples. Additionally, a number of samples from Room 16 were excavated on a grid system containing ten samples arranged in two rows of five to best capture any variability in plant remains within this room. By contrast, Rooms 4, 6, 13 and 18 are only represented by one archaeobotanical sample and the preservation of this material is generally poor.

The differing levels of charred plant preservation between the rooms in the TC oval may be indicative of where the fire was hottest. Certainly the rooms containing the

best preserved material (indicative of charring at a lower temperature with reduced oxygen levels) appear to be in the middle of the structure whilst those with the worst preservation are located at the edges of the structure (Emberling & McDonald, 2001). Overall, the density of plant remains was very high across the entire assemblage. Average plant item/litre of soil floated was 6276.1 and the range was 48.46 – 90,557.3 plant item/litre. Such high concentrations of charred plant remains are to be expected in storage contexts, where large quantities of processed crops are kept within a single room or structure. There were, however, five samples without a recorded soil volume for which plant item density could not be calculated. It would seem likely, based on the densities present within the rest of the assemblage, that these samples would have an equally high plant item/litre of soil values.

Figure 7.1 summarizes the proportions of major archaeobotanical categories identified within the TC oval building sorted to emphasize the contrast between those samples dominated by cereal grains, on the one hand, and those dominated by weed/wild taxa, on the other. Cereal grains are by far the most dominant component of the assemblage with 49 of the 58 samples containing over 50% cereal grain, and 41 samples containing over 90% cereal grain. All samples, however, contain a mixture of cereal grains, cereal chaff, pulses and weed/wild taxa but the respective percentages of cereal chaff, pulses and weed/wild taxa are all relatively low. The maximum cereal chaff contained in one sample was 12.5%, but in general the percentage of cereal chaff ranged from between 1-5% of each individual sample and a number of samples contained no cereal chaff at all. Weed/wild percentages were higher, with nine samples containing over 40% weed/wild taxa and one sample containing 79%. As with cereal chaff percentages, however, most samples contained a much smaller percentage of weed/wild taxa, ranging generally from 5-10%. Pulses were very poorly represented

throughout the assemblage; the maximum percentage of pulse remains contained in one sample was 5.3% but generally most samples contained less than 1% of these taxa. The very high proportions of cereal grain recovered throughout the TC oval building are what would be expected from a grain storage facility. The very low proportions of cereal chaff and weed/wild taxa indicate that the cereal crops from Tell Brak may have been through several stages of crop processing before storage, perhaps because these cereals were destined for human consumption rather than animal fodder. Specific crop processing analysis will be carried out below (**Section 7.10**) to explore these hypotheses in greater detail.

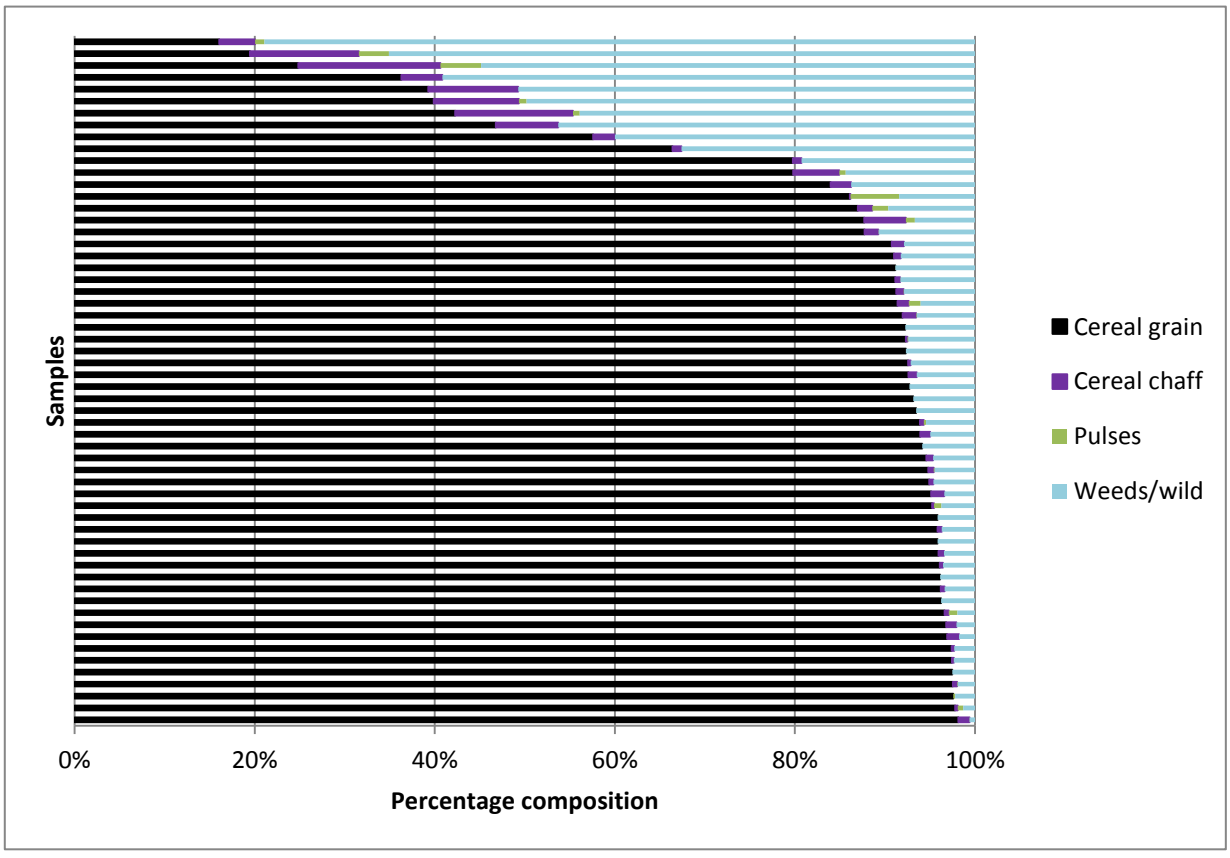


Figure 7.1 - Percentage stacked bar chart of all samples from Tell Brak showing the proportions of the four major categories of plant remains.

7.2 Overview of the assemblage

Figure 7.2 shows samples arranged by room number; pulses have also been removed from this plot as although they were present in multiple rooms, these taxa contribute little to the overall assemblage composition. Only Rooms 8, 12, 16, 17 and the North Courtyard (Ncy) have been included in this figure as they contained three or more samples. Again, the data have been ordered to emphasize the contrast between cereal grain-dominated samples and weed/wild-dominated samples. With the samples arranged by room, it becomes clear that there is a spatial element to sample composition and that different spaces within the TC oval building were potentially being used for different purposes. For example, it appears that samples from Room 8 and Room 16 are generally dominated by cereal grain. Indeed, all samples from these rooms, with the exception of one from Room 16, contain over 90% cereal grain. This suggests that these rooms were primarily used for the storage of clean, processed crops before the distribution of these grains as workers rations or final food preparation.

By contrast, Rooms 12 and the North Courtyard appear to have a more mixed composition, with generally higher proportions of cereal chaff and weed/wild taxa. This is most apparent in the samples from the North Courtyard, which contained the highest percentages of weed/wild taxa and possibly indicates the use of this space as a processing area. Room 12 has the most variable composition, however, with seven samples containing over 90% cereal grain and three samples containing over 40% weed/wild taxa. Again, this composition may suggest that this room was used for a number of different activities including grain storage and crop processing. These patterns will be explored further below through spatial composition analysis (**Section 7.8**) and crop processing analysis (**Section 7.10**).

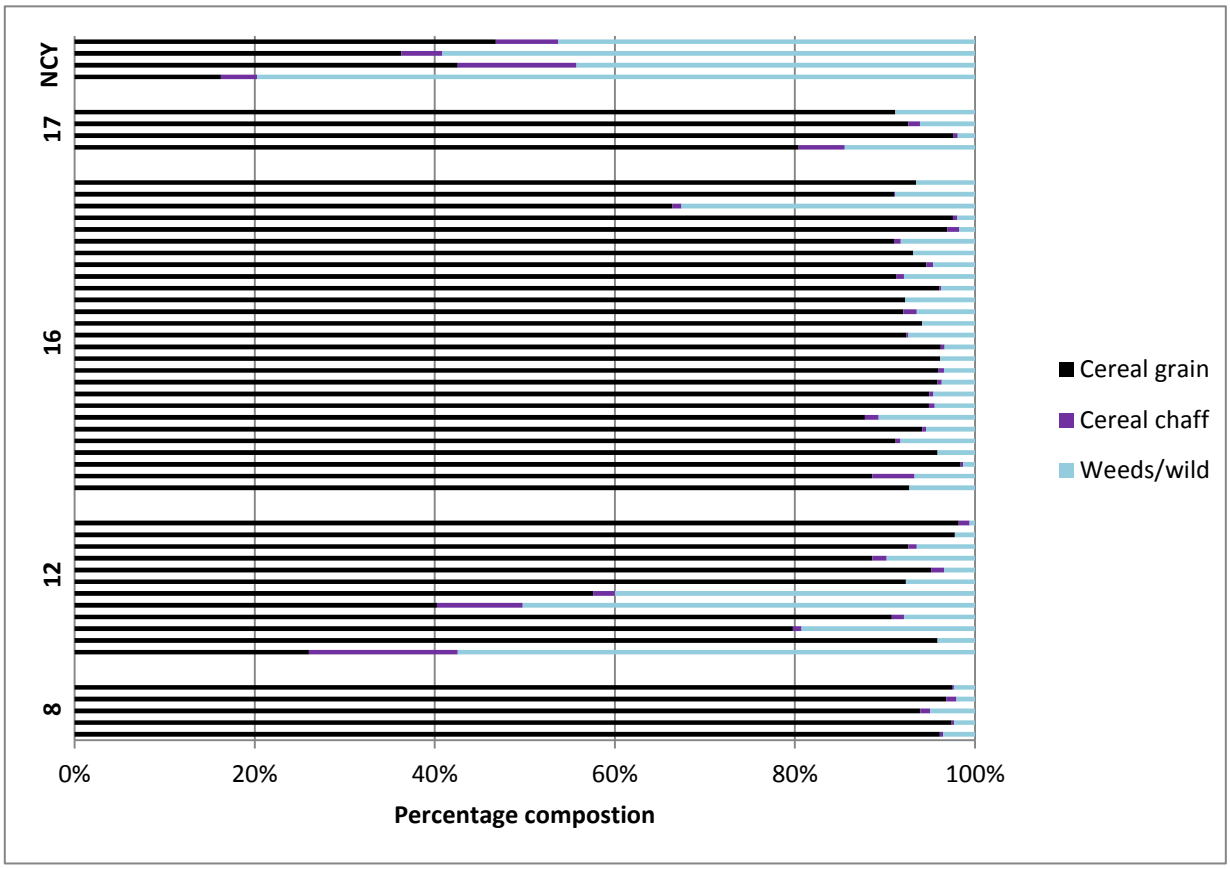


Figure 7.2 – Percentage stacked bar chart of all samples, classified by major plant remains and arrange by room number.

Thirty-three samples also contained small amounts of charcoal (>2mm fragments), recorded in millilitres. The highest volumes recorded from the assemblage were 29ml and 48ml, respectively, in two samples from Room 12. By contrast, the majority of samples only contained trace amounts of charcoal of 1-2ml. The interpretation of these varying amounts of charcoal is problematic, however, as the charcoal volumes from the 25 samples identified as part of the preliminary study undertaken by Mette Marie Hald (see **Section 2.6**, **Chapter 2**) were only recorded as presence/absence data (Emberling & McDonald, 2001). Overall, it does appear that charcoal was present within the majority of samples (only 20 samples contained no charcoal at all), but beyond this no room specific patterning emerges from the data.

7.3 Major crops

The major crops identified from the TC oval building are 2-row hulled barley, which was identified in 58/58 (100%) of samples studied, glume wheats (emmer wheat and einkorn wheat), which occurred in 32/58 (55%) and 13/58 (22%) of samples, respectively, and free-threshing wheat, which occurred in 22/58 (38%) of samples (see **Figure 7.3** and **Table 7.1**). There was also a small amount of pulse material, lentil and *Lathyrus sativus* being the most commonly identified, occurring in 12/58 (21%) and 7/58 (12%) of samples, respectively, although only in very small quantities (see **Table 7.1**). Overall, it appears that the TC oval building was primarily used for cereal crop storage. Further spatial analysis of crop distribution within the TC oval building will take place in **Section 7.8** (below).

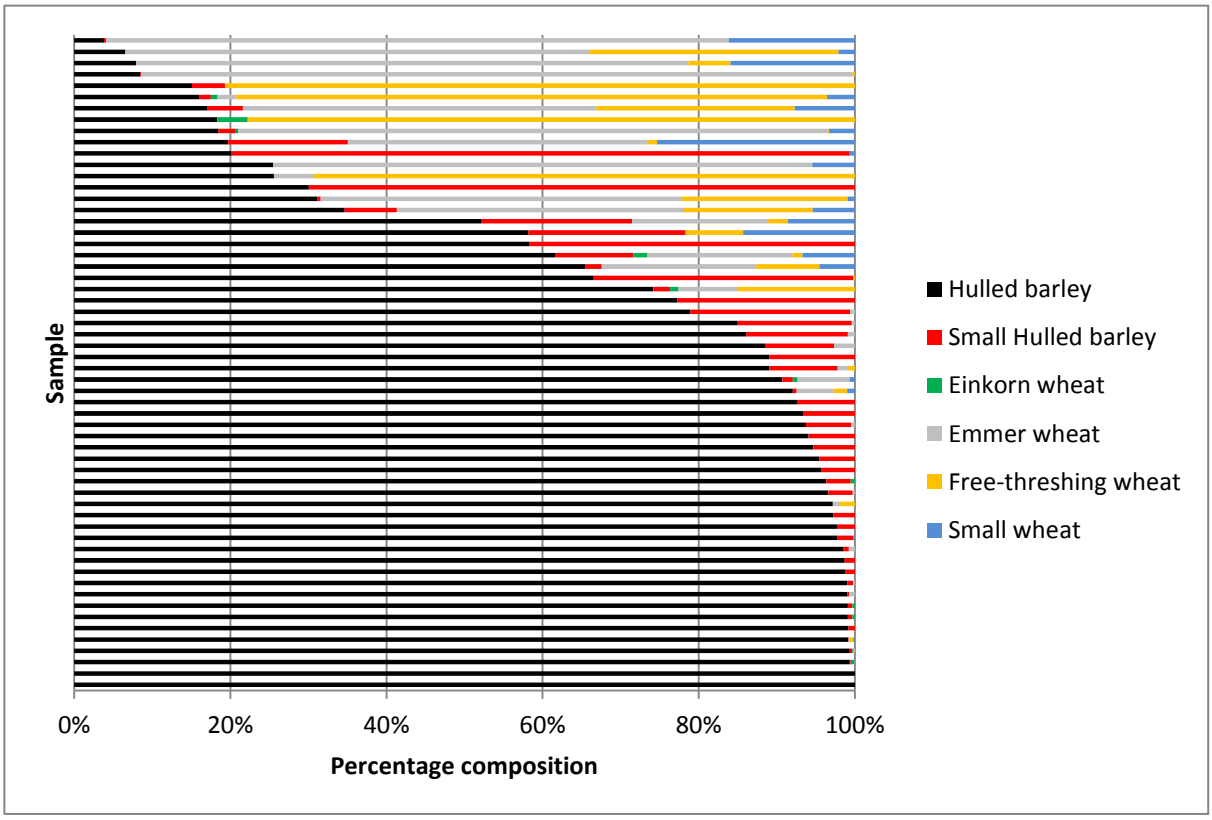


Figure 7.3 – Percentage stacked bar chart of all samples showing major crop proportions.

Table 7.1 – Summary of the frequency and abundance of major plant taxa.

Plant item	Presence	Ubiquity (%)	Max/sample	Sum
Cereal grains				
Straight hulled barley	58	100	193280	563629
Small hulled barley	50	86	33024	47914
Glume wheat Total	37	64	7579	29014
Einkorn wheat	13	22	256	732
Emmer wheat	32	55	7579	28266
Free-threshing wheat	22	38	3432	11136
Small wheat	20	34	1112	4860
Wheat indet.	7	12	24	66
Chaff				
Emmer wheat glume base	15	26	768	2128
Einkorn wheat glume base	6	10	132	256
Glume base indet.	22	38	384	1117
Free-threshing wheat rachis	5	9	256	310
Hulled barley rachis	16	28	768	1242
Culm Nodes Total	21	36	128	376
Pulses				
Lens culinaris	12	21	128	278
Pisum sativum	2	3	8	9
Lathyrus sativus	7	12	12	31
Vicia ervilia	1	2	1	1
Vicia/lathyrus type	6	10	256	294
Large pulse indet.	12	21	20	90
Weeds				
Weed/wild chaff Total	54	93	18588	35317
Weed/wild Total	58	100	2048	17786

7.3.1 Hulled barley

Hulled barley was only represented in the assemblage by morphologically straight grains, leading to the inference that only 2-row barley was being stored in the TC oval building, with no evidence of the 6-row variety. Supporting this inference is the

observation that all hulled barley rachis identified (present in 16/58; 28% of samples) was of the 2-row type. Hulled barley was by far the most dominant component of the entire assemblage, totalling 563,629 grains and with 100% ubiquity. **Figure 7.3** also shows that the number of samples composed primarily of hulled barley grain far outweighs the proportions of all other species of cereal put together. This would indicate that at least part of the TC oval building was likely to have been a dedicated hulled barley grain store, but this patterning will be explored further below in spatial composition analysis (see **Section 7.8**)

7.3.2 Glume wheats

The glume wheats are represented by two different species, emmer wheat (*Triticum dicoccum*) and einkorn wheat (*Triticum monococcum*). By comparison with hulled barley, however, both appear in much smaller proportions within the TC oval assemblage (see **Table 7.1**). Emmer wheat grain is the most commonly identified species of the two, totalling 28,266 grains and with 55% (32/58 of samples) ubiquity. By contrast, einkorn wheat grain was far less frequently identified, with only 732 grains and a ubiquity of 22% (13/58 of samples). This becomes particularly apparent from **Figure 7.3** where einkorn wheat grain seems barely visible. A similar ratio between the two species was also observed in terms of identified glume bases. Emmer wheat chaff was identified in 15/58 (26%) of samples whilst einkorn wheat chaff was only present in 6/58 (10%) of samples. These discrepancies in quantity between the two glume wheats suggest that emmer was by far the most predominant glume wheat crop stored within the TC oval building. Additionally, the very low quantities of einkorn wheat grain and chaff identified may indicate that this species was in fact a contaminant of the

emmer wheat harvest rather than having been grown as a separate crop for storage in the TC oval building.

7.3.3 Free-threshing wheat

The final cereal crop from the TC oval assemblage is a free-threshing wheat species (*Triticum aestivum/durum*). Although this species was identified in much lower numbers than emmer wheat grain (see **Table 7.1)**, with a total number of 11,136 free-threshing wheat grains and a ubiquity of 38% (22/58 of samples), this species still appear to be a purposefully stored crop rather than a crop contaminant. Additionally, it appears from **Figure 7.3** that even though free-threshing wheat has a relatively low ubiquity, when it was identified it could be a dominant component of that particular sample. For example, four samples contained over 65% free-threshing wheat grain potentially indicating that this was a dedicated store of this species. Free-threshing wheat rachis was identified in much lower quantities with a ubiquity of only 9% (5/58 of samples). This is to be expected with free-threshing wheat chaff, however, as this would most likely have been removed during the winnowing process (Jones, 1984a), or destroyed during the charring process (Boardman & Jones, 1990; Charles *et al*. 2015).

7.3.4 Small cereal grain varieties

Throughout the Tell Brak TC oval assemblage many conspicuously small wheat and barley grains were identified (see **Figure 7.3** and **Table 7.1**). Small hulled barley grains were observed in 50/58 (86%) of samples, whilst small wheat grains occurred in 20/58 (34%) of samples. These grains ranged from 1.5-0.5mm in length, when

compared with other 'normal' cereal grains from the TC oval assemblage which ranged from 4.5-3mm in length (see **Figure 7.4**). Morphologically, this grain size distribution was bimodal and the smaller grains clearly belonged to domesticated *Hordeum vulgare* sp. and *Triticum* sp. rather than a smaller wild species.

Figure 7.4 – Photos of the 'normal' and small hulled barley grain variety (left) and 'normal' and small wheat grain variety (right).

One hypothesis was that these smaller grains could represent the 'tail' grains commonly found in the distal florets of the cereal ear (Hillman, 1981). These smaller grains develop due to the process of floret growth within the ear. Glume primordia are initiated first, followed by the florets, after which spikelet growth decreases (Kirby & Appleyard, 1987). This leads to a gradient of floret development within the ear, with the most mature florets occurring at the base and in the middle of the ear, whilst the top florets tend to be underdeveloped. Grains developing in these top florets, therefore, tend to be smaller than grains from the lower and middle florets and in some cases a grain does not develop at all (Percival, 1921). This patterning of cereal grain growth can also

be exaggerated by unfavourable crop growing conditions, particularly arid conditions or periods of drought, leaving the lowest and top-most spikelets potentially devoid of fertile florets (Kirby, 2002). Considering the semi-arid nature of the Tell Brak climate and the low average annual rainfall in this region, therefore, the presence of 'tail' grains within the TC oval assemblage would not be implausible.

The sheer number of small cereal grains identified within the TC oval assemblage, however, is more than would be expected if all of these grains were 'tail' grains.[16] This is especially the case due to the fact that the TC oval samples represent storage deposits within a building and, therefore, have gone through some phases of crop processing. This will be discussed in greater detail below, but activities such as the use of sieves to remove weed seeds would also be expected to remove these smaller 'tail' grains suggesting that the probability of finding such a quantity of 'tail' grains would be very low (Hillman, 1981; Wilcox, 2004). Additionally, if the Tell Brak TC oval assemblage is compared with the stored cereals from the Hattusha assemblage, the lack of 'tail' grains identified from the underground silo, suggests that the high number of small grains from Tell Brak is distinctive.

A second hypothesis was that these smaller cereal grains may represent the cultivation of a distinct *variety* or landrace of small-grained domesticated wheat and hulled barley at Tell Brak. These varieties may have developed specifically to tolerate arid conditions and could potentially have been grown in less well-watered locations to maximise the use marginal farming regions/areas at Tell Brak. The classification of these small cereal grains will be explored in much greater detail below. Crop processing analysis will be used to indicate whether these small grains could be 'tail' grain from

[16] Small barley grain accounts for 8% of all identified hulled barley grain and small glume wheat grain accounts for 14% of all identified emmer wheat grain.

the normal crop (see **Section 7.10**) and crop stable isotope analysis will be used to assess whether these small grains may constitute a distinct cereal landrace (see **Section 8.1**, **Chapter 8**).

7.4 Other cultivated crops and collected plants

Aside from the major cereal crops a number of pulse crops were also identified within the TC oval assemblage (see **Table 7.1**). The ubiquities and total numbers of these species were significantly lower, however, and it appears unlikely that any were purposefully being stored within the building. The most commonly identified pulse was lentil (*Lens culinaris*) with a ubiquity of 21% (12/58 of samples) and a total count of 128 items. This species has been found in greater abundance in other areas of the site from the Late Early Dynastic III period (Charles & Bogaard, 2001), suggesting that lentil was being cultivated within the Tell Brak environs at this time. Its presence within the TC oval assemblage, therefore, could be due to contamination either in the fields or after the harvest in the city itself. Other pulse species were found in much lower proportions. For example, common pea (*Pisum sativum*) and grass pea (*Lathyrus sativus*) were found in only 2/58 (3%) of samples and 7/58 (12%) of samples, respectively. This would suggest that these species were also crop contaminants within the arable fields and were not being purposefully stored within the TC oval building. The low ubiquities of these pulses does not necessarily mean, however, that these species can be discounted as cultivated crops as they may well have been being cultivated for the domestic household in smaller garden plots, or in other areas of the city (Charles & Bogaard, 2001).

There was also a small amount of collected fruit/nut material present within the assemblage. These included grape seeds (*Vitis* sp.), pistachio (*Pistachio lentiscus* L.), almond (*Amygdalus* sp.), some fragments of fruit skin and fruit flesh/bread remains. All of these species have been found in other 4th millennium BC levels of the Tell Brak mound (Hald, 2005; 2008) and could potentially have been gathered for a number of purposes including human and animal consumption. The number of remains identified (all species had a ubiquity of under 10%; 6/58 of samples) within the TC oval assemblage, however, suggests that they were not being purposefully stored inside this building and entered the archaeobotanical record as minor contaminants of the cereal crops.

7.5 Weed/wild taxa

Figure 7.1 makes clear that weed/wild taxa were not a major component of the TC oval assemblage. Although weed/wild remains were identified within every sample (see **Table 7.1**) the actual numbers of weed/wild items were quite low, especially in comparison to the number of identified cereal grains. In total, 50 taxa, identified from type- to species level, were present within the TC oval building samples, but only 17 were found in more than 10% of samples (see **Table 7.2** for a list of the most common taxa). The most frequently identified remains were those of the wild grasses, particularly three species of *Aegilops* (*A. crassa* Boiss., *A. speltoides* Taush. and *A. tauschii* Coss.) and *Lolium* cf. *rigidum* Gaud. These species are all common arable weeds from cultivated fields and disturbed habitats (Guest, 1966) and are likely to have been found within the environs of Tell Brak. Additionally, the *Aegilops* species are known as crop mimics (Barrett, 1983; Anderson, 2006) and are very difficult to remove

from the crop either in the field or during post-harvest crop processing due to their appearance and size imitating that of domesticated barley and wheat grains. Further discussion of these weed/wild taxa will take place later in this chapter with reference to crop processing (see **Section 7.10**) and in **Chapter 8** through the use of functional weed ecology (see **Section 8.8**).

Table 7.2 – Summary of the frequency and abundance of major weed/wild taxa.

Weed/wild taxa	Presence	Ubiquity (%)	Max/sample	Sum
Aegilops crassa	38	66	538	1945
Aegilops speltoides	24	41	768	1216
Aegilops tauschii	28	48	397	1359
Gypsophila cf. pilosa	17	29	160	784
Lolium cf. rigidum	33	57	256	1222
Sinapis cf. arvensis	14	24	1200	2780
Vaccaria pyramidata	20	34	512	1232

7.6 Other

Fragments of sheep/goat dung pellets were identified in 2/58 (3%) of samples within the TC oval assemblage and were only present in very low volumes (>1.5ml). Whole dung pellets have been identified in slightly higher concentrations within other areas and levels of Tell Brak (Charles & Bogaard, 2001; Hald, 2005) indicating that dung may have been intentionally collected by inhabitants. The lack of dung remains from the TC oval, however, suggests that this resource was not stored within this building. Moreover, the crops identified within this structure appear to have been processed and purposefully stored, indicating that any weed/wild taxa are likely to have derived from harvested arable fields rather than having been brought to the site in dung pellets or dung cakes.

7.7 Exploratory analysis of sample composition

7.7.1 Correspondence analysis

Variation within the TC oval assemblage was investigated using correspondence analysis to explore similarities and differences amongst individual samples (see **Section 4.5.1**, **Chapter 4** for a detailed methodology). The following sets of analyses include those based on crops only, crop and weed/wild taxa and weed/wild taxa only. Correspondence analysis was carried out on all 58 samples and on all species which were present in five or more samples (i.e. had a ubiquity of 9% or more). This threshold was chosen to reduce the imbalance of species and sample numbers leading to greater statistical reliability (Ter Braak & Smilauer, 2012) and to remove all outlier species which would skew the analysis towards these taxa. Similarly, for analyses based on only weed/wild taxa, a minimum presence of five taxa was used and only samples that contained over 10 weed/wild items were included in the analysis. This led to the exclusion of one sample (sample 10 from Room 6). All taxon codes for correspondence analysis are explained in **Table 12.5**, **Appendix.**

7.7.1.1 Variation in crop composition

Correspondence analysis was initially carried out on cereal grains and chaff only, as a means of assessing the amount of species mixing that may have taken place inside the TC oval building. **Figure 7.5** is a scatterplot of the 11 major cereal crop remains. The most notable trends are that 2-row hulled barley grain and small hulled barley grain are located very close together on the origin of the plot. This reflects the ubiquity of these grains throughout the assemblage. By contrast, emmer wheat grains

and small wheat grain are separated from hulled barley grain, located towards the positive end of axis 1 and the negative end of axis 2. The position of small wheat grain on the negative end of axis 2 and adjacent to emmer wheat grain suggests that these smaller grains are likely to be a form of glume wheat rather than a free-threshing wheat, with the latter category pulling out towards the positive ends of both axes and being divided from the grain of all other major crop species. Additionally, the location of indeterminate wheat grain and indeterminate glume bases together at the positive end of both axes may denote a number of less well preserved samples either due to higher charring temperatures or taphonomic issues.

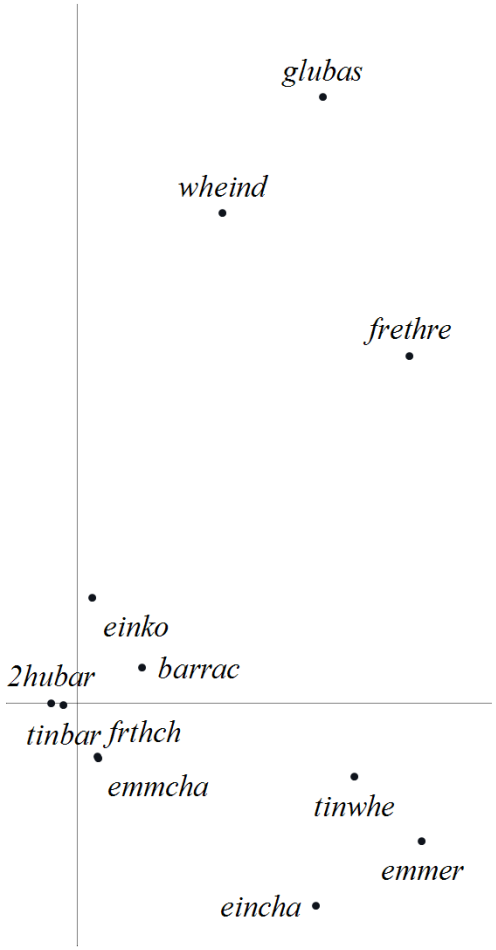


Figure 7.5 – CA Scatterplot of the 11 major cereal crop remains.

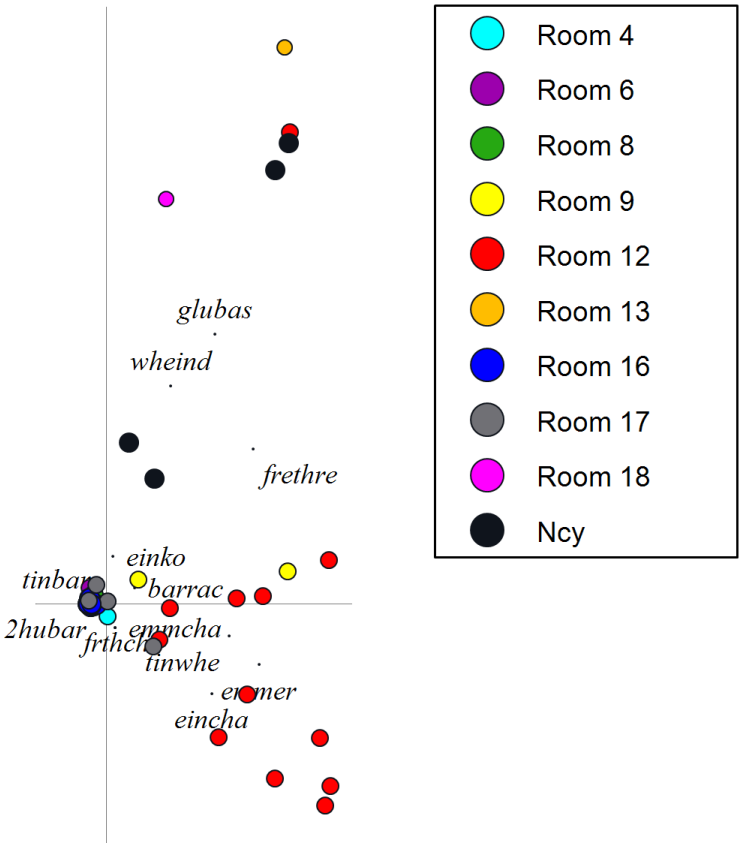


Figure 7.6 – CA plot of 58 samples and 11 taxa, coded by room number.

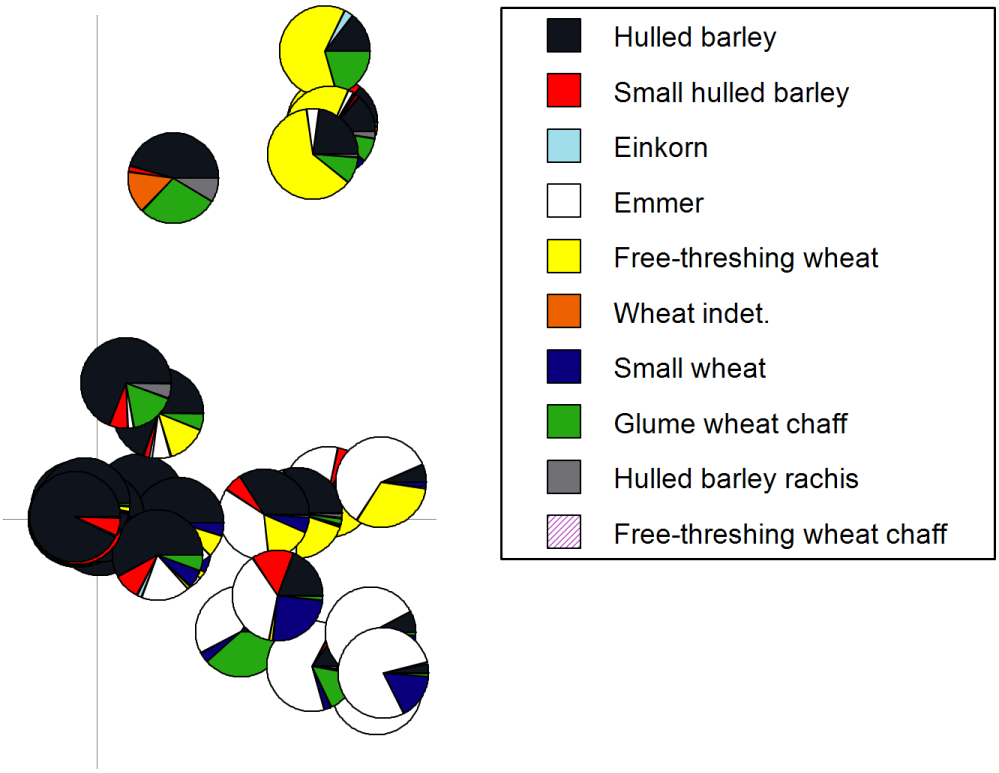


Figure 7.7 - CA plot of 58 samples with samples represented as pie charts showing proportions of major crop categories.

Figure 7.6 is a biplot showing all 58 samples, coded by room number, and the 11 major cereal crop categories. From this plot there appears to be significant compositional differences among the different rooms in the TC oval. The most obvious differences are between Room 12, located predominantly towards the positive end of axis 1 and the negative end of axis 2 and Rooms 4, 8, 16 and 17 located at the origin. The data points from the other rooms are more widely scattered, particularly towards the positive end of axis 2, but due to the low number of samples from each of these rooms inter- and intra-room variation is difficult to assess here. When comparing **Figure 7.6** with **Figure 7.7**, which shows the same analysis but with each sample displayed as a compositional pie-chart, it is clear that Rooms 16 and 17 samples are dominated almost entirely by hulled barley grain. By contrast, Room 12 has a more varied composition with some samples containing large proportions of glume wheat chaff, free-threshing wheat grain and small wheat grain. The majority of Room 12 samples, however, are dominated by emmer wheat grain, indicating a clear divide between a store of hulled barley grain in Rooms 8, 16 and 17 and a store primarily of glume wheat grain in Room 12. Moreover, samples containing principally free-threshing wheat are clearly divided from the rest of the assemblage at the positive end of axis 2. Further exploration of room composition will be continued below (see **Section 7.8**) with regard to specific spatial disparities between and within each room.

7.7.1.2 Variation in crop and weed/wild taxon composition

A correspondence analysis was carried out as a means of exploring the relationships among cereal crops and their associated weed/wild taxa. CA was conducted on all samples (58 samples) and all plant taxa present in over five samples

(41 taxa). **Figure 7.8** is a scatterplot of species and shows three discrete groups of plant taxa remains. Firstly, there is a cloud of species around the origin which includes hulled barley grain and small hulled barley grain alongside some of the most common weed species (e.g. *A. crassa*, *A. speltoides* and *A. tauschii*, *Lolium rigidum* and *Vaccaria pyramidata*), demonstrating their ubiquity throughout the assemblage. Secondly, there are a number of taxa located towards the positive ends of both axes (e.g. *Gypsophila* cf. *pilosa* Huds., *Sinapis* cf. *arvensis* L. and small-seeded legumes). These weed/wild species seem particularly associated with samples dominated by free-threshing wheat grain and suggest that the composition of these units is significantly different from those dominated by hulled barley. Finally, emmer wheat and small wheat grain are located towards the positive end of axis 1 and the negative end of axis 2, without an accompanying group of specific weed/wild taxa.

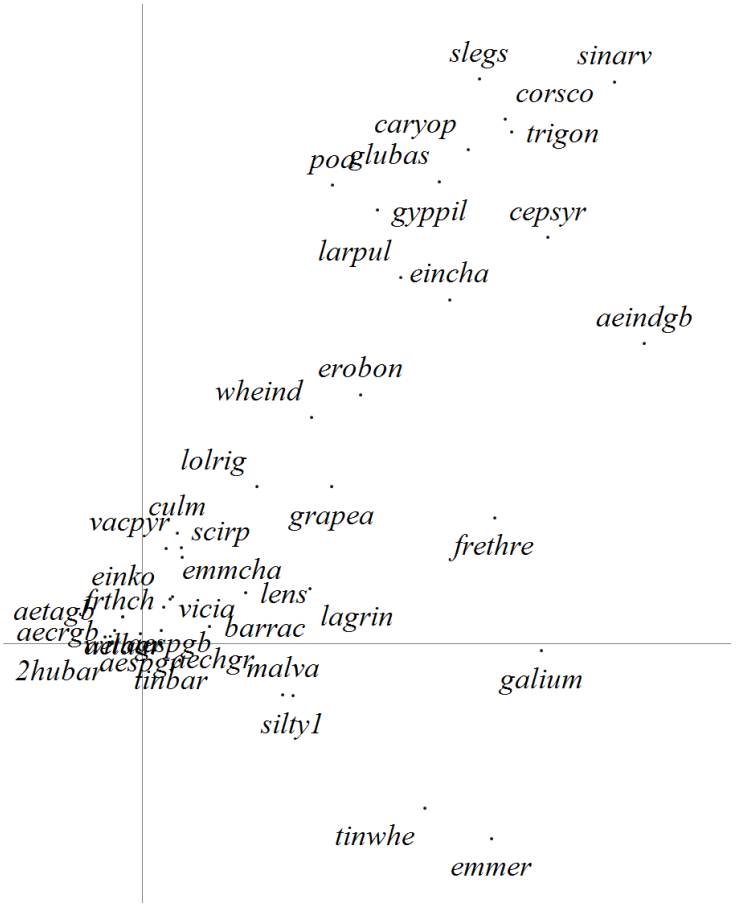


Figure 7.8 – CA scatterplot of 41 taxa.

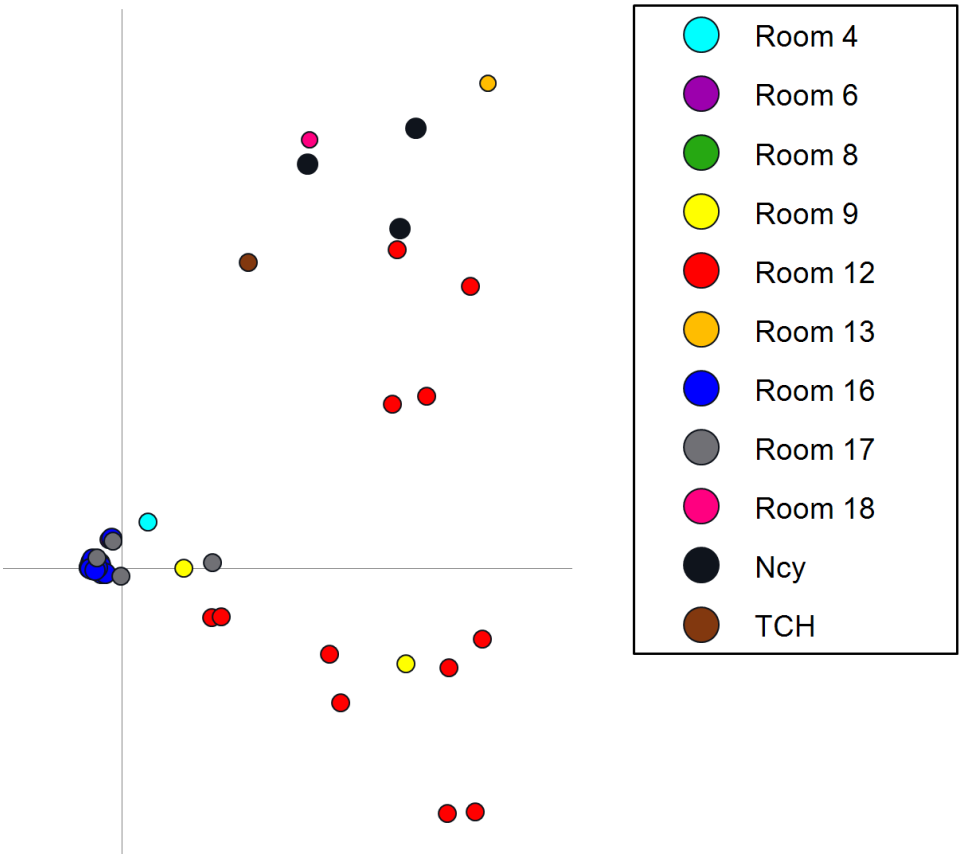


Figure 7.9 – CA plot of 58 samples and 41 taxa, coded by room number.

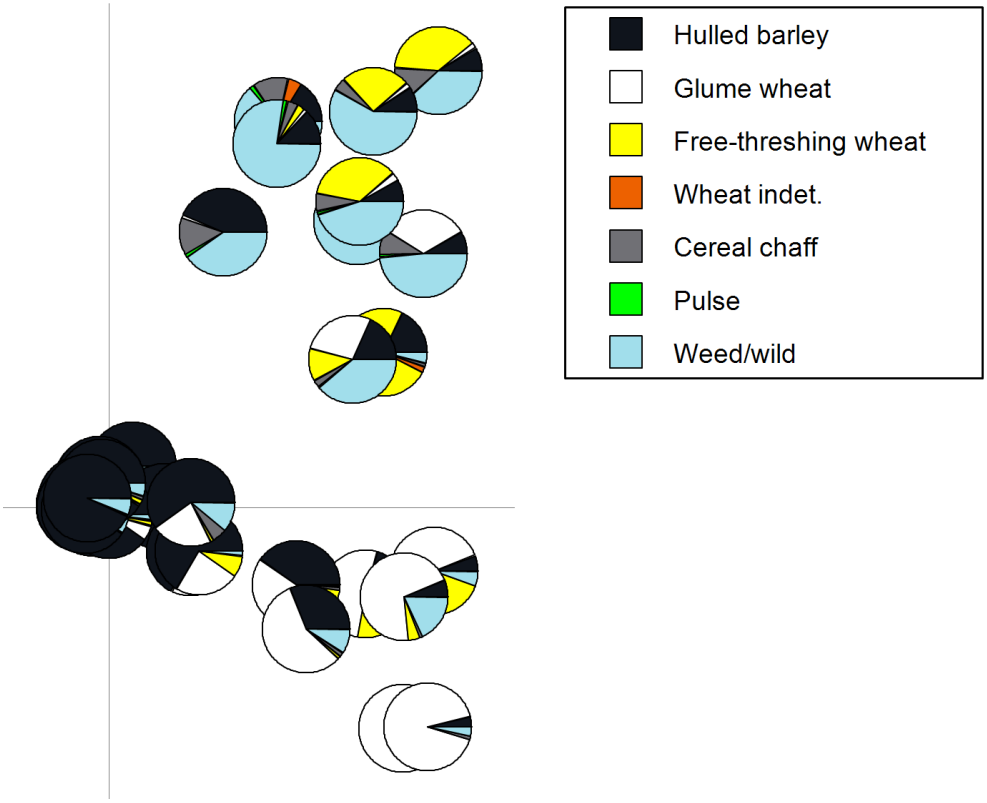


Figure 7.10 – CA plot of 58 samples with samples represented as pie charts showing the proportions of major plant item categories.

Figure 7.9 shows the sample scatterplot, coded by room number. As observed in the crop-only analysis, samples from Rooms 16 and 17 are clustered towards the origin of the graph, along with the samples from Rooms 4, 6 and 8. Samples from Rooms 13, 18 and the North Courtyard are located towards the positive ends of both axes, indicating a more varied composition. By contrast with the crop only analysis (**Figure 7.6**), however, samples from Room 12 have a wider distribution, with points located all along axis 2. This suggests that there are two separate groupings of samples within Room 12. Group 1, located towards the negative end of axis 2, are dominated by glume wheat grains whereas group 2, located on the positive side of axis 1, have a more varied composition with higher quantities of free-threshing wheat grain and weed/wild taxa.

These patterns are made even clearer by **Figure 7.10**, which shows the same analysis with samples displayed as compositional pie charts. This plot makes very clear the distinction between samples dominated by hulled barley grain, samples dominated by glume wheat grain and finally samples with a more variable composition of weed/wild taxa and free-threshing wheat. Moreover, it would appear that this group of more variable samples also contains the widest range of identified species. **Figure 7.11** demonstrates that the first two groupings, of hulled barley and glume wheat-dominated samples (those clustering around the origin and bottom right of plot respectively), contain about 10-15 identified taxa of plant remains each. By contrast, samples from the third more variable group, to the top right of the plot, contain around 20-28 species. These differences in terms of cereal grain species and associated weed/wild species composition may indicate that each crop was grown under unique husbandry conditions and that the inhabitants of Tell Brak were actively choosing to use a variety of farming strategies. Additionally, it may point towards the occurrence of different processing activities taking place within the TC oval building. These hypotheses will be explored

in further detail below with regard to crop processing stages (see **Section 7.10**), crop stable isotope analysis and functional ecological analysis of arable weed taxa (see **Chapter 8**).

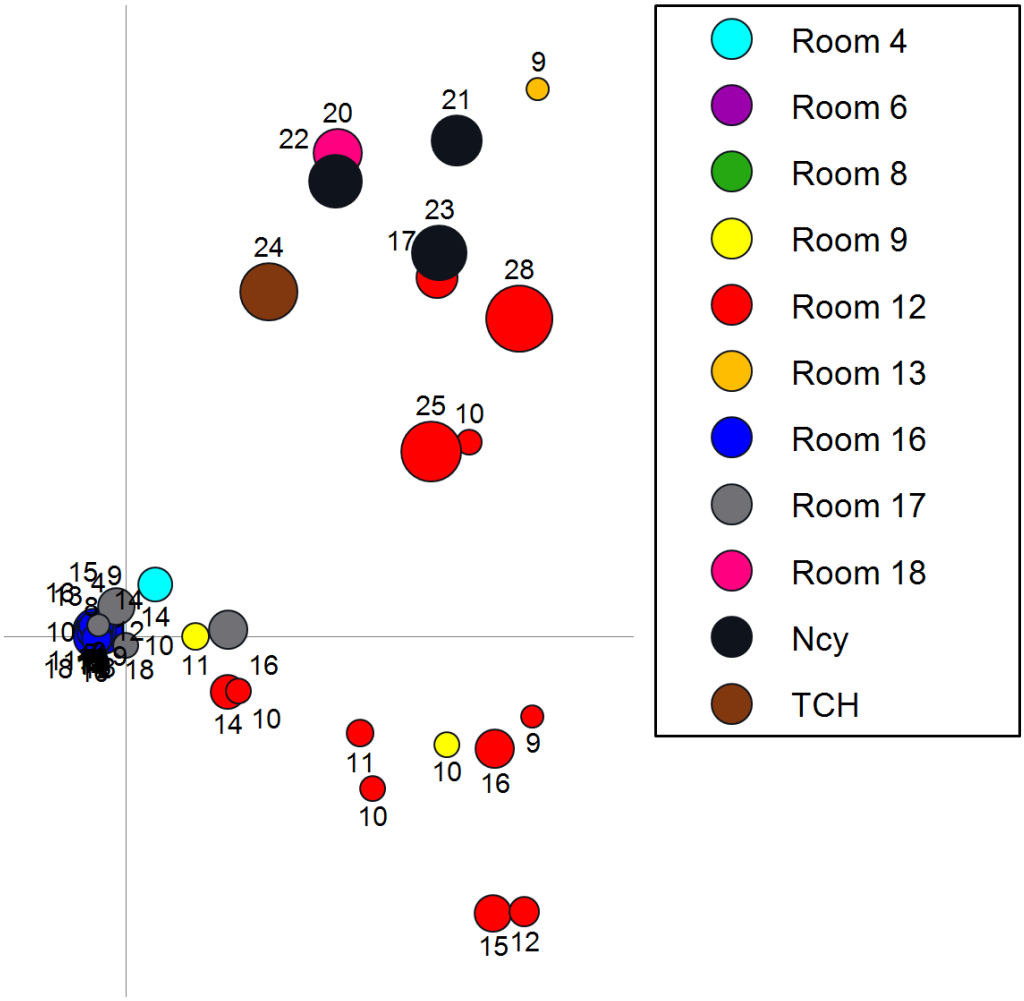


Figure 7.11 – CA plot of 58 samples and 41 taxa, coded by room number and displaying the number of taxa present in each sample.

7.7.1.3 Variation in weed composition

The above analyses have shown that the Tell Brak TC oval assemblage shows a certain level of variation in weed/wild taxon composition. An additional correspondence analysis based purely on weed/wild taxa was performed as a means of exploring this

aspect of variation amongst the samples, in the absence of crops. This analysis included 57 samples which contained 10 or more weed/wild taxa items (this included weed/wild taxa chaff) and species present in five or more samples (24 taxa). The initial plots produced (not shown) were, however, skewed by the presence of *Scirpus* sp. in some samples, so this species was removed for the following analysis. **Figure 7.12** shows that the majority of weed/wild taxa are located towards the positive ends of both axes or around the origin of the plot, with the exceptions of cf. *Cephalaria syriaca* L. and *Sinapis* cf. *arvensis*. The clearest patterning appears to be the dominance of *Aegilops* grain and chaff, *Hordeum spontaneum* and *Vaccaria pyramidata* towards the negative end and the origin of axis 1, indicating the ubiquity of these species throughout the assemblage.

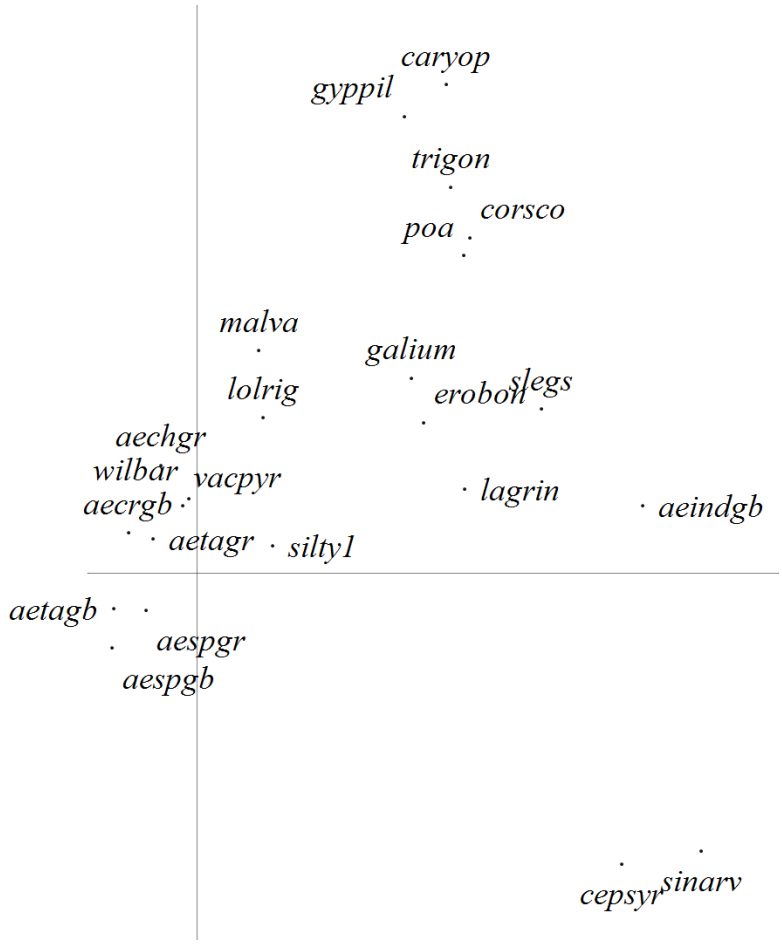


Figure 7.12 – CA scatterplot of 24 weed/wild taxa.

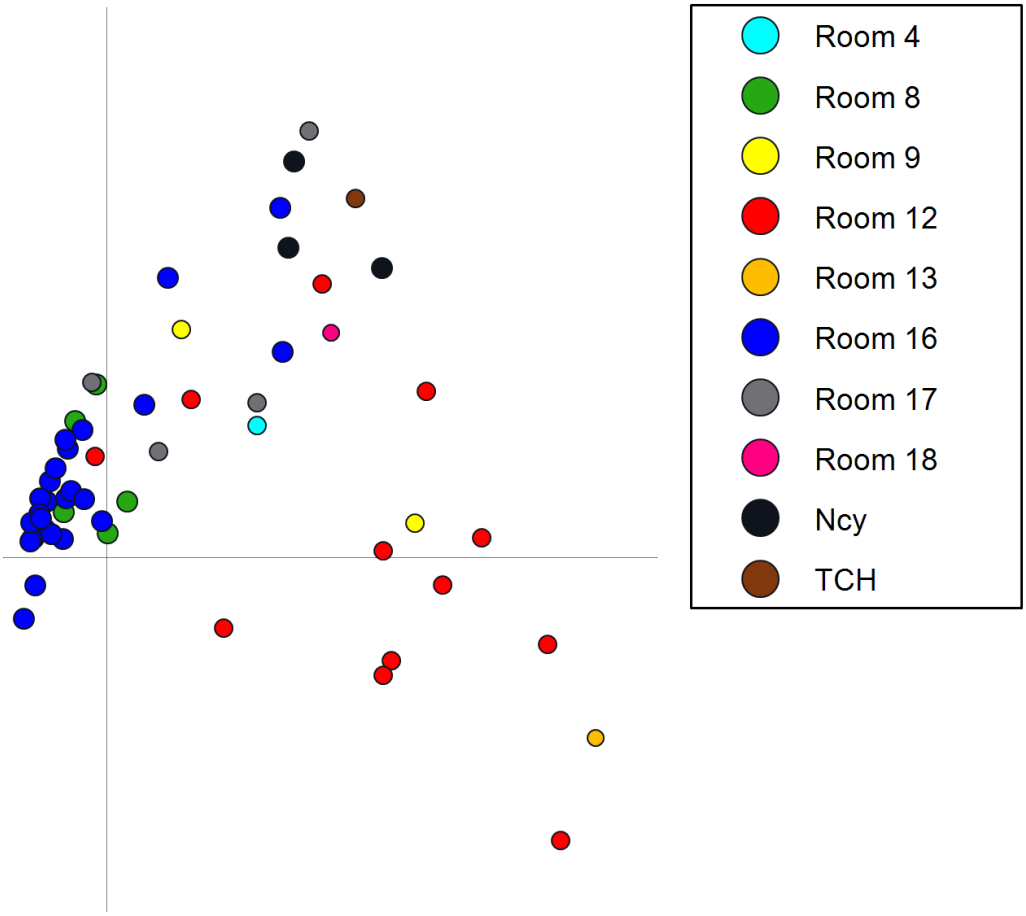


Figure 7.13 – CA plot of 57 samples and 24 weed/wild taxa, coded by room number.

Figure 7.13 shows the same weed/wild remains-only analysis as a sample scatterplot, coded by room number. As in **Figure 7.9** (above), there does appear to be some clustering of samples by location within the TC oval building. The most obvious of these patterns is the distinct grouping of points from Rooms 8 and 16 on the left side of the origin indicating that the weed/wild composition of these samples is dominated by *Aegilops* grain and chaff and *Vaccaria pyramidata*. By contrast, sample points from the other rooms appear more variable, in particular samples from Room 12. Furthermore, when comparing **Figure 7.13** with the summary room composition bar chart (see above **Figure 7.2**) the rooms which contained the highest numbers of weed/wild taxa items also have the most variable compositions. This is in direct

comparison to samples from Rooms 16 and 8 which had few weed/wild remains and seem comprised of only a few specific species. Additionally, samples from Room 17, which appeared to group consistently with samples from Room 16 with regards to crop based analyses (see **Figures 7.6** and **7.9**), have now separated themselves from Room 16 and are located primarily to the right of the origin. This would seem to indicate that even though samples from Room 17 have a similar crop composition to samples from Room 16, the two rooms appear to have separate weed/wild compositions. Again, this may indicate that cereals stored in different rooms of the TC oval building have been through varying stages of crop processing, or that these cereals may have been grown in multiple locations under differing crop husbandry conditions.

7.8 Spatial analysis

Further inter- and intra- room analysis has been conducted by combining sample positions with compositional pie-charts, as many of the rooms contained too few samples for the use of correspondence analysis. Also, as the TC oval building samples were all taken from the same stratigraphic level there is no vertical variation to consider. Pie-charts shown include all identified species as summarized plant item categories as well as pie-charts of individual cereal species, as these appear to be the principal component of the TC oval assemblage. This section will, therefore, focus on overall patterning within the TC oval building as well as examining any specific contextual differences between samples taken from the same room. Intra-room spatial analysis has, however, been limited by the number of rooms with only one sample and the lack of plans from Room 17 and the North Courtyard.

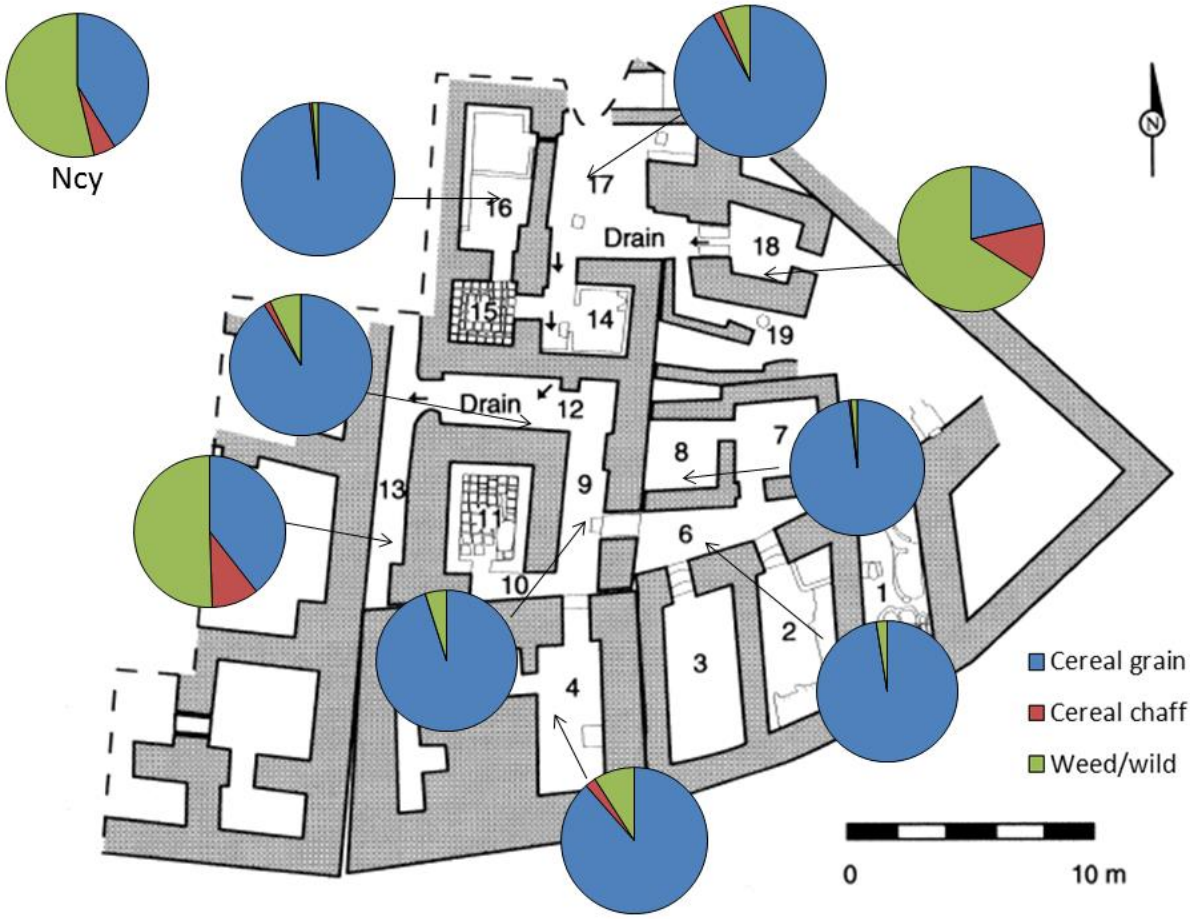


Figure 7.14 – Plan of the TC oval with samples for each room represented as compositional pie charts showing the three main plant categories.

7.8.1 TC oval overview

Figure 7.14 shows summary compositional pie charts for all rooms within the TC oval building. From this figure it is very clear that the composition of major plant categories varies by room. For instance, Rooms 6, 8, and 16 contain almost exclusively charred cereal grain, suggesting that these were the primary storage areas for cleaned and processed cereal grain. Similarly, Rooms 4, 9, 12 and 17 also contain dominant proportions of cereal grain, but include higher quantities of weed/wild taxa as well. Lastly, samples from Rooms 13, 18 and the North Courtyard have a completely

different composition, containing predominantly weed/wild taxa and much higher levels of cereal chaff than has been observed in the other rooms. This would seem to indicate that these rooms were being used for a different set of activities that may include crop processing, or the disposal of waste products from various stages of crop processing. These hypotheses will be explored further in **Section 7.10**.

Figure 7.15 - Plan of the TC oval with samples for each room represented as compositional pie charts showing the major crop remain categories.

These inter-room differences are clarified further when the varying proportions of major crops are shown. From **Figure 7.15** it is clear that rooms with the highest percentages of cereal grain are also almost solely dominated by hulled barley grain, further supporting the theory that these rooms (6, 8 and 16) are storage areas for

processed (hulled barley) crops. By contrast, Rooms 12 and 9 have a much greater level of variability in terms of identified crop species and include large concentrations of glume and free-threshing wheat grain as well as hulled barley grain. Finally, the rooms which contained the highest levels of weed/wild taxa (Rooms 13, 18 and the North Courtyard) contain strikingly different crop compositions. Room 13 and the North Courtyard are dominated by free-threshing wheat grain, whilst Room 18 contains the highest proportion of glume wheat chaff identified within the TC oval assemblage. This again would suggest that these rooms were used for a different set of activities from the primary storage rooms and could potentially have been used for crop processing or as a holding area for cereals that had yet to be (fully) processed.

Figure 7.16 - Plan of the Room 8 with samples represented as compositional pie charts showing the major crop remain categories.

7.8.2 Room 8

Room 8 had five samples taken from several different visible charred concentrations, and when excavated was designated a grain storage room by the archaeologists (Emberling & McDonald, 2001). All samples had a similar composition, containing almost exclusively charred cereal grain and a very small amount of weed/wild material. This sample uniformity is also discernible from **Figure 7.16**, a cereal species only plot, which confirms that this room was used principally for the storage of hulled barley grain.

7.8.3 Room 9

Only two samples were recovered from Room 9, and from the plant summary overview (plot not shown) both of them appear to have similar compositions; largely cereal grain dominated with a very small proportion of weed/wild taxa. From **Figure 7.17**, however, it appears that each sample contains a different dominant crop species. Sample 112, from the northern end of the room, has a high proportion of emmer wheat grain and free-threshing wheat grains. Juxtaposed to this, sample 55, from the southern end of the room, is dominated by hulled barley grain and small hulled barley grains. These differences in composition may be explained by the location of each of these samples within the room. Sample 112 was recovered from the join between Room 9 and the wheat dominated Room 12 whereas sample 55 was taken from nearer Room 6 and 4 which both contained large quantities of hulled barley grain. It is possible, therefore, that there may have been some mixing of samples in different rooms due to the effects of the fire or other post-depositional taphonomic processes. Alternatively, Room 9 may

have been used for two different purposes, the hulled barley grain storage at the southern end and wheat grain storage and/or crop processing at the northern end.

Figure 7.17 - Plan of the Room 9 with samples represented as compositional pie charts showing the major crop remain categories.

7.7.4 Room 12

Room 12, by contrast with Rooms 8 and 9, has a far more variable composition. From the summarized overview analysis (**Figure 7.18**) it appears that the eastern end of the room is dominated by cereal grain, whilst the western end contains larger proportions of weed/wild taxa and cereal chaff. This patterning becomes more complex in **Figure 7.19** which shows the individual crop species. Unlike Rooms 8, 9 and 16,

Room 12 contains greater quantities of emmer wheat grain than hulled barley grain, but also significant amounts of free-threshing wheat grain, glume wheat chaff and small wheat grains. Free-threshing wheat grains are primarily located towards the west of the room; in samples that also contained higher proportions of weed/wild taxa (see **Figure 7.18**). This is a trend that was also visible in samples from Room 13 and the North Courtyard (see **Figure 7.15**) where high percentages of free-threshing wheat grain were accompanied by large proportions of weed/wild taxa. In Room 12 high proportions of glume wheat chaff are only visible in two emmer wheat grain dominated samples located to the west of the room. These samples are taken from a slight alcove within the room and potentially represent a separate deposit from the other samples here which also contained large amounts of emmer wheat grain.

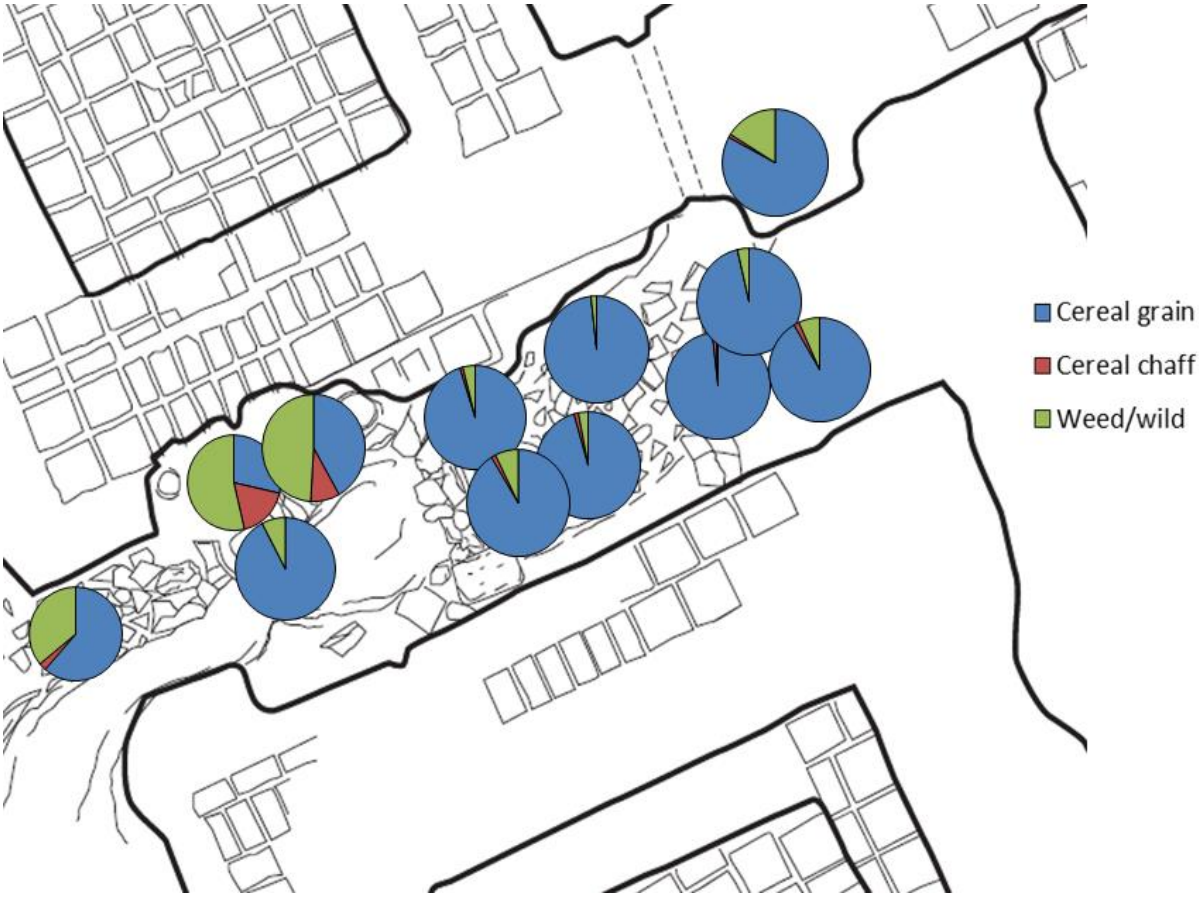


Figure 7.18 – Plan of the Room 12 with samples represented as compositional pie charts showing the three main plant categories.

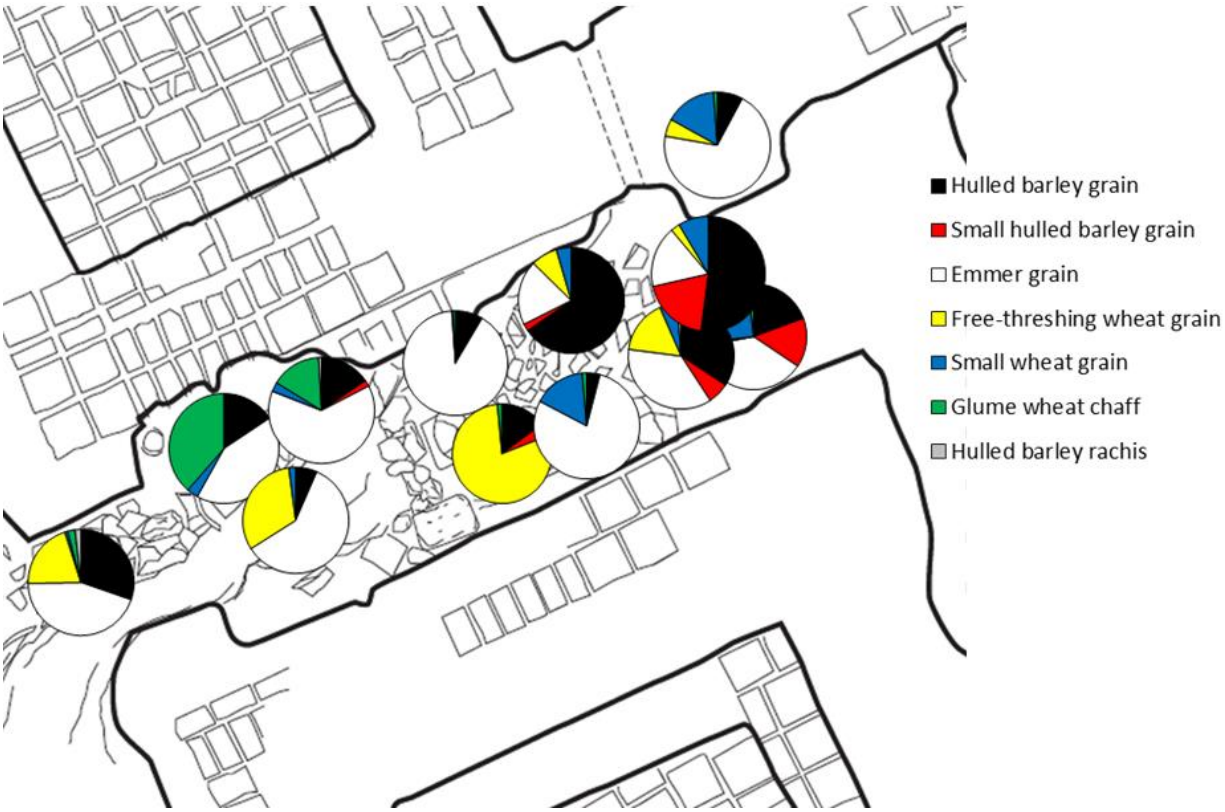


Figure 7.19 - Plan of the Room 12 with samples represented as compositional pie charts showing the major crop remain categories.

Figure 7.20 shows the plant items/litre of soil in each sample from Room 12 for which volumes were recorded (10 samples). A range of densities were recorded, with four samples producing 500 items or less per litre of soil, while the richest samples produced between 2501 and 5000 items per litre. The densest samples are located primarily in the middle and eastern ends of the room and generally contain the greatest proportions of emmer wheat grain or hulled barley grain. By comparison, the samples with the lowest densities appear to contain larger amounts of free-threshing wheat grain and/or glume wheat chaff. This intra-room seed density variation may be a result of various crop processing activities and will be explored in **Section 7.10**. The low seed densities (particularly when compared with Room 16 below) also highlight the fact that Room 12 was unlikely to have been used for the primary storage of cereal grain.

Figure 7.20 - Plan of the Room 12 with samples represented as pie charts showing the plant items/litre of soil.

7.7.5 Room 16

Room 16 has a very similar composition to that of Room 8, with all samples containing chiefly cereal grain (overview plot not shown). Similarly, from **Figures 7.21a** and **7.21b** it is clear that the majority of samples are dominated by hulled barley grain. The only exceptions to this rule are three samples located to the north of the room (see **Figure 7.21a**), adjacent to the outer wall (feature 642). These samples contain much higher proportions of small hulled barley grain than are seen anywhere else in the TC oval and support the theory that these remains may have been a purposefully grown

Figure 7.21a - Plan of the Room 16 with samples represented as compositional pie charts showing the major crop remain categories.

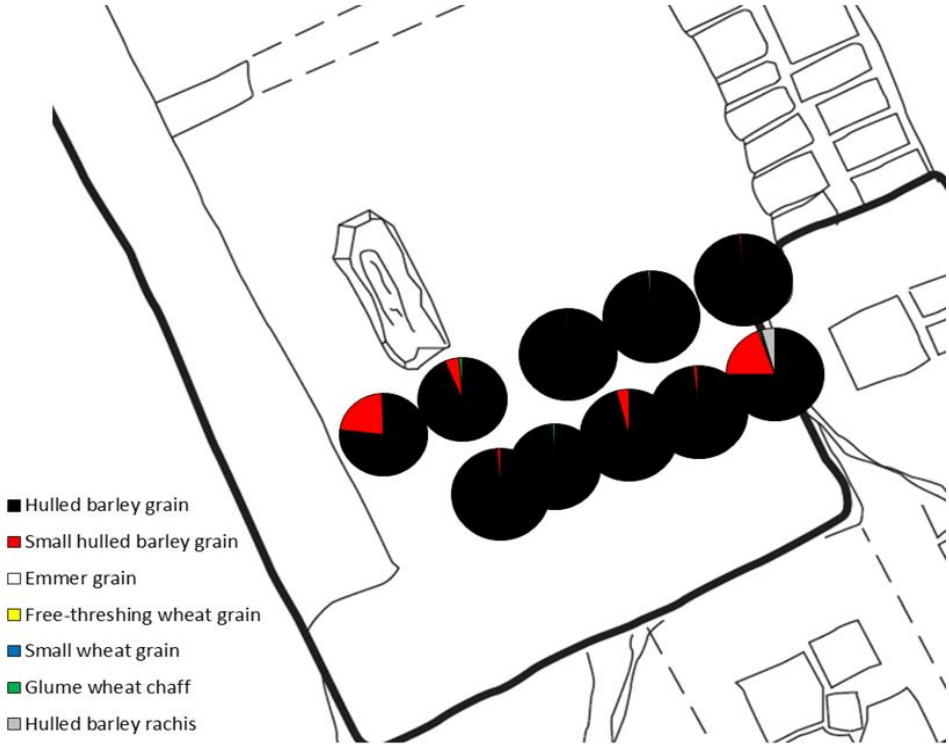


Figure 7.21b – Plan of Room 16 showing samples excavated on a grid system as compositional pie charts of major crop categories.

variety of small-grained hulled barley. Also supporting this inference is the fact that the samples that contain this smaller grain variety all cluster within one corner of the room, pointing to the fact that they may have been stored as a separate crop here. Additionally, if these grains were 'tail' grains or a contaminant of the principal hulled barley crop it would be expected that these remains would be more evenly distributed throughout the other samples in the room and amongst the wider assemblage.

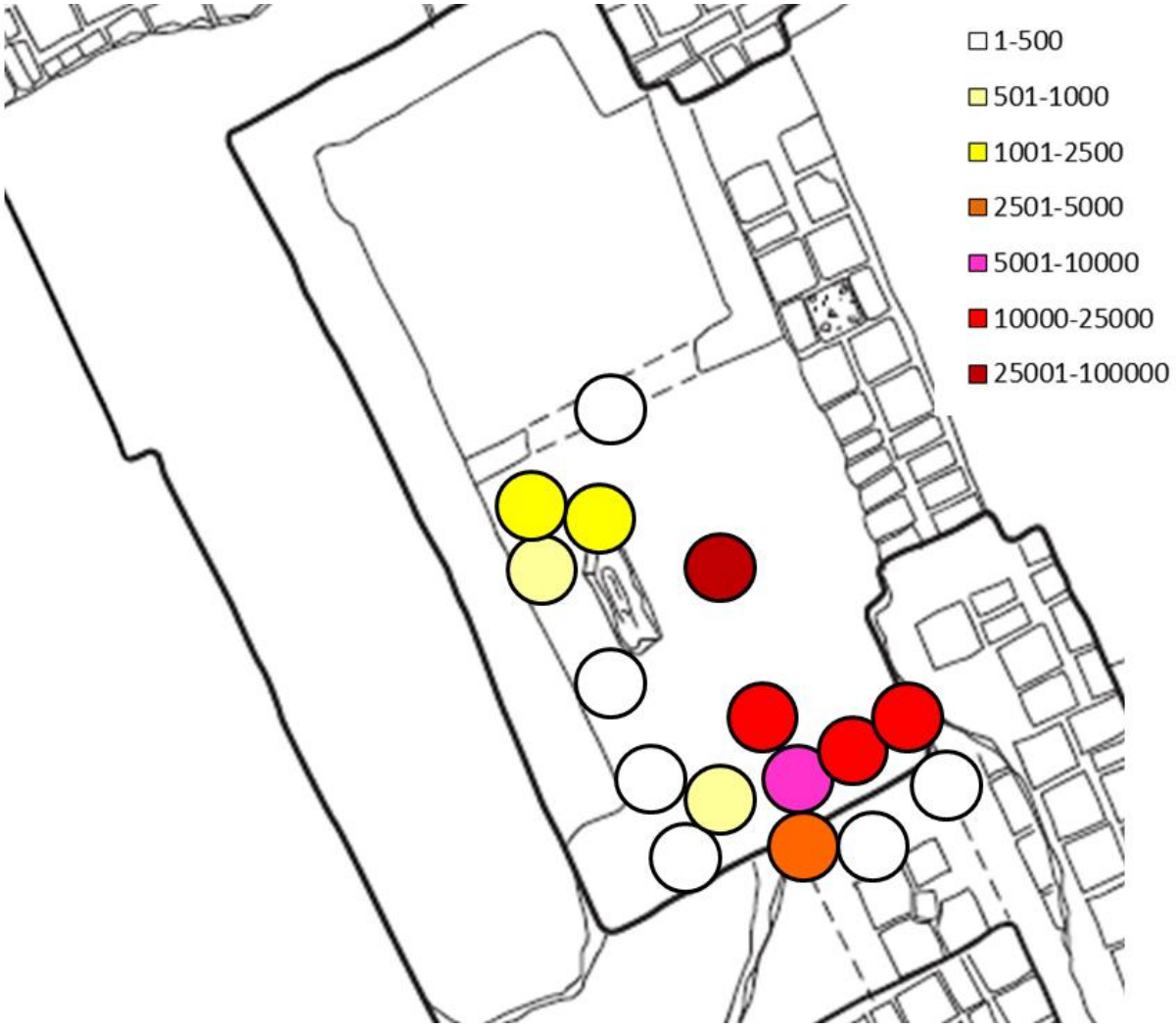


Figure 7.22a - Plan of the Room 16 with samples represented as pie charts showing the plant items/litre of soil.

Figure 7.22b – Plan of Room 16 showing samples excavated on a grid system as pie charts showing the plant items/litre of soil.

Seed density/litre of soil was also examined from Room 16 to identify potential specific storage loci. **Figures 7.22a** and **7.22b** indicate that seed density varied dramatically throughout the room (far exceeding the maximum recorded for Room 12). The most seed rich areas (up to 90,000 plant items/litre of soil) are located in the middle of the room. By contrast, samples taken from nearer the walls exhibited much lower densities (<500 plant items/litre of soil). When excavated, Room 16 was found to contain benches built into the outer walls (Emberling & McDonald, 2001), this coupled with the archaeobotanical evidence would, therefore, indicate that clean hulled barley grain was piled up, possibly in sacks, in the middle of the room leaving the benches relatively clear. It would also suggest that Room 16 was potentially not a purpose-built

storage room, but instead may have been a temporary storage location for grain before it was baked into bread, distributed as rations or transported to another location.

7.9 Summary of compositional and spatial analysis

This compositional and spatial analysis has highlighted considerable inter- and intra-room variation within the TC oval building. It has also indicated that different rooms may have been used for distinct purposes and/or the storage of different cereal crops. Firstly, it appears that hulled barley grain and the smaller grained hulled barley variety were stored separately from other cereal species within designated storage rooms. Archaeological evidence from Room 16, however, has indicated that these rooms may not have been originally constructed for this purpose, though they were certainly being used for grain storage at the time of the TC oval building's destruction. By contrast, samples from Rooms 13, 18 and the North Courtyard exhibit far more variable compositions and may represent the waste products from crop processing. The North Courtyard would have been particularly suited for these 'messy' activities as it appears to have located outside the main building. Finally, spatial analysis of Room 12 has indicated that this room had the highest levels of intra-room variability. **Figures 7.18**, **7.19** and **7.20** indicate that each end of the room may have been used for different purposes. The eastern end for the storage of emmer wheat grain, the smaller grained wheat variety and free-threshing wheat grain, whilst the western end (and in particular the small alcove area) may represent cereals yet to be fully processed. These hypotheses will be explored in greater detail below (**Section 7.10**) with reference to crop processing analysis.

7.10 Crop processing analysis

The TC oval building assemblage from Tell Brak is primarily composed of two major types of sample: those dominated by hulled barley grain, with very little chaff/rachis and weed/wild material, and more mixed samples containing a variety of cereal species, grain and chaff/rachis material, alongside much higher proportions of weed/wild seeds (see above **Section 7.2** for the assemblage overview). Assessment of crop processing stages will follow the procedure set out in **Section 4.5.2**, **Chapter 4** and will consider barley-dominated samples separately from those samples with a more varied composition. This separation of samples based on dominant composition will aim to take into account post-processing mixing as well as the potential cultivation of deliberately mixed (maslin) cereal crops.

Additionally, for crop processing analysis small hulled barley grain and small glume wheat grain have been added to the hulled barley and emmer wheat grain categories, respectively. As was seen above in **Section 7.3.4** and **Figure 7.21a** the small grain varieties are largely found in samples alongside their larger grained counterparts and, despite differences in size, would have had to go through a similar crop processing methodology in order to produce the final 'cleaned' product, albeit with the use of different size sieves. Finally, all weed/wild taxa are thought to have derived from the arable fields, rather than from animal dung, due again to both contextual and compositional data analysed above in **Section 7.3** and **7.7**. For the purposes of this analysis, therefore, no weed/wild species have been excluded unless clearly specified below. Crop processing analysis will be carried out using three primary approaches on a sample-by-sample basis. First, samples will be analysed on the basis of crop remains only. Secondly, crop remains and weed/wild remains will be analysed together. Finally, weed/wild remains will be examined in isolation.

7.10.1 Crop-based analysis

Figure 7.23 shows the relative proportions of the three major cereal types: hulled barley, glume wheat and free-threshing wheat (based on total counts of grain, chaff and rachis) in all 58 samples. Points have been colour-coded by room number (see **Figure 2.7**, **Chapter 2**) and compositional group number (discussed below in **Section 7.10.2**). The majority of samples (37) are dominated by hulled barley remains and are clustered in the right-hand corner of the triplot. This includes the samples from five different rooms (Rooms 4, 6, 8, 16 and 17) indicating their homogenous compositions. By comparison, the room with the greatest variability is Room 12, which contains samples individually dominated by all three cereal species. Additionally, Room 12 and Room 9 also contain samples located in the middle of the triplot, reflecting a mixture of all three crop species. It is unlikely, however, that free-threshing cereals (hulled barley and free-threshing wheat) and glume wheats were grown and processed together due to their differing processing requirements.

By contrast, samples from the North courtyard and Room 13 contain hulled barley and free-threshing wheat which are processed using the same techniques. This raises the possibility that these crops could have been grown together as a 'maslin'. Alternatively, these cereals may have been grown as separate crops and subsequently mixed, and this scenario will also be considered below. Furthermore, to make the Tell Brak results comparable with ethnobotanical data from Amorgos (Jones, 1990), the numbers of two-row hulled barley grain have been multiplied by three to better replicate the ratios of grain to chaff present within the six-row variety. Free-threshing wheat also has multiple grains (2-5 grains) per rachis internode making it comparable with both the multiplied up Tell Brak hulled barley results and the Amorgos ethnobotanical data (see **Section 4.5.2**, **Chapter 4** more further methodological details).

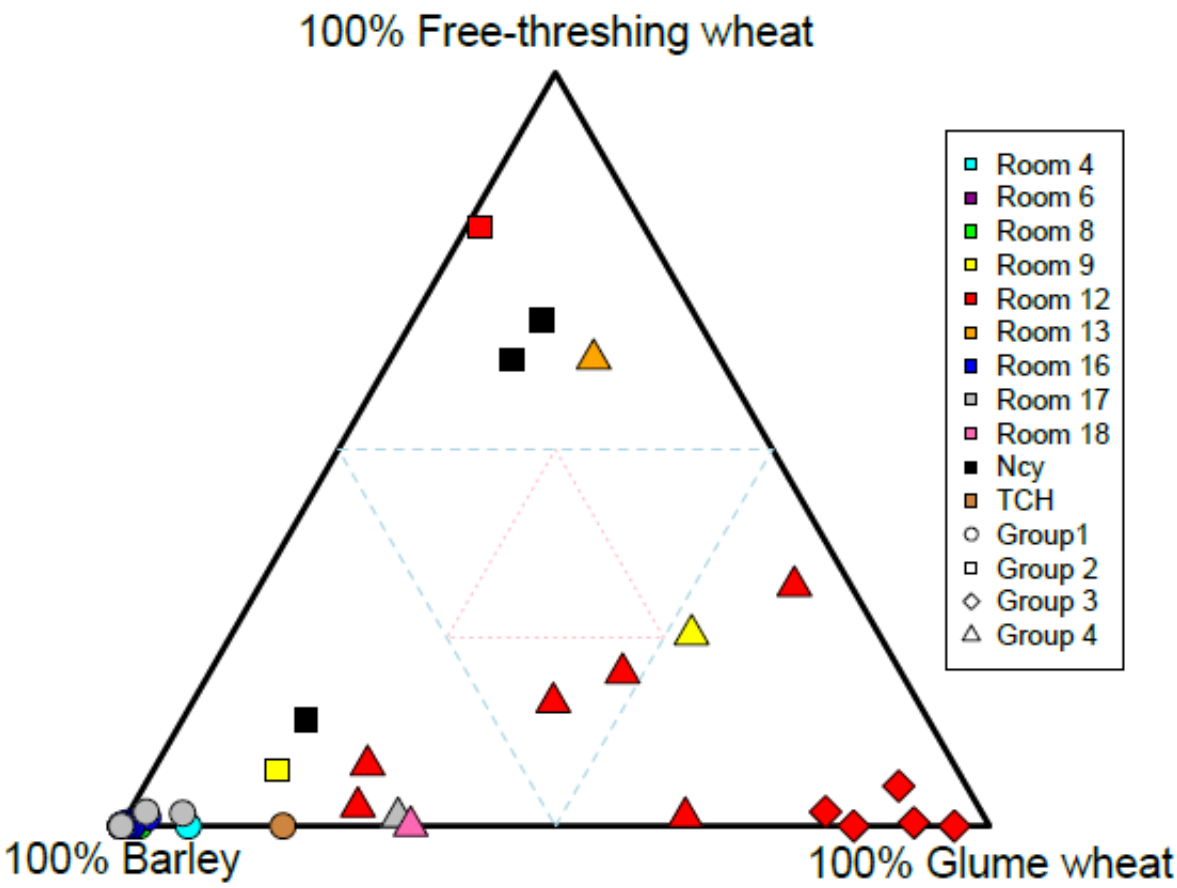


Figure 7.23 – Triplot showing the relative proportions of the three major cereal types in all 58 samples, coded by room number.

Within samples dominated by hulled barley and free-threshing wheat the ratio of grain to chaff was very high, indicating the presence of fully processed clean grain. Of the 43 samples containing high proportions of these cereal species, 30 did not contain any chaff at all and the average ratio of the remaining 13 samples was 1465.3 grains to rachis internode and ranged from 44,649 - 41.25 (see **Table 7.3**). When compared with Jones' (1990) ethnobotanical data, the results from the Tell Brak assemblage indicate that the majority of these samples (40 samples) represent clean product. The remaining three samples had ratios of less than 100 suggesting that they could be representative of fine sieving by-product. One of these samples (sample 70) came from Room 16, This

has been interpreted as a grain storage space and all other samples from Room 16 have a very high ratio of grain to chaff (average ratio of the samples that contain chaff is 1228.5), suggesting that this one anomalous sample is more likely to be clean product than fine sieving by-product. The other two samples are from the North Courtyard (samples 447 and 540) and TCH (sample 388), areas that seem more likely to have been used for crop processing. This interpretation will be explored further below. Additionally, the ratio of just free-threshing wheat grain to rachis from these samples was also considered but none of the five samples dominated by free-threshing wheat grain contained any identifiable free-threshing wheat rachis.

When considering the glume wheats, the average ratio of glume wheat grains to glume bases is significantly lower than that for hulled barley and free-threshing wheat. This is perhaps to be expected when considering the different processing requirements for glume wheats and free-threshing cereals (see **Section 3.2, Chapter 3)**. The five glume wheat-dominated samples, all from Room 12, had an average grain to chaff ratio of 23.3, with a range of 1.2 - 106.3 (see **Table 7.4**). This indicates that none of these samples contain crop processing waste derived from the de-husking of spikelets, but that one sample with a ratio of 1.2 does fall with the ratio range hypothesized to represent the presence of whole spikelets (see **Section 4.5.2**, **Chapter 4** for inferred spikelet range, Bogaard, 2011). The lack of other samples containing this ratio, alongside the generally more mixed composition of samples from Room 12, however, suggests that this one sample could be representative of the mixing of clean product and fine sieving by-product. By contrast, the four remaining samples contain high ratios of grain to chaff (see **Table 7.4**) suggesting that they are composed primarily of clean, processed grain.

Table 7.3 – Summary of hulled barley and free-threshing wheat grain to rachis ratio and product/by-product classification.

Room No.	Sample No.	Total Items	Total Barley grain (x3)	Total Free-threshing wheat grain	Total Barley rachis	Total Free-threshing wheat chaff	Ratio	Product/By Product classification
4	77	3272	3240		32		101.3	Fine sieve product
6	10	906	906				n/a	Fine sieve product
8	104	19888	19872		16		1242.0	Fine sieve product
8	147	16224	16224				n/a	Fine sieve product
8	144	89300	89298			2	44649.0	Fine sieve product
8	74	31983	31983				n/a	Fine sieve product
8	103	14316	14316				n/a	Fine sieve product
9	55	12048	11682	366			n/a	Fine sieve product
12	76	1436	600	836			n/a	Fine sieve product
16	70	12188	12132	36	8	12	608.4	Fine sieve product
16	97	14656	14640		16		915.0	Fine sieve product
16	115	18720	18720				n/a	Fine sieve product
16	116	1036	1020		16		63.8	Fine sieve by-product
16	117	19824	19824				n/a	Fine sieve product
16	121	36672	36672				n/a	Fine sieve product
16	124	147456	147456				n/a	Fine sieve product
16	127	20304	20304				n/a	Fine sieve product
16	150	20448	20448				n/a	Fine sieve product
16	152	22176	22176				n/a	Fine sieve product
16	159	42240	42240				n/a	Fine sieve product
16	225	6354	6354				n/a	Fine sieve product
16	227	3813	3813				n/a	Fine sieve product
16	71	19853	19815	30	8		2480.6	Fine sieve product
16	219	8190	8190				n/a	Fine sieve product
16	148	879	879				n/a	Fine sieve product
16	218	7064	7062		2		3531.0	Fine sieve product
16	123	75024	75024				n/a	Fine sieve product
16	118	87804	87804				n/a	Fine sieve product
16	138	148416	148416				n/a	Fine sieve product
16	131	679936	678912		768	256	663.0	Fine sieve product
16	105	128328	128328				n/a	Fine sieve product
16	98	2391	2391				n/a	Fine sieve product
16	130	1977	1977				n/a	Fine sieve product
16	140	4068	4056		12		338.0	Fine sieve product
16	226	11136	11136				n/a	Fine sieve product
16	239	6124	6120	4			n/a	Fine sieve product
17	168	9094	9039	55			n/a	Fine sieve product
17	167	10142	10077	65			n/a	Fine sieve product
17	169	6504	6504				n/a	Fine sieve product
Ncy	450	1483	594	857	32		45.3	Fine sieve by-product
Ncy	447	893	465	420	8		110.6	Fine sieve product
Ncy	165	227	213	14			n/a	Fine sieve product
TCH	388	676	660		16		41.3	Fine sieve by-product

Table 7.4 – Summary of glume wheat grain to chaff ratio and class classification.

Room No.	Sample No.	Total Items	Total Grain	Total Chaff	Ratio	Class Classification
12	113	5152	5104	48	106.3	Clean grain
12	149	151	82	69	1.2	Spikelet
12	120	1412	1148	264	4.3	Clean grain
12	67	590	582	8	72.8	Clean grain
12	111	3322	3274	48	68.2	Clean grain

7.10.2 Crop- and weed-based analysis

The second form of crop processing analysis involved the assessment of crop proportions alongside weed/wild remains. In this analysis free-threshing cereal remains were treated separately from glume wheat remains and it was assumed that all weed/wild taxa originated from the harvested crops. Samples were first classified into four groups based on dominant cereal species composition (**Table 12.6**, **Appendix**) as follows: Group 1. Samples containing at least 80% hulled barley remains (38 samples), Group 2. Samples with less than 80% hulled barley remains but at least 80% hulled barley and free-threshing wheat remains (five samples), Group 3. Samples with at least 80% glume wheat remains (five samples), Group 4. Samples with a mixed composition containing non-dominant proportions of all three cereal species (10 samples). Crop and weed analysis was only carried out on samples from Groups 1, 2 and 3 as samples from Group 4 were considered too 'mixed' and have been excluded from further analysis. The samples from Groups 1, 2 and 3 were compared with ethnographic data analysed by Jones (1990) to assess individual stages of crop processing.

Figure 7.24 shows the percentages of grain, rachis and weed/wild items for samples from Group 1 and Group 2; points are also colour-coded by room number. As

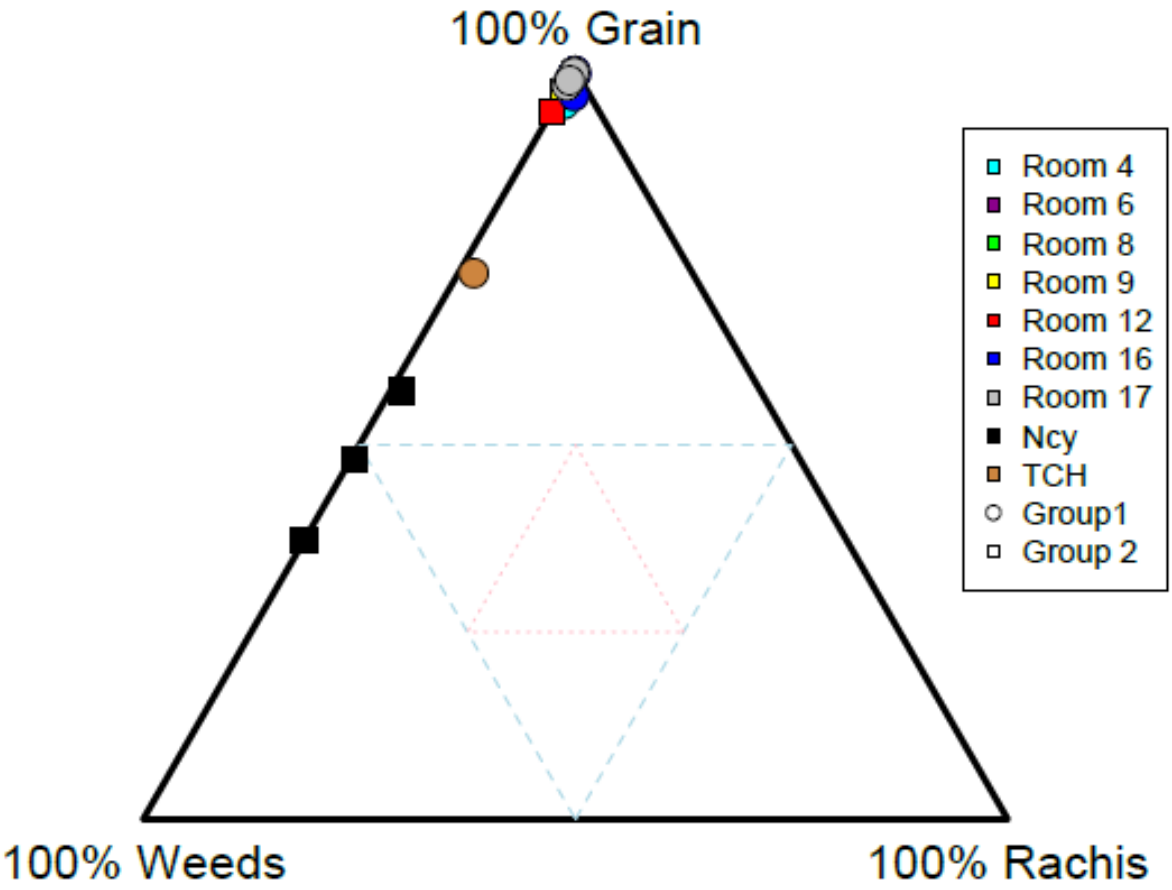


Figure 7.24 – Triplot showing the relative proportions of grain, rachis and weed/wild taxa for samples from Groups 1 and 2.

was suggested by the ratio of grains to rachis internodes discussed above, the majority of samples are clustered together at the 100% grain apex of the triplot. This indicates that these samples are comprised primarily of clean, processed grain. Moreover, most of these samples are from Rooms 4, 8, 9 and 16 and have been identified through spatial analysis (see **Section 7.8**) as likely storage areas for grain immediately prior to consumption or food preparation. By comparison, two samples from the North Courtyard appear to contain much higher proportions of weed/wild items and are indicative of fine sieve by-product. Spatially, this area was located outside the main TC building and would have been a suitable place for 'messy' crop processing activities. Furthermore, the identification of both hulled barley and free-threshing wheat within

these samples may represent crop mixing from repeated crop processing activities. Finally, samples from the North Courtyard also contained higher culm node to grain ratios than all other samples from the TC oval assemblage (average ratio of 2.3). Culm nodes are generally removed during the early phases of crop processing (i.e. winnowing and/or coarse sieving) as they are light and relatively small. The presence of higher proportions of culm nodes, therefore, again supports the hypothesis that these samples are composed of crop processing by-product, from the early phases of crop processing (Jones, 1990).

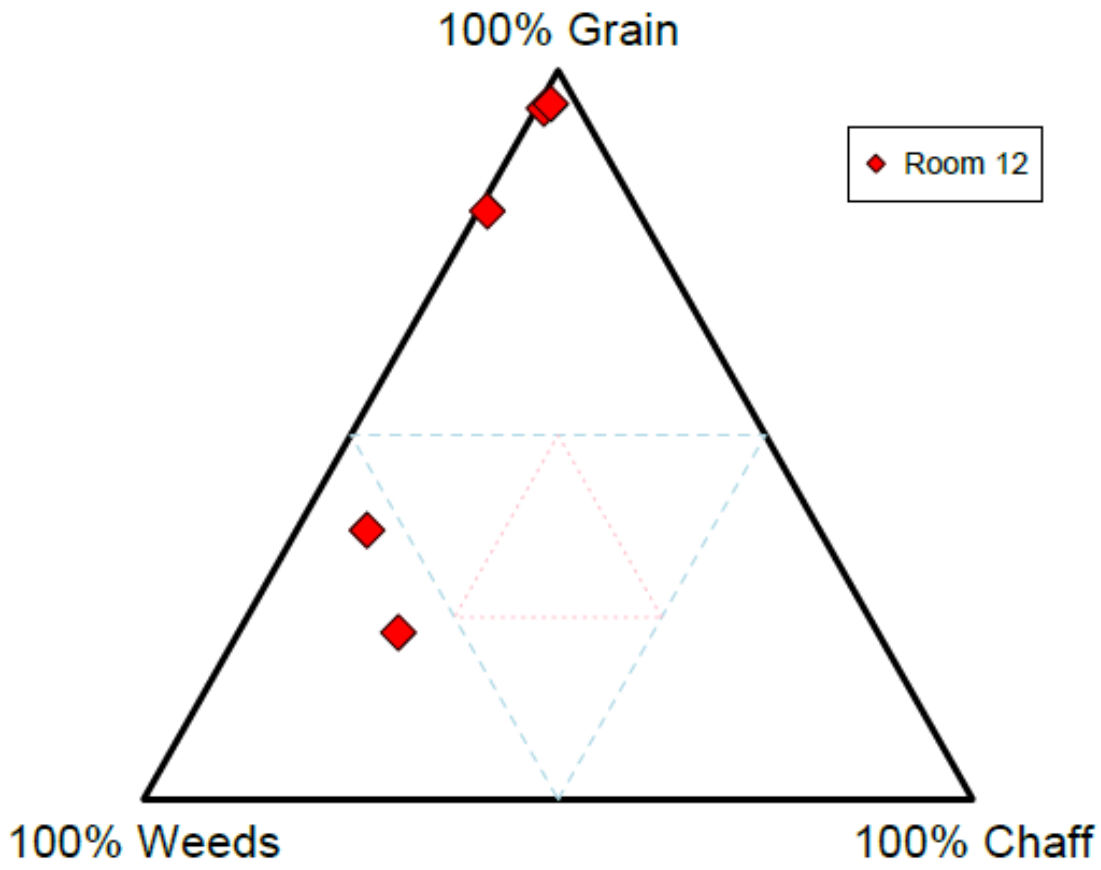


Figure 7.25 – Triplot showing the relative proportions of grain, rachis and weed/wild taxa for samples from Group 3.

Figure 7.25 shows the percentages of grain, chaff and weed/wild seeds for samples from Group 3. All of these samples are from Room 12. Three of the samples are located towards the 100% grain apex of the triplot and also contain very small amounts of chaff. This indicates that these samples are composed primarily of clean fine sieve product. By contrast, the other two samples contain much higher percentages of weed/wild items and chaff remains. When compared with Jones' (1990) ethnobotanical data these samples seem to derive from fine sieve by-product. Additionally, when examined spatially (see **Figure 7.19** in **Section 7.8**) these two samples are located adjacent to each other in the small alcove at the western end of Room 12, whilst the other three samples are located towards the eastern end. This supports the interpretation that Room 12 was used for a variety of different activities and that, potentially, the western end of the room was used for crop processing, whilst the clean grain was kept at the eastern end of the room closer to the main storage rooms. Furthermore, from **Figure 7.19** and **Figure 7.23**, it is clear that Room 12 also contained many samples with a mixed composition of all three cereal species. All of these samples have very low percentages of chaff/rachis material, suggesting they are representative of fine sieve product, but also their mixed compositions potentially indicate that multiple crops could be amalgamated for storage after the fine sieve crop processing stage.

Overall, by comparing **Figure 7.24** with **Figure 7.25** it appears that weeds/wild seeds were not associated with one particular cereal species. Instead it seems that samples with higher proportions of weed/wild seeds and rachis/chaff material are likely to represent fine sieve by-product and furthermore, that these samples are connected with specific rooms which may have been used for various crop processing activities.

7.10.3 Weed-based analysis

The final crop processing analysis approach was based on weed/wild remains only and the discriminant analysis of ethnobotanical weed/wild seed data from Jones (1983b; 1984a). Weed/wild items were classified by their aerodynamic properties of relevance to particular crop processing operations; seed item size and the propensity for seeds to remain in the head or pod (**Table 12.7**, **Appendix** for full list of classified weed/wild items). This analysis was only performed on samples that contained at least 10 weeds/wild remains that could be categorized, resulting in the exclusion of six samples (sample 10 from Room 6 and samples 227, 98, 130, 140 and 226 from Room 16). Additionally, this analysis could only be carried out on weeds identified to the genus level, leading to the exclusion of nine weed/wild groups identified only to the family level. For further details on the methodology of this analysis see **Section 4.5.2**, **Chapter 4**.

Figure 7.26 shows the results of the discriminant analysis, including Jones' (1983b; 1984a) ethnobotanical data and the Tell Brak archaeobotanical data, colour-coded by room number. From this plot it is clear that the majority of samples have been classified as either fine sieve product or fine sieve by-product. Samples classified as fine sieve product are primarily those from rooms that have been identified as grain stores from the crop-based processing analysis; Room 16, Room 8, two samples from Room 12 and two samples from Room 17. This discriminant analysis, therefore, supports the results from the crop-based analysis and crop and weed based analysis which indicated that all of these samples were clean, processed product. These samples were also generally classified with high probabilities (see **Table 7.5**) indicating that their identification as fine sieve product was statistically significant. Samples classified as fine sieve by-product encompass all samples from Room 12, with the exception of the

two samples classified as fine sieve product, one sample from Room 9, the samples from Room 4, Room 13 and Room 18 and the remaining two samples from Room 17. These samples were also generally classified with high probabilities (see **Table 7.5**).

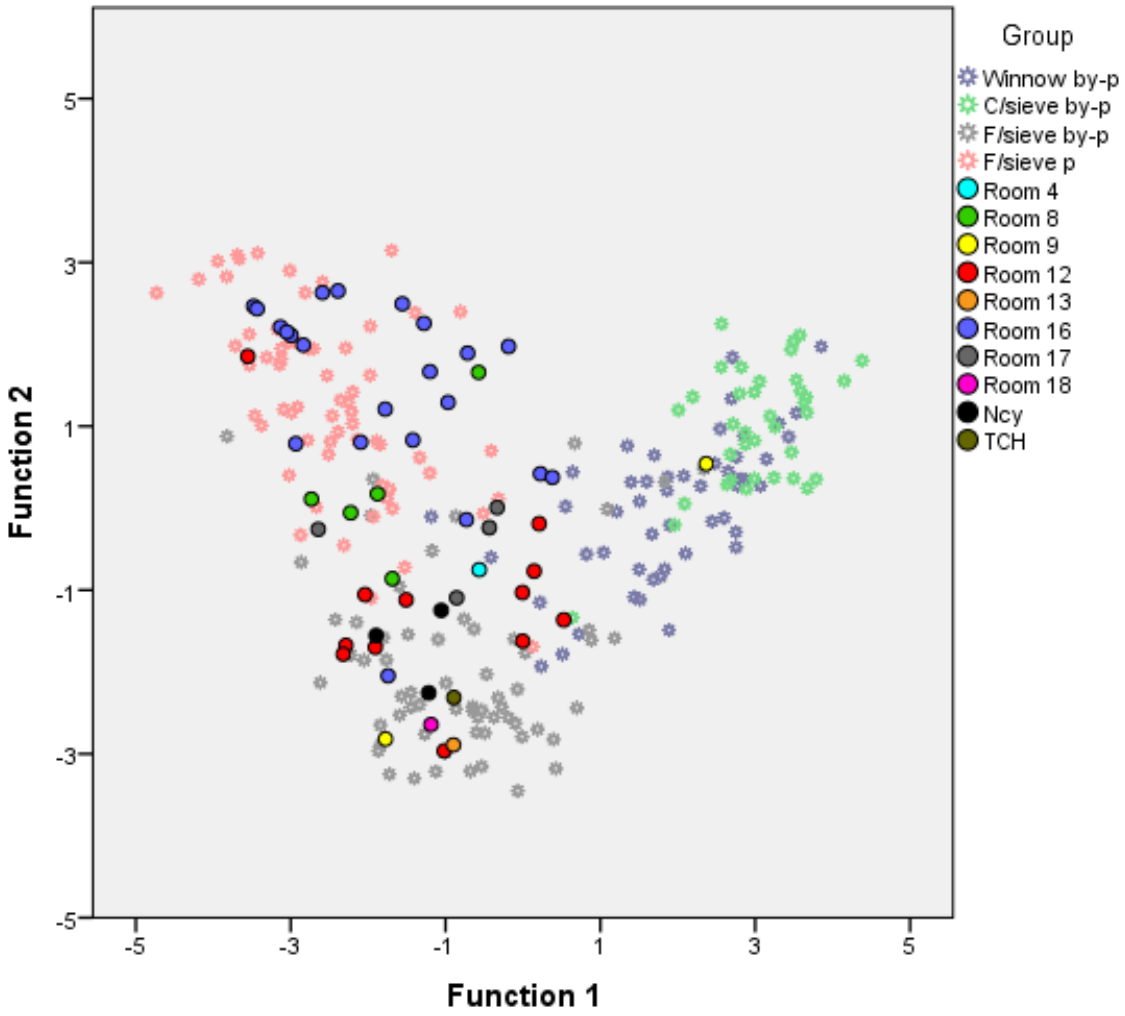


Figure 7.26 – Plot showing the results of the extracted discriminant function, including Jones' (1983b; 1984a) ethnobotanical data and the Tell Brak archaeobotanical data, colour coded by room number.

Overall, samples classified as fine sieve product contained very low quantities of categorized weed/wild remains, particularly in relation to the amount of cereal grain present within these samples. By contrast, the samples classified as fine sieve by-product contained much higher quantities of classified weed/wild remains and in

particular included a number of morphologically small species such as *Sinapis* cf. *arvensis*, *Papaver* sp. and several types of small-seeded legumes. These seeds are generally removed during the fine sieving stage of crop processing as this procedure removes the smaller weed seeds and chaff from the larger cereal grains. This suggests that these samples may have contained waste material from this process or alternatively had not been through fine sieving at all. Additionally, one sample from Room 9 was classified as coarse sieve by-product, again with a high statistical probability. This was likely due to a high proportion of large *Malva* sp. remains. Coarse sieve by-product, however, should also contain high percentages of chaff/rachis material and culm nodes (Jones, 1990), and this sample from Room 9 did not contain any. This issue, coupled with the fact that this sample also contained large amounts of hulled barley and glume wheat grain, suggests that this sample is actually unlikely to represent coarse sieve by-product, and is instead probably a mixture of residues from distinct activities/crop processing stages.

Finally, three samples (sample 78 from Room 12, samples 70 and 71 from Room 16) have been classified as winnowing by-products, although with lower statistical probabilities when compared with the rest of the assemblage. Again, these three samples contain very high proportions of cereal grain and very little chaff/rachis material, particularly samples 70 and 71 from Room 16 which from the crop based analysis and crop and weed analysis (**Figure 7.23)** appear to represent fine sieve product. These results, therefore, suggest that the classification of these three samples as winnowing by-product is erroneous and could be due to the fact that only a small range of weed/wild species were identified from them.

Table 7.5 – Summary of discriminant analysis classification for weed-based crop processing analysis.

Room No.	Sample No.	Crop processing classification	Probability (%)
4	77	Fine sieve by-product	0.958
8	104	Fine sieve product	0.879
8	147	Fine sieve product	0.962
8	144	Fine sieve product	0.865
8	74	Fine sieve by-product	0.840
8	103	Fine sieve product	0.940
9	55	Fine sieve by-product	1.000
9	112	Coarse sieve by-product	0.989
12	76	Fine sieve by-product	0.961
12	80	Fine sieve by-product	0.971
12	113	Fine sieve product	1.000
12	149	Fine sieve by-product	0.980
12	133	Fine sieve by-product	1.000
12	122	Fine sieve by-product	0.816
12	102	Fine sieve by-product	0.701
12	120	Fine sieve by-product	0.942
12	106	Fine sieve by-product	0.970
12	67	Fine sieve by-product	0.983
12	111	Fine sieve by-product	0.842
12	78	Winnowing by-product	0.563
13	228	Fine sieve by-product	0.999
16	70	Winnowing by-product	0.705
16	97	Fine sieve product	0.967
16	115	Fine sieve product	1.000
16	116	Fine sieve by-product	0.995
16	117	Fine sieve product	0.993
16	121	Fine sieve product	0.997
16	124	Fine sieve product	0.993
16	127	Fine sieve product	1.000
16	150	Fine sieve product	0.961
16	152	Fine sieve by-product	0.670
16	159	Fine sieve product	0.692
16	225	Fine sieve product	0.975
16	71	Winnowing by-product	0.787
16	219	Fine sieve product	1.000
16	148	Fine sieve product	1.000
16	218	Fine sieve product	1.000
16	123	Fine sieve product	1.000
16	118	Fine sieve product	0.998
16	138	Fine sieve product	0.987
16	131	Fine sieve product	1.000
16	105	Fine sieve product	1.000
16	239	Fine sieve product	1.000
17	168	Fine sieve by-product	0.861
17	217	Fine sieve by-product	0.977
17	167	Fine sieve product	0.873
17	169	Fine sieve by-product	0.569
18	383	Fine sieve by-product	0.999
Ncy	450	Fine sieve by-product	0.984

Room No.	Sample No.	Crop processing classification	Probability (%)
Ncy	447	Fine sieve by-product	0.999
Ncy	165	Fine sieve by-product	0.973
TCH	388	Fine sieve by-product	0.998

7.10.4 Crop processing analysis conclusions

In conclusion, the results from all three forms of crop processing analysis indicate that the samples from Level 11 of the TC oval building at Tell Brak are primarily representative of fine sieve product and fine sieve by-product. Samples from Rooms 4, 6, 8, 9, and 16 have generally been classified as fine sieve product in all three crop processing analyses due to high proportions of cereal grain and very low numbers of chaff/rachis material and weed/wild remains. This correlates with the results from the spatial and compositional analysis completed above in **Sections 7.7** and **7.8** which identified these areas as spaces for grain storage prior to consumption.

By contrast, samples from Rooms 12, 13, 17, 18, the North Courtyard and the TCH area appear to compare closely with fine sieve by-product. This was particularly the case with regards to the weed only analysis, as a number of samples from Room 12 had previously been classified as clean product by the crop only and crop and weed based analysis (see summary **Table 7.6** for comparative breakdown of all crop processing results). From these specific areas within the TC oval building it would appear that Rooms 13, 18, the North Courtyard and TCH appear the most likely locations for crop processing activities to have taken place. These areas were located either outside the main building or in outer corridors of the oval building (see **Figure 2.7 Chapter 2**) potentially making them more suitable for later stage 'messy' fine sieving activities. Additionally, samples from these areas contained the smallest

quantities of cereal grain and the highest amounts of weed/wild remains and chaff/rachis material, making a classification of fine sieve by-product conceivable.

Samples from Room 12, however, had a much more variable composition and were classified in **Figure 7.26** variously as both clean product and fine sieve by-product. Furthermore, six samples (sample numbers 78, 80, 102, 106, 122, and 133) contained high numbers of both hulled barley and glume wheat grain, indicating that these samples were not crop processing by-product. Instead, Room 12 was potentially used for multiple activities including crop processing and crop storage. Certainly, many of these samples represent a mixture of several different crop species that have been amalgamated after crop processing and it may be this amalgamation process that has caused the variable crop processing signature present in the weed only analysis. If each individual crop species was being grown under different husbandry conditions/in multiple locations they would necessarily have their own weed flora assemblages. The mixing of these different crops with their attendant weed/wild assemblages would, therefore, obscure the individual husbandry signatures that could be extracted from the composition of any one sample. This hypothesis will be considered in much greater detail below with regard to functional weed ecology and crop stable isotope analysis (see **Chapter 8**).

Finally, the results of this crop processing analysis support the theory that the small hulled barley and glume wheat grains represent specific varieties of cultivated crops rather than the tail grains of 2-row hulled barley and emmer wheat. This is because tail grains are normally removed during the fine sieving process (Hillman, 1981; Willcox, 2004) and are not generally found in grain stores. In the TC oval building at Tell Brak, however, the largest quantities of small grains were found in Rooms 8 and 16. Samples from these areas have been consistently classified as ‘clean’

fine product within each stage of the above crop processing analysis (see **Table 7.6**) suggesting that these rooms were being used as grain stores. Moreover, the samples that were classified as fine sieve by-product from Room 18 and the North Courtyard actually contained some of the lowest small grain numbers across the entire assemblage. These results from the crop processing analysis combined with the evidence from the spatial and compositional analysis, therefore, support the hypothesis that these small grains were not 'tail' grains of the larger seeded crops, but represent totally separate varieties/landraces of wheat and barley.

Table 7.6 – Summary of all crop-processing analysis for all samples from the Tell Brak TC oval building.

Room No.	Sample No.	Barley & Free-threshing wheat ratio classification	Glume wheat ratio classification	Composition	Group No.	Classification based on crop/weed analysis	Classification based on Jones' (1990) weed/wild analysis
4	77	Fine sieve product		Hulled barley	1	Fine sieve product	Fine sieve by-product
6	10	Fine sieve product		Hulled barley	1	Fine sieve product	
8	104	Fine sieve product		Hulled barley	1	Fine sieve product	Fine sieve product
8	147	Fine sieve product		Hulled barley	1	Fine sieve product	Fine sieve product
8	144	Fine sieve product		Hulled barley	1	Fine sieve product	Fine sieve product
8	74	Fine sieve product		Hulled barley	1	Fine sieve product	Fine sieve by-product
8	103	Fine sieve product		Hulled barley	1	Fine sieve product	Fine sieve product
9	55	Fine sieve product		Hulled barley & Free-threshing wheat	2	Fine sieve product	Fine sieve by-product
9	112			Mixed	4		Coarse sieve by-product
12	76	Fine sieve product		Hulled barley & Free-threshing wheat	2	Fine sieve product	Fine sieve product
12	113		Clean grain	Glume wheat	3	Fine sieve product	Fine sieve product
12	149		Spikelet	Glume wheat	3	Fine sieve by-product	Fine sieve by-product
12	120		Clean grain	Glume wheat	3	Fine sieve by-product	Fine sieve by-product
12	67		Clean grain	Glume wheat	3	Fine sieve product	Fine sieve by-product
12	111		Clean grain	Glume wheat	3	Fine sieve product	Fine sieve by-product
12	80			Mixed	4		Fine sieve product
12	133			Mixed	4		Fine sieve by-product
12	122			Mixed	4		Fine sieve by-product
12	102			Mixed	4		Fine sieve by-product
12	106			Mixed	4		Fine sieve by-product
12	78			Mixed	4		Winnowing by-product
13	228			Mixed	4		Fine sieve by-product
16	70	Fine sieve product		Hulled barley	1	Fine sieve product	Winnowing by-product
16	97	Fine sieve product		Hulled barley	1	Fine sieve product	Fine sieve product

Room No.	Sample No.	Barley and free-threshing wheat ratio classification	Glume wheat ratio classification	Composition	Group No.	Classification based on crop/weed analysis	Classification based on Jones' (1990) weed/wild analysis
16	115	Fine sieve product		Hulled barley	1	Fine sieve product	Fine sieve product
16	116	Fine sieve by-product		Hulled barley	1	Fine sieve product	Fine sieve by-product
16	117	Fine sieve product		Hulled barley	1	Fine sieve product	Fine sieve product
16	121	Fine sieve product		Hulled barley	1	Fine sieve product	Fine sieve product
16	124	Fine sieve product		Hulled barley	1	Fine sieve product	Fine sieve product
16	127	Fine sieve product		Hulled barley	1	Fine sieve product	Fine sieve product
16	150	Fine sieve product		Hulled barley	1	Fine sieve product	Fine sieve product
16	152	Fine sieve product		Hulled barley	1	Fine sieve product	Fine sieve by-product
16	159	Fine sieve product		Hulled barley	1	Fine sieve product	Fine sieve product
16	225	Fine sieve product		Hulled barley	1	Fine sieve product	Fine sieve product
16	227	Fine sieve product		Hulled barley	1	Fine sieve product	
16	71	Fine sieve product		Hulled barley	1	Fine sieve product	Winnowing by-product
16	219	Fine sieve product		Hulled barley	1	Fine sieve product	Fine sieve product
16	148	Fine sieve product		Hulled barley	1	Fine sieve product	Fine sieve product
16	218	Fine sieve product		Hulled barley	1	Fine sieve product	Fine sieve product
16	123	Fine sieve product		Hulled barley	1	Fine sieve product	Fine sieve product
16	118	Fine sieve product		Hulled barley	1	Fine sieve product	Fine sieve product
16	138	Fine sieve product		Hulled barley	1	Fine sieve product	Fine sieve product
16	131	Fine sieve product		Hulled barley	1	Fine sieve product	Fine sieve product
16	105	Fine sieve product		Hulled barley	1	Fine sieve product	Fine sieve product
16	98	Fine sieve product		Hulled barley	1	Fine sieve product	
16	130	Fine sieve product		Hulled barley	1	Fine sieve product	
16	140	Fine sieve product		Hulled barley	1	Fine sieve product	
16	226	Fine sieve product		Hulled barley	1	Fine sieve product	
16	239	Fine sieve product		Hulled barley	1	Fine sieve product	Fine sieve product
17	168	Fine sieve product		Hulled barley	1	Fine sieve product	Fine sieve by-product
17	167	Fine sieve product		Hulled barley	1	Fine sieve product	Fine sieve product
17	169	Fine sieve product		Hulled barley	1	Fine sieve product	Fine sieve by-product
17	217			Mixed	4		Fine sieve by-product

Room No.	Sample No.	Barley and free-threshing wheat ratio classification	Glume wheat ratio classification	Composition	Group No.	Classification based on crop/weed analysis	Classification based on Jones' (1990) weed/wild analysis
18	383			Mixed	4		Fine sieve by-product
Ncy	450	Fine sieve by-product		Hulled barley & Free-threshing wheat	2	Fine sieve by-product	Fine sieve by-product
Ncy	447	Fine sieve product		Hulled barley & Free-threshing wheat	2	Fine sieve by-product	Fine sieve by-product
Ncy	165	Fine sieve product		Hulled barley & Free-threshing wheat	2	Fine sieve product	Fine sieve by-product
TCH	388	Fine sieve by-product		Hulled barley	1	Fine sieve product	Fine sieve by-product

Chapter 8

Approaches to crop husbandry at Tell Brak

This chapter will explore approaches to crop husbandry at Tell Brak through the use of crop stable isotope analysis and functional weed ecology. These two methods produce complementary data that can be both compared and integrated to provide a detailed investigation into the use of different husbandry techniques and farming regimes. The first section will present the results from carbon and nitrogen crop stable isotope analysis, exploring variation between the different crop taxa and any sources of inter-room variability. The second section will present the results from functional ecological analysis. The final section will combine these two datasets to compare potential sources of variation *across* farming regimes.

8.1 Crop stable isotope analysis

This section will present the results of carbon and nitrogen stable isotope analysis carried out on two-row hulled barley grains, emmer wheat grains, small barley and small wheat grains from destruction level 11 of the Tell Brak TC oval building. These cereal grain taxa were taken from as many different rooms of the oval building as possible; however, the distinct composition of some rooms restricted the number of taxa analysed (see **Section 4.6.1.2**, **Chapter 4** for further information on sample selection). The results will focus first on the carbon stable isotope analysis followed by the

nitrogen stable isotope analysis. Differences among the four cereal taxa will be statistically analysed, but comparisons on a room-by-room level are limited by the number of samples studied. These results will then be used to assess potential crop husbandry practices, cereal growing conditions and land-use at the site of Tell Brak and to answer specific research questions set out in **Section 1.5**, **Chapter 1**.

8.2 Carbon – overview

Figure 8.1 shows the Tell Brak $\Delta^{13}C$ values and **Figure 8.2** shows the means and standard deviations for each taxa. The standard deviations for each taxon are fairly narrow, particularly the standard deviation for small wheat (see **Table 8.1**). All standard deviations, with the exception of small barley, fall within the ±0.5‰ value reported by Nitsch *et al*. (2015) for expected variation in $\Delta^{13}C$ values of cereals cultivated under the same growing conditions. This indicates the relative homogeneity of results within each taxon and suggests that each individual taxon was cultivated in one set of growing conditions. By contrast, there appears to be some differences in $\Delta^{13}C$ values between the taxa. From **Figure 8.1** the most visible differences are between the high values of hulled barley (n=22 - mean value of 17.23±0.47) and all other taxa (see **Table 8.1**). Moreover, small barley (n=9) had the lowest mean (15.91±0.59‰) and the greatest level of variability. The results of an ANOVA test performed on all samples confirm that there are significant differences among the taxa in terms of $\Delta^{13}C$ value (see **Table 8.2**). Additionally, the results of the post-hoc Tukey test prove that the differences visible from **Figure 8.1** are statistically significant; the large-grained hulled barley is statistically different from all other taxa in terms of $\Delta^{13}C$ values but there is no

statistical difference between the remaining three taxa (i.e. emmer wheat, small barley and small wheat). **Figure 8.3** displays the normalised $\delta^{13}C$ values.

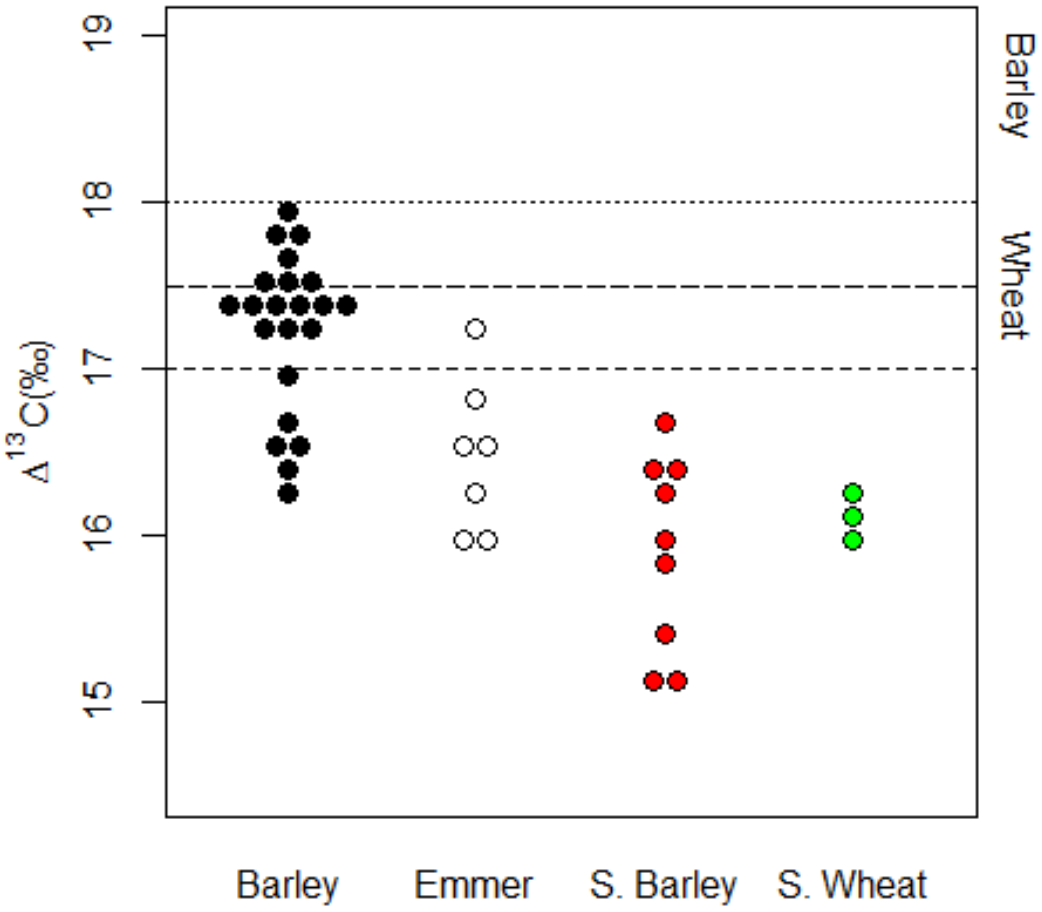


Figure 8.1 - $\Delta^{13}C$ values of the four major cereal taxa. The lower dashed line indicates the beginning of the 'well-watered' zone for wheat and the middle and upper dotted line, the beginning of the two potential 'well-watered' zones for barley.

Table 8.1 – The number of samples, means and standard deviations of $\delta^{13}C$ and $\Delta^{13}C$ values, by cereal taxa.

Taxon	No. of samples	Mean ($\delta^{13}C$ ‰)	Standard deviation ($\delta^{13}C$‰)	Mean ($\Delta^{13}C$ ‰)	Standard deviation ($\Delta^{13}C$ ‰)
Hulled barley	22	-23.2	0.45	17.23	0.47
Emmer	7	-22.47	0.42	16.47	0.43
Small barley	9	-21.93	0.57	15.91	0.59
Small wheat	3	-22.11	0.18	16.10	0.19

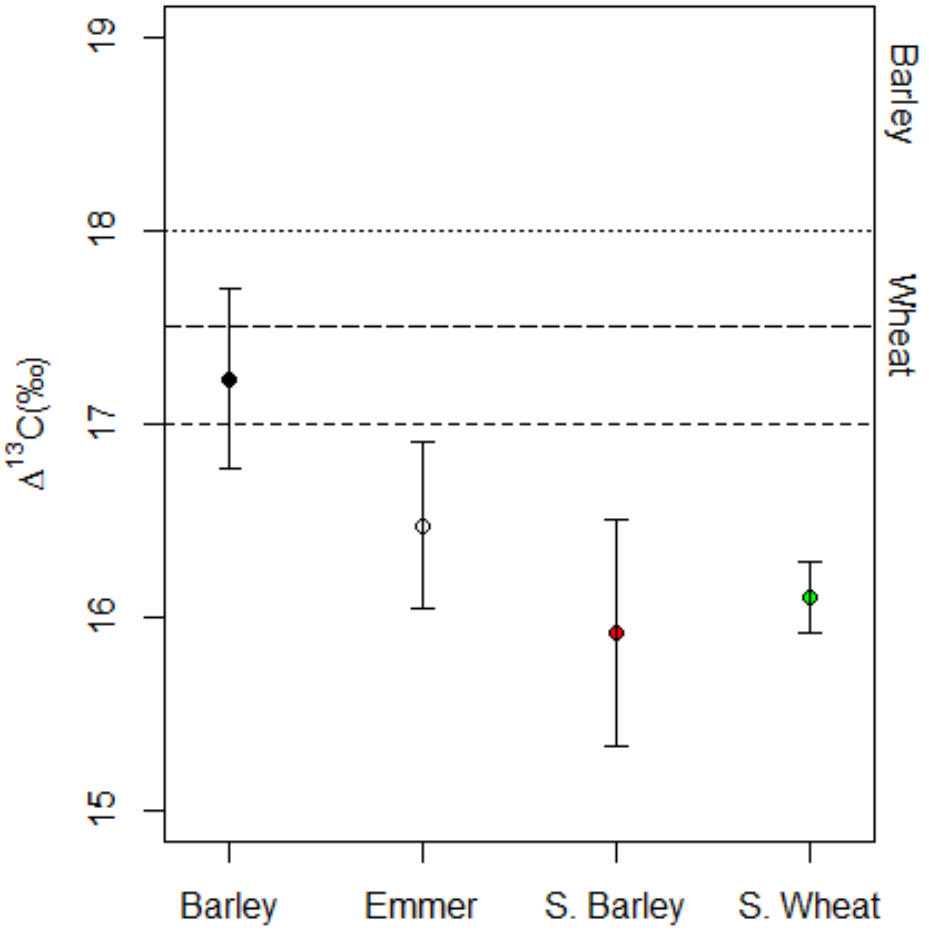


Figure 8.2 – The means and standard deviations of the $\Delta^{13}C$ values of the four cereal taxa.

Table 8.2 – Results of an ANOVA test and post-hoc analysis conducted on the $\Delta^{13}C$ values from all cereals with a 1‰, 0.5‰ and no offset applied to the barley.

Statistical Test	Species	Results (no offset)	Results (0.5‰ offset)	Results (1.0‰ offset)
ANOVA	All	F(3,37)=19.13, p=<0.0001	F(3,37)=16.51, p=<0.0001	F(3,37)=19.38, p=<0.0001
Post-hoc Tukey's Test	Emmer-Barley	0.00424	0.590	0.6465
Post-hoc Tukey's Test	S. Barley-Barley	<0.001	<0.001	<0.001
Post-hoc Tukey's Test	S. Wheat-Barley	0.00235	0.151	0.9679
Post-hoc Tukey's Test	S. Barley-Emmer	0.10876	<0.001	<0.001
Post-hoc Tukey's Test	S. Wheat-Emmer	0.66439	0.664	0.6643
Post-hoc Tukey's Test	S. Wheat-S. Barley	0.93559	0.151	0.0035

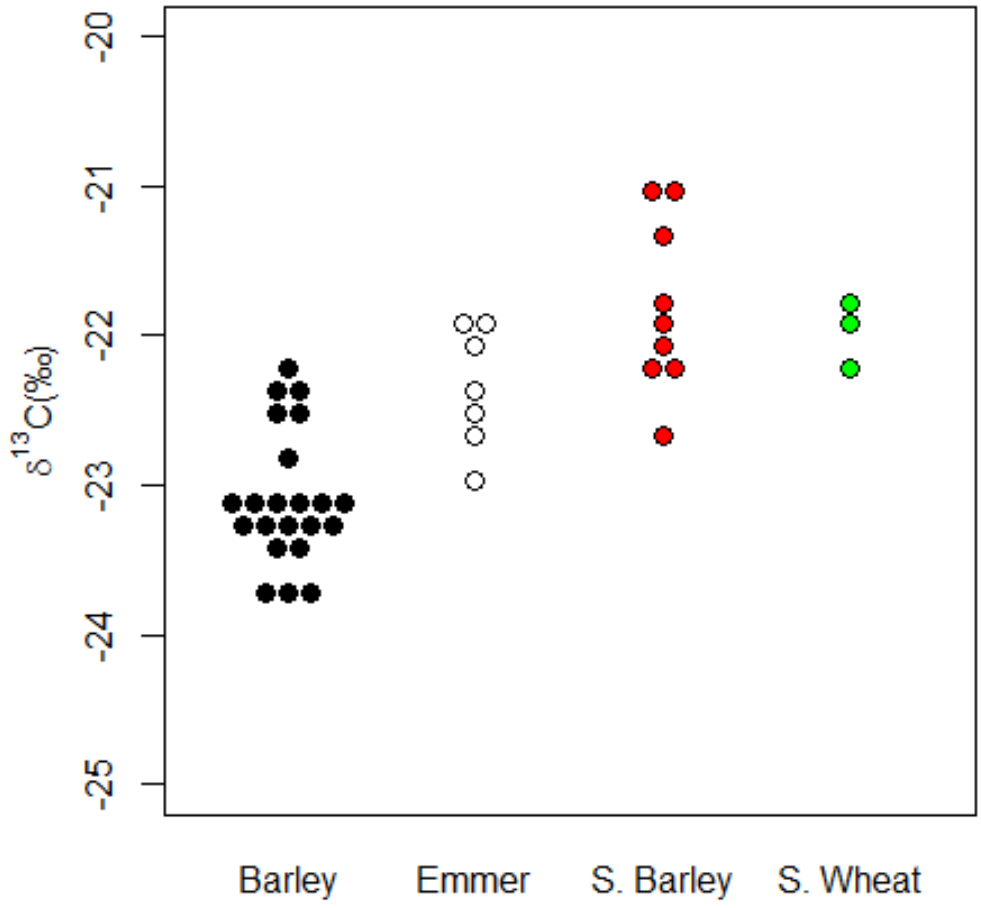


Figure 8.3 - $\delta^{13}C$ values of the four major cereal taxa.

This statistical difference may be due to physiological differences between wheat and barley, discussed in **Chapters 3** and **4.** Stable carbon isotope analysis of modern crops by Wallace *et al*. (2013) showed that there is a typical offset between specifically free-threshing wheat and 2-row hulled barley of 1-2‰ in $\delta^{13}C$ values. An offset of 1‰ and a slightly lower offset of 0.5‰ were applied to the hulled barley and small barley results to see whether this would affect the outcome of the initial ANOVA test result. The results of both ANOVA tests and post-hoc Tukey tests with applied offsets for the barley results are reported in **Table 8.2**. In both ANOVA tests there remains a significant statistical difference in $\Delta^{13}C$ values between the four taxa. The results of the post-hoc Tukey test, however, show that the differences between

individual pairings of cereals have changed. Without any offset large-grained hulled barley $\Delta^{13}C$ values were significantly different from all other taxa, but with offsets of both 0.5‰ and 1‰ this significant difference is erased. Instead, the $\Delta^{13}C$ values of small barley are significantly different from all other taxa, and particularly with regard to hulled barley and emmer ($p < 0.001$ in both cases).

These results indicate that whilst hulled barley, emmer wheat and small wheat were all grown under similar watering conditions, small barley was grown under considerably *drier* conditions. By comparison with the watering bands set out by Wallace *et al*. (2013) only one emmer wheat sample (14% of all emmer wheat values) falls within the well-watered range for wheat. All other samples fall markedly below this threshold (this includes all barley with and without an applied offset).

8.2.1 Carbon – inter-room variation

Figure 8.4 displays **Figure 8.1**, coded by room number. Due to the low number of samples extracted from some rooms, and the homogeneity of cereal taxa within specific rooms of the TC oval, each room is only represented by 1-2 samples or by a few samples from different taxa. This makes any analysis of intra- or inter-room isotopic variation very limited and **Figure 8.4** seems to show no clear patterning by room number. Indeed, the only rooms with enough samples for statistical analysis are the hulled barley and small barley samples from Rooms 12 and 16.

Welch's two-sample T-test was carried out on samples from Rooms 12 and 16 by taxon and indicates that hulled barley $\Delta^{13}C$ values from Room 12 were statistically

different from the results of Room 16 (see **Table 8.3**). By contrast, the small barley $\Delta^{13}C$ values from both rooms were not statistically different from each other, although these results may have been affected by the low number of small barley samples taken from Room 12. From **Figure 8.4** it appears that the hulled barley (n=5) values from Room 12 are slightly higher with a mean value of 17.44±0.11‰ indicating that these crops may have been grown under better watered conditions. By contrast, the hulled barley (n=10) $\Delta^{13}C$ values from Room 16 have a wider standard deviation and lower mean value, 17.03±0.51‰, indicating greater variation in terms of watering conditions. These conclusions regarding inter-room variation, however, are very tentative given the uneven distribution of analysed samples across rooms. **Figure 8.5** shows $\delta^{13}C$ values coded by room number.

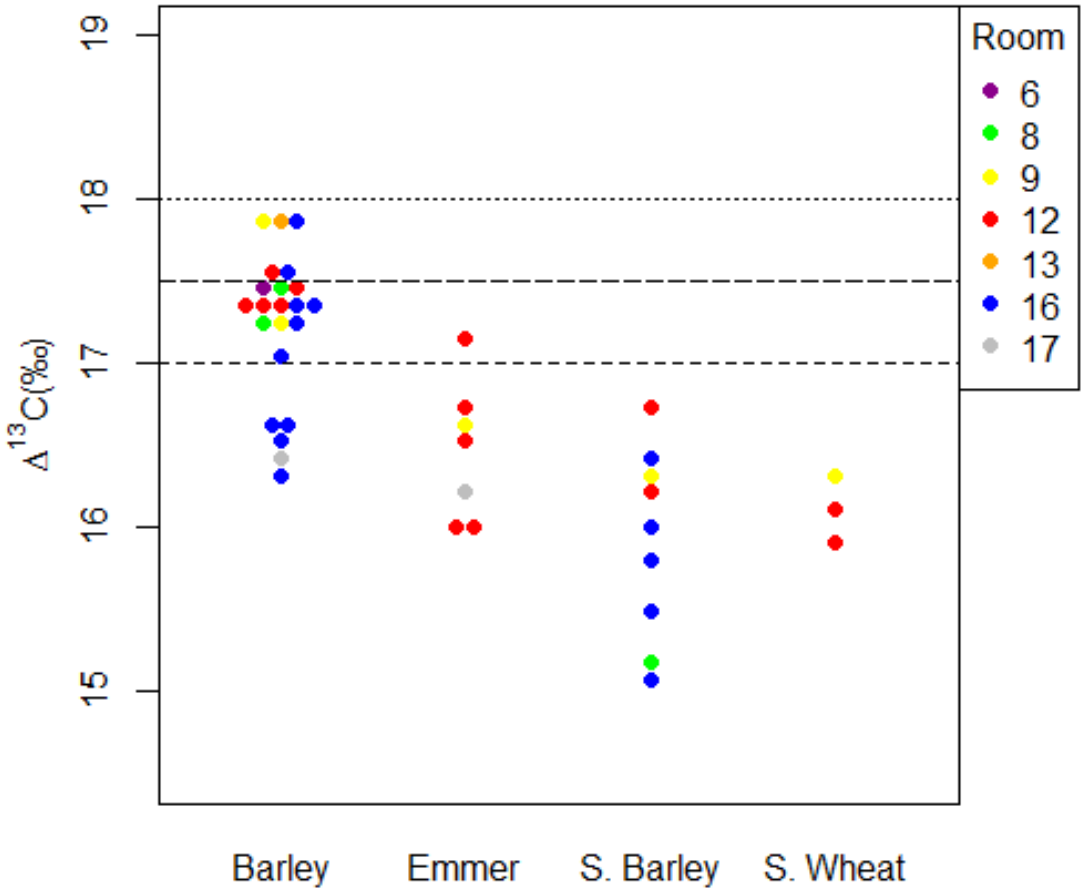


Figure 8.4 – $\Delta^{13}C$ values of the four major cereal taxa, coded by room number.

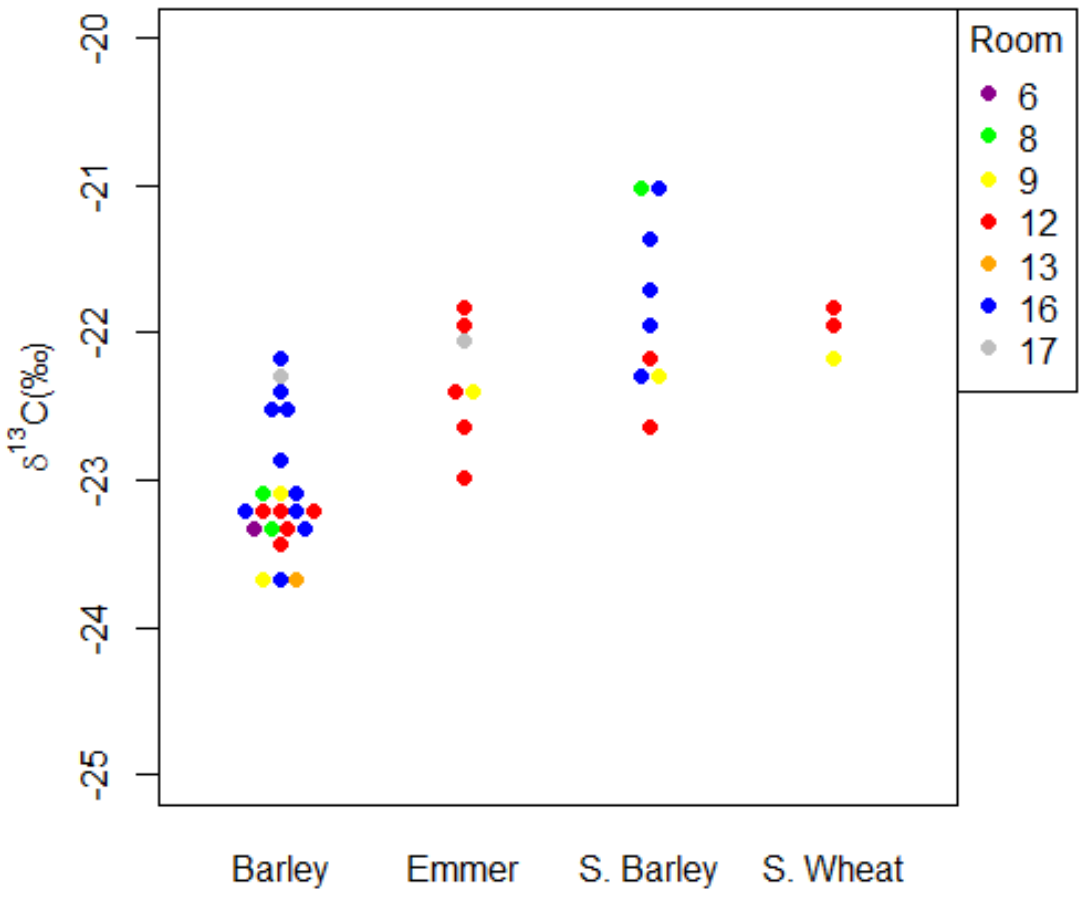


Figure 8.5 – $\delta^{13}C$ values of the four major cereal taxa, coded by room number.

Table 8.3 – Results of Welch's two sample T-test conducted on the $\Delta^{13}C$ and $\delta^{15}N$ values from Rooms 12 and 16.

Statistical Test	Isotopic Analysis	Species	Room No.	Results
Welch's two sample T-test	Carbon	Hulled barley	Twelve - Sixteen	T(10.60)=-2.41, p=0.0354
Welch's two-sample T-test	Carbon	Small barley	Twelve - Sixteen	T(2.86)=-2.26, p=0.113
Welch's two-sample T-test	Nitrogen	Hulled barley	Twelve - Sixteen	T(4.07)=-0.85, p=0.4416
Welch's two-sample T-test	Nitrogen	Small barley	Twelve - Sixteen	T(4.97)=0.38, p=0.7191

8.3 Nitrogen – overview

Figure 8.6 and **Figure 8.7** show the crop stable nitrogen isotope results alongside the means and standard deviations for each taxon. In comparison with the stable carbon isotope results there is a much wider range of values for all taxa, encompassing high values of 9.3‰ to low values of 1.9‰. Moreover, the standard deviations measured for all taxa (see **Table 8.4**) are wider than the 1‰ predicted variation value for crops cultivated within a single growing condition (Nitsch *et al*. 2015) and there are substantial differences between the results for each cereal taxon. For example, the mean $\delta^{15}N$ value for hulled barley (n=22) is quite low, 3.86±1.68‰, whilst the mean value for small wheat (n=3) is relatively high, 7.93±1.09‰. Similarly, the results of small barley (n=9) are the most variable with a standard deviation of 2.07‰ and from **Figure 8.6** it would appear that these values are grouped into two separate clusters. These values would suggest that hulled barley and small wheat were being grown separately and under varying conditions of artificial enrichment, but with a considerable amount of variability within each taxon. The results of an ANOVA test performed on all samples confirm that there are significant differences among the taxon $\delta^{15}N$ values (see **Table 8.5**). Furthermore, the results of the post-hoc Tukey test show that the $\delta^{15}N$ values of hulled barley are significantly different from the values of the other three cereals. By comparison emmer wheat, small barley and small wheat show no significant variation in $\delta^{15}N$ (see **Table 8.5**).

When comparing the $\delta^{15}N$ values from Tell Brak with the manuring levels constructed by Bogaard *et al*. (2013) for temperate Europe, it would seem that the cereal crops stored within the TC oval were grown in multiple conditions/locations with varying levels of artificial enrichment. Tell Brak, however, is located in a semi-arid environment with a low average rainfall which may have contributed to an ecosystemic

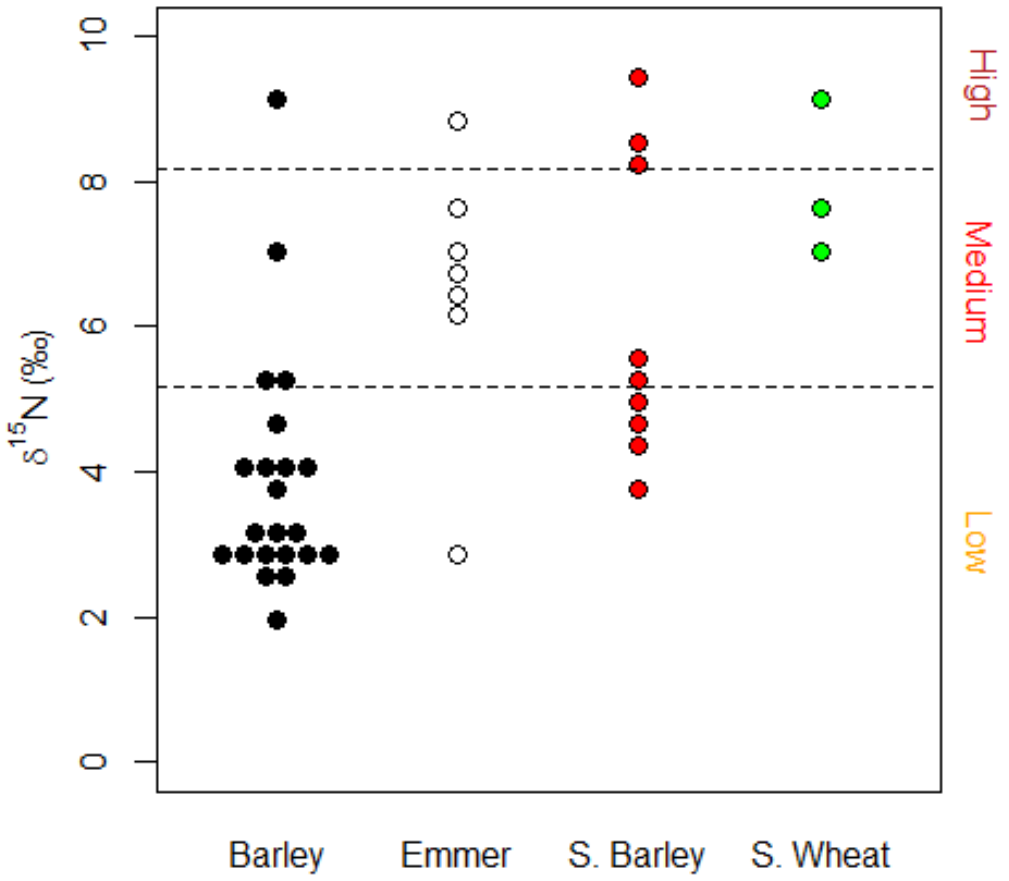


Figure 8.6 – $\delta^{15}N$ values of the four major cereal taxa, with manuring bands adjusted for aridity.

Table 8.4 – The number of samples, means and standard deviations of $\delta^{15}N$ values from all four cereal taxa.

Taxon	No. of samples	Mean (‰)	Standard deviation (‰)
Hulled barley	22	3.86	1.68
Emmer	7	6.50	1.87
Small barley	9	6.06	2.07
Small wheat	3	7.93	1.09

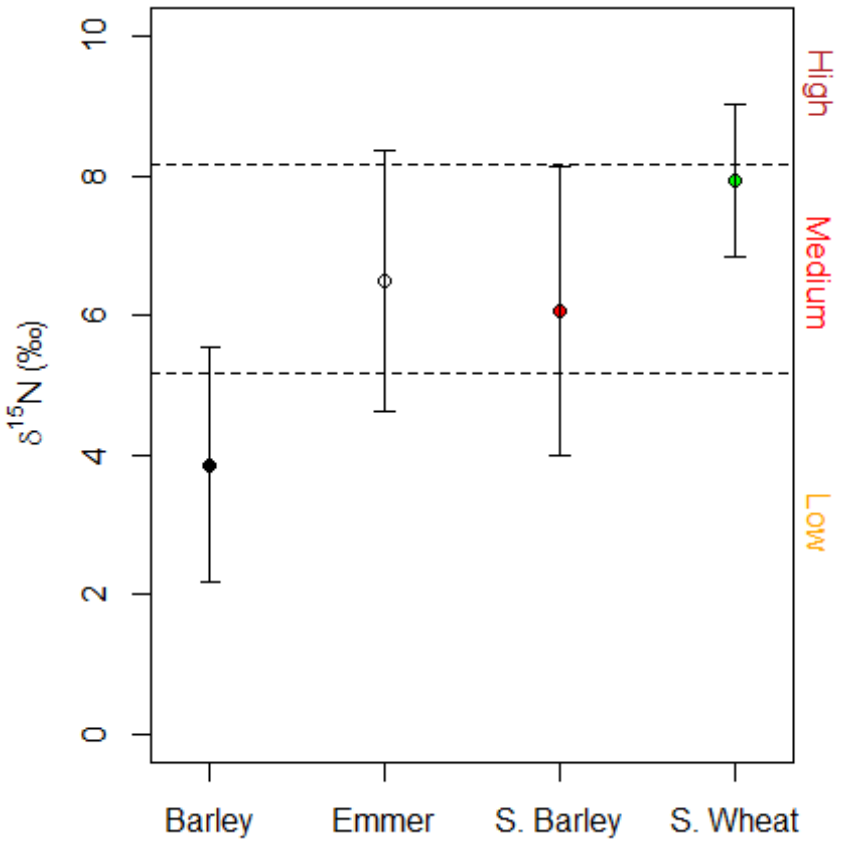


Figure 8.7 – The means and standard deviations of the $\delta^{15}N$ values of the four cereal taxa.

Table 8.5 – Results of an ANOVA test and post-hoc analysis on the $\delta^{15}N$ values of the four cereal taxa.

Statistical Test	Species	Results
ANOVA	All	F(3,37)=0.807, p=4981
Post-hoc Tukey's Test	Emmer-Barley	0.0076
Post-hoc Tukey's Test	S. Barley-Barley	0.0160
Post-hoc Tukey's Test	S. Wheat-Barley	0.0034
Post-hoc Tukey's Test	S. Barley-Emmer	0.9596
Post-hoc Tukey's Test	S. Wheat-Emmer	0.6404
Post-hoc Tukey's Test	S. Wheat-S. Barley	0.3926

enrichment in ^{15}N separate from any human activity. This aridity effect, therefore, has to be taken into account when interpreting these results by using a regression line first postulated by Hartman & Danin (2010) and modified by Styring *et al.* (2016a). Taken from the WorldClim database (Hijmans *et al*. 2005); the modern average rainfall at Tell Brak is 363mm/year. This value has, however, been adjusted using speleothem $\delta^{18}O$ values from Soreq Cave in Israel (Bar-Matthews & Ayalon, 2011) and the present-day calibration relationship between these values and rainfall. Past rainfall at Tell Brak during the Early Dynastic III period, therefore, has been estimated at 313mm/year (Styring *et al*. 2017). This level of aridity could potentially cause an increase of 1.8‰ in $\delta^{15}N$ values, although this value is corrected to 1.4‰ to take into account the offset between the cereal's grains and leaves (Styring *et al.* 2016a).

The manuring levels, consequently, have been adjusted to account for this aridity effect and to more accurately reflect the true level of artificial enrichment at Tell Brak. With this in mind, it would seem that a number of samples exhibit high $\delta^{15}N$ values that exceed the ^{15}N enrichment caused by aridity alone. Overall, hulled barley was apparently grown without the use of artificial enrichment, or with only very low amounts. By contrast, emmer wheat and small wheat seem to have been treated preferentially, receiving medium to high levels of artificial enrichment. Finally, the separation of small barley into two unique groups suggests that this crop was being grown in conditions of both high and low enrichment and/or in different areas of the Tell Brak landscape from the other cereals.

8.3.1 Nitrogen – inter-room variation

Figure 8.8 shows sample values coded by room number. As was evident from the carbon results there is no clear patterning by room. Hulled barley and small barley from Rooms 12 and 16 again were the only taxa that could be compared on an inter-room level. Welch's two-sample T-test was performed on these results and indicated that there was no significant difference between the two rooms (see **Table 8.3**). This may suggest that each room within the TC oval contained a mixture of cereal taxa grown under multiple conditions/in a variety of locations, and that each individual room did not contain the produce from one particular regime or farming area within the Tell Brak landscape.

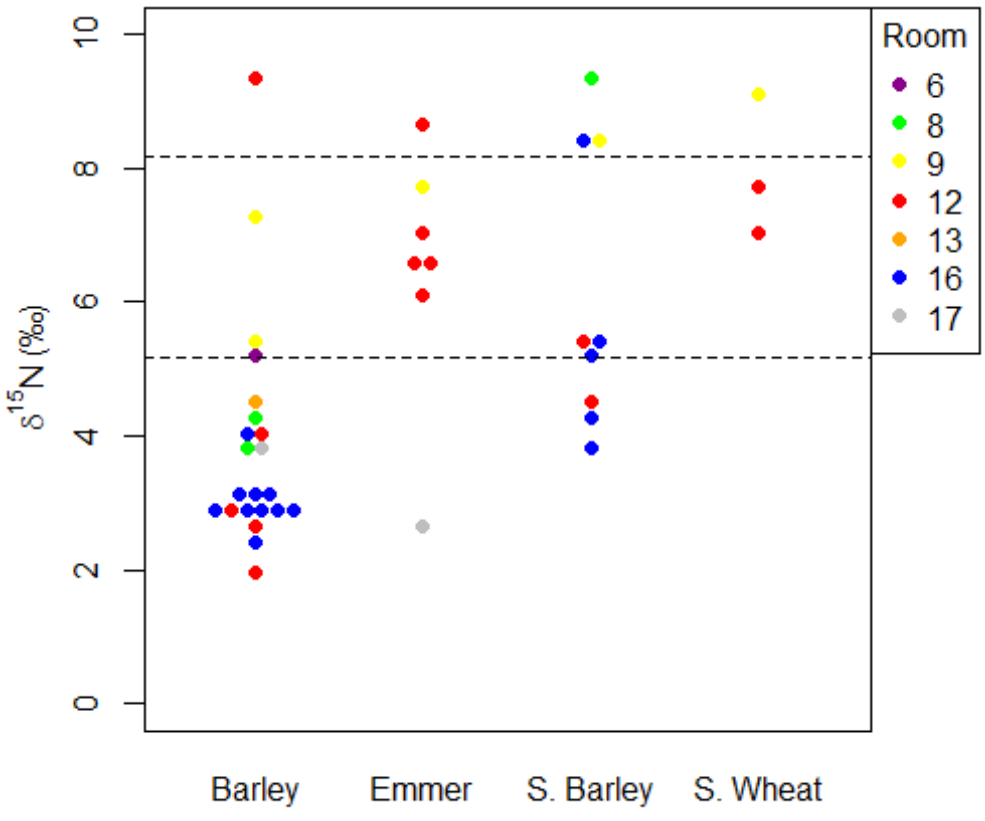


Figure 8.8 – $\delta^{15}N$ values of the four major cereal taxa, coded by room number.

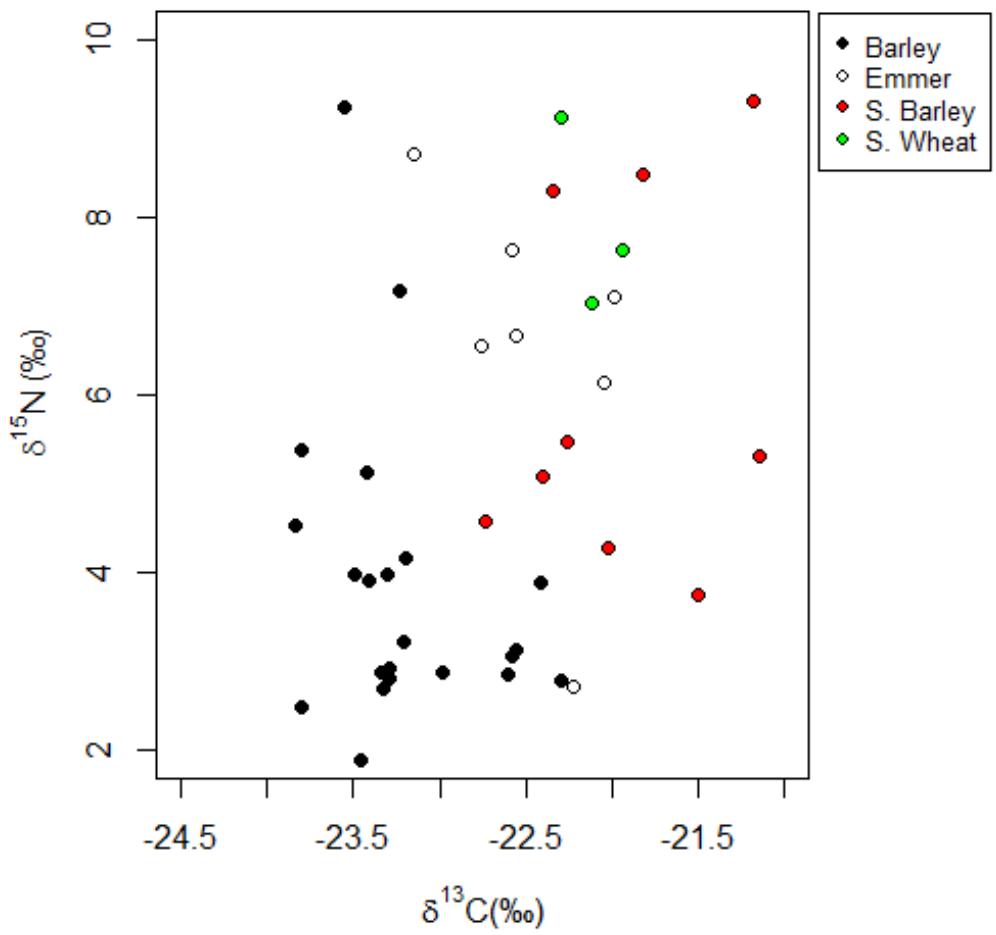


Figure 8.9 – Scatterplot of all crop stable isotope carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) values, coded by cereal taxon.

8.4 The relationship between carbon and nitrogen

Figure 8.9 shows a scatterplot of all crop stable isotope carbon and nitrogen values, coded by cereal taxon. Generally there appears to be some significant clustering of samples by taxa. This is most obvious with regards to values from hulled barley which are clustered together at the lower end of both axes. By contrast, the results of the small hulled barley variety appear to have consistently higher $\delta^{13}C$ values than hulled barley. In terms of $\delta^{15}N$ values, however, small hulled barley shows the greatest levels of variation of all taxa measured. By contrast, emmer wheat and small wheat have

generally higher $\delta^{13}C$ and $\delta^{15}N$ values. Overall, a slight positive correlation (correlation coefficient = 0.36) between high $\delta^{15}N$ values and high $\delta^{13}C$ values and between low $\delta^{15}N$ values and low $\delta^{13}C$ values is visible from all results. This correlation, however, is not statistically significant ($T(39)=2.38$, $p=0.0219$).The results of **Figure 8.9** have not been further coded by room number. This is because the number of samples taken from each individual room was very variable and any visible patterns would only reflect differences in cereal taxa stable isotope values, rather than any actual disparity by room.

8.5 Crop stable isotope analysis conclusions

The results of carbon and nitrogen stable isotope analysis of four different cereal crops from Tell Brak indicate that there was preferential treatment of certain crops in terms of both artificial enrichment and use of advantageous watering conditions. During the Early Dynastic III period Tell Brak was located in a marginal area for rain-fed farming and probably encompassed the southerly limits of this type of agriculture. Additionally, this landscape did not lend itself to large-scale irrigation and it is unlikely that these watering systems were established until the development of the petrol-driven water pump in the 20th century AD. Variation in $\Delta^{13}C$ values by taxon are, therefore, unlikely to be a result of artificial watering. Instead, these differences may have been caused by the utilization of better-watered soils, near the wadis, for the cultivation of wheat crops. By contrast, the low $\Delta^{13}C$ values of the small barley grains suggest that this taxon was a distinct variety grown under drier conditions within the Tell Brak landscape. Additionally, the unique treatment of small barley might indicate that this variety was initially selected and cultivated due to its drought-tolerant capabilities.

The variable nitrogen stable isotope results are also likely to be due to the preferential treatment of some crop taxa. The low $\delta^{15}N$ values reported for hulled barley would suggest that this taxon was being cultivated on land without any form of artificial enrichment. By contrast, the values for emmer wheat and small wheat indicate the use of some form of manure/middening material within the land-use history of the areas where these taxa were cultivated. Additionally, sherd scatters found within the landscape around Tell Brak support the use of manure/middening material within certain cultivation areas (Wilkinson, 1994). Recent work by Styring *et al*. (2017) has posited the use of a manuring/middening spectrum which fades in intensity with distance from the main mound due to the difficulty of transporting this bulky resource over long distances. Furthermore, stable isotope analysis of crops from late Chalcolithic domestic contexts at Tell Brak indicates that individual households had access to cereals grown under a range of conditions and/or a range of distances from the main city (Styring *et al*. 2017). These Late Chalcolithic stable isotope values complement the results from the TC oval building and suggest that different cereal taxa were planted in specific areas of the Tell Brak landscape to exploit both naturally occurring environmental conditions and artificially enhanced soils. Finally, the results from the inter-room analyses suggest that each of the rooms in the TC oval were used for storing an assortment of crops grown under multiple conditions/in multiple agricultural environments, rather than containing crops from one single regime/location.

8.6 Weed evidence and functional ecological analysis

This section will present the results of ecological analysis performed on the arable weed assemblage identified in the TC oval samples from Tell Brak. These

analyses will be used to investigate crop sowing times and to categorize the Tell Brak farming regimes as low and/or high-intensity (see **Section 4.6.2**, **Chapter 4** for a more detailed methodology). The results of the functional ecological analysis will be compared to those from the stable isotope analysis discussed in S**ections 8.2** and **8.3**. The combination of these results will be used to identify potential crop husbandry practices and cereal growing conditions used in the cultivation of cereal crops from the Early Dynastic III period at Tell Brak.

In **Chapter 7**, detailed species identification and crop processing analysis has allowed an understanding of the chief components of the TC oval assemblage and the formation processes that led to its eventual deposition. These techniques have indicated that the archaeobotanical material recovered from the TC oval is primarily representative of clean, processed cereal crops and that identified weed/wild taxa remains are likely to have derived from the arable fields. Ecological information from the *Flora of Iraq* (Guest, 1966-1985) has also been used to support the identification of these arable weeds and has indicated that the majority of identified weed/wild taxa are commonly found today in places of cultivation and fallow fields. Other plant related activities that may have had a taphonomic effect on the assemblage, such as the storage of dung and/or dung burning, have been ruled out due to the lack of identified dung-derived weed/wild taxa (Charles, 1998) and contextual evidence. These multiple strands of evidence suggest that the majority of weed taxa identified from the TC oval assemblage were directly associated with the cultivation of glume wheat and hulled barley crops stored within this building. The use of functional weed ecology will, therefore, provide evidence for crop husbandry techniques used in the production of these crops as well as indicating the degree of farming intensity employed by a segment of Tell Brak farmers from the Early Dynastic III period.

The permanence of agriculture at Tell Brak has been established using ecological information from the *Flora of Iraq* (Guest, 1966-1985) to assess the preferred habitats and lifecycles of identified arable weeds and environmental reconstructions of the region based on pollen and charcoal evidence. The majority of the arable weeds identified from the TC oval assemblage have an annual rather than perennial growing cycle and are suited to open, cultivated habitats and waste/fallow land (Guest, 1966-1985). Correspondingly, environmental reconstructions based on anthracological and palynological studies have shown that the extensive *Quercus* woodland surrounding Tell Brak was dramatically reduced during the Late Chalcolithic - Early Bronze Age due to a period of increased aridity (Bottema & Cappers, 2000; Deckers, 2011). The improving climate c. 3000 BC allowed inhabitants of the site to take advantage of this increase of cultivable land leading to an increase in grass/shrub steppe and agricultural fields. These two strands of evidence, coupled with the known history of cultivation at Tell Brak (Charles & Bogaard 2001; Hald, 2005; 2008) support the hypothesis that cereal cultivation during the Bronze Age was permanent and well-established.

8.7 Sowing time

Modern experimental research first developed in Germany by Bogaard *et al*. (2001) has sought to use information from the functional attributes of weed species to distinguish spring from autumn sown crops (see **Section 4.6.2**, **Chapter 4** for a more detailed methodology). Within this work it was established that the month of flowering onset and the length of the flowering period can be used to predict the initial germination time of these plants and thus the associated crop sowing time. To this

effect, autumn germinating plants flower in late spring/early summer and are associated with autumn sown crops, and spring germinating plants flower in the autumn and are associated with spring sown crops. In temperate Europe plants with a short flowering period (1-3 months) and an early flowering onset (January-June) are associated with an autumn sowing period. By contrast, plants with extended flowering periods and/or late flowering onsets are associated with spring sown crops. Many species, however, fall into an intermediate category, for example *Sinapis* cf. *arvensis* has an early flowering onset and a medium flowering period so cannot be correlated with either autumn or spring sown crops.

This research, however, must be adapted for use in north-eastern Syria as due to obvious climatic differences; the period of plant growth and harvest generally occur earlier in the year than the respective period in temperate Europe. Harvest time in north-eastern Syria falls during late May and June and the crops are generally sown during the autumn. This is done to take advantage of the winter and spring rains and to avoid the hot and dry summers that are common to this region (Charles *et al*. 2010). This harvest time is about two months earlier than the German harvest time used in the Bogaard *et al*. (2001) study, and so flowering categories have been modified to reflect this. All identified arable weed species from the TC oval assemblage with available flowering onset data from the *Flora of Iraq* (Guest, 1966-1985) were categorised (see **Table 8.6** for the specific criteria used for each category) as early/short flowering (early onset and short flowering periods), late flowering or long flowering. Weed species that did not fit into these categories were classified as indeterminate. Where weed remains had only been identified to the genus level, all weed species from the appropriate environmental and geographic region around Tell Brak were merged to create a single combined result.

Table 8.6 – Summary of flowering categories used for the Tell Brak weed/wild taxa based on flowering onset and flowering duration.

Month of flowering onset	Duration of flowering period	Flowering period classification
January-May	1-3 months	Short flowering/early-intermediate onset
June onwards	1-5 months	Late flowering
January-May	>5 months	Long flowering

Table 8.7 shows all flowering data for identified arable weed species. Of the 32 species for which information was available, 17 species fall within the early/short category and have been classified in the autumn sowing class. No species have late flowering onsets or late flowering periods so no species have been classified in the spring sowing class. **Figure 8.10** shows species number against the month of flowering onset, coded by flowering category. This shows that all identified species would have begun flowering early in the year (February-May), and again this is indicative of an autumn/winter germination period. Additionally, the majority of these species would have matured and produced seeds by late May/June and would have been harvested alongside the cereal crops. These results indicate that the crops recovered from the TC oval building were likely to have been sown in the autumn rather than the spring, due to the number of arable weed taxa identified as autumn germinating. Crop processing, however, can bias results against spring sown taxa (Bogaard *et al*. 2001) as these species are commonly removed during fine sieving. It is possible that any spring sown taxa may have been removed from the assemblage during processing and in particular from the very clean samples stored in Room 16. Samples from Room 12, however, have been classified as fine sieve by-products and do not contain any identifiable spring sown taxa. This would suggest that the omission of spring sown taxa from the rest of the assemblage is not due to a processing bias but rather a true representation of the range

Table 8.7 – All flowering data for identified arable weed taxa from Tell Brak, including overall sowing class.

Taxa	Species No.	Ubiquity of Taxa (%)	Flowering onset	Flowering onset class	Flowering duration class	Combined classification	Sowing class
Eremopyrum cf, bonaepartis	1	16	March	Early	Short	Early/Short	Autumn
Lolium temulentum	1	2	March	Early	Short	Early/Short	Autumn
Malva cf. parviflora	1	3	March	Early	Short	Early/Short	Autumn
Adonis sp.	3	7	March, April	Early	Short	Early/Short	Autumn
Alyssum sp.	6	2	March, April	Early	Short/medium	Early/Short	Autumn
Trigonella sp.	8	22	March, April	Early	Short	Early/Short	Autumn
Malva sp.	3	14	March, April	Early	Short	Early/Short	Autumn
Papaver sp.	7	5	March, April, May	Early/intermediate	Short/medium	Early/Short	Autumn
Aegilops crassa	1	69	April	Early	Short	Early/Short	Autumn
Aegilops speltoides	1	47	April	Early	Short	Early/Short	Autumn
Aegilops tauschii	1	55	April	Early	Short	Early/Short	Autumn
Gypsophila cf. pilosa	1	29	April	Early	Short	Early/Short	Autumn
Papaver cf. rhoeas	1	5	April	Early	Short	Early/Short	Autumn
Malva cf. sylvestris	1	5	April	Early	Short	Early/Short	Autumn
Coronilla scorpiodes	1	17	April	Early	Short	Early/Short	Autumn
Vaccaria pyramidata	1	34	April	Early	Short	Early/Short	Autumn
Valerianella cf. dentata	1	2	April	Early	Short	Early/Short	Autumn
Poa sp.	4	16	February, March	Early	Short/medium	Indeterminate	Indeterminate
Ornithogalum/Bellevalia/ Muscari sp.	16	7	February, March, April	Early	Short/medium	Indeterminate	Indeterminate
Muscari sp.	4	7	February, March, April	Early	Short/medium	Indeterminate	Indeterminate
Silene sp.	6	10	February, March, April	Early	Short/medium/long	Indeterminate	Indeterminate
Sinapis cf. arvensis	1	24	March	Early	Medium	Indeterminate	Indeterminate
Poa cf.annua	1	3	March	Early	Medium	Indeterminate	Indeterminate

Taxa	Species No.	Ubiquity of Taxa (%)	Flowering onset	Flowering onset class	Flowering duration class	Combined classification	Sowing class
Poa bulbosa	1	3	March	Early	Medium	Indeterminate	Indeterminate
Hordeum marinum cf.	1	7	March	Early	Medium	Indeterminate	Indeterminate
Hordeum spontaneum cf.	1	16	March	Early	Medium	Indeterminate	Indeterminate
Bromus sp	9	3	March, April, May	Early/intermediate	Short/medium	Indeterminate	Indeterminate
Galium sp.	10	19	March, April, May	Early/intermediate	Short/medium/long	Indeterminate	Indeterminate
Lolium cf. rigidum	1	57	April	Early	Medium	Indeterminate	Indeterminate
Chenopodium cf. album	1	2	May	Intermediate	Medium	Indeterminate	Indeterminate
Papaver cf. argemone	1	2	May	Intermediate	Short	Indeterminate	Indeterminate
Taeniatherum sp.	2	2	April, May	Intermediate	Short	Indeterminate	Indeterminate

of species present within the Tell Brak fields. A number of species, however, were classified as indeterminate due primarily to a medium flowering period. This would not necessarily prevent the inclusion of these species from an autumn sowing classification but does mean that they may have continued to flower throughout the crop harvesting period. Inclusion in the TC oval assemblage could, therefore, have potentially occurred after harvesting was completed indicating that these species were not directly associated with the crops. **Figure 8.11** and **Figure 8.12** show species number and month of flowering onset coded by room number and dominant cereal type. This was done to examine whether sowing time may have varied from room to room within the TC oval building, or by the dominant cereal type present within each sample. Both **Figure 8.11** and **Figure 8.12** show no apparent patterns indicating that all cereal species were autumn-sown and that individual rooms in the TC oval building were not used for storing crops that had been grown at different times during the year.

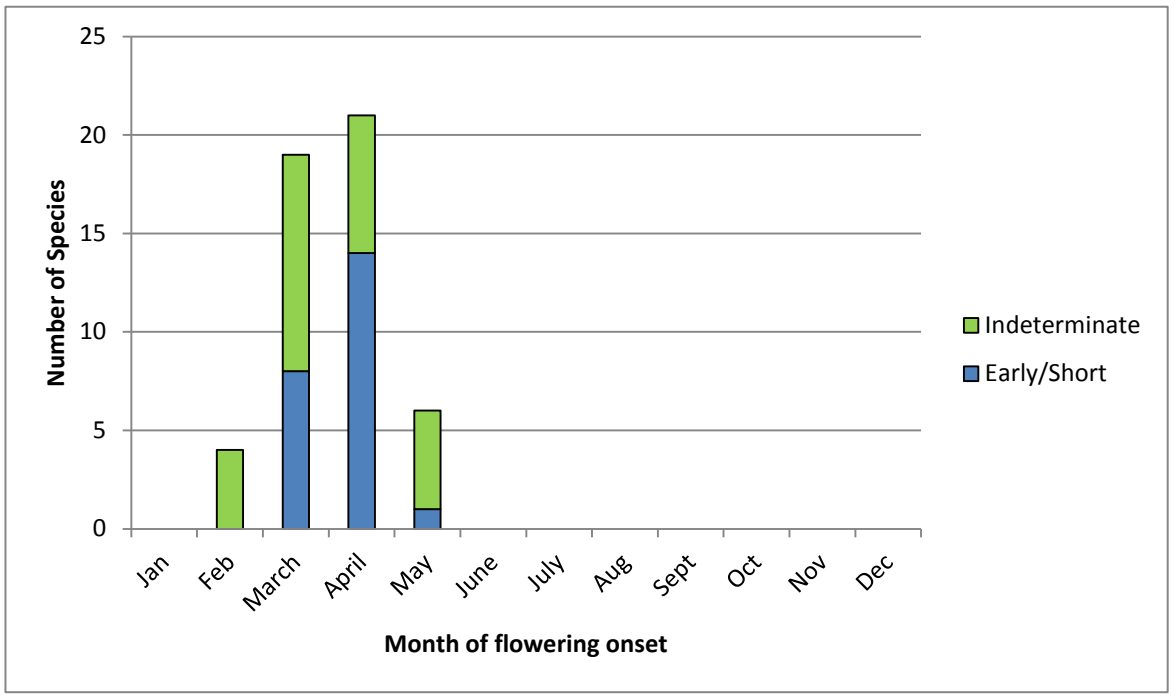


Figure 8.10 – Bar chart showing the number of weed taxa against the month of flowering onset, coded by flowering classification.

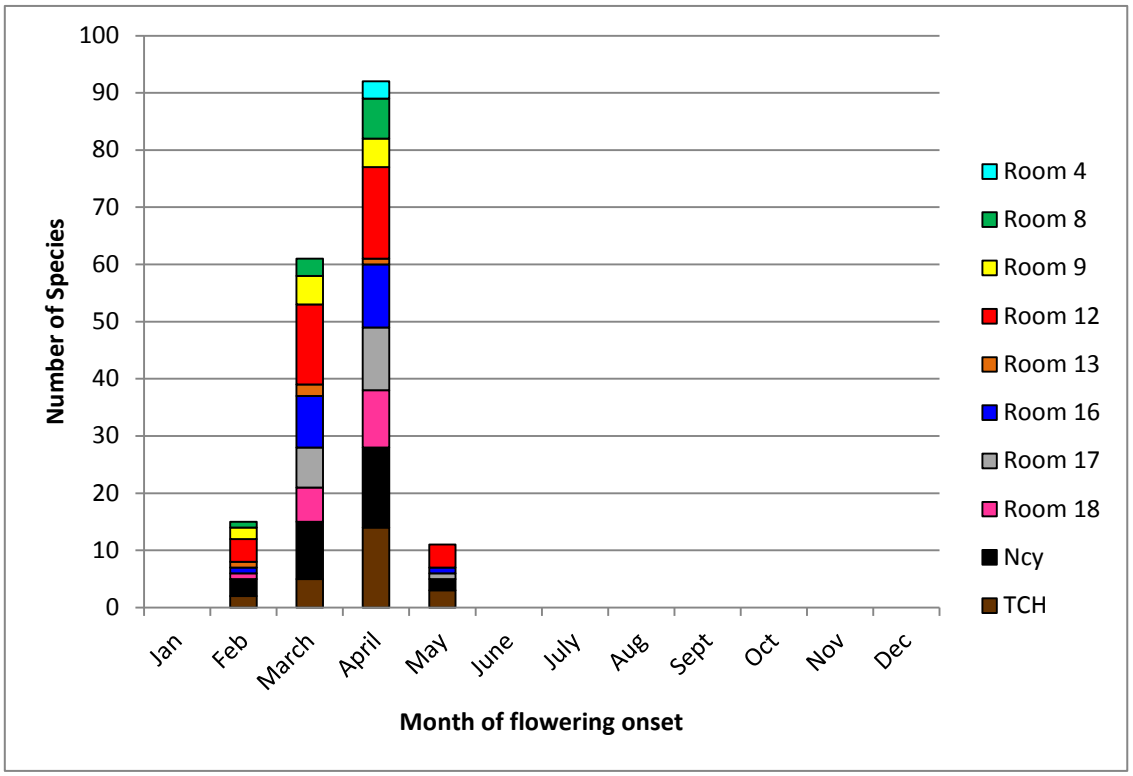


Figure 8.11 – Bar chart showing the number of weed taxa against the month of flowering onset, coded by room number.

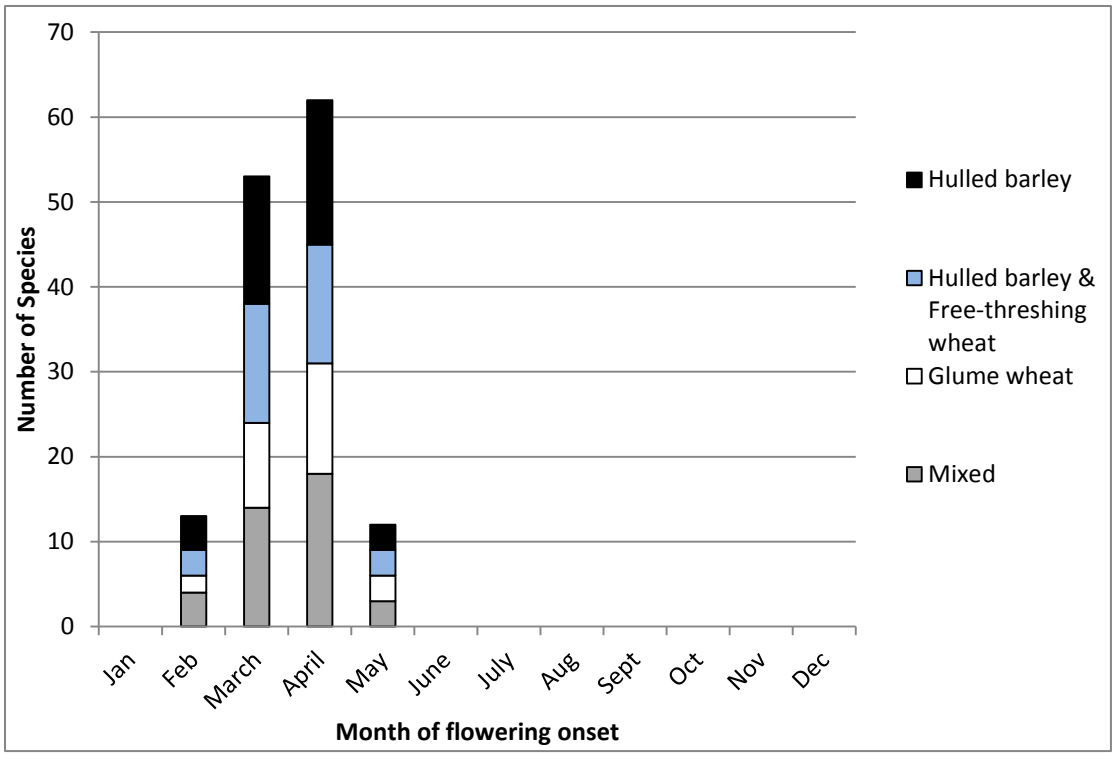


Figure 8.12 – Bar chart showing the number of weed taxa against the month of flowering onset, coded by dominant cereal taxa.

8.8 Intensity of cultivation

The intensity of cultivation was assessed by comparing semi-quantitative arable weed data from Tell Brak with modern field weed data using discriminant analysis. Arable weed data from Tell Brak included all remains identified to the species level, but excluded species that occurred in only one sample (see **Table 12.8**, **Appendix** for full list of species included). Additionally, only samples that contained 10 or more weed seeds were included leading to the exclusion of 12 samples (see **Table 12.9**, **Appendix** for list of samples excluded). One-off weed species and samples with very low quantities of weed seeds were removed from this analysis as their scores would have been unfairly weighted by one weed species. Modern comparative arable weed data has been taken from the amalgamated presence/absence field data of four modern field studies (e.g. Jones *et al*. 1999; Bogaard *et al*. 2016a; 2016b). These studies were undertaken in a variety of climate zones as well as a range of high- and low-intensity crop husbandry regimes (see **Section 3.3.2**, **Chapter 3** for further information).

Discriminant analysis was then used to maximise the separation between the pre-defined high- and low-intensity groups based on the functional ecological attributes of identified weed taxa (see **Section 4.6.2**, **Chapter 4** a more detailed methodology). **Figure 8.13** shows the individual field data from these modern studies with each field represented by one data point. These points have been classified into the two different intensity regimes; high-intensity agricultural regimes (black points) and low-intensity agricultural regimes (white points), with 94% of fields (179 out of 190 fields) correctly reclassified (Bogaard *et al*. 2016b). These points have also been used to create average scores for each type of regime, as illustrated by the larger group centroids.

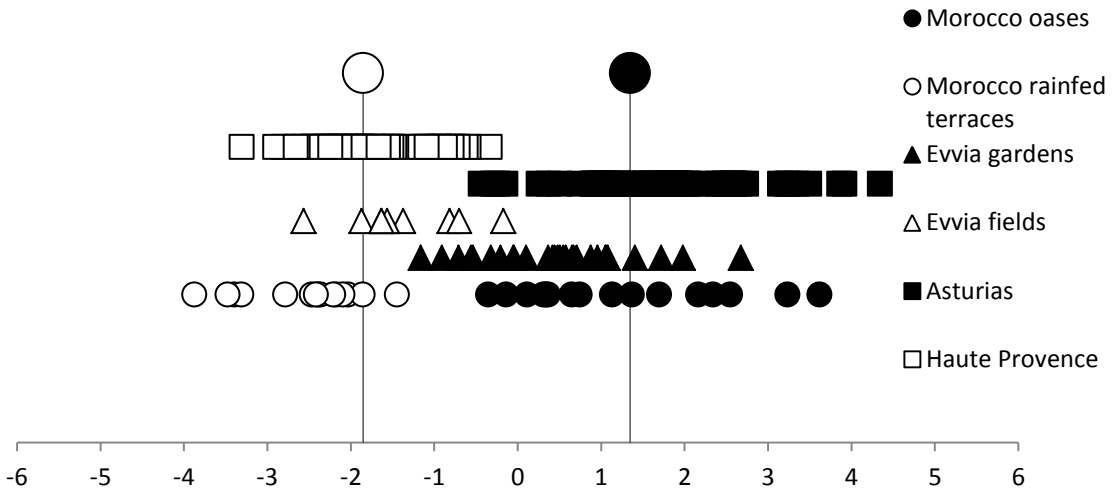


Figure 8.13 – Combined plot of modern field survey samples in relation to the discriminant function extracted to distinguish between high (black) and low (white) intensity crop husbandry regimes.

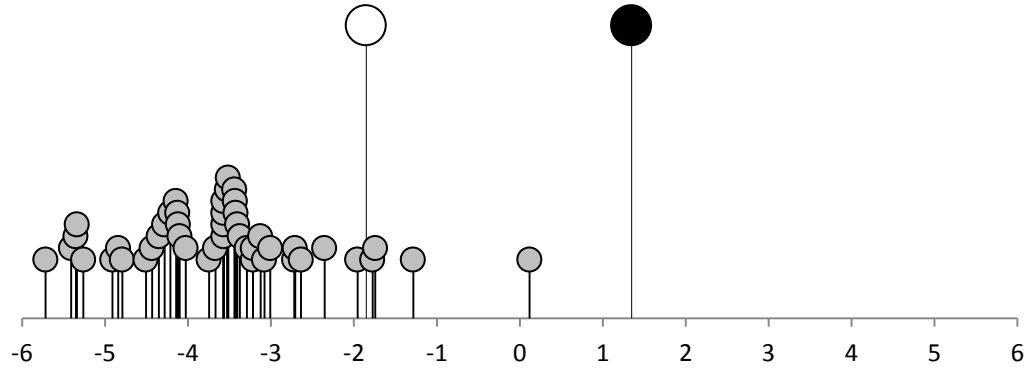


Figure 8.14 – Plot of Tell Brak samples in relation to the discriminant function extracted to distinguish between high and low intensity crop husbandry regimes.

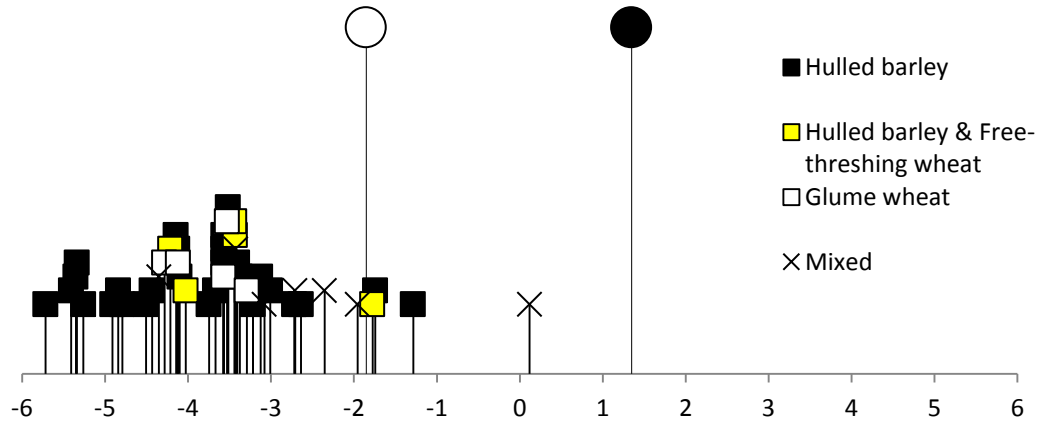


Figure 8.15– Plot of Tell Brak samples in relation to the discriminant function, coded by dominant crop taxa.

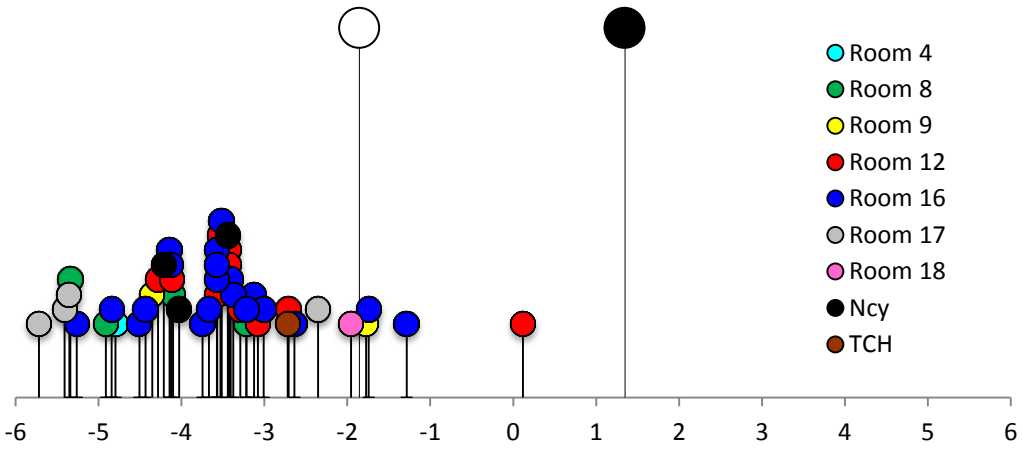


Figure 8.16 – Plot of Tell Brak samples in relation to the discriminant function, coded by room number.

This discriminant function was then used to classify the Tell Brak archaeobotanical samples as unknown cases. A total of 46 samples from the TC oval assemblage were classified; 12 samples were removed from the analysis due to a lack of weed/wild taxa. The discriminant analysis function extracted to maximise separation of the modern groups was then used to classify the archaeobotanical samples (average probability of 0.99) as either high-intensity or low-intensity (see **Table 8.8** for all probabilities). **Figure 8.14** displays the results of this discriminant analysis and from this it is clear that the vast majority of Tell Brak samples are classified as low-intensity and are located towards the far left of the axis and the low-intensity centroid. One sample from Room 12 has been classified as high-intensity. This sample is only just located on the positive side of the discriminant axis and had the lowest probability classification in the assemblage (0.76) suggesting that the classification of this sample as high-intensity is not reliable. All other samples were classified with very high probabilities (i.e. over 90%) and 40 samples were classified with 100% probability.

When compared with the discriminant analysis performed on modern weed datasets (**Figure 8.13**), it appears that the Tell Brak TC oval samples are significantly lower than all other results but that some points do overlap with samples from Haute Provence, France and the Moroccan rainfed terraces. These modern study areas were characterized by relatively low levels of disturbance, crop weeding, no large-scale irrigation systems and very limited use of manure. In this respect it would seem likely that the Tell Brak fields were managed in a similar fashion, although with possibly even lower level inputs of tillage, hand-weeding and artificial watering.

Figure 8.15 shows the same discriminant analysis plot of Tell Brak samples, coded by dominant cereal species using the groups laid out in **Table 12.6**, **Appendix**. From this plot there appears to be some patterning in relation to crop species, as the samples with the lowest discriminant scores are all barley dominated samples. By contrast, glume wheat dominated samples, mixed composition samples and samples containing free-threshing wheat appear to have slightly higher discriminant scores. This patterning may simply be due to the fact that the majority of Tell Brak samples are dominated by hulled barley and the overall distribution of these samples is fairly varied. By comparison, samples containing wheat are less well represented within the assemblage so sample distribution is inevitably narrower. Alternatively, it may suggest that some hulled barley was being cultivated under particularly low-intensity conditions when compared to the wheat, with very low inputs of weeding, tillage, manuring and artificial watering. This relationship will be explored in greater detail below with reference to the results of crop stable isotope analysis (see **Section 8.9). Figure 8.15** shows the same discriminant analysis plot coded by room number. Again, there does appear to be some slightly patterning, with samples from Rooms 8, 16 and 17 located at the extreme negative end of the axis whilst samples from Room 12 have some of the

highest discriminant scores. These patterns, however, are likely just reflections of the underlying dominant cereal rather than any true differences by room. This is because each room in the TC oval tends to contain primarily one species of cereal, so Rooms 8, 16 and 17 are all dominated by hulled barley whilst Room 12 contains larger proportions of glume wheat and free-threshing wheat.

8.9 Functional weed ecology conclusions

The results from weed analysis and functional weed ecology has indicated that the cereals stored within the TC temple oval were grown in permanently cultivated fields in open, ruderal environments. Crops appear to have been sown exclusively during the wetter autumn months and were harvested in late May-June to avoid the very hot and dry summer conditions present in this region. The results from functional ecology have demonstrated that all TC oval samples, with the exception of one low-probability sample from Room 12, can be classified as low-intensity. This indicates that both hulled barley and various wheat species were grown under low-input conditions and without the use of intensive manuring or weeding. Furthermore, the TC oval samples have much lower discriminant scores than comparative modern low-input agricultural regimes from Haute Provence and the Moroccan rainfed terraces suggesting that the TC oval crops are indicative of very extensive agricultural production systems. These very low discriminant scores, however, may have been due to the effects of aridity on the growth of weed species within the Tell Brak environs.

Table 8.8 – The number of taxa per sample from the Tell Brak assemblage used in the discriminant analysis as well as the results of the discriminant analysis showing the classification of each sample as high- or low-intensity, with high or low probability.

Sample no.	Room no.	No. of taxa	No. of items	Probability (%)	Intensity Class
77	4	3	48	1	Low
104	8	4	176	1	Low
147	8	4	32	1	Low
144	8	4	197	1	Low
103	8	3	48	1	Low
55	9	2	80	0.992	Low
112	9	3	104	1	Low
76	12	2	16	1	Low
113	12	3	168	1	Low
149	12	6	173	1	Low
120	12	9	1464	1	Low
67	12	5	79	1	Low
111	12	2	32	1	Low
80	12	10	608	1	Low
122	12	3	18	1	Low
102	12	3	120	0.766	High
78	12	2	96	1	Low
70	16	4	28	1	Low
97	16	3	112	1	Low
115	16	3	48	1	Low
117	16	2	48	1	Low
121	16	4	128	1	Low
127	16	3	64	1	Low
150	16	5	64	1	Low
152	16	3	80	1	Low
159	16	7	480	1	Low
225	16	3	80	1	Low
71	16	5	50	0.965	Low
219	16	4	40	1	Low
148	16	5	11	1	Low
218	16	8	58	0.992	Low
123	16	4	70	1	Low
118	16	5	344	1	Low
138	16	3	960	1	Low
131	16	5	2048	1	Low
105	16	3	640	1	Low
239	16	3	10	1	Low
168	17	2	16	1	Low
167	17	5	84	1	Low
169	17	3	48	1	Low
217	17	6	280	0.999	Low
383	18	11	34	0.996	Low
450	Ncy	9	564	1	Low
447	Ncy	8	300	1	Low
165	Ncy	9	192	1	Low
388	TCH	8	71	1	Low

8.10 Comparing the results of crop stable isotope analysis and functional weed ecological analysis

As stated above, it is likely that the majority of weed/wild remains identified within the TC oval assemblage grew alongside the cereals and are representative of the agricultural regime(s) in use at Tell Brak. Additionally, contextual evidence regarding cereal grain storage and recovery has reduced the potential for sample contamination. It has been possible, therefore, to directly compare the results of stable isotope analysis with the results of functional weed ecology on a sample-by-sample basis. Unfortunately, however, the number of samples with discriminant scores as well as stable isotope results was severely reduced when compared with the total number of samples available from the TC oval assemblage. This was due to the implementation of a stable isotope program designed to prioritise comparison among different cereal species rather than measuring values from every sample (methodology discussed in **Section 4.6.1.2**, **Chapter 4**). Furthermore, a number of samples with stable isotope results did not contain enough weed/wild remains to produce a discriminant score. In total, 26 samples chosen for stable isotope analysis also produced results from functional ecology (see **Table 8.9** for list of samples included).

Figures 8.17a and **8.17b** and **Figures 8.18a** and **8.18b** plot the results from carbon and nitrogen stable isotope analysis against the discriminant score produced from functional ecological analysis. Results have been separated by cereal species (hulled barley and emmer) and the small grain varieties have been plotted alongside their larger grained counterparts, as a means of investigating possible differences between varieties. Plots were also coded by room number to assess any possible room-by-room sources of variability. None of the scatterplots show a positive correlation between stable isotope values and discriminant scores, and in fact **Figures 8.17a**, **8.17a**

Table 8.9 – Summary of the 26 samples with both crop stable isotope values and functional ecology discriminant scores.

Sample No.	Room No.	Cereal species measured for stable isotope analysis
147	8	Hulled barley
55	9	Small barley
55	9	Hulled barley
112	9	Hulled barley
55	9	Small glume wheat
112	9	Emmer
122	12	Small barley
113	12	Hulled barley
120	12	Hulled barley
122	12	Hulled barley
122	12	Small glume wheat
120	12	Emmer
122	12	Emmer
149	12	Emmer
148	16	Small barley
225	16	Small barley
239	16	Small barley
71	16	Hulled barley
117	16	Hulled barley
121	16	Hulled barley
127	16	Hulled barley
138	16	Hulled barley
148	16	Hulled barley
225	16	Hulled barley
217	17	Hulled barley
217	17	Emmer

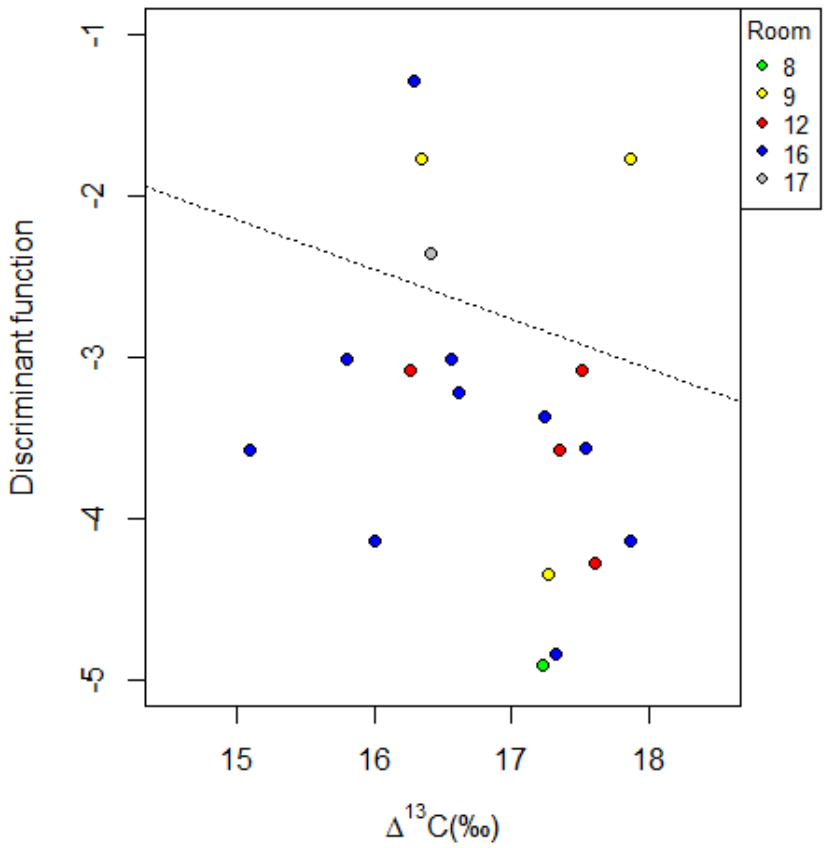
Table 8.10 – Results of simple linear regressions carried out to examine the relationship between $\Delta^{13}C$, $\delta^{15}N$ and discriminant function.

Species	Stable isotope	Results
Barley	Carbon ($\Delta^{13}C$)	R^2=0.01369, p=0.2791
Barley	Nitrogen ($\delta^{15}N$)	R^2=-0.05787, p=0.9029
Emmer	Carbon ($\Delta^{13}C$)	R^2=0.2751, p=0.13
Emmer	Nitrogen ($\delta^{15}N$)	R^2=-0.1253, p=0.5895

and **8.18b** show a negative correlation. Simple linear regressions were carried out to examine the relationship between $\Delta^{13}C$ values, $\delta^{15}N$ values and discriminant function score in more detail (see **Table 8.10**). None of these statistical tests indicated that there was a significant relationship between stable isotope results and functional ecology discriminant score. Additionally, there does not appear to be any visible patterning of results by room number with the exception of barley samples from Room 16 (**Figures 8.17a** and **8.17b**). In general, these samples appear to have both low $\delta^{15}N$ values as well as low discriminant scores, although there is still a fair amount of variation within the room.

Overall, modern experimental work (Bogaard *et al*. 2016a; 2016b) has shown that a positive correlation between results from stable isotope analysis and functional ecology would only be expected when there is a *spectrum* of low- to high-intensity regimes present. By comparison, there would be no corresponding correlation between results *within* regimes. The lack of a positive correlation between the results from the TC oval assemblage at Tell Brak, therefore, indicates that these crops, including both large-grained and small-grained varieties were not being grown under a range of different husbandry regimes. Instead these results may point to the preferential treatment, in terms of watering and the application of manure, of wheat crops over barley crops, within a wider agricultural regime. Moreover, these results may have been affected by the semi-arid conditions present at Tell Brak, causing greater variation in both stable isotope values and functional ecology results and reducing any correlation between these two strands of evidence.

A



B

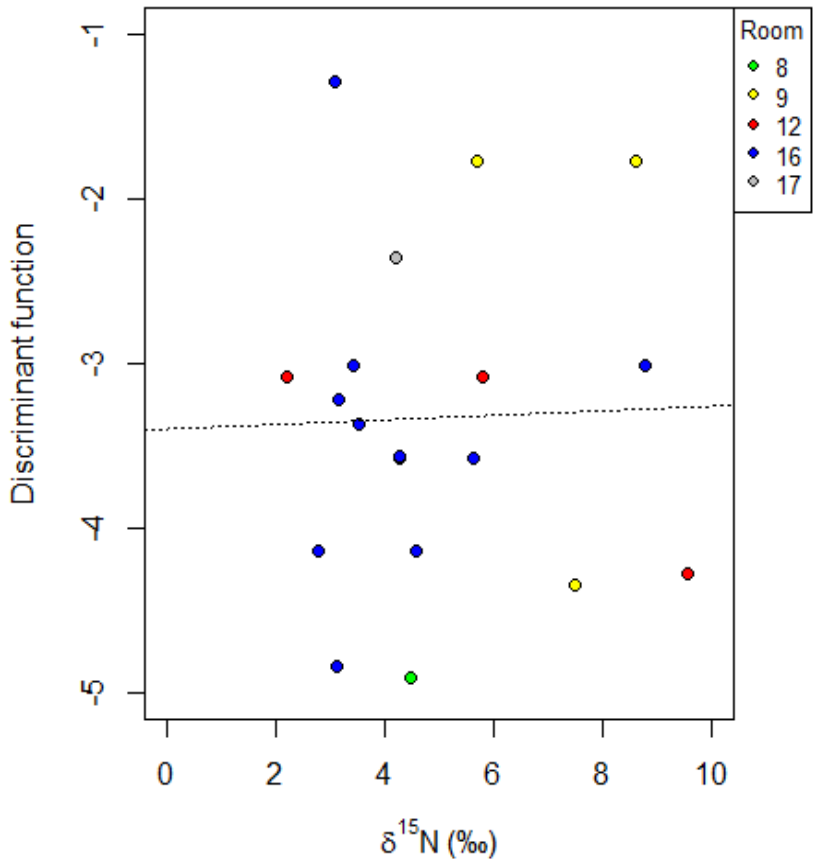
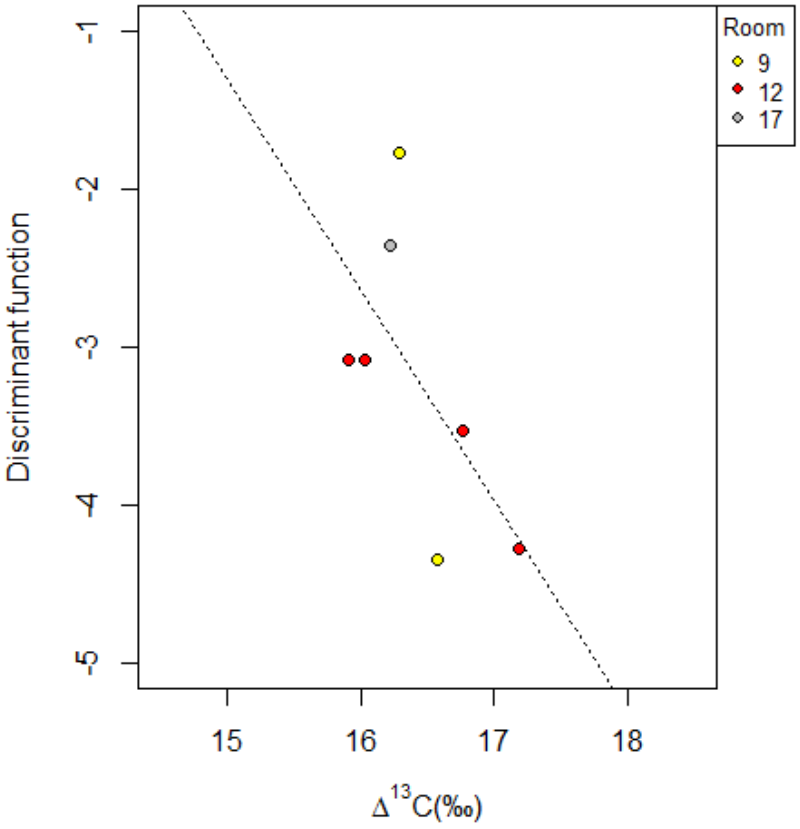


Figure 8.17a and b – Plots showing the relationship between weed discriminant function score and $\Delta^{13}C$ and $\delta^{15}N$ values for hulled barley.

A



B

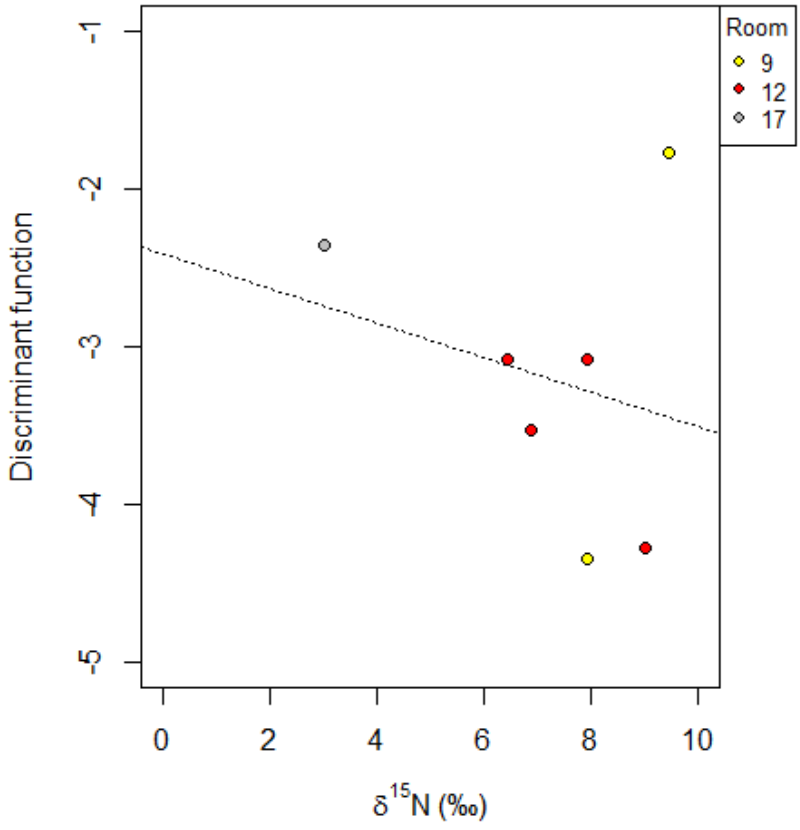


Figure 8.18a and b – Plots showing the relationship between weed discriminant function score and $\Delta^{13}C$ and $\delta^{15}N$ values for emmer wheat.

8.11 Summary of the combined stable isotope and functional ecology results

The combined results from functional ecology and crop stable isotope analysis did not return a statistically significant result between discriminant function and $\Delta^{13}C$ and $\delta^{15}N$ values. This would seem to indicate that at Tell Brak there is no correlation between low stable isotope values, indicating low inputs of water and manure, and corresponding low discriminant function scores. With regards to the results of emmer wheat, however, this may be due to the low sample size. This is in contrast to the results from modern regimes in Morocco and Provence (Bogaard *et al*. 2016a; 2016b) and would suggest that the TC oval cereals are representative of the preferential treatment, in terms of manure and access to slightly better watered soil, of certain cereals species within a larger low-input ('extensive') agricultural regime, rather than a spectrum of low- to high-intensity agricultural regimes.

Chapter 9

Discussion

The primary objective of this thesis was to assess the hypothesis that large Bronze Age urban communities were reliant on a range of agricultural regimes that involved varying degrees of 'extensification' and diversification for day-to-day food production as well as a storable surplus. The assessment of this hypothesis has involved a number of aims (see **Section 1.5**) chief of which has been an investigation into the nature of crop production at Hattusha, the Hittite capital located in Central Anatolia, and Tell Brak located in north-eastern Syria. This has involved an understanding of the archaeological taphonomy particular to each site, as well as the context of deposition for each archaeobotanical assemblage. Secondly, it has entailed the use of innovative methods, such as integrated crop stable isotope analysis and functional weed ecology, to interpret key archaeobotanical assemblages, and to provide evidence for the range of crop husbandry schemes and agricultural management systems used at both cities.

This chapter will seek to examine and build on the results presented in **Chapters 5, 6 7** and **8**, by first discussing the crop production systems in operation at Hattusha and Tell Brak separately. This will also include the contextualization of these systems within the wider agricultural economy at both sites and include discussions of how the results of this study fit with other text-based interpretations of farming during the Bronze Age. Additionally, the results from Tell Brak will be discussed alongside and compared with further archaeobotanical analysis completed from other chronological

periods at the site. This chapter will also seek to discuss the results of archaeobotanical analysis from Hattusha and Tell Brak within the broader context of archaeobotanical work previously conducted in Central Anatolia and northern Mesopotamia. Finally, the results from both sites will be used to assess the dual themes of risk and urban resilience as approaches to agricultural regime choice in large Bronze Age urban societies. It will finish by considering the nature of Bronze Age agriculture amongst urban populations within and beyond Central Anatolia and northern Mesopotamia.

9.1 Hattusha

9.1.1 Context of deposition – crop storage

At Hattusha, the context of archaeobotanical assemblage deposition has had a profound effect on both the visibly high level of charred plant preservation, on interpretations of where this material initially came from and its intended use. Certainly, the size and scale of underground storage space that the silo complex represents is amongst the largest known from Bronze Age western Eurasia and as such, discussions surrounding its use have been centred on themes of elite control and management.

Archaeobotanically, sources of post-depositional bias are less likely to affect storage contexts, particularly in cases of hermetic storage, as these systems have been designed to preserve grain for long periods of time. Hermetic storage works most effectively by sealing crops in an airtight container, thereby preventing moisture from reaching the grain (Villers *et al*. 2006). Moreover, biological activity caused by grain respiration inside the container creates a carbon dioxide enriched atmosphere lethal to insects and other pests already present in the produce (Reynold, 1974; Navarro &

Calderon, 1980). By using this type of storage, agricultural produce can be kept for extended periods of time, in some cases up to several years (Weinburg *et al*. 2007) as long as the airtight seal is left in place. Once breached, however, all produce must be removed at once to prevent decomposition and grain germination (Sigaut, 1980).

Archaeologically, hermetic storage systems have been found worldwide. The unambiguous identification of these storage structures as examples of hermetic crop storage has, however, been less common (Sigaut, 1988; Christakis, 2008: 1). Direct evidence, such as charred plant material, is often absent and has led some scholars to suggest alternative interpretations unrelated to the storage of crops, for example pits for the disposal of rubbish or tree planters (e.g. Strasser, 1997). The Hattusha underground silo complex, however, is unequivocal in terms of its identification as a very large hermetic storage system for the preservation of cultivated crops (Seeher, 2000a; 2000b; Neef, 2001; Diffey *et al*. 2017). When this archaeological and archaeobotanical evidence is combined with information from Hittite textual sources, it would seem likely that the underground silo complex is one very large example of a system of storage depots located throughout the Hittite empire. These facilities were thought to store grain collected as tax, as well as crops harvested from the cultivation of crown lands and vassal tributes (Yakar, 2000: 266; Bryce, 2002: 76). This interpretation of the underground silo will be discussed in greater detail below in direct relation to the archaeobotanical results presented in **Chapters 5** and **6**.

The capacity of the underground silo has been estimated to be between 7000-9000m^3 with each individual chamber capable of holding 219-281m^3 (Seeher, 2006: 81). This would have been enough grain to feed 20,000-30,000 people for a year, or roughly the estimated population of Hattusha during this period (c. 1590 BC). Calculations of how much land would be needed in order to grow this quantity of food per year are

necessarily complex as they must take into account the local topography, the differential yields of wheat and barley, the presence of weed seeds and other cultivars within the silo etc. Nevertheless, some rough estimations of the amount of land required have been calculated using pre-mechanized grain yields from the Çorum region in Central Anatolia (Stratil-Sauer, 1933). **Table 9.1** shows the estimated land requirements needed to grow enough wheat and barley to fill the silo to capacity, as well as the estimated land requirements to fill just one chamber. These calculations have been based on the assessment that 1 tonne of cereal grain fills approximately 1.27m^3 of storage space (www.acqua-calc.com). Using the average wheat and barley yields from pre-mechanized agriculture in the Çorum region local to Hattusha (300 tonnes/km^2 and 120 tonnes/km^2 respectively – Stratil-Sauer, 1933) this figure has then been used to calculate the minimum and maximum land extents needed for cereal cultivation on the basis of one harvest. Wheat and barley cultivation extents have been treated separately here due to the differential yields of these two cereal species.

These land estimations are severely limited by the fact that 20th century AD grain yields and weights are likely to be greater than the equivalent values for the Bronze Age, nevertheless, it is clear that the amount of cultivated land needed to fill the silo would have been significant. It should be noted, however, that the singular construction of the silo meant that the whole complex would not have had to be in use at the same time and could have been used to store harvests/taxed produce from multiple years. If this was the case the estimated land requirements needed to fill the silo would be dramatically reduced and could easily be accommodated within the Hattusha environs. Further work (discussed in **Section 10.3**) will seek to refine these estimations at Hattusha by taking into account local topography and the use of predictive modelling.

Table 9.1 - The estimated cereal weight capacities of the entire silo and one chamber, and the estimated amounts of land needed for cultivation based on one harvest.

Potential storage volume of the entire silo (m^3)	7000	8000	9000
Potential cereal weight of the entire silo (tonnes)	5512	6299	7087
Estimated land needed for wheat cultivation to fill the silo (km^2)	18	21	24
Estimated land needed for barley cultivation to fill the silo (km^2)	46	52	59
Potential storage volume of one chamber (m^3)	219	250	281
Potential cereal weight in one chamber (tonnes)	172	197	221
Estimated land needed for wheat cultivation in one chamber (km^2)	0.6	0.7	0.8
Estimated land needed for barley cultivation in one chamber (km^2)	1.4	1.6	1.8

The hermetic underground nature of the Hattusha silo has also preserved some specific plant parts that do not often occur within the archaeobotanical record. For example, cereal chaff is frequently less well preserved than cereal grain (Boardman & Jones, 1990; Charles *et al*. 2015) and similarly, many small weed/wild species do not tend to survive the charring process. The hermetic character of the silo would have caused the fire to burn at a relatively low temperature (200-380°C) lightly 'toasting' the plant material rather than destroying it (Neef, 2001; Seeher, 2006: 46). Furthermore, after the fire the underground silo was not uncovered or disturbed, meaning that the plant remains were preserved *in situ*. The plant remains stored within the underground silo have thus not been subject to sources of post-depositional bias, with the exception of Chamber 12 which had been disturbed by moles, and therefore, provides an accurate representation of 'end product' crops from the environs of the city and the Central Anatolian Plateau region.

9.1.2 Crops and other utilized plants

As was established in **Chapter 5** the primary crops stored in the underground silo at Hattusha are 2-row and 6-row hulled barley, emmer wheat and einkorn wheat. This is consistent both with crop species recorded within Hittite texts (e.g. Hoffner, 1974; Singer, 1984) and with archaeobotanical evidence recovered from other excavated Hittite sites (e.g. Kaman-Kalehöyük, Fairbairn & Omura, 2005). Other potential cultivated crops found within the silo were: free-threshing wheat, naked barley, *Vicia faba* var. *minuta*, lentil, grass pea and bitter vetch. These other species were found in much lower quantities and seem unlikely to have been purposefully stored within the silo. Instead they may represent crops being cultivated in nearby fields that have encroached on and contaminated the cereal fields.

9.1.2.1 The importance of cereals

Evidence from Hittite texts has long-established the crucial role played by cereals within the diets of both humans and livestock as well as their economic importance within the Hittite empire. A quote from the Hittite analogic magic text states, “Just as grain preserves the lives of men, oxen, sheep and wildlife, in the same way let this grain also preserve from the prodigious thing the lives of the king and queen and this house!” (Hoffner, 1974: 60-61), thereby confirming that cereal grain was the staple food source and the foundation of the agricultural system (Nesbitt, 1995; Yakar, 2000: 274). This view has been further corroborated by evidence from the

underground silo complex at Hattusha in which 66%[17] of the entire assemblage has been identified as hulled barley or glume wheat grains.

Of the primary crops, hulled barley was the most commonly identified within the silo complex and was present in very large quantities per sample (one sample from Chamber 32 contained 8694 grains). Referred to commonly as *halkiš* or *ewa(n)* in Hittite texts (Hoffner, 1974: 37), both 2-row and 6-row hulled barley are the most frequently identified crops from all other Hittite sites (see **Table 2.2**) at which archaeobotanical remains have been recovered. This postulated preference for hulled barley (both 2-row and 6-row hulled barley varieties) has been attributed to the fact that this crop is generally more tolerant than both bread and glume wheats, of poor growing conditions (Yakar, 2000: 274), and can retain a regular yield even in times of drought (Hillman, 1985; Nesbitt, 1996). This would have been particularly important within Bronze Age Central Anatolia where the average rainfall could fluctuate radically from year to year and drought was a frequent threat. Hulled barley, however, is also a very versatile crop and could have been used for multiple purposes including the production of flat bread, groats (Pasternak, 1998; Dörfler *et al*. 2001), the brewing of beer (Brouwer, 1972; Ünal, 1983: 15-17), fodder for livestock (e.g. Zohary *et al*. 2012) as well as the use of by-products for mudbrick tempering and animal bedding (Seeher, 2000a). Additionally, the lemma and palea of hulled barley protected the grains from pest damage and rapid decomposition (Hillman, 1985) allowing grains to be easily transported and stored for long periods of time.

The hulled barley from Hattusha seems to have been processed before being put into the underground silo. Certainly, as **Figure 5.25** shows, all hulled barley-dominated samples contain clean grain with only small amounts of rachis and weed/wild material.

[17] This figure does not include totals of cereal chaff and rachis remains.

Some samples, particularly from Chambers 29 and 30, contained such low ratios of rachis and weed/wild seeds to cereal grain that it is possible that these hulled barley crops had been subject to weeding within the field and/or had been more rigorously processed before being stored. This high level of processing would have been time consuming and may indicate that this barley grain was destined for human consumption rather than for livestock. Additionally, there is no evidence that this hulled barley was to be used in the production of beer as no germinated grains were identified from the assemblage. Many of the hulled barley grains from Chamber 30 were also found with the lemma and palea still attached. Hulled barley grain requires pounding to remove these final chaff layers, a step that is usually performed before cooking and consumption. As mentioned above, these may have been left on as a protective measure against pests and would support the theory that these crops were going to be stored for an extended period. Hulled barley grains from the other chambers had no visible lemma and palea still attached, although the epidermis was intact, but this could be due to the less favourable preservation levels present in these chambers. By contrast, the plant material in Chamber 30 was exceptionally well-preserved which may have biased towards the survival of the very light chaff remains (Boardman & Jones, 1990).

The second most prevalent plant species within the silo complex were the glume (hulled) wheats, represented by 1- and 2-grain emmer and einkorn wheat. From these species, the two varieties of emmer wheat were far more ubiquitous than einkorn and this would fit the general pattern of glume wheat identification at other Hittite sites (van Zeist & Bakker-Heeres, 1975; Fairbairn & Omura, 2005). It also correlates with wider chronological trends established at other Central and southern Anatolian settlements where a preference for emmer wheat has been visible from the Neolithic (Bogaard *et al*. 2013) and Chalcolithic periods (Stroud, 2016). This trend is in direct contrast to

archaeobotanical evidence from Greece which would suggest that during the Late Bronze Age in northern Greece and Thessaly einkorn was a more "common find" (Hansen, 1988: 43). Explanations for this have focused around the fact that einkorn may have been better adapted to the colder climactic conditions present in northern Greece (Valamoti, 2004: 114) whilst emmer, in general, is more suited to dry, warm plains (Christidis, 1963). Overall, however, both glume wheat species are resistant to adverse growing conditions and are better protected from pest damage, particularly when compared with free-threshing wheat species (Hillman, 1981; Sigaut, 1988). Species selection, therefore, may have been due to cultural choice and a local tradition of cultivating emmer wheat.

At Hattusha the choice of emmer over einkorn may have been due to the greater *potential* yields provided by emmer. The identification of 1-grain emmer though would seem to negate this theory. 1-grain emmer has previously only been identified at two sites in Turkey: Bronze Age Kaman-Kalehöyük and Neolithic Höyücek (Nesbitt, 1993; Martinoli & Nesbitt, 2003). This lack of representation within the archaeobotanical record however, could be due to difficulties with 1-grain emmer grain identification and the true number of sites with 1-grain emmer could be a lot higher. Certainly, at Hattusha the number of 1-grain emmer spikelets identified (1728) was significantly higher than 2-grain emmer spikelets (653), even though the relative ubiquities of both varieties were relatively similar (40% 1-grain, 44% 2-grain). It is difficult to estimate though whether the 1-grain emmer variety was widespread throughout the Hattusha silo assemblage as it could only be positively identified from within intact spikelets, and the true number of grains is likely much higher. Additionally, as spikelets were only recovered from Chamber 30 it has been impossible to ascertain if 1-grain emmer was specific to a particular agricultural regime (discussed in greater detail below) or was a common

Hittite cultivar. Overall, it would seem likely that both varieties of emmer wheat were cultivated together on Hittite farms and that the choice of emmer over einkorn wheat was due to cultural choice rather than environmental considerations.

Much like the hulled barley crop, both glume wheat crops were stored in a processed state (see **Figure 5.26**). The ratio of grain to weed/wild seeds and chaff remains, however, was considerably higher than the equivalent ratio for hulled barley. This may be due to the fact that the glume wheats were not as intensively weeded within the arable fields and at least some of this grain was stored in the spikelet and would have required de-husking before human consumption. Alternatively, the presence of intact spikelets and significant quantities of glume wheat chaff may suggest that glume wheat crop processing was delayed to gain the benefits of grain protection from the glumes in storage (Hillman, 1981). Similarly, if these grains were intended for use as animal fodder de-husking is usually omitted (Nesbitt *et al*. 1996; Peña-Chocarro, 1999). The higher ratio of weed/wild seeds also indicates that the greater portion of these species were growing in the wheat fields rather than the barley fields, and this has repercussions for the conclusions made from combined functional weed ecology and stable isotope results (discussed below). Furthermore, this difference in weed/wild seed to grain ratios implies that hulled barley and the glume wheats were not being grown together as a maslin crop, and were likely combined for storage after the fine-sieving processing stage. Only Chamber 30 was found to contain intact glume wheat spikelets. This could be a preservation bias (as mentioned above), but crop processing analysis (**Figure 5.26**) has indicated that Chambers 12 and 29 were unlikely to have contained spikelets and Chamber 32 only had one sample that may have contained spikelets. This discrepancy between chambers may reflect the fact that crops stored in different chambers had different and diverse final intended uses. Evidence for this, however, is

lacking and instead this difference further highlights the level of variation present between crops stored in each chamber.

Overall, it is difficult to define an ultimate use for the cereals stored within the underground silo complex (Jones, 1998). Ethnographic studies from Greece have shown that the use of grain as either human food or animal fodder could depend on the status of the most recent harvest (Jones & Halstead, 1995) and additionally Jones (1998) has shown that farmers themselves often do not make a division between crops grown for fodder or food. The excavator of the silo, Jürgen Seeher (2006: 49), has suggested that the silo was a store of fodder for state-owned plough oxen (Privitera, 2014). Certainly, the Hittite texts state that the king directly owned a large number of cattle, but these were generally kept in mountain pastures during the summer months and fed secondary harvest products in the winter (Yakar, 2000: 278). Similarly, it is impossible to state categorically whether these grains were intended as 'seed corn' for the following year's crop. The presence of intact glume wheat spikelets within Chamber 30 *may* indicate that some of this grain was destined for replanting as ethnographically the planting of spikelets has been reported from Greece (Halstead, 2014: 158). Just as likely, however, was the fact that glume wheat grain was stored in the spikelet to preserve it from pest damage whilst in storage (e.g. Sigaut, 1988) and that further processing stages would have been necessary for human consumption.

9.1.2.2 The wider agricultural economy

Although cereals may have been the most ubiquitous and important part of the Hittite agricultural economy as represented by the Hattusha underground silo, these species were by no means the only cultivated or managed plants in use during the Late

Bronze Age. For example, four species of pulse were also identified from the silo (lentil, grass pea, *Vicia faba* var. *minuta* and bitter vetch). Pulses, particularly lentil, have also been found at all other Hittite sites with archaeobotanical assemblages (see **Table 2.2**). Additionally, Hittite texts record a number of words for various pulse species (Nesbitt, 1993) including those listed above as well as chickpea and beans. Pulses, however, are thought to have been cultivated on a much smaller scale by individual families, primarily for domestic consumption and to supplement staple cereal-based foods (Yakar, 2000: 274). The identification of pulses from the silo may attest that pulses were being grown in close proximity to the cereal fields and have become contaminants of the primary crop. This may be the case with particular regard to *Vicia faba* var. *minuta* which comprises over 50% of plant remains in a number of samples from Chambers 12 and 32. These samples point to the cultivation of pulses within the same agricultural area as the cereals and/or that these fields had been used for the cultivation of pulses during the previous agricultural year. Traditional farming practices in modern Anatolia utilize a fallowing system in which the land is planted alternately with cereals and pulses followed by a fallow year during which the field may be used for animal grazing (Yakar, 2000: 277). It is possible that the Hittites may have employed a similar system and that the high numbers of *Vicia faba* var. *minuta* in Chambers 12 and 32 may, therefore, be due to the growth of latent pulse seeds within the cereal fields. Both of these theories for the presence of pulses (contamination from nearby fields and the growth of latent pulse seeds in a fallowing system) indicate that the cereal crop fields would have been incredibly 'weed choked'. Ethnographically, weed choked cereal fields and specifically pulse choked fields have been recorded in Haute Provence, France and Asturias, Spain and point to inadequate tillage and hand-weeding of the crops (Bogaard, *pers comm*.) Alternatively, *Vicia faba* var. *minuta* may

have been mixed into the cereal stores by accident after crop processing and before final deposition.

Hittite texts also record the importance of horticulture, including the management of vines, olive trees and orchards (Riemschneider, 1958; Hoffner, 1995), demonstrating the importance of olive oil and wine production in the Hittite economy. Similarly, the Hittite Laws indicate that fruit trees were occasionally irrigated and it is thought that cold resistant fruits such as apples and pears may have been grown within the Hattusha environs (Yakar, 2000: 276). It is most likely that vines and fruit trees were grown in places unsuitable for arable agriculture such as hill slopes and stony soils, or in gardens attached to domestic houses. A number of fruit and nut species were identified within the silo (*Pistacia* sp., *Pyrus/Malus* sp., *Prunus* sp. and *Rubus* sp.) as well as domesticated grape. All of these species, however, were only represented by single seeds or fragments of nut shell so it is difficult to assess their importance within the Hittite diet. Certainly, the Hittite laws record that viticulture was already firmly established and highly developed during the Old Kingdom period, when the silo was in use, and wine was often used for religious rituals in the temples as well as domestic consumption (Hoffner, 1974: 116-118).

The final segment of the wider agricultural economy discussed within the Hittite texts involved multi-species animal husbandry on both a domestic and state-controlled level. Documentary evidence records that cattle, sheep, goats, pigs, horses and donkeys were kept by individual farmers in rural villages, but the excavation of Hittite sites has, to date, failed to produce physical evidence for pens or stables within the settlements (Yakar, 2000: 278). This may suggest that most large-scale animal herding took place up in the high mountain meadows for much of the agricultural year and that the animals were only brought down for the worst of the winter months (Klengel, 1986). With

regards to the arable economy, the ownership of plough-oxen was particularly important and Article 63 of the Hittite Laws indicates that the plough-ox was the most expensive cattle type (Ertem, 1965). It is unlikely that plough-oxen were owned by every Hittite farmer, however, as their upkeep could be very costly (Halstead, 1995a). Instead, documentary evidence from the Hittite laws suggests that most plough-oxen would be owned by the king and/or wealthy landowners and rented out to farmers for a fee (Yakar, 2000: 278).

This arrangement seems very similar to the ownership and use of plough-oxen at Mycenaean Knossos where evidence from Ce, Ch and C texts suggest that the palace would lend farmers teams of plough oxen during the planting season and in return farmers would provide the palace with crops to feed both palace inhabitants and the large oxen teams (Halstead, 1999). Similarly, Knossian oxen teams could also be assigned to *damos* (community) land, where food would be grown to provide rations for urban workers (Killen, 2004). Certainly, the use of plough-oxen in the Hittite kingdom increased the amount of land able to be cultivated, but also increased social inequality between those who owned oxen or could rent them, and those that could not afford to (cf. Halstead, 1995a). Furthermore, oxen and other livestock produce manure which could also be used to increase the fertility of the arable fields. Access to this resource could, therefore, also further social divisions, and this will be discussed in greater detail below with reference to crop husbandry.

9.1.3 Crop production and agricultural practice

At Hattusha, the hermetic nature of the underground silo complex and the exceptional preservation of both cereal grains and arable weeds, has meant that two

recently developed techniques within archaeobotany, crop stable isotope analysis (e.g. Bogaard *et al*. 2007; Styring *et al*. 2017) and functional weed ecology (e.g. Bogaard *et al*. 2016a; 2016b), could be used to interpret specific husbandry practices. Methods of crop husbandry rely heavily on the type of environment under cultivation. Site location may provide challenges to be overcome or opportunities to be exploited, restricting or dictating the range of husbandry practices that can be used. Additionally, cultural choice, site organization and control of labour and land also play pivotal roles in the selection of agricultural strategy. Thus, the nature of crop production is likely to have been specific to each farming society.

9.1.3.1 Sowing time

As was discussed in **Chapter 6**, today the period of crop sowing on the Central Anatolian plateau generally takes place during the autumn months to take advantage of seasonal rainfall. Crops are then harvested within the months of July and August (Yakar, 2000: 277). Evidence from arable weeds identified within the silo complex at Hattusha has indicated that this timeframe for crop planting is likely to have been the same during the Old Kingdom Hittite period with the majority of weed species flowering in April and May. This theory is supported by evidence from Hittite texts that record the third season of the year (*zena* – correlating with the autumn months) as the start of planting and food processing (Yakar, 2000: 278). During this season fields would have been prepared for crop sowing by ploughing using teams of draught-oxen, removing weeds and fieldstones (Hoffner, 1974: 96). As discussed above, not all families would have owned oxen due to the expense of having to feed and house them. Instead the Hittite laws record that a plough ox could be rented for one silver shekel a

month (Klengel, 1986). According to the Hittite texts barley could also be planted during the spring and harvested during the late summer (Hoffner, 1974: 16) and within the Hattusha silo assemblage there are some weed species, for example *Polygonum aviculare*, that are more indicative of a spring sown crop. From **Figure 6.13**, however, there is no evidence that hulled barley was more likely to have been spring sown than the glume wheat crops, and it is reasonable to assume that the majority of the assemblage is dominated by autumn sown crops.

9.1.3.2 Crop watering and manuring

The average annual precipitation on the Central Anatolian plateau is c. 450mm/year, and would have been capable of supporting rainfed agriculture in this region. Similarly, there is no archaeological evidence for the construction of large-scale irrigation systems and such structures are not mentioned within the Hittite texts. The practice of rain-fed agriculture is supported by the results of carbon crop stable isotope analysis (**Figure 6.1**). These results indicate that hulled barley and emmer wheat crops were not particularly well-watered and are unlikely to have been artificially irrigated, but still received adequate water for crop growth and grain filling. Within each species, however, there is significant variation between the highest and the lowest results. This could be a consequence of the mountainous landscape around Hattusha and may indicate the exploitation of a variety of agricultural locations around the city. Certainly, topographic analysis performed on crop stable isotope data from modern agricultural regimes in Haute Provence, France have shown that there is a positive correlation between slope gradient (°) and lower carbon ($\delta^{13}C$) stable isotope values (Bogaard *et al*. 2016a). This is because the steeper the slope the greater the chance of surface water run-

off and the less water permeating the soil. Moreover, the evidence from the Provence study showed that even slight changes in slope gradient could have a visible effect on carbon stable isotope values. Furthermore, proximity to a river or stream saw a slight increase in carbon stable isotope values. With regards to the Hattusha crops, it would appear that some crops, in particular crops from Chambers 12 and 32 were grown in better watered soils and that access to these locations may have been restricted by land ownership, social status or arable field location. By comparison, crops from Chambers 29 and 30 were grown under significantly drier conditions.

Variability in terms of $\delta^{15}N$ crop isotope values indicate that both hulled barley and emmer wheat were grown under a range of manuring conditions spanning high manuring levels to low manuring levels (see **Figure 6.5**). The use of manure has been well documented from agricultural communities in the Neolithic (e.g. Bogaard *et al*. 2013; Vaiglova *et al*. 2014a) where its application on the fields was used to improve soil fertility and thus crop growth and yield. The use of manure, however, has two limiting factors, firstly its availability and secondly the fact that it is a heavy and difficult resource to transport. The use of manure is generally limited, therefore, to the immediate environs of a domestic settlement where livestock are kept or kitchen midden material is disposed of (Wilkinson, 1994). At Hattusha the range of $\delta^{15}N$ values again varies by chamber number. Crops from Chambers 12 and 32 were grown with generally high manure inputs suggesting that these cereal fields had preferential access to manure and that these farmers were engaged in a more intensive system of agriculture. Furthermore, the slightly higher manure values for the cereal fields represented in Chambers 12 and 32 may have encouraged the growth of the *Vicia faba* var. *minuta* pulse species in surrounding fields, or directly if growing as a latent crop. Certainly, the higher carbon (water) and nitrogen (manuring) values would not have reduced the

number of weeds that were able to grow in these fields. Equally, crops from Chambers 29 and 30 had much lower manure inputs potentially indicating the use of various different husbandry regimes. The combined cereal stable carbon ($\Delta^{13}C$) and nitrogen ($\delta^{15}N$) results from each chamber would also suggest that these crops were not being grown within different precipitation zones on the Central Anatolian plateau but are consistent with adequate rainfed agriculture. If crops had been affected by aridity it would be expected that the lowest $\Delta^{13}C$ values would correspond with slightly elevated $\delta^{15}N$ values whereas values from Chamber 12 and 32 consistently show that the highest carbon values correlate with the highest nitrogen values.

These isotopic results are also supported by results from functional weed ecology. Overall, the functional ecology discriminant scores indicated that each chamber fell within the less intensive (or 'extensive') range of productivity and was most analogous with modern weed survey data from Haute Provence, France (Bogaard *et al*. 2016a). Moreover, when this data was combined with the results from stable isotope analysis a positive correlation between high stable isotope results and high discriminant function scores was observed (**Figures 6.17b** and **6.18b**). In this sense, the results from functional weed ecology and crop stable isotope analysis complement each other and are concurrent in the information they are providing about the nature of Hittite agriculture. Additionally, these results seemingly clustered into the various chamber groupings, particularly with regards to Chamber 30, indicating that the crops stored in each chamber were grown under a crop husbandry regime unique to that chamber.

9.1.3.3 The range of crop husbandry regimes

The division of archaeobotanical results on a chamber-by-chamber basis has been the most striking feature of the underground silo at Hattusha and has been consistent in terms of the plant species identified and throughout all forms of analysis (correspondence analysis, crop processing analysis, stable isotope analysis and functional weed ecological analysis). Put simply; Chambers 12 and 32 have a relatively small range of weed species, although these species (particularly *Galium tricornutum* and *Polygonum aviculare*) do occur in significant numbers. These chambers also display the highest crop stable isotope values, indicating greater inputs of water and manure. They also have the highest discriminant scores from functional ecology indicating that they were grown under more intensive regimes, with higher levels of soil fertility. By contrast, Chambers 29 and 30 contain a far larger range of weed species, the lowest crop stable isotope values and the lowest discriminant scores. In particular, Chamber 30 distinguishes itself from the other chambers by consistently encompassing the lowest isotope and functional ecology values from the entire assemblage and this was made particularly clear from **Figures 6.18a** and **b**.

This separation of the chambers strongly indicates that the crops from the Hattusha underground silo were being cultivated under a range of different husbandry regimes and/or were grown in a variety of locations around the environs of the central city of Hattusha. Certainly, the scale of potential grain storage represented by the underground silo could not have been generated by one large farm or one agricultural area. Moreover, it is unlikely that the silo represents the storage of produce from a single agricultural area over the course of multiple agricultural years. This is due to the fact that the addition of manure to soil artificially elevates $\delta^{15}N$ values for a number of years after its initial application. Similarly, in order to produce $\delta^{15}N$ values

correspondent with low manuring levels manure would not have been applied to the fields within the last 3+ years (Bogaard *et al*. 2007; Fraser *et al*. 2011; Styring *et al.* 2017). Rather it would seem that the silo was used for the collection and amalgamation of arable products from a *certain* variety of relatively extensive agricultural regimes, and this interpretation is supported by the results of this archaeobotanical analysis.

Results from the combined stable isotope analysis and functional ecological analysis, however, have shown that overall the differences between the chambers were not as highly pronounced as the visible disparities would initially have suggested (with the possible exception of Chamber 30). Indeed, the results of multiple linear regression models indicated that the individual chamber did not have a statistical effect on discriminant function or stable isotope value (see **Section 6.10**). This result is very similar to modern agricultural case studies from Morocco and Haute Provence, France where a correlation in results was only found *across* contrasting regimes rather than within one homogenous agrosystem (Bogaard *et al*. 2016a; 2016b). When using this evidence to aid the interpretation of the Hattusha data it would suggest that these crops represent the produce of five differing agricultural regimes. These regimes, however, were not radically different from each other but were instead utilizing variations of the same basic crop husbandry pattern. Key to this would have been the use of traction to expand the amount of available cultivable land; limited use of hand weeding and restricted use of manuring to improve soil fertility within specific regimes. Furthermore, the fact that each chamber appears demonstrative of a different agricultural regime, but that these regimes represent variations on a theme, does not appear indicative of the use of a range of different geographical regions within the Central Anatolian plateau. If this had been the case, it would be likely that the combined stable isotope and functional ecology results would have been more distinguishable by chamber as representative of

location. Additionally, if crops had been coming from beyond the rural hinterland, it is likely that aridity would have had an effect on cereal stable nitrogen values due to the range of precipitation zones present within the Hittite Kingdom during this period. Additionally, it would be likely that each chamber would have a unique weed/wild flora specific to the local region, rather than sharing so many of the species between chambers. Instead, these differences in results illustrate the use of discrete crop husbandry systems.

Reasons behind the use of these multiple crop husbandry systems are likely due to a combination of reasons including locational and spatial factors, social factors and wealth distribution. For example, different social groups may have had restricted access to manure due to unequal ownership of domesticated animals. Similarly, the amount of available human and animal labour may have been a limiting factor due to uneven wealth distribution between rural communities. Finally, other forms of social inequality such as the distribution and ownership of arable land and the location of this land in relation to the settlement would have had an effect on the choice of regime implemented. During the Neolithic period in Europe and western Asia it has been shown that agricultural intensity/input by farm plot decreases with distance from the settlement (Halstead & Jones, 1989; Bogaard, 2005; 2011). This is likely to have continued into the Bronze Age and been exacerbated by an increase in the amount of land under cultivation and the need for more and more human labour. With this in mind, it is likely that fields located in close proximity to the settlement would be cultivated more intensively, whilst outfield areas received lower inputs of labour and manure due to the time needed to travel to these locations. At Hattusha, the use of different farming regimes is likely to have been a combination of these factors combined with the choice of individual farmers/farming communities.

9.1.4 Taxation and the management of agricultural risk

Evidence from Hittite documents indicates that the majority of Hittites did not live in large urban settlements but instead lived in rural villages and were directly engaged in agricultural production (Yakar & Dinçol, 1974; Yakar, 1980). This has been confirmed, to some extent, by archaeological surveys which have shown that the number of small settlement mounds far outstrips the number of towns or cities (Bryce, 2002: 51). Within these villages not all inhabitants would have had independent ownership of private land and many would have leased land directly from the crown through various sharecropping arrangements (Diakonoff, 1956). All inhabitants would, however, have been subject to taxation, unless explicitly exempted by the king. These taxation systems (as discussed in **Chapter 2**) encompassed the *luzzi* service which included the harvesting of crown fields and vineyards, and the *sahhan* which required producers to supply the crown or high status bureaucrats with various products including cereal grain and livestock (Yakar, 2000: 270). Scott (2017: 21) argues that the use of cereal grains as the basis for taxation led to greater levels of state control throughout societies within Western Asia, due to the ease with which cereals can be assessed and amassed by tax collectors. The nature of cereal cultivation involves annual fixed activities of soil preparation, planting, tending and finally harvesting that made the ultimate yield difficult to hide from state administrators. The prevalence of cereal cultivation in Central Anatolia meant that Hittite farmers were, therefore, subject to an extensive and controlling taxation system that may have taken c. 1/5 of their annual harvest on behalf of the state (Scott, 2017: 123). Throughout the empire taxed grain would then have been stored in large storage depots. Previously Bryce (2002: 77) had identified the Hattusha silo as a potential depot for the storage of taxed products. The archaeobotanical results presented as part of this thesis and the identification of a

number of crop husbandry systems would appear to support this theory by illustrating the presence of grain from multiple origins.

As discussed above, the separation of the chambers by archaeobotanical composition points to the storage of produce from various different agricultural management systems. If these crops do represent produce collected as part of the *sahhan* or generated from *luzzi* service on crown lands, this could potentially be the best explanation for the presence of cereal grain grown under different systems but kept within the same facility. Additionally, this interpretation allows for the suggestion that each chamber within the silo represents the tax from a different rural village or large plot of crown land situated within the Hattusha hinterland. Different villages would necessarily utilize slightly different crop husbandry schemes due to the quality, quantity and topography of their arable land, as well as their access to human and animal labour. Furthermore, it is possible that crops from rural villages destined for taxation payments may have been deliberately less well tended than fields planned for domestic use. Archaeobotanical work by Pasternak (1998: 163-64) at the Hittite site of Kuşakli-Sarissa found that grain deposits from two monumental structures in Temple 1 and Building C were generally of poor quality, with small grains and large quantities of weed seeds. This led to the hypothesis that farmers were deliberately mismanaging intended taxed produce as a form of 'rural resistance' or insubordination to state controlled taxation systems (Scott, 1990). When considering the crops from the underground silo as taxed produce, therefore, this hypothesis of agricultural sabotage may explain the large numbers of weed seeds and other species such as *Vicia faba var. minuta* within the assemblage. Without comparable archaeobotanical finds from domestic contexts within the rural hinterland of Hattusha, however, it is very difficult to

ascertain the extent to which this form of resistance was practiced towards the elite of the city.

Overall, the type of agriculture exploited to generate cereal grain for tax is likely to have been broadly similar throughout the rural hinterland, and would have included the increasing expansion of agricultural land to produce greater quantities of grain for the state, but utilizing limited resources (e.g. Wright *et al.* 2015). Taxed produce would then have been stored in the underground silo for times of uncertainty or crisis, such as war or drought caused famine. In terms of managing agricultural risk, the long-term storage of taxed grain would have allowed the city of Hattusha to lessen the effects of a sudden drought or harvest failure whilst also providing food for the large number of non-producers who lived within its walls. Towards the end of the Hittite empire (c. 13th century BC), however, the level of economic risk began to outweigh and overcome the resilience of the city of Hattusha and the Hittites as a civilization. During the last few centuries droughts thought to have lasted up to three years began to occur every decade (Erinç, 1978; Chernoff & Harnischfeger, 1996) completely decimating the Hittite agricultural system. At this time Egyptian documentation records that the Hittite ruler, Hattusili III wrote to Ramses II of Egypt requesting aid in the form of grain shipments (Bryce, 2002: 95). This is in reference to one of multiple consignments thought to have been sent by the Egyptians to the Hittites via the port of Ugarit to Hattusha (Singer, 1977). This grain would have been kept at Hattusha before redistribution to the rural communities, but depending on the time of year, more remote villages may have been totally cut off by the winter snows leading to their eventual abandonment. The loss of any rural villages would potentially have been devastating for the Hittites as they were so reliant on produce from the hinterland for their survival. Ultimately, it may have

been this loss of crop producing populations that led to the collapse of the Hittite civilization exacerbated by drought and regional climate change (Ünal, 1983).

9.2 Tell Brak

9.2.1 Context of deposition

At Tell Brak the context of deposition is again primarily the direct storage of cereal crops within a structure potentially designed for this reason. The type of crop storage present within the TC oval, however, is fundamentally different from that represented by the underground silo complex at Hattusha. At Tell Brak the TC oval was used for the short-term storage of fully-processed crops before consumption (Emberling & McDonald, 2001) whereas the underground silo was used for hermetic, long-term crop storage. Similarly, the excavator's interpretation of the TC oval as a public building associated with the administration of grain to a specific segment of the Tell Brak population (Emberling & MacDonald, 2001) will inevitably inform the interpretation of archaeobotanical material recovered from it. Certainly, the identification of rooms containing ovens (Room 2) and potential reception rooms around the inner courtyard (Emberling *et al*. 1999) indicate that this building was not constructed purely for crop storage. Additionally, the TC oval also contains rooms/spaces that seem likely to have been used for crop processing, or the disposal of processing by-products as well as store rooms. This mixture of storage contexts allows a nuanced understanding of crop processing and crop consumption at Tell Brak, as well as providing information regarding the initial crop husbandry regimes in use during the 3rd millennium BC in northern Mesopotamia.

The archaeobotanical analysis of crop storage contexts has previously been well studied from the Late Chalcolithic period (Hald, 2008) and from other areas of the Tell Brak main mound during the 3rd millennium BC (Charles & Bogaard, 2001; Colledge, 2003). These studies have been primarily based around the excavation of domestic contexts, with the exception of a small number of samples recovered from an Akkadian public building in Trench FS (Charles & Bogaard, 2001). The results from the TC oval, therefore, provide a complementary examination of public/state production and storage during this period. In terms of preservation, the majority of samples from the TC oval were very well preserved, and included the survival of cereal chaff and small weed/wild species that are often totally destroyed (Boardman & Jones, 1990; Charles *et al*. 2015). There was some variation in preservation level by room; for example plant remains from Room 18 were not well preserved, indicating that the fire burned at different temperatures and/or varying lengths of time in separate areas of the building. The building does not seem to have been disturbed or re-used after destruction and indeed when it was finally excavated it had been buried under 3m of soil overburden (Mallowan, 1947: 79). This suggests that the plant remains stored in the TC oval were not subject to any significant sources of post-depositional bias and are an accurate representation of the final products from crop production in the Early Dynastic III period.

9.2.2 Crops and other utilized plants

The archaeobotanical results from Tell Brak have indicated that the major crops stored within the TC oval building during the mid-3rd millennium BC include 2-row hulled barley, the glume wheats, emmer wheat and einkorn wheat and small amounts of

free-threshing wheat (see **Section 7.3**). Additionally, small-grained varieties of both hulled barley and emmer wheat were also identified throughout the assemblage. This range of crops is very similar to those identified from other mid-late 3rd millennium BC areas of the Tell Brak mound (Charles & Bogaard, 2001) and from earlier Chalcolithic periods of occupation at the site (Hald, 2008). Other crops identified included small quantities of pulses: lentil, grass pea, and common pea. These species have also been identified from other areas of the site, but seem unlikely to have been purposefully stored within the TC oval and may represent crop contaminants.

9.2.2.1 The role of cereals

Archaeobotanical evidence from a number of sites in both Upper and Lower Mesopotamia (see **Table 2.5**) alongside documentary evidence from Tell Beydar (Van Lerberghe, 1996) and other archives from palaces in the south (Postgate, 1992: 170) indicate that cereal cultivation was the mainstay of the agricultural economy throughout Mesopotamia during the 3rd millennium BC. The staple cereal economy is thought to have supported the expansion of Late Chalcolithic settlements during the early 4th millennium BC and the growth of large non-producing populations particularly in northern Mesopotamia. Moreover, the cultivation of cereals sustained these settlements through a period of urban 'devolution' during the Early Bronze Age (Wilkinson, 2000) and the succeeding phase of re-urbanization that followed in the 3rd millennium BC (Ur, 2010). At Tell Brak the cultivation and use of cereals is well attested from multiple periods (Colledge, 2003; Hald, 2008) and cereal grain seems to have been the primary source of food for human consumption with by-products used for animal fodder. Cereal grain is also likely to have been an important resource for trade purposes, both between

other cities and satellite sites to the north of Tell Brak, and with the major settlements of Lower Mesopotamia via the Euphrates River (Forrest *et al*. 2004).

Of the cereals recovered from the TC oval, 2-row hulled barley was by far the most commonly identified and this single crop represented the most dominant component of the entire assemblage. The cultivation of 2-row hulled barley rather than the more productive 6-row variety, which has been recorded in southern Mesopotamia (Renfrew, 1984), may be due to the lower water requirements of 2-row hulled barley (Townsend *et al*. 1966: 85). Within the TC oval the number of hulled barley grains identified far outweighs all other cereal species and has a 100% ubiquity throughout the assemblage. This has led to the suggestion that the TC oval was potentially a dedicated hulled barley grain store. Certainly, Rooms 4, 6, 8 and 16 contained almost exclusively hulled barley grain, indicating that these rooms may have been intermediate storage of fully processed barley grain prior to its milling for flour (Eidem *et al*. 2001) or distribution as fodder (Jones & Halstead, 1995). Hulled barley grain has also been recorded in large quantities from other 3rd millennium BC domestic and public contexts of Tell Brak (Charles & Bogaard, 2001) indicating its importance on a site-wide basis.

The predominance of hulled barley is consistent with a number of other sites located in northern Mesopotamia including Tell Leilan (Miller, 1991) and Tell Bderi (van Zeist, 1999). Archaeobotanical evidence from the Khabur Basin Project (McCorriston & Weisberg, 2002), however, suggests that hulled barley had not always been the primary cereal crop cultivated in northern Mesopotamia. Instead they suggest that during the 5th and 4th millenniums BC, emmer and einkorn glume wheats were the dominant crops and that the cultivation and consumption of hulled barley did not expand until the early 3rd millennium BC. Evidence for these changes to cereal production systems have been identified from a number of sites, such as Tell es-

Sweyhat in eastern Syria[18] (Miller, 1997), Tell Atij in western Syria (McCorriston, 1995), a number of sites within the middle Khabur Basin (e.g. Hole, 1991; Zeder, 1994) and from cuneiform evidence in southern Mesopotamia (Jacobsen & Adams, 1981). Reasons for this change from wheat to barley are often associated with the period of aridity at the end of the 4th millennium BC as hulled barley requires less water for cultivation than emmer wheat and tends to cope better with periods of drought (Hillman, 1985; Nesbitt, 1996; Riehl, 2009). Additionally, hulled barley is thought to be more resistant to saline conditions and tolerant of poor soils (McCorriston & Weisberg, 2002) so could be grown in more marginal conditions around the settlement. This theory will be discussed in greater detail below with reference to crop husbandry and agricultural production.

Other explanations suggest that increased hulled barley production is connected with an expansion in animal herding and an equivalent need for large quantities of fodder (Miller, 1997). This is supported by texts from Tell Beydar that indicate hulled barley was primarily used for fodder (Van Lerberghe, 1996) as well as a regional expansion in cattle herding during this period (Zeder, 2003). At Tell Brak, glume wheat grains and chaff do appear to have been more prevalent than hulled barley during the Late Chalcolithic period (Hald, 2005). Hulled barley when identified, however, was found in a number of storage contexts and, contrary to the theories mentioned above, was thought to have been destined for human consumption due to its highly processed state (Hald, 2005: 122). Hulled barley grain from the Early Dynastic III TC oval building, was recovered in a similarly well processed state, particularly from barley grain dominated samples in Rooms 8 and 16. Moreover, these samples contained very little barley rachis or weed/wild remains potentially signifying that this hulled barley

[18] The lack of glume wheat grains identified at Tell es-Sweyhat could be due to the small number of samples recovered from this site.

grain had been rigorously processed before storage. As was mentioned above with regard to the hulled barley from the Hattusha underground silo, this high level of processing would have been very time consuming and does suggest that this grain was intended for human consumption rather than animal fodder. Beer made from barley was also a common product in Bronze Age Mesopotamia (Postgate, 1992: 170; McCorriston & Weisberg, 2002) but the lack of germinating grains from the TC oval suggests that the barley stored there was not destined for brewing (Brouwer, 1972).

In direct contrast to the increase in cultivation of hulled barley, the cultivation of glume wheats seems to have decreased within the northern Mesopotamian region during the Bronze Age. At Tell Brak, glume wheats decrease from the Early Uruk period (Colledge, 2003) and in the north Syrian Euphrates region the cultivation of emmer wheat is radically reduced during the Early Bronze Age (van Zeist & Bakker-Heeres, 1988). Similarly, when all the archaeobotanical results from Tell Brak are examined chronologically a decrease in the cultivation and use of glume wheats is apparent. In the TC oval, however, the glume wheats were the second most numerous crop varieties recovered, albeit in much lower quantities than those of hulled barley grain. Of these species, emmer wheat was the most common with a ubiquity of 55% whereas the identification of einkorn wheat was far less frequent (see **Table 7.1**), indicating that it may have been a crop contaminant of emmer rather than a cultivated crop in its own right. There have been a number of theories regarding this decrease in emmer wheat production, including social choice and the worsening climatic conditions present in the Late Uruk period favouring the production of hulled barley. McCorriston & Weisberg (2002) also suggest that the reduced visibility of glume wheat within the archaeobotanical record during the 3rd millennium BC is because the glume wheats require different methods of processing and so were stored separately from free-

threshing hulled barley crops. Certainly, extra crop processing stages are needed in order to de-husk glume wheat spikelets which would have required more human labour investment (Hillman, 1985; Jones, 1990). With this in mind, it has been suggested that glume wheats may have been grown primarily within the domestic sphere (McCorriston & Weisberg, 2002) and were, therefore, stored at the level of the individual household. De-husking would then have occurred on an ad-hoc basis directly before consumption.

Within the TC oval, emmer wheat grain and chaff were found in two different rooms separate from the main hulled barley storerooms. Room 12 in particular contained five samples dominated by emmer grain and Room 9 had one mixed composition sample (see **Figures 7.17** and **7.18**). Furthermore, the emmer wheat samples from Room 12 also appeared to have been through a different stage of crop processing, with higher numbers of weed/wild species classified as big, free and heavy indicating that these samples were primarily fine-sieving by-product (see **Figure 7.26**). Overall, the emmer wheat grain from the TC oval does appear to have been fully processed although possibly in a less rigorous manner to the processing of hulled barley. Similarly, it was stored in mixed crop deposits alongside hulled barley and free-threshing wheat. This indicates that glume wheat and hulled barley were not grown as a maslin crop, but were combined for storage after processing activities. Finally, the identification of emmer wheat grain primarily within one room may indicate that this species had a different intended use from that of hulled barley.

Other cereal species from the TC oval include the small barley and wheat grain identified within 86% and 34% of samples, respectively. Evidence from crop processing indicated that these grains were very unlikely to be the tail grains of the larger wheat and barley species, but instead represent separate varieties of hulled barley and emmer wheat. The role of these smaller varieties will be discussed further below with regards

to crop husbandry, but it would seem probable that these cereals were cultivated to take advantage of more marginal farming environments within the Tell Brak environs. This is because the production of smaller grains likely required less water during the grain filling period of plant growth allowing these varieties to be cultivated in more arid soils.

The final cereal crop identified from the TC oval was free-threshing wheat, and like the glume wheats this species was primarily identified within two rooms, Room 13 and the North Courtyard. The grain was found in a fully processed state, but in far lower quantities than equivalent hulled barley and glume wheat grains and in samples that contained quite high proportions of glume wheat chaff (see **Figure 7.15**). Additionally, crop processing analysis has identified all of the samples from these two rooms as fine-sieving by-products (see **Figure 7.26**), leading to the inference that these rooms may have been used for this activity. Overall, it is possible that free-threshing wheat, like emmer wheat, had a different intended use from that of hulled barley, and that was why it was being kept separate from the other cereal species (cf. Hillman, 1985). The recovery of few samples from Room 13 and the North Courtyard, alongside a lack of contextual information from these areas, however, means that any inferences about the use and consumption of free-threshing wheat are tenuous at best.

As was discussed above with regards to the Hattusha underground silo assemblage, it is difficult to define the overall intended use for stored cereals (Jones, 1998), and this continues to be the case at Tell Brak. Documentary evidence from the later Akkadian period at Tell Brak records the payment of barley flour rations to workmen (Eidem *et al*. 2001) and it seems reasonable to suggest that the fully processed hulled barley grain stored in the TC oval was also intended for this purpose. Texts from other northern Mesopotamian cities, however, suggest that hulled barley was a major source of animal fodder (Van Lerberghe, 1996). The fluid division between food and

fodder has been well recorded ethnographically (e.g. Halstead & Jones, 1989; Halstead, 2014) and it is possible that the TC oval grains could have been used for multiple purposes. The storage of clean hulled barley grain inside specific rooms of a potential administration building, however, supports the theory that these grains were intended for human consumption. Similarly, the storage of wheat in separate rooms from hulled barley in the TC oval may indicate that wheat grains were not intended as worker's rations, but for another form of domestic human consumption within the greater TC oval structure.

9.2.2.2 The wider agricultural economy

Although the primary function of the TC oval seems to have been to store cereal grain prior to its final consumption, a number of pulse species were also identified in the assemblage and attest to the cultivation and consumption of other crop species within the Tell Brak environs. A variety of pulses, and lentils in particular, have been found in multiple contexts at Tell Brak from the Uruk period and throughout the Late Chalcolithic period, although as part of primary fill contexts rather than as stored resources (Hald, 2005: 124). Additionally, they have also been identified from the 3rd millennium BC as stored products within domestic contexts (Charles & Bogaard, 2001). The lack of pulse species recovered from state level or 'public' buildings, however, has led to the suggestion that pulses were mainly cultivated in northern Mesopotamia at the household level as a supplement to the staple cereal crops. This would seem to be in contrast to the status of pulse cultivation in southern Mesopotamia where various species were recorded in the Ur III archives (Postgate, 1992: 170). Pulse cultivation generally requires more water than cereal cultivation and may have been more

widespread in the south as it could be supported by large irrigation systems. Northern Mesopotamian cities, by contrast, relied primarily on annual rainfall to support their agricultural systems which may not have been enough to support large-scale pulse cultivation. The identification of small amounts of lentil, common pea and grass pea from the TC oval suggests that these species were being grown in close proximity to the cereal fields and have become contaminants of the primary crop. This then is a similar situation to that identified from the Hattusha underground silo where pulses were not being cultivated or stored at the state level but were being grown on a much smaller scale within the wider landscape.

Other cultivated and managed plants mentioned in the Ur III texts include a number of fruit trees: pomegranate, apple, mixed date palm (Landsberger, 1967) and tamarisk as well as figs and vines (Postgate, 1992: 170). This wide range of managed fruit and nut sources from southern Mesopotamian sites, however, are not well attested to archaeobotanically at northern Mesopotamian sites. During the Late Chalcolithic period at Tell Brak, Hald (2005: 125) only identified grape and fig and neither of these species were found in great numbers. Similarly, only grape, *Pistacia lentiscus* and almond (*Amygdalus* sp.) were found in very small amounts in the TC oval assemblage. The lack of identified fruit and nut remains from this period, however, does not signify that these species were not an important part of the human diet. Certainly, the storage of fruit and nuts would not be expected within state or public owned buildings as these species were most likely managed, gathered and consumed on a more domestic level. The one exception to this may have been the production of wine which has been recorded as part of the royal menu at the palace at Mari (Postgate, 1992: 145) and as a potential liquid offering at the Sin Temple at Khafajah during the Early Dynastic II period (Delougaz & Lloyd, 1942: 41). This would suggest that wine was likely

produced on a large scale and may have been partially controlled by the temple and/or the palace. Finally, it is likely that the majority of fruit and nut species would have been consumed in a 'raw' state and were unlikely to become accidentally charred and preserved archaeobotanically.

Domesticated livestock such as sheep, goats, cattle and pigs were also an important feature of the wider economy and were kept for secondary products as well as meat. In southern Mesopotamia sheep seem to have been the most important species and were used for milk, wool and meat (Postgate, 1992: 158). Small flocks owned by individual farmers were often allowed to graze on the edges of cultivated areas and on fields that had been left fallow, enriching soils with manure and encouraging plant growth through 'tillering'. Documentary evidence from Lagaš, Larsa and Ur also indicate that the state/temple owned very large flocks used primarily for wool and that these would be managed by specialist shepherds away from the main urban areas (Postgate, 1992: 161).

At Tell Brak, sheep and goat species comprise the largest portion of the Akkadian faunal assemblage (Clutton-Brock *et al*. 2001) and texts from Tell Beydar indicate that several breeds of both species were present in the Khabur region. Again, these large flocks are thought to have been owned by the state/temple for wool and milk (van Lerberghe, 1996) and were likely to have been herded in upland pastures rather than within the city environs. Cattle and particularly specialised plough-oxen were also commonly owned by the state due to the costs involved in their upkeep (Halstead, 1995a). Faunal evidence shows that cattle herding experienced a dramatic expansion during the Early Bronze Age throughout northern Mesopotamia (Zeder, 2003). This was possibly due to the equivalent expansion of the arable economy and an increased need for traction and ox-drawn vehicles. As was discussed above in **Section 9.1.2.2**, the use

of plough-oxen amplified the amount of cultivable land whilst also providing a ready source of manure. The cost of their maintenance, however, was much higher than sheep/goats as they were unable to graze whilst working and would have needed to be fed cereal grain or cereal by-products. It is likely then that these animals were owned by the state/temple and rented out to farmers during the ploughing and planting season. Evidence for this system has been found at Ur III where administrators calculated cultivation costs by including oxen feed with the seed corn (Postgate, 1992: 164) and from textual sources and cylinder seals at Tell Beydar (Ismail *et al.* 1996).

9.2.3 Crop production and agricultural practice

As was discussed above with reference to Hattusha, this thesis has employed both crop stable isotope analysis and functional weed ecology to interpret the practices and processes used to cultivate domesticated crops. The choice of farming regime at Tell Brak would have been tailored to overcome the specific environmental challenges faced by the inhabitants of the city but would also have depended on access to land and control of the labour force. In this respect, the nature of crop production at Tell Brak is likely to been different to the nature of crop production at Hattusha even though both societies were engaged in the cultivation of the same range of cereal species.

9.2.3.1 Sowing time

According to the Sumerian text 'The Farmer's Instructions' from Ur III (Postgate, 1992: 167) the agricultural year in southern Mesopotamia began in late summer as the land was prepared for the planting of next year's crops. Sowing would

then occur in the early autumn using a seeder-plough pulled by cattle. Other texts from the Early Dynastic period at Lagaš record how farmers would calculate the amount of seed corn needed for a given area to achieve the best rate of yield in relation to seed corn planted, rather than the maximum yield per field area (Halstead, 1990; Postgate, 1992: 167). Harvest would then have taken place in late April and May with the barley ripening slightly before the wheat. In northern Mesopotamia the sowing and harvesting of crops is likely to have taken place 1-2 months later than in the south due to the higher latitude and to take advantage of the winter and spring rains (Charles *et al*. 2010). Today in north-eastern Syria, crops are generally sown from October-December and harvested in late May and June. It is also unlikely that spring sown crops could have been grown in this region before the introduction of petrol driven water pumps in the 20th century AD (Oates & Oates, 1976). Weed evidence from the TC oval supports this theory and indicates that crops grown in the Early Dynastic III period were also sown in the autumn and likely harvested by late May/June (see **Figure 8.10**). Furthermore, the lack of any identified spring sown weed taxa signals that the cereal crops were not planted during this period of the year.

9.2.3.2 Crop watering and manuring

The semi-arid location of Tell Brak is very marginal for rainfed agriculture, situated just within the lowest annual rainfall isohyets that could have supported this type of farming (Charles *et al*. 2010). Additionally, there is no conclusive archaeological evidence for large-scale irrigation systems such as those constructed in southern Mesopotamia during the Uruk period and the Early Bronze Age (e.g. Pemberton *et al*. 1988). There is some textual evidence for the hand watering of gardens

and small crop stands from Ur III (Postgate, 1992: 177) and the nearby wadis of Radd and Jaghjagh at Tell Brak would have provided some access to better-watered soils. These water sources may well have been seasonal, however, and dependant on rainfall in the hilly regions to the north of the site (French, 2003). The control of these water sources and the constant threat of drought would, therefore, have been of great concern to the inhabitants of Tell Brak (Oates, 1990), and have led to the suggestion that the city was also likely importing large amounts of staple crops from sites to the north located in more favourable areas for rainfed agriculture (e.g. McCorriston, 1995; Wilkinson, 2000). This theory will be discussed in greater detail below but has been introduced here as it may have a direct impact on the interpretation of the crop husbandry schemes in use at Tell Brak.

Carbon stable isotope analysis (**Figure 8.1**) on cereal grains from the TC oval indicates significant variation in $\Delta^{13}C$ values between the different cereal species. This provides potential insight into how the natural hydrology of the landscape around Tell Brak was exploited and may also indicate the preferential treatment of specific species and/or the importation of some crops from northern settlements. None of the cereal species appear to have been grown in markedly wet conditions, but a portion of the hulled barley and the smaller grained barley variety appear substantially drier than emmer or the small wheat grains (Wallace *et al*. 2013). This could indicate that both varieties of hulled barley were grown in drier soils away from the wadis, possibly because it is more tolerant of drought than the glume wheats (Hillman, 1985; Riehl, 2009) and could have survived in more marginal conditions. Certainly, the isotopic values for the smaller barley variety indicate that this crop was grown in the driest conditions represented by the TC oval assemblage. As was mentioned above, the production of small grains would have required less water than the production of large

grains, allowing these smaller varieties to grow in more arid soils. To date, these smaller grain varieties have not been reported from other sites in Mesopotamia, suggesting that they may have been developed and cultivated specifically at Tell Brak to take advantage of marginal farming conditions around the main mound. Additionally, barley may have been restricted to these drier areas because farmers had chosen to grow emmer wheat in the better watered soils. The lack of uneven topography in the environs of Tell Brak means that slope was not a causal factor of the variable $\Delta^{13}C$ values so must have been due to deliberate human choice. A final explanation for the amount of variation seen within the stable carbon isotope results at Tell Brak was that emmer wheat and a portion of the hulled barley was being imported from settlements in the north. At these sites the higher annual rainfall would automatically have provided better watered conditions than those available at Tell Brak and would, therefore, account for these higher $\Delta^{13}C$ values.

The use of manure or any other form of fertilization for agriculture is barely mentioned at all in texts from the Bronze Age because, as Postgate (1992: 172) says, it was of no concern to the official scribes. Use of artificial enrichment in the crop fields has been documented archaeologically, however, from scatters of abraded pottery dated to the 3rd millennium BC at Tell Brak (Wilkinson, 1994; Ur & Colantoni, 2010). Similarly, manure use has been attested at Tell Brak through the use of nitrogen crop stable isotope analysis (Bogaard *et al*. 2016b; Styring *et al*. 2017). The results of nitrogen ($\delta^{15}N$) stable isotope analysis from the TC oval seemingly mirror the carbon results and indicate that emmer and the small wheat variety were preferentially treated over hulled barley and the small-grained barley variety. **Figure 8.6** clearly shows that hulled barley and the majority of the small barley isotope values fall within the low manuring band, indicating that manure/middening material had not been applied to the fields in which these crops were grown within the last 3+ years (Bogaard *et al*. 2007;

Fraser *et al*. 2011; Styring *et al.* 2017). By contrast, the isotope values for emmer and small-grained wheat show that these crops were being grown in soils artificially enriched through the application of medium-high inputs of manure. Furthermore, if emmer wheat was being grown in the better watered soils near the wadis, these alluvium soils would also be naturally enriched with nutrients (French, 2003). As was discussed above, the use of manure has two limiting factors, availability and transportation. These limitations suggest that the glume wheats were being grown in the immediate 'infield' areas of Tell Brak where access to manure or kitchen midden material would have been less constrained. The better watered soils near the wadis are located c. 3km away from the main mound at Tell Brak so the transportation of manure to these areas would have required the use of oxen/cattle dragging carts or sledges. By contrast, hulled barley and the smaller grained variety may have been being cultivated within the 'outfield' region further away from the urban centre. This model of agricultural spatial patterning seemingly fits with the 'halos' of sherd scatters located near the main city mound (Wilkinson, 1994) and the linear trackways ('hollow ways') that radiate from the site and extend beyond these scatters thought to mark the limits of agricultural land at Tell Brak (Ur, 2003).

The preferential treatment of emmer wheat and the smaller grained wheat variety over both types of hulled barley in terms of access to better watered soils and artificial enrichment may reflect farmers' awareness that hulled barley is capable of surviving in much more marginal conditions. Additionally, these results may indicate that wheat was primarily grown for human consumption, whilst hulled barley was used for animal fodder as well as food. This division between cereal species has been observed at the Neolithic site of Kouphovouno in southern Greece, where stable isotope analysis indicated that free-threshing wheat was grown under preferential conditions for

human consumption whilst hulled barley was grown in more marginal conditions mainly as a fodder source (Vaiglova *et al*. 2014a).

When comparing the results from crop stable isotope analysis with the functional weed ecology, however, all samples (with the exception of one) were classified within the 'extensive' range. Furthermore, the functional ecology results (see **Figure 8.13**) from Tell Brak appear considerably more 'extensive' than the functional ecology results from the Hattusha underground silo. These results indicate that the fertility levels within the arable fields, regardless of the cereal species cultivated, were fairly low during the Early Dynastic III period, and are consistent with overall low inputs of manure and water. The combined stable isotope and functional ecology results further support this theory, as there appears to be no correlation between isotope values and discriminant function. As was discussed above with reference to the Hattusha underground silo results, a correlation between discriminant function and stable isotope results suggest the presence of several different crop husbandry regimes. Indeed, at Hattusha this correlation led to the interpretation that both species of crops stored in each chamber were representative of a different crop husbandry system as has been observed from modern agricultural survey data (Bogaard, *et al*. 2016a; 2016b). By comparison, the functional ecology results from Tell Brak indicate that all cereal species were grown under a similar 'extensive' management scheme, but that within this system the glume wheat crops received higher inputs of water and manure.

9.2.3.3 Crop production in northern Mesopotamia

The results of crop stable isotope analysis from the TC oval and the theory of 'extensive' crop production at Early Dynastic III Tell Brak, correlate with the findings

of other stable isotope studies from sites such as Tell Leilan, Hamoukar, Tell Sabi Abyad and Tell Zeidan in northern Mesopotamia. Previous work by Riehl *et al*. (2014) and Styring *et al*. (2017) has found that there appears to be no significant changes to crop $\Delta^{13}C$ values from the Ubaid period to the Bronze Age (5300-2500 cal. BC) at all sites in this region, a factor that would be expected if crops were reliant solely on variable annual rainfall. Instead, this lack of isotopic variation indicates that there was some type of water resource management, even if this was only the strategic sowing of certain crops in better-watered soils around the site. Work by Styring *et al*. (2017) has also shown that wheats and pulses, throughout sites in northern Mesopotamia, tend to be better watered than hulled barley crops. This again corresponds directly with the stable isotope results from the TC oval and indicates that the preferential treatment of some crops was a strategy to maximise yields in poor arable conditions at Late Chalcolithic and Bronze Age settlements in this region, rather than a practice unique to one site.

In terms of nitrogen crop stable isotope analysis, results from Araus *et al*. (2014) and Styring *et al*. (2017) indicate that there was a general decrease in cereal grain $\delta^{15}N$ values through time at various sites in the Near East and northern Mesopotamia. This has been linked with an overall decrease in soil fertility due to the increased exploitation of arable areas (Araus *et al*. 2014) and the cultivation of more marginal agricultural zones. Additionally, Styring *et al*. (2017) have linked the decrease in $\delta^{15}N$ values with an equivalent increase in site size as populations expanded during the Bronze Age. Increased population sizes would have required the production of greater quantities of grain and the expansion of agricultural areas beyond the immediate environs of the main settlement. These 'outfield' plots would necessarily receive lower inputs of manure due to the difficulty associated with the transportation of this resource over long distances. The combined stable isotope and functional ecology results from

the TC oval seem to fit within this model (Styring *et al*. 2017) and as was discussed above, may indicate that wheat crops were grown within the 'infield' areas close to the Tell Brak main mound whilst barley was primarily cultivated within the 'outfield'. The combination of these crops within the same storage area then would suggest that agricultural land ownership was spread over both of these disparate areas and that this spatially variable method of production may have been a risk-buffering mechanism.

9.2.4 Trade and the management of agricultural risk

A key question with regards to the agricultural economy of Tell Brak is whether the plant remains recovered from the site are actually representative of crops grown in the immediate environs of the city, or whether crops were imported from other urban sites in northern Mesopotamia. Indeed, the semi-arid environment of Tell Brak and the sensitivity of arable agriculture, in this area, to even small changes in annual rainfall (Riehl, 2009) have led to suggestions that Tell Brak would not have been able to survive without the assistance of regional trade networks. A number of models have been devised to categorise sites into crop producers or crop consumers, these models have tended to focus on the composition of plant parts found on a site as a means of identifying various plant-based activities (Hillman, 1981; 1984; van der Veen & Jones, 2006). Varying lines of evidence including the identification of early stage crop processing activities from the mid-3rd millennium BC at Tell Brak (Charles & Bogaard, 2001) and presence of sherd scatters and the 'hollow ways' (Wilkinson, 1994; Ur, 2003) certainly indicate that some form of arable agriculture was taking place at the site. This evidence, coupled with the marginal conditions for farming present during the Early Dynastic III period may indicate that Tell Brak was both cultivating its own crops and

trading produce from other regions at this time. In particular, it is thought that crops were being imported from sites located to the north of Tell Brak, such as Tell Leilan (Weiss *et al*. 2002). These settlements were situated in more favourable climates for rainfed agriculture, and may have provided Tell Brak with staple products, including the cereals stored in the TC oval (Wilkinson, 2000).

Documentary evidence from Tell Beydar suggests that trade networks and a system of economic interdependency between Tell Brak and other nearby settlements were well established by the 3rd millennium BC, and are likely to have existed from the early 4th millennium BC (Wilkinson, 1994; McCorriston, 1995). In fact, the location of Tell Brak, coupled with the size of both the city and its estimated population density, has led to suggestions that the site was perfectly positioned to control regional trade on both a micro- and macro-scale (Eidem & Warburton, 1996). Micro-level trade would have involved the exchange of goods with satellite sites (e.g. T2) located within the immediate environs of Tell Brak (Emberling & MacDonald, 2001; McMahon, 2013). By contrast, macro-level trade networks would have existed between Tell Brak, smaller settlements within the wider Khabur region and other major cities in both southern and northern Mesopotamia. Tell Brak was well placed to exert considerable control over these trade networks as its status as the 'gateway city' allowed it to manage access to the agricultural lands of the Khabur valley and the main road to the northern Levant (Oates *et al*. 2001). Textual sources from the city of Mari also indicate that at least part of this trade system was concerned with the export and import of surplus grain to the major urban settlements (Akkermans & Schwartz, 2003: 222). Furthermore, the excavation of mud-brick architecture associated with large-scale crop processing and storage at the smaller 3rd millennium BC 'village' sites of Tell Kerma (Saghieh, 1991; McCorriston, 1995), Tell Raqa'i (Curvers & Schwartz, 1990; Schwartz, 1994; van

Zeist, 2003; Schwartz, 2015), Tell Atij (Fortin, 1998) and Tell Knedig located in the middle Khabur region have led to suggestions that this area was engaged in specialist arable production and crop storage for a central authority at Tell Brak and/or Mari (Schwartz & Curvers, 1992; Schwartz, 2015). Evidence from southern Mesopotamia has indicated that 3rd millennium BC large-scale cereal cultivation, mobilization and storage were largely controlled by the temple and the palace (Postgate, 1992: 170) and it would seem likely that this was also the case in northern Mesopotamia and at Tell Brak.

The lack of textual sources from Tell Brak during the Early Dynastic III period has, however, precluded the specific identification of these trade networks and made it very difficult to ascertain exactly where traded crops, including the TC oval material, may have been being received from. The assessment of carbon crop stable isotope values may provide some indication as to the area in which the crops were originally cultivated. As was discussed above with reference to crop stable isotope analysis, it is likely that all cities in northern Mesopotamia were reliant on rainfed agriculture and water resource management rather than artificial irrigation systems. Similarly, it would appear that hulled barley was generally grown in less well-watered conditions in comparison to glume wheat species.

The carbon stable isotope values from a specific site can, therefore, be seen as representative of the rainfall from that area and/or water management practices. With this in mind, it is possible to compare the values from crops stored in the TC oval with values from mid-3rd millennium BC crops recovered from Tell Leilan (Styring *et al*. 2017) and Tell Mozan (Riehl *et al*. 2013) located above the 400mm/year rainfall isohyet to the north of Tell Brak, as well as with other sites to the south within the middle Khabur valley (Riehl *et al*. 2013). Crops from the more northerly sites are expected to have been grown under wetter conditions due to the higher annual rainfall in this area. If

the crops from the TC oval originally came from these sites, the stable carbon isotope values would be expected to match these equivalent values. Comparison of the TC results with carbon stable isotope values from Tell Leilan (Styring *et al*. 2017), however, indicates that the Tell Brak material was grown under significantly drier conditions overall. Furthermore, even the carbon stable isotope values for emmer wheat from the TC oval, thought to have been grown in better-watered soils, still appear significantly *drier* than carbon values for glume wheat at Tell Leilan (see **Table 9.2** for results of Welch's T-test between values from Tell Brak and Tell Leilan).

Table 9.2 – Results of Welch's two sample T-test between $\Delta^{13}C$ values from Tell Brak and Tell Leilan (Styring *et al*. 2017).

Statistical Test	Isotopic Analysis	Species	Sites	Results
Welch's two sample T-test	Carbon	Hulled barley	Tell Brak - Tell Leilan	T(16.83)=-5.94, p=<0.005
Welch's two sample T-test	Carbon	Emmer wheat	Tell Brak - Tell Leilan	T(5.77)=-8.03, p=0.0002

Table 9.3 – Mean stable carbon isotope values measured from five mid-3rd millennium BC sites within the middle Khabur valley (Riehl *et al*. 2013).

Site	Taxon	Mean ($\Delta^{13}C$ ‰)
Tell Brak	Hulled barley	17.23
Tell Brak	Small barley	15.91
Tell Kerma	Hulled barley	15.88
Tell Atij	Hulled barley	16.39
Tell Raqa'i	Hulled barley	16.75
Tell Mozan	Hulled barley	16.51

These results indicate that the crops stored within the TC oval were not grown in the higher rainfall zone of Tell Leilan, and by extension at other northern sites located within the higher rainfall isohyets. Instead the stable carbon isotope results from Tell Brak seem to fit roughly with carbon isotope results from other mid-3rd millennium BC sites in the middle Khabur valley located within the same rainfall isohyet (see **Table 9.2** of mean carbon stable isotope values).[19] Generally, the results from Tell Brak are a fraction higher than the middle Khabur sites, but this may be reflective of Tell Brak's slightly higher annual rainfall due to latitude or the management and use of better watered soils near the wadis. The mean value for small-grained barley, however, which has been grown under less well-watered conditions at Tell Brak, is remarkably similar to the mean stable carbon isotope values for hulled barley at Tell Kerma and Tell Atij (see **Table 9.3**).

On the whole, comparison of carbon stable isotope results from the TC oval with other 3rd millennium BC sites in northern Mesopotamia indicates that the TC oval crops were not imported from other urban sites located further north. Instead, these crops are most likely to have been grown within the environs of Tell Brak or within the greater Khabur valley region. This does not lessen the role of Tell Brak with regards to the trade of goods and staple products with other sites in both northern and southern Mesopotamia, however, and it would still seem very likely that the site was importing crops to store and redistribute to workers during this period (Powell, 1990). With regards to risk management, it may have been Tell Brak's placement at the centre of a number of trade networks that allowed it to survive the period of devolution at the end of the 4th millennium BC. The importation of agricultural produce from regions to the

[19]Unfortunately, it is not possible to carry out statistical tests on the stable carbon isotope values from other sites from the Middle Khabur valley as the raw isotope data was not available, instead only mean values were recorded (Riehl *et al*. 2013).

north that had been less affected by climatic changes allowed the site to absorb the shocks caused by harvest failure without massive population loss. At the same time, however, the management of agricultural risk may explain why populations moved back to rural villages during this period, as risk and the effects of a poor harvest are much easier to manage at the smaller rural level. Overall, the import of staple foods combined with a low variance production system and the cultivation of both 'infield' and 'outfield' areas increased the resilience of the Tell Brak agricultural system. This allowed the site and its population to survive fluctuations to annual arable yields caused by shifts in rainfall levels, whilst also providing enough food for daily consumption and storage.

9.3 Risk management and urban resilience

As discussed in **Chapter 1**, agricultural risk and the concept of 'uncertainty' are particularly heightened in urban environments like Hattusha and Tell Brak due to higher percentages of the population not directly contributing to the agricultural economy (e.g. Barthel & Isendahl, 2003; Marston, 2011). The level of urban resilience needed to survive unpredicted shocks is, therefore, necessarily higher within each city than it would be in a rural village. Additionally, the inhabitants of both sites had to cope with a range of environmental problems which further increased the probability of food loss or total subsistence failure. The city of Hattusha was spatially restricted by local topography and at risk of sudden, catastrophic drought. Similarly, Tell Brak was situated in a relatively marginal environment for rainfed arable agriculture so the control and management of water would have been of extreme importance. To this end, the inhabitants of Hattusha and Tell Brak necessarily participated in several systems of risk

management to ensure that the city and its populace were able to survive ecological disasters without collapse and with the ability to continue developing afterwards (Barthel & Isendahl, 2013). At both cities socio-ecological memory of past subsistence failures essentially led to the development of risk management strategies (Barthel *et al*. 2010) specific to the society that implemented them, but with a number of similar aspects. The central features of agricultural risk management at Hattusha and Tell Brak were; investment in a low variance system of farming, the pooling of resources from different agricultural areas and the storage of produce for times of hardship. When compared with Marston's (2011) three categories of agricultural diversification (discussed in **Section1.3**), these strategies seem to fit within the categories of spatial diversification and temporal diversification. Noticeably missing, however, is the category of *crop* diversification, as both the Hattusha and Tell Brak agricultural economies were based predominantly around the cultivation of cereal crops.

During the earlier Neolithic period, crop diversification, alongside storage of the 'normal' surplus (Halstead, 1989), was of primary importance for the survival of small villages and farming communities (Halstead, 1994). Archaeobotanical and zoological evidence from the Near East (e.g. Willcox, 2014), Turkey (e.g. Bogaard *et al.* 2017), Greece (e.g. Valamoti, 2004; Diffey, *unpublished*) and Central Europe (e.g. Bogaard, 2004) have revealed that Neolithic societies adopted a broad-spectrum approach to agriculture, combining the intensive cultivation of a wide range of domesticates and the husbandry of livestock, alongside small-scale use of wild plant and animal resources. These practices are thought to have varied greatly by region and were dependant on cultural and environmental factors specific to each society and location. The cultivation of a range of crops and the use of selected wild resources would have helped spread seasonal labour requirements for individual households and/or small communities.

Furthermore, the use of intensive farming techniques would have maximised the yield from the small parcels of land cultivated by Neolithic farmers thus reducing the risk of complete crop failure (Halstead, 1994).

Towards the end of the Neolithic period and the beginning of the Early Bronze Age, populations began to expand and the constraints on farming caused by lack of available labour were greatly reduced. Instead, ever greater supplies of food were needed to support a new class of non-producers and to store for times of crisis. This was achieved by increasing the amount of land under cultivation and spreading labour costs over a wider area rather than increasing labour inputs per unit of land. To this end, control of agricultural land became critically important and contributed heavily to the creation and maintenance of lasting social inequalities (Kohler *et al*. 2017; Bogaard *et al*. 2018). This move towards a less intensive or 'extensive' form of agriculture is thought to have started at the household level as individual farming households sought to increase their annual yields, and gradually expanded as urban populations grew and even greater quantities of food were needed. Additionally, the growth of less intensive farming systems were necessarily focused on cereals as these species require less labour investment, are easily assessable for taxation purposes (Scott, 2017: 21), can grow in unfavourable climatic conditions and survive well in long-term storage (e.g. Sigaut, 1988). Documentary and archaeobotanical evidence from Hattusha and Tell Brak also prove that cereals were easily taxable and could be used as payment or 'rations' for workers (Yakar, 2000; Eidem *et al*. 2001). Pulses, by contrast, were certainly still cultivated within these societies but these crops seem to have been relegated to the domestic sphere and did not play an important role within the urban agricultural economy (Halstead, 1999).

To this end, the development of low-input (or 'extensive') agriculture was both driven by a rapidly expanding and urbanizing population but also a driving force of this expansion. Within this system, the cultivation of more land became the easiest method for creating larger quantities of agricultural produce to not only feed the city but support and maintain the city during times of crisis. 'Extensive' farming as a form of risk management, however, was tailored to the type of society/city it was designed to support, and this is clearly the case at both Hattusha and Tell Brak. At Hattusha the underground silo represented the collection of taxed cereals grown under a number of different agricultural regimes (including lower and higher input systems) and potentially a number of different agricultural areas located in the wider environs of the city. The use of different regimes and the dispersion of fields within a wide agricultural zone meant that farmers could utilize a range of microenvironments. Furthermore, it meant that if one area suffered from harvest failure the stream of taxed produce would continue from the other regions. Finally, the long-term storage of taxed grain provided the inhabitants of Hattusha with the means to survive several years of poor harvest without complete collapse.[20] By comparison, the cereals in the TC oval at Tell Brak all seem to have been grown under a low input system within the immediate environs of the site. Within this area, however, stable isotope analysis has shown that Tell Brak farmers were actively cultivating different cereal species in different areas of the landscape to maximise overall yields. Thus, emmer wheat appears to have been grown in wetter soils near the wadis, whereas the small hulled barley variety was grown in much drier conditions. Additionally, it is possible that this smaller variety was selected specifically to take advantage of these less favourable conditions that could not have supported the growth of larger species. There is also textual evidence that Tell Brak was

[20] This conclusion further highlights what a catastrophe the burning of the fire may have been at the time, as it may have taken several years to recoup the produce lost.

supplementing its agricultural economy with imported produce from northern cities and smaller urban areas in the Khabur valley, again reducing the risk from harvest failure in one particular area. At both of these sites then, it was the use of low input ('extensive') farming regimes that provided inhabitants with the food required for daily consumption and storage, but it was the society specific tailoring of each regime that raised the capacity of each socio-ecological system to absorb shocks without immediate collapse.

9.4 The nature of Bronze Age agriculture

The emergence of low-input ('extensive') agricultural systems during the Bronze Age was the culmination of a series of social and environmental processes that had their roots in the earlier Neolithic period. As discussed above, Neolithic agriculture in western Asia was characterized by mixed, small-scale intensive cultivation. These regimes would have involved high-inputs of labour including the use of manuring and artificial watering as a means of enriching agricultural land, as well as methods of enhancing cultivation habitats, such as tillage and hand-weeding (Halstead, 1981; 1987; 1989; 1996; Bogaard, 2004; 2005). Key to these farming regimes was the integration of domesticated animals used for traction, a source of manure and other secondary products as well as consumption (e.g. Sherratt, 1981; Evershed *et al*. 2008). Towards the end of the Neolithic period, however, domestic producers began to engage in larger-scale, lower-input forms of farming as a means of maximising arable yields and to produce a surplus capable of supporting a new population of non-producers. By the Middle Bronze Age the agricultural economy seems to have split into a number of different spheres of production. Firstly, the state/temple controlled sphere of production, including produce grown for taxation and the cultivation of crown-owned lands, was

focused exclusively on the production of cereals alongside the separate pastoral management of large livestock herds and specialized plough-oxen. The nature of these state-controlled agro-economies was fairly homogenous, reliant on low input cereal crop husbandry systems with limited use of manuring, hand-weeding or artificial watering. Instead these regimes were focused on maximising the yield per amount of seed corn planted, rather than per unit of land cultivated. As discussed above in **Section 9.3**, however, evidence from Hattusha and Tell Brak has shown that these types of farming systems were modified by the society implementing them to overcome specific environmental and social challenges faced by that city.

The second sphere of production was focused around the domestic household and was based on smaller-scale arable agriculture, horticulture and management of livestock. This domestic sphere was far more diverse than the state-controlled sphere and included the cultivation of a much wider range of crops not regularly mentioned in Bronze Age documents. Identification of pulse species from within the Hattusha underground silo and the Tell Brak TC oval[21] indicate that these crops were likely cultivated in the vicinity of the city. Yet, the number of pulse remains found and the lack of documentary evidence regarding their cultivation suggests that these crops were restricted to the domestic economy. This theory is supported by new evidence from the Bronze Age palace of Knossos, Crete. Recent excavations of a Late Bronze Age Knossian house on the Gypsades hill located to the south of the palace have identified a wide range of pulse species (Bogaard & Diffey, *unpublished*), namely, grass pea (*Lathyrus sativus*), Celtic bean (*Vicia faba*), bitter vetch (*Vicia ervilia*), lentil (*Lens culinaris*), pea (*Pisum sativum*) and Cyprus vetch (*Lathyrus ochrus*). However, while texts from the archives at Knossos indicate that the palace was directly involved in the

[21] Pulses have also been found in other contexts at Tell Brak during the Early Dynastic III period (Charles & Bogaard, 2001).

large-scale production of staple crops and the management of olive trees (Jones, 1984b; Halstead, 1995b: 1999: 2004: 2005), they do not mention the cultivation of pulses. These pulse remains, therefore, have been interpreted as the produce from small plots located in-between houses and in nearby gardens. These would have been cultivated purely for domestic consumption and would not have played a role in the state-controlled agro-economy (Nitsch *et al*. in press; Bogaard & Diffey, *unpublished*). With this in mind, it is likely that the inhabitants of Hattusha, Tell Brak and other Bronze Age cities were also cultivating pulses for domestic consumption particularly in hinterland villages but also in small plots within the city itself. In this respect, the domestic sphere somewhat resembles the earlier Neolithic agricultural economy, encompassing a far more mixed system of production. It is likely, however, that individual farming households were involved in both the state/temple sphere and the domestic sphere, working on crown-land or producing food on a more 'extensive' scale for taxation as well as growing crops in much smaller plots for their own personal consumption.

The nature of Bronze Age agriculture is also inextricably linked with the rise and development of significant levels of lasting social inequality within both urban and rural society. As was discussed above, the move towards a less intense (or 'extensive') form of agriculture began during the Neolithic period as individual households gradually moved to increase their arable production through the cultivation of ever larger plots of land. The annual 'normal surplus' was, therefore, increased allowing households the resources to purchase labour and/or livestock as well as providing them with the ability to invest in more land and provide aid for struggling neighbours (e.g. Halstead, 1989; 2006). The development of labour-saving technology, such as the ox-drawn ard, increased the amount of land that could be cultivated at any one time permitting the creation of large-scale surplus production. These systems of production, however, are

'wasteful' of land and promote land shortages between landowners and those that cannot afford to buy their own land (Goody, 1976; Sherratt, 1981).

Gradually, towards the Late Neolithic/Chalcolithic period it was the land itself that had become the most important resource in the agricultural economy, rather than the amount of labour that could be invested into a specific plot (Bogaard *et al*. 2018; Bogaard *et al*. submitted). Land became the greatest source of wealth, and equally the greatest cause of social inequality as it could easily be transferred inter-generationally through inheritance (Borgerhoff Mulder *et al*. 2009). Thus, land 'monopolies' could be created whereby one family or temple controlled large swathes of arable land and thus, the agricultural economy. Nowhere is this situation clearer than in the Hittite empire where the crown nominally owned all arable land but directly retained land, known as the 'king's share' from every rural settlement in certain proportion to the size of the community (Yakar, 2000: 267). These parcels of land would then either be granted to individuals as 'fiefs' or worked by the community as part of their *luzzi* service (Diakonoff, 1982; Giorgadze, 1991) with all produce given to the king as tax.

Furthermore, by linking land to agricultural output, particularly with regard to cereal cultivation, it automatically becomes easier to calculate appropriate taxation levels, increasing bureaucratic control over the storage of surplus produce and the agricultural economy in general (Scott, 2017: 131). At Bronze Age Hattusha and Tell Brak the disparity between the land-rich and the land-poor had widened to the extent that the wealthy were also able to control regional and long-distance trade, access to rations, taxation systems and most crucially the surplus stored for times of crisis. This effective control of the populace is seen throughout the archaeological record and is heightened in the case of Eastern Mediterranean cities where the construction of palace and temple complexes exist in stark contrast to the house footprints of rural farmers

(Kohler *et al*. 2017). In this regard, the expansion of Bronze Age farming and the investment in land and cereal cultivation, rather than labour can be considered a fundamental feature of the rapid rise in social inequality seen during this period.

Finally, it would appear that the nature of Bronze Age farming both shaped and helped to shape the development and growth of the city and its wider hinterland throughout the Bronze Age. Furthermore, by comparing the results of this thesis with other studies from Central Anatolia and the Near East (e.g. Hald, 2008; Bogaard *et al*. 2013; Stroud, 2016; Styring *et al*. 2017) the move to a more extensive agricultural system in this period seems to have been a common factor throughout these regions. As discussed above, the shared features of this system include the expansion of cultivation areas to include 'infield' and 'outfield' zones, a focus on the growth of cereal crops, and the limited use of enrichment and artificial watering mechanisms.

An over-arching definition of Bronze Age agriculture, however, is still problematic due to the range of husbandry regimes and practices used during this period. Evidence from Hattusha has signified that the Hittite agricultural economy was founded on the use of a variety of farming regimes, including lower and higher intensity systems. By contrast, evidence from the TC oval at Tell Brak has indicated that crops were grown in a range of agricultural conditions around the site and included the favourable treatment of some crop species as a means of maximising the overall yield. Each of these systems was developed to support a particular Bronze Age society and as such, the differences seen between the two sites should be interpreted as adaptations to specific environmental challenges, the structure of each society and the physical construction of the city itself. Overall, feeding the Bronze Age city involved the use of a range of agricultural practices, as well as systems of taxation and trade, and it was this

diversity of mechanisms that allowed these urban landscapes to flourish for hundreds of years.

Chapter 10

Conclusion

This project has sought to provide a comparative study of agricultural production in Bronze Age urban systems by analysing the nature of crop production at the cities of Hattusha in Central Anatolia and Tell Brak in north-eastern Syria. Through the application of traditional archaeobotanical techniques alongside crop stable isotope analysis and a functional ecological approach to the interpretation of arable weed taxa, this study has provided a new body of archaeobotanical data for the Bronze Age in these areas. It has also offered new insights into the variety of farming methods used within and between early urban contexts and has allowed a new discussion regarding the social and ecological consequences of farming practice under conditions of lasting social differentiation. This final chapter will summarize the major findings of this study before considering the future direction of research into Bronze Age agricultural systems.

10.1 Assessing the research aims

10.1.1 To investigate the nature of crop production at two well-established Bronze Age cities in Central Anatolia and northern Mesopotamia

Archaeobotanical analysis of plant remains from Hattusha and Tell Brak has revealed that both cities were reliant on low-input, low variance agricultural systems to provide food for daily consumption and long-term storage. These systems were focused

primarily on the rainfed cultivation of cereal species, in particular hulled barley, as these crops were able to provide reasonable yields even under marginal growing conditions. Cereal grain can also be easily regulated for bureaucratic purposes and tends to survive well in long-term storage. This study has, however, also highlighted the level of variation that exists *within* low-input systems at each site. Inhabitants from Hattusha and Tell Brak necessarily tailored their crop production regimes to overcome environmental and societal challenges associated specifically with each city. At Hattusha it was evident that the underground silo was being used to store cereals that had been cultivated in a range of different growing conditions. Correspondence analysis and crop stable isotope analysis indicated that hulled barley and glume wheat stored within each chamber of the silo corresponded with the use of a slightly different crop husbandry regime. For example, the cereals from Chamber 30 were grown under a low-intensity system with low inputs of water and medium-low inputs of manure. By contrast, cereals from Chamber 12 were grown under a higher-intensity system with medium inputs of water and high inputs of manure. The existence of cereals grown under multiple regimes within the same storage facility would suggest that the city of Hattusha was actively pooling resources, through taxation, from different areas in its agricultural hinterland for subsistence. This would have been necessary due to the region's rugged topography and the lack of large agricultural areas surrounding the city (Bryce, 2002: 72). Instead, fertile soil for agriculture was located primarily in nearby valleys and was likely farmed by small rural communities under management by the city or using sharecropping arrangements (Yakar, 2000: 278).

By contrast, the city of Tell Brak was surrounded by flat land suitable for arable agriculture and the presence of radiating 'hollow-ways' (Wilkinson, 2000; Ur, 2003) would suggest that farmers walked out to the fields from the city each day. Instead, the

primary challenge faced by Tell Brak farmers was the management of limited water resources in an area that was fairly marginal for rainfed cultivation (Charles *et al*. 2010). Use of crop stable isotope analysis has revealed that different crops were likely grown in different areas of the Tell Brak landscape to take advantage of the uneven environmental conditions. These results suggest that glume wheat crops were grown in wetter soils surrounding the nearby wadis whilst hulled barley, and the small hulled barley variety in particular, were grown in drier areas with little artificial enrichment. This use of both 'infield' and 'outfield' areas around the main city would have allowed the cultivation of large areas of land with limited labour resources whilst also maximising the potential arable yield by exploiting the stress-tolerant nature of barley for use in marginal environmental conditions.

10.1.2 To assess how diverse management practices may have affected social organization within both the city and smaller rural communities

The development of less intensive ('extensive') forms of agricultural production seems to have been both a cause and a consequence of the emergence of lasting social inequality between agricultural producers and the bureaucratic elite (Bogaard *et al*. 2018). One of the primary causes of this change appears to have been the shift from labour-focused agricultural systems to land-focused agricultural systems with arable land itself becoming the most important and quantifiable resource within the agricultural economy (Bogaard *et al*. submitted). Divisions between the land-rich and the land-poor may have led to the creation of the different spheres of production, the state/temple land-rich sphere able to force farmers to work on behalf of the elite and the domestic land-poor sphere which produced food purely for household consumption. At

Hattusha social divisions are displayed prominently around the city in the forms of monumental architecture, the underground silo itself is situated directly below the acropolis so that the king could keep an eye on it (Seeher, 2006: 81) and the Hittite Law Codes which clearly state the rules surrounding the ownership of land as well as documenting the various taxation systems (Yakar, 2000: 267). In fact, it would appear that farmers were unlikely to have lived within the walls of Hattusha at all, but rather were based primarily in rural settlements around the city's hinterland. Results from the underground silo also indicate some level of social division between farmers in the smaller rural communities surrounding the city. The range of crop husbandry regimes, as denoted by stable isotope analysis and functional ecology, would suggest that some Hittite farmers had preferential access to better watered soils and/or supplies of manure. Additionally, documentary evidence states that ownership of plough-oxen was not widespread and that most farmers had to rent oxen by the day. This would have been a considerable expense for domestic producers whilst also consolidating power within the hands of oxen-owners.

At Tell Brak the uneven distribution of prime agricultural land along with access to human and animal labour sources was also likely to have been a major source of social division within the city. The storage of both hulled barley and glume wheat within the TC oval, however, would suggest that farmers had access to parcels of land in both the 'infield' and 'outfield' cultivation zones, rather than the state/temple controlling the 'infield' and relegating domestic producers to the 'outfield'. Archaeological evidence from other sites in the Khabur valley region (e.g. Schwartz & Curvers, 1992) has also suggested that smaller rural settlements were engaged in specialist arable production for a central authority. If this authority was the state/temple at Tell Brak, it would indicate that the city had direct control over a very large

hinterland region and that rural producers were also subject to management from the bureaucratic elite.

10.1.3 To use the dual themes of risk and urban resilience as approaches to agricultural regime choice

Key to the maintenance of the city was the implementation of several risk-buffering mechanisms designed to allow the population to survive sudden catastrophes such as drought, harvest failure or war. During the Neolithic, these mechanisms included the intensive cultivation of a range of domesticates and the sharing of resources amongst neighbours. During the Chalcolithic period, the emergence of a non-producing class, however, required the creation of large agricultural surpluses that were not capable of being produced by small-scale, intensive agriculture. At both Hattusha and Tell Brak these requirements were heightened by the rapid growth in population size, but the choice and implementation of agricultural system was constrained by environmental and climatic challenges local to each city. The Central Anatolian plateau and north-eastern Syria are both regions prone to unexpected drought that can continue for several years at a time. The development of low-intensity, low-variance agricultural production systems then would have been essential to these societies as a means of establishing a level of urban resilience capable of absorbing agricultural shocks.

Archaeobotanical analysis from both sites has revealed that ‘extensive’ farming systems at Hattusha and Tell Brak were tailored specifically to support each type of society/city and to overcome the unique environmental challenges present in each region. At Hattusha this included the exploitation of different agricultural areas, the use of a range of agricultural regime intensities and the use of large-scale long-term storage.

By comparison, agricultural production at Tell Brak revolved around the cultivation of 'infield' and 'outfield' areas, the preferential treatment of some cereal species to maximise yields and the importation of staple products from other geographical regions. Both of these systems were also part of a much wider agricultural economy that included large-scale animal herding, horticulture and the cultivation of a range of other domesticates. Overall, regime choice was due to a number of interconnected factors, including social structure, city location and social history. Agricultural risk, however, was an issue experienced by every Bronze Age city and to this end, the themes of risk and urban resilience are useful approaches for explaining the amount of variation seen both *within* the agricultural systems present at Hattusha and Tell Brak and also *between* the two cities as a whole.

10.1.4 To use innovative methods to interpret key archaeobotanical assemblages

This study has sought, wherever possible, to use the innovative methods of crop stable isotope analysis and the functional interpretation of arable weed taxa as a means of furthering the interpretation of archaeobotanical assemblages. A number of previous studies have applied one or other of these methodologies to various sites in the Near East; in particular crop stable isotope analysis has been used to assess the effects of regional climate change (e.g. Riehl *et al*. 2013). The combination of both techniques, however, has rarely been applied, primarily due to the lack of archaeobotanical assemblages rich enough for this type of analysis. This study represents the first time that both of these methods have been used on material from Bronze Age Central Anatolia and also the first time that both methods have been used on the same archaeobotanical assemblage from Bronze Age Syria.

At Hattusha and Tell Brak the use of this combination of analytical methods has provided a completely new set of data regarding the nature of crop production and the choice of agricultural regime. This has advanced a far more detailed view of urban farming at both sites and within the wider Near East, as well as allowing a detailed interpretation of specific crop husbandry techniques and the relationship between food production and the city. Furthermore, this work is the first time that resultant archaeological stable isotope and functional ecology datasets have been combined together as a means of directly comparing ecological information from both the cereal grain and associated arable weeds. This has allowed the assessment of variation both *within* and *between* agricultural regimes and highlighted the range of farming methods practiced in one urban system.

10.2 Feeding the city

The development of Near Eastern urban landscapes during the Bronze Age necessarily saw major changes in terms of social organization, architecture and agricultural economy, but they also signify major changes in methods of archaeological interpretation and the creation of archaeological data. During the earlier Neolithic period, the origins of agriculture, plant domestication and the establishment of the domestic mode of production have been well studied using a range of specialisms and techniques (e.g. Halstead, 1989; Bogaard, 2004; Evershed *et al*. 2008). By comparison, the discovery of texts and pictographic representations of agriculture at Bronze Age cities has seemingly reduced the desire to explore and analyse the specific nature of the agricultural economy used by these societies. Instead, agriculture has been thought of as primarily state-controlled (e.g. Childe, 1950) and relegated to a rural hinterland that was

divorced from life in the city (Gallagher & McIntosh, 2015). The results of this thesis have provided two snapshots of Bronze Age farming in Central Anatolia and north-eastern Syria, emphasizing the high level of variation both within these societies but also between these two different urban regions. Farming at both Hattusha and Tell Brak appears to have been a dynamic, flexible system that was adapted to overcome environmental and social challenges faced by each specific city. To this end, the Bronze Age does not signify the end of the 'agricultural origins' story (Smith, 2003) but rather a continuation and extension of cultivation practices that began in the Neolithic.

This study has also categorically shown that the management of the agricultural economy was an integral part of city life. At all Bronze Age cities it appears that the hinterland region performed a key role in sustaining and supporting the city to the extent that the hinterland should directly factor into the definition of the city itself (Sinclair, 2010; Gallagher & McIntosh, 2015). At both Hattusha and Tell Brak the separation of 'urban' vs. 'rural' areas should perhaps be reconsidered due to the amount of overlap that existed between these two zones. At Hattusha, the city would never have existed, let alone have been capable of supporting 30+ temples, without the implementation of an intense system of agricultural management and massive taxation from nearby crop-producing settlements. Correspondingly, it seems likely that Tell Brak was surrounded by arable fields and that many farmers lived within the confines of the settlement. To this end, the study of 'urban' agricultural production is necessarily also a study of the city itself as these systems were essential for the development and maintenance of these societies.

10.3 Further work and future directions

One of the limiting factors particular to the undertaking of a project such as this with a wide-reaching hypothesis and set of objectives, is time. Although, this project has been able to address the research aims set out in **Chapter 1**, a number of areas at both Hattusha and Tell Brak would benefit from further work to create a truly in-depth study of Bronze Age agricultural production. At both sites, an additional program of stable isotope analysis, focusing on the 1-grain emmer and einkorn grain at Hattusha and the free-threshing wheat at Tell Brak, alongside the improvement of arable weed taxa identification for functional weed ecology, would further refine the classification of crop growing conditions presented in this study. Furthermore, the application of geographical information systems (GIS) on data from both sites could be used to help locate agricultural regimes within their hinterland (Verhagen & Whitley, 2012). In particular, the use of predictive modelling based on common environmental variables, such as elevation and hydrology (Conolly & Lake, 2006) in combination with detailed weed functional ecology data could be used to constrain the environmental parameters in which agriculture could potentially be taking place. These datasets could then be used to create precise geographical models indicating the *potential* minimum and maximum agricultural zone around each city. Further work would also benefit greatly from the contextualization of the underground silo and TC oval assemblages with other agricultural and subsistence-based activities taking place across the site. This would be achieved through the analysis of archaeobotanical material recovered from other areas of each city and from different chronological time periods. This work would allow a more detailed examination of the different spheres of production operating within each city on a domestic and a state-controlled level, as well as assessing change and continuity in farming practices throughout the Bronze Age.

The results of this thesis have highlighted the need for much further research into the nature of Bronze Age agricultural production systems both within the Near East and in other geographical regions. In particular, it has stressed the discrepancies between what has been recorded in the texts and the actual diversity of practices that existed in reality. To this end, the excavation of all Bronze Age settlements should involve a strategic environmental sampling system to maximise the recovery of archaeobotanical remains. This study has also emphasized the value of crop stable carbon and nitrogen isotope analysis alongside the functional analysis of arable weed taxa as a methodology for understanding and interpreting specific crop husbandry regimes. Future research into the nature of agriculture, regardless of period or region, should, therefore, seek to incorporate both of these methodologies as a means of creating a more detailed, evidence-based view of ancient agricultural economies.

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Appendix

Table 12.1 – List of all taxa and their respective correspondence analysis codes from the Hattusha assemblage.

Taxa	CA Code	Taxa	CA Code
Hulled barley grain	hulbar	*Scirpus sylvaticus*	scirp
Naked barley grain	nakbar	*Cephalaria syriaca*	cepsyr
Einkorn wheat grain	eingr	*Avena cf. sterilis*	aveste
Emmer wheat grain	emmgr	*Avena cf. sterilis* chaff	oatcha
Free-threshing wheat grain	frthgr	*Hordeum cf. spontaneum*	horspo
Cereal indet. grain	cerind	*Bromus cf. sterilis*	broste
Einkorn wheat glume base	eingb	*Bromus cf. tectorum*	brotec
Emmer wheat glume base	emmgb	*Bromus* type	bromsp
Free-threshing wheat rachis	frthra	Large grass indet.	lgrind
Hulled barley rachis	hbarac	*Lolium persicum*	lolipers
Culm node	culm	*Phalaris* sp.	phala
Lens culinaris	lens	*Poa bulbosum*	poabul
Lathyrus sativus	latsat	*Ajuga chamaepitys*	ajucha
Vicia ervilia	vicerv	Labiatae	labiat
Large Vicia faba var. minuta	lvicfab	*Lallemantia iberica*	lalibe
Small Vicia faba var. minuta	svicfab	*cf. Lamium*	lami
Apiaceae	umbell	*Salvia* sp.	salvia
Bifora radians	bifrad	*cf. Stachys* sp.	stachy
Bupleurum sp.	buplsp	*Teucrium* sp.	teucr
Caucalis platycarpos	caucpla	*cf. Ziziphora* sp.	zizip
Turgenia latifolia	turglat	*Coronilla scorpiodes*	corsco
Bugloissoides arvensis	bugarv	*Medicago arabica/polymorpha*	medara
Bugloissoides tenuiflorum	bugten	*Medicago truncatula*	medtru
Bugloissoides sp.	buggsp	*Medicago* sp.	medisp
Agrostemma githago	agrogit	*cf. Melilotus* sp.	melil
Silene sp.	silene	*Onobrychis vicifolia*	onovic
Vaccaria pyramidata	vacpyr	*Onobrychis* sp.	onoare
Chenopodium album	chenop	*cf. Vicia* sp.	vicia
Compositae	compsp	*cf. Bellevalia* sp.	belle
Centaurea sp.	centa	*Ornithogalum* sp.	ornith
cf. Calystegia sepium	calysep	*Linum* sp.	linum
Convolvulus sp.	convsp	*Fumaria parviflora*	fumpar
Convolvulus arvensis	convarv	*Glaucium corniculatum*	glacor
Alyssum sp.	alyss	*Polygonum aviculare*	polavi

Brassica nigra	brasnig	*Polygonum convolvulus*	polcon
Boreava aptera	borapt	*cf. Polygonum* sp.	polyg
Boreava orientalis	borori	*Rumex cf. acetosella*	rumace
Bunias orientalis	bunori	*Adonis aestavalis*	adoaes
cf. Bunias/Boreava sp.	bun_bor	*Adonis cf. annua*	adoann
Cardaria draba	cardra	*Adonis sp.*	adonsp
Camelina sativa	camsat	*Consolida regalis*	conreg
Conringia orientalis	corori	*Delphinium staphisagria*	delpsta
cf. Conringia orientalis/Camelina sativa sp.	camcon	*Ranunculus arvensis*	ranuarv
Cruciferae	crucif	*cf. Ranunculus* sp.	ranusp
Lepidium latifoliatum	leplat	*Cruciata laevipes*	crulae
Lepidium perfoliatum	lepper	*Galium spurium*	galspu
Lepidium sp.	lepisp	*Galium triconutum*	galtri
Neslia paniculata	nespan	*Veronica hederifolia*	verohed
Thlaspi arvense	thlarv	*Thymelea passerina*	thypas
Carex sp.	carex		

Table 12.2 – List of group classifications used in crop processing analysis for each sample from the Hattusha assemblage alongside their dominant crop composition.

Chamber No.	Sample Code	Group No.	Composition
12	12_108_515	1	Hulled barley
12	12_119_505	1	Hulled barley
12	12_120_516	1	Hulled barley
12	12_125_517	1	Hulled barley
12	12_129_520	1	Hulled barley
28	28_2_100	1	Hulled barley
29	29_191_503	1	Hulled barley
29	29_206_509	1	Hulled barley
29	29_271_6	1	Hulled barley
29	29_271_7	1	Hulled barley
30	30_245_3	1	Hulled barley
30	30_259_8	1	Hulled barley
30	30_259_11	1	Hulled barley
30	30_262_11	1	Hulled barley
12	12_135_9	2	Glume wheat
12	12_137_6	2	Glume wheat
12	12_141_6	2	Glume wheat
12	12_141_10	2	Glume wheat
29	29_278_1	2	Glume wheat
29	29_278_6	2	Glume wheat
30	30_245_4	2	Glume wheat
30	30_245_8	2	Glume wheat
30	30_252_3	2	Glume wheat
30	30_252_13	2	Glume wheat
30	30_259_7	2	Glume wheat

30	30_262_13	2	Glume wheat
30	30_268_8	2	Glume wheat
30	30_268_13	2	Glume wheat
30	30_273_11	2	Glume wheat
30	30_273_13	2	Glume wheat
32	32_72	2	Glume wheat
32	32_74	2	Glume wheat
12	12_79_502	3	Mixed
12	12_118_506	3	Mixed
12	12_135_7	3	Mixed
29	29_512_123	3	Mixed
30	30_245_9	3	Mixed
30	30_252_8	3	Mixed
30	30_252_11	3	Mixed
30	30_259_13	3	Mixed
30	30_268_11	3	Mixed
32	32_64	3	Mixed
32	32_66	3	Mixed
32	32_70	3	Mixed
32	32_71	3	Mixed

Table 12.3 – List of all weed/wild taxa from the Hattusha assemblage and their classification by physical weed seed type (Jones, 1984a) used in weed-only crop processing analysis.

Weed/wild taxa	Weed-only crop processing classification	Weed/wild taxa	Weed-only crop processing classification
Asperugo procumbens	BFH	*Brassica nigra*	SFH
Anchusa officinalis	BFH	*cf. Conringia orientalis/Camelina sativa* sp.	SFH
Agrostemma githago	BFH	*Camelina sativa*	SFH
Carthamus tinctorius	BFH	*Conringia orientalis*	SFH
Onopordum acanthium	BFH	*Neslia paniculata*	SFH
Convolvulus sp.	BFH	*Thlaspi arvense*	SFH
Convolvulus arvensis	BFH	*Carex* sp.	SFH
cf. *Calystegia sepium*	BFH	*Scirpus sylvaticus*	SFH
Cephalaria syriaca	BFH	cf. *Phalaris* sp.	SFH
Lolium persicum	BFH	*Poa bulbosum*	SFH
Lallemantia iberica	BFH	*Lamium* sp.	SFH
Salvia sp.	BFH	*Teucrium* sp.	SFH
cf. *Stachys* sp.	BFH	*Ajuga chamaepitys*	SFH
Scorpiurus sp.	BFH	cf. *Ziziphora* sp.	SFH
cf. *Geranium* sp.	BFH	*Bellevalia* sp.	SFH
Glaucium corniculatum	BFH	*Ornithogalum* sp.	SFH
Polygonum aviculare	BFH	*Vicia* sp.	SFH

Polygonum convolvulus	BFH	Small- seeded legumes	SFH
Polygonum sp.	BFH	*Melilotus* sp.	SFH
Ranunculus sp.	BFH	*Fumaria parviflora*	SFH
Ranunculus arvensis	BFH	*Rumex acetosella*	SFH
Cruciata laevipes	BFH	*Consolida regalis*	SFH
Galium sp.	BFH	*Delphinium staphisagria*	SFH
Galium triconutum	BFH	*Adonis* sp.	SFH
Veronica hederifolia	BFH	*Adonis* cf. *annua*	SFH
Bifora radians	BFH	*Adonis aestavalis*	SFH
Bupleurum sp.	BFH	cf. *Potentilla* sp.	SFH
Caucalis platycarpos	BFH	*Galium spurium*	SFH
Turgenia latifolia	BFH	cf. *Helianthemum* sp.	SFL
cf. *Bunias/Boreava* sp.	BHH	*Tineatherum caput-medusae*	SFL
Bunias orientalis	BHH	*Bromus* cf.	SFL
Boreava orientalis	BHH	*Bromus* cf. *sterilis*	SFL
Boreava aptera	BHH	*Bromus* cf. *tectorum*	SFL
Avena sterilis	BHH	*Linum* sp.	SFL
Medicago arabica/polymorpha	BHH	*Silene* sp.	SHH
Medicago truncatula	BHH	*Coronilla scorpiodes*	SHH
Onobrychis sp.	BHH	*Medicago* sp.	SHH
Onobrychis vicifolia	BHH	*Alyssum* sp.	SHL
Thymelea passerina	BHH	*Cardaria draba*	SHL
cf. *Heliotropium* sp.	SFH	*Coronopus squamatus*	SHL
Buglossoides sp.	SFH	*Lepidium* sp.	SHL
Buglossoides arvensis	SFH	*Lepidium latifoliatum*	SHL
Buglossoides tenuiflorum	SFH	*Lepidium perfoliatum*	SHL
Stellaria sp.	SFH	*Hordeum spontaneum*	SHL
Vaccaria pyramidata	SFH	cf. *Festuca* sp.	SHL
Chenopodium album	SFH	*Papaver* cf. *somniferum*	SHL
Centaurea sp.	SFH		

Table 12.4 – List of all weed/wild species/taxa and their ubiquity within the Hattusha assemblage that were included in the functional ecological analysis.

Weed/wild species/taxa	Ubiquity (%)	Weed/wild species/taxa	Ubiquity (%)
Adonis aestavalis	12	*Turgenia latifolia*	34
Adonis annua	19	*Vaccaria pyramidata*	41
Bifora radians	42	*Veronica hederifolia*	32
Buglossoides arvensis	33	*Agrostemma githago*	12
Buglossoides tenuiflorum	20	*Ajuga chamaepitys*	2
Bunias orientalis	11	*Avena sterilis*	25

Caucalis platycarpos	31	*Brassica nigra*	3
Conringia orientalis	17	*Bromus sterilis*	2
Consolida regalis	3	*Bromus tectorum*	11
Cruciata laevipes	31	*Calystegia sepium*	2
Galium spurium	39	*Camelina sativa*	9
Galium triconutum	44	*Cardaria draba*	7
Hordeum spontaneum	3	*Cephalaria syriaca*	20
Lepidium latifoliatum	10	*Convolvulus arvensis*	11
Lolium persicum	26	*Coronilla scorpiodes*	3
Medicago arabica/polymorpha	4	*Polygonum convolvulus*	7
Medicago sp.	10	*Fumaria parviflora*	3
Neslia paniculata	33	*Glaucium corniculatum*	9
Polygonum aviculare	42	*Lallemantia iberica*	15
Ranunculus arvensis	42	*Onobrychis vicifolia*	6
Thlaspi arvense	11	*Poa bulbosum*	8
Thymelea passerina	9	*Rumex acetosella*	14

Table 12.5 – List of all taxa and their respective correspondence analysis codes from the Tell Brak assemblage.

Taxa	CA code	Taxa	CA code
2-row Hulled barley grain	2hubar	*Sinapis* cf. *arvensis*	sinarv
Small hulled barley grain	tinbar	Cyperaceae	scirp
Einkorn wheat grain	einko	*Cephalaria* cf. *syriaca*	cepsyr
Emmer wheat grain	emmer	*Aegilops crassa* glume base	aecrgb
Free-threshing wheat grain	frethre	*Aegilops speltoides* glume base	aespgb
Wheat indet. grain	wheind	*Aegilops tauschii* glume base	aetagb
Small wheat grain	tinwhe	*Aegilops* sp. glume base	aeindgb
Einkorn wheat glume base	eincha	*Aegilops crassa* grain	aechgr
Emmer wheat glume base	emmcha	*Aegilops speltoides* grain	aespgr
Glume wheat indet. glume base	glubas	*Aegilops tauschii* grain	aetagr
2-row hulled barley rachis	barrac	*Eremopyrum* cf. *bonaepartis*	erobon
Free-threshing wheat rachis	frthch	*Hordeum* cf. *spontaneum*	wilbar
Culm nodes	culm	Large grass indet.	lagrin
Lens culinaris	lens	*Lolium* cf. *rigidum*	lolrig
Lathyrus sativus	grapea	*Poa* sp.	poa
Vicia sp.	vicia	*Coronilla scorpiodes*	corsco
Pulse indet.	larpul	Small-seeded legumes	slegs
Caryophyllaceae	caryop	*Trigonella* sp.	trigon
Gypsophila cf. *pilosa*	gyppil	*Malva* sp.	malva
Silene sp. Type 1.	silty1	*Galium* sp.	galium
Vaccaria pyramidata	vacpyr		

Table 12.6 – List of group classifications used in crop processing analysis for each samples from the Tell Brak assemblage alongside their dominant crop composition.

Room No.	Sample No.	Group No.	Composition
4	77	1	Hulled barley
6	10	1	Hulled barley
8	104	1	Hulled barley
8	147	1	Hulled barley
8	144	1	Hulled barley
8	74	1	Hulled barley
8	103	1	Hulled barley
16	70	1	Hulled barley
16	97	1	Hulled barley
16	115	1	Hulled barley
16	116	1	Hulled barley
16	117	1	Hulled barley
16	121	1	Hulled barley
16	124	1	Hulled barley
16	127	1	Hulled barley
16	150	1	Hulled barley
16	152	1	Hulled barley
16	159	1	Hulled barley
16	225	1	Hulled barley
16	227	1	Hulled barley
16	71	1	Hulled barley
16	219	1	Hulled barley
16	148	1	Hulled barley
16	218	1	Hulled barley
16	123	1	Hulled barley
16	118	1	Hulled barley
16	138	1	Hulled barley
16	131	1	Hulled barley
16	105	1	Hulled barley
16	98	1	Hulled barley
16	130	1	Hulled barley
16	140	1	Hulled barley
16	226	1	Hulled barley
16	239	1	Hulled barley
17	168	1	Hulled barley
17	167	1	Hulled barley
17	169	1	Hulled barley
TCH	388	1	Hulled barley
9	55	2	Hulled barley & Free-threshing wheat
12	76	2	Hulled barley & Free-threshing wheat
Ncy	450	2	Hulled barley & Free-threshing wheat
Ncy	447	2	Hulled barley & Free-threshing wheat
Ncy	165	2	Hulled barley & Free-threshing wheat
12	113	3	Glume wheat
12	149	3	Glume wheat
12	120	3	Glume wheat
12	67	3	Glume wheat
12	111	3	Glume wheat

9	112	4	Mixed
12	80	4	Mixed
12	133	4	Mixed
12	122	4	Mixed
12	102	4	Mixed
12	106	4	Mixed
12	78	4	Mixed
13	228	4	Mixed
17	217	4	Mixed
18	383	4	Mixed

Table 12.7 – List of all weed/wild taxa from the Tell Brak assemblage and their classification by physical weed seed type (Jones, 1984a) used in weed-only crop processing analysis.

Weed/wild taxa	Weed-only crop processing classification	Weed/wild taxa	Weed-only crop processing classification
Convolvulus sp.	BFH	*Poa bulbosum*	SFH
Bromus sp.	BFH	*Artemesia* sp.	SFH
Galium sp.	BFH	Small-seeded legumes	SFH
Taeniatherum sp.	BFH	cf. *Trigonella* sp.	SFH
Eremopyrum cf. *bonaepartis*	BFH	cf. *Teucrium* sp.	SFH
Cephalaria cf. *syriaca*	BFH	*Valerianella* sp.	SFH
Lolium temulentum	BFH	cf. *Verbascum* sp.	SFL
Scorpirus sp.	BFH	*Silene* sp. Type 1.	SHH
Hordeum cf. *spontaneum*	BFH	*Silene* sp. Type 2.	SHH
Vaccaria pyramidata	BFH	*Malva* cf. *sylvestris*	SHH
Adonis sp.	SFH	*Malva* cf. *parviflora*	SHH
cf. *Muscari* sp.	SFH	*Malva* sp.	SHH
Ornithogalum/Bellevalia/Muscari sp.	SFH	*Coronilla scorpiodes*	SHH
Gypsophila cf. *pilosa*	SFH	*Alyssum* sp.	SHL
Chenopodium album	SFH	cf. *Chrysanthemum*	SHL
Centaurea sp.	SFH	*Papaver* cf. *rhoeas*	SHL
Cyperaceae	SFH	*Papaver* cf. *argemone*	SHL
Sinapis cf. *arvensis*	SFH	*Papaver* sp.	SHL
Poa sp.	SFH	*Lolium* cf. *rigidum*	SHL
Poa cf. *annua*	SFH	*Hordeum* cf. *murinum*	SHL

Table 12.8 – List of all weed/wild species and their ubiquity within the Hattusha assemblage that were included in the functional ecological analysis.

Species/taxa	Ubiquity
Aegilops crassa	34
Aegilops speltoides	23
Aegilops tauschii	25
Gypsophila pilosa	16
Sinapis arvensis	11
Poa annua	2
Poa bulbosum	2
Papaver rhoeas	3
Eremopyrum bonaepartis	9
Cephalaria syriaca	5
Lolium rigidum	32
Malva sylvestris	3
Malva parviflora	2
Coronilla scorpiodes	10
Vaccaria pyramidata	19
Hordeum murinum	4
Hordeum spontaneum	9

Table 12.9 – List of samples from the Tell Brak assemblage that were excluded from the functional ecological analysis.

Sample No.	Room No.
10	6
74	8
106	12
133	12
228	13
98	16
116	16
124	16
130	16
140	16
226	16
227	16

Table 12.10 – $\delta^{13}C$, $\delta^{15}N$ and $\Delta^{13}C$ values for all crop stable isotope samples from Hattusha (values have been adjusted for charring).

Chamber	Sample Code	Crop species	Lab ID	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	$\Delta^{13}C$ (‰)
12	12_108_515	Hulled barley	HAT01	-23.8	7.1	17.9
12	12_108_515	Emmer wheat	HAT02	-23.1	6.6	17.1
12	12_118_506	Hulled barley	HAT03	-23.4	7.2	17.4
12	12_118_506	Emmer wheat	HAT04	-23.7	6.7	17.7
12	12_119_505	Hulled barley	HAT05	-23.4	6.7	17.5
12	12_119_505	Emmer wheat	HAT06	-22.9	6.5	16.9
12	12_120_514/516	Hulled barley	HAT07	-23.6	7.0	17.6
12	12_120_514/516	Emmer wheat	HAT08	-23.0	6.5	17.0
12	12_125_517	Hulled barley	HAT09	-23.5	7.3	17.5
12	12_125_517	Emmer wheat	HAT10	-22.5	6.9	16.5
12	12_129_520	Hulled barley	HAT11	-23.3	6.2	17.3
12	12_129_520	Emmer wheat	HAT12	-23.1	6.5	17.1
12	12_135_7	Hulled barley	HAT13	-22.6	6.2	16.6
12	12_135_7	Emmer wheat	HAT14	-22.7	6.7	16.7
12	12_137_6	Emmer wheat	HAT15	-23.0	7.1	17.0
12	12_141_6	Hulled barley	HAT16	-22.7	5.7	16.7
12	12_141_6	Emmer wheat	HAT17	-22.5	6.3	16.5
12	12_141_10	Emmer wheat	HAT18	-22.7	5.9	16.7
28	28_2_100	Hulled barley	HAT19	-22.6	5.8	16.5
28	28_2_100	Emmer wheat	HAT20	-22.3	7.1	16.2
29	29_191_503	Hulled barley	HAT21	-22.9	3.0	16.9
29	29_206_509	Hulled barley	HAT22	-22.7	4.2	16.6
29	29_206_509	Emmer wheat	HAT23	-23.1	3.9	17.1
29	29_271_6	Hulled barley	HAT24	-22.5	5.8	16.5
29	29_271_6	Emmer wheat	HAT25	-22.3	6.1	16.2
29	29_271_7	Hulled barley	HAT26	-23.1	6.3	17.1
29	29_271_7	Emmer wheat	HAT27	-22.4	6.1	16.4
29	29_278_1	Emmer wheat	HAT28	-22.2	4.7	16.2
29	29_278_6	Emmer wheat	HAT29	-22.3	6.8	16.3
30	30_245_3	Hulled barley	HAT30	-22.9	4.2	16.9
30	30_245_3	Emmer wheat	HAT31	-22.6	4.4	16.6
30	30_245_4	Emmer wheat	HAT32	-23.3	5.2	17.3
30	30_245_8	Emmer wheat	HAT33	-23.0	5.6	17.0
30	30_245_9	Hulled barley	HAT34	-23.0	5.0	17.0
30	30_245_9	Emmer wheat	HAT35	-22.8	5.1	16.8
30	30_252_3	Emmer wheat	HAT36	-22.0	8.4	15.9
30	30_252_8	Hulled barley	HAT37	-22.6	5.0	16.6
30	30_252_8	Emmer wheat	HAT38	-21.9	5.5	15.9
30	30_252_11	Hulled barley	HAT39	-23.2	3.8	17.2
30	30_252_11	Emmer wheat	HAT40	-22.6	3.3	16.6
30	30_252_13	Emmer wheat	HAT41	-22.1	3.1	16.0

30	30_259_8	Hulled barley	HAT42	-22.7	4.9	16.7
30	30_259_8	Emmer wheat	HAT43	-22.2	4.6	16.2
30	30_259_11	Emmer wheat	HAT45	-21.9	4.5	15.9
30	30_259_13	Hulled barley	HAT46	-22.0	3.7	16.0
30	30_259_13	Emmer wheat	HAT47	-22.2	3.9	16.1
30	30_262_11	Hulled barley	HAT48	-22.6	5.9	16.6
30	30_262_11	Emmer wheat	HAT49	-21.6	4.6	15.6
30	30_262_13	Hulled barley	HAT50	-23.0	3.3	17.0
30	30_262_13	Emmer wheat	HAT51	-22.0	4.2	15.9
30	30_268_8	Emmer wheat	HAT52	-22.1	3.1	16.1
30	30_268_11	Hulled barley	HAT53	-22.6	5.8	16.5
30	30_268_11	Emmer wheat	HAT54	-22.2	3.5	16.2
30	30_268_13	Emmer wheat	HAT55	-21.9	3.6	15.9
30	30_273_11	Emmer wheat	HAT56	-21.5	4.7	15.4
30	30_273_13	Emmer wheat	HAT57	-21.7	4.6	15.7
32	32_64	Hulled barley	HAT58	-23.8	9.1	17.8
32	32_64	Emmer wheat	HAT59	-23.0	7.1	17.0
32	32_66	Emmer wheat	HAT60	-22.9	6.7	16.9
32	32_70	Hulled barley	HAT61	-24.1	5.9	18.2
32	32_70	Emmer wheat	HAT62	-23.1	7.7	17.1
32	32_71	Emmer wheat	HAT63	-23.1	7.7	17.1
32	32_72	Emmer wheat	HAT64	-23.2	5.9	17.3
32	32_74	Emmer wheat	HAT65	-23.3	6.7	17.3

Table 12.11 – $\delta^{13}C$, $\delta^{15}N$ and $\Delta^{13}C$ values for all crop stable isotope samples from Tell Brak (values have been adjusted for charring).

Room No.	Sample No.	Crop Species	Lab ID	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	$\Delta^{13}C$ (‰)
6	10	Hulled barley	TB14	-23.4	5.1	17.5
8	74	Small Barley	TB04	-21.2	9.3	15.1
8	74	Hulled barley	TB17	-23.4	3.9	17.4
8	147	Hulled barley	TB19	-23.2	4.2	17.2
9	112	Emmer wheat	TB08	-22.6	7.6	16.6
9	55	Hulled barley	TB12	-23.8	5.4	17.9
9	55	Small wheat	TB16	-22.3	9.1	16.3
9	112	Hulled barley	TB25	-23.2	7.2	17.3
9	55	Small barley	TB28	-22.3	8.3	16.3
12	133	Emmer wheat	TB03	-22.6	6.7	16.6
12	106	Emmer wheat	TB05	-22.0	7.1	16.0
12	133	Hulled barley	TB07	-23.3	2.9	17.4
12	149	Emmer wheat	TB09	-22.8	6.6	16.8
12	122	Small barley	TB10	-22.3	5.5	16.3
12	133	Small barley	TB11	-22.7	4.6	16.7
12	106	Hulled barley	TB21	-23.3	2.7	17.4
12	106	Small wheat	TB24	-22.1	7.0	16.1
12	122	Hulled barley	TB26	-23.5	1.9	17.5
12	122	Emmer wheat	TB29	-22.0	6.1	16.0
12	122	Small wheat	TB31	-21.9	7.6	15.9
12	120	Hulled barley	TB35	-23.6	9.2	17.6
12	120	Emmer wheat	TB40	-23.1	8.7	17.2
12	113	Hulled barley	TB41	-23.3	4.0	17.3
13	228	Hulled barley	TB18	-23.8	4.5	17.9
16	225	Small barley	TB01	-22.0	4.3	16.0
16	227	Small barley	TB02	-22.4	5.1	16.4
16	124	Hulled barley	TB06	-23.3	2.9	17.3
16	227	Hulled barley	TB13	-23.0	2.9	17.0
16	225	Hulled barley	TB15	-23.8	2.5	17.9
16	71	Hulled barley	TB20	-22.3	2.8	16.3
16	148	Small barley	TB22	-21.8	8.5	15.8
16	239	Small barley	TB23	-21.1	5.3	15.1
16	226	Small barley	TB27	-21.5	3.7	15.5
16	148	Hulled barley	TB30	-22.6	3.1	16.6
16	117	Hulled barley	TB32	-23.2	3.2	17.2
16	138	Hulled barley	TB33	-22.6	2.8	16.6
16	98	Hulled barley	TB34	-22.6	3.0	16.6
16	127	Hulled barley	TB36	-23.5	4.0	17.5
16	121	Hulled barley	TB37	-23.3	2.8	17.3
17	217	Emmer wheat	TB38	-22.2	2.7	16.2
17	217	Hulled barley	TB39	-22.4	3.9	16.4

Table 12.12 - $\delta^{13}C$ and $\Delta^{13}C$ values for crop stable isotope samples from Tell Brak and Tell Leilan used in the statistical tests presented in Table 9.1 (values have been adjusted for charring).

Site	Crop species	$\delta^{13}C$ (‰)	Δ13C (‰)
Tell Brak	Hulled barley	-23.1	17.2
Tell Brak	Hulled barley	-23.7	17.9
Tell Brak	Hulled barley	-23.1	17.3
Tell Brak	Hulled barley	-23.2	17.3
Tell Brak	Hulled barley	-23.4	17.6
Tell Brak	Hulled barley	-23.4	17.5
Tell Brak	Hulled barley	-22.2	16.3
Tell Brak	Hulled barley	-23.1	17.2
Tell Brak	Hulled barley	-23.2	17.3
Tell Brak	Hulled barley	-23.4	17.5
Tell Brak	Hulled barley	-22.5	16.6
Tell Brak	Hulled barley	-22.4	16.6
Tell Brak	Hulled barley	-23.7	17.9
Tell Brak	Hulled barley	-22.3	16.4
Tell Brak	Emmer wheat	-22.6	16.6
Tell Brak	Emmer wheat	-23	17.2
Tell Brak	Emmer wheat	-22	16.0
Tell Brak	Emmer wheat	-22.6	16.8
Tell Brak	Emmer wheat	-22.1	16.2
Tell Leilan	Hulled barley	-23.9	18.0
Tell Leilan	Hulled barley	-23.9	18.0
Tell Leilan	Hulled barley	-23.8	17.9
Tell Leilan	Hulled barley	-24.1	18.2
Tell Leilan	Hulled barley	-23.4	17.5
Tell Leilan	Hulled barley	-23.9	18.0
Tell Leilan	Hulled barley	-23.9	18.0
Tell Leilan	Hulled barley	-24.3	18.4
Tell Leilan	Hulled barley	-23.7	17.8
Tell Leilan	Hulled barley	-23.6	17.7
Tell Leilan	Hulled barley	-23.7	17.8
Tell Leilan	Hulled barley	-23.9	18.0
Tell Leilan	Hulled barley	-24.2	18.3
Tell Leilan	Hulled barley	-24.1	18.2
Tell Leilan	Hulled barley	-24.3	18.4
Tell Leilan	Hulled barley	-24.4	18.6
Tell Leilan	Hulled barley	-24.1	18.2
Tell Leilan	Hulled barley	-23.6	17.7
Tell Leilan	Hulled barley	-23.9	18.0
Tell Leilan	Hulled barley	-24	18.1
Tell Leilan	Hulled barley	-24	18.1

Tell Leilan	Hulled barley	-24.1	18.3
Tell Leilan	Hulled barley	-23.9	18.0
Tell Leilan	Hulled barley	-24.2	18.3
Tell Leilan	Emmer wheat	-24.5	18.7
Tell Leilan	Emmer wheat	-24.2	18.3
Tell Leilan	Emmer wheat	-24	18.1
Tell Leilan	Emmer wheat	-23.9	18.0
Tell Leilan	Emmer wheat	-24	18.1
Tell Leilan	Emmer wheat	-24.4	18.6
Tell Leilan	Emmer wheat	-24.3	18.4
Tell Leilan	Emmer wheat	-24.5	18.6

Table 12.13 – Raw data from the Hattusha assemblage, showing all quantified items.

Sample No.		**12_79_502**	**12_108_515**	**12_118_506**	**12_119_505**	**12_120_516**	**12_125_517**	**12_129_520**	**12_135_7**	**12_135_9**	**12_137_6**	**12_141_6**
Quadrant		502	515	506	505	516	517	520	7	9	6	6
Section		309/344	309/344	309/344	309/344	309/344	309/344	309/344	309/344	309/344	309/344	309/344
Spit		79	108	118	119	120	125	129	135	135	137	141
Chamber No.		12	12	12	12	12	12	12	12	12	12	12
Taxa	**Plant part**											
Crops												
Hordeum vulgare L.	Grain	6	2224	265	1600	758	1710	684	168		37	34
Hordeum vulgare var. *nudum* L.	Grain							2				
Triticum monococcum L.	Grain		1		3			3	2			1
Triticum dicoccum Schübl.	Grain	2	343	40	196	110	188	101	293	16	181	324
Triticum aestivum L./*durum* Desf.	Grain					8	14					
Cereal indet.	Grain											2
Hordeum vulgare L.	Rachis	4	15	16			18	54	2			
Triticum monococcum L.	Glume base		2							2		7
Triticum dicoccum Schübl.	Glume base	4	198	174	70	64	248	159	80	3	4	4
Triticum aestivum L./*durum* Desf.	Rachis							1				
Culm	Node	1	44	20	14		79	32				

Sample No.		12_79_502	12_108_515	12_118_506	12_119_505	12_120_516	12_125_517	12_129_520	12_135_7	12_135_9	12_137_6	12_141_6
Lathyrus sativus L.	Seed							1	3			
Lens culinaris Medik.	Seed					1						
Vicia ervilia L. Willd.	Seed			1	2	8		2	5			
Vicia faba L. var. *minuta*	Seed	6	357	189	177	119	206	84	421	53	340	398
Pulse indet.	Seed											
Fruit/Nut												
Pistacia sp.	Nut shell frag.											
Pyrus/Malus sp.	Seed											
Prunus sp.	Nut shell frag.											
Rubus sp.	Seed											
Vitis vinifera L.	Seed											
Weed/wild												
Apiaceae	Seed											
Bifora radians M. Bieb.	Seed	1	27	1	2		12	16	32		9	8
cf. *Bupleurum* sp.	Seed		5		1						1	
Caucalis platycarpos L.	Seed		3				2	2	2			
Turgenia latifolia L. Hoffm.	Seed		4		2	8	8	4	3			
Anchusa officinalis L.	Seed											

Sample No.		12_79_502	12_108_515	12_118_506	12_119_505	12_120_516	12_125_517	12_129_520	12_135_7	12_135_9	12_137_6	12_141_6
Asperugo procumbens L.	Seed											
Buglossoides arvensis L.	Seed		73	15	9	8		7	4	1		18
Buglossoides tenuiflorum L. fil.	Seed		11	15	10		2	1				
Buglossoides sp.	Seed			8	1		8					
cf. *Heliotropium* sp.	Seed											
Agrostemma githago L.	Seed											
Silene sp.	Seed											
Stellaria sp.	Seed											
Vaccaria pyramidata Medik.	Seed	5	12	10	9	32	8	24	7	1		6
Chenopodium album L.	Seed							24				
cf. *Helianthemum* sp.	Seed											
Compositae	Seed		17	4		16	16					1
Carthamus tinctorius L.	Seed											
Centaurea sp.	Seed		2	2					1			1
Onopordum acanthium L.	Seed											
cf. *Calystegia sepium* L. R. Br.	Seed											
Convolvulus sp.	Seed											

Sample No.		12_79_502	12_108_515	12_118_506	12_119_505	12_120_516	12_125_517	12_129_520	12_135_7	12_135_9	12_137_6	12_141_6
Convolvulus cf. *arvensis* L.	Seed											
Alyssum sp.	Seed				1							
Brassica cf. *nigra*	Seed											
Boreava aptera Boiss. & Heldr.	Seed	3	17	11	17	2	6	13	38		5	4
Boreava orientalis Jaub. & Spach	Seed			2	1			2				
Bunias orientalis L.	Seed		24				8	2			3	
cf. *Bunias/Boreava* sp.	Seed		27	18		16	16	4	1			
Camelina sativa L.	Seed											
Camelina sp.	Pod											
Cardaria draba L.	Seed											
Cardaria draba L.	Pod											
Conringia orientalis L.	Seed							1				
cf. *Conringia orientalis/Camelina sativa* sp.	Seed											
Coronopus squamatus Forssk.	Seed											
Cruciferae	Pod							1				
Cruciferae	Seed			18	5		16	2	4	3		
Lepidium cf. *latifoliatum* L.	Seed		1					1				
Lepidium cf. *perfoliatum* L.	Seed											

Sample No.		12_79_502	12_108_515	12_118_506	12_119_505	12_120_516	12_125_517	12_129_520	12_135_7	12_135_9	12_137_6	12_141_6
Lepidium sp.	Pod											
Lepidium sp.	Seed											
Neslia paniculata L.	Seed		12		4			2	6	2	6	3
Thlaspi arvense L.	Seed											1
Carex sp.	Seed											
Scirpus sylvaticus L.	Seed											
Cephalaria syriaca L. Schrad.	Seed											
cf. *Geranium* sp.	Seed											
Avena cf. *sterilis* L.	Grain											
Avena cf. *sterilis* L.	Spikelet											
Avena cf. *sterilis* L.	Spikelet base											
Avena cf. *sterilis* L.	Glume base											
Bromus cf. *sterilis* L.	Grain											
Bromus cf. *tectorum* L.	Grain											
cf. *Bromus* sp.	Grain				1			1				
cf. *Festuca* sp.	Grain											
Hordeum cf. *spontaneum* K. Koch	Grain						2	6				
Large grass indet.	Grain											
Lolium persicum Boiss. & Hohen.	Grain						8					
Phalaris sp.	Grain											
Poa bulbosa L.	Grain											

Sample No.		12_79_502	12_108_515	12_118_506	12_119_505	12_120_516	12_125_517	12_129_520	12_135_7	12_135_9	12_137_6	12_141_6
Taeniatherum caput-medusae L.	Grain											
Ajuga chamaepitys L. Schreb.	Seed											
Labiatae	Seed		1	2	2			1				
Lallemantia iberica M. Bieb.	Seed											
cf. *Lamium* sp.	Seed							16				
Salvia sp.	Seed											
cf. *Stachys* sp.	Seed											
Teucrium sp.	Seed											
cf. *Ziziphora* sp.	Seed						8					
Coronilla cf. *scorpiodes* L.	Seed											
Leguminosae	Pod frag.											
Medicago cf. *arabica/polymorpha* L.	Pod				2							
Medicago cf. *truncatula* Gaertn.	Pod		4				1	2	3			
Medicago sp.	Pod frag.			2								
Medicago sp.	Seed										1	
cf. *Melilotus* sp.	Seed											
cf. *Melilotus* sp.	Pod frag.											
Onobrychis cf. *viciifolia* Scop.	Seed											
Onobrychis sp.	Seed											

Sample No.		12_79_502	12_108_515	12_118_506	12_119_505	12_120_516	12_125_517	12_129_520	12_135_7	12_135_9	12_137_6	12_141_6
cf. *Scorpiurus* sp.	Seed											
Small-seed legumes	Seed											
Legume indet.	Pod							1				
cf. *Vicia* sp.	Seed											4
cf. *Bellevalia* sp.	Seed		1									
Ornithogalum sp.	Seed											
Linum sp.	Seed											
Linum sp.	Pod											
Fumaria parviflora Lam.	Seed											
Glaucium corniculatum L.	Seed											
Papaver cf. *somniferum* L.	Seed											
Polygonaceae	Seed											
Polygonum aviculare L.	Seed	8	103	74	39	104	144	262	77	8	9	19
Polygonum cf. *convolvulus* L.	Seed											
cf. *Polygonum* sp.	Seed											
Rumex cf. *acetosella* L.	Seed											
Adonis aestavalis L.	Seed							1				
Adonis cf. *annua* L.	Seed				1			2				
Adonis sp.	Seed		3									
Consolida regalis S. F. Gray	Seed								1			

Sample No.		12_79_502	12_108_515	12_118_506	12_119_505	12_120_516	12_125_517	12_129_520	12_135_7	12_135_9	12_137_6	12_141_6
Delphinium staphisagria L.	Seed											
Ranunculus arvensis L.	Seed		14		9	25	24	16	18	2	5	12
cf. *Ranunculus* sp.	Seed											
cf. *Potentilla* sp.	Seed											
Cruciata laevipes Opiz.	Seed	2	10		12		2		4	2		1
Galium triconutum Dandy.	Seed	10	131	55	73	32	112	55	166	8	76	154
Galium spurium L.	Seed		12		4	8	8	2	4	1	2	1
Galium sp.	Seed											
Veronica sp.	Seed											
Veronica hederifolia L.	Seed		10		1		8	3	6	3	4	9
Thymelaea cf. *passerina* L.	Seed			2								
Weed/wild indeterminate	Seed			32		16	6	27	2			

Sample No.		**12_141_10**	**28_2_100**	**29_512_123**	**29_191_503**	**29_206_509**	**29_271_6**	**29_271_7**	**29_278_1**	**29_278_6**	**30_245_3**	**30_245_4**
Quadrant		10	2	512	503	509	6	7	1	6	3	4
Section		309/344	308/343	309/344	309/343	309/343	309/343	309/343	309/343	309/343	309/343	309/343
Spit		141	100	123	191	206	271	271	278	278	245	245
Chamber No.		12	28	29	29	29	29	29	29	29	30	30
Taxa	**Plant part**											
Crops												
Hordeum vulgare L.	Grain	12	941	3	386	1382	2189	3712	38	10	4785	69
Hordeum vulgare var. *nudum* L.	Grain				1				1			
Triticum monococcum L.	Grain	4				6	55	48	42	13	163	108
Triticum dicoccum Schübl.	Grain	713	196		19	132	600	515	432	331	730	490
Triticum aestivum L./*durum* Desf.	Grain		16					8	13			1
Cereal indet.	Grain		3							1		6
Hordeum vulgare L.	Rachis		5			5					14	17
Triticum monococcum L.	Glume base	2	2	2		40			6	4	206	135
Triticum dicoccum Schübl.	Glume base	53	128		56	297	38	22	27	12	572	514
Triticum aestivum L./*durum* Desf.	Rachis					2					11	6
Culm	Node			2		19	2				34	5
Lathyrus sativus L.	Seed	4						1				1

Sample No.		12_141_10	28_2_100	29_512_123	29_191_503	29_206_509	29_271_6	29_271_7	29_278_1	29_278_6	30_245_3	30_245_4
Lens culinaris Medik.	Seed			1				1	5	3	4	
Vicia ervilia L. Willd.	Seed	11		1			3	6	3		6	6
Vicia faba L. var. *minuta*	Seed	349	6	3	1	13	58	45	37	30	30	34
Pulse indet.	Seed											
Fruit/Nut												
Pistacia sp.	Nut shell frag.					1						
Pyrus/Malus sp.	Seed											1
Prunus sp.	Nut shell frag.											
Rubus sp.	Seed											
Vitis vinifera L.	Seed										1	
Weed/wild												
Apiaceae	Seed							8				6
Bifora radians M. Bieb.	Seed	61	1		14	59	6	6	6	2	133	145
cf. *Bupleurum* sp.	Seed	6				7	12		5		11	
Caucalis platycarpos L.	Seed	3			1	1	3		2	1	32	8
Turgenia latifolia L. Hoffm.	Seed	3			2	7	4	3	3		49	42
Anchusa officinalis L.	Seed											
Asperugo procumbens L.	Seed											1

Sample No.		12_141_10	28_2_100	29_512_123	29_191_503	29_206_509	29_271_6	29_271_7	29_278_1	29_278_6	30_245_3	30_245_4
Buglossoides arvensis L.	Seed	4			2	10	2	11	1	8	9	3
Buglossoides tenuiflorum L. fil.	Seed	6				11	1					2
Buglossoides sp.	Seed											4
cf. *Heliotropium* sp.	Seed											
Agrostemma githago L.	Seed		3									1
Silene sp.	Seed		1			1	1					2
Stellaria sp.	Seed		1									
Vaccaria pyramidata Medik.	Seed	23	10				10	6	6	1	23	37
Chenopodium album L.	Seed											
cf. *Helianthemum* sp.	Seed		4									
Compositae	Seed										2	
Carthamus tinctorius L.	Seed											
Centaurea sp.	Seed	1	4		1	1	1		1			4
Onopordum acanthium L.	Seed											1
cf. *Calystegia sepium* L. R. Br.	Seed								1			
Convolvulus sp.	Seed					4						
Convolvulus cf. *arvensis* L.	Seed										2	
Alyssum sp.	Seed		11									1

Sample No.		12_141_10	28_2_100	29_512_123	29_191_503	29_206_509	29_271_6	29_271_7	29_278_1	29_278_6	30_245_3	30_245_4
Brassica cf. *nigra*	Seed											
Boreava aptera Boiss. & Heldr.	Seed	20			4	5	4			1	2	1
Boreava orientalis Jaub. & Spach	Seed											2
Bunias orientalis L.	Seed	3					3				7	
cf. *Bunias/Boreava* sp.	Seed	1			1	5		1				1
Camelina sativa L.	Seed							2	2			1
Camelina sp.	Pod											
Cardaria draba L.	Seed					6					1	3
Cardaria draba L.	Pod											1
Conringia orientalis L.	Seed		2			2						1
cf. *Conringia orientalis/Camelina sativa* sp.	Seed										2	
Coronopus squamatus Forssk.	Seed											
Cruciferae	Pod	8			4	5						
Cruciferae	Seed					6	2					
Lepidium cf. *latifoliatum* L.	Seed				3							
Lepidium cf. *perfoliatum* L.	Seed											
Lepidium sp.	Pod											
Lepidium sp.	Seed											
Neslia paniculata L.	Seed	5			1	5	2			1	4	4

Sample No.		12_141_10	28_2_100	29_512_123	29_191_503	29_206_509	29_271_6	29_271_7	29_278_1	29_278_6	30_245_3	30_245_4
Thlaspi arvense L.	Seed											3
Carex sp.	Seed											1
Scirpus sylvaticus L.	Seed					1					1	1
Cephalaria syriaca L. Schrad.	Seed						1		1		2	1
cf. *Geranium* sp.	Seed							2				
Avena cf. *sterilis* L.	Grain						7	8	1		5	1
Avena cf. *sterilis* L.	Spikelet										2	
Avena cf. *sterilis* L.	Spikelet base											
Avena cf. *sterilis* L.	Glume base											
Bromus cf. *sterilis* L.	Grain											
Bromus cf. *tectorum* L.	Grain		1			3	1					
cf. *Bromus* sp.	Grain		1									
cf. *Festuca* sp.	Grain											
Hordeum cf. *spontaneum* K. Koch	Grain											
Large grass indet.	Grain											1
Lolium persicum Boiss. & Hohen.	Grain					2	2	4		1	20	9
Phalaris sp.	Grain		1									
Poa bulbosa L.	Grain											
Taeniatherum caput-medusae L.	Grain											

Sample No.		12_141_10	28_2_100	29_512_123	29_191_503	29_206_509	29_271_6	29_271_7	29_278_1	29_278_6	30_245_3	30_245_4
Ajuga chamaepitys L. Schreb.	Seed											
Labiatae	Seed				1							
Lallemantia iberica M. Bieb.	Seed					4			1			1
cf. *Lamium* sp.	Seed											
Salvia sp.	Seed					4					2	1
cf. *Stachys* sp.	Seed								1			
Teucrium sp.	Seed							1				
cf. *Ziziphora* sp.	Seed											
Coronilla cf. *scorpiodes* L.	Seed											
Leguminosae	Pod frag.											
Medicago cf. *arabica/polymorpha* L.	Pod											
Medicago cf. *truncatula* Gaertn.	Pod	2									7	1
Medicago sp.	Pod frag.	1										
Medicago sp.	Seed		1			1					1	2
cf. *Melilotus* sp.	Seed											
cf. *Melilotus* sp.	Pod frag.											
Onobrychis cf. *viciifolia* Scop.	Seed							1				
Onobrychis sp.	Seed											
cf. *Scorpiurus* sp.	Seed											
Small-seed legumes	Seed		3									

Sample No.		12_141_10	28_2_100	29_512_123	29_191_503	29_206_509	29_271_6	29_271_7	29_278_1	29_278_6	30_245_3	30_245_4
Legume indet.	Pod										2	
cf. *Vicia* sp.	Seed	118							13			8
cf. *Bellevalia* sp.	Seed										1	
Ornithogalum sp.	Seed								2	1		
Linum sp.	Seed											4
Linum sp.	Pod										1	
Fumaria parviflora Lam.	Seed								1		1	
Glaucium corniculatum L.	Seed					1						
Papaver cf. *somniferum* L.	Seed											
Polygonaceae	Seed							10				
Polygonum aviculare L.	Seed	30	7		4	50	21		25	3	21	20
Polygonum cf. *convolvulus* L.	Seed											
cf. *Polygonum* sp.	Seed											
Rumex cf. *acetosella* L.	Seed				1						2	
Adonis aestavalis L.	Seed					1					1	
Adonis cf. *annua* L.	Seed	1			1	2						2
Adonis sp.	Seed						2					
Consolida regalis S. F. Gray	Seed											
Delphinium staphisagria L.	Seed											

Sample No.		12_141_10	28_2_100	29_512_123	29_191_503	29_206_509	29_271_6	29_271_7	29_278_1	29_278_6	30_245_3	30_245_4
Ranunculus arvensis L.	Seed	17	2		10	40	19	15	15	1	88	89
cf. *Ranunculus* sp.	Seed					1						
cf. *Potentilla* sp.	Seed											
Cruciata laevipes Opiz.	Seed	5	1		1	4	3	3	2		2	3
Galium triconutum Dandy.	Seed	265	13	1	13	132	344	238	169	60	295	170
Galium spurium L.	Seed	4			5	7	10	3	10	4	13	14
Galium sp.	Seed											
Veronica sp.	Seed											
Veronica hederifolia L.	Seed	10				1	1	2	2		3	4
Thymelaea cf. *passerina* L.	Seed											
Weed/wild indeterminate	Seed	1	3		1	3					9	

Sample No.		**30_245_8**	**30_245_9**	**30_252_3**	**30_252_8**	**30_252_11**	**30_252_13**	**30_259_7**	**30_259_8**	**30_259_11**	**30_259_13**	**30_262_11**
Quadrant		8	9	3	8	11	13	7	8	11	13	11
Section		309/343	309/343	309/343	309/343	309/343	309/343	309/343	309/343	309/343	309/343	309/343
Spit		245	245	252	252	252	252	259	259	259	259	262
Chamber No.		30	30	30	30	30	30	30	30	30	30	30
Taxa	**Plant part**											
Crops												
Hordeum vulgare L.	Grain	12	1960	17	4219	4140	4	10	5909	7846	3612	6257
Hordeum vulgare var. *nudum* L.	Grain				4	2					5	8
Triticum monococcum L.	Grain	58	258	89	278	151	113	18	276	243	350	86
Triticum dicoccum Schübl.	Grain	675	773	396	913	999	244	75	740	807	920	905
Triticum aestivum L./*durum* Desf.	Grain		4		1							2
Cereal indet.	Grain		2									
Hordeum vulgare L.	Rachis		31	8	72	15	8	4	76	60	31	25
Triticum monococcum L.	Glume base	10	420	66	324	203	104	34	285	264	350	221
Triticum dicoccum Schübl.	Glume base	73	999	164	830	777	246	94	874	892	842	655
Triticum aestivum L./*durum* Desf.	Rachis		17		7	30	2	2	17	2	3	4
Culm	Node		18		29	61			16	19	9	18
Lathyrus sativus L.	Seed			1						1		

Sample No.		30_245_8	30_245_9	30_252_3	30_252_8	30_252_11	30_252_13	30_259_7	30_259_8	30_259_11	30_259_13	30_262_11
Lens culinaris Medik.	Seed		1		6		6		3		4	2
Vicia ervilia L. Willd.	Seed	1	2	2	1	7	3		4	2	3	2
Vicia faba L. var. *minuta*	Seed	74	40	25	42	66	34	38	46	43	30	69
Pulse indet.	Seed								4			
Fruit/Nut												
Pistacia sp.	Nut shell frag.											
Pyrus/Malus sp.	Seed											
Prunus sp.	Nut shell frag.										1	
Rubus sp.	Seed										2	
Vitis vinifera L.	Seed											
Weed/wild												
Apiaceae	Seed											
Bifora radians M. Bieb.	Seed	66	178	70	155	129	71	67	144	112	136	107
cf. *Bupleurum* sp.	Seed	1		17	9	12	3		11	3		10
Caucalis platycarpos L.	Seed	2	19	8	23	22	4	2	30	33	27	19
Turgenia latifolia L. Hoffm.	Seed	5	59	7	36	48	7	9	35	62	48	23
Anchusa officinalis L.	Seed											
Asperugo procumbens L.	Seed											

Sample No.		30_245_8	30_245_9	30_252_3	30_252_8	30_252_11	30_252_13	30_259_7	30_259_8	30_259_11	30_259_13	30_262_11
Buglossoides arvensis L.	Seed		14	5	8	5	1		11	10		14
Buglossoides tenuiflorum L. fil.	Seed		3		7	4	1	3			7	
Buglossoides sp.	Seed		5							1		
cf. *Heliotropium* sp.	Seed											
Agrostemma githago L.	Seed				2	1			1	1	3	2
Silene sp.	Seed		2						4		3	4
Stellaria sp.	Seed											
Vaccaria pyramidata Medik.	Seed	4	56	16	52	20	7	7	74	46	74	53
Chenopodium album L.	Seed											1
cf. *Helianthemum* sp.	Seed											
Compositae	Seed		1			1						
Carthamus tinctorius L.	Seed				2							
Centaurea sp.	Seed	2	8		4	5	1		5		6	2
Onopordum acanthium L.	Seed											
cf. *Calystegia sepium* L. R. Br.	Seed											
Convolvulus sp.	Seed						1		9	8	7	
Convolvulus cf. *arvensis* L.	Seed		1	1	4	3	2					6
Alyssum sp.	Seed		2		1				1		7	11

Sample No.		30_245_8	30_245_9	30_252_3	30_252_8	30_252_11	30_252_13	30_259_7	30_259_8	30_259_11	30_259_13	30_262_11
Brassica cf. *nigra*	Seed		1						2	1		
Boreava aptera Boiss. & Heldr.	Seed	1	1			3	1	4				
Boreava orientalis Jaub. & Spach	Seed		1								1	
Bunias orientalis L.	Seed				1	5						
cf. *Bunias/Boreava* sp.	Seed		9						1	1		
Camelina sativa L.	Seed					2						
Camelina sp.	Pod		1						1			
Cardaria draba L.	Seed				1		3	2			15	
Cardaria draba L.	Pod											
Conringia orientalis L.	Seed		6		2		1		21	9	12	21
cf. *Conringia orientalis/Camelina sativa* sp.	Seed											
Coronopus squamatus Forssk.	Seed									1		
Cruciferae	Pod											
Cruciferae	Seed	3	1				1					
Lepidium cf. *latifoliatum* L.	Seed		8			5			7			14
Lepidium cf. *perfoliatum* L.	Seed								1	1		
Lepidium sp.	Pod		1								1	
Lepidium sp.	Seed								3	9		
Neslia paniculata L.	Seed	1	8	3	4	7	3	1	10	5	8	6

Sample No.		30_245_8	30_245_9	30_252_3	30_252_8	30_252_11	30_252_13	30_259_7	30_259_8	30_259_11	30_259_13	30_262_11
Thlaspi arvense L.	Seed		1					2	1		4	3
Carex sp.	Seed					1			2		1	2
Scirpus sylvaticus L.	Seed											
Cephalaria syriaca L. Schrad.	Seed		10	2	7	5	4	2	31	21	25	33
cf. *Geranium* sp.	Seed											
Avena cf. *sterilis* L.	Grain	1	3	9	47	22	10	2	31	26	51	33
Avena cf. *sterilis* L.	Spikelet		2				2		14	12	19	6
Avena cf. *sterilis* L.	Spikelet base											3
Avena cf. *sterilis* L.	Glume base											
Bromus cf. *sterilis* L.	Grain											
Bromus cf. *tectorum* L.	Grain			1	2				1		5	3
cf. *Bromus* sp.	Grain								3	2		
cf. *Festuca* sp.	Grain											
Hordeum cf. *spontaneum* K. Koch	Grain								1			
Large grass indet.	Grain		2				2		4	13		
Lolium persicum Boiss. & Hohen.	Grain		23	15	46	26	9	5	94	62	71	50
Phalaris sp.	Grain											
Poa bulbosa L.	Grain		1	1				1		2		3
Taeniatherum caput-medusae L.	Grain											

Sample No.		30_245_8	30_245_9	30_252_3	30_252_8	30_252_11	30_252_13	30_259_7	30_259_8	30_259_11	30_259_13	30_262_11
Ajuga chamaepitys L. Schreb.	Seed								1			1
Labiatae	Seed		1	6	1					2		9
Lallemantia iberica M. Bieb.	Seed		1	1				2	10	4	1	5
cf. *Lamium* sp.	Seed											
Salvia sp.	Seed	1						4			28	
cf. *Stachys* sp.	Seed		12		12	7	1		11	11		12
Teucrium sp.	Seed					1			2			2
cf. *Ziziphora* sp.	Seed											
Coronilla cf. *scorpiodes* L.	Seed							1			4	
Leguminosae	Pod frag.								1			2
Medicago cf. *arabica/polymorpha* L.	Pod	1										
Medicago cf. *truncatula* Gaertn.	Pod		1			4						
Medicago sp.	Pod frag.											
Medicago sp.	Seed		3		1	1		1				1
cf. *Melilotus* sp.	Seed									2		
cf. *Melilotus* sp.	Pod frag.			2	1	1			1	2		1
Onobrychis cf. *viciifolia* Scop.	Seed							1		2	2	
Onobrychis sp.	Seed				1				1			1
cf. *Scorpiurus* sp.	Seed											
Small-seed legumes	Seed											

Sample No.		30_245_8	30_245_9	30_252_3	30_252_8	30_252_11	30_252_13	30_259_7	30_259_8	30_259_11	30_259_13	30_262_11
Legume indet.	Pod		1								1	
cf. *Vicia* sp.	Seed								5	1		
cf. *Bellevalia* sp.	Seed						3					
Ornithogalum sp.	Seed											
Linum sp.	Seed											1
Linum sp.	Pod		1									1
Fumaria parviflora Lam.	Seed											
Glaucium corniculatum L.	Seed				1				3			1
Papaver cf. *somniferum* L.	Seed		1									
Polygonaceae	Seed											
Polygonum aviculare L.	Seed	3	40	8	16	28	24	9	95	40	62	74
Polygonum cf. *convolvulus* L.	Seed		1			1				2	1	3
cf. *Polygonum* sp.	Seed		1									
Rumex cf. *acetosella* L.	Seed		4		4			1	5	3	3	6
Adonis aestavalis L.	Seed		1			4			1	2	2	4
Adonis cf. *annua* L.	Seed		1		2			1		1	1	2
Adonis sp.	Seed						1				1	
Consolida regalis S. F. Gray	Seed								1			
Delphinium staphisagria L.	Seed								1			

Sample No.		30_245_8	30_245_9	30_252_3	30_252_8	30_252_11	30_252_13	30_259_7	30_259_8	30_259_11	30_259_13	30_262_11
Ranunculus arvensis L.	Seed	61	119	14	64	100	35	54	58	50	54	34
cf. *Ranunculus* sp.	Seed								2	3		2
cf. *Potentilla* sp.	Seed											
Cruciata laevipes Opiz.	Seed	11	2	4		4	10			3		
Galium triconutum Dandy.	Seed	52	296	243	466	296	249	62	393	411	373	443
Galium spurium L.	Seed		10	8	7	23	13	5	10	14	20	22
Galium sp.	Seed		2									
Veronica sp.	Seed											
Veronica hederifolia L.	Seed	2	3		3	2			6	4	3	3
Thymelaea cf. *passerina* L.	Seed		1	1					1	1		
Weed/wild indeterminate	Seed		10									

Sample No.		**30_262_13**	**30_268_8**	**30_268_11**	**30_268_13**	**30_273_11**	**30_273_13**	**32_64**	**32_66**	**32_70**	**32_71**	**32_72**	**32_74**
Quadrant		13	8	11	13	11	13						
Section		309/ 343	309/343	309/343	309/343	309/343	309/343	311/ 342	311/ 342	311/ 342	311/ 343	311/ 342	311/ 342
Spit		262	268	268	268	273	273	64	66	70	71	72	74
Chamber No.		30	30	30	30	30	30	32	32	32	32	32	32
Taxa	**Plant part**												
Crops													
Hordeum vulgare L.	Grain	67	41	4717	104	16	16	8694	164	288	4721	336	2
Hordeum vulgare var. *nudum* L.	Grain	1		1				1					
Triticum monococcum L.	Grain	164	251	525	557	394	308	112				6	
Triticum dicoccum Schübl.	Grain	421	552	1028	1041	464	512	3394	329	460	5536	652	143
Triticum aestivum L./*durum* Desf.	Grain			1	2		2					5	
Cereal indet.	Grain	2											
Hordeum vulgare L.	Rachis	2	1	17	26	1	1	14					
Triticum monococcum L.	Glume base	86	60	240	331	118	96	2				4	
Triticum dicoccum Schübl.	Glume base	419	172	630	706	173	112	878	47	192	256	1072	76
Triticum aestivum L./*durum* Desf.	Rachis	3	4	3	4			7					
Culm	Node	3		20	5	1		3					
Lathyrus sativus L.	Seed												1

Sample No.		30_262_13	30_268_8	30_268_11	30_268_13	30_273_11	30_273_13	32_64	32_66	32_70	32_71	32_72	32_74
Lens culinaris Medik.	Seed	3		1	10		4						
Vicia ervilia L. Willd.	Seed	4	2	4	4	2	4	78	21	9	144	36	63
Vicia faba L. var. *minuta*	Seed	35	46	68	72	28	31	1106	592	624	568	1237	1028
Pulse indet.	Seed												
Fruit/Nut													
Pistacia sp.	Nut shell frag.												
Pyrus/Malus sp.	Seed												
Prunus sp.	Nut shell frag.												
Rubus sp.	Seed												
Vitis vinifera L.	Seed												
Weed/wild													
Apiaceae	Seed									1			
Bifora radians M. Bieb.	Seed	70	49	111	112	68	50	75	8	2	8	180	7
cf. *Bupleurum* sp.	Seed	11	9	17	21	20	10	66	9	6		18	2
Caucalis platycarpos L.	Seed	9	10	13	20	9	7	23		1			
Turgenia latifolia L. Hoffm.	Seed	10	11	16	25	7	4	45		10		26	
Anchusa officinalis L.	Seed							1					
Asperugo procumbens L.	Seed												

Sample No.		30_262_13	30_268_8	30_268_11	30_268_13	30_273_11	30_273_13	32_64	32_66	32_70	32_71	32_72	32_74
Buglossoides arvensis L.	Seed	4		8			2	19	3	1		3	1
Buglossoides tenuiflorum L. fil.	Seed			2	1	2		2					2
Buglossoides sp.	Seed				3			2					
cf. *Heliotropium* sp.	Seed				2								
Agrostemma githago L.	Seed	1		1	2	3							
Silene sp.	Seed	2		2		1		18		2		1	
Stellaria sp.	Seed												
Vaccaria pyramidata Medik.	Seed	76	20	75	75	37	14	191	74	200	16	177	109
Chenopodium album L.	Seed	2											
cf. *Helianthemum* sp.	Seed												
Compositae	Seed							9	3	3			
Carthamus tinctorius L.	Seed												
Centaurea sp.	Seed	6	4	3	7	3		13		6		9	
Onopordum acanthium L.	Seed												
cf. *Calystegia sepium* L. R. Br.	Seed	6											
Convolvulus sp.	Seed			1	2	1	1						
Convolvulus cf. *arvensis* L.	Seed			1	5	1	1						
Alyssum sp.	Seed	10		1	3			1					

Sample No.		30_262_13	30_268_8	30_268_11	30_268_13	30_273_11	30_273_13	32_64	32_66	32_70	32_71	32_72	32_74
Brassica cf. *nigra*	Seed												
Boreava aptera Boiss. & Heldr.	Seed								2				
Boreava orientalis Jaub. & Spach	Seed				3								
Bunias orientalis L.	Seed			2				2					
cf. *Bunias/Boreava* sp.	Seed	1						18	5	11		10	
Camelina sativa L.	Seed			11	8	4		4				1	
Camelina sp.	Pod												
Cardaria draba L.	Seed												
Cardaria draba L.	Pod												
Conringia orientalis L.	Seed	7			3	2	5	2		11			
cf. *Conringia orientalis/Camelina sativa* sp.	Seed	1											
Coronopus squamatus Forssk.	Seed												
Cruciferae	Pod												
Cruciferae	Seed					1				1			
Lepidium cf. *latifoliatum* L.	Seed	24			23	3							
Lepidium cf. *perfoliatum* L.	Seed												
Lepidium sp.	Pod	1					1						
Lepidium sp.	Seed			11			1	1					
Neslia paniculata L.	Seed	9	2	2	10	5	3			2		4	

Sample No.		30_262_13	30_268_8	30_268_11	30_268_13	30_273_11	30_273_13	32_64	32_66	32_70	32_71	32_72	32_74
Thlaspi arvense L.	Seed	4			3			4		5			
Carex sp.	Seed												
Scirpus sylvaticus L.	Seed							1					
Cephalaria syriaca L. Schrad.	Seed	18		14	24	4	1	38					
cf. *Geranium* sp.	Seed												
Avena cf. *sterilis* L.	Grain	15	11	16	29	18	28	20	1			2	
Avena cf. *sterilis* L.	Spikelet				5								
Avena cf. *sterilis* L.	Spikelet base				4								
Avena cf. *sterilis* L.	Glume base	6											
Bromus cf. *sterilis* L.	Grain		1		1								
Bromus cf. *tectorum* L.	Grain		1	3				1					
cf. *Bromus* sp.	Grain	1				3	1					1	
cf. *Festuca* sp.	Grain	1											
Hordeum cf. *spontaneum* K. Koch	Grain												
Large grass indet.	Grain			11	8	2						1	
Lolium persicum Boiss. & Hohen.	Grain	24	2	25	46	5	6	7	1				2
Phalaris sp.	Grain							2					1
Poa bulbosa L.	Grain	1			3						8		
Taeniatherum caput-medusae L.	Grain			1									

Sample No.		30_262_13	30_268_8	30_268_11	30_268_13	30_273_11	30_273_13	32_64	32_66	32_70	32_71	32_72	32_74
Ajuga chamaepitys L. Schreb.	Seed												
Labiatae	Seed	5		5						1			
Lallemantia iberica M. Bieb.	Seed	4	1	1	5				1				
cf. *Lamium* sp.	Seed	1											
Salvia sp.	Seed												
cf. *Stachys* sp.	Seed	4		6	13	1							
Teucrium sp.	Seed		1	1	2	1							
cf. *Ziziphora* sp.	Seed				1								
Coronilla cf. *scorpiodes* L.	Seed		1										
Leguminosae	Pod frag.												
Medicago cf. *arabica/polymorpha* L.	Pod									1		3	
Medicago cf. *truncatula* Gaertn.	Pod												2
Medicago sp.	Pod frag.												
Medicago sp.	Seed			1				4			16	1	
cf. *Melilotus* sp.	Seed				1								
cf. *Melilotus* sp.	Pod frag.	1			3								
Onobrychis cf. *viciifolia* Scop.	Seed			4			1						
Onobrychis sp.	Seed				2								
cf. *Scorpiurus* sp.	Seed	1											
Small-seed legumes	Seed												

Sample No.		30_262_13	30_268_8	30_268_11	30_268_13	30_273_11	30_273_13	32_64	32_66	32_70	32_71	32_72	32_74
Legume indet.	Pod									1			
cf. *Vicia* sp.	Seed	11							6			17	1
cf. *Bellevalia* sp.	Seed			9									
Ornithogalum sp.	Seed					1							
Linum sp.	Seed		1	1									
Linum sp.	Pod			1									
Fumaria parviflora Lam.	Seed				1								
Glaucium corniculatum L.	Seed	1		1	2	1	1						
Papaver cf. *somniferum* L.	Seed												
Polygonaceae	Seed												
Polygonum aviculare L.	Seed	68	7	35	54	34	13	145	21	91		140	33
Polygonum cf. *convolvulus* L.	Seed				2	2							
cf. *Polygonum* sp.	Seed									1			
Rumex cf. *acetosella* L.	Seed	3	1	4	4	1							
Adonis aestavalis L.	Seed		1	1	1								
Adonis cf. *annua* L.	Seed	3	1	4	1	1	3					1	
Adonis sp.	Seed			1									
Consolida regalis S. F. Gray	Seed							2					
Delphinium staphisagria L.	Seed				2								

Sample No.		30_262_13	30_268_8	30_268_11	30_268_13	30_273_11	30_273_13	32_64	32_66	32_70	32_71	32_72	32_74
Ranunculus arvensis L.	Seed	12	40	48	75	30	11	197	117	106	24	163	13
cf. *Ranunculus* sp.	Seed	2				1							
cf. *Potentilla* sp.	Seed							1					
Cruciata laevipes Opiz.	Seed			1	1	4	4	38	28	51		5	30
Galium triconutum Dandy.	Seed	483	329	463	544	241	203	1296	489	607	96	1126	268
Galium spurium L.	Seed	27	9	16	18	17	15	150	45	95		24	38
Galium sp.	Seed												
Veronica sp.	Seed	3											
Veronica hederifolia L.	Seed	5		3	6	5		9	10	5		22	2
Thymelaea cf. *passerina* L.	Seed	1		1	2				1				
Weed/wild indeterminate	Seed			10	7	5		4		2	16		

Table 12.14 – Raw data from the Tell Brak assemblage, showing all quantified items.

Flot No.		**77**	**10**	**104**	**147**	**144**	**74**	**103**	**55**	**112**	**76**	**80**	**113**
Unique Locus		614	635.2	696.5	624.5	624.6	624.1	696.7	618	618.6	672.1	672.22	672.31
Room No.		4	6	8	8	8	8	8	9	9	12	12	12
Taxa	**Plant part**												
Crops													
Hordeum vulgare var. *vulgare* L.	Grain	1064	302	6240	5376	29573	9257	4419	2893	942	156	530	472
Hordeum vulgare var. *vulgare* L.	Rachis	32		16								32	
Hordeum vulgare sp.	Grain	16		384	32	193	1404	353	1001	248	44	8	8
Triticum monoccum L.	Grain	7			16								
Triticum monoccum L.	Glume base			32	16							40	
Triticum dicoccum Schübl.	Grain	78		32		227	95			2496		789	5104
Triticum dicoccum Schübl.	Glume base			16									48
Triticum monoccum/ dicoccum	Grain												
Triticum monoccum/ dicoccum	Glume base					68	128	16			16		
Triticum aestivum L./*durum* Desf.	Grain								366	1402	836	361	16
Triticum aestivum L./*durum* Desf.	Rachis					2							8

Flot No.		**77**	**10**	**104**	**147**	**144**	**74**	**103**	**55**	**112**	**76**	**80**	**113**
Triticum sp.	Grain		6					17			24		
Triticum sp.	Grain	8							711	424		16	
Culm	Node			16					16				
Culm top	Node												
Culm with straw (bottom of ear)	Node												
Lens culinaris Medik.	Seed	4				32						8	
Pisum sativum L.	Seed											8	
Lathyrus sativus L.	Seed	1	12										
Vicia ervilia L. Willd.	Seed												
Vicia sp.	Seed											8	8
Pulse indet.	Seed		8				4						
Fruit/Nut													
Vitis vinifera L.	Seed	2											
Sambucus sp.	Seed	2											
Pistacia lentiscus L.	Nut shell					32							
Amygdalus sp.	Nut shell frag.	8											
Fruit/nut shell (smooth)	Nut shell frag.						64						
Fruit/nut indet.	Nut shell frag.												
Fruit indet. (ml)	Frag.												
Fruit flesh/bread (ml)	Frag.						19.2						

Flot No.		77	10	104	147	144	74	103	55	112	76	80	113
Fruit skin	Frag.												
Weed/wild													
Boraginaceae	Seed												
Caryophyllaceae	Seed												
Gypsophila cf. *pilosa* Hudson	Seed			32	16								
Silene sp. Type 1.	Seed												
Silene sp. Type 2.	Seed												
Vaccaria pyramidata Medik.	Seed										8	64	
Chenopodium album L.	Seed												
Chenopodiaceae	Seed												
Artemisia sp.	Seed												
Centaurea sp.	Seed		8								16	16	
cf. *Chrysanthemum*	Seed												
Compositae	Seed												
Convolvulus sp.	Seed												
Alyssum sp.	Seed												
Cruciferae	Seed												
Cruciferae	Pod stalk												
Sinapis cf. *arvensis* L.	Seed								64			360	
Cyperaceae	Seed						128					16	
Cephalaria cf. *syriaca* L. Schrad.	Seed											32	
Adonis	Seed										8		

Flot No.		77	10	104	147	144	74	103	55	112	76	80	113
Aegilops cf. *crassa* Boiss.	Grain			112	4	67	80	1				18	113
Aegilops crassa Boiss.	Glume base			160	24	180	16	2				86	106
Aegilops cf. *speltoides* Tausch.	Grain	11			8	66				8		13	37
Aegilops speltoides Tausch.	Glume base	48			48	180				32		64	36
Aegilops cf. *tauschii* Coss.	Grain	5			4			31	16			9	18
Aegilops tauschii Coss.	Glume base	24			24			96	24			42	18
Aegilops sp.	Glume base										8		
Aegilops sp.	Grain												
Bromus sp.	Grain										8		
Eremopyrum cf. *bonaepartis* Spreng.	Grain											16	
Hordeum cf. *murinum* L.	Grain												
Hordeum cf. *spontaneum* K. Koch.	Grain			16		32							
Large grass indet.	Grain						4	32	152				
Lolium cf. *rigidum* Gaud.	Grain			16		32		16		64	8	72	
Lolium temulentum L.	Grain												

Flot No.		77	10	104	147	144	74	103	55	112	76	80	113
Poa cf. *annua* L.	Grain												
Poa bulbosa L.	Grain												
Poa sp.	Grain								16				
Taeniatherum sp.	Grain												
cf. *Teucrium* sp.	Seed										16		
Coronilla scorpiodes L.	Seed	32								32		8	
Small-seeded legumes	Seed	72				128			48			144	
Scorpirus sp.	Seed												
cf. *Trigonella* sp.	Seed			16							12	176	16
cf. *Muscari* sp.	Seed					32						8	
Ornithogalum/ Bellevalia/ Muscari sp.	Seed									16			
Malva cf. *parviflora* L.	Seed												
Malva cf. *sylvestris* L.	Seed												
Malva sp.	Seed									64			
Papaver cf. *rhoeas* L.	Seed												
Papaver cf. *argemone* L.	Seed											16	
Papaver sp.	Seed												
Polygonaceae	Seed												
Galium sp.	Seed										8	16	48
cf. *Verbascum* sp.	Seed												
cf. *Valerianella* sp.	Seed												

Flot No.		77	10	104	147	144	74	103	55	112	76	80	113
Weed/wild indeterminate	Pod												
Weed/wild indeterminate	Seed								64			8	
Charcoal >4mm/presence (ml)	Frag.	0.1	X	X	X		2.8	0.7	3		X	X	X

Flot No.		149	133	122	102	120	106	67	111	78	228	70	97
Unique Locus		672.18	672.15	672.26	672.17	672.19	672.15	684.1	672.11	672.14	809.2	657.4	657.26
Room No.		12	12	12	12	12	12	12	12	12	13	16	16
Taxa	**Plant part**												
Crops													
Hordeum vulgare var. *vulgare* L.	Grain	28	7157	347	176	268	685	53	130	8752	276	3684	4864
Hordeum vulgare var. *vulgare* L.	Rachis		256			16						8	16
Hordeum vulgare sp.	Grain		1376	129		32	532		10	288		360	16
Triticum monoccum L.	Grain					4					59	4	8
Triticum monoccum L.	Glume base					132							
Triticum dicoccum Schübl.	Grain	76	7579	116	1602	1096	1332	475	2723	2647		52	8
Triticum dicoccum Schübl.	Glume base	69				132						48	8
Triticum monoccum/ dicoccum	Grain												

Flot No.		149	133	122	102	120	106	67	111	78	228	70	97
Triticum monoccum/ dicoccum	Glume base						64	8	48		384		
Triticum aestivum L./*durum* Desf.	Grain		3432	17	858	1	43	36		1081	1173	36	
Triticum aestivum L./*durum* Desf.	Rachis					32						12	
Triticum sp.	Grain												
Triticum sp.	Grain	6	1112	57	56	48	880	107	551	608			
Culm	Node	1				8			4			4	8
Culm top	Node					8							
Culm with straw (bottom of ear)	Node					16							
Lens culinaris Medik.	Seed	2	64	1		10							
Pisum sativum L.	Seed			1									
Lathyrus sativus L.	Seed		8	1		3					4		
Vicia ervilia L. Willd.	Seed							1					
Vicia sp.	Seed					17			1				
Pulse indet.	Seed			1		20				16	8		
Fruit/Nut													
Vitis vinifera L.	Seed												
Sambucus sp.	Seed												
Pistacia lentiscus L.	Nut shell												
Amygdalus sp.	Nut shell frag.								1				
Fruit/nut shell (smooth)	Nut shell frag.												

Flot No.		149	133	122	102	120	106	67	111	78	228	70	97
Fruit/nut indet.	Nut shell frag.												
Fruit indet. (ml)	Frag.												
Fruit flesh/bread (ml)	Frag.												
Fruit skin	Frag.												
Weed/wild													
Boraginaceae	Seed							8					
Caryophyllaceae	Seed	16			8							8	
Gypsophila cf. *pilosa* Hudson	Seed					16			16				
Silene sp. Type 1.	Seed						128						
Silene sp. Type 2.	Seed										4		
Vaccaria pyramidata Medik.	Seed							12					16
Chenopodium album L.	Seed												
Chenopodiaceae	Seed				8								
Artemisia sp.	Seed												
Centaurea sp.	Seed									16			
cf. *Chrysanthemum*	Seed									64			
Compositae	Seed												
Convolvulus sp.	Seed												
Alyssum sp.	Seed												
Cruciferae	Seed										768		
Cruciferae	Pod stalk					8							
Sinapis cf. *arvensis* L.	Seed	116	32	12	88	1200	64	48	16		768		

Flot No.		149	133	122	102	120	106	67	111	78	228	70	97
Cyperaceae	Seed							4					
Cephalaria cf. *syriaca* L. Schrad.	Seed	1				144		12					
Adonis	Seed												
Aegilops cf. *crassa* Boiss.	Grain	3				12				64		2	56
Aegilops crassa Boiss.	Glume base	27				41				64		268	112
Aegilops cf. *speltoides* Tausch.	Grain	1				20		3				1	
Aegilops speltoides Tausch.	Glume base	5		4		73	128	28				114	
Aegilops cf. *tauschii* Coss.	Grain											1	
Aegilops tauschii Coss.	Glume base	4						3				78	
Aegilops sp.	Glume base								14		16		
Aegilops sp.	Grain										8		
Bromus sp.	Grain					8							
Eremopyrum cf. *bonaepartis* Spreng.	Grain					32							
Hordeum cf. *murinum* L.	Grain												
Hordeum cf. *spontaneum* K. Koch.	Grain			2		8							
Large grass indet.	Grain		64	6		24		8	40				

Flot No.		149	133	122	102	120	106	67	111	78	228	70	97
Lolium cf. *rigidum* Gaud.	Grain	19		4	8	16		4		32		24	40
Lolium temulentum L.	Grain												
Poa cf. *annua* L.	Grain												
Poa bulbosa L.	Grain												
Poa sp.	Grain	16										8	
Taeniatherum sp.	Grain												
cf. *Teucrium* sp.	Seed												
Coronilla scorpiodes L.	Seed	33				16							
Small-seeded legumes	Seed		32		48	96		24		64	384		
Scorpirus sp.	Seed												
cf. *Trigonella* sp.	Seed												8
cf. *Muscari* sp.	Seed	2						4					
Ornithogalum/ Bellevalia/ Muscari sp.	Seed						32						
Malva cf. *parviflora* L.	Seed												
Malva cf. *sylvestris* L.	Seed												
Malva sp.	Seed			1				4					
Papaver cf. *rhoeas* L.	Seed				24								
Papaver cf. *argemone* L.	Seed												
Papaver sp.	Seed				24	80							
Polygonaceae	Seed												
Galium sp.	Seed				8		32		37				

Flot No.		149	133	122	102	120	106	67	111	78	228	70	97
cf. *Verbascum* sp.	Seed												
cf. *Valerianella* sp.	Seed												
Weed/wild indeterminate	Pod					16							
Weed/wild indeterminate	Seed				8								
Charcoal >4mm/presence (ml)	Frag.	X	29		0.1		2			48	2	X	X

Flot No		115	116	117	121	124	127	150	152	159	225	227	71
Unique Locus		657.24	657.23	657.22	657.14	657.7	657.27	657.25	657.8	657.15	841.18	841.12	657.5
Room No.		16	16	16	16	16	16	16	16	16	16	16	16
Taxa	**Plant part**												
Crops													
Hordeum vulgare var. *vulgare* L.	Grain	6160	270	6560	11840	47616	6480	6800	7392	13696	636	258	6603
Hordeum vulgare var. *vulgare* L.	Rachis		16										8
Hordeum vulgare sp.	Grain	80	70	48	384	1536	288	16		384	1482	1013	2
Triticum monoccum L.	Grain				64								
Triticum monoccum L.	Glume base							32					
Triticum dicoccum Schübl.	Grain		2	16		128		48					10
Triticum dicoccum Schübl.	Glume base	32	2			256				192			

Flot No		115	116	117	121	124	127	150	152	159	225	227	71
Triticum monoccum/ dicoccum	Grain	16											
Triticum monoccum/ dicoccum	Glume base			32					16			4	14
Triticum aestivum L./*durum* Desf.	Grain												30
Triticum aestivum L./*durum* Desf.	Rachis												
Triticum sp.	Grain												
Triticum sp.	Grain											8	12
Culm	Node					128				32			18
Culm top	Node												
Culm with straw (bottom of ear)	Node												
Lens culinaris Medik.	Seed										8		
Pisum sativum L.	Seed												
Lathyrus sativus L.	Seed												
Vicia ervilia L. Willd.	Seed												
Vicia sp.	Seed												
Pulse indet.	Seed												4
Fruit/Nut													
Vitis vinifera L.	Seed												
Sambucus sp.	Seed												
Pistacia lentiscus L.	Nut shell												
Amygdalus sp.	Nut shell frag.												

Flot No		115	116	117	121	124	127	150	152	159	225	227	71
Fruit/nut shell (smooth)	Nut shell frag.											4	
Fruit/nut indet.	Nut shell frag.		16										
Fruit indet. (ml)	Frag.											1	
Fruit flesh/bread (ml)	Frag.												
Fruit skin	Frag.												
Weed/wild													
Boraginaceae	Seed												2
Caryophyllaceae	Seed											8	
Gypsophila cf. *pilosa* Hudson	Seed				32			16	32				
Silene sp. Type 1.	Seed			16						128			
Silene sp. Type 2.	Seed												
Vaccaria pyramidata Medik.	Seed				32	256	16	16	32				
Chenopodium album L.	Seed												
Chenopodiaceae	Seed												
Artemisia sp.	Seed												
Centaurea sp.	Seed												
cf. *Chrysanthemum*	Seed												
Compositae	Seed												
Convolvulus sp.	Seed												
Alyssum sp.	Seed												
Cruciferae	Seed												
Cruciferae	Pod stalk												

Flot No		115	116	117	121	124	127	150	152	159	225	227	71
Sinapis cf. *arvensis* L.	Seed												
Cyperaceae	Seed												
Cephalaria cf. *syriaca* L. Schrad.	Seed									32			
Adonis	Seed												2
Aegilops cf. c*rassa* Boiss.	Grain	14		39	57		40	15		35	16		5
Aegilops crassa Boiss.	Glume base	222		157	544	1280	173	160	478	32	4		153
Aegilops cf. s*peltoides* Tausch.	Grain	2			7					71			1
Aegilops speltoides Tausch.	Glume base	34			64	256				64			19
Aegilops cf. *tauschii* Coss.	Grain		4	9			8	1		214		2	
Aegilops tauschii Coss.	Glume base		6	35		512	35	16	34	192		3	
Aegilops sp.	Glume base												
Aegilops sp.	Grain												
Bromus sp.	Grain												
Eremopyrum cf. *bonaepartis* Spreng.	Grain	32											4
Hordeum cf. *murinum* L.	Grain												32
Hordeum cf. *spontaneum* K. Koch.	Grain										32		

Flot No		115	116	117	121	124	127	150	152	159	225	227	71
Large grass indet.	Grain										8	4	6
Lolium cf. *rigidum* Gaud.	Grain							16	16	64	32		8
Lolium temulentum L.	Grain												
Poa cf. *annua* L.	Grain												
Poa bulbosa L.	Grain									32			
Poa sp.	Grain		8										4
Taeniatherum sp.	Grain												
cf. *Teucrium* sp.	Seed												
Coronilla scorpiodes L.	Seed												
Small-seeded legumes	Seed		8										4
Scorpirus sp.	Seed												
cf. *Trigonella* sp.	Seed												
cf. *Muscari* sp.	Seed												
Ornithogalum/ Bellevalia/ Muscari sp.	Seed												
Malva cf. *parviflora* L.	Seed									32			
Malva cf. *sylvestris* L.	Seed												
Malva sp.	Seed									96			
Papaver cf. *rhoeas* L.	Seed												
Papaver cf. *argemone* L.	Seed												
Papaver sp.	Seed												
Polygonaceae	Seed												

Flot No		**115**	**116**	**117**	**121**	**124**	**127**	**150**	**152**	**159**	**225**	**227**	**71**
Galium sp.	Seed												
cf. *Verbascum* sp.	Seed												
cf. *Valerianella* sp.	Seed												
Weed/wild indeterminate	Pod												
Weed/wild indeterminate	Seed				32	128							
Charcoal >4mm/presence (ml)	Frag.		X	X	X	X		X			2	0.2	1.5

Flot No.		**219**	**148**	**218**	**123**	**118**	**138**	**131**	**105**	**98**	**130**	**140**	**226**
Unique Locus		841.10	657.9	841.7	657.12	657.13	657.28	813.14	657.28	657.3	657.29	841.2	841.11
Room No.		16	16	16	16	16	16	16	16	16	16	16	16
Taxa	**Plant part**												
Crops													
Hordeum vulgare var. *vulgare* L.	Grain	2674	171	2302	24804	29228	48896	193280	42520	616	624	1272	3304
Hordeum vulgare var. *vulgare* L.	Rachis			2				768				12	
Hordeum vulgare sp.	Grain	56	122	52	204	40	576	33024	256	181	35	80	408
Triticum monoccum L.	Grain					128		256	128				
Triticum monoccum L.	Glume base			4									
Triticum dicoccum Schübl.	Grain					20		768					
Triticum dicoccum Schübl.	Glume base							768	385	4	8		

Flot No.		219	148	218	123	118	138	131	105	98	130	140	226
Triticum monoccum/ dicoccum	Grain												
Triticum monoccum/ dicoccum	Glume base	8		8								8	
Triticum aestivum L./*durum* Desf.	Grain												
Triticum aestivum L./*durum* Desf.	Rachis							256					
Triticum sp.	Grain			2	2								
Triticum sp.	Grain	4				4							
Culm	Node	4				64					1		
Culm top	Node												
Culm with straw (bottom of ear)	Node												
Lens culinaris Medik.	Seed					128							
Pisum sativum L.	Seed												
Lathyrus sativus L.	Seed												
Vicia ervilia L. Willd.	Seed												
Vicia sp.	Seed							256					
Pulse indet.	Seed												
Fruit/Nut													
Vitis vinifera L.	Seed												
Sambucus sp.	Seed												
Pistacia lentiscus L.	Nut shell												
Amygdalus sp.	Nut shell frag.												

Flot No.		219	148	218	123	118	138	131	105	98	130	140	226
Fruit/nut shell (smooth)	Nut shell frag.												
Fruit/nut indet.	Nut shell frag.												
Fruit indet. (ml)	Frag.												
Fruit flesh/bread (ml)	Frag.												
Fruit skin	Frag.												
Weed/wild													
Boraginaceae	Seed			20									
Caryophyllaceae	Seed												
Gypsophila cf. *pilosa* Hudson	Seed										2		
Silene sp. Type 1.	Seed												
Silene sp. Type 2.	Seed												
Vaccaria pyramidata Medik.	Seed		2	18	4	72		512					
Chenopodium album L.	Seed												
Chenopodiaceae	Seed		2										
Artemisia sp.	Seed												
Centaurea sp.	Seed												
cf. *Chrysanthemum*	Seed												
Compositae	Seed												
Convolvulus sp.	Seed												
Alyssum sp.	Seed												
Cruciferae	Seed												
Cruciferae	Pod stalk												

Flot No.		219	148	218	123	118	138	131	105	98	130	140	226
Sinapis cf. *arvensis* L.	Seed			2									
Cyperaceae	Seed												
Cephalaria cf. *syriaca* L. Schrad.	Seed												
Adonis	Seed						256						
Aegilops cf. c*rassa* Boiss.	Grain	13	1	4	28	3	538	115	371	5	1	2	7
Aegilops crassa Boiss.	Glume base	61	3	59	847	162	1459	1720	1792	10	5	443	299
Aegilops cf. s*peltoides* Tausch.	Grain	2		3	37			768	109			1	1
Aegilops speltoides Tausch.	Glume base	9		35	1100			11113	512			100	53
Aegilops cf. *tauschii* Coss.	Grain	9	4	3	1	13	358	397	160			1	
Aegilops tauschii Coss.	Glume base	44	7	42	21	646	973	5755	768			113	
Aegilops sp.	Glume base												
Aegilops sp.	Grain												
Bromus sp.	Grain												
Eremopyrum cf. *bonaepartis* Spreng.	Grain		2	8									
Hordeum cf. *murinum* L.	Grain			8									
Hordeum cf. *spontaneum* K. Koch.	Grain	16				128							

Flot No.		219	148	218	123	118	138	131	105	98	130	140	226
Large grass indet.	Grain				64								
Lolium cf. *rigidum* Gaud.	Grain		2	12		128	64	256			1		
Lolium temulentum L.	Grain												
Poa cf. *annua* L.	Grain												
Poa bulbosa L.	Grain												
Poa sp.	Grain												
Taeniatherum sp.	Grain												
cf. *Teucrium* sp.	Seed												
Coronilla scorpiodes L.	Seed												
Small-seeded legumes	Seed											4	
Scorpirus sp.	Seed												
cf. *Trigonella* sp.	Seed									1	2		
cf. *Muscari* sp.	Seed												
Ornithogalum/ Bellevalia/ Muscari sp.	Seed												
Malva cf. *parviflora* L.	Seed												
Malva cf. *sylvestris* L.	Seed												
Malva sp.	Seed										1		
Papaver cf. *rhoeas* L.	Seed												
Papaver cf. *argemone* L.	Seed												
Papaver sp.	Seed												
Polygonaceae	Seed												

Flot No.		219	148	218	123	118	138	131	105	98	130	140	226
Galium sp.	Seed												
cf. *Verbascum* sp.	Seed												
cf. *Valerianella* sp.	Seed												
Weed/wild indeterminate	Pod												
Weed/wild indeterminate	Seed	4											
Charcoal >4mm/presence (ml)	Frag.		10							X	X	X	X

Flot No.		239	168	217	167	169	383	450	447	165	388
Unique Locus		843.2	870.1	870.18	870.3	870.11	TCJ-1695	TCJ-1656	TCJ-1656	TCJ-2246	TCH-1395
Room No.		16	17	17	17	17	18	Ncy	Ncy	Ncy	TCH
Taxa	**Plant part**										
Crops											
Hordeum vulgare var. *vulgare* L.	Grain	1360	2997	1616	3359	2024	21	182	155	69	200
Hordeum vulgare var. *vulgare* L.	Rachis						4	32	8		16
Hordeum vulgare sp.	Grain	680	16	264		144	1	16		2	20
Triticum monoccum L.	Grain			47				10		1	
Triticum monoccum L.	Glume base										
Triticum dicoccum Schübl.	Grain		156	488	32			27	31	7	6

Flot No.		239	168	217	167	169	383	450	447	165	388
Triticum dicoccum Schübl.	Glume base			160							
Triticum monoccum/ dicoccum	Grain										
Triticum monoccum/ dicoccum	Glume base		16		36		13	112	64	6	48
Triticum aestivum L./*durum* Desf.	Grain	4	55	33	65			857	420	14	
Triticum aestivum L./*durum* Desf.	Rachis										
Triticum sp.	Grain					8	7				
Triticum sp.	Grain		32	176				40			
Culm	Node	2		8	12		1	24	2	17	6
Culm top	Node								2		
Culm with straw (bottom of ear)	Node										
Lens culinaris Medik.	Seed						2	16			3
Pisum sativum L.	Seed										
Lathyrus sativus L.	Seed	2									
Vicia ervilia L. Willd.	Seed										
Vicia sp.	Seed									4	
Pulse indet.	Seed					8		12	2	4	3
Fruit/Nut											
Vitis vinifera L.	Seed						1	4		4	
Sambucus sp.	Seed										
Pistacia lentiscus L.	Nut shell										

Flot No.		239	168	217	167	169	383	450	447	165	388
Amygdalus sp.	Nut shell frag.										
Fruit/nut shell (smooth)	Nut shell frag.								8		
Fruit/nut indet.	Nut shell frag.										
Fruit indet. (ml)	Frag.										
Fruit flesh/bread (ml)	Frag.										
Fruit skin	Frag.				4						
Weed/wild											
Boraginaceae	Seed									2	
Caryophyllaceae	Seed			16				96			8
Gypsophila cf. *pilosa* Hudson	Seed		8	144	16	16	2	160	128	114	34
Silene sp. Type 1.	Seed							16	8		
Silene sp. Type 2.	Seed										
Vaccaria pyramidata Medik.	Seed			40			4	96	16	14	2
Chenopodium album L.	Seed								8		
Chenopodiaceae	Seed					8				20	
Artemisia sp.	Seed						2				
Centaurea sp.	Seed										
cf. *Chrysanthemum*	Seed										
Compositae	Seed			16							
Convolvulus sp.	Seed							4			
Alyssum sp.	Seed			16							

Flot No.		239	168	217	167	169	383	450	447	165	388
Cruciferae	Seed										
Cruciferae	Pod stalk										
Sinapis cf. *arvensis* L.	Seed						2		8		
Cyperaceae	Seed						2				10
Cephalaria cf. *syriaca* L. Schrad.	Seed										
Adonis	Seed						1				
Aegilops cf. c*rassa* Boiss.	Grain	7	8				9	60		13	7
Aegilops crassa Boiss.	Glume base	146	40				8	64		51	4
Aegilops cf. s*peltoides* Tausch.	Grain	2			30				14		
Aegilops speltoides Tausch.	Glume base	27			8				20		
Aegilops cf. *tauschii* Coss.	Grain	1			30	16			14	26	4
Aegilops tauschii Coss.	Glume base	9			8	64			20	25	2
Aegilops sp.	Glume base										
Aegilops sp.	Grain			40							
Bromus sp.	Grain										
Eremopyrum cf. *bonaepartis* Spreng.	Grain			32			1	16			
Hordeum cf. *murinum* L.	Grain									8	2

Flot No.		239	168	217	167	169	383	450	447	165	388
Hordeum cf. *spontaneum* K. Koch.	Grain				4					1	
Large grass indet.	Grain				8	32	2		48		2
Lolium cf. *rigidum* Gaud.	Grain			32	4	16	8	128	56	8	16
Lolium temulentum L.	Grain							8			
Poa cf. *annua* L.	Grain			16			1				
Poa bulbosa L.	Grain							8			
Poa sp.	Grain						8	8		8	36
Taeniatherum sp.	Grain										4
cf. *Teucrium* sp.	Seed										2
Coronilla scorpiodes L.	Seed						3	80	56	4	2
Small-seeded legumes	Seed			48	64		36	104	464	124	66
Scorpirus sp.	Seed			16							
cf. *Trigonella* sp.	Seed			16			1	256	64	20	4
cf. *Muscari* sp.	Seed										
Ornithogalum/ Bellevalia/ Muscari sp.	Seed								8		2
Malva cf. *parviflora* L.	Seed							8			
Malva cf. *sylvestris* L.	Seed			16			2			4	
Malva sp.	Seed		8	16							4
Papaver cf. *rhoeas* L.	Seed						1				4

Flot No.		239	168	217	167	169	383	450	447	165	388
Papaver cf. *argemone* L.	Seed										
Papaver sp.	Seed										8
Polygonaceae	Seed						2	8	8		2
Galium sp.	Seed	6			4				32	15	2
cf. *Verbascum* sp.	Seed						1				
cf. *Valerianella* sp.	Seed						1				
Weed/wild indeterminate	Pod										
Weed/wild indeterminate	Seed	2		8	52				16		8
Charcoal >4mm/presence (ml)	Frag.	X		X	12			0.4	2	2	0.2

Weed Species Identification Catalogue

Wild taxa are listed alphabetically by family following the *Flora of Turkey* (Davis 1966-1989) and site:

Apiaceae:

Bifora radians M. Bieb. - Hattusha
Identified in 42 samples, these specimens were rounded and circular in shape with a distinctive 'beak-like' pit in one side. This pit had a slightly raised edge and tapered to a point at one end. The surface pattern was striated with radial lines, although these were quite faint due to charring.

Caucalis platycarpos L. – Hattusha
Identified in 31 samples, these specimens were narrowly ellipsoid with a flat ventral face. The dorsal surface had quite large, prominent spines that were often slightly hooked at the ends. These spines were arranged along distinct ridges. When the seed was removed from the mericarp it was quite long and cylindrical with a distinct fold on the ventral side. The surface also had linear grooves running the length of the seed.

Turgenia latifolia L. Hoffm. – Hattusha
Identified in 34 samples, these specimens were narrowly ovoid with a flat ventral face. The dorsal surface was densely spiny with distinct ridges. When compared with *Caucalis platycarpos* this species was significantly smaller with smaller but more densely clustered spines. When the seed was removed from the mericarp it was broadly ovate with a distinct fold and linear grooves running down the length of the seed.

Boraginaeceae:

Anchusa officinalis L. – Hattusha
Identified in one sample by R. Neef (*pers. comm*) and was not available for description.

Asperugo procumbens L. - Hattusha
Identified in one sample by R. Neef (*pers. comm*) and was not available for description. This species is also monotypic.

Buglossoides arvensis L. – Hattusha
Identified in 33 samples, specimens are irregularly ovoid and can be slightly angular with a tapering stem and a flatter top. The surface has distinctive radial ridges that extend down the side to the stem. When compared with *B. tenuiflora*, these remains tend to be more irregular in shape and the ridges are more distinct.

Buglossoides tenuiflora L. fil. - Hattusha
Identified in 20 samples, specimens are irregularly ovoid with a tapering stem. When compared with *B. arvensis* this species has a slightly more slender and pointed stem and smaller protruding papillae all over the apex end.

Caryophyllaceae

Agrostemma githago L. – Hattusha
Identified in 12 samples, specimens were cuneate in shape although the sides could be relatively flat. The face of each side had a small depression in the middle leading down to a prominent subbasal notch. The surface of each was

covered in closely spaced raised spines or 'prickles'. Other species of *Silene* sp. were also considered but these specimens were all considerably larger and had more prominent spines than any reference collection material examined.

Gypsophila cf. *pilosa* Hudson – Tell Brak
Identified in 17 samples, specimens were elliptic-cuneate in shape with an elongated radicle that protruded from one side of the seed. The sides of the seed were slightly concave and slanted down towards the radicle. Each seed, however, had a small, round depression in the middle. The surface was distinctly marked with linear rows of spines/papillae. *G. viscosa* was also considered but this species was generally too flat and the spines were not protuberant enough.

Vaccaria pyramidata Medik. – Hattusha
Identified in 41 samples, this species is monotypic. Specimens were generally circular or ovate in shape with a slightly protruding hilum. The surface of the outer casing was very highly textured with very small, raised papillae. When the outer casing was removed, however, the inner seed was generally smooth with a distinct and deep radicular furrow that often caused the seed to split into two parts.

Vaccaria pyramidata Medik. – Tell Brak
Identified in 20 samples, these specimens were poorly preserved in comparison to the specimens from the Hattusha assemblage. The outer casing was very rarely preserved and in most examples the seed had split into two separate parts along the radicular furrow.

Chenopodiaceae:

Chenopodium album L. – Hattusha
Identified in three samples, specimens were oval/lenticular in shape with a defined keel around the outer edge. There was no visible surface patterning and seeds were generally shiny and smooth. *C. botrys* and *C. vulvaria* were also considered but both of these species were generally smaller and did not have such a prominent outer keel.

Chenopodium album L. – Tell Brak
Identified in one sample, seeds were largely lenticular in shape with a very defined keel around the edge. The surface of the seed was shiny and smooth.

Compositae:

Carthamus tinctorius L. – Hattusha
Identified in one sample by R. Neef (*pers. comm*) and was not available for description.

Onopordum acanthium L. – Hattusha
Identified in one sample by R. Neef (*pers. comm*) and was not available for description

Convolvulaceae:

cf. *Calystegia sepium* L. R. Br. – Hattusha
Identified in two samples, these specimens were very similar in shape to *Convolvulus arvensis* with an ovate-trullate shape that tapered towards the embryo. These seeds, however, had slightly more convex sides and a more prominent keel. Additionally, the embryo is more horseshoe-shaped rather than rounded.

Convolvulus cf. *arvensis* L. – Hattusha

Identified in 11 samples, specimens were roughly ovate-trullate in shape with a rounded apex that tapers towards the embryo. The embryo itself is rounded in shape. The sides were slightly convex and came to a prominent keel that ran along the length of the seeds. Surface pattern is reticulate with slightly raised ribs.

Cruciferae:

Boreava aptera Boiss. & Heldr. – Hattusha
Identified in 23 samples, these specimens were ovate in shape and considerably flatter than *B. orientalis*. Each seed also came to a flat, triangular point at the apical end. The surface pattern was distinctively reticulate with small raised ribs, but this species did not have the wings that define *B. orientalis*. When these seeds were removed from their outer casing it became impossible to tell them apart from *Boreava orientalis*.

Boreava orientalis Jaub. & Spach – Hattusha
Identified in seven samples, specimens were quite round and concave in shape but tapered to a pointed tip at the apical end. The most distinctive feature of these seeds, however, was the presence of four 'wavy' wings that ran the length of the seed. The surface of each seed was also unevenly textured but the pattern was not identifiable. When these seeds were removed from their outer casing it became impossible to tell them apart from *Boreava aptera*.

Brassica cf. *nigra* L. – Hattusha
Identified in three samples, the shape of these specimens was irregularly elliptic with slightly flattened ends, although the shape overall seemed quite variable. Surface pattern was very distinct with small reticulate pockmarks. *Sinapis arvensis* was also considered but this species was generally too small.

Bunias orientalis L. – Hattusha
Identified in 11 samples, the shape of these specimens was similar to *Boreva orientalis* but without the distinct wings and with a far more bulbous, rounded appearance. The apex of each seed was tapered to a 'beak-like' point. The surface of each seed was covered with irregular protuberances and no distinct pattern was visible.

Camelina sativa L. – Hattusha
Identified in nine samples, specimens were elliptic with a distinct radical that was slightly shorter or the same length as the cotyledons. These seeds were compared to *Conringia orientalis* but were generally smaller and slightly flatter in shape. Surface pattern was very distinct with small papillae spaced at close intervals.

Cardaria draba L. – Hattusha
Identified in seven samples, this species is monotypic. Specimens were obovate and the radicle was generally shorter than the cotyledons. The radicular ridge was not as visibly distinct as those seen in *Lepidium* sp. as the radicle was compressed to the cotyledonary part of the seed. This species was identified by R. Neef.

Conringia orientalis L. – Hattusha
Identified in 17 samples, these specimens were elliptic in shape with a distinct radical that was the same length as the cotyledons. Specimens were fatter and blunter at the apical end than *Camelina sativa*. Seeds also had a visible surface pattern with very small, irregularly spaced papillae.

Coronopus squamatus Forssk. – Hattusha

Identified in one sample by R. Neef (*pers. comm*) and was not available for description.

Lepidium cf. *latifolium* L. – Hattusha
Identified in 10 samples, specimens were elliptic in shape although were somewhat more rounded than *L. perfoliatum*, *L. ruderale* and *L. sativum.* The radicle was slightly longer than the cotyledons, tapered to a point and curved slightly inwards. These specimens also had a distinct radicular ridge running down the length of the seed.

Lepidium cf. *perfoliatum* L. – Hattusha
Identified in two samples, specimens were obovate in shape but flattened. The radical was slightly shorter than the cotyledons and somewhat curved inwards at the tip. The most prominent feature of these seeds, however, was the flat ridge that ran around the edge of the entire seed. This ridge was marginally less pronounced on the radicle side, but still visible.

Neslia paniculata L. – Hattusha
Identified in 33 samples, this species is monotypic. Circular or slightly elliptic in shape, but with slightly pointed ends. The surface pattern was honeycombed with small ribs, but with one distinctive ridge down the middle of the seed.

Sinapis cf. *arvensis* L. – Tell Brak
Identified in 14 samples, these specimens were fairly rounded and 'ball-shaped', although some were slightly more irregular in shape. Charring seemed to have destroyed any obvious surface patterning but some of the slightly better preserved examples had the remains of a small, round indentation at the top. Other *Brassica* sp. were considered but all of these species were too big and were not as rounded in shape.

Thlaspi arvense L. – Hattusha
Identified in 11 samples, specimens were ovate in shape, although there tended to be one slightly straighter edge on each seed. The surface pattern was very distinct with ribs concentrically arranged and diminishing in size from the edge to the middle of the seed.

Cyperaceae:

Scirpus sylvaticus L. – Hattusha
Identified in four samples, these specimens were obovate in shape and quite flat, with a very slight keel down the middle of the seed. Surface texture was smooth with no obvious patterning. This species is monotypic.

Dipsacaceae:

Cephalaria syriaca L. Schrad. – Hattusha
Identified in 20 samples, specimens are generally ovoid in shape but can be quite flat with a rounded apical end. The top portion of the seed finishes at a flared and pointed-ended 'skirt' which then tapers down to a narrower, point. The surface is covered in linear grooves that run the length of the seed.

Cephalaria cf. *syriaca* L. Schrad. – Tell Brak.
Identified in five samples, specimens in general were less well preserved than the seeds from Hattusha. The distinctive 'skirt', pointed end and linear grooves, however, were all visible.

Gramineae:

Aegilops crassa Boiss. – Tell Brak
Identified in 40 samples on the basis of chaff remains rather than grain. Chaff remains were the largest and most

robust of the *Aegilops* sp. The scar was square-ended and horseshoe shaped.

Aegilops speltoides Tausch. – Tell Brak
Identified in 27 samples on the basis of chaff remains rather than grain. Chaff remains were significantly smaller than other *Aegilops* sp. The scar was rounded and very small.

Aegilops tauschii Coss. – Tell Brak
Identified in 32 samples on the basis of chaff remains rather than grain. Chaff remains are of similar size to *A. crassa* but are generally less robust. The scar is also horseshoe shaped, but has a convex base .

Avena cf. *sterilis* L. – Hattusha
Identified in 25 samples from grain and chaff remains. Grains have a rounded apical end, with a relatively shallow ventral groove. Grains also have a secondary groove running down the ventral side. *A. sativa* was also considered but all archaeological grains have a rounded scar which is not present in that species.

Bromus cf. *sterilis* L. – Hattusha
Identified in two samples, the grains were slightly thicker and tapered more towards the apical end than those identified as *B. tectorum*. Additionally, the ventral groove extended all the way to the tip of the apical end.

Bromus cf. *tectorum* L. – Hattusha
Identified in 11 samples, these grains were quite long, thin and flat when compared with *B. sterilis*. The apical end was also slightly rounded and the ventral groove did not extend all the way to the tip.

Eremopyrum cf. *bonaepartis* Spreng. – Tell Brak
Identified in nine samples, grains had a reasonably wide ventral groove that tapered away towards the apical end. There was also a prominent ridge that ran the length of the middle of the dorsal side. Finally, there were two clear grooves on the sides of the grain. *E. orientale* was also considered but the ventral groove of this species was noticeably narrower than the archaeological specimens.

Hordeum cf. *murinum* L. – Tell Brak
Identified in four samples, grains were significantly smaller than the domesticated variety of *Hordeum* sp. The apical end was rounded and the ventral groove was not as well defined.

Hordeum cf. *spontaneum* K. Koch. – Hattusha
Identified in three samples, these grains were noticeably narrower and thinner than the domesticated variety of *Hordeum* sp. Additionally, the ventral groove of the archaeological material was wide and shallow and the apical end was slightly square.

Hordeum cf. *spontaneum* K. Koch. - Tell Brak
Identified in nine samples, these grains were similar to the *H. spontaneum* identified from the Hattusha assemblage. Grains were noticeably narrower and thinner than domesticated *Hordeum* sp. with a shallow ventral groove.

Lolium persicum Boiss. & Hohen. – Hattusha
Identified in 26 samples, grains were all long and thin and significantly tapered towards the apical ends. *L. multiflorum, L. perenne* and *L. rigidum* were all considered but the archaeological remains were all considerably larger and thinner than any modern reference material

Lolium cf. *rigidum* Gaud. – Tell Brak
Identified in 33 samples, grains were quite flat with a wide and flat ventral

groove. Grains were also rounded at the apical end but were significantly smaller than *L. persicum* identified at Hattusha.

Lolium temulentum L. – Tell Brak
Identified in one sample. This single grain was significantly fatter, shorter and wider than all other *Lolium* sp. identified from the Tell Brak assemblage. This grain also had a much higher back and a very faint line running down the dorsal side.

Poa cf. *annua* L. – Tell Brak
Identified in two samples, these grains were very similar in shape to all other *Poa* sp. but tapered quite strongly towards the apical end and the hilum was rounded and stuck out from the grain slightly.

Poa bulbosa L. – Hattusha
Identified in eight samples, these grains were very distinctive from all other *Poa* sp. as the glumes contained small bubils surrounded by sheaths rather than florets containing caryopses.

Poa bulbosa L. – Tell Brak
Identified in two samples, these grains were very similar to the *P. bulbosa* identified from Hattusha and contained the small bubils surrounded by sheaths.

Taeniatherum caput-medusae L. - Hattusha
Identified in one sample by R. Neef (*pers. comm*) and was not available for description.

Labiatae:

Ajuga chamaepitys L. Schreb. – Hattusha
Identified in two samples, these specimens were almost cylindrical in shape and were curved at the top and bottom. Surface pattern was reticulate with small raised ribs. Specimens were compared with *A. orientalis, A. reptans* and a number of *Teucrium* sp. but in all cases the archaeological seeds were considerably longer and slenderer than modern reference material.

Lallemantia iberica M. Bieb. – Hattusha
Identified in 15 samples, specimens were fairly oblong in shape with a rounded apex end that tapered to a triangular point at the embryo end. Seeds also had a prominent keel on the ventral side and a roughly triangular shaped embryo.

Leguminosae:

Coronilla cf. *scorpiodes* L. – Hattusha
Identified in three samples, specimens were narrowly ellipsoid with rounded edges. *C. varia* was also considered but was generally a bit fatter and not as long as the archaeological seeds. Additionally, *C. varia* also had a distinctive longitudinal rib that was missing in the archaeological specimens.

Coronilla scorpiodes L. – Tell Brak
Identified in 10 samples, this species is monotypic in Syria/Iraq. Seeds were long and slightly curved with smooth outer surface and rounded ends.

Medicago cf. *arabica/polymorpha* L. – Hattusha
Identified in four samples, specimens were found preserved in the pod. The pods in general were tightly coiled spirals with distinct ‘layers’. The surface had pronounced spikes in two rows that slightly hooked at the ends. *M. rigidula* was also considered as it was the right shape and size, but did not have the double row of spikes that were visible in the archaeological material.

Medicago cf. *truncatula* Gaertn. – Hattusha
Identified in 10 samples, specimens were found preserved in the pod. The pods in general were large and very robust, with at least four tightly coiled spirals. The surface also had a single row of spikes, but the spikes themselves were considerably larger than those seen on *M. Arabica/Polymorpha.*

Onobrychis cf. *viciifolia* Scop. – Hattusha
Identified in six samples, specimens were found preserved in the pod. Overall shape was roughly obovoid and laterally flattened. The surface was strongly reticulate with small spines on the ribs. Spines were also located around the outer edge of the seed. This species was identified by R. Neef

Malvaceae:

Malva cf. *parviflora* L. – Tell Brak
Identified in two samples, specimens were smoothly elliptic and relatively flat in shape with a slightly protuberant hilum. Seeds had a visible surface pattern of small ridges arranged transversely. *M. neglecta* was also considered but the hilum did not protrude as much and this species was generally rare in the steppe.

Malva cf. *sylvestris* L. – Tell Brak
Identified in three samples, these specimens were subcircular in shape with angular edges that had vertical raised ridges on them. The middle of the seed was slightly concave. The top-edge had a distinct reticulate pattern with radial ribs located towards the dorsal margin.

Papaveraceae:

Fumaria parviflora Lam. – Hattusha
Identified in three samples, specimens were elliptical in shape with rounded, convex sides. One edge had a deep pit (caused by the apical pits on the fruit). Seeds also had a very prominent keel around the edge. *F. densiflora* and *F. officinalis* were also considered but the former did not have such a prominent keel and the latter was slightly more rectangular in shape.

Glaucium corniculatum L. – Hattusha
Identified in nine samples, specimens were crescent to reniform shaped but with convex sides and a very distinct keel along the flat edge. All seeds had a very distinctive surface pattern with quite deeply incised rectangular depressions arranged in concentric rows. These seeds were generally smaller than *G. grandiflorum* although were very similar in shape.

Papaver cf. *argemone* L. – Tell Brak
Only identified in one sample. Seeds were reniform in shape but in some cases almost cylindrical. Surface pattern was comprised of small rhombus-shaped ribs on both faces of the seed arranged in concentric rows. These seeds were very similar to *P. dubium* but the surface pattern of that species is slightly squarer and less well-defined.

Papaver cf. *rhoeas* L. – Tell Brak
Identified in three samples, specimens were similar in shape to *P.* cf. *argemone* but slightly smaller and significantly more concave. All seeds had an irregular honeycomb patterning that was defined with raised ridges.

Papaver cf. *somniferum* L. – Hattusha
Only one specimen was identified in the assemblage and was fairly poorly preserved. Shape was broadly reniform with a convex dorsal edge and a

concave ventral edge. Surface pattern was reticulate and defined by ribs, although these were less distinct than those seen on *P. argemone*, *P. dubium* and *P. rhoeas.*

Polygonaceae:

Polygonum aviculare L. – Hattusha
Identified in 42 samples, specimens are triangular/trullate in shape but can be irregular with one side often narrower than the others. Also tends to have an elongated apex. All seeds had a smooth surface pattern.

Polygonum cf. *convolvulus* L. – Hattusha
Identified in seven samples, specimens are similar in shape to *P. aviculare* but are generally larger, fatter and with slightly concave sides. Additionally all sides of the seed were the same length. Specimens had a smooth surface pattern but with a raised keel down the middle.

Rumex cf. *acetosella* L. – Hattusha
Identified in 14 samples, specimens were elliptic-rhombic in shape with blunt ends. The sides were slightly concave and without a defined keel. Surface texture was smooth and without any defined patterning.

Ranunculaceae:

Adonis aestavalis L. – Hattusha
Identified in 12 samples, specimens were semi-ovate but very angular and tapered strongly to a point at the base (this tapering was far more defined than *A. annua* or *A. flammea*). Surface pattern was strongly ribbed.

Adonis cf. *annua* L. – Hattusha
Identified in 19 samples, specimens were generally ovate (considerably more ovate than *A. aestavalis*) but with a slightly tapered base. Specimens were also considerably larger than modern examples of *A. microcarpa*. These seeds also had surface abaxial ribs but these were not as defined as those seen on *A. aestavalis* or *A. flammea*.

Consolida regalis S.F. Gray. – Hattusha
Identified in three samples, specimens were cuneate and flattened at one end. The surface of the seeds had small wing-like scales arranged in rows. This species was identified by R. Neef.

Delphinium staphisagria L. – Hattusha
Identified in two samples, specimens were slightly flattened and irregularly three-angled. Surface pattern was uneven and reticulate. This species was identified by R. Neef.

Ranunculus arvensis L. – Hattusha
Identified in 42 samples, seeds were ovate but flattened and curved up to a slight point at each end. The seed wall had small spines all over it, with the longest spines (c. 2mm) located near the edge of the seed. If the seed wall had been removed the surface pattern was characterised by reticulate small divots.

Rubiaceae:

Cruciata laevipes Opiz. – Hattusha
Identified in 31 samples, specimens were oval in shape with a large oval opening across the ventral side. In most specimens this opening was slightly 'pinched' giving a 'beak-like' appearance. This distinguished these specimens from *Galium* sp. as the opening was larger and squarer in shape. There was no visible surface texture, but on occasion small ridges could be seen inside the seed itself.

Galium spurium L. – Hattusha
Identified in 31 samples, specimens were oval in shape with an oval opening

on the ventral side. Some seeds also had a rounded-square cell pattern arranged in linear rows across the back. This species was distinguished from *G. tricornutum* as it was significantly smaller and oval in shape. Additionally, *Asperula* sp. was ruled out as there was no prominent inner ridge inside the seed.

Galium tricornutum Dandy. – Hattusha
Identified in 45 samples, specimens were rounded in shape with a large, rounded opening on the ventral side. This species was identified by R. Neef.

Scrophulariaceae:

Veronica hederifolia L. – Hattusha
Identified in 32 samples, these specimens were similar in shape to *Cruciata laevipes* with an oval outline and a large oval opening on the ventral side. The distinguishing feature, however, was the very distinct surface texturing visible on these seeds. Prominent ridges ran the length of the dorsal and extended to the edge of the opening. Additionally, a large inner ridge was visible inside the seed.

Thymelaeaceae:

Thymelaea cf. *passerina* L. – Hattusha
Identified in nine samples, seeds had a rounded bulbous head that tapered significantly to a pointed 'stalk'. Surface texture was very smooth.