Agriculture and citadel in the Bronze Age Aegean: the view from western Anatolia

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Abstract

This project aims to assess how agricultural production was adapted to the changing social and economic environments of Late Chalcolithic to Late Bronze Age western Anatolia. In doing so, it aims to suggest how arable farming contributed to the formation and collapse of elite social and economic structures within the citadel and lower town settlements of the Early Bronze Age (EB/EBA) II-III. This is achieved through a suite of analyses conducted on archaeobotanical assemblages from four sites in the Izmir region of western Anatolia: Liman Tepe, Bakla Tepe, Kocabaş Tepe and Çeşme-Bağlararası. In particular, stable isotope analysis of crop remains and functional ecological analysis of their associated weeds are used to establish crop husbandry and arable land management practices. These data are synthesised with archaeological evidence for the social morphology of settlements to provide insights into the organisation of the agricultural economy. They are also interpreted with reference to the climatic and ecological contexts of agricultural production.

The archaeobotanical analyses indicate that cereal cultivation was 'low-input' throughout the occupations of the study sites, with low arable fertility and limited mechanical disturbance. While variable, cereals tended to be grown on fields that received moderate to low levels of manure but were well-watered. In contrast, pulses were grown on more intensively manured plots that had correspondingly higher soil fertility and mechanical disturbance. This attests to a spatial differentiation in crop cultivation that resembles the practices of recent non-mechanised farmers in the Aegean engaged in extensive systems of land use. Land management strategies were adapted to the tolerances of different crops, with barley grown on drier fields than

glume wheats in the Late Chalcolithic. A shift in agricultural strategies is apparent between the EB I-II and late EBA-early Middle Bronze Age, with a focus on drought-tolerant cereals cultivated on drier soils with water management practices redirected towards pulses. This was plausibly a response to drier climatic conditions following the 4.2ka event.

Extensive farming systems were integrated within varying social environments across the occupations of the study sites. In the Late Chalcolithic, potentially communal and highly visible extra-household storage may have been used to maintain cooperative relationships between small households in order to meet acute labour demands at key points in the agricultural year. The adoption of the longhouse as the basic socio-economic unit in EB I-II settlements was likely associated with more extended family households capable of achieving greater autonomy in agricultural production. This scenario of independent households engaged in extensive farming systems is likely to have created the potential for sustained high wealth inequality within settlements. This appears to have fostered the emergence of centralising social structures designed to dampen inequalities in arable production. Burial evidence from settlements with highly developed and corporate centralising structures, however, suggests that these ostensibly equalising institutions facilitated the emergence of high status and wealthy individuals. This suggests that they were the precursors to the elite economies of the EB II-III.

Co-authorship statement

Following the article-based thesis route, this thesis is composed of three papers framed by a unifying introduction and conclusion. The papers include the names of several co-authors who are the directors of the excavations from which my study material was recovered. The first paper has been accepted for publication in *Journal of Mediterranean Archaeology*. Vasıf Şahoğlu and Rıza Tuncel provided brief comments on a draft of the paper prior to submission, and we discussed comments received by reviewers. The analysis, theorisation and writing of the articles was otherwise completed in its entirety by myself.

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A number of colleagues provided assistance, information and inspiration during the completion of this project. Mustafa Incirlili helped implement flotation and find and translate site documents. Valasia Isaakidou first connected me with IRERP and provided initial information about the study material as well as sampling and processing strategies. Ourania Kouka provided site plans and information about Liman Tepe. Alexandra Livarda provided information about material that had been sampled from the assemblages. Elizabeth Stroud and Peter Ditchfield were essential sources of advice regarding stable isotope analysis. Laura Green provided access to her key to help with archaeobotanical identifications. Charlotte Diffey provided early archaeobotanical training at Knossos. Michelle Massa and Benjamin Irvine were brilliant sources of discussion and advice both in Ankara and at conferences abroad. Michelle also provided crucial (and patient) advice on GIS and map making. I would also like to thank the British Institute at Ankara for allowing me to use the seed reference collection once housed there. The BIAA was a welcoming home during my stay in Ankara. I am also grateful to Sue Colledge and Dorian Fuller at UCL for allowing me to use the seed reference collection housed there. I would also like to thank Emel Oybak Dönmez for permission

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Introduction

Farming has played a central role within narratives of urbanisation and the rise of social and economic inequality in the prehistoric Aegean. It is implicated in the earliest emergence of wealth inequality (e.g., Halstead and O'Shea 1989; Leppard 2019), the antecedents of urban society (e.g., Renfrew 1972; Whitelaw 2004) and the functioning and maintenance of mature urban centres (e.g., Halstead 2007; 2011; *cf.* Nakassis 2010). These narratives have tended to focus on mainland Greece and the southern Aegean, however, with comparable developments in the eastern Aegean poorly understood. In western Anatolia (defined here as the region west of, and including, the provinces of Eskişehir and Antalya—Figure 1) and the neighbouring islands, the first regional centres containing evidence for pronounced social and economic inequality emerged in the later Early Bronze Age (EB/EBA) and took the form of fortified citadels surrounded by lower towns. A number of these settlements were occupied into the Late Bronze Age (LBA), when they emerged as a major urban centres exercising control of their surrounding hinterlands. Despite evidence to suggest that agricultural production was a crucial source of elite wealth and power from the later EBA onwards, considerations of the role(s) played by arable farming in the emergence of these settlements are limited.

The aim of this project is to address this gap in research through analysis of archaeobotanical assemblages from four sites in the Izmir region of coastal western Anatolia (the latter defined here as the provinces bordering the western coastline): Liman Tepe, Bakla Tepe, Kocabaş Tepe and Çeşme-Bağlararası (Figure 2). The dataset spans the Late Chalcolithic to Late Bronze Age (Table 1) and provides a focussed

Figure 1: Map of Turkey and the Aegean showing the regions referred to in text. Western Anatolia and eastern Aegean islands with archaeological remains indicating a cultural *koine* with the mainland are shaded red. The borders of Turkish provinces are shown.



Figure 2: Topographic map showing the locations of the study sites.

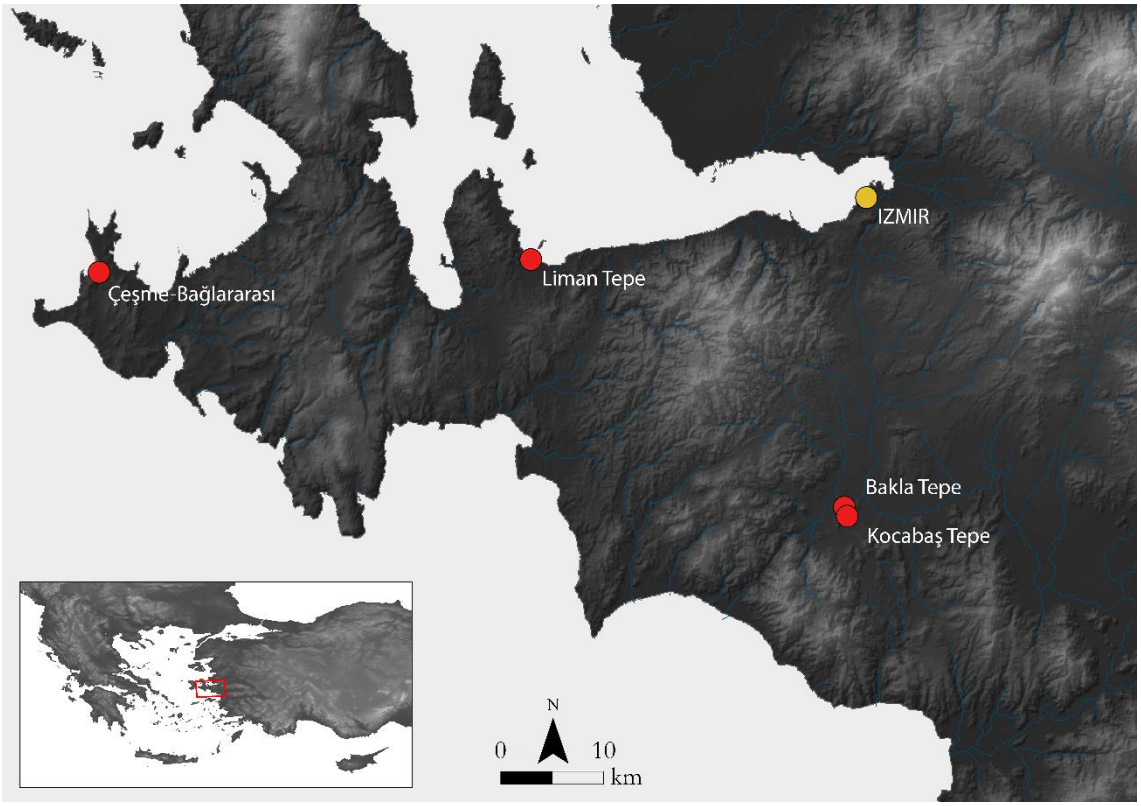


Table 1: Simplified western Anatolian chronology with the occupations of each study site shaded. X = archaeobotanical samples from this phase are analysed in this project.

Liman Tepe	Bakla Tepe	Kocabaş Tepe	Çeşme-Bağlararası	Chronology	Date (BC)
X		X	X	LBA	1200
X		X	X	MBA	2000
		X		EB III (late)	
				EB III (early)	
	X		X	EB II (late)	
X			X	EB II (early)	
X	X			EB I	3000
X	X			Late Chalcolithic	

case study with which to assess adaptations in the nature and organisation of agricultural production to the changing social and ecological environments of these periods. I use a suite of archaeobotanical analyses, including the recently developed 'weed + isotope' approach (Bogaard *et al*. 2016; 2018), in order to investigate crop husbandry and arable land management strategies. I synthesise these data with

archaeological evidence for social morphology and the organisation of the agricultural economy.

In the remainder of this section, I outline the archaeological narrative of western Anatolia and the eastern Aegean islands from the Neolithic to the Late Bronze Age. I pay particular attention to evidence for social morphology and the organisation of the agricultural economy within settlements. I discuss the first citadels of the later EBA and outline the models put forward to explain their emergence. I highlight the potential importance of agricultural production and its limited consideration within these models and discuss available evidence for the nature of farming across the region from the Neolithic to Late Bronze Age. Finally, I outline the objectives and structure of the thesis, noting how it will address current gaps in research.

1. The archaeological and environmental background of western Anatolia and the eastern Aegean islands

*1.1 Early Neolithic to Early Chalcolithic (*c. *7000-5500/5400 BC)*

The Early Pottery Neolithic (*c.* 7000-6500/6400 BC) saw fully-fledged farming communities become firmly established in the central Anatolian Plateau and expand west (Özdoğan 2014). A relatively limited number of Early Neolithic contexts are known so far from western Anatolia and the eastern Aegean islands. In the coastal region, remains have been recovered from Çukuriçi Höyük and Ulucak in Izmir and Uğurlu on the island of Gökçeada (Horejs 2019). Further inland, Early Neolithic contexts are known from Barcın Höyük, Bursa, and Bademağacı Höyük, Höyücek and Hacılar in the Burdur-Antalya region (Duru 2012; Horejs 2019). Well-preserved architectural remains were

uncovered at Bademağacı Höyük, characterised by free-standing or conjoined rectangular houses containing ovens, grinding stones and clay storage boxes (Duru 2012). Multi-chambered clay silos of various sizes were also uncovered in the open spaces between houses, likely reflecting communal storage of agricultural products. At Höyücek, five conjoined structures were uncovered and have been interpreted as a ritual complex (Duru 2012). Similar conjoined rectangular structures recently reported from Barcın Höyük were interpreted as houses, however (Gerritsen and Özbal 2019).

The Late Neolithic (*c.* 6500/6400-6100/6000 BC) is more well-represented within the region. The most extensively excavated settlement in central western Anatolia is Ulucak (Figure 3), where early sixth millennium BC levels contained rectangular houses clustered around an open area (Çilingiroğlu *et al.* 2012). Ovens, hearths, storage bins and working areas were located both inside the houses and in domestic courtyards separated from communal areas by thin fences. Architectural remains dating to the second half of the seventh millennium BC are less well-exposed but are broadly consistent with this layout. Elsewhere in the Izmir region, Late Neolithic remains from Yeşilova Höyük and Ege Gübre also reveal rectangular buildings organised around central courtyards (Derin 2012; Sağlamtimur 2012). In the Burdur-Antalya region, architectural remains from Hacılar resemble those from Ulucak, with a block of single-roomed houses sharing walls excavated by Mellaart (1970, 11-15 Fig. 7). Houses contained plastered bins and deposits of grain that were likely stored in perishable containers. Screen walls concealed part of the rooms and lightly constructed cubicles that likely served as kitchens were often attached to an outer wall. In northwest Anatolia, free-standing circular structures with sunken floors were uncovered at Fikirtepe, Istanbul, and Pendik, to the southeast (Özdoğan 2013). Similar structures

Figure 3: Early sixth millennium BC Ulucak (after Derin 2005, 89 Fig. 3).



were excavated at Aktopraklık, Bursa, with food preparation and related activities taking place in the open space around them (Karul and Avcı 2013). Rectangular structures sharing walls and containing storage bins were excavated at Yenikapı, Istanbul (Kiziltan and Polat 2013), and Asağı Pınar, Edirne (Özdoğan 2013).

The Early Chalcolithic (*c.* 6100/6000-5500/5400 BC) saw a continuation of Neolithic lifeways across the Anatolian Plateau, distinguished only by new pottery styles in the south and north (Schoop 2011a). Occupation of the well-known site of Ilıpınar, on the western shore of Lake Iznik in northwest Anatolia, is characterised by two-story rectangular buildings containing an array of built-in facilities for food processing and storage (Roodenberg 2011). Limited floor space meant that courtyards were key extensions to the living area (Roodenberg and Alpaslan Roodenberg 2013). Broadly similar architectural remains were uncovered at nearby Menteşe Höyük (Roodenberg and Alpaslan Roodenberg 2013). In contrast, the Early Chalcolithic occupation of Hacılar differed strongly from the preceding period and was represented by a well-organised settlement that contained multi-partitioned houses and a dedicated granary in part of the settlement (Mellaart 1970, 28-34; Fig. 20).

Several key developments are visible in this brief overview of Early Neolithic to Early Chalcolithic western Anatolia. The presence of plausibly communal storage structures at Early Neolithic Bademağacı and the focus on household storage in the Late Neolithic suggests different attitudes to cooperation and sharing between the two periods. This aligns with changes in settlement morphology between the earlier and later Neolithic occupation of Çatalhöyük, central Anatolia, reflecting the emergence of the household as an autonomous socio-economic unit (Marciniak and Czerniak 2007). This appears to have been negotiated against broader community relationships and obligations through the active use of open space and courtyards in Late Neolithic and Early Chalcolithic settlements, however, attesting to high degrees of social monitoring and plausibly entailing the sharing of domestic labour and resources (*cf*. Halstead 1995). Extra-household storage at Early Chalcolithic Hacılar possessed a different character to that at

Early Neolithic Bademağacı. The Early Chalcolithic houses were narrow and deep with internal partitioning, indicating an orientation towards privacy (Steadman 2000; Cutting 2005, 130), and combining with the existence of formal public spaces to suggest that a more formal division between household and community governed social morphology at Hacılar than Bademağacı.

*1.2 Middle and Late Chalcolithic (*c. *5500/5400-3100/3000 BC)*

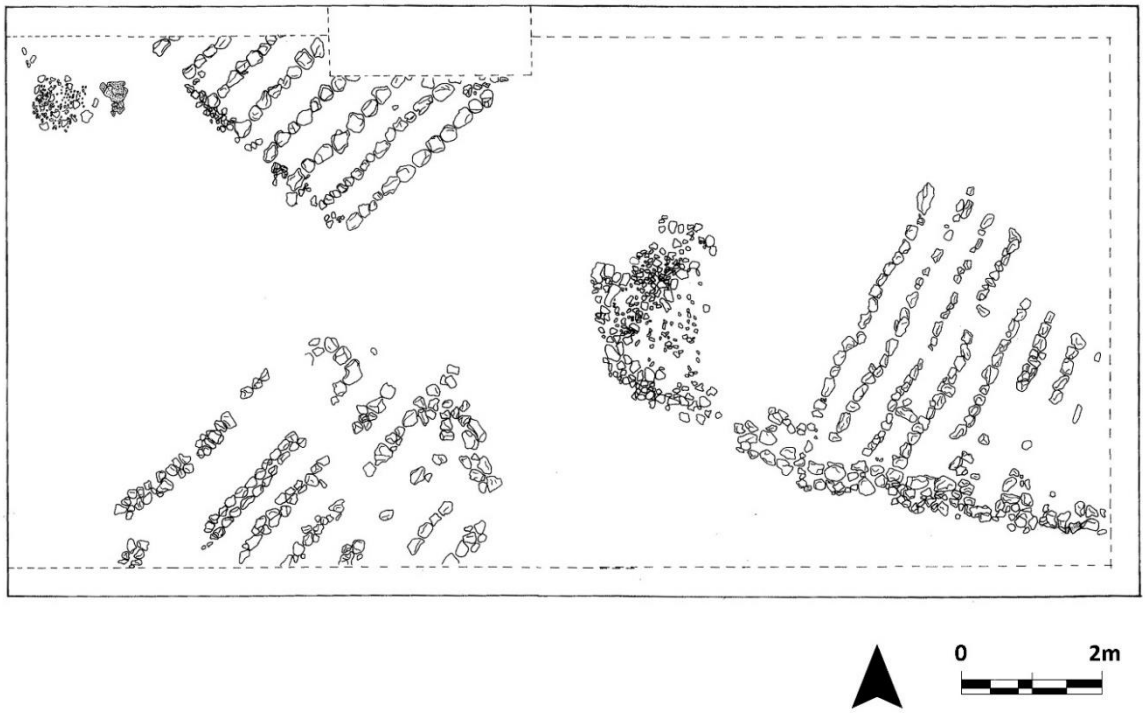
The onset of the Middle Chalcolithic (*c.* 5500-4250 BC) was marked by the abandonment of settlements across the Anatolian Plateau (Abay 2011; Özdoğan 2014). Throughout the period, there was limited occupation within the alluvial plains and newly founded settlements were largely restricted to hilltops or valleys. In western Anatolia, Middle Chalcolithic contexts have been identified at a number of settlements (Schoop 2011a, 158-9) but well-preserved architectural remains are limited. At Gülpınar, in the Troad, a settlement composed of adjoined rectangular rooms containing hearths, ovens and stone platforms was uncovered (Takaoğlu and Özdemir 2018). Some rooms also contained the bases of small silos and/or large storage jars, while hearths outside the structures attested to the use of open space. Limited Middle Chalcolithic architectural remains have been revealed at Yeşilova Höyük and Liman Tepe, Izmir, consisting of circular pit dwellings and a wall and circular feature, respectively (Derin and Caymaz 2018; Tuncel and Şahoğlu 2018). A large number of storage pits were also excavated at Barcın Höyük (Gerritsen 2021).

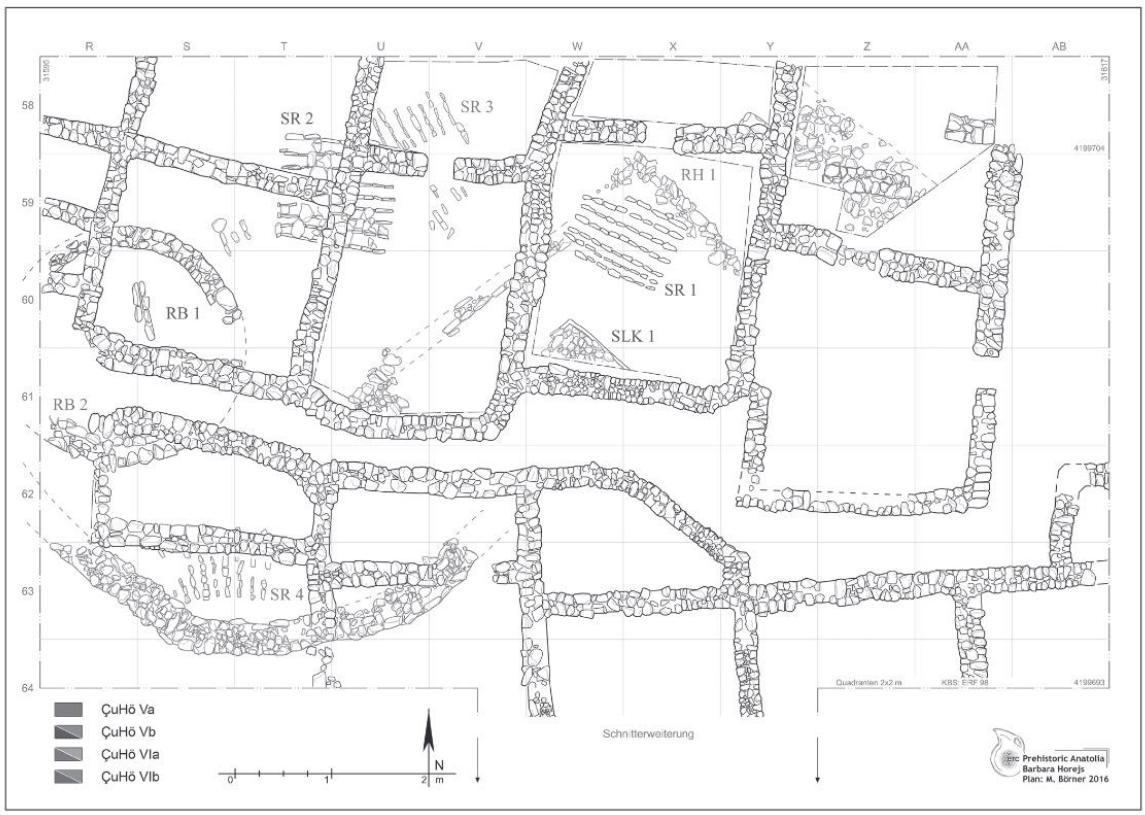
The Late Chalcolithic (*c*. 4250-3100/3000 BC) saw the infilling of alluvial plains across the Plateau with both the foundation of new settlements and reoccupation of older ones (Abay 2011; Özdoğan 2014). While the Late Chalcolithic remains poorly understood

compared with later periods, an increasing number of excavated sites in western Anatolia are beginning to provide evidence for settlement organisation and economic developments. In coastal western Anatolia, the Late Chalcolithic occupation of Bakla Tepe, Izmir, was characterised by free-standing grill-plan structures, sometimes with apsidal ends, interpreted as houses (Figure 4) (Erkanal and Özkan 1999; Şahoğlu and Tuncel 2014). The stone grills created a raised floor, plausibly as a means to keep stored grain dry, and indicate concerns with provisioning for the storage of agricultural products within the houses. Free-standing circular structures lined with small stones were also uncovered and were interpreted as the bases of silos used to store grain. Elsewhere in the Izmir region, Late Chalcolithic grill-plan structures were also excavated alongside apsidal structures at Liman Tepe and rectangular structures at Çukuriçi Höyük (Figure 4) (Schwall and Horejs 2018; Tuncel and Şahoğlu 2018). The grill-plan structures from Çukuriçi Höyük are smaller than those from Bakla Tepe and have been interpreted as fruit-drying platforms but may also have been used to store grain (*cf.* comparable examples at Çamlıbel Tarlası, central Anatolia—Schoop 2010). Architectural remains from Poliochni and Myrina-Richa Nera, Lemnos, and Miletus, Aydın, are more limited but include free-standing circular structures comparable to those at Bakla Tepe (Kouka 2014). Limited architectural remains from Kumtepe, in the Troad, attest to rectangular buildings (Sperling 1976).

Further inland, the Late Chalcolithic occupation of Beycesultan, Denizli, was characterised by small rectangular rooms sharing walls and containing hearths and plastered grain bins (Lloyd and Mellaart 1962, 25). Comparable remains were also uncovered at Kuruçay, Burdur, where complexes of rooms were separated by courtyards and streets that were later filled with structures (Duru 1996, 115). Similar to

Figure 4: Late Chalcolithic grill-plan structures from Bakla Tepe (top) and Çukuriçi Höyük (bottom). Image of Bakla Tepe after Tuğcu (2019, 443 Fig. 8), image of Çukuriçi Höyük after Schwall and Horejs (2018, 68 Fig. 4).





Beycesultan, rooms contained independent walls or mudbrick stelae 1-1.5 m in length and large storage vessels (Duru 1996, Plates 15, 26, 30; 1999, 64). The Late Chalcolithic settlement of Karataş, Antalya, was characterised by free-standing rectangular structures (Eslick 1992, 16). Limited architectural remains from Orman Fidanlığı include an apsidal room different in form to those from coastal western Anatolia (Efe 2001, 11).

Several authors have noted the differences in architectural forms between Late Chalcolithic sites from coastal western Anatolia and the eastern Aegean islands and those from inland western Anatolia (Kouka 2014; Horejs and Schwall 2018). The ubiquity of circular, apsidal and grill-plan structures in the west contrasts with the dominance of rectangular architecture further inland, the latter aligning with settlements in central Anatolia (e.g., Çadır Höyük—Steadman *et al*. 2019, Çamlıbel Tarlası—Schoop 2010, Canhasan—French 1998 and Middle Chalcolithic Güvercinkayası—Çayli *et al*. 2021). Grill-plan structures comparable those at Çukuriçi Höyük were excavated at Çamlıbel Tarlası and free-standing structures comparable to those at Bakla Tepe at Late Chalcolithic Güvercinkayası, but these are isolated examples compared to their frequency in the west. The presence of comparable architectural forms in coastal western Anatolia and the eastern Aegean islands indicates the existence of strong cultural contacts between these regions, also visible in shared ceramic styles and the distribution of marble artefacts and Melian obsidian, such that Kouka (2014) has suggested the existence of a cultural *koine* in the Late Chalcolithic preceding that of the third millennium BC.

Düring (2011) has also noted the diversity of settlement forms across the Anatolian Plateau during the Chalcolithic, suggesting that some variability may be due to the

permanence of occupation, with lightly constructed and/or ephemeral settlements indicative of mobile communities. This line of reasoning has been robustly critiqued for the Neolithic of Greece (Halstead 1999), however, and there is, at present, no evidence for seasonality from faunal and/or botanical remains. Specific to coastal western Anatolia, Horejs (2014) has linked the diversity in settlement forms to functional differentiation between settlements exploiting local resources. More site-specific data on craft production and resource exploitation are required to test this hypothesis, but the intensive exchange networks that Horejs suggests would result from this do appear to have been in place during the Middle and Late Chalcolithic. Production for exchange is indicated by large numbers of blanks, waste by-products and manufacturing rejects of marble vessels and figurines at Kulaksızlar, Manisa (Takaoğlu 2002; Düring 2011). As noted already, the distribution of marble artefacts alongside Melian obsidian and ceramic forms indicates close cultural contacts through exchange across coastal western Anatolia and the Aegean islands (Horejs 2014; Kouka 2014).

Developments are also visible in craft and economic production across the Plateau during the Late Chalcolithic. Evidence for metallurgical production from sites such as Bakla Tepe (Şahoğlu and Tuncel 2014), Çukuriçi Höyük (Horejs 2014) and Çamlıbel Tarlası (Schoop 2015) contribute to a picture of frequent extraction, production and distribution of semi-finished and ready metal products and experimentation with new copper alloys by the mid-fourth millennium BC (Massa 2016, 169-70). A significant increase in the distribution of spindle whorls and loom weights at sites across the Plateau at the onset of the Late Chalcolithic indicates a surge in activities relating to textile production (Schoop 2014). Finds particularly cluster around the mountainous zones of southwest and north-central Anatolia, indicating regional centres of

production. Schwall and Horejs (2018) have suggested that the broad range of architectural forms dedicated to storage in the Late Chalcolithic indicates the production of greater agricultural surplus than earlier periods. Archaeobotanical evidence for the nature of agricultural production is required to test this hypothesis, however.

Insights into the social morphology of Middle and Late Chalcolithic settlements are hindered by the limited contextual analysis of artefactual remains, but some key aspects of the evidence can be collated here. The organisation of settlements into individual houses that contained storage and cooking installations is consistent with the continued importance of the household as a basic socio-economic unit. The presence of hearths outside the houses at Gülpınar aligns with the frequent presence of hearths in the open spaces between houses at Bakla Tepe (Şahoğlu and Tuncel 2014) and artefactual evidence for the use of open space for domestic tasks at Çukuriçi Höyük (Horejs and Schwall 2018). As in the Late Neolithic and Early Chalcolithic, this is consistent with the negotiation of the household with broader community obligations and relationships. Steadman (2000) analysed architectural evidence for social morphology across the Neolithic and Chalcolithic in central and southwestern Anatolia. She proposed a trajectory of greater internal division and concerns with privacy within households through time, linked to increasing social complexity. Cutting (2005) has since questioned the presence of a single regional trend, however, highlighting the variability in site-specific trajectories for the case studies used in Steadman's analysis. The evidence from western Anatolia is also variable at the site-specific level. Concerns with privacy are visible in the use of screens to block of parts of rooms at Beycesultan and Kuruçay as well as the orientation of doorways so that the internal spaces of houses remain hidden at the latter site (Steadman 2000). This contrasts with the highly visible nature of extra-

household storage at Bakla Tepe and possibly Çukuriçi Höyük, however. The variability in architectural forms in Late Chalcolithic western Anatolia thus plausibly reflects differences in social morphology between sites. Whether this corresponds to differences in the nature and/or organisation of economic production is, at present, unclear.

*1.3 Early Bronze Age I-II (early) (*c. *3100/3000-2600 BC)*

The EBA of western Anatolia can be broadly divided into three periods, each encompassing key episodes of cultural development: the EB I to early EB II (EB I-II), the late EB II to early EB III (EB II-III) and the late EB III. The EB I-II saw the emergence of the longhouse as the primary form of domestic architecture across the region (Figure 5) (Fidan *et al*. 2015). Differences in settlement organisation between the coastal and inland parts of the region continue, however. Settlements on the coast are characterised by blocks of houses separated by streets (e.g., Bakla Tepe—Gündöğan *et al*. 2019, Çeşme-Bağlararası—Şahoğlu 2015 and Çukuriçi Höyük—Horejs *et al*. 2017 in Izmir; Troy—Ivanova 2013 in the northwest and Poliochni—Bernabo-Brèa 1964, Thermi—Lamb 1936 and Heraion—Kouka and Menelaou 2018 on the eastern Aegean islands). Those further inland possess radial settlement plans (e.g., Demircihöyük—Korfmann 1983 and Küllüoba—Efe 2003 in Eskişehir; Hacılar Büyük Höyük—Umurtak and Duru 2013 and Bademağacı—Duru and Umurtak 2008 in the Burdur-Antalya region and Keçiçayırı—Fidan 2016 in the Phrygian highlands). Recent geophysical survey results from Tavşanlı Höyük in Eskişehir revealed a settlement pattern more similar to those of the coastal region (Fidan 2021a), however, suggesting a more complex picture may emerge as more settlements are excavated. EBA settlements tended to be enclosed,

Figure 5: EB I-II architectural remains from Liman Tepe (after Erkanal and Şahoğlu 2016 160 Fig. 3).



with robustly built fortification walls in the coastal region (e.g., Liman Tepe—Erkanal and Şahoğlu 2016 and Bakla Tepe, Izmir) and smaller ones based on the backs of houses further inland (e.g., Küllüoba and Demircihöyük). Similarities in settlement form between coastal western Anatolia and the eastern Aegean islands combine with the

distribution of shared artefactual styles and raw materials to indicate the existence of intensive trade interactions and a cultural *koine* between these two regions during the EBA (Kouka 2016; Massa 2016, 218-25).

Artefactual evidence within longhouses points to their use as multi-functional spaces for both domestic activities and craft production. At Liman Tepe, a tuyere, mould and slag pieces indicative of metallurgical production were recovered from inside one longhouse and loom weights for textile production within another (Erkanal and Şahoğlu 2016). Similarly, at Bakla Tepe, spindle whorls and loom weights were recovered from nearly every house, while artefacts indicative of metallurgical production were present in both longhouses and dedicated workshops (Gündöğan *et al*. 2019). Artefactual remains from Çeşme-Bağlararası (Şahoğlu 2015), Demircihöyük (Bachhuber 2015, 56-61) and Yenibademli Höyük, Gökçeada (Hüryılmaz 2021), also suggest that craft production took place within longhouses. At Çukuriçi Höyük, longhouse architecture was integrated within domestic complexes which contained dedicated spaces for craft production (Horejs *et al.* 2017).

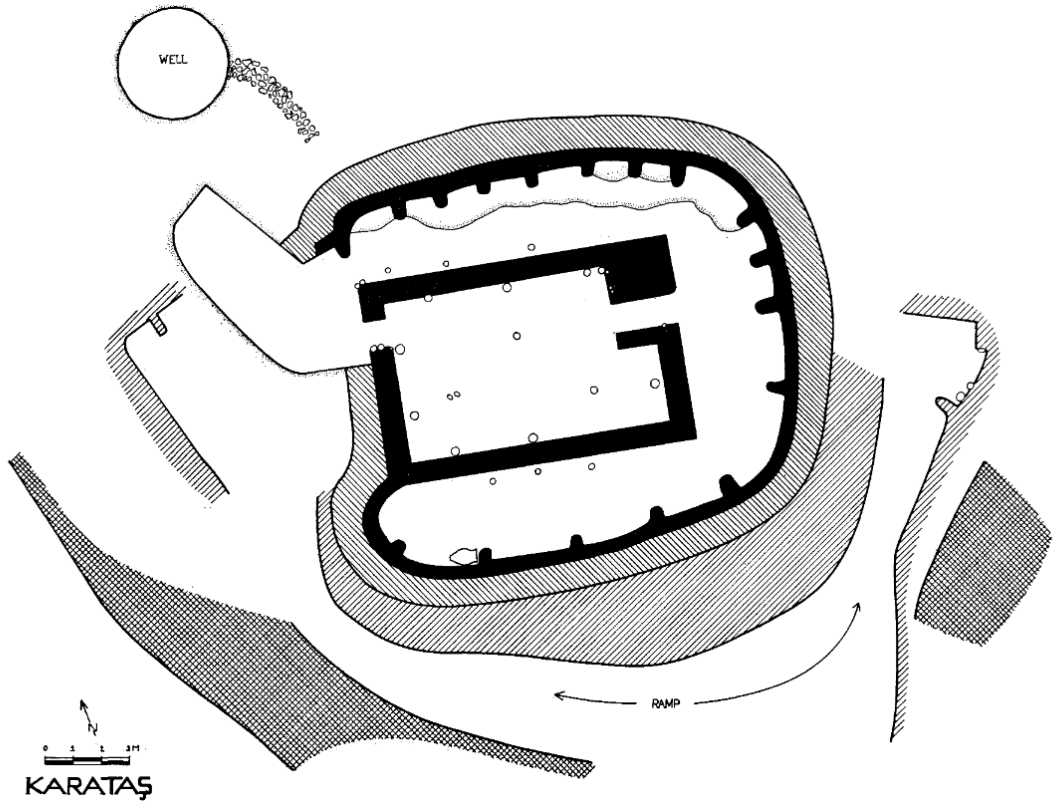
Domestic storage of agricultural products was also largely confined to the interiors of longhouses, with dedicated storage bins excavated at Çeşme-Bağlararası (Şahoğlu 2015) and Beycesultan (Lloyd and Mellaart 1962, 29-33 Figs. 7-8) and large storage vessels at Koukonisi, Lemnos (Dova 2008). At Thermi (Town I), dedicated storage rooms contained rows of holes to support *pithoi* (Lamb 1936, 10), but their relationship with domestic architecture is not clear. Storage rooms were identified within the domestic complexes of Çukuriçi Höyük (Horejs *et al*. 2017). A well-known exception to this trend is Demircihöyük, where household granaries were located in the centre of the radial

settlement (Korfmann 1983 Fig. 3). At Bakla Tepe, storage installations were located within the front porches of longhouses or attached to the outer wall next to the entrance (Gündöğan *et al*. 2019). No storage structures were recovered within the longhouses of Troy I, but Ivanova (2013) suggests that domestic agricultural storage would have been located inside them.

In addition to household storage, some settlements contained larger, central storage structures sometimes associated with non-domestic buildings. At Poliochni (Blue phase), a rectangular room measuring *c.* 17 x 2.5-4 m was interpreted as a large granary (Bernabo-Brèa 1964, 187). The granary was associated with an open air, arena-like structure thought to possess a socio-political function (Bachhuber 2015, 78). At Heraion, a robustly constructed two-story building contained areas for food preparation and storage and was interpreted as a communal structure (Kouka and Menelaou 2012, 121). At Karataş, a central complex containing a two-storey building and courtyard was constructed on top of a natural rise in the landscape encircled by a buttressed enclosure (Figure 6) (Mellink 1965). The building was distinguished from the wattle-and-daub domestic structures surrounding the central complex by its mudbrick construction and contained 12 clay-lined pits, two of which had *pithoi* sunk into them, likely used for storage (Mellink 1965; Warner 1994, 178). At Troy, a sounding into Troy I layers revealed two plastered rooms, one *c.* 4 x 7.5 m in size, in which large amounts of carbonised wheat were found (Thumm-Doğrayan 2016). These have been interpreted as communal granaries.

Particularly at Karataş, EB I-II non-domestic complexes have been interpreted as housing elite individuals and the rulers of settlements (e.g., Fidan *et al*. 2015, 68). The absence

Figure 6: The central complex at Karataş (after Mellink 1965, 246 Ill. 2).



of high-status artefacts in the central complex at Karataş and the similarities in ceramic assemblages recovered from it and other parts of the settlement (Eslick 2009) have, however, led Bachhuber (2015, 77) to suggest that it represents a socially inclusive corporate space. He suggests that central complexes within EB I-II settlements were integrative facilities where formal events and community wide decision making may have taken place (Bachhuber 2015, 82). This suggests the emergence of new social structures during the EBA with more formalised community cooperation, decision making and leadership than earlier periods. The presence of large, central storage structures at the sites described above suggests that this included the centralisation of

farming products. Despite this inclusivity, however, the cemetery of Karataş contains the clearest evidence for social and wealth inequality in EB I-II western Anatolia. Here, a single adult was buried in a stone-built chamber covered by a stone tumulus several metres wide while the rest of the cemetery was composed of *pithos* burials (Mellink 1969; Massa and Şahoğlu 2011). Burials of both adults and children around the chamber contained the most elaborate jewellery and the majority of gold and silver grave goods within the cemetery (Mellink 1969, 327; Alpers-Bordaz 1978, 262-78). The cemeteries of smaller settlements without highly developed corporate structures, such as Bakla Tepe (Şahoğlu 2016) and Demircihöyük (Massa 2014), contain an absence of evidence for pronounced social and/or wealth inequality. This suggests that the high status and wealthy individuals in the cemetery of Karataş may have been those associated with the central complex. The lack of artefactual evidence for social status and wealth inequality within the settlement, and its sporadic presence within EB I-II sites more broadly, suggests that inequality was downplayed in the everyday lives of individuals. As suggested by Bachhuber (2015, 82), this aligns with a model of 'vertical egalitarianism' in which privileged status and decision-making power was possessed by certain members of the community within a broader context of household self-sufficiency and economic equality (Frangipane 2007, 153).

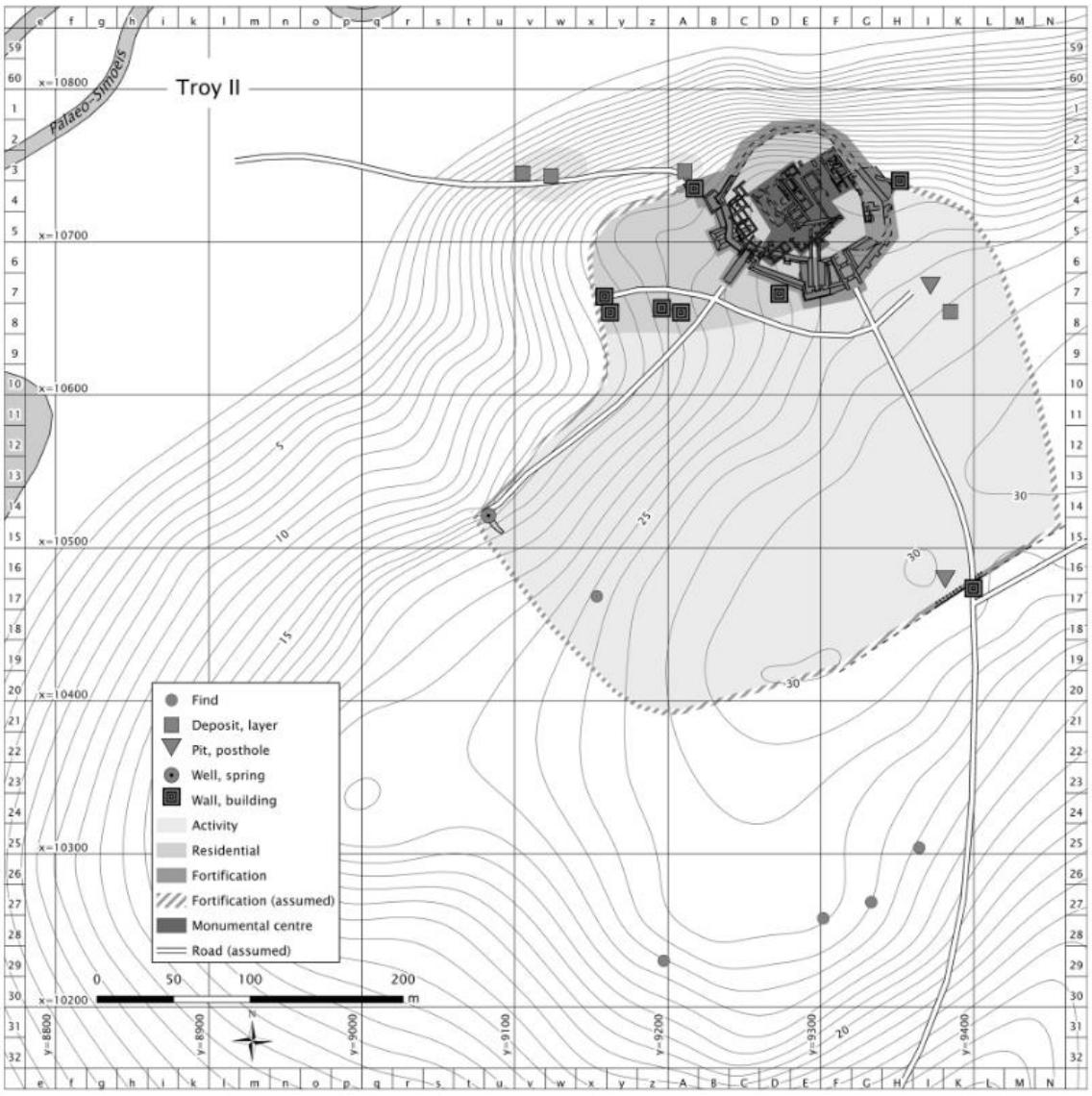
The location of craft production within the interiors of longhouses and the focus on intra-household storage of agricultural products during the EB I-II has important social implications. The deep structure and internal partitioning of longhouses likely allowed households to control access to private spaces in which these activities took place despite the high population density of settlements (Steadman 2000). This contrast with the frequent use of courtyards and open spaces alongside extra-household storage in

the Late Neolithic and Chalcolithic and is consistent with the emergence of the household as a more formal socio-economic unit in the EBA (*cf.* Bachhuber 2015, 58-59). The larger size of EBA longhouses compared with earlier domestic structures (e.g., the 100 m^2 longhouses at Liman Tepe—Erkanal and Şahoğlu 2016) suggests that they housed more extended family units (*cf*. Flannery 2002), plausibly capable of achieving greater autonomy in the domestic economy and therefore less reliant on frequent reciprocity and sharing between households. Indeed, a proliferation of metallic skeuomorph vessels and innovations in the presentation and pouring of liquids in the EB I-II indicate new concerns with the presentation of eating and drinking (Bachhuber 2015, 63). This was plausibly associated with more formalised relationships of reciprocity and cooperation between EBA households than earlier periods. Other developments in craft production during the EB I-II were relatively minor, with a comparable repertoire of metal finds to the Late Chalcolithic (Fidan *et al*. 2015), although interregional exchange networks expanded in reach considerably between the late fourth and early third millennia BC (Massa 2016, 272-74).

*1.4 Early Bronze Age II (late)-III (early) (*c*. 2600-2200 BC)*

The EB II-III saw a number of settlements increase in size and become surrounded by lower towns to form the 'citadel and lower town' settlement plan characteristic of the region. The most intensively studied of these is Troy, where a heavily fortified citadel contained a complex of five parallel free-standing megaron buildings up to 40 m in length (Figure 7) (Jablonka 2011). A palisade and gate excavated *c.* 200 m south of the citadel attest to the existence of an enclosed lower town *c*. 1 ha in size (Jablonka 2016). Alongside the monumentality of the fortification systems, deposits of gold and precious

Figure 7: The citadel and enclosed lower town of Troy II (after Jablonka 2011, 68 Fig. 7).



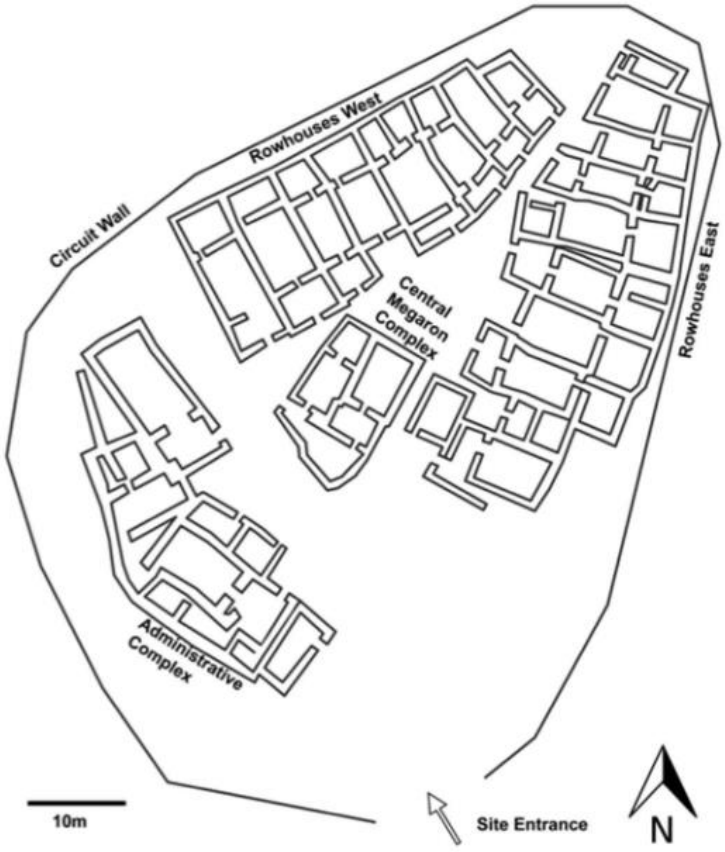
metal items ('Priam's Treasure'), although likely post-dating the abandonment of the central megaron complex (Bachhuber 2009), attest to elites within the citadels and high levels of political and wealth inequality. Records of around 600 large storage vessels recovered from the citadel (Thumm-Doğrayan 2016) suggest that agricultural production was a key source of elite wealth. Elsewhere in the coastal region, a fortified

citadel including a monumental bastion extending over 20 m from a fortification wall was uncovered at Liman Tepe (Erkanal and Şahoğlu 2016). Structures inside the citadel include a central complex, an open area interpreted as a public space and two towers constructed on a terrace wall thought to demarcate an inner 'fortress' (Erkanal et al. 2003, 427; Erkanal *et al*. 2009, 307; Erkanal and Şahoğlu 2016). Within the central complex, finds of fine-ware vessels, a rhyton sherd, a number of stone phalli, a marble idol and a stamp seal point to ritual and sealing activities. A bastion and part of a fortification wall excavated 500 m southeast of the citadel attests to a fortified lower town covering an area of *c.* 10-15 ha (Ersoy *et al*. 2011, 171). On the eastern Aegean islands, the settlement of Poliochni (Red and Yellow period), Lemnos, possesses a sprawling layout across an area of 2 ha (Cultraro 2007). The layout of the settlement appears more planned than earlier periods, with residential blocks regularly arranged along streets that were oriented to provide access to open areas and public buildings. Within the Yellow period settlement, a large megaron located within a highly visible square in the north of the site contained three large *pithoi*, a wide range of pouring and drinking vessels and two three-legged cauldrons dug into the floor (Bernabo-Brèa 1976, 79-80) and is thought to represent a public building used for communal gatherings and rituals (Cultraro 2007a). Other megara were surrounded by smaller annex buildings and courtyards forming insulae and plausibly represent households. The annexes around one megaron (506) contained large amounts of storage vessels, while imported artefacts including a Mesopotamian stamp seal were recovered from another (Megaron 605) (Cultraro 2007). Gold and precious metal artefacts indicative of elites were recovered from both the Red and Yellow settlements, most notably a large deposit of gold items from an annex associated with the Yellow period Megaron 605 (Bernabo-Brèa 1964,

284-92; 1976, plates CCXL-CCLI). The smaller settlement of Heraion, Samos, saw the construction of a 2 m thick fortification wall and gate in the EB II-III (Kouka and Menelaou 2012). A rectangular tripartite building of monumental construction 18.5 x 8 m in size is thought to possess a special socio-political function but no finds were recovered inside it that would provide evidence for this.

The citadels of inland western Anatolia were smaller than their coastal counterparts but possessed similar features. The site of Küllüoba contained an upper and lower settlement, the former of which had a linear settlement plan with longhouses that shared walls and the backs of which created a boundary wall (Efe and Fidan 2008). Three large complexes including megara within the upper town are thought to possess administrative and/or ritual functions (Efe and Fidan 2008). One of these, complex II, contained provisions for agricultural storage, including a magazine with seven *pithoi* recovered *in situ* (Fidan 2018). The site of Seyitömer, Kütahya, is composed of a small citadel surrounded by a circuit wall but without evidence for a lower town (Figure 8) (Bilgen 2021; Harrison 2021). The citadel contained two complexes of longhouses sharing walls as well as a free-standing 'administrative complex' and 'central megaron complex'. The central megaron complex occupied a central location within the settlement and was composed of a megaron with two attached storerooms and a courtyard. A group of anthropomorphic and zoomorphic rhytons recovered *in situ* from the megaron point to a ritual function (Harrison 2021). The administrative complex was composed of a main central room, finds from which include ten Akkadian cylinder seals, and several storage rooms (Bilgen 2021). At Beycesultan, relatively limited EB II-III layers were exposed but architectural remains included three megara *c*. 50 m^2 in size (Lloyd and Mellaart, 58-59).

Figure 8: The citadel of Seyitömer (after Harrison 2021, 167 Fig. 12.2).



Debate exists as to whether these developments indicate a process of 'urbanisation' or the 'centralisation' of populations on a smaller scale (Çevik 2007; Massa and Tuna 2019, 70; Fidan 2021b). However it is labelled, the EB II-III saw the emergence of the largest settlements thus far known to western Anatolia and the first evidence for overt expressions of elite status and pronounced wealth inequality. Massa and Tuna (2019) suggest that elites ruled small territorial polities, indicated by the foundation of fortified sites at key access points to alluvial plains (Massa and Şahoğlu 2015, 69 Fig. 7). Differences in the size of settlements, the monumentality of citadels, finds of precious metals and capacities for agricultural storage between sites in coastal western Anatolia

and the Aegean islands compared with inland western Anatolia indicate pronounced differences in the extent of elite wealth and power. Architecturally, the citadels of inland western Anatolia are not drastically different in scale or form to EB I-II settlements with highly developed corporate structures such as Karataş. A key difference is the 'social logic' expressed by artefactual remains, with those from EB II-III citadels expressing elite wealth and status (*cf*. Bachhuber 2015, 107-209).

Despite differences in scale, citadels across western Anatolia shared several characteristics that suggest they functioned in broadly similar ways. Ritual artefacts and ceramics associated with consumption recovered from central complexes point to their roles as ritual centres. Capacities for the storage of grain at supra-household scales suggest that the production and/or centralisation of farming products was a key dimension of elite wealth. Small amounts of stamp seals within citadels point to low-level sealing activities. These finds have traditionally been interpreted as evidence for administrative functions but have recently been reassessed as a means to 'brand' certain commodities (Massa and Tuna 2019). Imported ceramics and artefacts recovered from citadels indicate the importance of long-distance trade networks to elite identities and, possibly, wealth. Indeed, the emergence of citadel and lower town coincided with the appearance of wheel-made pottery, new pottery shapes (notably *depas* cups and 'Syrian bottles') and tin bronzes across a wide geographical area, indicating the emergence of intensive interregional contact and exchange networks (Şahoğlu 2005; Efe 2007). The appearance of tin bronze objects is one of several developments in metallurgy that occurred during this period, with new production techniques and a general influx of complex and high-status metal objects (Fidan *et al*. 2015). Accordingly, control of the raw materials and production of metals has been considered an important dimension to

elite wealth and power (Şahoğlu 2005; Massa 2016, 269-72). Though it has received less attention, artefactual evidence for textile production on a large scale within citadels suggests that the production and distribution of textiles was also an aspect of elite economies (Bachhuber 2016).

*1.5 Early Bronze Age III (late) (*c. *2200-2000 BC)*

The beginning of the late EB III is marked by burnt horizons indicating episodes of destruction at a number of sites across western Anatolia (Massa and Şahoğlu 2015). At Liman Tepe, the use of the central complex ended. Limited architectural remains have been found from the EB III occupation, indicating an absence of large buildings (Erkanal 2011). The population of Troy appears to have decreased in size and retreated to a more defensible part of the mound (Easton and Weninger 2018). The number of settlements in the Upper Meander Basin, around Beycesultan, decreased sharply in the EB III and no new settlements were founded throughout the period, although larger settlements in the basin increased in size (Abay 2011; Massa and Şahoğlu 2015). These developments coincided with evidence for the rapid onset of drier climatic conditions (the '4.2ka event'), which has accordingly been implicated in the collapse of citadel and lower town settlements (Blum and Riehl 2015; Massa and Şahoğlu 2015; *cf*. Rahmstorf 2015). Evidence for the impacts of the 4.2ka event will be assessed further below.

*1.6 Middle and Late Bronze Age (*c. *2000-1200 BC)*

Following this period of collapse, the citadels described above exhibit varying trajectories of development in the Middle Bronze Age (MBA). The MBA occupation of Liman Tepe remained simple, characterised by oval houses containing utilitarian artefactual remains and arranged around squares (Erkanal and Günel 1995, 268; Erkanal

et al. 2011, 449). A single larger, rectangular building with subterranean storage structures was constructed on a terrace built onto the EB II-III bastion (Erkanal 1999, 328; Erkanal and Artzy 2002, 377), resembling the central non-domestic structures of the EBA. The settlement of Panaztepe appears to replace Liman Tepe as the dominant site in the Izmir region during the MBA, with a well-established harbour settlement overlooked by a hilltop 'palace' (A. Erkanal 1992; Fidan 2018). The MBA occupation of Troy is poorly understood but houses uncovered to the west of the citadel indicate that the settlement was growing again (Jablonka 2011). Both Poliochni and Heraion continued to be occupied into the MBA, with a large stone fortification wall and free-standing megaron-style longhouses uncovered at the latter site (Bernabo-Brèa 1976, 335-39; Cultraro 2007; Kouka 2019). Küllüoba was abandoned after the EB III, but the occupation of Seyitömer continued with a strong fortification wall containing buildings utilitarian in character and without the organised settlement plan of the EBA (Bilgen 2021). As touched on above, Beycesultan grew in size in the EB III and continued to flourish into the MBA. Well-known remains from this period include a 'burnt palace' *c.* 80 x 55 m in size surrounding a central courtyard and two 'religious sanctuaries' elsewhere on the mound (Lloyd and Mellaart 1965, 4-25; 39-42).

Large settlements continued to grow in size into the LBA, during which time Hittite texts record the presence of a number of kingdoms in the *Arzawa* lands of western Anatolia (Bryce 2011). Troy peaked in its size and prosperity during this period as the likely capital of the kingdom of *Wiluša* (Jablonka 2011). The fortification system was expanded to enclose an area of *c.* 2 ha surrounded by an enclosed lower town of *c.* 30 ha from which further occupied areas may also have extended. Rows of magazines containing *pithoi*, some of which contained the burnt remains of wheat, lined the inside of the fortification

system (Thumm-Doğrayan *et al*. 2019), attesting to the mobilisation of agricultural products on scale comparable with the urban centres of central Anatolia (e.g., Hattuša —Diffey *et al*. 2020). Imported and locally produced ceramics and crafts attest to the influences of both the Mycenaean and Hittite worlds on western Anatolia during this period (Yakar 2000, 334-37).

1.7 Climate and the natural environment

Western Anatolia spans a number of climatic zones (Türkeş 1996). The coastal region experiences a markedly seasonal 'true Mediterranean' climate of hot dry summers and cool winters with heavy rain. The 'Mediterranean to central Anatolian transition' zone, further inland, experiences moderate rainy winters and spring, while the 'Mediterranean to Black Sea transition' in the north has a uniform rainy climate and a light rainy summer. A large number of studies have been conducted into the prehistoric climate of Anatolia and the eastern Mediterranean (e.g., Eastwood *et al*. 2007; Kuzucuoğlu *et al*. 2011; Roberts *et al*. 2011). Studies based on different climatic proxies from different regions show variable patterns over the short-term, but a general picture exists of a wetter climate than today followed by a drying trend towards modern climatic conditions from around 4500-4000 BC. A number of episodes of rapid and pronounced climate change between the Neolithic and Late Bronze Age have been recorded in various proxies across Anatolia and the eastern Aegean. Those visible around 3200 BC (the '5.2 ka event') and 2200 BC (the '4.2 ka event') are particularly relevant to this project and will be considered here.

The onset of drier conditions around 2200 BC has been recorded from a number of proxies in western Anatolia and the neighbouring regions. Pollen and oxygen isotope

evidence from Kureysler, Kütahya, suggest the onset of drought conditions at around 2200 BC (Ocakoğlu *et al*. 2019). A decrease in the level of Lake Iznik, Bursa, is also consistent with drier conditions around this time (Ulgen *et al*. 201d2). In central Anatolia, drier conditions are suggested by a negative water balance at Nar Gölü, Aksaray/Niğde between *c.* 2300-2150 BC (Dean *et al*. 2015). In the northern Aegean sea, a range of proxies analysed from cores suggest drier conditions around this time (Ehrmann *et al*. 2007; Kuhnt *et al*. 2007; Dormoy *et al*. 2009). Bini *et al*. (2019) emphasise caution in reconstructing climate models at the regional scale from site-specific proxies, however, highlighting the persistence of wetter conditions within some parts of the Mediterranean Basin. Heterogenous climate patterns across western Anatolia are indicated by climate proxies from Karağol, Antalya, which show a peak in lake levels around 2000 BC (Foss 2006). Evidence for the impacts of the 4.2ka event on agricultural production in western Anatolia has been sought at Troy (Blum and Riehl 2015). A decrease by 0.5‰ in the average values of stable carbon isotopes of barley grains between Troy II and Troy IV (the latter contemporary with the 4.2ka event) indicate slightly drier growing conditions over time. Whether this can be linked to the onset of drier climatic conditions is unclear, however, as it may also reflect the cultivation of barley on different, drier fields in Troy IV than Troy II.

Evidence for the 5.2ka event is also recorded across a number of proxies in western Anatolia and the neighbouring regions. Oxygen and carbon isotope values from Lake Gölhisar, Burdur, indicate the onset of drier conditions around 3200 BC (Eastwood *et al*. 2007). Analysis of sediments from the Konya Plain in central Anatolia indicate droughted conditions around 3000 BC (Fontugne *et al*. 1999). Sediments from Tecer Lake, Sivas, also indicate drier conditions around 3200 BC (Kuzucuoğlu *et al*. 2011). Again, variable

climate patterns are recorded in different locations, however, with an amelioration of climatic conditions indicated by isotope values, pollen, and sediments in cores taken from the Kureyşler Valley in Kütahya (Ocakoğlu *et al*. 2019). The potential impacts of the 5.2ka event on cultural development on the Anatolian Plateau has received less attention than the 4.2ka event, but Riehl *et al*. (2014) have proposed a link between it and the reduced importance of pulses in the EBA northern Aegean compared with the Neolithic. von Baeyer *et al*. (2021) also suggest that a shift from foddering animals to grazing them on the steppe during the Late Chalcolithic occupation of Çadır Höyük was a response to the onset of drier conditions during the 5.2ka event.

The vegetation of the Mediterranean and Aegean regions of Anatolia is characterised by maquis taxa up to 600-800 m following the degradation of red pine woodland due to human activities (Atalay 2017). Most are evergreen and fast-growing species such as olive, kermes oak and species of *Pistacia*. In the lowlands, spiny or aromatic dwarf shrubs dominate in areas where natural vegetation and cultivated fields were degraded and abandoned. In the transitional climate zones outlined above, taxa reflect the influence of wetter (to the north) and drier (to the east) climates. Paleoenvironmental analysis suggests that recognisably 'modern' vegetation and landscape ecosystems had development in the Mediterranean Basin by the mid-third millennium BC due to anthropogenic activities and a drying climate (Roberts *et al*. 2011). Prior to this, pollen cores from Belevi, Izmir, and Bafa Gölü, Muğla-Aydın, indicate a dominance of deciduous oak from the end of the seventh to the beginning of the fourth millennia BC in western Anatolia (Stock *et al*. 2005; Knipping 2008). At Troy, deciduous oak and pine species dominate the charcoal assemblage from the Neolithic until the end of the EBA (Riehl and Marinova 2016). The opening of the landscape around Troy is visible over the course of

the EBA, with increasing proportions of taxa indicative of open vegetation, shrub and maquis communities.

2. Theories for the emergence of Early Bronze Age citadels

Within the archaeological narrative outlined above, the EBA II-III emerges as a key period in which forms of economic and social organisation emerged that would, from then on, dominate the cultural landscape of western Anatolia and the eastern Aegean islands. While the importance of this period is reflected in a number of volumes dedicated to it (e.g., Bachhuber 2015; Pernicka *et al*. 2016), the processes by which citadels and the elite individuals that occupied them emerged has received less attention. Traditional narratives point to the importance of metals and long-distance trade, suggesting that control over the extraction and distribution of metals and intensive trade with the Mesopotamian world facilitated the rise of wealthy settlements ruled by elites (Şahoğlu 2005; Efe 2007). These narratives do not, however, outline the process(es) by which metals and trade may have been transformed into elite wealth. Furthermore, Schoop (2011b) has questioned the extent to which precious metals and items from long-distance trade were economically important at all levels of society and therefore facilitated elite wealth and social control. He emphasises the need to understand the broader nature of economic change associated with the developments of the EB II-III to reveal how elite wealth was created and extracted at the base of society. Çevik (2007) has also questioned long-distance trade as a catalyst for the emergence of elites, suggesting that the involvement of Anatolia within these networks resulted from existing elites who sought to reinforce their power. Both of these arguments highlight

the potential for processes of economic development with their origins in earlier periods.

The Late Chalcolithic is widely considered to have been the period in which the basic social and economic foundations of Bronze Age societies were laid on the Anatolian Plateau (Özdoğan 2014). A number of authors have presented causal models for the emergence of EBA elites and wealth inequality with their origins in the Late Chalcolithic. Applying Kemp's (1989) model for urbanisation in Predynastic Egypt, Horejs (2014) suggests that functional diversity between Late Chalcolithic settlements in coastal western Anatolia fostered intensive exchange networks and technological developments that facilitated the transition from egalitarian communities with simple subsistence patterns to the 'urban' societies of the EBA. Similarly, Düring (2011) suggests that the rise of exchange-oriented production across the Plateau in the Late Chalcolithic facilitated the maintenance of long-distance relationships between groups that fostered the rise of EBA elite settlements. Arbuckle (2012) has suggested that a shift towards the management of sheep for wool production at Çadır Höyük reflects a broader trend of increased textile production used by emergent elites to create wealth and power differentiation in Late Chalcolithic central Anatolia. The architectural basis on which the presence of elites within central Anatolia was inferred has since been critiqued, however (Düring 2011), aligning with the broader evidence for limited social and wealth inequality across the Plateau during the fifth and fourth millennia BC. Schoop (2014) has since conducted a review of evidence for wool textile production across the Anatolian Plateau during the Chalcolithic. He identified a lack of evidence for a marked increase in the scale of caprine pastoralism as suggested by Arbuckle (2012). Despite this, however, artefactual evidence points to a dramatic increase in textile production activities from

the onset of the Late Chalcolithic, with the faunal evidence from Çadır Höyük suggesting that this utilised wool. Schoop suggests that is consistent with wool textile production embedded within systems of circulation towards the production of social, as opposed to economic, capital. The emergence of pronounced wealth inequality in the EB II-III suggests that structures designed to dampen the potential for economic inequality within this system broke down.

Each of the models described above considers an area of economic production that was plausibly important to elite economies within EB II-III citadels (metallurgical and craft production, textile production and long-distance exchange). Despite evidence to suggest that arable production was a key source of elite wealth (e.g., Bachhuber 2015, 130-49; Thumm-Doğrayan 2016), however, considerations of the potential agricultural basis for the emergence of EBA citadels, whether originating in the EBA or earlier periods, are conspicuously absent (*cf.* Schoop 2011b). This is likely due to the small number of archaeobotanical studies of remains from the Chalcolithic and EBA, limiting our understanding of the nature of agricultural production during these periods. In the following section, I summarise what is known about farming in western Anatolia from the Neolithic to the LBA and highlight key gaps in current understanding.

3. Evidence for farming practices and the agricultural economy in Neolithic to Late Bronze Age western Anatolia

3.1 Farming systems and the potential for emergent wealth inequality

Prior to discussing the evidence for farming in prehistoric western Anatolia, it is worthwhile to outline some key concepts used in the definition of farming systems and

assess their implications for the process of emergent wealth inequality. A key distinction I make in this research is between higher-input (or 'intensive') and lower-input (or 'extensive') farming systems (Halstead 1981; 1987; 1995; 2014; Bogaard *et al*. 2019; Halstead and Isaakidou 2020). Intensive farming is characterised by higher labour inputs per unit area, using techniques such as manuring, weeding and tillage to enhance arable productivity. In contrast, extensive farming is characterised by lower labour inputs per unit area, with correspondingly lower arable fertility offset by the cultivation of larger areas of land using specialised draught cattle. A key difference between these systems is the limiting factor to production (Bogaard *et al*. 2019). Production within intensive systems is tied to the amount of labour that can be invested to enhance arable productivity within a given area, making them 'labour-limited'. This reliance on labour limits the scales of production within intensive systems and makes them well-adapted to the requirements of small-scale farming households (Bogaard 2005). Within extensive systems, labour-saving but land-intensive strategies means that production is tied to the amount of land that can be taken under cultivation, making them 'land-limited'. By removing labour as a limiting factor, extensive farming can be practiced on much larger scales than intensive farming and is therefore associated with urban settlements with large non-producing populations (Styring *et al*. 2017).

While the need to feed expanding populations links extensive farming systems to urbanisation, a second (though often related) stimulus is the role of distance. In a study of non-mechanised farmers in Evvia, Greece, Jones *et al*. (1999) identified a correlation between the distance of arable plots from the home and cultivation intensity. Plots closest to the settlement tended to be smaller and higher-input 'gardens', while those further away tended to be larger and lower-input fields. Similarly, in a synthesis of

ethnographic studies from southern Europe, Halstead (2014, 217) notes that the difficulties of transporting stall manure meant that the majority tended to be dumped within *c*. 500 m of settlements. For smaller, non-urban populations, the adoption of lower-input farming systems is therefore linked to nucleated settlement patterns and/or the occupation of environmentally marginal locations, both of which push arable land some distances from the home (e.g., Halstead and Jones 1989).

Bogaard *et al*. (2019) have identified a link between the adoption of land-limited farming systems and the emergence of sustained high wealth inequality across western Eurasia. A key factor in this is that differences in productive capacity resulting from inequality in land ownership and other forms of material wealth, such as draught cattle, can far surpass those resulting from the ability to mobilise labour. Additionally, material wealth is more readily inherited across generations than the ability to mobilise labour, fostering the maintenance and accumulation of wealth inequality over the long-term. While theoretical, this model aligns with pathways to the accumulation of wealth described by recent farmers in the Aegean (Halstead 2014). For the Neolithic of Europe, Bogucki (1993) also sketched a process by which cattle may have facilitated the accumulation of wealth and inequality, with the interplay of animal traction, secondary products and agricultural productivity setting households without adequate livestock at a disadvantage. While loans of labour and food are a common method of creating reciprocal obligations that can be called on during times of shortage ('social storage'—Halstead and O'Shea 1982), loans of cattle from wealthy to needy households may have facilitated debt and relationships of dependency. The potential for accumulated capital to create rapid wealth inequality in environments in which agriculture is prone to failure

(such as the Aegean) also formed the basis for Leppard's (2019) recent model for emergent social inequality in the Mediterranean.

3.2 Neolithic to Early Chalcolithic

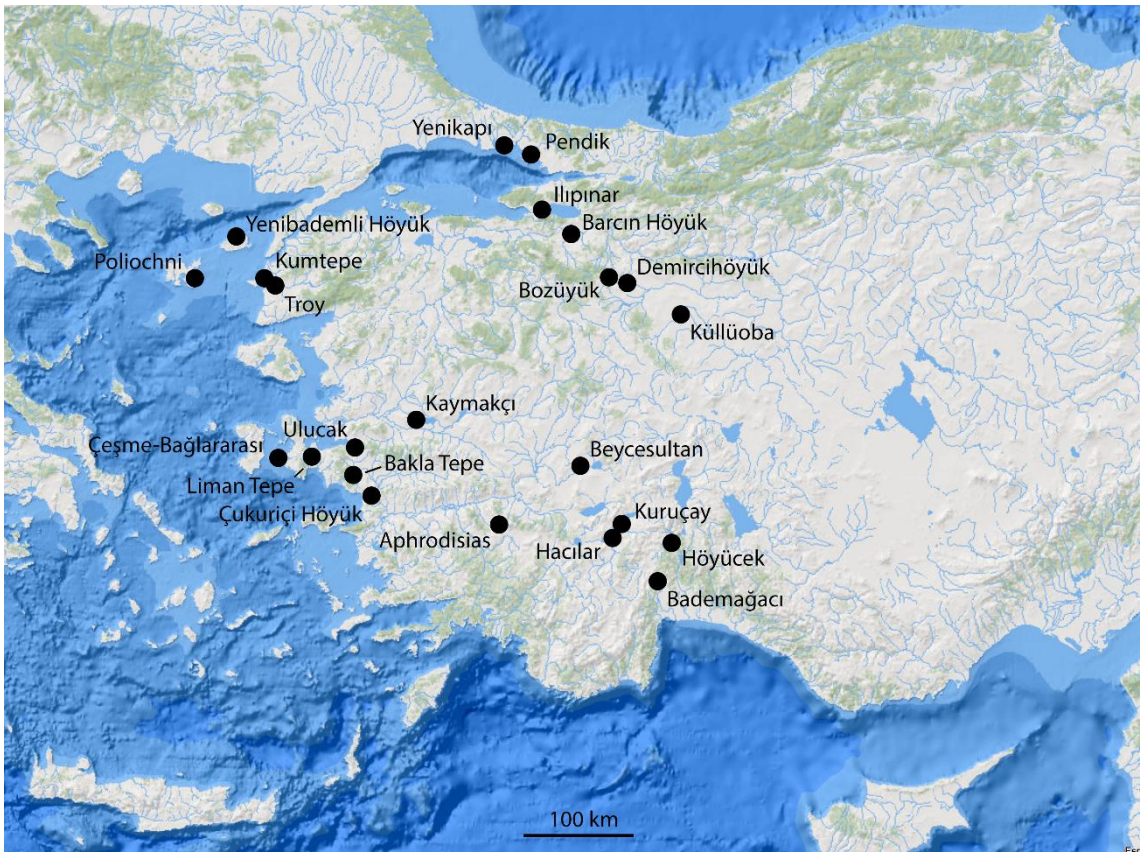
A list of the sites in western Anatolia and the eastern Aegean islands from which archaeobotanical remains have been reported is provided in Table 2. The locations of the sites are shown in Figure 9. Archaeobotanical remains from Early Neolithic contexts in western Anatolia have only been reported from Bademağacı. Martinoli (in Duru and Umurtak 2008) reports a broad spectrum of domestic taxa, containing einkorn (*Triticum monococcum* L.), emmer (*T. dicoccum* Schrank ex Schübl.), free-threshing wheat (*T. aestivum* L./*durum* Desf.), barley (*Hordeum vulgare* L.), lentil (*Lens culinaris* Medikus), chickpea (*Cicer arietinum* L.), pea (*Pisum sativum* L.) and vetch (*Lathyrus* L.). This crop diversity continues into the Late Neolithic, with assemblages from Ulucak (Megaloudi 2005; Çilingiroğlu *et al*. 2012); Höyücek (Martinoli and Nesbitt 2003), Barcın Höyük (Balci *et al*. 2019), Hacılar (Helbaek in Mellaart 1970) and Yenikapı (Ulaş 2020) variously containing five or more of these taxa with the addition of bitter vetch (*Vicia ervilia* (L.) Willd.) and grass pea (*Lathyrus sativus* L.). Early Chalcolithic remains from Ilıpınar (Cappers 2006) and Hacılar also contain broad selections of these taxa. This mirrors archaeobotanical data from central Anatolia, where experimentation with a diverse range of crops is recorded across the Early Neolithic to Early Chalcolithic occupations of Çatalhöyük (Bogaard *et al*. 2017). Elsewhere in western Anatolia, a small assemblage was reported from Pendik Höyük (Ulaş 2020) but is too small to accurately reflect the range of crops cultivated at this site.

Table 2: List of the sites in western Anatolia and the eastern Aegean islands from which archaeobotanical remains have been reported.

Period	Site	Location	Reference
LBA	Beycesultan	Denizli	Helbaek 1961
	Çeşme-Bağlararası	Izmir	Reported here
	Kaymakçı	Manisa	Shin *et al*. 2021
	Kocabaş Tepe	Izmir	Reported here
	Liman Tepe	Izmir	Reported here
	Troy	Çannakale	Riehl 1999
MBA	Çeşme-Bağlararası	Izmir	Reported here
	Liman Tepe	Izmir	Reported here
MBA/EBA	Kocabaş Tepe	Izmir	Reported here
EBA	Aphrodisias	Aydın	Greaves 2008
	Bakla Tepe	Izmir	Reported here
	Beycesultan	Denizli	Lloyd and Mellaart 1962
	Bozüyük	Eskişehir	Wittmack 1896
	Çeşme-Bağlararası	Izmir	Reported here
	Çukuriçi Höyük	Izmir	Horejs *et al*. 2011
	Demircihöyük	Eskişehir	Schlichtherle 1977/78
	Küllüoba	Eskişehir	Çizer 2015
	Liman Tepe	Izmir	Reported here
	Poliochni	Lemnos	Arobba *et al*. 2008
	Troy	Çannakale	Riehl 1999
	Yenibademli Höyük	Gökçeada	Oybak 2005
EBA/Late Chalcolithic	Çukuriçi Höyük	Izmir	Horejs *et al*. 2011
Late Chalcolithic	Bakla Tepe	Izmir	Reported here
	Beycesultan	Denizli	Lloyd and Mellaart 1962
	Kumtepe	Çannakale	Riehl 1999
	Kuruçay	Burdur	Stroud 2016
	Liman Tepe	Izmir	Reported here

Early Chalcolithic	Hacılar	Burdur	Helbaek in Mellaart 1970
	Ilıpınar	Bursa	Cappers 2008
Late Neolithic	Barcın Höyük	Bursa	Balci *et al*. 2019
	Hacılar	Burdur	Helbaek in Mellaart 1970
	Höyücek	Burdur	Martinoli and Nesbitt 2003
	Pendik Höyük	Istanbul	Ulaş 2020
	Ulucak	Izmir	Megaloudi 2005; Çilingiroğlu *et al*. 2012
	Yenikapı	Istanbul	Ulaş 2020
Early Neolithic	Bademağacı	Antalya	Martinoli in Duru and Umurtak 2008

Figure 9: The locations of sites in western Anatolia and the eastern Aegean islands from which archaeobotanical remains have been reported.



For recent farmers in the Aegean, the cultivation of diverse suites of crops allowed the labour of reaping to be spread across the harvest season and the potential for wholesale crop failure to be spread across taxa with slightly differing ecological requirements (Forbes 1976; Halstead 2014, 105). It is, therefore, commonly observed within small-scale, intensive farming systems, aligning well with the model of Neolithic farming as intensive (recently summarised by Halstead and Isaakidou 2020). At Çatalhöyük, this is supported by evidence from functional weed ecology and stable isotope analysis for intensive farming practices in the early-mid Neolithic (Filipović 2014: 133) and continuing in a diversified form into the mid-late Neolithic (Green *et al*. 2018) and Early Chalcolithic (Stroud *et al*. 2021).

Faunal remains from Ulucak reveal that sheep, goat, cattle and pig were exploited from the beginning of the seventh millennium BC (Çakırlar 2012; 2013). Culling profiles from Bademağacı and Ulucak suggest that sheep and goat exploitation evolved from a primarily meat-based exploitation strategy to one involving milk production over the Neolithic. Culling profiles from the Late Neolithic and Early Chalcolithic occupation of Ilıpınar are also consistent with mixed meat and secondary product exploitation (Buttenhuis 2008). Cappers (2008, 120) identified barley chaff remains in animal dung from Ilıpınar and linked this to a diet provided for cattle used for ploughing. While pathological evidence for the use of cattle for traction is known from the Neolithic southern Aegean (Isaakidou 2006), however, no clear evidence exists for this practice in western Anatolia (Çakırlar 2012).

3.3 Middle and Late Chalcolithic

No archaeobotanical remains have so far been reported from Middle Chalcolithic contexts in western Anatolia. Late Chalcolithic remains have been reported from a few sites, with large assemblages from Kumtepe (Riehl 1999) and Kuruçay (Stroud 2016). A broad range of crops was recovered at Kuruçay, including einkorn and emmer wheat, free-threshing wheat, barley, lentil, pea and grass pea (Stroud 2016, 204). This aligns with comparably broad crop spectra from Late Chalcolithic Çamlıbel Tarlası (Stroud 2016, 191) and Çadır Höyük (von Baeyer *et al*. 2021) in central Anatolia. A narrower crop spectrum was identified at Kumtepe, composed of einkorn and emmer wheat, barley, lentil and bitter vetch (Riehl 1999, appendix 1). Whether or not this indicates different agricultural strategies at Kumtepe and Kuruçay is unclear. Evidence from functional weed ecology and stable isotope analysis suggest that farming systems at Kuruçay and Çamlıbel Tarlası were of moderate intensity (Stroud *et al*. 2021). In contrast, for recent farmers in the Aegean, the cultivation of narrower ranges of crop taxa was a feature of more extensive agricultural systems geared towards surplus production (Halstead 2014, 105). This aligns with Horejs and Schwall's (2018) suggestion for the appearance of significant surplus production in coastal western Anatolia during the Late Chalcolithic based on the diversity of architectural forms dedicated to storage. No data on the nature of farming strategies at Kumtepe are available with which to test this hypothesis, however. A very small assemblage from Çukuriçi Höyük (Horejs *et al*. 2011) and sporadic mentions of remains encountered during the excavations of Beycesultan (Lloyd and Mellaart 1962) provide limited insights into agricultural production at these sites.

Faunal remains have also been studied from a limited number of Middle and Late Chalcolithic sites in western Anatolia. Culling profiles from Çamlıbel Tarlası indicate that pigs were killed at young ages and therefore exploited only for meat, while adult cattle may have been exploited for milk and/or traction (Bartosiewicz and Gillis 2011). Sheep and goat were killed at ages indicating that they were exploited for both meat and secondary products. A similar pattern is visible at Barcın Höyük, with mixed ovicaprine exploitation and most cattle surviving into adulthood (Gerritsen *et al*. 2010; Galik 2014). At Orman Fidanlığı, most cattle were killed when subadult, with some surviving into adulthood but no old animals (Uerpmann in Efe 2001). A small fragment of pelvic bone from this site had a pathology sometimes seen in draught cattle, but this was a single specimen and it is not clear whether it derives from Late Chalcolithic or earlier contexts. The exploitation of domestic animals appears to change relatively little between the Neolithic and Late Chalcolithic in western Anatolia, therefore, with mixed economies of meat and secondary products in both periods. Schoop (2014) identified a potential trend towards the increased survival of adult sheep between the Early and Late Chalcolithic across central and western Anatolia, potentially indicating an increase in the use of secondary products. There is no evidence from western Anatolia indicating a focus on secondary products comparable to that at Çadır Höyük (Arbuckle 2012), however. While, apart from a single specimen from Orman Fidanlığı, no pathological evidence for the use of cattle for traction is known from the Middle or Late Chalcolithic, the maintenance of costly adult cattle at some sites hints at their use for secondary products and labour.

3.4 Early Bronze Age

The EBA is the period in western Anatolia from which the most amount of archaeobotanical remains have been reported. Large archaeobotanical assemblages have been reported from Yenibademli Höyük (Oybak 2005), Troy (Riehl 1999) and Küllüoba (Çizer 2015), with smaller assemblages from Bozüyük (Wittmack 1896), Çukuriçi Höyük (Horejs *et al*. 2011), Poliochni (Arobba *et al*. 2008), Aphrodisias (Greaves 2008) and Demircihöyük (Schlichtherle 1977/78). Again, archaeobotanical remains encountered during excavation were noted from Beycesultan (Lloyd and Mellaart 1962). A general trend is apparent, with the glume wheats, einkorn and emmer, dominating assemblages with barley as a secondary crop. Free-threshing wheat has a more sporadic presence. The pulse spectrum is more variable, with lentil and bitter vetch the most frequently encountered species but the significant presence of other taxa at a number of sites.

Evidence for the nature of agricultural production during this period is limited. Isotopic data from Troy suggest that barley was grown on well-watered soils that received moderate levels of manure in Troy I/II and both moderate and low levels of manure in Troy IV (Riehl and Marinova 2016). This possibly indicates the emergence of lower-input cultivation strategies in the later period, but a number of studies have demonstrated the flexible roles assigned to barley when cultivated as a secondary species within Aegean agrosystems (Nitsch *et al*. 2017; Vaiglova *et al.* 2014; 2020; 2021), making generalisations based on this taxon difficult. For the large scales of agricultural storage in Troy II, analogy with the elite agro-economies of the LBA Aegean (Nitsch *et al*. 2019) and Anatolia (Diffey *et al*. 2020) suggests that extensive, surplus producing farming

systems were used to amass arable wealth. While supra-household scales of storage are also known to the non-domestic central structures of the EB I-II, the differing social contexts of these institutions makes similar inferences difficult.

Gündem (2010) has collated faunal data from a number of EBA sites (including Troy) across western and central Anatolia. Culling profiles indicate that most sheep survived into adulthood and were therefore exploited for their secondary products (Gündem 2020, 200-201). Cattle were primarily kept for meat, but some survived into old age and were potentially castrated, consistent with their use for traction. These data point to an intensification in the exploitation of animals for their secondary products in the EBA. While unambiguous evidence for cattle traction in the form of pathologies are still absent (Çakırlar 2016), the remains of old, and potentially castrated male, cattle is consistent with their use for ploughing and the potential for extensive farming systems (although ploughing with *cows* may be a feature of Neolithic intensive farming in the southern Aegean—Isaakidou 2006; Nitsch *et al*. 2019).

3.5 Middle and Late Bronze Age

No archaeobotanical remains have so far been reported from MBA contexts in western Anatolia. LBA remains have been reported from three sites. Those from Troy show a comparable range of crop taxa to the EBA but with a dominance of barley (Riehl 1999, 43). Small amounts of millet were also recovered. Barley also dominated the archaeobotanical assemblage from Kaymakçı, Manisa, where free-threshing wheat and chickpea were also recovered (Shin *et al*. 2021). A similar dominance of barley was identified at Gordion and Hattuša in central Anatolia (Marston 2012; Diffey *et al*. 2020). No proportions have been reported from Beycesultan, but, like Troy, the LBA

assemblage also contains the typical EBA spectrum with the addition of free-threshing wheat (Helbaek 1961). Again, comparison with the elite agro-economies of the Aegean and central Anatolia suggests that LBA citadels utilised extensive, surplus producing farming systems. This is supported by phytosociological analysis of arable weeds from Troy (Riehl 1999, 67), while isotopic data indicate that barley was moderately watered and manured (Riehl and Marinova 2016).

Faunal data from Kaymakçı display distinct patterns of culling for sheep and goat, with sheep kept to older ages, consistent a mixed economy involving meat and secondary products, and a focus on meat for goats (Marston *et al*. 2021). Pigs were culled at early ages, while most cattle were kept into adulthood, indicating a focus on milk production and/or traction. At Beycesultan, Ducos (in Lloyd and Mellaart 1965) suggests that cattle were used for secondary products while smaller livestock were kept for meat. LBA Troy (VI period) saw the first appearance of horse and donkey at the site (Uerpmann 2003).

4. Aims and structure of the thesis

4.1 Aims of the thesis

The aim of this project is to assess how agricultural production was adapted to the changing social and ecological environments of western Anatolia from the Late Chalcolithic to Late Bronze Age. In doing so, I aim to suggest how arable farming may have contributed to the formation (and collapse) of the elite social and economic structures of the EB II-III. In order to achieve this aim, I address five objectives, outlined below, based on gaps in our understanding within the archaeological narrative described above:

1 – Assess how the agricultural economy was organised within Late Chalcolithic settlements in western Anatolia.

Differences in architectural forms between Late Chalcolithic settlements in coastal western Anatolia and the eastern Aegean islands compared with inland western Anatolia have been interpreted in a number of ways (e.g., seasonality/intensity of occupation and functional diversity). That many of these architectural forms relate to storage, plausibly of arable products, raises the potential for differences in the organisation of the agricultural economy between the two regions. If developments during the Late Chalcolithic are to have laid the foundations for the emergence of EBA citadels (see objective 2), then understanding how agricultural production was organised during this period is essential. This would also provide further evidence for a cultural *koine* between the coast and its neighbouring islands.

2 – Document and interpret evidence for the nature of crop husbandry and arable land management strategies in Late Chalcolithic western Anatolia.

Key economic aspects of EBA citadels (craft and textile production, long distance trade) have been shown to have their origins in the Late Chalcolithic, raising the potential for a causal process of cultural development towards elite wealth and power over the *longue durée.* Despite evidence to suggest that agricultural production was a key source of wealth within citadels, however, the nature of Late Chalcolithic arable farming is poorly understood. Crop husbandry strategies have been investigated from only a single site from inland western Anatolia (Kuruçay). Further case studies are essential to understand whether the agroecological foundations of EBA elite wealth were laid in the Late Chalcolithic, particularly in the coastal zone where the largest citadels developed.

3 – Investigate the nature and organisation of agricultural production in the EB I-II and its implications for the emergence of EB II-III elite agro-economies.

The EB I-II saw the emergence of a new form of social organisation across western Anatolia, characterised by more autonomous households bound together by centralising corporate structures. A key question is whether this was associated with changes in the nature of agricultural production or, if not, how continuity in farming from the Late Chalcolithic interacted with these transformations in social organisation. Immediately preceding the emergence of citadel and lower town, the nature and organisation of agricultural production in the EB I-II has direct implications for its potential role(s) in the emergence of EB II-III citadels and the elite wealth that characterised them.

4 – Assess archaeobotanical evidence for the impact of the 4.2ka event on agricultural production and its potential role in the collapse of EBA citadels.

The potential role of the 4.2ka event in the collapse of EB II-III citadels is a key question within the prehistory of western Anatolia. At present, there is no clear evidence for its impacts on agricultural production or decision making. The archaeobotanical assemblages analysed in this project span the periods before and after the 4.2ka event and therefore provide a crucial opportunity to assess new evidence for its potential impacts.

5 – Examine how farming strategies were adapted to different settlement forms and environmental conditions across Late Chalcolithic and Bronze Age western Anatolia.

An increasing number of studies are using high-resolution archaeobotanical analyses to identify how agricultural production was adapted to the challenges of different settlement forms and natural landscapes within the prehistoric Aegean. Case studies exist for Greece and the southern Aegean, but not western Anatolia and the eastern Aegean islands, which remain poorly understood. By conducting a suite of high-resolution analyses on archaeobotanical remains from four sites spanning three landscapes and almost two millennia, this project is well-placed to address this gap in understanding.

4.2 Structure of the thesis

The thesis is structured as three articles, each addressing a combination of these objectives. In paper 1, I present a contextual analysis archaeobotanical remains recovered from Late Chalcolithic Liman Tepe and Bakla Tepe. Addressing objective 1, I analyse how crops were stored and processed and synthesise these data with archaeological evidence for social morphology to investigate the organisation of the agricultural economy. I then assess the extent to which the organisation of the agricultural economy and crop choice differed between settlements in western Anatolia and the eastern Aegean islands compared with inland western and central Anatolia and the implications that this has for a cultural *koine* between the former two regions. Addressing objective 2, I outline evidence for changes in the nature of arable farming systems between the Late Neolithic and Late Chalcolithic western Anatolia through changes in storage capacity and crop choice.

In paper 2, I present the results of functional weed ecology and stable isotope analysis of archaeobotanical remains from Late Chalcolithic Liman Tepe and Bakla Tepe.

Addressing objective 2, I outline evidence for crop husbandry and land management practices at the sites. Addressing objective 5, I assess how farming strategies were adapted to the different arable landscapes surrounding the two settlements. Finally, addressing objective 1, I synthesise the results of these analyses with those from paper 1 to produce new insights into the organisation of agricultural production within the settlements.

In paper 3, I present archaeobotanical remains recovered from Bronze Age Liman Tepe, Bakla Tepe, Kocabaş Tepe and Çeşme-Bağlararası and the results of functional weed ecology and stable isotope analysis conducted on them. Addressing objective 3, I outline evidence for crop husbandry and land management practices at the sites and synthesise these data with archaeological evidence for social morphology to investigate the organisation of the agricultural economy during the EB I-II. I go on to discuss the implications of this for the emergence of the elite agro-economies of the EB II-III. Addressing objective 4, I assess the evidence for changes in agricultural strategies between the periods directly preceding and succeeding the 4.2ka event and the implications of this for the collapse of EB II-III citadels. Addressing objective 5, I outline how agricultural practices may have been adapted to the changing natural environment around Liman Tepe as well as the drier climate of the 4.2ka event. The thesis closes with a conclusion in which I summarise how this project has addressed its aim via each of the objectives alongside potential directions for further research.

Paper 1

Prehistoric farming settlements in western Anatolia: archaeobotanical insights into the Late Chalcolithic of the Izmir region, Turkey

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Abstract

Recovery of archaeobotanical assemblages from Late Chalcolithic Bakla Tepe and Liman Tepe in western Anatolia has provided the opportunity for in-depth analysis of agricultural strategies and the organisation of farming-related activity at the two sites. We find that Late Chalcolithic farmers utilised five major crop taxa, potentially including mixed cereal and pulse crops, each combining two species. This includes the first evidence for Spanish vetchling and winged vetchling cultivation in prehistoric Anatolia and the earliest evidence for this practice to date. We suggest that the settlements were organised into small, co-residential households that processed and stored their own crops but we also propose that potentially communal extra-household storage and high levels of social monitoring may attest to supra-household cooperation. The later agricultural history of the vetchling species and the prevalence of extra-household storage at sites in coastal western Anatolia and the eastern Aegean islands add to

evidence for a cultural *koine* between these regions in the fourth and third millennia BC. We also suggest that the large size of extra-household storage structures and the narrow range of crops cultivated at Late Chalcolithic sites are consistent with the emergence of more extensive farming systems than those of earlier periods. Evidence for the use of extensive agricultural production to amass arable wealth by the citadel elites of later Early Bronze Age western Anatolia suggests that the agroecological foundations for emergent wealth inequality within the region were laid during the Late Chalcolithic. Testing this hypothesis through direct evidence for the nature of Late Chalcolithic farming systems is a key aim of ongoing research.

1. Introduction

The fortified citadels of Early Bronze Age (EB/EBA) (*c.* 3100/3000-2000 BC) western Anatolia played a key role in the cultural landscape of the eastern Aegean. They acted as focal points for large-scale trade networks and cultural transmission (Şahoğlu 2005; Efe 2007) and were locations of centralisation and regional political power (Çevik 2007; Bachhuber 2015, 122-29). Monumental architecture and rich artefactual remains provide the first clear evidence for elite wealth and power within the region. Similarities in domestic and communal architecture, fortification systems and local and imported artefacts between settlements in western Anatolia and the eastern Aegean islands indicate the existence of a distinct cultural *koine* during this period (Şahoğlu 2005; Kouka 2016; Massa 2016, 252).

Cultural and technological developments during the Late Chalcolithic (*c.* 4250-3100/3000 BC) are widely considered to have laid the foundations upon which this cultural and economic *milieu* emerged. Despite evidence which suggests that

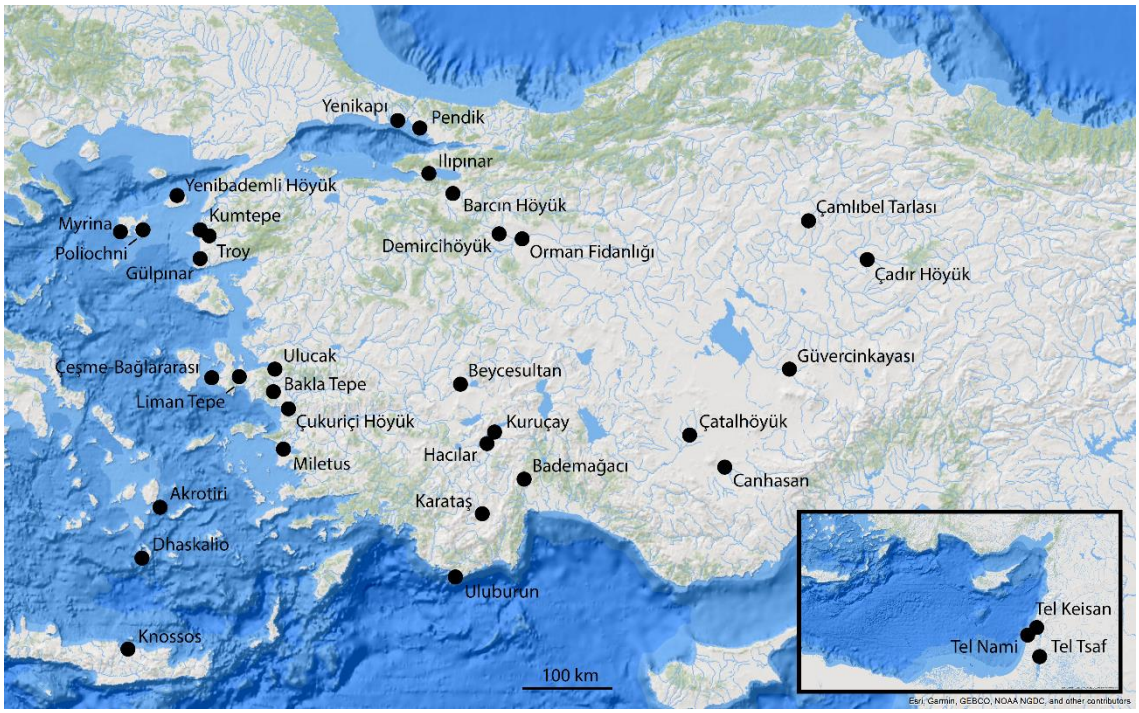
agricultural wealth played a significant role within EBA power structures in western Anatolia (Bachhuber 2015, 130-49; *cf.* Thumm-Doğrayan 2016), however, research into Late Chalcolithic arable economies is limited. Archaeobotanical remains have been published from only a few sites (Kumtepe—Riehl 1999 and Çukuriçi Höyük—Horejs *et al*. 2011 in coastal western Anatolia and Kuruçay—Stroud 2016 and Beycesultan—Lloyd and Mellaart 1962, further inland), thus hindering a comprehensive understanding of the nature of Late Chalcolithic agricultural production and the social scales at which it was organised. These issues have vital implications for the process(es) by which agrarian wealth and power subsequently emerged.

In this study, we begin to address this gap in understanding through an in-depth analysis of archaeobotanical remains recovered from Late Chalcolithic Bakla Tepe and Liman Tepe, Izmir Province, western Anatolia (Figure 1), excavated as part of the Ankara University Izmir Region Excavation and Research Project (IRERP). This paper builds on previous analyses of Late Chalcolithic archaeobotanical remains from the sites conducted by Oybak Dönmez (2006) and Oybak and Doğan (2008).

2. The Late Chalcolithic on the Anatolian Plateau

Following the widespread abandonment of settlements at the end of the Early Chalcolithic (*c*. 5500 BC), the Late Chalcolithic saw the reoccupation of alluvial plains across the Anatolian Plateau (Özdoğan 2014). At present, data on the nature of Late Chalcolithic settlements is patchy and restricted to smaller sites, with larger ones disrupted by Bronze Age occupation layers. The available data suggest that settlements were rural in character, with little evidence for the specialised or public buildings and elite individuals that characterised the EBA (Özdoğan 2002).

Figure 1: Locations of the sites mentioned in text.



Against these general trends, a range of settlement forms reflect a diversity of social and economic lifeways across the plateau (Düring 2011; Horejs and Schwall 2015). In western Anatolia, this phenomenon has been linked to functional diversity between populations that exploited local resources, fostering intensive exchange systems (Horejs 2014). Strong contacts between the Aegean islands and western Anatolia, particularly the coast, are visible in shared architectural forms, ceramic styles and the presence of marble items and Melian obsidian at sites that would go on to form the western Anatolian/eastern Aegean cultural *koine* (Horejs 2014; Kouka 2014; Horejs and Schwall 2015; Yeğingil *et al*. 2020). Accordingly, Kouka (2014) has suggested that parts of the *koine* were already in place by the Late Chalcolithic.

Similarities in architectural forms are particularly localised, with a number of sites in central coastal western Anatolia and the eastern Aegean islands containing free-standing elliptical/apsidal buildings (Myrina, Poliochni, Bakla Tepe, Liman Tepe), circular storage structures (Myrina, Poliochni, Bakla Tepe, Miletus) and grill-plan structures (Çukuriçi Höyük, Bakla Tepe, Liman Tepe) (Kouka 2014; Schwall and Horejs 2015). This contrasts with the overwhelming dominance of rectangular architecture in the Troad (e.g., Kumtepe—Sperling 1976 and Gülpınar—Takaoğlu and Özdemir 2018), inland and southern western Anatolia (e.g., Beycesultan—Lloyd and Mellaart 1962, Kuruçay—Duru 1996 and Karataş—Eslick 1992) and central Anatolia (e.g., Canhasan—French 1998 and Çadır Höyük—Steadman *et al.* 2019). An isolated apsidal structure is known from Orman Fidanlığı, Eskişehir (Efe 2001), but differs in form from those the west. A small number of grill-plan structures were also uncovered at Çamlıbel Tarlası, Çorum (Schoop 2010). In this study, we assess the implications of these divergent architectural trends for socio-economic organisation in light of new archaeobotanical data from Bakla Tepe and Liman Tepe. We also assess whether cultural contacts between western Anatolia and the eastern Aegean islands are visible in other aspects of the agricultural economy.

The onset of the Late Chalcolithic also saw significant developments in textile production, with a dramatic increase in the number of relevant artefactual remains across the plateau (Schoop 2014). These are particularly prevalent in the mountainous zones of southwestern and north-central Anatolia, the latter of which also contains zooarchaeological evidence for increased wool production (Arbuckle 2009). Evidence for metallurgical production also suggests that the extraction, production and distribution of metal products and experimentation with new copper alloys had become widespread by the mid-fourth millennium BC (Massa 2016, 169-70 and references therein).

Each of these economic spheres (exchange networks, textile production and metallurgical production) appears to have been an important source of elite wealth and power within the later EBA citadels of western Anatolia (Şahoğlu 2005; Efe 2007; Bachhuber 2016; Massa 2016, 269-72). Developments that occurred during the Late Chalcolithic are therefore considered to have laid the economic foundations for the emergence of EBA elites. As highlighted above, however, research into comparable developments in Late Chalcolithic agricultural production is limited. Recent theoretical approaches to the emergence of agricultural wealth inequality in the Mediterranean (e.g., Leppard 2019) have utilised macro-scale models that provide few insights into the fundamental economic process(es) by which it occurred. In Anatolian archaeology, this is likely due in part to the limited history of archaeobotanical research in periods after the Neolithic, which has resulted in an absence of well-defined research questions. In what follows, we briefly outline key evidence for the nature of farming systems on the Anatolian Plateau between the Neolithic and EBA and highlight a key research question to be addressed in this paper.

3. Arable farming on the Anatolian Plateau from the Neolithic to the EBA

Models of Neolithic farming in western Eurasia suggest that arable production was small-scale and utilised high labour inputs to enhance productivity, akin to a form of 'intensive horticulture' (Halstead 1989; Bogaard 2005; Halstead and Isaakidou 2020). This has found empirical support in the form of direct evidence for past crop growing conditions and land management practices. In Europe, the cultivation of fertile plots with high levels of tillage and manuring has been identified in Neolithic central Europe (Bogaard 2004; Styring *et al*. 2016) and Greece (Nitsch *et al*. 2019; Vaiglova *et al*. 2014;

2021). On the Anatolian Plateau, comparable farming systems have been identified at early-mid Neolithic Çatalhöyük (Filipović 2014, 133), continuing in diversified forms into the mid-later Neolithic (Green *et al*. 2018) and Early Chalcolithic (Stroud *et al*. 2021).

The high labour inputs associated with intensive farming systems are a limiting factor to the scale of production and therefore favour the small household labour forces of nuclear families (Bogaard 2005). The large scales of agricultural storage within the citadels of later EBA western Anatolia are therefore incompatible with the productive capacities of small-scale, intensive farming. Analogy with the elite agro-economies of LBA Anatolia (Diffey *et al.* 2020) suggest that they were produced using extensive farming systems oriented towards the production of surplus. Extensive farming is characterised by the use of draught cattle to facilitate the cultivation of crops over large areas of land with low inputs (Halstead 2014, 55-56; Bogaard *et al*. 2019). While low inputs result in lower yields per unit area compared with intensive systems, the labour-augmenting role of cattle facilitates cultivation on larger scales and the production of significant arable surplus. Accordingly, the adoption of extensive farming has been linked to the emergence of sustained high wealth equality across western Eurasia (Bogaard *et al*. 2019).

A key question, therefore, is whether the Late Chalcolithic saw a continuation of Neolithic style intensive farming or the emergence of more extensive systems that laid the agroecological foundations for the elite economies of the later EBA. In other words, was the emergence of extensive farming one of several developments in the domestic economy that occurred during the Late Chalcolithic or did it result from elite decision making in the EBA? This question highlights the need for data-driven research to reveal

the driving forces behind the emergence of agricultural wealth inequality. In this study, we begin to address this need by assessing evidence for changes in the scale of crop husbandry between the Neolithic and Late Chalcolithic.

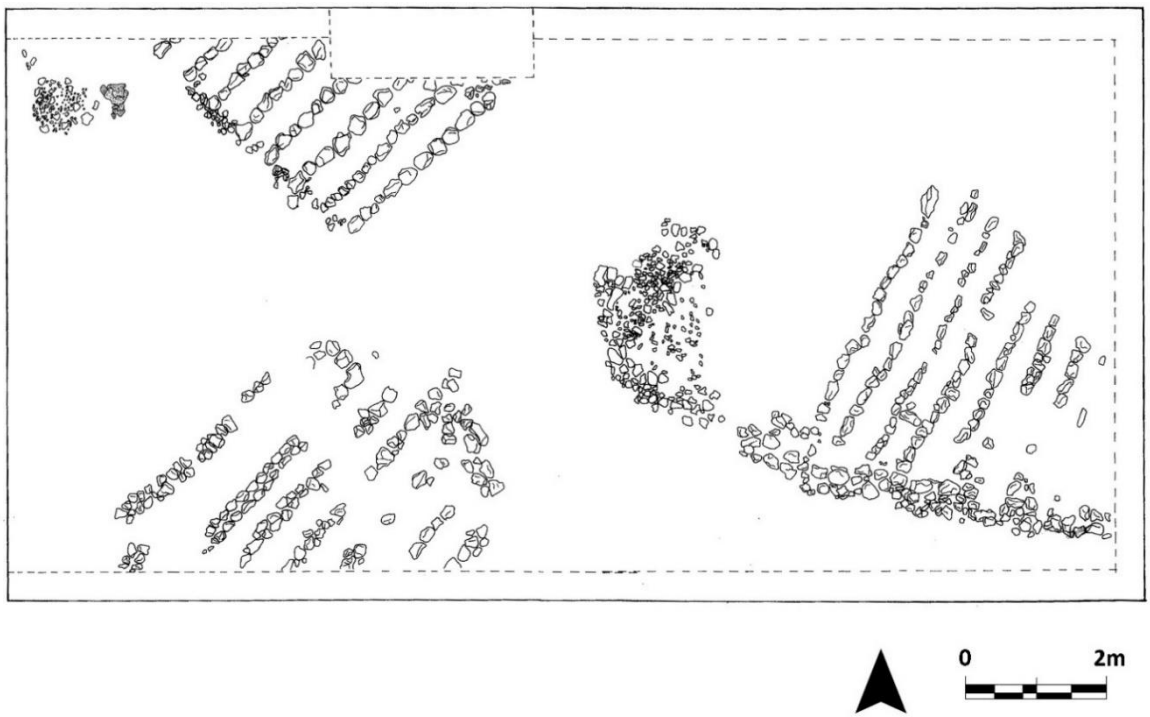
4. Archaeological background of the study sites

4.1 Bakla Tepe

Bakla Tepe is a settlement mound located next to the southeast bank of the Tahtalı River, north of Bulgurca village in the Cumaovası plain, southern Izmir (Figure 1). An extensive Late Chalcolithic (*c.* 3300-3140 cal. BC) settlement spread across an area of approximately 8.75 ha was revealed at the site (Erkanal and Özkan 1999a; Şahoğlu and Tuncel 2014). Architectural remains show a dispersed settlement pattern suggesting that, despite its size, the site did not contain an exceptionally large population. Architectural remains are dominated by grill-plan structures, sometimes with an additional apsidal end (Figure 2), as well as non-grill-plan apsidal buildings (Tuğcu 2019). The size of the structures (the grill-plans averaging *c.* 27.5 m^2 alone and 41 m^2 with the apsidal end) and their distribution across the settlement as the primary architectural unit suggest that they were occupied as domestic buildings.

The stone grills are likely to have created an inner raised floor, plausibly as a means to keep grain stored in the houses dry and reflecting concerns with provisioning for the storage of agricultural products within the settlement. Free-standing circular structures, some 1-3 m in diameter, excavated near the houses also have raised floors lined with small stones and are hypothesised to have been used to store grain (Erkanal and Özkan 1999b; Erkanal and Özkan 2000). Broadly contemporary examples are known from Poliochni and Myrina on Lemnos, Miletus in western Anatolia and Güvercinkayası in

Figure 2: Late Chalcolithic grill-plan structures from Bakla Tepe (after Tuğcu 2019, 443 Fig. 8).



central Anatolia (Kouka 2014; Çaylı *et al.* 2020). Charred grain found in very similar structures from sixth millennium BC Tel Tsaf in Israel supports their use as grain storage silos (Garfinkel *et al*. 2009).

Evidence for socio-economic organisation is limited but suggests an absence of pronounced inequality or central authority. The overall character of the settlement is one of a relatively egalitarian village, albeit one concerned with both intra- and extramural storage of grain, suggesting large-scale domestic storage.

4.2 Liman Tepe

Liman Tepe occupies a peninsula extending into the Aegean Sea from the southwest coast of the Gulf of Izmir, in the Iskele quarter of Urla, Izmir (Figure 1). Hydrological

analysis suggests that the peninsula became connected to the mainland by *c.* 3000 BC, prior to which only the upper part of the mound existed above sea level and was accessed via a weak sandbar (Goodman *et al*. 2008; Riddick *et al*. 2020). The Urla-Iskele plain spreads to the southeast of the mound, bordered by rocky hills to the northwest and southeast.

The earliest stratified deposits at the site belong to the Middle Chalcolithic (*c*. 4500-4300 cal. BC), after which a gap in occupation was followed by a largely uninterrupted sequence of remains from the Late Chalcolithic to the LBA (Erkanal and Şahoğlu 2016; Tuncel and Şahoğlu 2018). Stratified Late Chalcolithic deposits are restricted to the upper part of the mound, where architectural remains resemble those from Bakla Tepe, with two grill-plan structures and part of a severely burnt wattle-and-daub house uncovered (for more details on these structures, see Erkanal *et al.* 2017; Tuncel and Şahoğlu 2018).

Large quantities of carbonised crop grains/seeds spread across an area of *c*. 10 m^2 were recovered *in situ* from the floor of the burnt house, sealed by collapsed architectural debris (Erkanal *et al*. 2017; Tuncel and Şahoğlu 2018). Crops were likely stored in perishable containers such as sacks or wooden vessels and plausibly represent the harvest of a single year. Carbonised grains from this deposit have been radiocarbon dated to 3190-3130 cal. BC (Tuncel and Şahoğlu 2018, 527 Table 53.1). The limited Late Chalcolithic deposits excavated thus far provide little information as to the social morphology of the settlement. Crops recovered from the burnt house form the bulk of the archaeobotanical remains analysed in this study.

5. Analytical methods

The procedures for the sampling, recovery and identification of archaeobotanical remains from Liman Tepe and Bakla Tepe are outlined fully in the supplementary material. A key analysis in our study is that of crop processing activities, which have implications for the routines and timing of agricultural labour and can, therefore, be indicative of the socio-economic organisation of arable production. The methodology for this analysis is described in the supplementary material, where we also investigate the presence of wild taxa within the assemblage that were not brought to the sites as arable weeds.

6. Archaeobotanical results

6.1 Overview of the samples

We analysed 67 samples from Liman Tepe, all but one originating from the floor and destruction layer of the burnt house. Samples recovered adjacent to one another and showing similar crop and weed contents were amalgamated (Jones 1991), resulting in 32 samples containing almost 400,000 crop grains/seeds. A single sample was recovered from a secondary deposit of Late Chalcolithic material 50 m south of the burnt house. Six samples were analysed from Bakla Tepe, the majority deriving from miscellaneous fills, but one was recovered from the floor of a grill-plan house. In the supplementary material, we discuss the quality and representativeness of the archaeobotanical data from each site and how this may have influenced the results of our analyses.

Table 1: Abundance and ubiquity of crops and economic taxa within each sample. Counts are of grains/seeds unless shown otherwise.

Taxon	Common name	Bakla Tepe abundance (n = 6408)	Liman Tepe abundance (n = 381996)	Ubiquity (/39 samples)
Major crop taxa				
Triticum monococcum L.	Einkorn wheat	4295	81833	39
Triticum dicoccum Schübl.	Emmer wheat	1905	64600	39
Hordeum vulgare L.	Hulled barley	37	215703	31
Lathyrus clymenum L.	Spanish vetchling	2	10086	25
Lathyrus ochrus L.	Winged vetchling	10	794	12
Minor crop/contaminant taxa				
Triticum spelta L. (glume base)	Spelt wheat	3	48	3
Lens culinaris Medik.	Lentil	7	185	16
Vicia ervilia (L.) Willd.	Bitter vetch	5	151	9
Lathyrus sativus L.	Grass pea	2	24	3
Linum usitatissimum L.	Domestic flax	-	1	1
Fruit taxa				
Vitis L.	Grape	14	149	12
Olea europaea L.	Olive	-	5	3
Ficus carica L.	Fig	-	3014	24

6.2 Crops and economic taxa

The relative abundance and ubiquity of the crop and economic taxa from each site are shown in Table 1. Five major crop taxa were identified across both sites: einkorn (*Triticum monococcum* L.) and emmer wheat (*Triticum dicoccum* Schübl.); hulled barley (*Hordeum vulgare* L.); and two pulses, Spanish vetchling (*Lathyrus clymenum* L.) and winged vetchling (*Lathyrus ochrus* (L.) DC.). Rachis remains of both two-row (*H. vulgare distichum* L.) and six-row (*H. vulgare vulgare* L.) barley were identified, suggesting the cultivation of both subspecies. Lentil (*Lens culinaris* Medikus) and bitter vetch (*Vicia ervilia* (L.) Willd.) were recovered in minor quantities from Liman Tepe, but in comparable quantities to Spanish vetchling and winged vetchling at Bakla Tepe. Pulses are heavily underrepresented at the latter site, where they make up less than 1% of recovered crop grains/seeds. Further differences between the two sites are visible in the proportions of hulled barley, which makes up just over half of recovered crop grains/seeds from Liman Tepe but only a minor proportion of those from Bakla Tepe. This situation, however, may be an artefact of the limited number of samples from the latter site rather than an accurate reflection of its secondary importance as a crop.

Grains of einkorn and emmer wheat were recovered together in every sample from both sites. As glume wheats, grains of both species remain in their spikelets upon initial threshing and require a second threshing ('dehusking') to remove the chaff (Hillman 1984). Their co-occurrence and ability to be processed in the same way suggests that they may have been grown together as a mixed crop (Hillman 1984; Jones and Halstead 1995), but it is also possible that they were combined during processing or storage. Spanish vetchling and winged vetchling were also often recovered together (see

supplementary material for further analysis) and may likewise have been cultivated and/or processed and stored together.

Remains of spelt wheat (*T. spelta* L.) and grass pea (*Lathyrus sativus* L.) were recovered in minor quantities from both sites and may represent contaminants of other crop harvests rather than purposefully cultivated taxa (Jones and Halstead 1995). Fruit taxa are not well represented in the assemblage but remains of grape (*Vitis* L.), olive (*Olea europaea* L.) and fig (*Ficus carica* L.) were recovered. At present, these are the earliest olive stones recovered from western Anatolia, although earlier finds are recorded from Greece (Valamoti *et al*. 2018). It is not clear whether they represent cultivated or gathered resources. A single domestic flax (*Linum usitatissimum* L.) seed was also recovered from the Liman Tepe burnt house. Flax cultivation is better attested at other Late Chalcolithic sites in Anatolia (Stroud 2016; von Baeyer *et al*. 2021).

6.3 Contexts of deposition

6.3.1 Bakla Tepe

A single sample from Bakla Tepe was associated with architectural remains and was recovered from the eastern part of a grill-plan surface. The sample is composed almost entirely of glume wheat grains and likely represents crops stored within the structure. This strongly suggests that glume wheats were cultivated at Bakla Tepe. The more marginal presence of barley and pulses at the site means that their status as crops is less clear, although strong evidence for their cultivation at Liman Tepe and the overall similarities in crop spectra between the two sites suggest that they were also cultivated at Bakla Tepe.

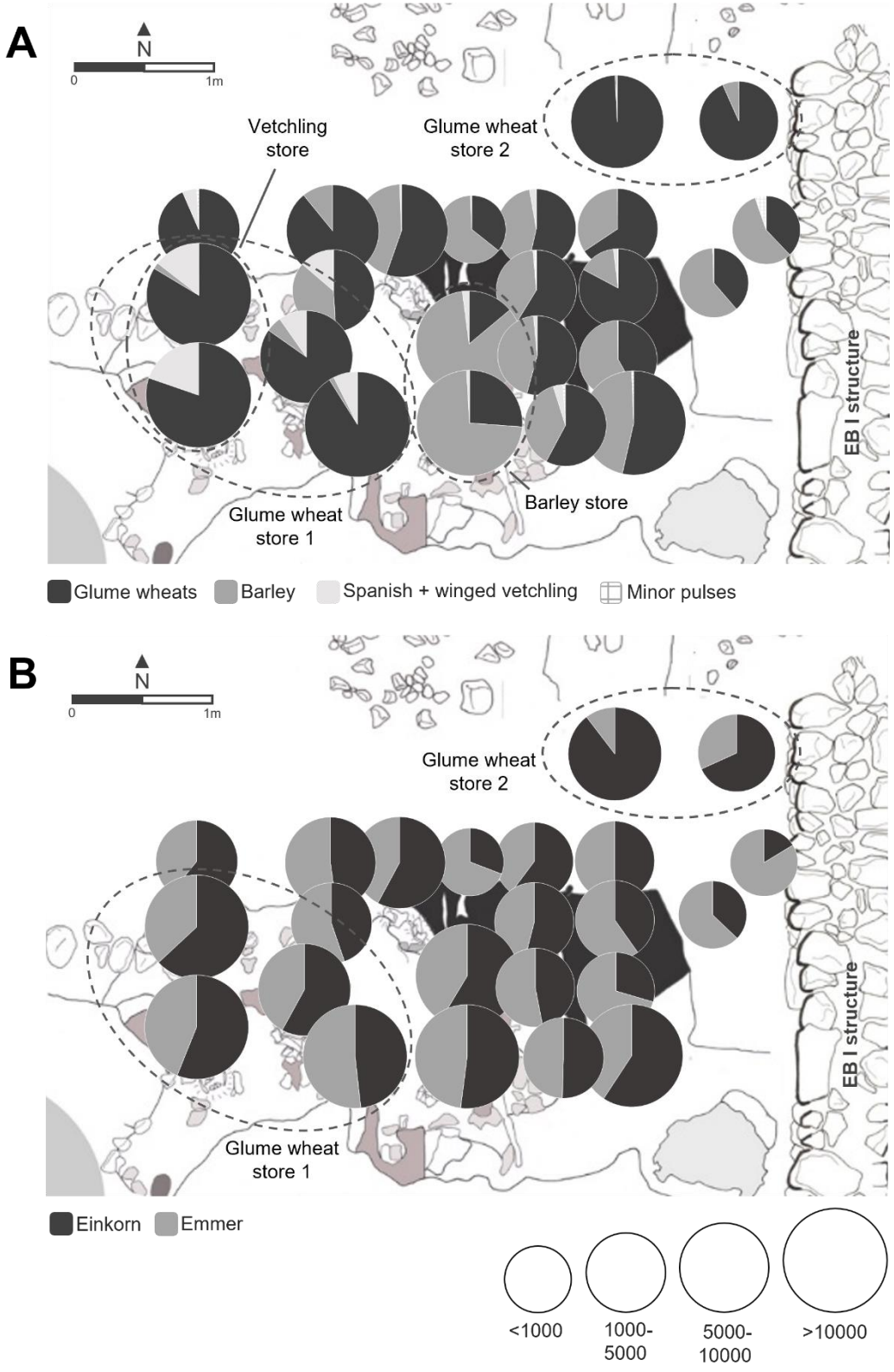
6.3.2 Liman Tepe

As stated above, the large numbers of crop grains/seeds recovered *in situ* from the Liman Tepe burnt house provide clear evidence for the storage of cultivated crops.

Figure 3a presents the distribution, size and crop content of samples recovered from the floor of the burnt house. This can be used to identify where crops were stored, on the assumption that the purest and largest concentrations of each taxon represent the original storage location. The largest concentrations of grain were recovered from the southwestern part of the floor. The presence of distinct and relatively pure concentrations of glume wheat and barley in this area suggest that the crops were stored next to each other on the southwest (glume wheat) and south-central (barley) parts of the floor. A smaller and relatively pure concentration of glume wheat was also recovered from the north-eastern part of the floor, indicative of another storage deposit. The remaining distributions of glume wheat and barley can be explained by grains having spread from these deposits upon the destruction of the house. Seeds of Spanish vetchling and winged vetchling are largely restricted to samples dominated by glume wheats in the west of the house and were likely stored there.

Figure 3b shows that einkorn and emmer were largely present in roughly equal proportions within each sample. This strongly supports the inference that they were stored together, and perhaps also cultivated and/or processed as a mixed crop. It is noteworthy that the samples from the north-eastern part of the floor contain higher proportions of einkorn than the samples from the southwestern part of the floor, suggesting that the two deposits may derive from discrete harvests with differing

Figure 3: The distribution of archaeobotanical samples across the floor of the Liman Tepe burnt house, showing: a) proportions of different crop taxa and inferred locations of storage entities; b) proportions of einkorn and emmer wheat. The size of the pie charts depicts the number of grains/seeds within each sample.



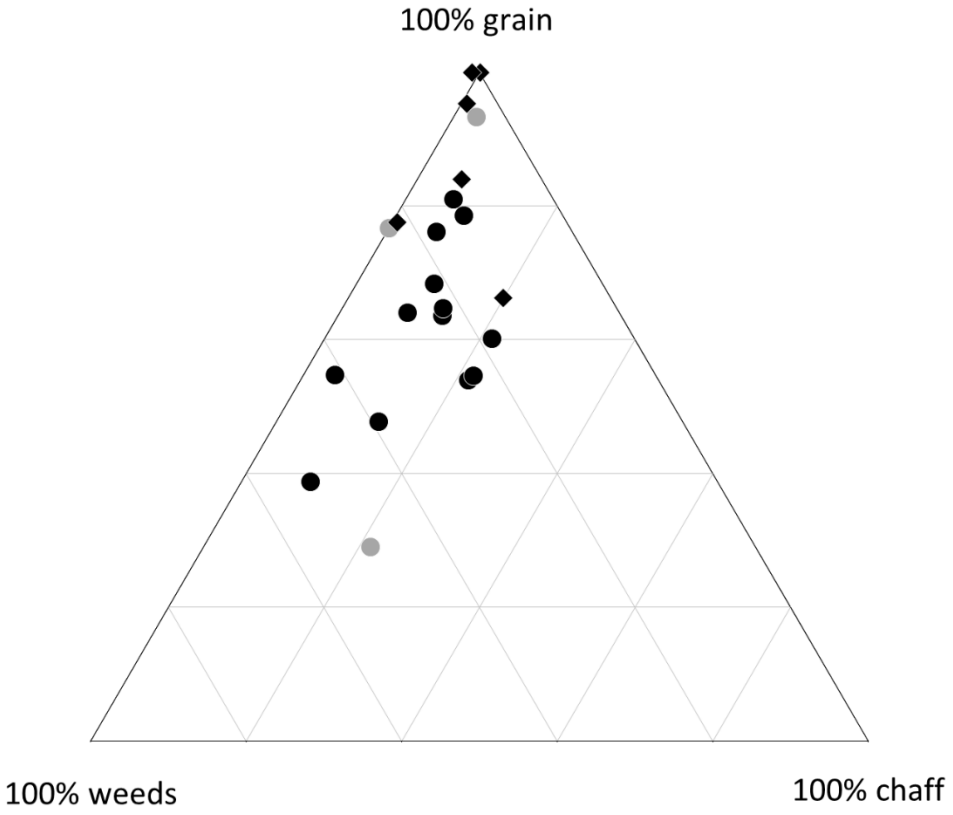
proportions of the two glume wheats. This further supports the inference that they represent distinct storage deposits.

6.4 Crop processing

Results of the crop processing analyses are shown in Figure 4 and supplementary Table 3. Most samples from Liman Tepe and all samples from Bakla Tepe were identified as products, suggesting that they represent deposits of fully processed grain. The pure concentration of glume wheat grains recovered from the floor of the Bakla Tepe grill-plan house may therefore represent a store of cleaned grain. Five samples from the Liman Tepe burnt house contained higher proportions of glume bases than expected for fully processed grain and/or arable weed taxa consistent with the by-products of fine-sieving. This is consistent with a minor source of crop processing waste within the house, possibly that discarded in a domestic fire.

Figure 4 shows that arable weeds retained a significant presence in the stores of processed cereal crops, in some cases making up over 50% of the seeds within a sample. This is largely due to a single species, darnel (*Lolium temulentum* L.), which makes up some 86% of weed seeds within the assemblage (supplementary Table 2). This anthropophyte species has evolved to mimic the size and shape of cereal grains and is able to pass through crop processing alongside them (Thomas *et al*. 2011). It was found in similar proportions in the grain stores of Iron Age Tel Keisan, Israel (Kislev 1980, 363 Table 1), and remains an abundant contaminant of cereals in the Aegean (Halstead 2014, 236). Seeds of darnel contain phytotoxins and are commonly infested with the toxic ergot fungus (Thomas *et al*. 2011); they were therefore likely removed piecemeal along with the remaining chaff prior to consumption (Hillman 1984, 133-34).

Figure 4: Tri-plot showing the results of the crop processing analysis based on proportions of crop grains, chaff and arable weed seeds. Circles: Liman Tepe; diamonds: Bakla Tepe, black: sample dominated (>70%) by glume wheat grains, grey: sample dominated by barley grains. Tri-plot produced following Graham and Midgley (2000).



7. Implications for a cultural *koine* between western Anatolia and the eastern Aegean islands in the Late Chalcolithic

By providing new data on farming practices and the organisation of the agricultural economy in Late Chalcolithic western Anatolia, our study provides further evidence with which to assess the presence of a cultural *koine* between this region and the eastern Aegean islands.

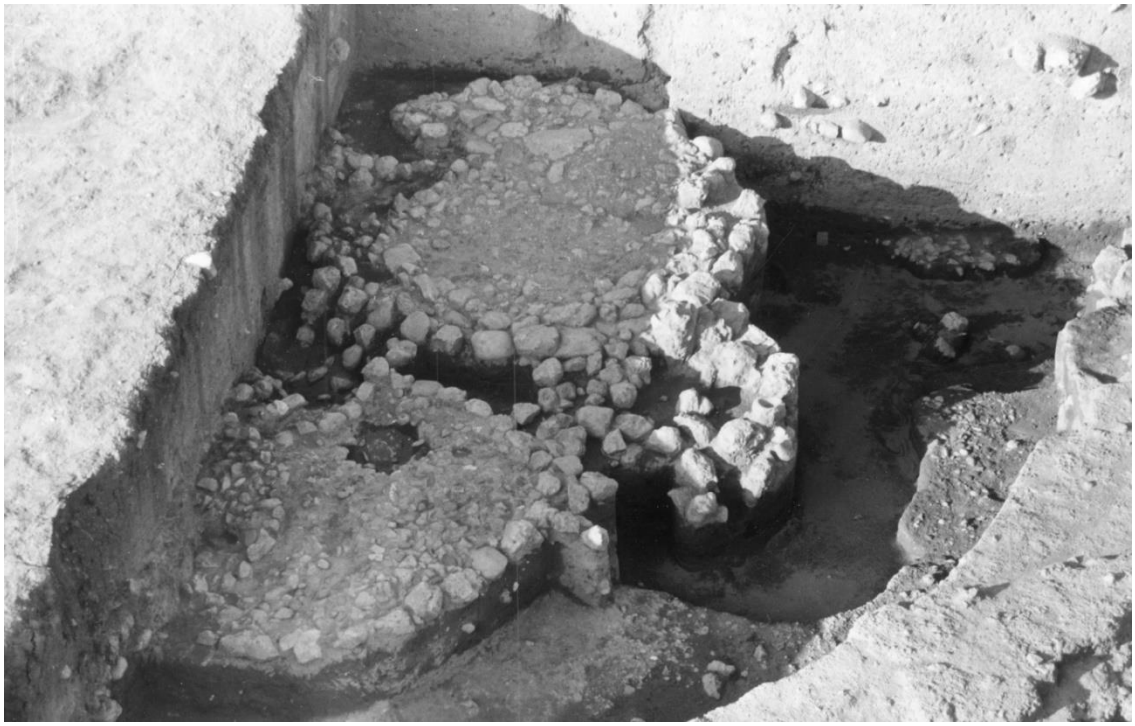
7.1 Storage, crop processing and the organisation of the agricultural economy

Deposits of clean grain within the houses at Liman Tepe and Bakla Tepe provide evidence for the storage and, presumably, consumption of arable produce by individual households. By-products of fine-sieving discarded in a hearth within the Liman Tepe burnt house and the large quantities of crop-mimicking weeds and chaff in deposits of grain at both sites further suggest that individual households undertook crop processing both prior to and after storage.

If the free-standing structures at Bakla Tepe indeed contained grain, then extra-household storage appears to have supplemented that within the household. Like the grill-plan houses, superstructures of wattle-and-daub were likely built up from the stone foundations of the free-standing structures (Figure 5) and thus resemble the plastered baskets covered and sealed with dung used for long-term grain storage by recent farmers in the Aegean (Halstead 2014, 159-60). Long-term storage within the extra-household structures from Bakla Tepe is also harmonious with the abundance of crop-mimicking weeds and chaff within grain recovered from elsewhere in the settlement, consistent with storage over a significant time period and suggesting that grain for domestic consumption throughout the year was stored within the houses.

Similar free-standing structures at Poliochni, Myrina-Richa Nera and Miletus (Kouka 2014) also suggests the presence of extra-household, potentially long-term, storage of agricultural products. Larger (*c*. 4 and 3 m in diameter) circular buildings at Çukuriçi Höyük have also been interpreted as storage rooms (Schwall and Horejs 2018). Grill-plan structures from this site, *c*. 1 m^2 in size, have been interpreted as fruit-drying platforms but may rather have been used for storage, as suggested at Çamlıbel Tarlası (Schoop

Figure 5: The free-standing circular structures from Bakla Tepe. Photograph courtesy of IRERP.



2010) and Bakla Tepe (Şahoğlu and Tuncel 2014). Evidence for extra-household storage is also present at Middle Chalcolithic Barcin Höyük, northwest Anatolia, where a large number of storage pits were uncovered (Gerritsen 2021). Elsewhere in western Anatolia, storage is restricted to within the household, visible at Beycesultan (Lloyd and Mellaart 1962, 25), Gülpınar (Takaoğlu and Özdemir 2018) and Kuruçay (Duru 1996, Plates 15, 20, 30). This matches data from central Anatolia, with storage bins inside houses at Canhasan (French 1998), Çadır Höyük (Steadman *et al.* 2019) and Middle Chalcolithic Güvercinkayası (Çaylı *et al.* 2020). Exceptions to this trend are extra-household grill-plan structures from Çamlıbel Tarlası (Schoop 2010) and free-standing circular structures at Late Chalcolithic Güvercinkayası (Çaylı *et al.* 2020), but these are isolated examples compared to the frequency of these forms in the west.

While more data are needed to investigate these trends further, two broad groups of settlements are recognisable during the Middle/Late Chalcolithic: those with rectangular architecture and storage primarily within the household and those with more varied architectural forms and extra-household storage. The greater frequency of the latter in coastal western Anatolia and the neighbouring islands provides further evidence for a cultural *koine* between these regions. This aligns well with artefactual data from the EBA, showing particularly intense interactions between central coastal western Anatolia and the eastern Aegean (Massa 2016, 252). Below, we assess the extent to which differences in settlement and storage patterns can be correlated with social morphology and the organisation of the agricultural economy.

Well-preserved architectural remains from a number of sites provide an outline of the social morphology of settlements with rectangular architecture and household storage. In the earlier Late Chalcolithic phase of Çadır Höyük, conjoined rooms were clustered into residential 'compounds' surrounding small courtyards and separated by pathways (Steadman *et al.* 2019). Grain was stored inside the rooms, but hearths, pottery and lithic scatters suggest that the courtyards were used for food preparation and other production activities. This has been interpreted as consistent with small, self-sufficient groups that lived closely together in potentially kin-related residential compounds (Steadman *et al.* 2019). At Kuruçay, the storage of glume wheats in spikelet form (Stroud 2016, 308) means that they would have to be dehusked prior to consumption and is consistent with the division of labour into modular households. Food processing installations and storage vessels inside buildings (Duru 1996, Plates 15, 20, 30) similarly indicate domestic control over crop processing and consumption, while the orientation of house entrances to face walls instead of household interiors indicates concerns with

privacy (Steadman 2000). Similar concerns are visible at Beycesultan, where a house contained plastered bins hidden by a mudbrick screen (Lloyd and Mellaart 1962, 25). Food processing and storage installations were located within houses at Gülpınar, but hearths were often located outdoors (Takaoğlu and Özdemir 2018).

Like Bakla Tepe and Liman Tepe, crop storage and processing within the houses in these examples are consistent with the household as the basic unit of arable production and consumption. Architectural features blocking outside visibility of household interiors at Kuruçay and Beycesultan indicate particular concerns with privacy at these sites. This was likely negotiated against community relationships and obligations through the use of courtyards and open spaces for some domestic tasks, plausibly entailing the sharing of domestic labour (see also Halstead 1995). The negotiation of private and public within the domestic economy is also observed elsewhere within the prehistoric Aegean (Halstead 1995) and Anatolia (Bogaard *et al*. 2009). This aligns with the behaviours of recent small-scale farming households oriented towards self-sufficiency but facing the necessity of household interdependence to cope with inevitable bad years (Halstead 1989).

In contrast to the individualised storage practices outlined above, the limited number of the extra-household storage structures at Bakla Tepe and their apparent lack of associations with individual houses (Şahoğlu and Tuncel 2014) hints at their use by multiple households. While circumstantial, the spatial ambiguity of the structures can be contrasted with the clear associations between the extra-household granaries and individual longhouses at EBA Demircihöyük, inland western Anatolia, despite the former being clustered in an open space at the centre of the settlement (Korfmann 1983, Fig.

3). Ethnographic examples of closely related but residentially separate households functioning as a single economic unit are also known from the recent past in the Aegean (Forbes 2007, 123). The internal partitioning of a free-standing structure from Myrina-Richa Nera (Kouka 2014) may reflect its use by multiple households, although it may also have divided grain of different crops. Whether used by multiple households or not, however, the free-standing structures at Bakla Tepe represent an overtly visible form of storage that contrasts with concerns over privacy in the settlements described above. The ubiquity of hearths excavated in the open areas between the houses at Bakla Tepe also likely acted as public spaces in which to prepare food and/or undertake domestic activities. Elsewhere, limited horizontal exposure of Late Chalcolithic levels at Çukuriçi Höyük suggest that the grill-plan structures also occupied open spaces in the settlement (Horejs and Schwall 2018, 67, Fig. 3). Artefacts indicative of food preparation were located close to the structures and suggest the use of open space for domestic tasks.

This brief analysis reveals a key difference between the two forms of settlement described above. In both cases, the modular household appears to have operated as a basic socio-economic unit, mediated against broader social obligations through the use of public space and potential sharing of labour for domestic tasks. Significantly, however, highly visible, and potentially communal, extra-household storage at some settlements in coastal western Anatolia and the neighbouring islands suggests that agricultural production was also bound with obligations to cooperate at the supra-household level. The broad range of architectural forms dedicated to storage within these regions and the large size of the free-standing structures at Bakla Tepe suggests that this may be linked to the emergence of more extensive forms of farming oriented towards the production of surplus (Horejs and Schwall 2015, 60). We assess this further

below by comparing storage capacity and crop choice between settlements in Neolithic and Late Chalcolithic western Anatolia.

7.2 Crop choice

While more samples are needed to confirm the archaeobotanical results from Bakla Tepe, our data reveal marked similarities in the range of crops recovered from this site and Liman Tepe. The occupants of both sites may have cultivated mixed crops of einkorn and emmer wheat. Further analysis is required to confirm this, but remains of these species were also frequently recovered together at Late Chalcolithic Kumtepe (Riehl 1999, 28) and, alongside remains of the 'new glume wheat', at Çadır Höyük (von Baeyer *et al*. 2021), Kuruçay (Stroud 2016, 201) and Çamlıbel Tarlası (Stroud 2016, 186), suggesting that mixed glume wheat crops may have been common across the Anatolian Plateau.

More striking is the cultivation of Spanish vetchling and winged vetchling at Liman Tepe and, possibly, at Bakla Tepe, hitherto unique within mainland Anatolia and the earliest evidence of this practice to date. First identified at LBA Akrotiri on Thera (Sarpaki and Jones 1990), and in the Unexplored Mansion at Knossos on Crete (Jones 1992), the cultivation of these species has been increasingly recognised within the archaeological record but previously restricted to Bronze Age settlements on the Aegean islands (at Yenibademli Höyük, Gökçeada—Oybak 2005 and Dhaskalio, Keros—Margaritis 2013 in addition to Crete and Thera, with an apparent import at Tel Nami, Israel—Kislev *et al.* 1998). Elsewhere on the Anatolian Plateau, the Late Chalcolithic pulse spectra of Kumtepe (Riehl 1999, 28), Çadır Höyük (von Baeyer *et al*. 2021) and Çamlıbel Tarlası (Stroud 2016, 191 Table 5.8) are dominated by lentil and bitter vetch, alongside minor

quantities of grass pea, chickpea (*Cicer arietinum* L.) and pea (*Pisum sativum* L.) at the last site. Three seeds of winged vetchling were also recovered from Çamlıbel Tarlası but are likely to have been a weed of cultivation. At Kuruçay, lentil predominates alongside pea and grass pea (Stroud 2016, 204 Table 5.12). References to archaeobotanical pulses encountered during the excavations of Beycesultan attest only to lentil (Lloyd and Mellaart 1962, 20-21).

While further studies are necessary to flesh out this picture, there is an apparent divergence in crop choice between the Izmir region and elsewhere on the Anatolian Plateau. The potential reasons for this are difficult to assess. Modern cultivation of the vetchling species is restricted to the Aegean region, with Spanish vetchling grown on a number of Cycladic islands and winged vetchling on the southwest coast of Turkey (Ertuğ 2004; Ralli *et al*. 2020). Within Turkey, wild specimens of both taxa are primarily recorded along the Aegean coast (Davis 1970, 365-66). The vetchling species are therefore well adapted to the environs of Liman Tepe and Bakla Tepe, but the extent to which this favoured their cultivation over other pulses is unclear. Both sites are surrounded by fertile plains of Quaternary alluvium (Simsek *et al*. 2008, 295; Uzel *et al*. 2012, 442 Fig. 2) and, at 682 mm, the average annual rainfall of Izmir exceeds that of the other Anatolian sites mentioned above (Türkeş 1996, 1063 Table II). Rainfall patterns are more variable than further inland, however, with greater risk of drought on a given year (Türkeş and Tatlı 2009, 2279 Fig. 10). This may have favoured the drought tolerance attributes of Spanish vetchling (Ralli *et al*. 2020), but bitter vetch is also known as a drought tolerant pulse (Basheer-Salimia *et al*. 2021) and was cultivated alongside lentil during the EBA occupation of Liman Tepe (Oybak 2006). It is possible that Late Chalcolithic farmers were responding to the onset of drier climatic conditions associated

with the '5.2ka event' (Kuzucuoğlu *et al*. 2011; *cf.* von Baeyer *et al*. 2021) by cultivating crops well-adapted to local environmental conditions. Without evidence for a change in crop choice or growing conditions coinciding with the 5.2ka event, however, this remains conjectural.

In any case, the cultivation of the vetchling species in the Izmir region likely held cultural significance. As a phenomenon closely bound to notions of tradition, the presence of regional cuisines in the archaeobotanical record is increasingly recognised as a means by which shared cultural identities may be discerned (Valamoti 2017). Thus, alongside regional architectural and ceramic styles (Tuncel and Şahoğlu 2018), the cultivation of Spanish vetchling and winged vetchling appear to be part of a localised suite of practices within the Izmir region that hint at the existence of a distinct cultural identity during the late fourth millennium BC. The extent to which these taxa may have been part of the broader western Anatolian/eastern Aegean cultural *koine* is unclear. As noted above, no evidence for their cultivation is known from Kumtepe or Kuruçay, but Late Chalcolithic archaeobotanical remains are yet to be recovered from the islands neighbouring the Anatolian coast. Elsewhere within the Izmir region, a small archaeobotanical assemblage containing barley, lentil and fruit taxa has been reported from late fourth millennium BC levels at Çukuriçi Höyük (Horejs *et al.* 2011, 51 Table 1), but further samples are needed to infer more reliably the absence of the vetchling species at this site. In either case, however, the prevalence of the vetchling species in the eastern Aegean by the EBA suggests that they were indeed part of the longer-term cultural *koine* between this region and western Anatolia (see also Kouka 2016; Massa 2016, 252).

8. Implications for changes in farming strategies and socio-economic organisation between Neolithic and Late Chalcolithic western Anatolia

As outlined above, large-scale agricultural storage within later EBA citadels suggest that elites utilised agricultural systems radically different from those of the Neolithic in order to amass arable wealth. A key question is whether these agricultural developments were elite-driven or whether, like other aspects of the economy, they emerged within domestic contexts in earlier periods. Here, we compare farming strategies and the organisation of arable production between the Late Neolithic and Late Chalcolithic (*c.* 6500-3100/3000 BC) in order to assess the presence of these developments.

By providing evidence for the size of crop harvests, the capacities of storage structures have direct implications for the scale of arable production. Calculations of storage capacity are subject to issues of both underestimation (not all modes of storage are likely to have preserved) and overestimation (storage structures may be built to hold the maximum expectable harvest, which rarely occurred—Forbes 2007, 231), but have been successfully used to infer the nature and scale of agricultural production in prehistoric contexts (e.g., Bogaard *et al*. 2009; Prats *et al*. 2020).

In Table 2, we show the volumes of storage structures from Late Neolithic to Late Chalcolithic settlements in western Anatolia. The methods we used to estimate storage volume are outlined in the supplementary material. The volume of storage structures from the Late Neolithic sites, Middle Chalcolithic Barcın Höyük and Late Chalcolithic Beycesultan are comparable and broadly align with the amount of grain needed to sustain a small family for a year (*c*. 1300 to 3000 litres including normal surpluses—Halstead 2014, 162). While not all storage structures may have contained grain (whether

Table 2: Estimated volumes of storage structures from Late Neolithic to Late Chalcolithic sites in western Anatolia. The average volumes of storage from Barcın Höyük and Ilıpınar were extracted from Gerritsen (2021) and Roodenberg (2011), respectively. Storage volume from the remaining sites was calculated as described in the supplementary material.

Period	Site	Structure/context	Estimated volume (l)	Reference
Late Chalcolithic	Bakla Tepe	Free-standing circular structures (combined volume)	10370-20740	Figure 5; Şahoğlu and Tuncel 2014
	Poliochni	Free-standing circular structure	6160-12320	Kouka 2014
	Myrina-Richa Nera	Free-standing circular structure	1770-3540	Kouka 2014
	Miletus	Free-standing circular structure	1540-3080	Kouka 2014
	Beycesultan	Household bins, Level XXXI A	590-1180	Mellaart and Lloyd 1962, 22 Fig. 5
		Household bins, Level XXXI B	1180-2360	Mellaart and Lloyd 1962, 22 Fig. 5
		Household bins, Level XXVII	300-600	Mellaart and Lloyd 1962, 24 Fig. 6
		Household bins, Level XXVIII	670-1340	Mellaart and Lloyd 1962, 24 Fig. 6
Middle Chalcolithic	Barcın Höyük	Storage pits (average volume)	1400	Gerritsen 2021
Early Chalcolithic	Hacılar	Granary bins	14630	Mellaart 1970, 73 Fig. 20
		Room 6 household bins	140-280	Mellaart 1970, 73 Fig. 20
Late Neolithic	Hacılar	House 4 household bins	1320	Mellaart 1970, 13 Fig. 7
		House 3 household bins	1680	Mellaart 1970, 13 Fig. 7
	Ilıpınar	Household storage (average volume)	1000	Roodenberg 2011
	Ulucak	Building 30 storage	2540-4790	Çilingiroğlu *et al*. 2012, 146

for human or animal consumption), which may also have been stored in perishable containers, this suggests that the occupants aimed for self-sufficiency, including a modest normal surplus (Halstead 1989). This aligns with the productive capacities of small-scale, intensive farming systems. The volumes of the granary bins from Early Chalcolithic Hacılar are difficult to estimate but it is likely that they contained enough grain for multiple households. Communal use of the granary is supported by the small volume of storage within a nearby house.

The free-standing circular structures from Late Chalcolithic Bakla Tepe and other sites show a range of storage capacities. Those from Miletus and Myrina-Richa Nera are consistent with the volumes of household storage described above. Considering that the structures may have supplemented household storage, this could point to the production of significant arable surplus. It may also, however, reflect their use by more than one household. The capacities of the structures from Bakla Tepe and Poliochni far exceed the amount of grain required for domestic consumption. This suggests that they contained the pooled harvests of numerous households producing modest normal surpluses (as many as 16 at Bakla Tepe and nine at Poliochni, even without storage inside the house) or those of fewer households engaged in the production of arable surplus on a scale incompatible with small-scale, intensive farming. The latter would indicate the utilisation of more extensive farming systems than those of the Neolithic.

We can investigate this further by comparing crop spectra between the Late Neolithic and Late Chalcolithic. As touched on above, the cultivation of numerous crops with differing ripening times allows household labour to be spread across the harvest season and is commonly observed within intensive farming systems (Halstead 2014, 105). In

contrast, farmers engaged in extensive farming oriented towards the production of surplus rely on a reduced range of crops with complementary ripening times due to the labour demands of reaping on a large scale. Extensive farming also favours cereal cultivation due to the difficulties of reaping scrambling pulses (Halstead 2014, 199).

Table 3 shows that archaeobotanical assemblages from Late Chalcolithic sites in western Anatolia tend to contain fewer crop species, particularly pulses, than earlier sites. One must note, however, the limited number of large archaeobotanical assemblages from the Late Chalcolithic, with a lack of archaeobotanical sampling at Beycesultan, while those from Çukuriçi Höyük and Bakla Tepe are hindered by low numbers of remains. Most of the archaeobotanical samples from Liman Tepe come from a single house and are therefore not representative of the settlement as a whole (although the sample from a secondary deposit 50 m to the south contained the same narrow range of crops). As theorised by Bogaard *et al.* (2019), however, in its early stages the emergence of more extensive farming systems plausibly occurred at the level of individual households, meaning that the limited range of crop taxa within the Liman Tepe burnt house is informative. Alongside that from Kumtepe, these data therefore reliably demonstrate the cultivation of fewer crop species than in earlier periods. An exception to this trend is Kuruçay, aligning with isotopic evidence for moderate cultivation intensities (Stroud *et al*. 2021) and the absence of large-scale agricultural storage at the site.

Together, the large scales of agriculture storage and narrow ranges of crops cultivated at some sites in western Anatolia are consistent with the practices of recent non-mechanised farmers in the Aegean utilising extensive farming systems. While more data on agricultural storage and crop choice are needed, this hypothesis is supported by

Table 3: Crop taxa recovered from Late Neolithic to Late Chalcolithic sites in western Anatolia. X – likely cultivated, (X) – cultivation status uncertain due to limited remains. *No sampling for archaeobotanical remains during excavation. **No proportional data provided in publication. F/t wheat: free-threshing wheat. S/w vetch: Spanish/winged vetchling.

Period	Site	Glume wheat	F/t wheat	Barley	Lentil	Bitter vetch	Pea	Grass pea	Chick-pea	S/w vetch	Total	Reference
Late Chalcolithic/EBA	Çukuriçi Höyük			(X)	(X)						**(2)**	Horejs *et al*. 2011
Late Chalcolithic	Bakla Tepe	X		(X)	(X)	(X)				(X)	**1+(4)**	
	Liman Tepe	X		X						X	**3**	
	Kumtepe	X		X	X	X					**4**	Riehl 1999
	Beycesultan*	X			X						**2**	Mellaart and Lloyd 1962: 19-26
	Kuruçay	X	X	X	X		X	X			**6**	Stroud 2016: 204
Early Chalcolithic – Late Neolithic	Hacılar	X	X	X	X	X	X				**6**	Helbaaek 1970
	Ilıpınar	X		X	X	X	X	X	X		**7**	Cappers 2008
Late Neolithic	Barcın Höyük	X	X	X	X	X			X		**6**	Balcı *et al*. 2019
	Höyücek	X	X	(X)	X	X			X		**5+(1)**	Martinoli and Nesbit 2003
	Pendik Höyük	(X)		(X)			(X)	(X)			**(4)**	Ulaş 2020
	Ulucak**	X	X	X	X	X	X				**6**	Çilingiroğlu *et al*. 2012
	Yenikapı	X	X	X	X	X	X				**6**	Ulaş 2020

preliminary results from stable isotope and ecological analysis of archaeobotanical remains from Bakla Tepe and Liman Tepe, providing direct evidence for the low-input cultivation strategies characteristic of extensive farming (Maltas *et al*. in prep).

The adoption of more extensive farming systems would align well with the emergence of highly visible, potentially communal, extra-household storage. For recent farmers in the Aegean, large scales of cultivation resulting from extensive land use created acute time stress during the harvest and when attempting to complete ploughing in advance of sowing (Halstead and Jones 1989). Under these conditions, the ability to mobilise agricultural labour was key to agricultural success, and losses to household workforces a major hazard (Halstead 2004). The scales of household storage outlined in Table 2 suggest that Neolithic and Chalcolithic households were composed of small families, meaning that cooperation beyond the immediate household may have been essential to the long-term sustainability of arable production. High levels of social monitoring in the agricultural economy, collective storage and the obligations to share in the fortunes of good and bad years that went with them may have provided a means of sustaining cooperative ties at the supra-household level.

While these features of the agricultural economy indicate the emergence of more extensive farming systems at some sites in coastal western Anatolia and the neighbouring islands, their absence across much of the broader region suggests that these developments were highly localised. The persistence of Neolithic style farming systems is indicated by the volume of storage at Beycesultan and the broad crop spectrum and moderate cultivation intensities at Kuruçay. This suggests that, perhaps unsurprisingly, agricultural developments occurred on a sporadic, site or region-specific

basis in response to local environmental and/or socio-economic conditions. This does not appear to be restricted to western Anatolia and may also be indicated by storage structures comparable to those at Bakla Tepe at Late Chalcolithic Güvercinkayası, central Anatolia (Çaylı *et al.* 2020).

9. Conclusion

Through an in-depth analysis of archaeobotanical remains, our study has offered insights into the arable farming practices and organisation of domestic labour that shaped Late Chalcolithic populations at Bakla Tepe and Liman Tepe. Farmers at both sites utilised a spectrum of five major crop taxa, potentially including mixed crops of two glume wheat and vetchling species. Hitherto unique within mainland Anatolia, cultivation of the vetchling species hints at a regional cultural identity within the Izmir region. Crop processing and domestic storage appears to have been undertaken individually by small-scale, co-residential households, but highly visible and potentially communal extramural storage attests to a significant degree of social monitoring and, likely, cooperation in the agricultural economy.

While more archaeobotanical data are needed from western Anatolia and the neighbouring islands, the later agricultural history of the vetchling species places the Izmir region firmly within the long-term cultural sphere of the Aegean world. The range of architectural forms and the frequency of extra-household storage on the eastern Aegean islands and parts of coastal western Anatolia further distinguishes them from inland western and central Anatolia during the Late Chalcolithic. The large size of storage structures and narrow crop spectra at some sites in this region may be linked to the emergence of more extensive forms of agricultural production oriented towards the

production of surplus. This is supported by preliminary results from stable isotope and ecological analysis of archaeobotanical remains from Late Chalcolithic Bakla Tepe and Liman Tepe (Maltas *et al*. in prep). This aligns well with the potential of highly visible, possibly communal, extra-household storage as a means of maintaining cooperative ties between small households in order to meet the acute seasonal labour demands of extensive farming systems. Agricultural production may therefore have been one of several areas of the domestic economy in which developments during the Late Chalcolithic laid the foundations for the emergence of later EBA citadels. At present, this remains a tentative hypothesis based on several harmonious, but ultimately indirect, lines of evidence. Direct evidence for the nature of Late Chalcolithic farming is crucial and is the focus of ongoing research.

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Prehistoric farming settlements in western Anatolia: archaeobotanical insights into the Late Chalcolithic of the Izmir region, Turkey

Supplementary material

1. Analytical methods

1.1 Sampling, recovery and identification

The majority of the archaeobotanical samples were recovered prior to the establishment of a systematic sampling strategy. Material was typically sampled from visible concentrations of archaeobotanical remains or visibly burnt deposits. Samples from Liman Tepe were processed by water flotation using an Ankara type flotation tank (French 1971). Remains that floated (the flot) were collected in a 300 µm mesh and the rest (the heavy residue) was retained in a 1 mm mesh. A single sample from Bakla Tepe was processed in this way but the majority underwent bucket flotation carried out on-site. At both sites, the majority of the heavy residue was discarded and only the flots retained for analysis.

Samples were analysed using a low-power stereo microscope (7-45x) at the Ankara University Research Center for Maritime Archaeology (ANKÜSAM), Izmir. All samples were briefly scanned in order to establish their archaeobotanical richness. Those from Bakla Tepe that contained 30 or more crop grains/seeds were selected for further analysis. A threshold of 30 identifiable items was chosen as the minimum amount considered to reflect the relative proportions of taxa within a sample to a reasonable degree of accuracy and reliability. A threshold of 100 or more crop grains/seeds was applied to the richer samples from Liman Tepe. Samples were sieved into >1 mm

(coarse) and >300 µm (fine) fractions. Coarse fractions that were estimated to contain over 600 crop grains/seeds were randomly sub-sampled using a riffle box sample splitter such that a subsample of at least 300 identifiable items were extracted and analysed for each sample. This minimum number reflects the relative proportions of taxa to a high degree of accuracy and reliability (van der Veen and Fieller 1982). The fine fractions were sub-sampled such that 10-30 weed/wild seeds were identified where possible (excluding seeds of *Lolium* species, which dominated the weed assemblage). Counts of items in each fraction were multiplied up to provide the total counts for 100% of each sample.

Items were quantified to establish the 'minimum number of plant parts' represented using 'diagnostic zones' in order to prevent individual plant parts from being counted more than once (Jones 1991). The embryo ends of cereal and *Lolium* grains and the bases of glumes were counted. For dicotyledonous taxa such as pulses, seeds of which often split in two halves, half seeds were counted as 0.5 and the total rounded up to a whole number. The minimum number of seeds and other plant parts was estimated for non-*Lolium* weed/wild and fruit taxa by visual inspection.

Plant taxa were identified by comparison with modern seeds from the reference collections at the Institute of Archaeology, University of Oxford, the Institute of Archaeology, University College London and the British Institute at Ankara, alongside published sources (e.g., Jones 1992; Nesbitt 2006; Sarpaki and Jones 1990). Lists of species geographically relevant to the sites were extracted from *Flora of Turkey* (Davis 1968-2000).

1.2 Criteria used to identify non-arable wild taxa

Arable weeds harvested with crops are interpreted in the crop processing analyses conducted in this study. Remains of wild taxa can enter the archaeological record from a number of alternative pathways, however, including the burning of animal dung for fuel (Charles 1998) and as gathered resources. It is therefore essential to identify taxa that derived from non-arable pathways prior to the analysis of arable weed flora.

Following Charles (1998), Wallace and Charles (2013) and Bogaard *et al.* (2013), we used several criteria to establish the likelihood of archaeobotanical taxa to have derived from non-arable pathways. Those that fruit outside of the likely period of crop harvest, that would be unlikely to set seed under arable conditions and/or those that favour wetland or maritime habitats were considered unlikely to have grown and/or been harvested in seed with arable crops. We considered a June/July harvest period to be likely based on the practices of recent non-mechanised farmers from comparable climates elsewhere in the Aegean (Halstead and Jones 1989; Halstead 2014, 25). We identified potential non-arable wild taxa further by assessing the likelihood of seeds to derive from animal dung burnt as fuel. Feeding experiments by Wallace and Charles (2013) identified that small and hard coated seeds were more likely to survive digestion by sheep, with a size threshold of 1.18 mm for maximum survival identified by Poppi *et al*. (1985). Gardener *et al*. (1993) found only a weakly negative correlation between size and survivability, however, with seed density showing a stronger positive correlation. We therefore considered taxa with dense or hard coated seeds and/or those smaller than 1.18 mm to have a greater chance of being dung-derived.

We assessed seed size for the archaeobotanical taxa with reference to modern specimens in order to consider potential changes in size due to charring (Charles *et al*. 2015). Data on seed hardness were sourced from the botanical literature (e.g., Bryson and Carter 2008). Data on flowering period and habitat preference were extracted from *Flora of Turkey* (Davis 1968-2000). We calculated fruiting time as starting one month after flowering onset and continuing until one month after the cessation of flowering.

1.3 Crop processing analysis

Following Jones (1983; 1984; 1987; 1990) and Bogaard (2011), the relative proportions of weeds with different aerodynamic properties and crop grain and chaff were used to infer the processing stage(s) from which crops and their associated weeds derived. Crop processing is a major way in which the composition of the archaeobotanical record is shaped (Dennell 1974; Hillman 1984; Jones 1984) and must therefore be understood in order to reveal the presence and direction of biases that may impact interpretations based on composition. The large deposits of crop grain/seeds preserved *in situ* in the Liman Tepe burnt house provide relatively unambiguous evidence for the storage of cultivated crops. The level of processing prior to storage and the degree of mixing with material from other sources, however, are unclear. The depositional contexts of the remains from Bakla Tepe provide no indications of the processing stage(s) from which they derive.

1.4 Estimating storage capacity within Neolithic to Late Chalcolithic settlements

For household bins/silos, we estimated the minimum and maximum volume from plans extrapolated to heights of 0.5 and 1 m. This is based on the preserved heights of bins/silos from Early Neolithic Bademağacı (0.65-0.7 m—Duru 1998, 716) and Late

Neolithic Hacılar (1 m—Mellaart 1970, 15). It also aligns with estimates of bin size from mid-later Neolithic Çatalhöyük (Bogaard *et al.* 2009). For the free-standing circular structures, we extrapolated to heights of 1 and 2 m. This is based on ethnographic examples of comparable structures from the Middle East, all of which are taller than they are wide and stand as high as 2 m (Aurenche 1981, Fig. 207; Kramer 1982; *cf.* Garfinkel *et al*. 2009). An absence of clear archaeological/ethnographic parallels makes the volume of the granary bins from Early Chalcolithic Hacılar. We therefore extrapolated to a height of 1 m for comparative purposes.

2. Archaeobotanical results

2.1 Crops and economic taxa

Clusters of Spanish vetchling seeds were recovered without winged vetchling, but the latter was never recovered in significant quantities (>5 grains) without Spanish vetchling. This may suggest that winged vetchling was a weed of Spanish vetchling cultivation. Winged vetchling, however, is well-represented in the few heavy residues that were retained from Liman Tepe, suggesting that this inequity was in part due to a bias against its recovery in the flot (remains recovered in a 300 µm mesh during flotation, see recovery methods outlined above). In the five samples that contained remains from both the flot and heavy residue, the two vetchling species were always recovered together, and winged vetchling made up 18% (n = 1958) of vetchling seeds (supplementary Table 1). This suggests that winged vetchling may have been part of a mixed *Lathyrus* crop rather than a weedy contaminant, although this distinction may be arbitrary (Jones and Halstead 1995). As with the glume wheats, however, they could also have been cultivated separately and processed or stored together. Spanish vetchling and

Supplementary Table 1: The proportion of vetchling seeds made up of winged vetchling within each sample type from Liman Tepe. HR = heavy residue.

Sample type	Flot	HR	Flot + HR
Number of vetchling seeds	10877	1101	1958
% winged vetchling	7	50	18

winged vetchling were recovered together in the only sample from Bakla Tepe containing either taxon.

2.2 Non-arable Wild Taxa

Fifteen of the 66 analysed taxa are considered likely to have entered the archaeobotanical record via non-arable pathways (supplementary Table 2). These include taxa adapted to wetland or coastal environments and species of shrubs that are unlikely to set seed under arable conditions. We excluded these taxa from subsequent analysis focussed on arable weeds. A further 15 taxa were classified as ambiguous in origin and may have entered the archaeobotanical record as arable weeds or via alternative pathways. This group was primarily composed of small and/or hard seeded taxa from dryland environments that could have derived from dung burning.

A number of taxa likely to have been arable weeds are also known as gathered or cultivated resources today. The green parts of species of *Brassica*, *Sinapis*, *Silene*, *Malva* and *Rumex* are consumed in Aegean Turkey (Ertuğ 2004). The seeds and green parts of *Coriandrum sativum* (coriander) are also widely consumed (Dogan 2012), a practice known in Late Bronze Age western Anatolia from large numbers of seeds recovered from the Uluburun shipwreck (Haldane 1993). None of these taxa, however, were recovered

Supplementary Table 2: The abundance and likely depositional pathways of arable weed/wild taxa. Only taxa present in three or more samples are shown. Taxa within each category are sorted by their abundance.

Family	Genus/species/type	Abundance (n = 49240)	Depositional pathway
Cistaceae	*Cistus creticus* L. type	52	Likely non-arable pathway
Lamiaceae	*Vitex agnus-castus* L.	25	
Isoetaeceae	*Isoetes histrix* Bory type	13	
Cyperaceae	*Cladium mariscus* (L.) Pohl	555	
Apiaceae	*Apium* L./*Bupleurum* L. type	92	
Fabaceae	Small Fabaceae spp.	400	Arable weeds/ non-arable pathway
Chenopodiaceae	*Chenopodium album* L. /*opulifolium* Schrad. ex Koch & Ziz	43	
Poaceae	*Poa trivialis* L. type	66	
Poaceae	*Phleum subulatum* (Savi) Asch. & Graebn/*exaratum* Hochst. ex Griseb	46	
Polygonaceae	*Rumex acetosella* L.	63	
Caryophyllaceae	*Silene* L. sp.	22	
Fabaceae	*Vicia hirsuta* (L.) Gray type	34	
Poaceae	*Lolium remotum* Schrank type	574	Likely arable weeds
	Phalaris coerulescens Desf./*truncata* Guss. Ex Bertol/*brachystachys* Link type	153	
	Phalaris L. sp.	168	

	Phalaris aquatica L./ *paradoxa* L./*canariensis* L. type	106
Lamiaceae	*Marrubium* L. type	67
Poaceae	Large Poaceae indet. spp.	60
	Avena L. sp.	30
Plantaginaceae	*Plantago scabra* Moench	71
Ranunculaceae	*Ranunculus* L. smooth type	28
Poaceae	*Lolium temulentum* L.	42096
	Lolium L. small type	3492
	Triticum boeoticum Boiss	278
Malvaceae	Malvaceae	91
Poaceae	*Hordeum spontaneum* (K. Koch) Thell.	47
Polygonaceae	*Rumex conglomeratus* Murray*/sanguineus* L.	39
Brassicaceae	*Bunias erucago* L.	15
Fabaceae	*Scorpiurus muricatus* L.	31
Poaceae	*Brachypodium distachyon* (L.) P. Beauv. type	11
	Bromus Scop. sp.	13
Rubiaceae	*Asperula* L. sp.	11

as a cache of seeds indicative of storage in the assemblages under study here; nor were they restricted to samples containing crop processing waste (see below) and thus the discarded by-products of processing for consumption. Rather, their recovery alongside

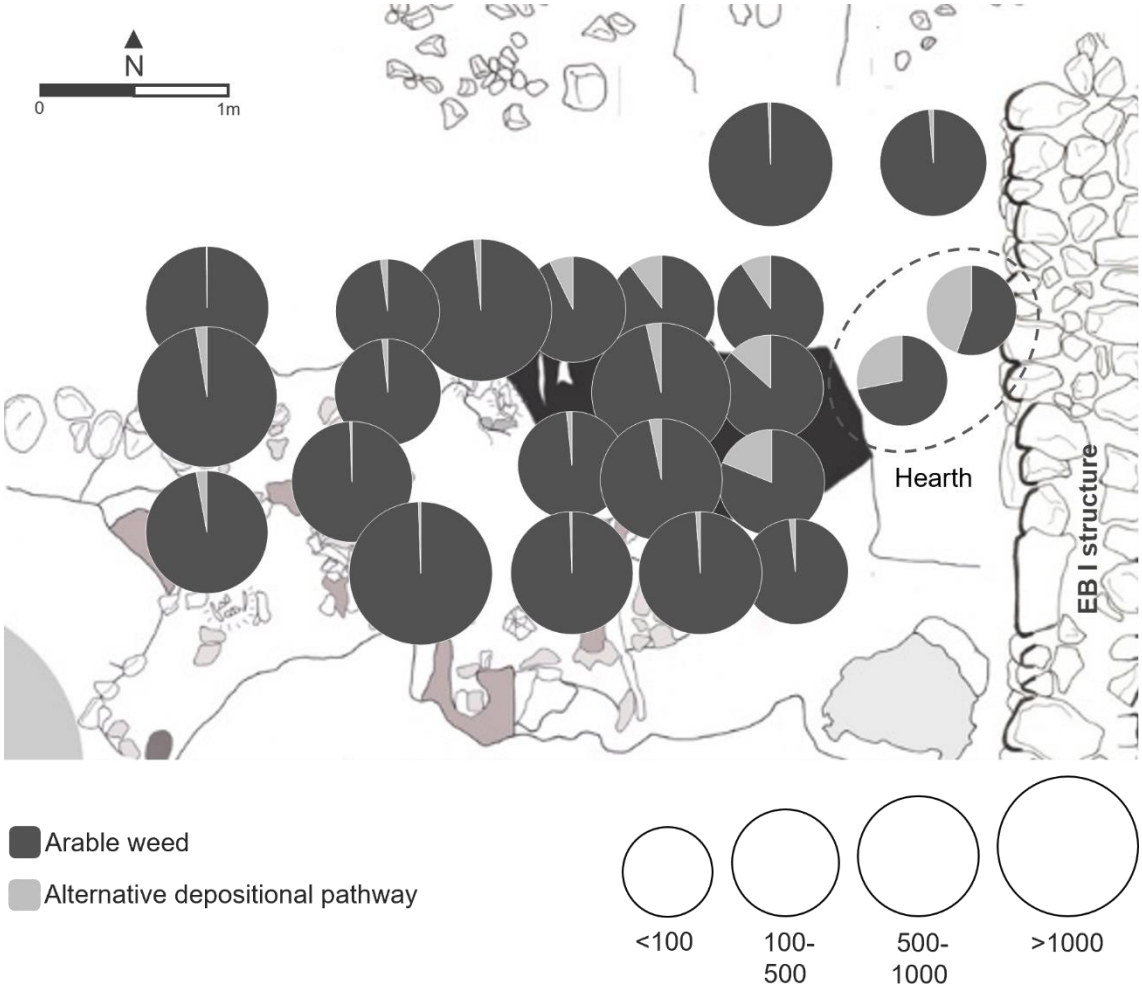
large numbers of obligatory weeds and crop grains suggests that they represent arable weeds.

Proportions of non-arable wild taxa also show patterning across the floor of the Liman Tepe burnt house, with high proportions in two samples from the eastern part of the floor (supplementary Figure 1). These are primarily small or dense-seeded taxa that are likely to survive digestion by ruminants (Gardener *et al*. 1993; Poppi *et al*. 1985; Wallace and Charles 2013) and thus may have been deposited in animal dung. Dung burnt as fuel is a common source of dung-derived remains within domestic contexts, suggesting that a hearth may have been located on this part of the floor. It is also possible that the remains may have derived from a storage structure; dung-lined baskets were used to store grain by recent farmers in the Aegean (Halstead 2014, 159-60). The mixed crop composition of these samples, however, is not consistent with a storage container in this location.

2.3 Data quality and representativeness

Differences in the recovery of archaeobotanical remains from the two sites in our study are likely to have created differing biases shaping the composition of the assemblages. The lack of a systematic sampling strategy and the use of bucket flotation for most of the samples from Bakla Tepe is likely to have favoured the recovery of large remains that floated (cereal grains) and hindered the recovery of small remains (arable weeds and chaff) and those that often do not float (large pulse seeds). This may have shaped the results of our analyses in two ways. The poor recovery of pulses would lead to their underrepresentation compared to cereals. This is clearly reflected in the very limited number of pulses in the assemblage from Bakla Tepe. The poor recovery of chaff and

Supplementary Figure 1: The distribution of archaeobotanical samples across the floor of the Liman Tepe burnt house, showing proportions of arable weeds and taxa from alternative depositional pathways.



weeds would lead to their underrepresentation compared to grains, in turn impacting the crop processing analyses based on the proportions of grain to chaff and weeds. This is most pronounced for the ratios of glume wheat grain to chaff shown in supplementary Table 3, meaning that the categorisation of the samples as products could result from recovery biases. These biases would have a more complicated impact on the weed-based processing analysis. A bias against the recovery of small seeds would hinder the

Supplementary Table 3: The results of the crop-based and weed-based crop processing analyses.

Site	Sample	Glume wheat grain:chaff ratio	Processing stage (Bogaard 2011)	Barley grain:chaff ratio	Processing stage (Jones 1990)	Weed-based processing stage (Jones 1987)
BT	H15	*c.* 2.5:1	Product	<30 grains	-	Product
	17324	*c.* 88:1	Product	<30 grains	-	Product
	22357/A	*c.* 113:1	Product	<30 grains	-	Product
	22285B	1:0	Product	<30 grains	-	<10 weeds
LT					F/s by-product	Product
	8385/1.1	<30 grains	-	4:1		
	8385/1.2	<30 grains	-	<30 grains		Product
	28271/7	*c.* 3:1	Product	1:0	Product	Product
	27331/1	*c.* 3:1	Product	<30 grains	-	Product
	27310/4	*c.* 4:1	Product	<30 grains	-	Product
	27358/4	*c.* 51:1	Product	1:0	Product	Product
	28339/1	*c.* 6:1	Product	1:0	Product	Product
	27394/1	1:0	Product	ca. 136:1	F/s by-product/ product	Product
	27381/2	*c.* 4:1	Product	<30 grains		Product
	27374/9	11:1	Product	1:0	Product	Product
	27393/1	*c.* 7:1	Product	1:0	Product	Product
	27395/4	5:1	Product	1:0	Product	Product
	27372/11	*c.* 3:1	Product	<30 grains	-	Product
	27398/1	4:1	Product	1:0	Product	Product

27398/7	10:1	Product	ca. 125:1	F/s by-product/ product	Product
27398/13	12:1	Product	1:0	Product	Product
28410/5	*c*. 3:1	Product	1:0	Product	F/s by-product
G012C1	*c*. 6.5:1	Product	1:0	Product	Product
G012C2	5.5:1	Product	1:0	Product	Product
G012C3	3:1	Product	1:0	Product	Product
G3C1	*c*. 3:1	Product	1:0	Product	Product
G4C1	5.5:1	Product	1:0	Product	Product
G4C2	*c*. 10:1	Product	1:0	Product	Product
SEC1	*c*. 1:1	Spikelet	1:0	Product	F/s by-product
DestrC1	*c*. 4:1	Product	1:0	Product	Product
FloorC1	*c*. 5.5:1	Product	159:1	F/s by-product/ product	Product
Floor C2	*c*. 4:1	Product	<30 grains	-	Product
NEC1	*c*. 11:1	Product	ca. 22:1	F/s by-product	Product
2004C1	*c*. 2:1	Product	<30 grains	-	Product
2004C2	*c*. 8:1	Product	1:0	Product	Product
2004C3	*c*. 2.5:1	Product	<30 grains	-	Product
NEC2	*c*. 13:1	Product	<30 grains	-	Product
FloorC3	*c*. 11:1	Product	1:0	Product	Product
7196	1:0	Product	1:0	Product	<10 weeds
24132A	672:1	Product	<30 grains	-	<10 weeds
17264B	1:0	Product	<30 grains	-	<10 weeds

detection of crop processing residues dominated by small-seeded weeds (winnowing and fine sieving by-products—Jones 1984). Both coarse sieving by-products and cleaned products contain large-seeded weeds, however, meaning that processing by-products may still be detected with the biases outlined above. For three of the four samples included in the crop processing analyses, the categorisation of samples based on the proportions of grain and chaff are supported by the categorisation based on the aerodynamic properties of the weeds. The one sample that did not contain enough weeds for the weed-based processing analysis is more reliably interpreted as a cleaned product based on the proportions of grain to chaff for the reasons outlined below.

A further important point is how these biases may have shaped our broader interpretation of the results. Contextual information is known for a single sample from Bakla Tepe (22285B), derived from a grill-plan house and categorised as a cleaned product in the crop processing analysis. We therefore infer that this sample represents crops that were stored in the house. For the reasons outlined above, it is possible that the categorisation of this sample as a clean product was due to biases against the recovery of chaff and arable weeds. While these categories of remains were present (although perhaps in reduced numbers) in the other samples from Bakla Tepe, however, this sample was almost entirely composed of cereal grains. This relative cleanness supports the interpretation of the sample as deriving from stored grain.

A further limitation to the data from Bakla Tepe is the small number of samples included in our study. An important factor in this is our minimum threshold of 30 crop grains/seeds for samples to be analysed. As outlined above, this reflects the relative proportions of taxa within the sample to a reasonable degree of accuracy and reliability.

The samples from Bakla Tepe (allowing for the recovery biases outlined above) therefore provide more reliable data for the floristic composition of their contexts than if the assemblage was composed of a higher number of smaller samples. Despite this, it is worth considering how the small number of samples from Bakla Tepe may have impacted our interpretations. The key inferences we draw from the archaeobotanical results from Bakla Tepe are:

1- the household storage of grain

2- the potential cultivation of einkorn and emmer wheat as a mixed crop

3- the potential cultivation of Spanish vetchling and winged vetchling.

Regarding point 1, we suggest that the archaeobotanical remains recovered from the grill-plan house are consistent with a cleaned crop store for the reasons outlined above. Whether this was also practiced within other grill-plan houses is unclear, but this does not hinder our broader interpretations regarding agricultural strategies at Bakla Tepe. Our hypothesis for extensive agricultural production is based on the volume of the free-standing structures being sufficient to hold the amount of grain needed to support up to 16 families even without storage inside the grill-plan houses.

Regarding point 2, this inference is supported by the abundant glume wheat remains in the samples from Bakla Tepe, as well as the frequent co-occurrence of these taxa in the samples at Liman Tepe. As highlighted in the main text, however, this inference requires further analysis to confirm. This is a key question to be addressed in ongoing stable isotope analysis of archaeobotanical remains from Bakla Tepe and Liman Tepe.

Regarding point 3, the presence of both Spanish vetchling and winged vetchling at Bakla Tepe alongside their evident cultivation at Liman Tepe and the total absence of Spanish vetchling within other archaeobotanical assemblages in Anatolia is striking. We remain cautious in our interpretation regarding the cultivation of these taxa at Bakla Tepe, however, which must be confirmed by further samples from this site.

The primary limitation to the archaeobotanical assemblage from Liman Tepe is that all but one sample derive from a single house. It is therefore possible that other households cultivated crop taxa that were not present in the burnt house, although the same narrow range of crops from the burnt house is present in the sample recovered from a secondary deposit 50 m to the south. As highlighted in the main text, the emergence of extensive farming practices as evidenced in the reduced range of crops cultivated at Liman Tepe compared to earlier sites (and supported by preliminary results from isotopic analysis of crop remains from the burnt house) also need not apply to the settlement as a whole. As outlined by Bogaard *et al*. (2019), it is likely that extensive farming systems first emerged within communities in which different households cultivated crops under a range of intensities.

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Paper 2

From horticulture to agriculture: new data on farming practices in Late Chalcolithic western Anatolia

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Abstract

We combine stable isotope analysis of crop remains with functional ecological analysis of their associated weeds to investigate arable farming strategies at Late Chalcolithic Bakla Tepe and Liman Tepe, western Anatolia. Our results reveal 'low-input' cultivation practices at both sites, with cereals cultivated on plots with low soil fertility that received low to moderate levels of manuring. In contrast, water supply was unlikely to have been a limiting factor to crop cultivation. Land management strategies were adapted to the tolerances of different crops, with pulses more intensively manured than cereals at Liman Tepe and barley cultivated on drier soils than glume wheats at both sites. This attests to a spatial differentiation in crop cultivation that resembles the practices of recent farmers in the Aegean engaged in extensive systems of land use. Expanded forms of these agricultural systems were used to amass agrarian wealth by elites occupying the citadels of later Early Bronze Age (EB/EBA) western Anatolia, suggesting that the

agroecological foundations of this phenomenon were already in place by the late fourth millennium BC. In contrast to the pronounced wealth inequality visible in EBA citadels, however, we suggest that extensive land use fostered productive equality through cooperation between the small-scale households of the Late Chalcolithic. It was only with the emergence of more extended domestic units in the EBA, capable of greater autonomy in arable farming, that disparities in production could be maintained over the long-term. This shift may have been crucial to the emergence of sustained high wealth inequality in the later EBA.

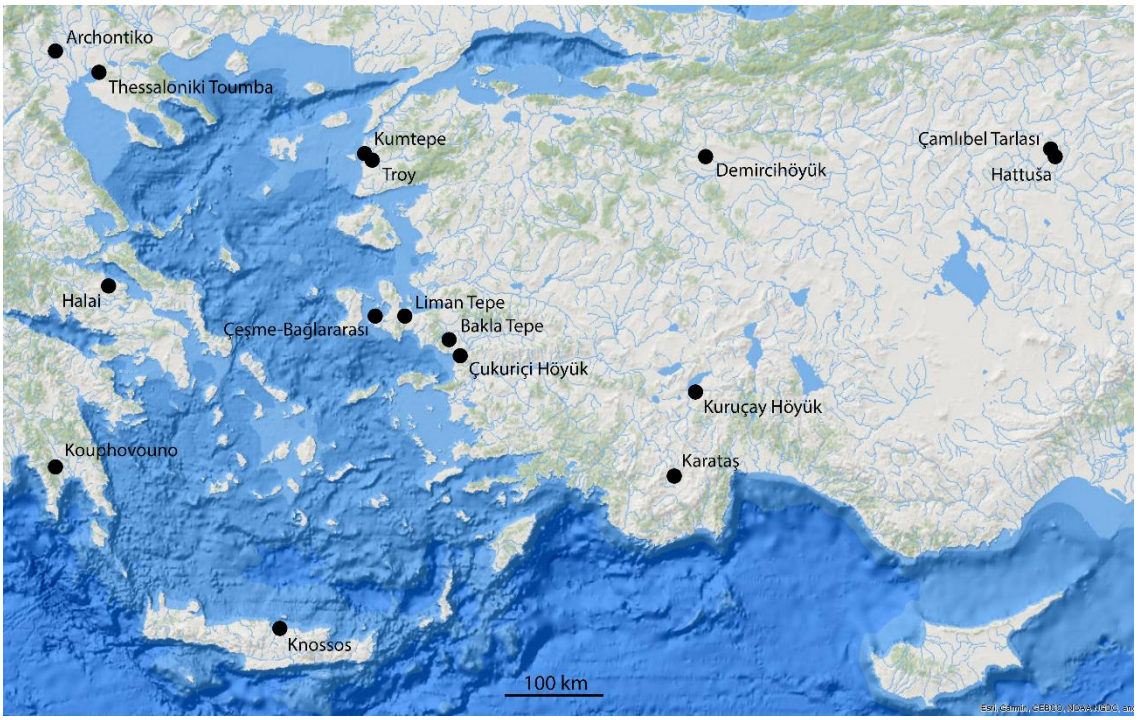
1. Introduction

Models of Neolithic farming in western Eurasia suggest that agricultural systems were small-scale and characterised by high labour inputs to enhance productivity, akin to a form of 'intensive horticulture' (Halstead 1981; 1987; 1989; 2014; Bogaard 2005; Halstead and Isaakidou 2020). This has found empirical support in the form of direct evidence for past crop growing conditions and land management practices. The cultivation of fertile plots with high levels of tillage and manuring have been identified in Neolithic central Europe (Bogaard 2004; Styring *et al*. 2016) and Greece (Vaiglova *et al*. 2014; 2020; 2021; Nitsch *et al*. 2019), continuing in a diversified form into the Bronze Age in northern Greece (Jones 1992; Nitsch *et al*. 2017). By the Late Bronze Age (LBA), many regions saw the emergence of large urban settlements supported by extensive agricultural systems in which draught cattle facilitated the cultivation of crops over large areas of land with low inputs (Styring *et al*. 2017a; 2017b; Nitsch *et al*. 2019; Diffey *et al*. 2020). These agricultural developments may have been crucial to the emergence of the pronounced and sustained wealth inequality visible within later prehistoric western

Eurasia as extensive land use increased the important of land-based wealth that could be amassed and inherited across generations (Bogaard *et al*. 2019).

Case studies providing insights into arable production strategies exist for the ends of this agricultural spectrum, but data from societies utilising intermediate farming systems are limited. Analogy with recent non-mechanised farmers suggests that these took the form of non-urban settlements in which domestic production utilised low-input forms of crop cultivation (e.g., Halstead and Jones 1989). In western Anatolia, the reoccupation of alluvial plains and expansion of settlement into coastal zones during the Late Chalcolithic (*c*. 4250-3100/3000 BC) plausibly entailed the emergence of such forms of production, as large settlement areas and restrictions on cultivable land potentially enforced extensive patterns of land use. Evidence for large-scale agricultural storage within the citadel of later Early Bronze Age (EB/EBA) Troy (Thumm-Doğrayan 2016; Thumm-Doğrayan *et al*. 2019) suggests that extensive forms of arable production played an important role in elite power within the first regional centres of later EBA western Anatolia (*cf.* Bachhuber 2015, 130-49). If low-input cultivation was utilised in the Late Chalcolithic, it would suggest that the agroecological foundations of Bronze Age complexity within this region were laid prior to the third millennium BC. In an earlier study, we suggested that large-scale storage structures and narrow crop spectra at Late Chalcolithic settlements in coastal western Anatolia were consistent with the emergence of more extensive forms of crop cultivation that in the Neolithic (Maltas *et al*. forthcoming). In this paper, we test this hypothesis through a novel combination of archaeobotanical analyses, stable isotopes and functional weed ecology, employed to investigate crop growing conditions at Late Chalcolithic Bakla Tepe and Liman Tepe, Izmir, western Anatolia (Figure 1). We also aim to shed new light on how agricultural

Figure 1: Locations of the sites mentioned in the text.



strategies were adapted to site-specific ecologies within coastal western Anatolia and thus the diversity of farming practices employed within the prehistoric Aegean.

2. The 'weed + isotope' approach to establishing crop husbandry practices and arable land management strategies

In this study, we interpret the arable weed assemblage using a functional ecological approach (Hodgson 1989; 1990; 1991). The methodological background of this approach to archaeobotany is outlined in Charles *et al*. (1997) and Jones (2002). In brief, the functional approach utilises measurements of key physical or behavioural traits ('functional attributes') of weed taxa that are indicative of species' potential in relation to major ecological variables that constitute specific growing environments. Functional

attribute measurements of *modern* specimens of *archaeological* weed species are compared to those of weed floras in modern fields and used to reconstruct the ecological factors making up past crop growing conditions. This allows both the translation of modern cultivation practices to the past as well as the detection of novel combinations of practices that are not known today (Jones 2002). Through studies of the floristic composition and functional ecological profiles of weed flora from traditionally cultivated fields in southern Europe (Jones *et al*. 2000; Bogaard *et al*. 2016) and Morocco (Bogaard *et al*. 2018), a set of functional attributes has been identified that successfully distinguishes between the weed flora of cultivation regimes with higher and lower levels of soil productivity and/or mechanical disturbance (i.e., cultivation intensity). To distinguish between cultivation regimes, discriminant analysis is used to extract a discriminant function combining the functional attributes to maximise the separation between regimes (Bogaard *et al*. 2016). The discriminant function can be used to classify archaeobotanical weed floras as indicative of higher or lower intensity regimes by entering them into the classification phase as samples of an 'unknown' regime.

Stable isotope analysis of crop remains provides a complementary means of investigating past arable land management strategies. For C_3 crops such as wheat, barley and pulses, $\delta^{13}C$ (the ratio of the isotopes ^{13}C:^{12}C relative to a universal standard) values are influenced by the movement of carbon dioxide through stomata, which is in turn influenced by crop water status, with the greatest discrimination against the heavier isotope ^{13}C when stomata are open during periods when water is readily available during carbon fixation (Farquhar *et al*. 1989). In dry conditions where water availability can restrict plant growth, the water status of archaeological grains can be interpreted with

reference to both climate and agricultural strategies aimed at preventing water stress (Wallace *et al*. 2013; 2015). Crop $\delta^{15}N$ (the ratio of the isotopes ^{15}N:^{14}N) values largely reflect the soil nitrogen composition when the crop was grown. Crop $\delta^{15}N$ values may be influenced by a range of factors, such as aridity (Heaton 1987; Aranibar *et al*. 2004; Styring *et al*. 2017a) and exposure to saltwater spray (Virginia and Delwiche 1982; Heaton 1987), but a major potential factor is manuring, with applications of animal manure found to increase the $\delta^{15}N$ of arable crops by up to 10‰ based on the amount and frequency of manuring (Fraser *et al*. 2011). Manuring has a much smaller impact on the $\delta^{15}N$ values of pulses, which fix nitrogen directly from the atmosphere, but particularly intensive manuring has been shown to elevate pulse $\delta^{15}N$ values (Fraser *et al*. 2011).

A number of recent studies (Bogaard *et al*. 2016; 2018; Styring *et al*. 2017b; Diffey *et al*. 2020) have combined functional weed ecology and stable isotope analysis to reconstruct past agricultural systems. The two approaches complement each other by providing evidence for the general type and productivity of cultivation as well as the contributions of specific land management practices. They are also subject to different sources of error and ambiguity, meaning that interpretations based on evidence from both approaches are more robust than those based on a single form of evidence (Bogaard 2015).

3. The study sites

3.1 Liman Tepe

The settlement mound of Liman Tepe occupies a peninsula extending into the Aegean Sea from the southwest coast of the Gulf of Izmir (Figure 1). Paleogeographic reconstruction of the ancient coastline around Liman Tepe suggests that the mound was

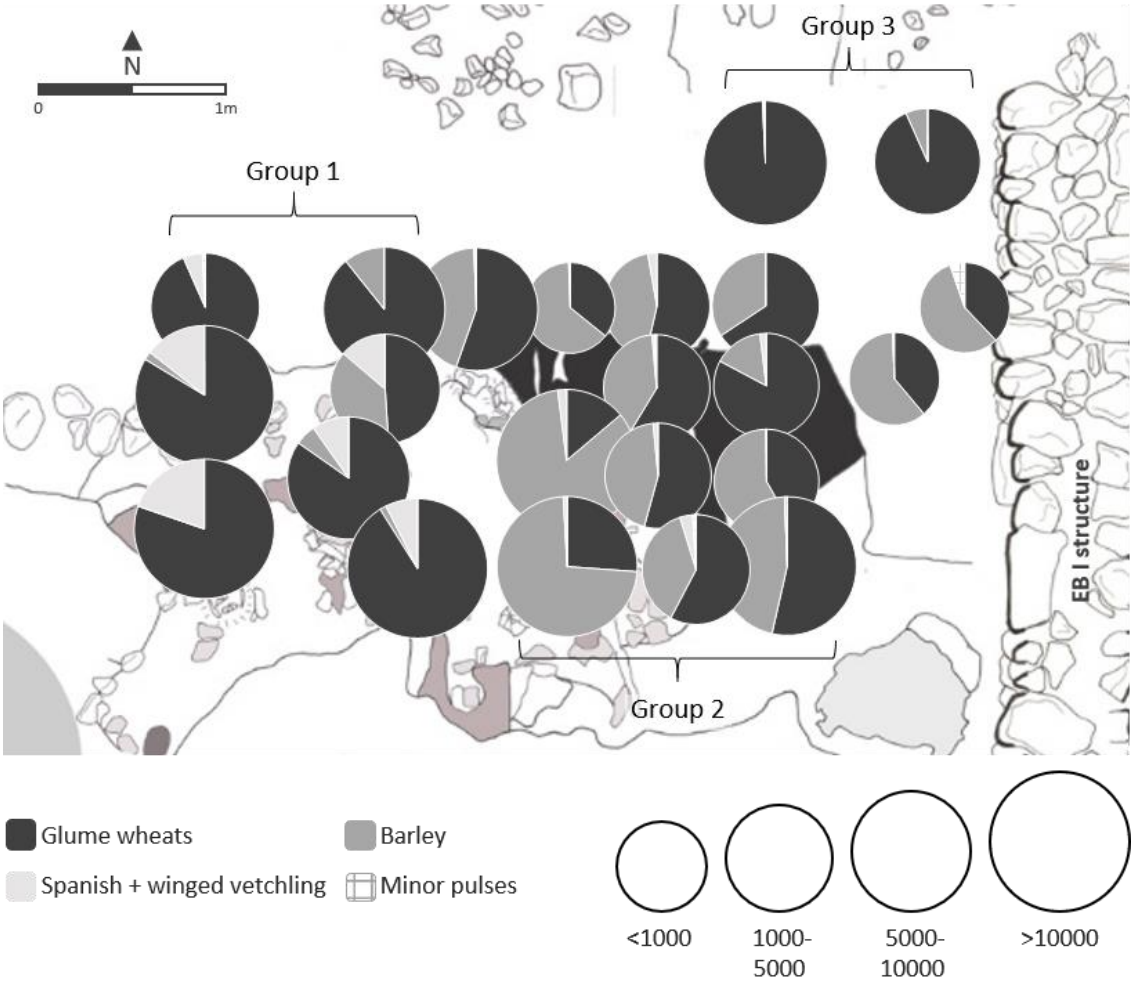
some 150 metres off the coast of the mainland during the Late Chalcolithic and was accessed via a weak sandbar (Goodman *et al*. 2009; Riddick *et al.* 2020). The Urla-Iskele plain spreads to the southeast of the mound and is enclosed by rocky hills.

Limited Late Chalcolithic remains have so far been uncovered, but a settlement area of *c*. 1-1.5 ha in size is plausible based on the area of the mound present above sea level. Excavated remains include part of a severely burnt house from which large quantities of grain were recovered *in situ* (Figure 2) (Tuncel and Şahoğlu 2018; Maltas *et al*. forthcoming). Grain from the deposit was radiocarbon dated to 3190-3130 cal. BC (Tuncel and Şahoğlu 2018). The grain was fully processed and plausibly represented the stored harvest of a single year (Maltas *et al*. forthcoming). Crop remains recovered from the burnt house were dominated by einkorn (*Triticum monococcum* L.) and emmer (*T. dicoccum* Schübl.) ('glume wheats'), hulled barley (*Hordeum vulgare* L.), Spanish vetchling (*Lathryus clymenum* L.) and winged vetchling (*Lathyrus ochrus* (L.) DC.) (Figure 2; Figure 3). Distinct concentrations of glume wheat and barley grains on the house floor were consistent with the separate storage deposits of each crop. Einkorn and emmer wheat were recovered together in every archaeobotanical sample and are hypothesised to have been cultivated as mixed crop and/or processed and stored together. Spanish vetchling and winged vetchling also frequently co-occurred and may have been grown and/or processed and stored together.

3.2 Bakla Tepe

Bakla Tepe is a settlement mound in the Cumaovası plain, southern Izmir (Figure 1). The Tahtalı River that ran next to the site was dammed in 1999, submerging all but the upper parts of the mound.

Figure 2: Plan of the Liman Tepe burnt house showing the size and composition of archaeobotanical samples recovered from the house floor. The groups of glume wheat grains are defined based on their composition and location on the floor.



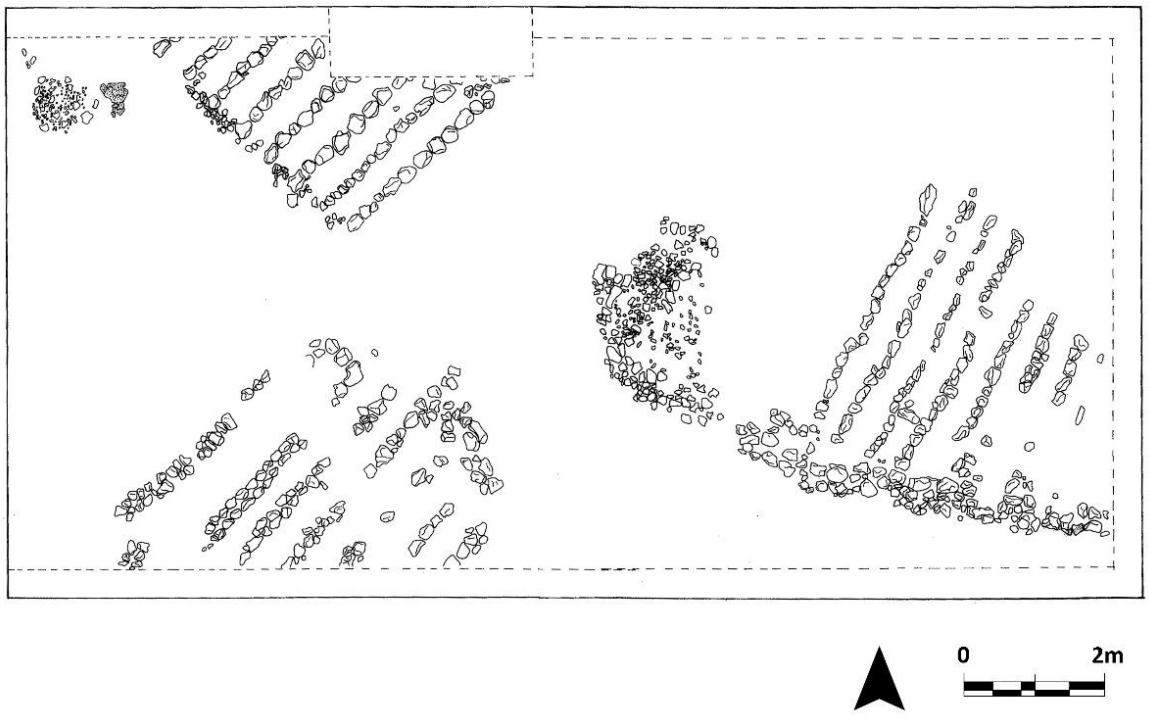
The Late Chalcolithic (3300-3140 cal. BC) settlement is characterised by free-standing grill-plan structures (Figure 4), sometimes with an apsidal end, as well as non-grill plan apsidal structures spread across an area of *c.* 8.75 ha (Erkanal and Özkan 1999; Şahoğlu and Tuncel 2014; Tuğcu 2019). The spacing of architectural remains across the settlement suggests that it was not densely occupied. As the primary architectural unit

Figure 3: Archaeobotanical crop remains recovered from the Liman Tepe burnt house, all in lateral view. a: einkorn, b: emmer, c: barley, d: Spanish vetchling.



at the site, the grill-plan structures are interpreted as houses and their size (averaging 27.5 m^2 for the grill-plan structures alone and 41 m^2 with the apsidal end) suggests that they were occupied by small families (*cf.* Watson 1978, 138; Kramer 1979, 155). This aligns with evidence for agricultural storage on scales consistent with small families elsewhere in Late Chalcolithic western Anatolia (Maltas *et al.* forthcoming). Free-standing circular structures 1-3 m in diameter were uncovered close to the houses and are interpreted as extramural storage containers for grain. Their large estimated volumes and lack of associations with individual grill-plan houses suggest that they may

Figure 4: Late Chalcolithic grill-plan structures from Bakla Tepe (after Tuğcu 2019, 435 Fig. 8).



have been used by multiple households (Maltas *et al.* forthcoming). Evidence for the social morphology of the settlement is limited but suggests an absence of marked socio-economic inequality or a central authority. Crop remains recovered from Bakla Tepe are dominated by einkorn, emmer and barley, with small quantities of pulses including Spanish vetchling and winged vetchling (Maltas *et al*. forthcoming). As at Liman Tepe, einkorn and emmer wheat were frequently recovered together and are hypothesised to have been grown as a mixed crop and/or processed and stored together.

4. Materials and methods

4.1 Functional ecological analysis of arable weeds

Following Bogaard *et al*. (2018), we used a suite of functional attributes primarily related to arable fertility but also influenced by mechanical disturbance to infer the intensity of crop cultivation. The functional attributes used were mean specific leaf area (SLA: leaf area/dry leaf weight), leaf area per node/leaf thickness, canopy diameter and canopy height. Full descriptions and the ecological significance of each attribute are outlined in Jones *et al*. (2000) and Bogaard (2004). Weed taxa identified to genus level were included in the analyses if they represented fewer than five potential species. In these cases, values of the functional attributes for each potential species were averaged. In an earlier study, we established the likelihood of wild taxa recovered alongside crop grains to have been deposited as arable weeds or via alternative depositional pathways (Maltas *et al*. forthcoming, supplementary material). We consider the results of the functional ecological analysis with potentially non-arable taxa included and excluded. Only samples containing ten or more seeds of three or more weed taxa were included in the analyses to maintain a reasonable degree of representativeness.

Twenty-five samples (24 from Liman Tepe and one from Bakla Tepe) were included in the functional ecological analysis, all of which were dominated (>70%) by grains of glume wheats and/or barley.

4.2 Sampling and preparation of crop remains for stable isotope analysis

For stable isotope analysis, we sampled grains from the *in situ* storage deposits on the floor of the Liman Tepe burnt house and from inside a grill-plan house from Bakla Tepe.

Grains of einkorn, emmer, hulled barley and Spanish vetchling were analysed from the burnt house. Both einkorn and emmer were analysed from each of three clusters of grain ('groups') on the house floor in order to assess the inference that they represent two discrete storage deposits (groups 1 and 3) and grain that spread from them (group 2) (Figure 2) (Maltas *et al*. forthcoming). We also aimed to test the hypothesis that einkorn and emmer were grown together as a mixed crop, arising from their frequent co-occurrence in archaeobotanical samples from both sites. Grains of einkorn, emmer and hulled barley were analysed from the grill-plan house from Bakla Tepe. The grains were fully processed and plausibly represent stored crops but may also derive from tertiary context that contained grain from multiple sources.

In this study, we analysed single grains individually, as opposed to bulk samples of multiple grains (*cf*. Kanstrup *et al*. 2012), in order to reveal the variation in carbon and nitrogen isotope values between grains within individual archaeobotanical samples. This granularity is important to assess the spatial patterning of crop isotope values within the Liman Tepe burnt house, where the boundaries between the clusters of grain comprising each group are not clear meaning that individual archaeobotanical samples may contain grain from multiple groups. Carbon and nitrogen isotope values are highly variable at the level of individual grains, with variations of up to 2‰ in $\delta^{15}N$ and 0.7‰ in $\delta^{13}C$ between cereal grains in a single ear (Bogaard *et al*. 2007; Heaton *et al*. 2009). As such, we also considered the average values for each archaeobotanical sample when comparing the isotopic values of different crop species or samples. Where possible, we aimed to analyse 10 grains from each archaeobotanical sample. This number was found to adequately characterise the mean $\delta^{15}N$ value for a given group of grains (Kanstrup *et al*. 2012).

A total of 124 grains from 13 archaeobotanical samples were analysed from the two sites. Only grains showing little to no morphological distortion and with dense interior structures consistent with charring within the 'optimal charring window' of 215-260°C (Charles *et al*. 2015; Nitsch *et al*. 2015) were selected for analysis. The presence of soil-derived contaminants within the archaeological grains that may have required pre-treatment to remove prior to analysis (*cf*. Vaiglova *et al*. 2014) was identified using a Fourier Transform Infrared Spectroscopy with Attenuated Total Reflectance (FTIR-ATR). FTIR was conducted on each taxon from the Liman Tepe burnt house and einkorn from the Bakla Tepe grill-plan house. The resulting FTIR spectra were baseline corrected using Agilent Resolution Pro. No contamination comparable to grains experimentally contaminated by Vaiglova *et al*. (2014) was identified in archaeobotanical grains that were gently scraped to remove any surface contamination visible under x7-45 magnification (see supplementary material). They were therefore not subject to pre-treatment.

4.3 Stable isotope analysis

Single grains were crushed using an agate mortar and pestle. The resulting powders were weighed into tin capsules for IRMS analysis on a Sercon EA-GSL mass spectrometer. Raw isotope ratios were calculated using an internal alanine standard. Three-point normalisation of $\delta^{13}C$ determinations to the Vienna Peedee Belemnite scale (VPDB) and $\delta^{15}N$ determinations to atmospheric N_2 was carried out using the standards alanine, seal collagen and cow collagen. EMA P2 and leucine were used as check standards. Following Kragten (1994), measurement uncertainties were calculated as the combined uncertainty of the raw measurement and reference standards. The calculations were

carried out using the statistical programming language R (3.2.3). The average measurement uncertainties for $\delta^{13}C$ and $\delta^{15}N$ values of carbonised crop remains were 0.25‰ and 0.43‰ for Liman Tepe and 0.25‰ and 0.38‰ for Bakla Tepe, respectively. $\delta^{13}C$ and $\delta^{15}N$ values of archaeological grains were corrected for the effect of charring by subtracting 0.11‰ and 0.31‰, respectively. These are the average offsets between uncarbonised crop grains and those experimentally charred at a range of time intervals and temperatures within the optimal charring window that result in undistorted charred seeds with dense interior structures (Nitsch *et al*. 2015). $\delta^{13}C$ values were converted into $\Delta^{13}C$ values to allow comparison between archaeological and modern reference stable carbon isotope determinations. $\Delta^{13}C$ values were calculated from the determined $\delta^{13}C$ values ($\delta^{13}C_{plant}$) and a $\delta^{13}C_{air}$ value approximated by the AIRCO2_LOESS system (Ferrio *et al*. 2005). The equation follows Farquhar *et al*. (1989):

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

4.4 Statistical analysis

Statistical analysis was carried out using SPSS 27. Two-tailed oneway ANOVA and post-hoc Tukey's tests were used to compare more than two groups with equal variance. Two-tailed Kruskall-Wallis and post-hoc Dunn tests were used to compare more than two groups with non-equal variance. Two groups were compared using t-tests. Equality of variance was established using Levene's test.

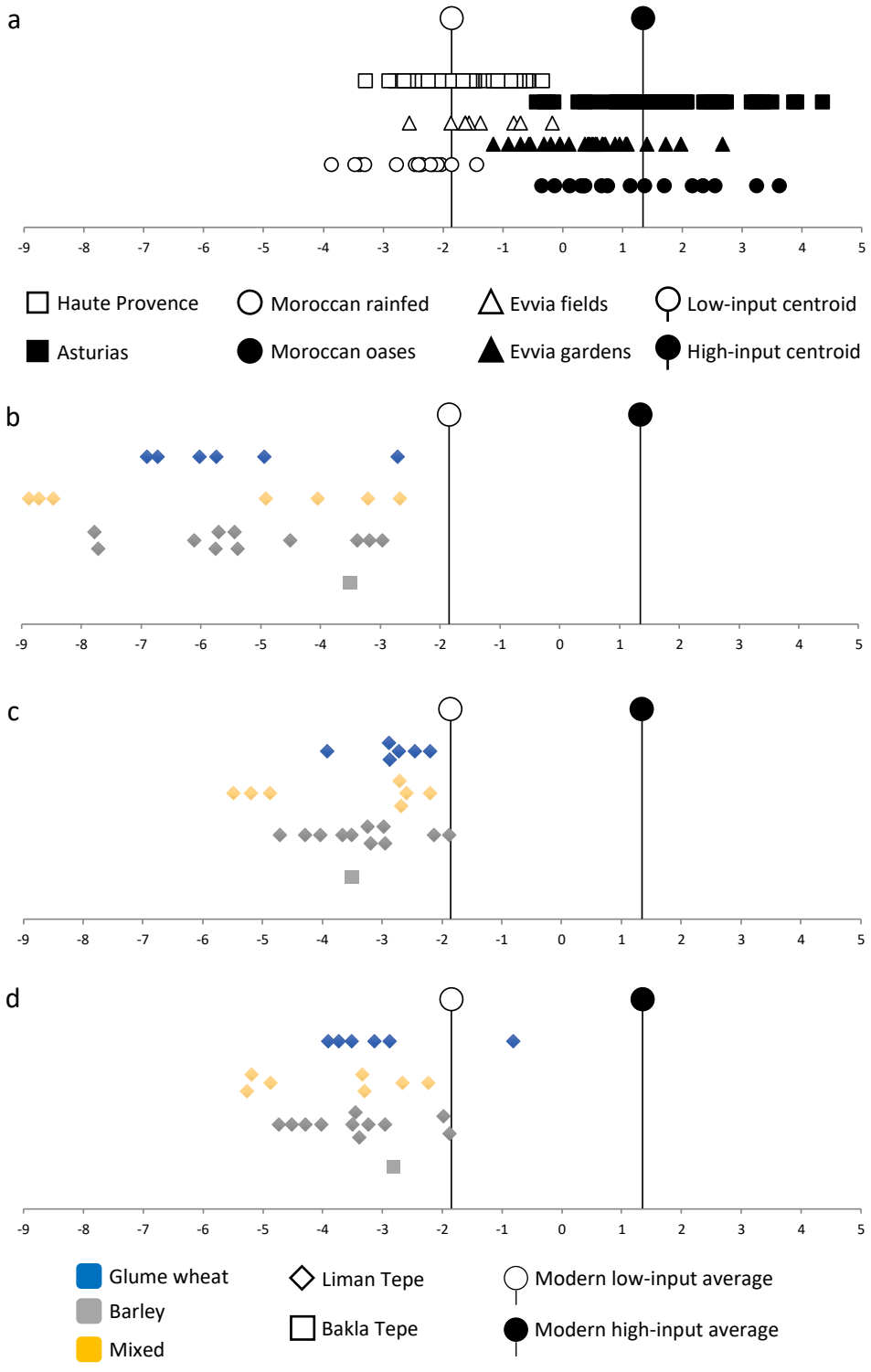
5. Results

5.1 Functional ecological analysis

Figure 5 compares the discriminant scores of the samples including all weed/wild taxa (Figure 2b), arable weeds and taxa of ambiguous origin only (Figure 2c) and arable weeds only (Figure 2d) with those of modern agrosystems (Figure 2a). With all three datasets, the majority of samples loaded towards the negative end of the discriminant function and were classified as 'low-input', suggesting that crops were cultivated under conditions of low fertility and likely also low disturbance. It is unlikely that this is due to differences in climate or local environment between the study sites and those surveyed. The average annual rainfall of the study sites exceeds that of Evvia and the southern Moroccan rainfed fields (Turkreş 1996; Bogaard *et al.* 2016b; Hellenic National Meteorological Service 2019;). The geology and natural vegetation of the study sites and the Evvia study region (Jones *et al*. 1999) are also extremely similar.

The inclusion of wild taxa that were unlikely to have been arable weeds had a significant impact on the results. When these taxa were removed, the samples from Liman Tepe loaded more positively along the discriminant function and mostly within the range of the modern low-input agrosystems. This was likely due to the removal of taxa from the Cyperaceae family, characteristic of relatively unproductive wetland environments (Davis 1968-2000; *cf*. Green *et al*. 2018, 35). Indeed, their removal had no impact on the sample from Bakla Tepe, located further inland. Taxa of ambiguous origin had only a minor impact on the results. When removed, some samples from Liman Tepe and the sample from Bakla Tepe loaded slightly more positively along the discriminant function

Figure 5: The relationship of archaeobotanical samples to the discriminant function produced from modern surveyed fields. Archaeobotanical samples are coded according to their dominant crop content (>60%). a: modern surveyed fields (adapted from Bogaard *et al.* 2018), b: archaeobotanical samples including all weed/wild taxa, c: including likely arable weeds and ambiguous taxa, d: including likely arable weeds only.



but still within the range of the modern low-input agrosystems. The classification of the samples as low-input is therefore considered robust. Excluding non-arable wild taxa, the distribution of the archaeological samples is most comparable to the Moroccan rainfed terraces (*cf*. Bogaard *et al*. 2016b). The samples from Liman Tepe show a greater degree of variability, however, including more negative scores indicative of even less productive arable environments. This suggests that the crops from Liman Tepe were cultivated under variable levels of (low) fertility.

5.2 Stable isotope analysis

Full results of the stable isotope analysis are provided in supplementary Table 1. We assessed the reliability of the stable isotope measurements by comparing their C:N ratios to those of modern cereals and pulses experimentally charred by Fraser *et al*. (2013). We infer that similar C:N ratios to modern seeds suggest that the original $\delta^{13}C$ and $\delta^{15}N$ can be obtained from the archaeobotanical remains as they have not been too distorted by post-depositional processes. The ratios of archaeobotanical cereal grains were compared to modern einkorn, emmer and hulled barley. No data was available for modern Spanish vetchling so the ratios of archaeobotanical pulse seeds were compared to modern pea, lentil and broad bean. The C:N ratios of the archaeobotanical cereal grains range from 17.6 to 36.0, compared to 17.9 to 28.2 for the modern grains. The ratios of the archaeobotanical pulse seeds range from 9.1 to 13.7, compared to 8.8 to 13.1 for the modern seeds. In both cases, the differences between the archaeobotanical and modern ratios were not significant (two-tailed t-test between the ratios of archaeobotanical and modern cereals, p = .235; between the ratios of archaeobotanical

and modern pulses, p = .995). The archaeobotanical remains also follow the higher %N in pulses than cereals observed in the experimentally charred seeds.

Following Szpak and Chiou (2019), we also plotted grain $\delta^{15}N$ values against their C:N ratio in order to assess the presence of patterns indicative of post-burial alteration of $\delta^{15}N$ values through mechanisms such as bacterial degradation (Hartman *et al*. 2020). The plots are provided in supplementary Figure 2. No correlations were apparent, suggesting an absence of post-burial alterations to $\delta^{15}N$ values.

5.2.1 Results from Liman Tepe

The isotope results from Liman Tepe are summarised in Table 1 and Figure 6a. The average $\delta^{13}C$ values of einkorn and emmer are similar, although emmer has a broader range than einkorn. The $\delta^{13}C$ values for six-row barley are similar to the glume wheats. $\delta^{13}C$ values of modern barley grains tend to be higher than wheat grown under the same water availability, however, with a difference of *c*. 2‰ for six-row barley and *c*. 1% for two-row barley (Wallace *et al*. 2013). $\delta^{13}C$ determinations of Neolithic grains from southern Germany suggest that the latter value is also applicable to *ancient* six-row barley; wheat and six-row barley grown in the same year were found to have $\delta^{13}C$ values 1.1‰ different despite being unlikely to have been cultivated under differently watered soils (Styring *et al*. 2017). The $\delta^{13}C$ values of Spanish vetchling show a similar range to emmer but the highest standard deviation of any taxon. This is consistent with modern experimental data suggesting that pulse $\delta^{13}C$ values are more sensitive to variation in water availability than cereals (Wallace *et al*. 2013).

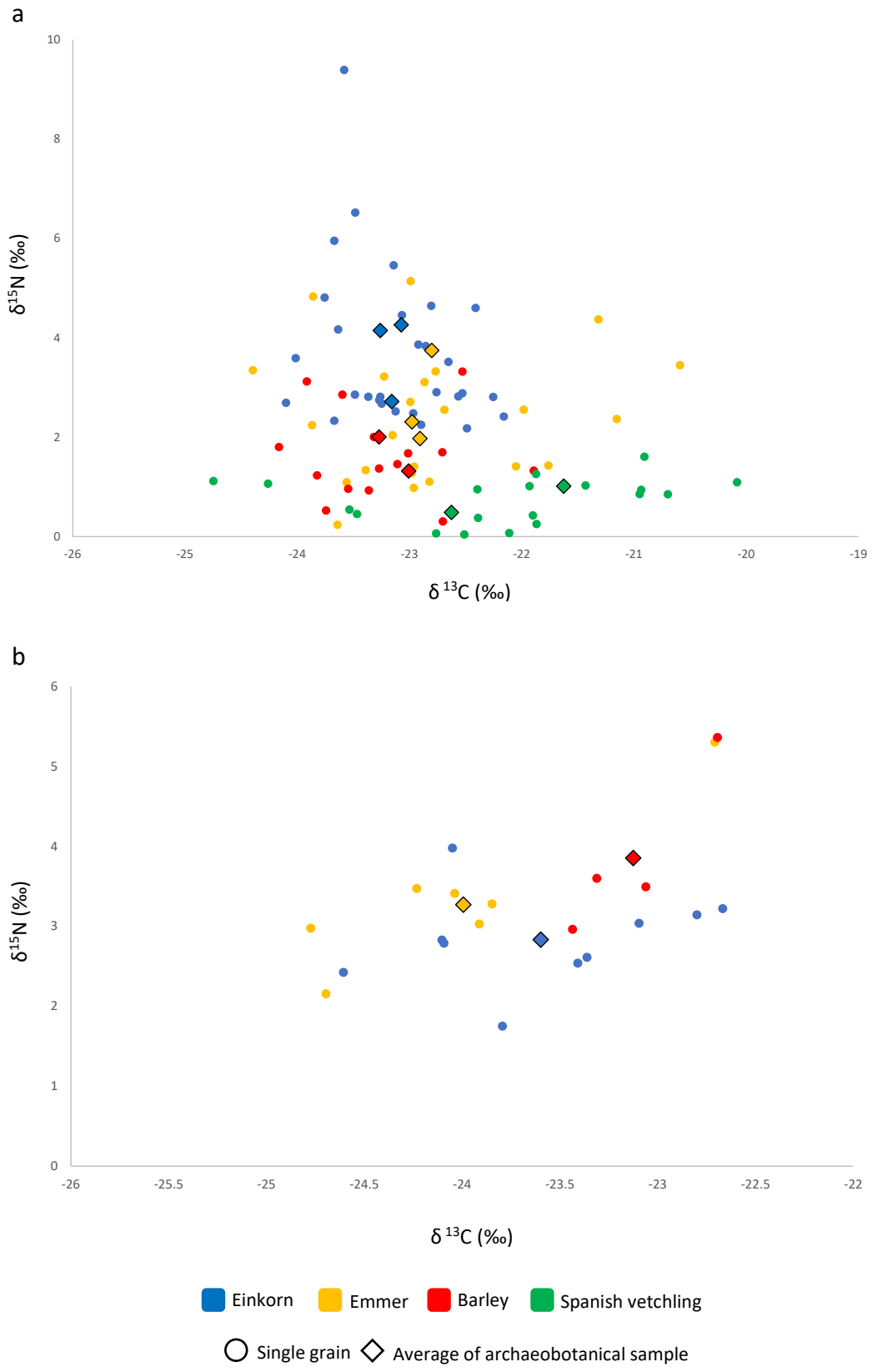
The broad range of $\delta^{15}N$ values of einkorn is due to a particularly high value of a single grain, with all other grains falling below 7‰. Emmer has a narrow range of $\delta^{15}N$ value,

Table 1: Stable isotope results from Liman Tepe and Bakla Tepe. Values have been corrected for a charring offset of -0.11‰ for $\delta^{13}C$ and -0.31‰ for $\delta^{15}N$.

	Liman Tepe						
	Species	**No. grains**	**High**	**Low**	**Average**	**Std. deviation**	**Range**
$\delta^{13}C$ (‰)	Einkorn	30	-22.2	-24.8	-23.2	0.6	2.6
	Emmer	28	-20.6	-24.4	-22.9	0.9	3.8
	Barley	20	-21.8	-24.2	-23.1	0.7	2.3
	Spanish vetchling	20	-20.1	-24.8	-22.1	1.2	4.7
$\delta^{15}N$ (‰)	Einkorn	29	9.4	2.2	3.7	1.6	7.2
	Emmer	27	5.1	0.2	2.6	1.2	4.9
	Barley	14	3.3	0.3	1.6	0.9	3.0
	Spanish vetchling	19	1.6	0.1	0.7	0.4	1.6
	Bakla Tepe						
$\delta^{13}C$ (‰)	Einkorn	10	-22.7	-24.6	-23.6	0.6	1.9
	Emmer	9	-22.7	-24.8	-24.0	0.6	2.1
	Barley	4	-22.7	-23.4	-23.1	0.3	0.7
$\delta^{15}N$ (‰)	Einkorn	10	4.0	1.8	2.8	0.6	2.2
	Emmer	8	5.3	2.2	3.3	0.9	3.2
	Barley	5	5.4	3.0	4.1	0.9	2.4

and a slightly lower average than einkorn. The $\delta^{15}N$ values of barley are lower than both glume wheats. The particularly low values of Spanish vetchling are typical for pulses, which obtain most of their nitrogen from the atmosphere (with a $\delta^{15}N$ value of 0‰) and are therefore less affected by soil ^{15}N enrichment than cereals (Fraser *et al*. 2011).

Figure 6: δ ^{13}C and δ^{15}N values of archaeobotanical grains from a: Liman Tepe and b: Bakla Tepe.



5.2.2 Results from Bakla Tepe

The isotope results from Bakla Tepe are summarised in Table 1 and Figure 6b. The $\delta^{13}C$ values of einkorn and emmer are very similar in both their range and average. The $\delta^{13}C$ values of barley are lower than the glume wheats and have a narrower range, indicating less variable conditions of water availability. The $\delta^{15}N$ values of emmer from Bakla Tepe are slightly higher than einkorn. In contrast to Liman Tepe, barley has the highest $\delta^{15}N$ values of any species from Bakla Tepe.

6. Discussion

6.1 Cereal cultivation strategies at Liman Tepe and Bakla Tepe

Figures 7 and 8 compare crop $\Delta^{13}C$ values from Liman Tepe and Bakla Tepe with bands for poorly to well-watered crops, based on the ranges of $\Delta^{13}C$ values of modern crops grown under known watering conditions (Wallace *et al*. 2013). The majority of glume wheat $\Delta^{13}C$ values from the two sites are consistent with moderate to well-watered crops. The $\Delta^{13}C$ values of einkorn and emmer are not significantly different at either site (two-tailed oneway ANOVA and post hoc Tukey's test between einkorn and emmer from Liman Tepe, p = .663; between einkorn and emmer from Bakla Tepe, p = .323), suggesting they were grown on comparably watered soils, although six emmer grains from Liman Tepe have values lower than any einkorn grains from this site. Glume wheat $\Delta^{13}C$ values at Bakla Tepe are significantly higher than those from Liman Tepe (two-tailed oneway ANOVA and post hoc Tukey's, p = .001), suggesting access to more well-watered soils.

Figure 7: $\Delta^{13}C$ and $\delta^{15}N$ values of archaeobotanical grains from Liman Tepe. Dashed lines represent suggested 'boundaries' between crops grown under poor (low values), moderate and high (high values) water availability ($\Delta^{13}C$) based on analysis of modern crops (Wallace *et al*. 2013). The boundaries are adapted for a 1‰ difference between wheat and barley grown under the same conditions.

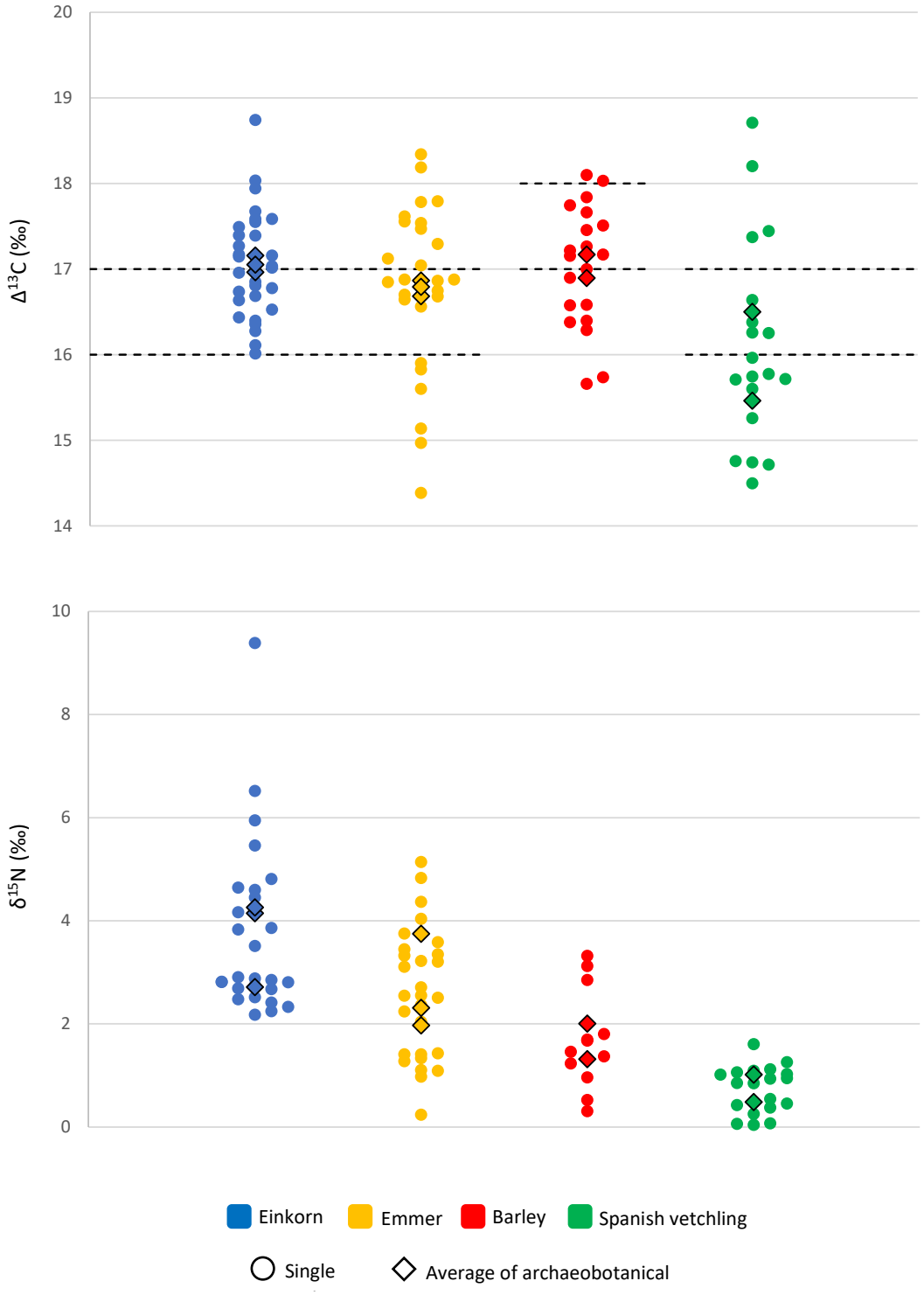
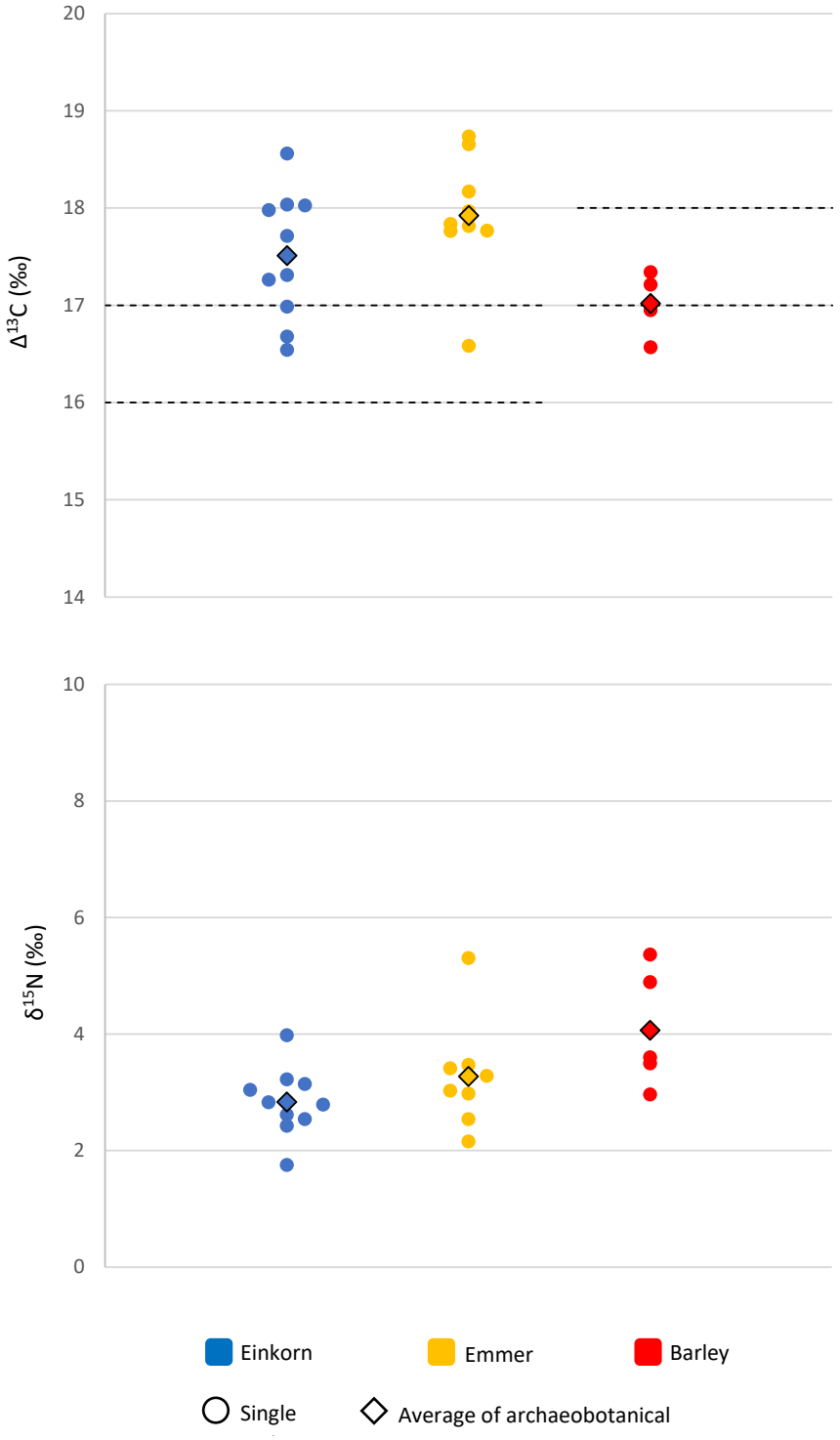


Figure 8: $\Delta^{13}C$ and $\delta^{15}N$ values of archaeobotanical grains from Bakla Tepe. Dashed lines represent suggested 'boundaries' between crops grown under poor (low values), moderate and high (high values) water availability ($\Delta^{13}C$) based on analysis of modern crops (Wallace *et al*. 2013). The boundaries are adapted for a 1‰ difference between wheat and barley grown under the same conditions.



Barley $\Delta^{13}C$ values from both sites are consistent with moderate to poorly-watered crops when adjusted for a 1‰ difference to wheat grown in the same conditions and are significantly lower than the glume wheats (two-tailed oneway ANOVA and post hoc Tukey's between einkorn and barley -1‰ from Liman Tepe, p = <.001; between emmer and barley -1‰ from Liman Tepe, p = .024; between einkorn and barley -1‰ from Bakla Tepe, p = .001; between emmer and barley -1‰ from Bakla Tepe p = <.001), suggesting they grew on drier soils. No data are available for the expected variation between $\Delta^{13}C$ values of single grains from a single condition of water availability, but the ranges of *average* values for each cereal species are consistent with a single growing condition, based on a range of up to 1‰ for *bulk* samples of modern crops from the same growing condition (Wallace *et al*. 2013; Bogaard *et al*. 2016).

The carbon isotope data from Liman Tepe and Bakla Tepe thus suggest similar cereal watering practices at the two sites. The cultivation of barley on drier soils than wheat is consistent with a deliberate water management strategy that took advantage of the greater tolerance of barley to less-favourable growing conditions than wheat (Ceccarelli *et al*. 2007; Guo *et al*. 2009; *cf.* Riehl 2009). This practice is commonly observed at Bronze Age sites in the Middle East but is more variable in the prehistoric Aegean (Wallace *et al.* 2015; Nitsch *et al*. 2017; Vaiglova *et al.* 2020; 2021), likely due to greater precipitation and/or local water availability in parts of the latter. Elsewhere in Anatolia, carbon isotope values of Late Chalcolithic crops from Çamlıbel Tarlası, central Anatolia, suggest that wheat and barley were subject to similar levels of low-moderate watering (Stroud *et al*. 2021). Carbon values of barley grains from Late Chalcolithic Kumtepe in the Troad are consistent with moderate water status (Riehl *et al*. 2016, 376 Fig. 6), but no data are available for wheat from this site.

Figures 7 and 8 compare the $\delta^{15}N$ values of cereals from Liman Tepe and Bakla Tepe. These can be compared to reference values for different manuring intensities based on the ranges of modern crops from known growing conditions (Fraser *et al*. 2011; Bogaard *et al*. 2013). The mean annual rainfall of Izmir is 682 mm (Turkreş 1996, 1063 Table II), and palaeoclimatic reconstructions suggest that precipitation was slightly higher than today during the fourth millennium BC (Roberts *et al*. 2011). Under these environmental conditions, aridity is unlikely to have elevated soil $\delta^{15}N$ and unmanured cereals would be expected to have values similar to those in temperate Europe (Fraser *et al.* 2011; Bogaard *et al*. 2013). $\delta^{15}N$ values of unmanured soils may also be estimated by projecting the values of the forage consumed by local herbivores (*cf*. Bogaard *et al*. 2013), but these data were not available for the sites in our study. Some cereal grains from Liman Tepe have $\delta^{15}N$ values close to 0‰, however, suggesting that they were cultivated on soils with little to no $\delta^{15}N$ enrichment (Fraser *et al*. 2011). $\delta^{15}N$ values of modern barley have a range of up to 2.1‰ for single grains from the same unmanured field (Larsson *et al*. 2019), suggesting that the range of values for non-enriched soils at Liman Tepe lies between 0 and 2.1‰. This aligns well with modern unmanured crops grown in central Europe, which had $\delta^{15}N$ values of <2.5‰ (Fraser *et al*. 2011).

Due to the proximity of Liman Tepe to the coast, the possible enrichment of soil $\delta^{15}N$ due to sea-spray (Virginia and Delwiche 1982; Heaton 1987) must also be considered. Saline rich environments are associated with high $\delta^{13}C$ values in cereals (Isla *et al*. 1998), suggesting that $\delta^{15}N$ enrichment from sea water should be visible in a positive correlation between $\delta^{15}N$ and $\delta^{13}C$. No significant correlation was found in the samples from Liman Tepe (two-tailed Pearson correlation of $\delta^{15}N$ and $\delta^{13}C$ across all samples, r =

-.133, p = .212). Soil nitrogen enrichment at Liman Tepe is therefore more likely to result from (moderate and variable, see below) manuring.

The $\delta^{15}N$ values of both glume wheats from Liman Tepe and Bakla Tepe are consistent with reference values for moderate (*c.* 2.5-6‰) to low/no (<2.5‰) manuring (Fraser *et al*. 2011). Moderate manuring encompasses both long term applications of lower (10-15 tonnes/ha) levels of manure and the residual effects after a period of intensive manuring (Fraser *et al*. 2011; Bogaard *et al*. 2013). Both scenarios (regular low-level manuring and infrequent intensive manuring) are consistent with the overall low levels of arable fertility reflected in the functional ecology of arable weeds. $\delta^{15}N$ values of einkorn and emmer are not significantly different at either site (two-tailed Kruskal-Wallis and post hoc Dunn's between einkorn and emmer from Liman Tepe, p = .172; two-tailed oneway ANOVA and post hoc Tukey's between einkorn and emmer from Bakla Tepe, p = .505), suggesting that they were grown under comparable manuring regimes. The absence of significant differences between the $\Delta^{13}C$ and $\delta^{15}N$ values of einkorn and emmer supports the hypothesis that they were grown together as a mixed crop.

The standard deviations of einkorn and emmer $\delta^{15}N$ values from both sites (Table 1) are lower than that of single grains of modern barley cultivated on the same manured field (1.64‰) (Larsson *et al*. 2019, Table 2), suggesting that they grew in less variable conditions than the modern barley. This is consistent with the grains from the grill-plan house at Bakla Tepe having derived from a single storage deposit rather than a tertiary context containing grain from multiple sources. It also indicates a single growing condition for barley within the grill-plan house. While less variable than the modern

barley, the average values of each glume wheat sample from Liman Tepe form two distinct clusters at *c.* 4 and 2.5‰, suggesting *some* variability in manuring intensity between the deposits sampled within the burnt house. Spatial patterning of isotope values within the burnt house will be explored further below.

$\delta^{15}N$ values of barley from Liman Tepe are consistent with little to no manuring (Fraser *et al*. 2011). The standard deviation is lower than that of single grains of modern barley from the same manured field (1.64‰), but higher than those from the same unmanured field (0.56‰) (Larsson *et al*. 2019, Table 2). This suggests that barley received low intensity manuring at Liman Tepe. $\delta^{15}N$ values of barley from Bakla Tepe are significantly higher than those from Liman Tepe (two-tailed ANOVA and post hoc Tukey's test, p = .004) and are consistent with a single condition of moderate manuring (*cf*. Larsson *et al*. 2019, Table 2).

$\delta^{15}N$ values of barley from Liman Tepe are significantly lower than einkorn (two-tailed Kruskal-Wallis and post hoc Dunn's, p = .001) but not emmer (p = .298). Barley $\delta^{15}N$ values are significantly lower than *both* glume wheats when the values of einkorn and emmer are grouped, however (two-tailed oneway ANOVA and post hoc Tukey's, p = .003). This suggests that, while there is overlap, the glume wheats were overall more intensively manured than barley. $\delta^{15}N$ values of barley from Bakla Tepe are also significantly different to einkorn (two-tailed oneway ANOVA and post hoc Tukey's, p = .032) but not emmer (p = .230). In this case, the $\delta^{15}N$ values of barley are not significantly different to the glume wheats when the values of einkorn and emmer are grouped (p = .038), suggesting a greater degree of overlap in manuring intensity at Bakla Tepe than Liman Tepe.

While the glume wheats appear to have been subject to comparable levels of manuring at the two sites (two-tailed Kruskal-Wallis and post hoc Dunn's, p = .988), the more intensive manuring of barley at Bakla Tepe than Liman Tepe attests to divergent arable land management strategies. At Liman Tepe, the cultivation of barley on drier plots that received less manure than the glume wheats, despite being the more abundant crop in the burnt house, betrays a significant investment in its ability to tolerate less favourable growing condition than wheat. This was perhaps a response to the restricted area of arable land within the immediate vicinity of Liman Tepe due to its coastal location (discussed further below), necessitating the cultivation of plots some distance from the settlement to which the transport costs of hauling manure were prohibitive (*cf*. Jones *et al*. 1999; Halstead 2014, 216-17). In contrast, the potentially *greater* quantities of manure applied to plots of barley than the glume wheats at Bakla Tepe attests to more intensive management of cereals than at Liman Tepe, albeit within an overall low-input regime. This implies that cereal plots were more accessible such that frictions of distance in the transport of manure were smaller and is consistent with the greater abundance of cultivable land on the Cumaovası plain surrounding the settlement. Manuring of barley at Bakla Tepe may have been utilised to encourage rigorous early growth on which livestock could be grazed, as practiced by recent Aegean farmers (Halstead 2006, 50) and suggested at Bronze Age Archontiko and Thessaloniki Toumba, northern Greece (Nitsch *et al*. 2017).

While variable between individual species, the overall low to moderate manuring of cereals at the two sites contrasts with the more intensive, albeit variable, cultivation strategies characteristic of the Neolithic Aegean (Vaiglova *et al*. 2014; 2020; 2021; Nitsch *et al*. 2019). Rather, cereal cultivation at Liman Tepe and Bakla Tepe is more comparable

to the Unexplored Mansion of LBA Knossos, where emmer wheat received low level manuring but was sown on well-watered soils, plausibly as a low-input way of ensuring adequate yields within an extensive cultivation system (Nitsch *et al*. 2019). This model aligns well with the overall low arable fertility of cereal plots at the study sites suggested by the functional ecological analysis, which produced discriminant scores similar to those of LBA Hattuša, central Anatolia (Diffey *et al*. 2020). The large urban population of this site was supported by an extensive system of land use in which draught cattle were used to grow cereals over large areas of land with low inputs.

Such low-input cultivation in Late Chalcolithic Izmir diverges from farming strategies at contemporary settlements elsewhere within Anatolia. At Çamlıbel Tarlası, nitrogen isotope values of wheat and barley are consistent with moderate manuring and align with intermediate cultivation intensity indicated by functional ecological analysis of arable weeds (Stroud *et al*. 2021). Functional ecological analysis of weeds from Kuruçay Höyük, inland western Anatolia, also indicate that cereals were cultivated under moderate intensity (Stroud *et al.* 2021). This plausibly resulted from differences in settlement size and the agricultural landscapes surrounding these sites compared to those in our study, which we will discuss further below.

6.2 Pulse cultivation strategies at Liman Tepe

$\Delta^{13}C$ values of Spanish vetchling recovered from the burnt house span the ranges of reference values for all three watering bands (Figure 7), but the majority are consistent with low and moderately watered crops. As there are no data on the expected range of $\Delta^{13}C$ values between single grains cultivated under the same condition of water availability, it is currently unclear if the range of values within each pulse sample from

Liman Tepe are consistent with single or multiple growing conditions. The *average* $\Delta^{13}C$ values of the two archaeobotanical samples of Spanish vetchling range by 1.06‰, just over the 1‰ range for bulk samples of modern crops cultivated under a single growing condition (Wallace *et al*. 2013; Bogaard *et al*. 2016), but are not significantly different (two-tailed t-test, p = .060). Modern cultivation experiments suggest that pulse $\Delta^{13}C$ values are more sensitive to changes in water status than cereals, such that they appear 'drier' in dry environments and 'wetter' in wet environments than wheat grown under the same conditions (Wallace *et al*. 2013). That the $\Delta^{13}C$ values of most Spanish vetchling seeds are comparable to or lower than the majority of glume wheat grains therefore suggests that they were cultivated on *less* well-watered soils. Considering the 1‰ difference between the $\Delta^{13}C$ values of barley and wheat from the same growing condition, the water status of Spanish vetchling is closer to barley than the glume wheats.

Bulk samples of modern broad beans grown in Evvia, southern Greece, provide reference values for pulses grown under different manuring intensities. Broad beans cultivated on 'dung-soil' produced by highly intensive manuring (Jones *et al*. 1999) had $\delta^{15}N$ values ranging from below 1 to over 4‰ and averaging 2.2 ± 1.4‰ (Fraser *et al*. 2011, 2800 Table 5c; Nitsch *et al*. 2019, 159 Fig. 3). Unmanured broad beans had $\delta^{15}N$ values predominantly below 1‰, with an average of 0.6 ± 0.4‰. Low level manuring elevates $\delta^{15}N$ values of pulses within the range of measurement error and is therefore indistinguishable from unmanured values (Fraser *et al*. 2011). Average $\delta^{15}N$ values of 0.61 ± 0.39‰ and 1.16 ± 0.3‰ for the two pulse samples from Liman Tepe, including numerous seeds with values well over 1‰, are thus consistent with intensive manuring.

This resembles pulse cultivation strategies elsewhere within the Neolithic and Bronze Age Aegean (Vaiglova *et al*. 2014; 2020; Nitsch *et al*. 2017; 2019).

Nitrogen in manure becomes available to crops over the course of several years, meaning that the differences in $\delta^{15}N$ values between Spanish vetchling and the cereals at Liman Tepe are the result of long-term differences in manuring intensity (Fraser *et al*. 2011). This suggests that they were not grown in rotation. Analogy with the practices of recent non-mechanised farmers in the Aegean suggests that Spanish vetchling may have been grown on small plots close to the home; the difficulty of transporting manure and harvesting the brittle pods of low-growing pulses are both strong limiting factors to the scale and distance from the home of intensive cultivation (Jones *et al*. 1999; Halstead 2014, 216-17; 119; 103). The cultivation of pulses on a smaller scale than cereals at Liman Tepe is also consistent with the overwhelming majority of the latter within the burnt house. The lower water status of Spanish vetchling than the glume wheats suggests that the more accessible plots were not those on the most well-watered soils in the Urla-Iskele plain.

The spatial differentiation of cereal and pulse cultivation at Liman Tepe provides a further point of departure from the intensive cultivation model, in which cereals and pulses are grown in rotation (Halstead and Isaakidou 2020). Isotopic evidence for comparable manuring intensity between cereals and pulses is known from Neolithic Knossos (Nitsch *et al*. 2019), Kouphovouno (Vaiglova *et al*. 2014; 2020) and Halai (Vaiglova *et al*. 2021), Greece, as well as several sites in Bronze Age northern Greece (Nitsch *et al*. 2017), and is consistent with rotation as part of intensive cultivation strategies at these sites. In this regard, arable farming at Liman Tepe again more closely

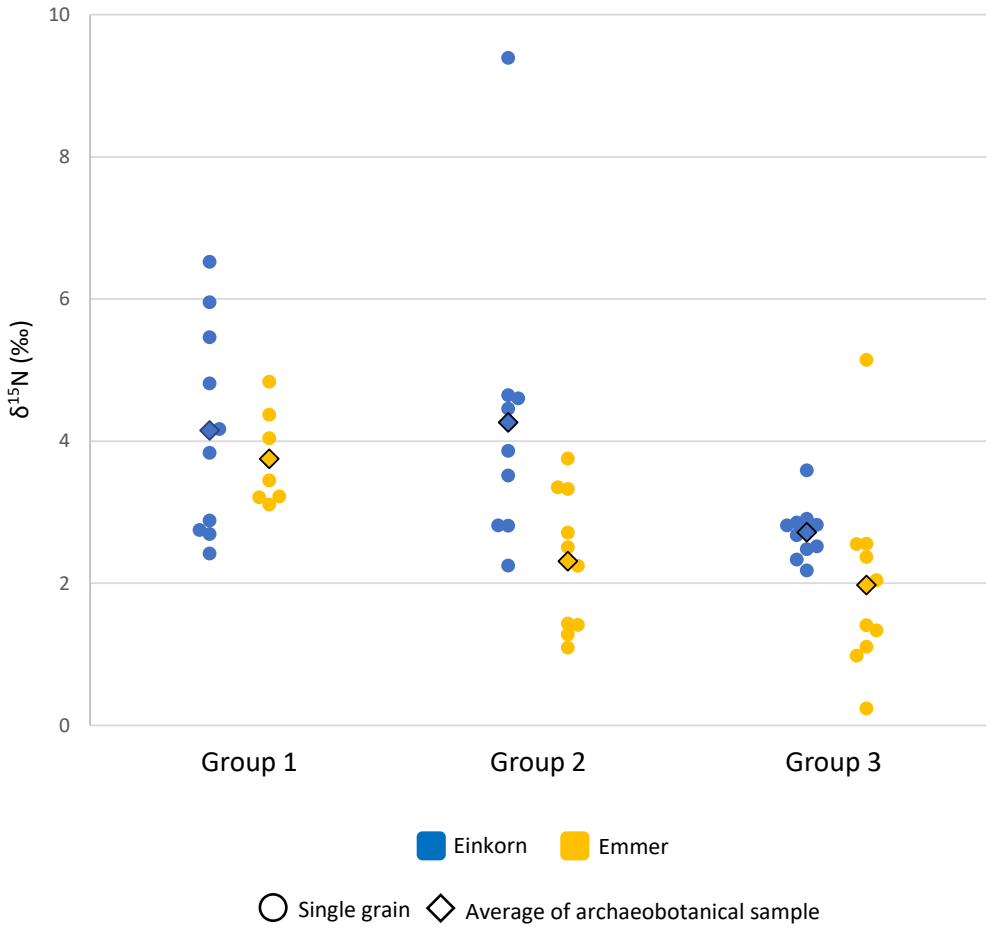
resembles that of LBA Knossos, where pulses were more intensively manured and variably watered than cereals and were plausibly grown on 'allotment' plots within or close to the settlement (Nitsch *et al*. 2019).

6.3 Spatial patterning of isotope values within the Liman Tepe burnt house

Glume wheat grains were sampled for stable isotope analysis from each of three distinct clusters ('groups') of grain across the floor of the burnt house (Figure 2). Compositional analysis of archaeobotanical samples across the floor suggests that groups 1 and 3 derived from discrete storage deposits, while the group 2 was formed by grains that spread from groups 1 and 3 (Maltas *et al*. forthcoming).

$\Delta^{13}C$ values of grains from each group are not significantly different (two-tailed Kruskal Wallis test, p = .705), nor are those of einkorn and emmer grains from the same groups (p = .761). Significant differences are present, however, in the $\delta^{15}N$ values of glume wheats between different locations on the floor of the burnt house (two-tailed one-way ANOVA, p = <.001). Plotted in Figure 9, the average $\delta^{15}N$ values of glume wheats from group 1 are *c.* 1-2‰ higher and significantly different (two-tailed one-way ANOVA and post hoc Tukey's, p = .003) from those from group 3. In contrast, the values of einkorn and emmer grains *within* groups 1 and 3 are not significantly different (einkorn and emmer from group 1, p = .989; einkorn and emmer from group 3, p = .794). This strongly indicates that the two deposits derived from distinct growing conditions, with the glume wheats from group 1 receiving more intensive manuring than those from group 3. Crop $\delta^{15}N$ values from group 2 are consistent with the inference that this group is composed of grains that spread from groups 1 and 3; values of einkorn grains from group 2 are significantly different from emmer grains from the same group (p = .023) but not glume

Figure 9: $\delta^{15}N$ values of glume wheat grains from the Liman Tepe burnt house, grouped by their location on the house floor.



wheat grains from group 1 (p = .955), while emmer grains from group 2 are not significantly different from glume wheat grains in group 3 (p = 1).

6.4 The implications of arable farming strategies for the social morphology of Bakla Tepe and Liman Tepe

Evidence for low-input cereal cultivation at Late Chalcolithic Bakla Tepe and Liman Tepe suggests that agricultural production resembled that of recent farmers in the Aegean (Halstead and Jones 1989) and Anatolia (Hillman 1973) engaged in extensive systems of

land use. In these examples, extensive land use was linked to nucleated settlement patterns that pushed arable plots significant distances from the home, reducing the viability of high inputs through manuring and tillage (Jones *et al*. 1999; Halstead 2014, 208-9; 216-18). Ethnographic data highlights the difficulties of hauling manure within non-mechanised contexts, with recent farmers in Greece dumping the majority within *c.* 500 m of settlements (Halstead 2014, 217). Similarly, plots that received frequent weeding in Evvia, Greece, tended to be located within 1 km of settlements (Jones 2005, 169 Table 1). In Figure 10, we estimate the areas of agricultural land needed to support the occupants of Bakla Tepe and Liman Tepe in order to assess if similar restrictions shaped crop management strategies at these sites. Table 2 shows the populations of the two sites at a range of population densities derived from ethnographic research on rural communities in the Middle East (Kramer 1979, 178; 1982, 162; Watson 1979, 35-47; Wossinik 2009; *cf.* Birch-Chapman *et al*. 2017, 7). EBA architectural remains from Liman Tepe reveal a nucleated settlement (Erkanal and Şahoğlu 2016), suggesting that the Late Chalcolithic occupation may have been similarly dense due to the limited space available on the mound. This suggests that the higher population densities in Table 2 are more appropriate, with a likely population of *c.* 145-200 people. For the more dispersed settlement of Bakla Tepe, the lower population densities are more appropriate suggesting a likely population of *c.* 790-1270 people. While estimates of both population size and areas of cultivated land rely on a range of assumptions and must therefore be interpreted with caution, Figure 10 suggests that, at both sites, populations could be supported by intensively cultivated plots within 1 km of the settlements, but distances of over 500 m were inevitable. This is particularly stark at Liman Tepe, where the *closest* plots were a minimum of 150 m from the settlement (a likely underestimate considering

Figure 10: Agricultural catchment areas around a) Liman Tepe and b) Bakla Tepe for populations of 145-200 and 790-1270, respectively, assuming high area yields resulting from intensive farming (1000-1500 kg/ha) and requirements of 250 kg of cereals per person per year (*cf.* Halstead 2014, 250; 299). Black solid line: late fourth millennium BC coastline adapted from Goodman *et al*. (2009), black dashed line: hypothetical extension of late fourth millennium BC coastline, white solid lines: area of land within 500 m and 1 km of each settlement, white dash-dot lines: the minimum and maximum areas of land needed to support the estimated populations of each settlement. Base maps sourced from ArcMap 10.8.

a

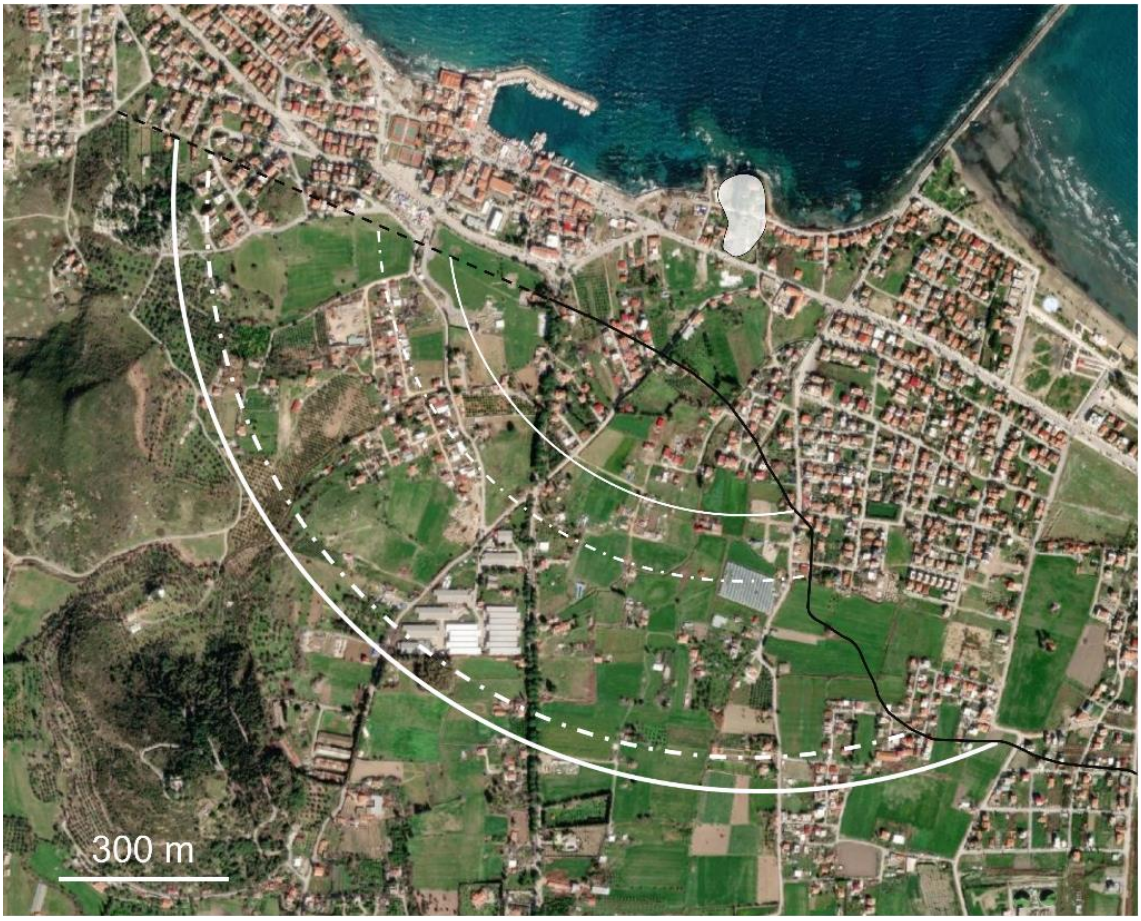


Figure 10 (continued)

b



Table 2: The estimated populations of Liman Tepe and Bakla Tepe at a range of ethnographically derived population densities. The likely population sizes based on the density of occupation indicated by the archaeological remains from each site are in bold.

	Settlement size (ha)	Population		
		90/ha	145/ha	200/ha
Liman Tepe	1	90	**145**	**200**
	1.5	135	**218**	**300**
Bakla Tepe	8.75	**790**	**1270**	1750

that they were plausibly located some distance from the coastline) and accessible via a weak sandbar. These data suggest that, like modern examples, frictions of distance favoured extensive systems of land use. This plausibly resulted from the coastal location of Liman Tepe and the large settlement size of Bakla Tepe and can be contrasted against the higher-input cultivation visible at Late Chalcolithic Çamlıbel Tarlası and Kuruçay Höyük (Stroud *et al*. 2021), both of which were small settlements located close to cultivable land. In recent examples, large scales of cultivation resulting from extensive land use created pronounced time stress during the harvest and to complete ploughing in advance of sowing (Halstead and Jones 1989). Under these conditions, the ability to mobilise agricultural labour was key to the success of arable production, and losses to household workforces a major hazard (Halstead 2004). By the EBA, settlements in western Anatolia were organised around the longhouse (Fidan *et al*. 2015; Gündoğan 2020), generally larger in size than earlier domestic structures (e.g., the *c.* 100 m^2 longhouses of EB I-II Liman Tepe—Erkanal and Şahoğlu 2016) and consistent with households of more extended family units (*cf*. Flannery 2002). This is likely to have provided more reliable sources of domestic labour. For the smaller domestic units of the Late Chalcolithic, however, cooperation beyond the household may have been essential to maintaining a consistent labour force and thus the long-term sustainability of arable production. Cooperation at the supra-household level is indicated by potentially communal extramural storage and high levels of social monitoring of farming-related activities at Bakla Tepe (Maltas *et al*. forthcoming), consistent with social obligations to share food and spread agricultural risk through reciprocity.

This focus on collective efforts, and the obligations to share in the fortunes of good and bad years that likely went with it, plausibly limited the potential for sustained productive

inequality between Late Chalcolithic households. This likely contributed to the absence of overt wealth inequality that characterises the period, despite the emergence of extensive farming systems that may have favoured productive inequality over the long-term through inheritance of land-based wealth (*cf.* Bogaard *et al*. 2019). Rather, it was plausibly the emergence of the longhouse in the EBA, occupied by larger farming households capable of maintaining greater autonomy in arable production, that facilitated the ability to hoard agricultural surplus and develop wealth inequality through strategic investment in social storage and the further expansion of agricultural production (*cf.* Halstead 1989; Bogucki 1993; Bogaard *et al.* 2019). Artefactual evidence supports a reorientation of the domestic economy towards household autonomy at many sites during this period, with agricultural storage and craft production frequently confined to the interiors of longhouses (e.g., Liman Tepe VI—Erkanal and Şahoğlu 2016, Bakla Tepe IV 1—Gündoğan *et al*. 2019, Çeşme-Bağlararası 3—Şahoğlu 2015 and Çukuriçi Höyük III-IV—Horejs *et al*. 2017 in the Izmir region). This coincides with the emergence of more elaborate forms of serving and consumption vessels on the Anatolian Plateau, indicating greater concerns with pouring and presenting (Bachhuber 2015, 62-63) and perhaps increasingly formal (i.e., less normalised) reciprocity between households. This appears to have fostered the emergence of institutions designed to dampen potential wealth inequality through social monitoring and/or the centralisation of farming products (e.g., EB I-II Demircihöyük and Karataş—Bachhuber 2015, 56-82). Evidence for high status and wealthy groups in the cemetery of Karataş (Mellink 1969; Massa and Şahoğlu 2011) suggests that these institutions laid the foundations for the emergence of later EBA elites. Archaeobotanical evidence for the nature of agricultural

production within EBA western Anatolia and its implications for the emergence of elite citadels is the focus of ongoing research (Maltas *et al*. in prep).

7. Conclusion

Provisions for large-scale agricultural storage within the citadel of Troy (Thumm-Doğrayan 2016; Thumm-Doğrayan *et al*. 2019) suggest that agrarian wealth produced under extensive farming systems was a key feature of elite power within the citadels of later EBA western Anatolia (*cf.* Bachhuber 2015, 130-49). Stable isotope analysis and functional ecological analysis of archaeobotanical remains from Liman Tepe and Bakla Tepe suggest that low-input production strategies were already utilised in domestic contexts in the Late Chalcolithic. Cereals were grown on plots with low to moderate manuring and correspondingly low soil fertility but with good water supply. Land management strategies were adapted to the ecological requirements of different cereals, but also different plots of the *same* cereals at Liman Tepe. Cultivation intensity diverged between the two sites in the different levels of manure applied to barley, with the occupants of Liman Tepe investing more heavily its ability to tolerate less favourable growing conditions than wheat, plausibly in response to differing challenges within the arable landscapes around each settlement. At Liman Tepe, pulses were intensively manured but less well-watered than the glume wheats and may have been grown on a smaller scale closer to the settlement. That the archaeobotanical remains from the burnt house likely derive from a single harvest demonstrates that this variability is not simply a reflection of the practices of different households, but an individual household within a single year. This snapshot of diversity hints at a flexibility employed by recent non-mechanised farmers in the Aegean, in which decisions regarding which crops to

grow where, when and how were governed by a host of temporally specific considerations including environmental factors, the availability of labour and recent 'case histories' of the performance of individual plots (Halstead and Jones 1989). This 'precision farming' (*cf*. Dobermann *et al*. 2004) is increasingly being recognised within prehistoric Europe and the Middle East and may have been an essential dimension to the long-term survivability of early farming settlements (*cf.* Bogaard *et al*. 2017).

The smaller house sizes of the Late Chalcolithic than later periods suggests that cooperation beyond the household was key to sustaining the large scales of cultivation associated with extensive land use. This cooperative atmosphere likely limited long-term productive inequality between households. Rather, it was plausibly the emergence of more extended domestic units in the EBA that allowed households to maintain autonomy in crop cultivation and facilitated the potential for sustained productive inequality within settlements. Centralising institutions designed to dampen this potential for emergent wealth inequality in the EBA may have laid the foundations for the later emergence of citadel elites. This suggests that, while the agricultural foundations of Bronze Age citadels were in place by the late fourth millennium BC, the sustained high wealth inequality that characterise them resulted from a coalescence of complementary agroecological and social conditions at the onset of the EBA.

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From horticulture to agriculture: new data on farming practices in Late Chalcolithic western Anatolia

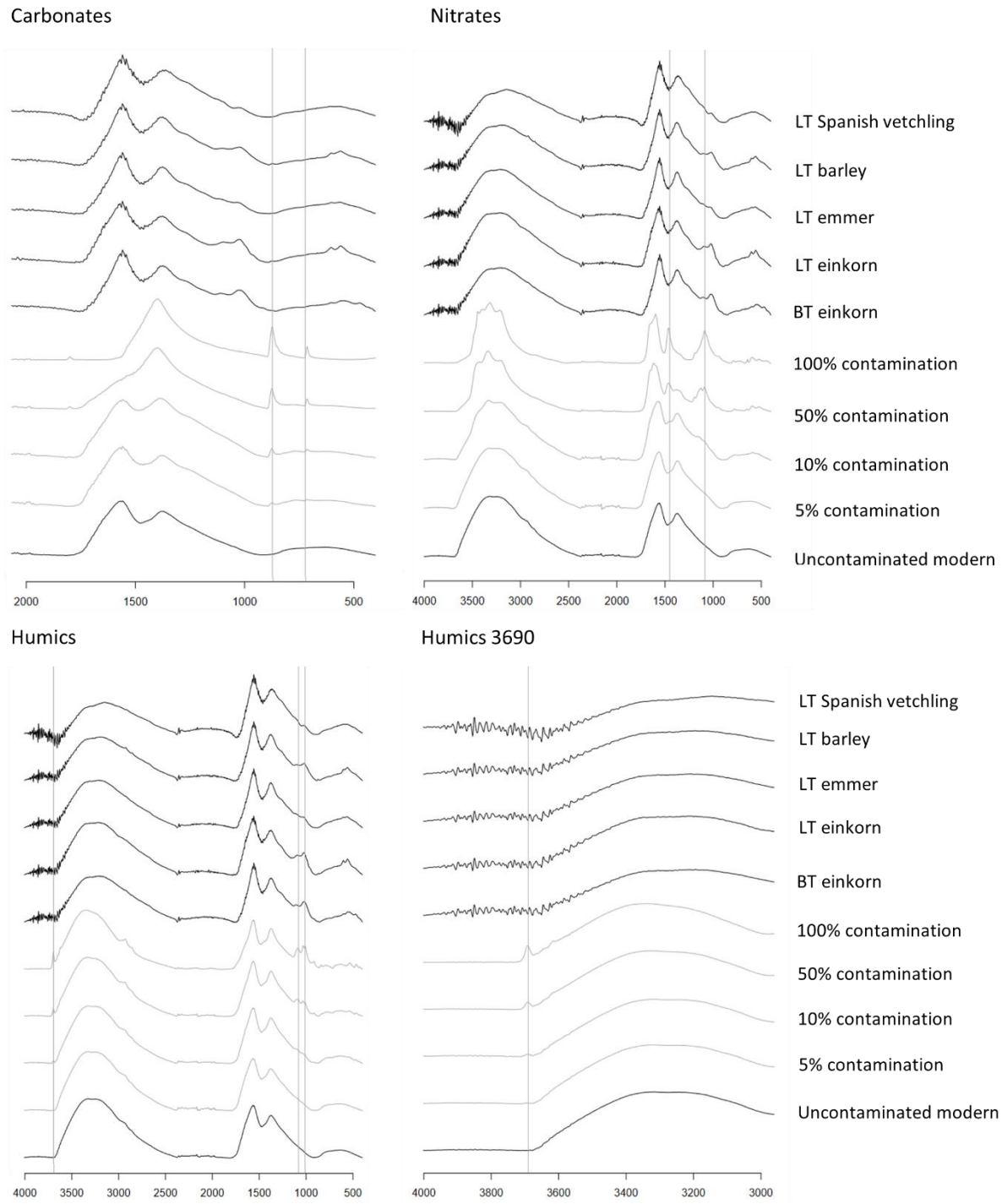
Supplementary material

1. FTIR results

In supplementary Figure 1, the FTIR spectra of archaeobotanical grains from Bakla Tepe and Liman Tepe are compared to modern grains experimentally contaminated by Vaiglova *et al*. (2014). A minor source of humic contamination is indicated by peaks at 1080 and 1010 cm^{-1} in the spectra of crushed grains prior to the removal of surface contaminants (supplementary Figure 1a). Peaks at 1080, 1010 and 3690 cm^{-1} in the spectrum of sediment scraped off a grain from Bakla Tepe (supplementary Figure 1b) are consistent with the presence of humics, suggesting that this was the source of contamination in the crushed grains. After grains were gently scraped to remove any surface contaminants visible at x7-45 magnification, the resulting FTIR spectra showed an absence of humic contamination (supplementary Figure 1b).

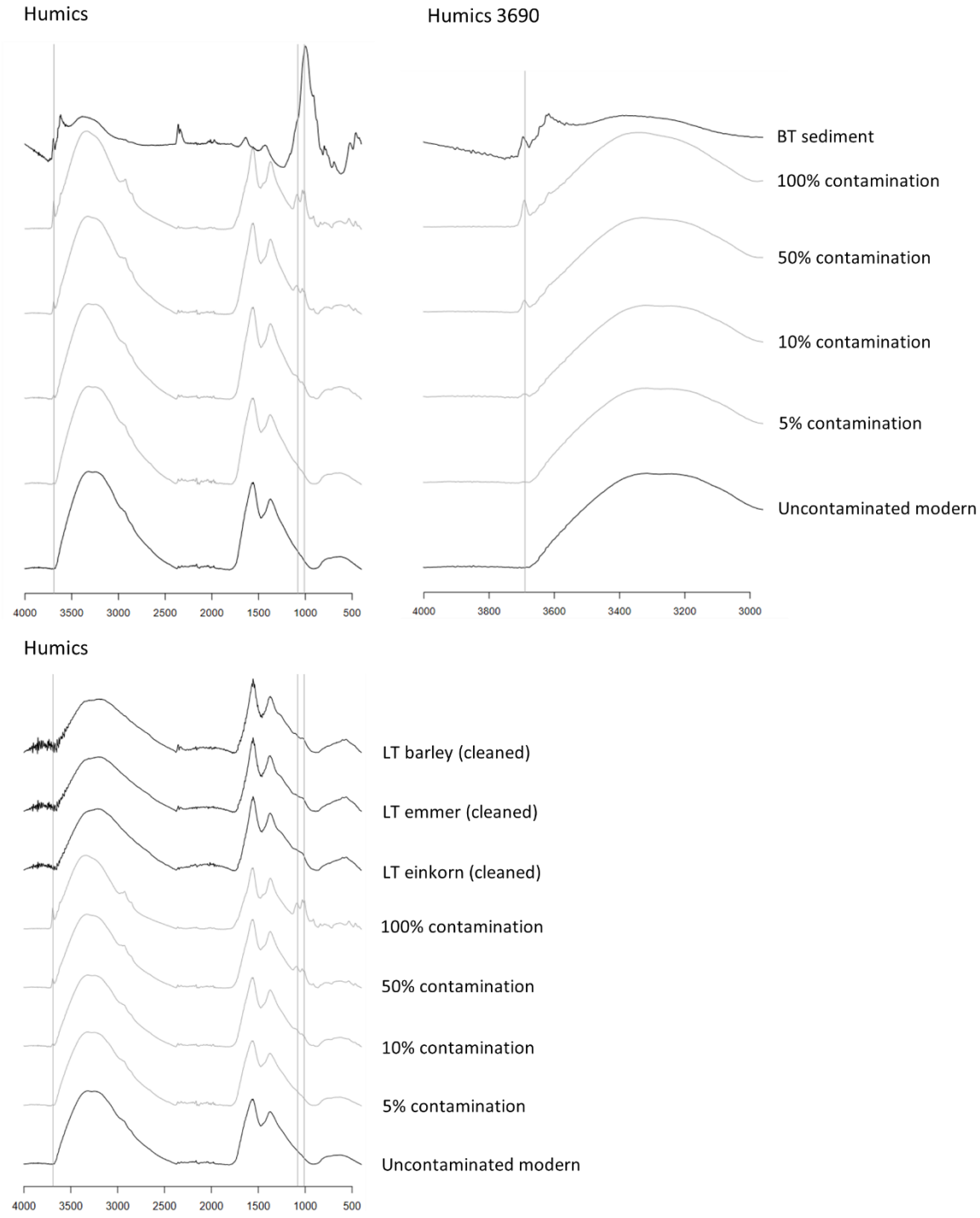
Supplementary Figure 1: The FTIR spectra of archaeobotanical crop grains and sediment from Liman Tepe and Bakla Tepe compared to modern grains experimentally contaminated by Vaiglova *et al*. (2014). LT – Liman Tepe, BT – Bakla Tepe.

a



Supplementary Figure 1 (continued)

b



Supplementary Table 1: Full results of the stable isotope analysis. A charring offset of 0.11‰ and 0.31‰ have been subtracted from the values of δ13C and δ15N, respectively (Nitsch *et al*. 2015). Δ13C values were calculated after the charring offset was subtracted from δ13C. Grains are grouped by their archaeobotanical samples.

Grain	Site	Taxon	δ13C (‰)	Δ13C (‰)	N (µg)	δ15N (‰)	%C	%N	C:N
LT024	Liman Tepe	Einkorn	-24.1	18.0	57.4	2.7	47.5	2.3	24.5
LT0210	Liman Tepe	Einkorn	-23.8	17.7	72.2	4.8	46.4	2.8	19.1
LT026	Liman Tepe	Einkorn	-22.2	16.0	79.9	2.4	47.3	3.1	17.6
LT029	Liman Tepe	Einkorn	-23.5	17.4	75.6	6.5	45.1	3.0	17.7
LT025	Liman Tepe	Einkorn	-23.6	17.6	64.3	4.2	47.1	2.6	21.2
LT023	Liman Tepe	Einkorn	-23.7	17.6	82.3	6.0	51.0	3.3	18.1
LT028	Liman Tepe	Einkorn	-23.3	17.2	66.6	2.7	51.1	2.7	22.5
LT022	Liman Tepe	Einkorn	-22.9	16.7	64.4	3.8	46.0	2.5	21.6
LT021	Liman Tepe	Einkorn	-23.1	17.0	83.1	5.5	50.0	3.1	18.5
LT027DAB	Liman Tepe	Einkorn	-22.5	16.4	69.1	2.9	48.5	2.7	21.2
LT039	Liman Tepe	Einkorn	-24.8	18.7	43.2		41.3		
LT034	Liman Tepe	Einkorn	-22.3	16.1	51.0	2.8	39.0	2.0	22.3
LT032	Liman Tepe	Einkorn	-22.7	16.5	78.8	3.5	46.5	3.0	18.1
LT035	Liman Tepe	Einkorn	-22.9	16.8	58.1	3.9	41.4	2.3	20.6
LT310	Liman Tepe	Einkorn	-22.8	16.7	54.9	4.6	43.7	2.2	23.1
LT033	Liman Tepe	Einkorn	-23.1	17.0	73.3	4.5	47.0	2.9	19.1
LT031	Liman Tepe	Einkorn	-22.9	16.8	70.5	2.2	44.9	2.7	19.4
LT038	Liman Tepe	Einkorn	-23.4	17.3	48.6	2.8	44.7	1.9	27.1
LT036	Liman Tepe	Einkorn	-23.6	17.5	68.4	9.4	46.0	2.7	20.0
LT037DAB	Liman Tepe	Einkorn	-22.4	16.3	68.6	4.6	43.4	2.7	18.4

LT012	Liman Tepe	Einkorn	-23.1	17.0	55.4	2.5	45.1	2.2	23.7
LT015	Liman Tepe	Einkorn	-23.0	16.9	68.7	2.5	33.7	1.8	21.4
LT0110	Liman Tepe	Einkorn	-23.5	17.4	69.5	2.9	39.2	1.8	25.7
LT019	Liman Tepe	Einkorn	-22.5	16.4	59.6	2.2	39.7	2.3	19.8
LT013	Liman Tepe	Einkorn	-23.2	17.1	50.9	2.7	45.1	2.0	25.8
LT014	Liman Tepe	Einkorn	-22.6	16.4	59.3	2.8	40.9	2.3	21.2
LT017	Liman Tepe	Einkorn	-23.7	17.6	53.5	2.3	44.8	2.1	24.9
LT018	Liman Tepe	Einkorn	-22.8	16.6	62.0	2.9	41.5	2.4	20.3
LT016DAB	Liman Tepe	Einkorn	-23.3	17.2	53.2	2.8	44.9	2.0	26.7
LT011	Liman Tepe	Einkorn	-24.0	17.9	62.6	3.6	46.4	1.8	28.5
LT085	Liman Tepe	Emmer	-23.6	17.6	63.6	3.4	44.5	1.8	27.1
LT087	Liman Tepe	Emmer	-22.7	16.6	41.3		44.4		
LT086	Liman Tepe	Emmer	-24.2	18.2	54.0	3.2	46.3	1.5	36.0
LT081	Liman Tepe	Emmer	-22.0	15.8	69.3	4.8	48.5	2.7	21.0
LT088	Liman Tepe	Emmer	-23.0	16.8	58.8	4.4	47.0	1.6	32.0
LT083	Liman Tepe	Emmer	-22.8	16.7	70.9	3.1	49.2	2.7	21.0
LT084	Liman Tepe	Emmer	-21.2	15.0	75.9	3.2	46.6	3.1	17.8
LT082DAB	Liman Tepe	Emmer	-22.9	16.8	54.1	4.0	46.1	1.5	33.4
LT069	Liman Tepe	Emmer	-23.0	16.9	59.5	3.3	42.7	2.3	21.9
LT0610	Liman Tepe	Emmer	-23.0	16.9	53.4	1.1	44.7	2.2	24.2
LT063	Liman Tepe	Emmer	-23.0	16.9	50.0	2.2	47.2	2.0	27.5
LT064	Liman Tepe	Emmer	-23.4	17.3	78.2	1.4	49.3	3.1	18.7
LT061	Liman Tepe	Emmer	-23.0	16.8	53.5	1.4	48.2	2.1	26.9
LT068	Liman Tepe	Emmer	-23.2	17.0	69.9	3.8	45.8	1.9	27.2
LT066	Liman Tepe	Emmer	-23.7	17.6	53.5	2.5	44.6	1.5	33.6

LT065	Liman Tepe	Emmer	-22.1	15.9	76.0	3.3	47.0	2.9	18.8
LT067	Liman Tepe	Emmer	-22.8	16.7	53.2	2.7	45.2	2.1	25.0
LT062DAB	Liman Tepe	Emmer	-22.8	16.6	54.2	1.3	48.3	2.1	26.8
LT098	Liman Tepe	Emmer	-20.6	14.4	71.2	5.1	45.1	2.7	19.3
LT094	Liman Tepe	Emmer	-23.6	17.5	62.4	1.3	42.3	1.7	26.4
LT099	Liman Tepe	Emmer	-23.9	17.8	52.1	1.0	47.4	2.1	26.4
LT097	Liman Tepe	Emmer	-21.3	15.1	57.9	2.0	44.6	2.2	23.6
LT096	Liman Tepe	Emmer	-22.9	16.7	65.1	2.6	37.6	1.8	24.1
LT095	Liman Tepe	Emmer	-23.2	17.1	56.1	1.4	46.4	2.2	24.7
LT091	Liman Tepe	Emmer	-24.4	18.3	62.7	1.1	44.7	1.7	28.6
LT0910	Liman Tepe	Emmer	-23.6	17.5	63.2	2.4	43.9	1.8	27.8
LT093	Liman Tepe	Emmer	-23.9	17.8	53.6	0.2	43.6	2.1	24.3
LT092DAB	Liman Tepe	Emmer	-21.8	15.6	69.4	2.5	43.6	2.7	18.5
LT056	Liman Tepe	Barley	-22.7	16.6	78.7	0.3	38.7	2.2	20.1
LT059	Liman Tepe	Barley	-21.8	15.7	41.8		45.4		
LT058	Liman Tepe	Barley	-23.9	17.8	49.4	3.1	40.6	1.4	33.7
LT051	Liman Tepe	Barley	-22.5	16.4	42.1		42.3		
LT054	Liman Tepe	Barley	-23.3	17.2	50.1	2.0	46.4	1.9	28.4
LT057	Liman Tepe	Barley	-23.7	17.7	56.6	0.5	44.2	1.6	31.9
LT052	Liman Tepe	Barley	-23.4	17.3	49.9	0.9	41.5	1.4	33.8
LT053	Liman Tepe	Barley	-23.3	17.2	50.1	1.4	37.8	1.4	31.3
LT0510	Liman Tepe	Barley	-21.9	15.7	89.7	1.3	40.6	2.6	18.0
LT055DA	Liman Tepe	Barley	-23.5	17.5	56.0	1.0	43.8	1.6	31.5
LT111	Liman Tepe	Barley	-23.0	16.9	67.2	1.7	43.1	1.9	25.8
LT1110	Liman Tepe	Barley	-23.6	17.5	69.5	2.9	39.7	2.0	24.9

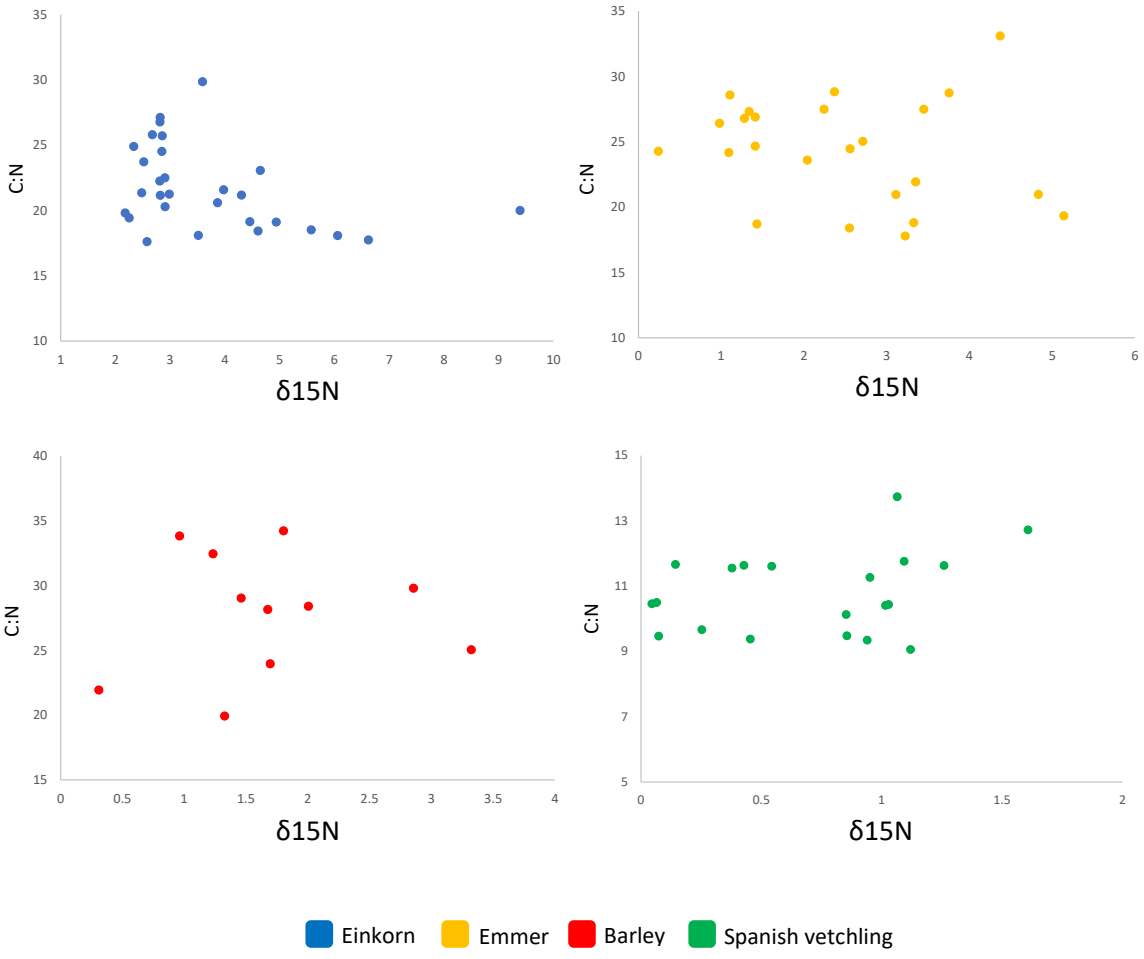
LT116	Liman Tepe	Barley	-23.8	17.7	53.6	1.2	40.7	1.5	31.4
LT119	Liman Tepe	Barley	-24.1	18.0	47.8		38.6	1.4	32.8
LT113	Liman Tepe	Barley	-23.3	17.2	47.8				
LT118	Liman Tepe	Barley	-23.1	17.0	51.6	1.5	1.5	1.9	29.0
LT115	Liman Tepe	Barley	-22.5	16.4	66.3	3.3	39.0	1.9	23.7
LT112	Liman Tepe	Barley	-22.4	16.3	47.3				
LT114	Liman Tepe	Barley	-22.7	16.6	67.6	1.7	36.6	1.9	22.3
LT117DA	Liman Tepe	Barley	-24.2	18.1	51.5	1.8	41.4	1.5	32.9
LT072	Liman Tepe	Spanish vetchling	-22.8	16.6	63.7	0.1	46.2	5.1	10.5
LT073	Liman Tepe	Spanish vetchling	-22.4	16.3	55.8	0.4	44.9	4.5	11.6
LT077	Liman Tepe	Spanish vetchling	-21.9	15.8	66.6	1.0	46.4	5.2	10.4
LT079	Liman Tepe	Spanish vetchling	-24.7	18.7	75.2	1.1	46.3	6.0	9.1
LT0710	Liman Tepe	Spanish vetchling	-22.1	16.0	70.7	0.1	44.2	5.4	9.5
LT075	Liman Tepe	Spanish vetchling	-20.9	14.7	77.8	0.9	47.2	5.9	9.3
LT071	Liman Tepe	Spanish vetchling	-21.9	15.7	76.6	0.3	49.6	6.0	9.7
LT074	Liman Tepe	Spanish vetchling	-23.5	17.4	76.5	0.5	49.2	6.1	9.4
LT076	Liman Tepe	Spanish vetchling	-22.5	16.4	68.8	0.0	45.4	5.1	10.5

LT078DAB	Liman Tepe	Spanish vetchling	-23.5	17.4	60.1	0.5	47.3	4.8	11.6
LT124	Liman Tepe	Spanish vetchling	-21.8	15.6	45.4		40.7		
LT125	Liman Tepe	Spanish vetchling	-20.9	14.8	74.9	0.9	48.3	1.3	9.5
LT123	Liman Tepe	Spanish vetchling	-20.7	14.5	70.2	0.9	46.6	1.3	10.1
LT1210	Liman Tepe	Spanish vetchling	-20.9	14.7	52.2	1.6	42.8	2.1	12.7
LT121	Liman Tepe	Spanish vetchling	-21.4	15.3	67.8	1.0	45.6	1.5	10.4
LT127	Liman Tepe	Spanish vetchling	-20.1	13.9	53.7	1.1	43.3	1.5	11.8
LT126	Liman Tepe	Spanish vetchling	-22.4	16.3	61.2	1.0	43.5	1.4	11.3
LT129	Liman Tepe	Spanish vetchling	-21.9	15.7	57.4	1.3	44.7	1.7	11.6
LT128	Liman Tepe	Spanish vetchling	-24.3	18.2	53.0	1.1	44.6	1.5	13.7
LT122DAB	Liman Tepe	Spanish vetchling	-21.9	15.7	64.4	0.4	49.7	1.3	11.7
BT151	Bakla Tepe	Einkorn	-23.4	17.3	67.2	2.5	34.1	1.6	21.9
BT152	Bakla Tepe	Einkorn	-24.6	18.6	71.0	2.4	36.2	1.8	21.7
BT153	Bakla Tepe	Einkorn	-23.1	17.0	60.7	3.0	42.7	2.4	19.0
BT154	Bakla Tepe	Einkorn	-24.1	18.0	81.0	2.8	39.8	2.0	21.0
BT155	Bakla Tepe	Einkorn	-22.7	16.5	62.7	3.2	41.6	2.5	18.1

BT156	Bakla Tepe	Einkorn	-22.8	16.7	51.1	3.1	39.4	2.0	20.8
BT157DAB	Bakla Tepe	Einkorn	-23.4	17.3	56.0	2.6	42.3	2.2	20.2
BT158	Bakla Tepe	Einkorn	-24.0	18.0	72.5	4.0	36.9	1.8	22.0
BT159	Bakla Tepe	Einkorn	-24.1	18.0	75.2	2.8	40.8	1.9	22.9
BT1510	Bakla Tepe	Einkorn	-23.8	17.7	60.2	1.8	33.0	1.5	23.4
BT141	Bakla Tepe	Emmer	-24.0	18.0	59.1	2.5	37.3	1.5	26.8
BT142	Bakla Tepe	Emmer	-24.8	18.7	82.8	3.4	44.1	2.3	20.3
BT143	Bakla Tepe	Emmer	-22.7	16.6	58.0	3.0	37.0	2.3	17.1
BT144	Bakla Tepe	Emmer	-23.8	17.8	69.2	5.3	37.2	2.0	19.9
BT145	Bakla Tepe	Emmer	-23.9	17.8	68.6	3.3	39.1	1.9	21.3
BT146	Bakla Tepe	Emmer	-24.7	18.7	66.1	3.0	40.5	1.9	22.9
BT147	Bakla Tepe	Emmer	-24.2	18.2	83.9	2.2	44.5	2.1	22.8
BT148DAB	Bakla Tepe	Emmer	-23.8	17.8	70.0	3.5	37.6	1.7	23.2
BT149	Bakla Tepe	Emmer	-23.9	17.8	40.6				
BT131	Bakla Tepe	Barley	-23.1	17.0	56.2	3.5	40.2	1.4	29.8
BT132	Bakla Tepe	Barley			59.8	4.9		1.5	
BT133	Bakla Tepe	Barley	-23.4	17.3	60.0	3.0	39.1	1.7	23.8
BT134	Bakla Tepe	Barley	-22.7	16.6	62.8	5.4	34.7	1.8	20.5
BT135	Bakla Tepe	Barley	-23.3	17.2	48.3	3.6	42.1	1.4	31.2

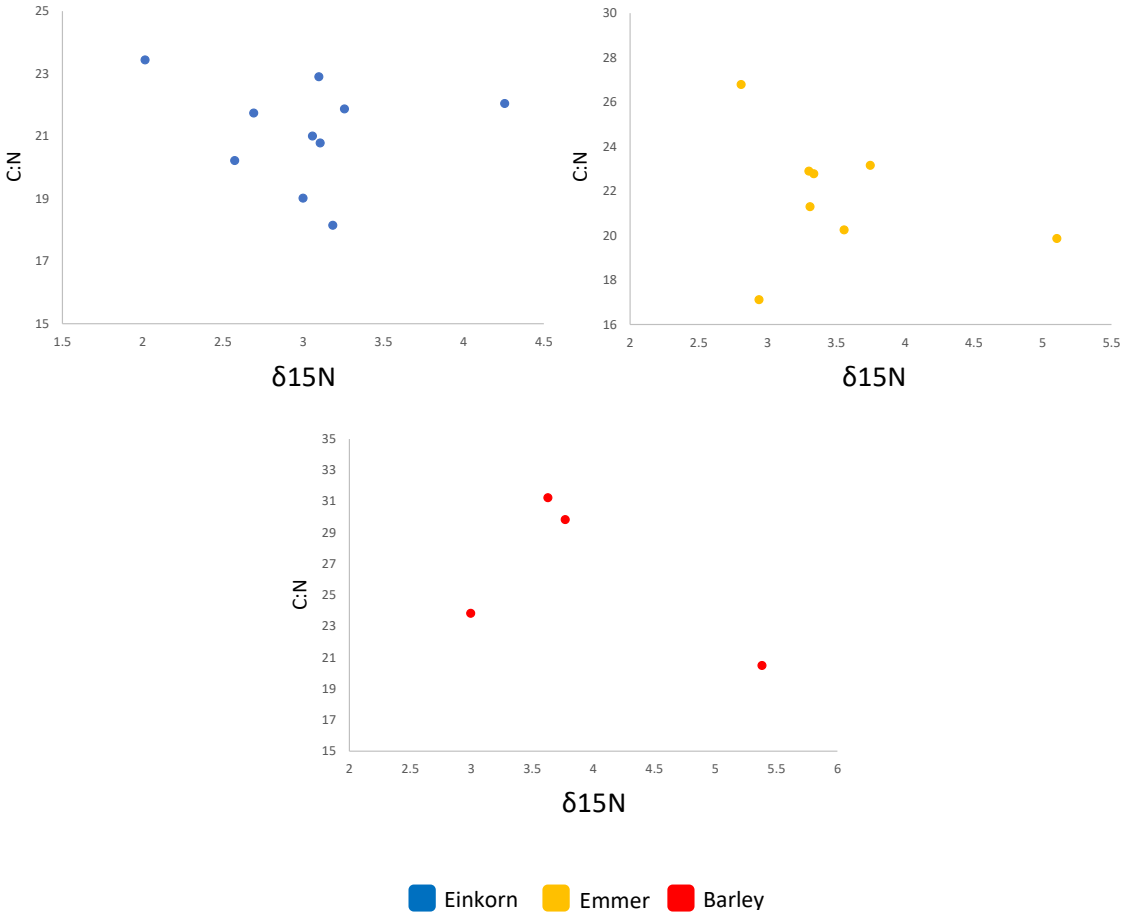
Supplementary Figure 2: C:N ratios of grains that underwent stable isotope analysis from a) Liman Tepe and b) Bakla Tepe plotted against $\delta^{15}N$ (*cf*. Szpak and Chiou 2019).

a



Supplementary Figure 2 (continued)

b



References

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Szpak, P. and Chiou, K. L. 2019. 'A comparison of nitrogen isotope compositions of charred and desiccated botanical remains from northern Peru'. *Vegetation History and Archaeobotany*, 29. 527-38

Vaiglova, P., Snoeck, C., Nitsch, E., Bogaard, A. and Lee-Thorp, J. 2014. 'Impact of contamination and pre-treatment on stable carbon and nitrogen isotopic composition of charred plant remains'. *Rapid Communications in Mass Spectrometry*, 28. 2497-510

Paper 3

Farming and land use strategies in Bronze Age western Anatolia and their implications for the emergence and collapse of coastal citadels

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Abstract

Archaeobotanical assemblages from Liman Tepe, Çeşme-Bağlararası, Bakla Tepe and Kocabaş Tepe provide the opportunity to reconstruct how farming strategies within the Izmir region of western Anatolia were adapted to the rapidly changing cultural and natural environments of the Bronze Age . We identify the staple crop species cultivated at the sites and combine stable isotope analysis and functional ecological analysis to investigate agricultural land use practices. During the Early Bronze Age (EB/EBA) I-II, five crop taxa were cultivated at the sites, replaced by a focus on drought-tolerant barley and bitter vetch at late EBA-early Middle Bronze Age (MBA) Liman Tepe and Kocabaş Tepe. Agricultural strategies at all four sites were 'low-input' throughout the Bronze Age, with cereals cultivated in fields with low soil fertility that received moderate levels of manure but were often well-watered. Pulses were grown on plots with higher soil fertility and more intensive manuring than cereals. Late EBA-early MBA barley was

cultivated on drier soils than EB I-II glume wheats, indicating a shift in agricultural strategies towards drought-tolerant cereal cultivation with water management practices redirected to pulses. This was plausibly a response to the onset of drier climatic conditions associated with the '4.2ka event'. The divergent cultivation intensities applied to cereals and pulses resembles the practices of recent farmers in the Aegean engaged in extensive systems of land use. Expanded forms of these agricultural systems were used to amass agrarian wealth by elites occupying the citadels of EB II-III western Anatolia. This indicates that the agroecological basis of elite wealth was also present in earlier periods with more limited evidence for high levels of wealth inequality. We suggest that changes in the organisation of the agricultural economy between the Late Chalcolithic and EB I-II were crucial to the later rise of citadel elites by fostering the creation of corporate institutions designed to dampen emergent arable wealth inequality at the community level. Burial evidence for high status and wealthy individuals in settlements with highly developed corporate institutions suggests that these may have been precursors to the elite citadels of the EB II-III.

1. Introduction

The Bronze Age (*c*. 3000/3100-1200 BC) of western Anatolia and the eastern Aegean islands was a period of pronounced social, economic and technological development. The earlier Early Bronze Age (EB/EBA) (EB I-II, *c*. 3000/3100-2600 BC) saw the widespread adoption of a common settlement type across the region, characterised by densely spaced longhouses surrounded by fortification walls (Ivanova 2013; Fidan *et al*. 2015; Kouka 2016). Central buildings that may have possessed public or corporate functions in some settlements (*cf.* Bachhuber 2015, 76-82) indicate the emergence of

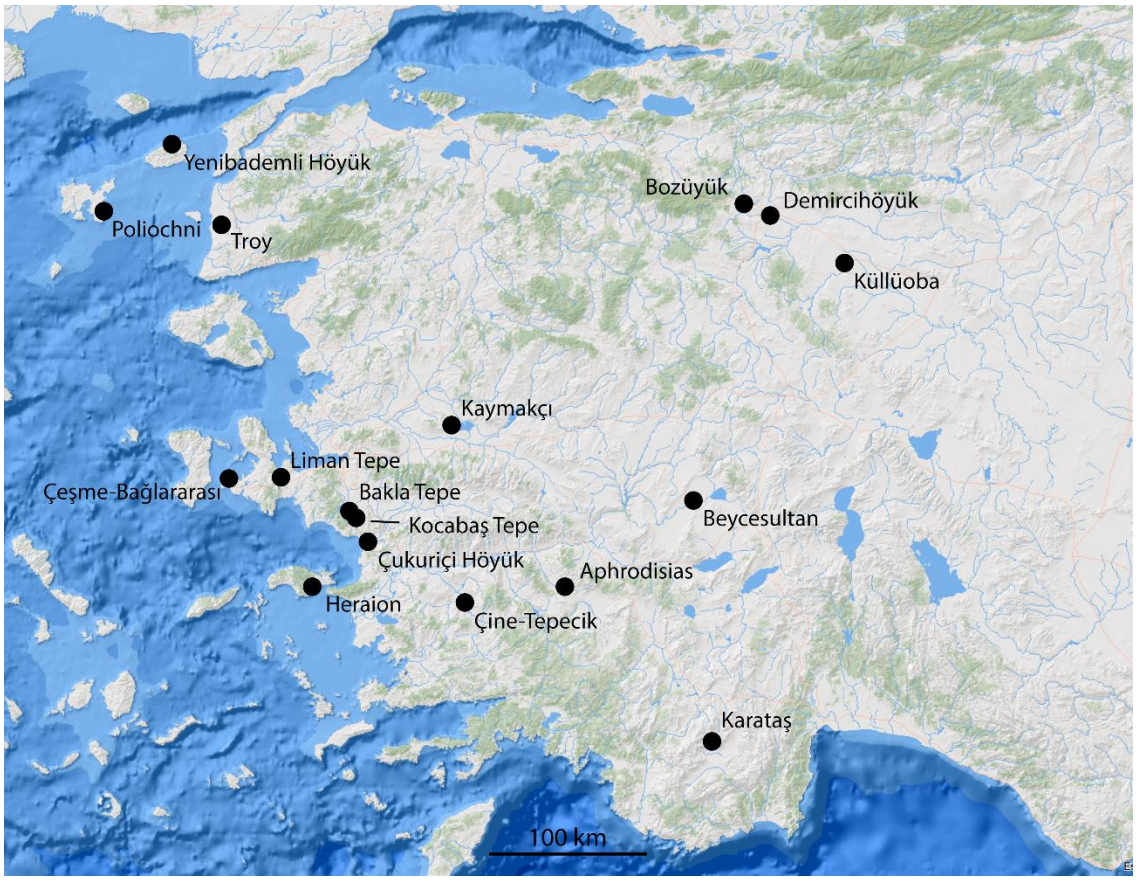
new forms of social morphology during this period. A period of rapid development in the mid-third millennium BC (marking the start of the later EBA, EB II-III, *c.* 2600-2000 BC) saw the expansion of some settlements to include lower towns surrounding fortified citadels that contained non-domestic structures and megara (Şahoğlu 2005; Çevik 2007; Kouka 2013; 2016; Fidan *et al*. 2015). The monumentality of some citadels and associated deposits of gold and metal artefacts suggest that they were occupied by elite individuals and attest to high levels of wealth inequality between citadel and lower town. This occurred alongside elaborations in the production and distribution of metals (notably gold, silver and tin) through long-distance trade networks, suggesting that control of this resource played a role in the blossoming of elite wealth and power (Şahoğlu 2005). Evidence for the destruction of a number of settlements in the EB III was often followed by simpler settlement patterns and has been linked to the rapid onset of drier climatic conditions around 2200 BC (the '4.2ka event'—Roberts *et al*. 2011; Massa and Şahoğlu 2015). A re-emergence of citadel and lower town in the MBA (*c.* 2000-1650 BC) and LBA (*c.* 1650-1200 BC) saw a number of sites hit their zenith in size and wealth as they developed into the centres of regional kingdoms (Bryce 2011).

Agricultural production and the administration of its products have been implicated at several key points in this narrative. Provisions for large-scale agricultural storage within later EBA citadels (e.g., Troy II—Thumm-Doğrayan 2016) suggest that the centralisation of farming products was a key aspect of elite wealth and power during this period (Bachhuber 2015, 130-49). The suggested links between the drier climate of the 4.2ka event and the collapse of later EBA citadels also implies disruption to agricultural production as a major driver of societal change. Archaeobotanical research into Bronze Age western Anatolia is limited, however. Archaeobotanical remains have been

published from a limited number of sites (Troy—Riehl 1999 and Yenibademli Höyük—Oybak 2005 in coastal western Anatolia and the eastern Aegean islands and Küllüoba—Çizer 2015; Kaymakçı—Shin *et al*. 2021 and LBA Beycesultan—Helbaek 1961 in inland western Anatolia, with limited remains from Çukuriçi Höyük, Izmir—Horejs *et al*. 2011; Aphrodisias, Aydın—Greaves 2008; Poliochni, Lemnos—Arobba *et al.* 2008; Demircihöyük, Eskişehir—Schlichtherle 1977/78; Bozüyük, Bilecik—Wittmack 1896 and EBA Beycesultan—Mellaart and Lloyd 1962), and with only limited reference to the nature of crop cultivation and arable land management strategies (see, however, Blum and Riehl 2015). Our knowledge of how the agricultural economy was adapted to the changing socio-political and environmental contexts of this period is therefore limited.

In this study, we begin to address this gap in research through a diachronic investigation of agricultural production across the Bronze Age occupations of four sites in the Izmir region of western Anatolia: Liman Tepe, Bakla Tepe, Kocabaş Tepe and Çeşme-Bağlararası (Figure 1). We use the recently developed 'weed + isotope' approach (Bogaard *et al*. 2016; 2018) to archaeobotanical analysis in order to reveal developments in crop husbandry and arable land management practices. We assess the implications of these developments for two key events in Bronze Age western Anatolia: the emergence of the elite citadels of the later EBA and the potential role of the 4.2ka event in their collapse. We also present the first MBA archaeobotanical remains published so far from western Anatolia.

Figure 1: Locations of the sites mentioned in the text.



2. Methodological and theoretical background

2.1 The 'weed + isotope' approach to establishing arable farming strategies

In this study, we interpret the arable weed assemblage using a functional ecological approach (Hodgson 1989, 1990, 1991), applied to archaeobotanical remains as outlined in Charles *et al*. (1997) and Jones (2002). In short, this approach utilises measurements of certain physical or behavioural traits ('functional attributes') of weeds, indicative of their potential in relation to major ecological variables that make up specific growing environments. This allows the identification of modern cultivation practices in the past alongside novel combinations of practices that are not known today (Jones 2002). A set

of functional attributes has been identified that successfully distinguishes between the weed flora of fields cultivated with higher and lower levels of soil productivity and/or mechanical disturbance (i.e., cultivation intensity) within traditional farming systems in southern Europe (Jones *et al*. 2000; Bogaard *et al*. 2016) and Morocco (Bogaard *et al*. 2018). We use discriminant analysis to classify archaeobotanical weed floras as deriving from higher or lower cultivation intensities in comparison to these traditional farming systems.

Stable isotope analysis of crop grains/seeds can complement the functional ecological approach by providing evidence for crop water status and manuring. $\delta^{13}C$ (the ratio of the isotopes ^{13}C:^{12}C relative to a universal standard) values in C_3 crops such as wheat, barley and pulses are influenced by the movement of carbon dioxide through stomata. This is influenced in turn by the water status of the crop, with the greatest discrimination against the heavier isotope ^{13}C when stomata are open when water is readily available during carbon fixation (Farquhar *et al*. 1989). In environments where the availability of water can restrict plant growth, the $\delta^{13}C$ values of archaeological grains can be interpreted with reference to climate and farming strategies aimed at preventing water stress (Wallace *et al*. 2013; 2015). The $\delta^{15}N$ (the ratio of the isotopes ^{15}N:^{14}N) values of crops are predominantly influenced by the soil nitrogen composition when they were grown. This may be influenced by a range of factors, including aridity (Heaton 1987; Aranibar *et al*. 2004; Styring *et al*. 2017a) and saltwater spray (Virginia and Delwiche 1982; Heaton 1987), but a major potential factor is manuring, which can increase the $\delta^{15}N$ values of crops by up to 10‰ (Fraser *et al*. 2011). These two approaches thus complement each other by providing evidence for the general type and productivity of cultivation as well as the contributions of specific land management practices.

2.2 Farming systems and their implications for emergent wealth inequality

A key distinction we make in this study is between higher-input, or 'intensive', and lower-input, or 'extensive', farming systems (Halstead 1981; 1987; 1995; 2014; Bogaard *et al*. 2019; Halstead and Isaakidou 2020). Intensive farming is characterised by higher labour inputs per unit area, with frequent tillage, weeding and manuring utilised to enhance the productivity of smaller arable plots. Extensive farming is characterised by lower labour inputs per unit area, with lower arable productivity offset by larger scales of cultivation using specialised draught animals. A key difference between these systems is the limiting factor to production. Within intensive systems, production is directly tied to the amount of labour that can be invested to enhance arable productivity within a given area, meaning that they are 'labour-limited'. In contrast, the labour-saving but land-intensive nature of extensive farming ties productivity to the amount of land that can be taken under cultivation. They are therefore 'land-limited'.

Bogaard *et al*. (2019) have revealed a link between the adoption of land-limited farming systems and the emergence of sustained high wealth inequality within western Eurasia. A key explanation for this is that differences in productive capacity resulting from inequity in land ownership and other forms of material wealth, such as draught oxen, may far surpass those from the ability to mobilise human labour. Differences in material wealth may also be inherited across generations more readily than the ability to mobilise labour, facilitating the maintenance of sustained wealth inequality. While theoretical, this aligns with pathways to wealth creation described by recent non-mechanised farmers in the Aegean (Halstead 2014). There is a diversity of pathways by which the transition from labour to land-limited farming may occur (Bogaard *et al*. 2019), but we

highlight the potential role of distance between fields and habitation. In a study of non-mechanised farmers in Evvia, Greece, Jones *et al*. (1999) found a direct correlation between cultivation intensity and the distance of arable plots from the home. Those closest to the settlement tended to be smaller and higher-input, while those further afield tended to be larger and lower-input. The organisation of populations into nucleated settlements therefore tends to be associated with low-input cultivation integrated within extensive systems of land use (e.g., Halstead and Jones 1989; Styring et al. 2017a). While ethnographic studies (e.g., Halstead 2014) demonstrate the complexity of farming as a continuum between the dichotomy presented here, we focus on the ends of the agricultural spectrum as an analytical framework from which to infer the practical implications of past farming systems.

3. The study sites

3.1 Liman Tepe

Liman Tepe is located on a peninsula in the Iskele quarter of Urla in the southwest coast of the Gulf of Izmir (Figure 1). The earliest remains from the settlement date to the Early Neolithic, with clear evidence for occupation from the Middle Chalcolithic until after the end of the Bronze Age (Erkanal and Şahoğlu 2016; Tuncel and Şahoğlu 2018). Occupation of the peninsula appears to have been linked to its accessibility from the mainland, becoming permanently connected to the coast by the late fourth millennium BC (Goodman *et al*. 2009; Riddick *et al*. 2020).

Three phases of occupation are recorded across the EBA, corresponding to the EB I-II, late EB II-early EB III and late EB III (Erkanal and Şahoğlu 2016). The EB I-II settlement is characterised by longhouses sharing walls and abutting a fortification wall (Figure 2).

Figure 2: EB I-II longhouses from Liman Tepe (after Erkanal and Şahoğlu 2016, 160 Fig. 3).



The houses share a common plan of a main room containing a central hearth and raised platform separated from a street by a smaller ante-room (Erkanal and Şahoğlu 2016). Artefactual evidence from the longhouses suggests that they were occupied as domestic

spaces, but also attest to a range of craft production activities taking place within them (Erkanal *et al*. 2004, 167; Erkanal *et al*. 2010, 351; Erkanal *et al*. 2011, 467). The EB II-III sees the expansion of the fortification system around the settlement, including a bastion that extends over 20 m underneath the Izmir-Çeşmealtı road (Erkanal and Şahoğlu 2016). A contemporary bastion and fortification wall was also uncovered 500 m to the southeast of the settlement, suggesting the existence of a fortified lower town (Ersoy *et al*. 2011). The settlement is estimated to occupy an area of *c.* 16 ha during this period, with the upper citadel *c.* 1.5-2 ha. Architectural remains within the citadel include a central complex composed of an open courtyard and storage rooms. Finds from the central complex include fine ware ceramics (Day *et al*. 2010), a bull rhyton and a number of stone phalli, indicating high status and potentially ceremonial activities (Erkanal and Şahoğlu 2016). The use of the central complex ended with a severe fire in the early EB III. Later EB III architectural remains were largely destroyed by later activity but suggest a smaller area of occupation within the earlier citadel.

The early MBA occupation of Liman Tepe differs markedly from the EBA. Oval houses containing hearths and domestic artefacts were uncovered in the EBA citadel (Erkanal and Günel 1995, 268-9; Erkanal and Günel 1997, 238). A single rectangular building associated with a number of subterranean storage structures was constructed on a terrace on the EB II-III bastion during this period (Erkanal and Artzy 2002, 377). LBA architectural remains were heavily damaged by modern construction on the mound but are consistent with workshops and houses lining streets (Mangaloğlu-Votruba 2014).

3.2 Bakla Tepe

Bakla Tepe is located in the Cumaovası plain in southern Izmir (Figure 1). Well-preserved architectural remains at the site reveal settlements dating to the Late Chalcolithic and EB I-II (Erkanal and Özkan 1999; Şahoğlu and Tuncel 2014). Like Liman Tepe, the EBA occupation is characterised by a fortified settlement containing longhouses sharing walls and separated into blocks by streets (Gündoğan *et al*. 2019). The houses share a common plan with central hearths and likely storage structures immediately outside or within the entrance. A single freestanding 'megaron' lined with benches has been interpreted as evidence for elites but may also have served a communal function. Artefactual evidence suggests that textile production was undertaken inside the longhouses, while metallurgical and chipped stone production was carried out in dedicated parts of the settlement (Gündoğan *et al*. 2019).

A cemetery contemporary to the EB I-II settlement was excavated just outside the eastern fortification wall (Şahoğlu 2016). A second cemetery dating to the EB II-III and containing *c.* 200 jar and *pithos* burials was also excavated on the south of the mound. Grave goods in the later cemetery included a wide variety of ceramics alongside bronze weapons and jewellery. A single adult female was buried with a unique range of grave goods and showed signs of trepanation (Erdal 2006), but no other evidence exists for 'elite' burials. Only very limited EB II-III architectural remains were uncovered on the mound.

3.3 Kocabaş Tepe

Kocabaş Tepe occupies a large rocky outcrop approximately 2 km southwest of Bakla Tepe (Figure 1). Archaeological remains that were originally dated to the MBA are

known from surveys and limited test excavations (Erkanal and Özkan 1999). Rows of large stones on the west of the mound may indicate the presence of a fortification wall. Semi-apsidal buildings containing *pithoi* and stone bins associated with carbonised crop remains were uncovered on the south of the mound and have been interpreted as storage rooms. Rectangular buildings next to the storage rooms contained metal slag and ceramic moulds and have been interpreted as workshops. Recent radiocarbon dates obtained from charred grains in the storage rooms are fully reported in supplementary Table 1 and supplementary Figure 1 and date to 2140-1970 cal. BC (EBA/MBA) and 1540-1450 cal. BC (LBA).

3.4 Çeşme-Bağlararası

Çeşme-Bağlararası is located within the city of Çeşme, near the western tip of the Urla-Çeşme peninsula (Figure 1). The earliest occupation of the site dates to the EB II and is represented by four longhouses sharing walls and opening onto streets (Şahoğlu 2015). The houses vary in their size and internal features, but all contain central hearths typically associated with plastered platforms. Artefactual evidence suggests that craft production took place within the houses (Şahoğlu *et al*. 2011).

After a gap in occupation, the site was reoccupied in the late MBA 30 m south of the EB II settlement. The MBA settlement is characterised by tightly clustered, predominantly single roomed buildings containing artefacts consistent with domestic functions (Şahoğlu 2015). Again, the rooms vary in size and internal features, but all contain an oven in the far-left corner opposite the entrance. A unique structure within the settlement is the ‘wine house’, so called because of a circular plastered basin linked to a smaller pit and interpreted as a structure for pressing grapes (Erkanal and Karaturgut

2004, 157). Three subterranean rooms attached to the main room are interpreted as a cistern and two storage rooms.

The LBA is characterised by two phases corresponding to the LM IA and LH IIIA2-IIIB (Şahoğlu 2015). Archaeological remains are known only from pits dug into the MBA settlement area and containing large amounts of imported Minoan and Mycenaean ceramics alongside animal and plant remains.

4. Materials and methods

4.1 Archaeobotanical sampling, identification and analysis

The methodology for the sampling, recovery and identification of archaeobotanical remains is outlined in the supplementary material. We analysed a total of 45 archaeobotanical samples containing over 19,000 grains/seeds. The number of samples and range of contexts analysed from each site and occupation phase are outlined in supplementary Table 2. In some cases, only a few samples from a site occupation phase matched our criteria for analysis. We therefore focus our interpretations on broader patterns incorporating numerous sites so that they may be based on a larger, more robust dataset. Our decision to only analyse samples containing at least 30 grains/seeds means that each one reflects the botanical composition of its context to a reasonable degree of accuracy and reliability, however (*cf*. van der Veen and Fieller 1982; Jones 1991).

Arable weeds harvested with crops form the basis of the functional ecological analysis used in this study. Remains of wild taxa can enter the archaeological record from a range of sources, however (e.g., animal dung—Charles 1998) meaning that it is essential to

identify those that may have derived from non-arable pathways. Following Charles (1998), Bogaard *et al*. (2013) and Wallace and Charles (2013), we used several criteria to identify plant taxa of likely non-arable origin. These are described, along with the results of the analysis, in the supplementary material.

4.2 Functional ecological analysis of arable weeds

In the functional ecological analysis, we inferred cultivation intensity using functional attributes primarily related to arable fertility but also influenced by mechanical disturbance (following Bogaard *et al*. 2018). The functional attributes we used were mean specific leaf area, leaf area per node/leaf thickness, canopy diameter and canopy height (see Jones *et al*. 2000 and Bogaard 2004 for full descriptions and the ecological significance of each attribute). Taxa identified to species level or genera that represent fewer than five potential species were included in the analysis. Only samples containing ten or more seeds of three or more weed taxa were included in order to maintain a reasonable degree of representativeness.

4.3 Sampling and preparation of crop remains for stable isotope analysis

The sampling strategy of grains for stable isotope analysis is described in the supplementary material. Archaeobotanical grains/seeds were selected for analysis if they showed little to no morphological distortion and had dense interior structures consistent with charring within the 'optimal charring window' of 215-260°C (Charles *et al*. 2015; Nitsch *et al*. 2015). We identified the presence of soil-derived contaminants within the selected grains/seeds using a Fourier Transform Infrared Spectroscopy with Attenuated Total Reflectance (FTIR-ATR). FTIR spectra were baseline corrected using Agilent Resolution Pro and compared to grains experimentally contaminated by Vaiglova

et al. (2014). The results are described in the supplementary material. We chose not to pre-treat grains/seeds prior to stable isotope analysis, but we gently scraped them to remove any surface contamination visible under x7-45 magnification.

We analysed single grains individually rather than bulk samples of multiple grains (*cf*. Kanstrup *et al*. 2012) in order to reveal variation in isotopic values between grains within individual archaeobotanical samples. This allowed us to assess whether the often relatively small numbers of grains recovered from tertiary archaeological contexts derived from the same growing environments. Where possible, following Kanstrup *et al*. (2012), we aimed to analysis 10 grains from each archaeobotanical sample. Where this was not possible, we analysed a minimum of three grains from each sample. This resulted in a total of 109 grains from 16 archaeobotanical samples from the four sites. The number of samples analysed from each site and occupation phase are outlined in supplementary Table 4.

4.4 Stable isotope analysis

Archaeological grains/seeds were crushed using an agate mortar and pestle and weighed into tin capsules for IRMS analysis on a Sercon EA-GSL mass spectrometer. Raw isotope ratios were calculated using an internal alanine standard. Three-point normalisation of $\delta^{13}C$ values to the Vienna Peedee Belemnite scale (VPDB) and $\delta^{15}N$ values to atmospheric N_2 was conducted using the standards alanine, seal collagen and cow collagen. EMA P2 and leucine were used as check standards. Measurement uncertainties were calculated as the combined uncertainty of the raw measurement and reference standards, following Kragten (1994). Calculations were carried out using the statistical programming language R (3.2.3). The average measurement uncertainties for

$\delta^{13}C$ were 0.27‰ for Liman Tepe, 0.25‰ for Bakla Tepe, 0.27‰ for Kocabaş Tepe and 0.29‰ for Çeşme-Bağlararası. For $\delta^{15}N$, they were 0.49‰ for Liman Tepe, 0.36‰ for Bakla Tepe, 0.47‰ for Kocabaş Tepe and 0.47‰ for Çeşme-Bağlararası.

The $\delta^{13}C$ and $\delta^{15}N$ values of archaeobotanical grains/seeds were corrected for the effects of charring by subtracting 0.11‰ and 0.31‰, respectively. These are the average offsets between crop grains that are uncarbonised and those that were experimentally charred at a range of intervals and temperatures that resulted in undistorted seeds with dense interior structures (Nitsch *et al*. 2015). Archaeological $\delta^{13}C$ values were converted into $\Delta^{13}C$ in order to compare them with modern reference stable isotope determinations. $\Delta^{13}C$ value were calculated from the determined $\delta^{13}C$ values ($\delta^{13}C_{plant}$) and a $\delta^{13}C_{air}$ value approximated by the AIRCO2_LOESS system (Ferrio *et al*. 2005). The equation follows Farquhar *et al*. (1989):

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

4.5 Statistical analysis

Statistical analyses were carried out using SPSS 27. Two-tailed oneway ANOVA and post-hoc Tukey's tests were used to compare more than two groups with equal variance. Two-tailed Kruskall-Wallis and post-hoc Dunn tests were used to compare more than two groups with non-equal variance. Two groups were compared using t-tests. Equality of variance was identified using Levene's test.

5. Results

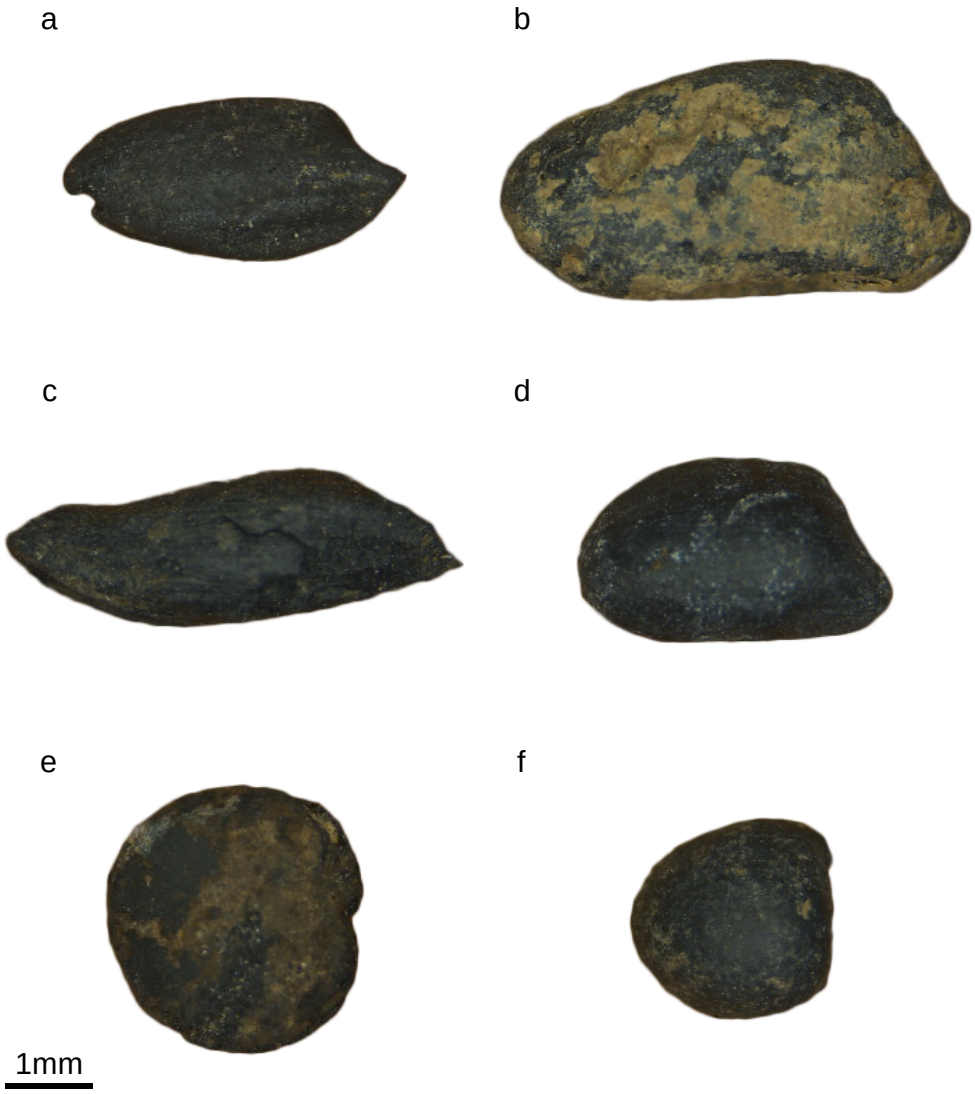
5.1 Crops and economic taxa

Six major crop taxa were identified within the assemblage (Figure 3): einkorn (*Triticum* monococcum L.), emmer (*T. dicoccum* Schrank ex Schübl.), free-threshing wheat (*T. aestivum* L./*durum* Desf.), hulled barley (*Hordeum vulgare* L.), bitter vetch (*Vicia ervilia* (L.) Willd.) and lentil (*Lens culinaris* Medikus). These taxa were recovered in significant quantities from multiple sites and occupation periods (Figure 4). Seeds of winged vetchling (*Lathyrus ochrus* (L.) DC.), Spanish vetchling (*Lathyrus clymenum* L.), grass pea (*Lathyrus sativus* L.), chickpea (*Cicer arietinum* L.), fava bean (*Vicia faba* L.) and glume bases of spelt wheat (*T. spelta* L.) were recovered in more minor quantities within the assemblages. Remains of fruit and nut taxa are typical for the region, with olive (*Olea europaea* L.), grape (*Vitis* L.), fig (*Ficus carica* L.), apple/pear (*Malus* Mill./*Pyrus* L.), plum (*Prunus* L.), and acorns (*Quercus* L.) identified at multiple sites and occupation periods. Domestic flax (*Linum usitatissimum* L.) was also recovered in small quantities across the assemblages.

Grains of einkorn and emmer were recovered together in *c*. 80% of samples and all site occupation periods that contained moderate quantities (>10 grains) of either taxon. As glume wheats, their ability to be processed in the same way (Hillman 1984) suggests that they may have been cultivated as a mixed crop, continuing a practice from Late Chalcolithic Liman Tepe and Bakla Tepe (Maltas *et al*. forthcoming; in prep), but they may also have been processed and/or stored together following separate cultivation.

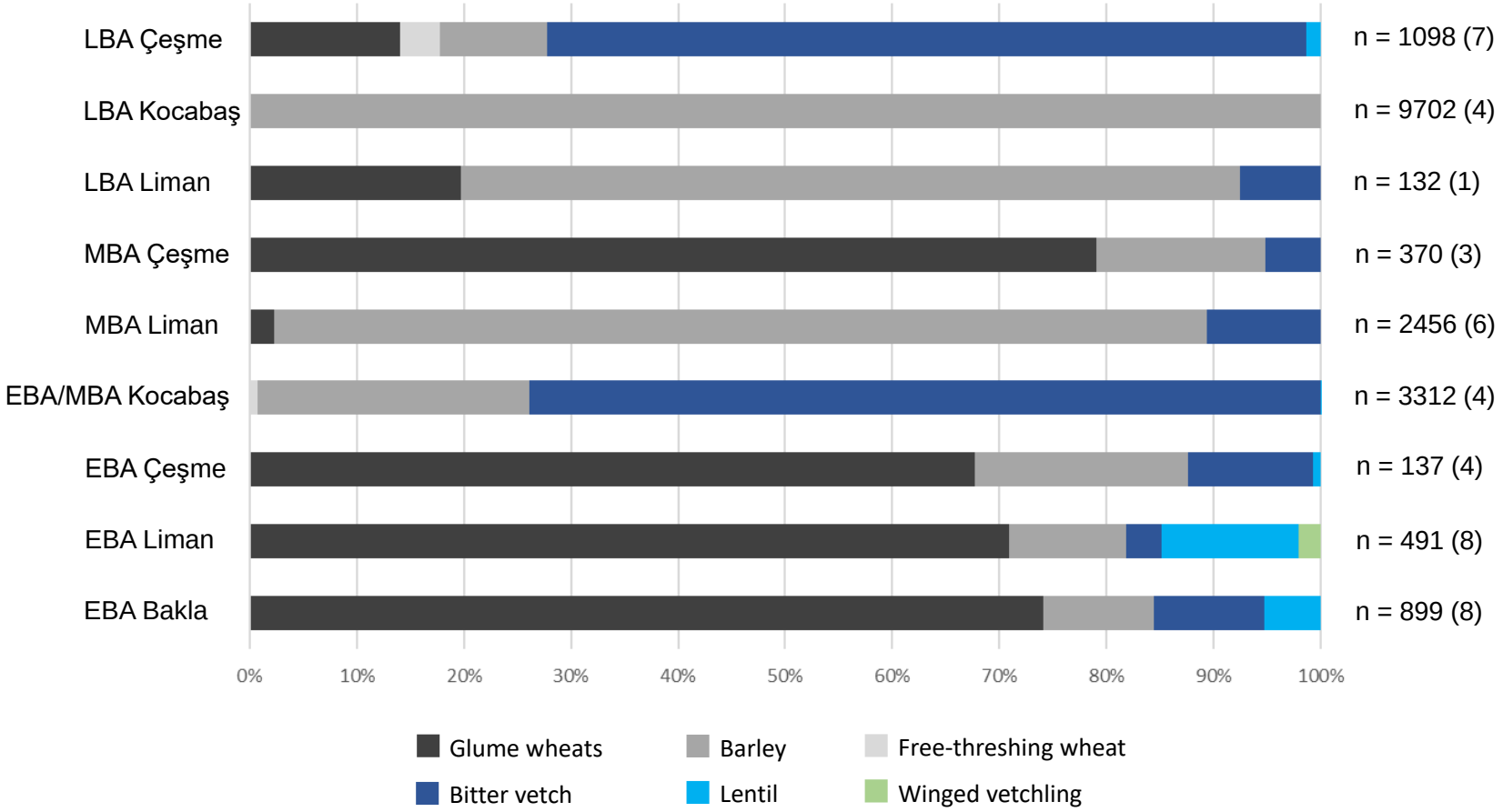
Several trends are visible in the proportions of major crop taxa within the assemblages (Figure 4). The crop spectra of the three EBA sites are dominated by glume wheats, with

Figure 3: Archaeobotanical crop remains from the sites in our study, all in lateral view. a: einkorn, MBA Çeşme-Bağlararası; b: emmer, EBA Bakla Tepe; c: barley, LBA Kocabaş Tepe; d: free-threshing wheat, LBA Çeşme-Bağlararası; e: lentil, EBA Liman Tepe; f: bitter vetch, EBA/MBA Kocabaş Tepe.



barley present in lower quantities, and varying proportions of bitter vetch and lentil. Exclusive to Liman Tepe is winged vetchling, making up *c.* 10% of the pulses recovered from this phase. It is not clear if this attests to its cultivation as a crop or a contaminant of lentil harvests, having been cultivated at Liman Tepe in the late fourth millennium BC

Figure 4: Proportions of major crop taxa during each period of occupation of the study sites. n = number of grains/seeds (number of samples).

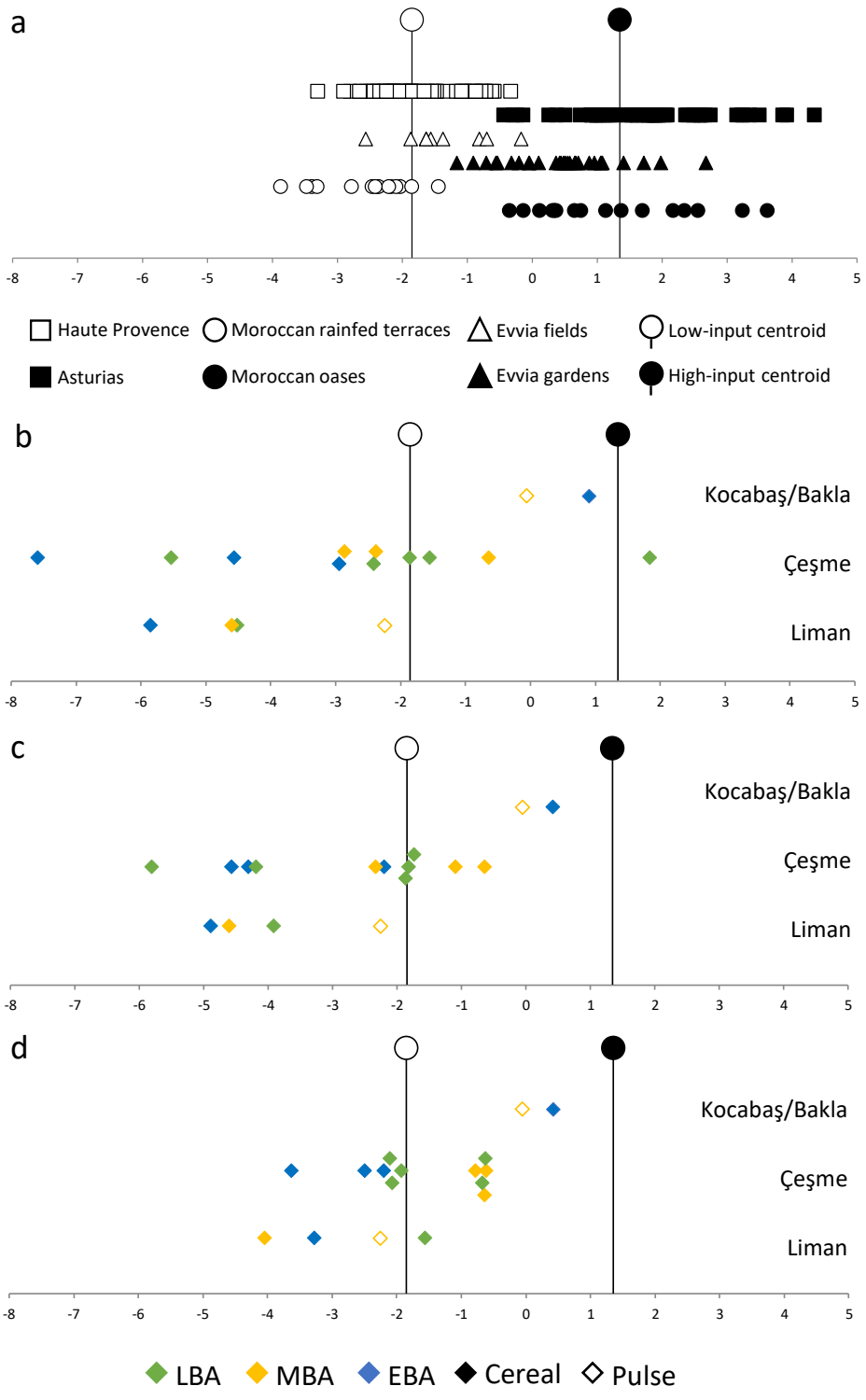


(Maltas *et al*. forthcoming; *cf.* Jones and Halstead 1990). In the MBA, the crop spectrum of Liman Tepe becomes heavily dominated by barley and bitter vetch. This is mirrored at EBA/MBA Kocabaş Tepe, where small amounts of free-threshing wheat were also recovered. The LBA samples from Kocabaş Tepe and Liman Tepe are also dominated by barley. In contrast, the crop spectrum of Çeşme-Bağlararası remains relatively consistent between the EBA and MBA, changing only in the LBA with the addition of free-threshing wheat and greater proportions of barley. The predominance of bitter vetch during this period is due to a single large sample composed entirely of this taxon. We consider the implications of the contexts and compositions of the archaeobotanical samples for their representativeness of the crop spectra from each site/phase in the supplementary material.

5.2 Functional ecological analysis

The results of the functional ecological analysis of arable weeds are shown in Figure 5. In Figure 5b, samples were analysed including all weed/wild taxa, including those that likely entered the archaeobotanical record in animal dung. Figure 5c shows the results of the analysis when likely dung-derived taxa were removed but taxa of ambiguous origin remained included. In Figure 5d, both taxa that were likely dung-derived and of ambiguous origin were removed, leaving only likely arable weeds. In all three analyses, the majority of samples loaded towards the negative end of the axis and were categorised as low-input, indicating low arable fertility and rates of disturbance relative to the modern agrosystems. The exclusion of ambiguous and likely dung-derived taxa had significant impacts on the results. Most samples from Çeşme-Bağlararası and Liman Tepe loaded less negatively along the axis and exhibited less variation between samples

Figure 5: The relationship of archaeobotanical samples to the discriminant function produced from modern surveyed fields. a: modern surveyed fields (adapted from Bogaard *et al*. 2018), b: archaeobotanical samples including all weed/wild taxa, c: including likely arable weeds and ambiguous taxa, d: including likely arable weeds only. Samples are coded according to their period and dominant crop content (>70%).



when these taxa were removed. This is likely due to the removal of taxa from the Cyperaceae family, typically associated with unproductive wetland habitats and abundant in the samples from Çeşme-Bağlararası and Liman Tepe (Davis 1968-2000; *cf*. Green *et al*. 2018, 35). The removal of dung-derived and ambiguous taxa had minor impacts on the discriminant scores of samples from Kocabaş Tepe and Bakla Tepe, located further inland. When only arable weeds were included in the analysis, the distribution of samples across the discriminant function was similar to surveyed fields from Haute Provence and the Moroccan rainfed terraces. This indicates comparable ranges of (low-input) crop growing conditions between the archaeological and modern fields.

The categorisation of the samples as low-input is unlikely to have been influenced by differences in climate or local environment between the sites in our study and those surveyed. The average annual rainfall of Izmir exceeds that of Evvia and the southern Moroccan rainfed fields (Türkeş 1996; Bogaard *et al.* 2018; Hellenic National Meteorological Service 2019). Izmir also has very similar geology and natural vegetation to the Evvia study region (Jones *et al*. 1999). This suggests that the results of the functional ecological analysis are robust.

5.3 Stable isotope analysis

The results of the stable isotope analysis are summarised in Table 1. The full results are provided in supplementary Table 5. The supplementary material also contains an assessment of the reliability of the stable isotope determinations.

Table 1: Results of the stable isotope analysis ordered by site and occupation phase. Values have been corrected for a charring offset of -0.11‰ for $\delta^{13}C$ and -0.31‰ for $\delta^{15}N$.

	Liman Tepe							
		Species	**No. grains**	**High**	**Low**	**Average**	**Std. deviation**	**Range**
EBA	$\delta^{13}C$ (‰)	Einkorn	8	-21.9	-24.8	-23.2	1.0	2.9
		Emmer	5	-22.3	-25.1	-24.0	1.1	2.8
		Lentil	9	-21.4	-24.7	-23.0	1.0	3.3
	$\delta^{15}N$ (‰)	Einkorn	10	6.3	3.8	5.2	0.9	2.5
		Emmer	5	5.3	4.0	4.6	0.5	1.4
		Lentil	9	2.7	0.6	1.5	0.6	2.0
MBA	$\delta^{13}C$ (‰)	Barley	16	-22.1	-25.0	-23.2	0.7	2.9
		Bitter vetch	10	-23.2	-25.1	-24.2	0.6	1.9
	$\delta^{15}N$ (‰)	Barley	16	6.8	3.5	5.0	1.0	3.3
		Bitter vetch	10	2.4	0.5	1.2	0.6	1.9
	Bakla Tepe							
EBA	$\delta^{13}C$ (‰)	Emmer	9	-22.5	-24.6	-23.7	0.7	2.1
	$\delta^{15}N$ (‰)		9	4.1	2.9	3.5	0.5	1.2
	Kocabaş Tepe							
EBA/	$\delta^{13}C$ (‰)	Barley	9	-22.3	-24.9	-23.6	0.9	2.5
MBA		Bitter vetch	10	-22.2	-26.0	-24.3	1.0	3.8
	$\delta^{15}N$ (‰)	Barley	9	5.7	2.3	4.2	1.1	3.5
		Bitter vetch	10	3.1	1.3	2.2	0.6	1.8
LBA	$\delta^{13}C$ (‰)	Barley	9	-21.2	-23.0	-21.9	0.6	1.8
	$\delta^{15}N$ (‰)		7	5.6	2.6	4.3	0.9	3.0
	Çeşme-Bağlararası							
EBA	$\delta^{13}C$ (‰)	Einkorn	2	-22.5	-23.5	-23.0	0.5	1.0
		Bitter vetch	3	-22.2	-24.8	-23.8	1.1	2.6
	$\delta^{15}N$ (‰)	Einkorn	4	6.2	5.0	5.8	0.5	1.2
		Bitter vetch	3	2.3	1.3	1.7	0.5	1.0
MBA	$\delta^{13}C$ (‰)	Bitter vetch	5	-21.2	-23.0	-21.9	0.6	1.8
	$\delta^{15}N$ (‰)		5	5.6	2.6	4.3	0.9	3.3

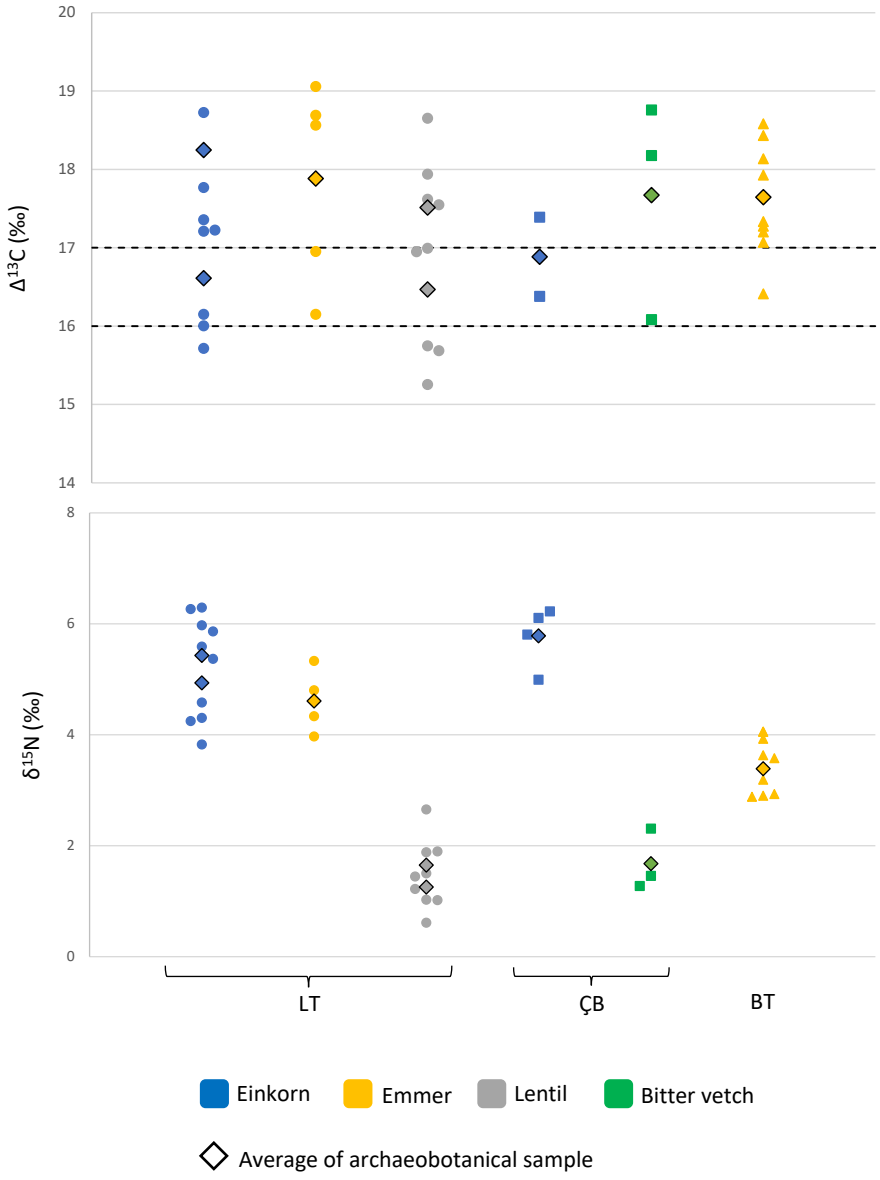
5.3.1 Early Bronze Age

5.3.1.1 Cereal cultivation

In Figure 6, the $\Delta^{13}C$ values of glume wheats from EBA Liman Tepe, Bakla Tepe and Çeşme-Bağlararası are compared to modern reference values for poorly to well-watered wheat (Wallace *et al*. 2013). The majority of grains from all three sites have values consistent with moderate to well-watered crops, suggesting that water availability was not a limiting factor to growth. The $\Delta^{13}C$ values of grains from each site are not significantly different (oneway ANOVA, $p = .651$), suggesting that they were grown under comparable watering regimes. The values of einkorn and emmer from Liman Tepe are also not significantly different (t-test, $p = .119$).

The $\delta^{15}N$ values of the glume wheats (Figure 6) can be interpreted with reference to values of modern crops grown under high to low levels of manuring (Fraser *et al*. 2011; Bogaard *et al*. 2013). Other potential causes of elevated soil $\delta^{15}N$ are aridity (Heaton 1987; Aranibar *et al*. 2004; Styring *et al*. 2017a) and soil salination from sea-spray (Virginia and Delwiche 1982; Heaton 1987). The mean annual rainfall of Izmir is 682 mm (Turkreş 1996, 1063 Table II), and palaeoclimatic studies suggest that precipitation was slightly higher than today during the third millennium BC (Roberts *et al*. 2011). It is unlikely that aridity would be a cause of elevated $\delta^{15}N$ under these conditions and unmanured cereals would be expected to have similar values to those grown in temperate Europe (Fraser *et al*. 2011; Bogaard *et al*. 2013). While we were not able to estimate the $\delta^{15}N$ values of unmanured soils by projecting the values of forage consumed by local herbivores (*cf*. Bogaard *et al*. 2013), Late Chalcolithic cereal grains from Liman Tepe had $\delta^{15}N$ values close to 0‰ (Maltas *et al*. in prep), suggesting that

Figure 6: $\Delta^{13}C$ and $\delta^{15}N$ values of EBA crops from the sites in our study. Dashed lines represent suggested 'boundaries' between crops grown under poor (low values), moderate and high (high values) water availability ($\Delta^{13}C$) based on analysis of modern crops (Wallace *et al*. 2013).



they were grown on soils with little to no $\delta^{15}N$ enrichment (Fraser *et al*. 2011). We may therefore tentatively infer that the $\delta^{15}N$ values for non-enriched soils at the sites in our

study lie between 0 and 2.1‰, the latter being the range of $\delta^{15}N$ values of single grains of modern barley grown in the same unmanured field (Larsson *et al*. 2019). This is consistent with values below 2.5‰ for modern unmanured crops from central Europe (Fraser *et al*. 2011). Sea-spray is a potential cause of enrichment at Çeşme-Bağlararası and Liman Tepe due to their proximities to the coast. Cereals exhibit high $\delta^{13}C$ values in saline rich environments (Isla *et al*. 1998), meaning that $\delta^{15}N$ enrichment from salt water may be visible in a positive correlation between $\delta^{13}C$ and $\delta^{15}N$ values. $\delta^{13}C$ and $\delta^{15}N$ values of EBA (and MBA) cereals from Liman Tepe and Çeşme-Bağlararası are not significantly correlated (Pearson correlation, r = -.095, p = .675). Soil nitrogen enrichment at the sites in our study may therefore be interpreted with reference to manuring practices.

The glume wheat $\delta^{15}N$ values are comparable to modern cereals from central Europe that received moderate levels of manuring (*c.* 2.5-6‰—Fraser *et al*. 2011). The standard deviations of $\delta^{15}N$ from each site are lower than that of modern barley grains grown in the same manured plot (1.64‰—Larsson *et al*. 2019), suggesting that the grains derived from homogenous manuring regimes. The reference values of moderately manured cereals incorporate both long term applications of modest quantities of manure (e.g., biennial applications of 20-30 tonnes/acre) and the residual effects after a period of intensive manuring (Fraser *et al*. 2011; Bogaard *et al*. 2013). Both regular low-level manuring and infrequent intensive manuring are consistent with the low to moderate arable fertility indicated by the functional ecology of arable weeds.

The $\delta^{15}N$ values of einkorn and emmer from Liman Tepe are not significantly different (t-test, p = .116). Nitrogen in manure becomes available to crops over the course of

several years, meaning that the comparable $\delta^{15}N$ values are the result of long-term similarities in manuring (Fraser *et al*. 2011). Coupled with the comparable $\Delta^{13}C$ values between the two crops, the isotopic data supports the inference that they were cultivated as a mixed crop (Maltas *et al*. in prep). Between the sites, glume wheat values from Bakla Tepe are significantly lower than those from Liman Tepe and Çeşme-Bağlararası (oneway ANOVA and post hoc Tukey's between emmer from Bakla Tepe and glume wheats from Liman Tepe, $p = <.001$; between emmer from Bakla Tepe and einkorn from Çeşme-Bağlararası, $p = <.001$), suggesting that they received less manure.

Elsewhere in western Anatolia, isotopic data from Troy suggest that water availability was not a major limiting factor to barley cultivation across the EBA occupation of the site (Riehl *et al*. 2014, 376 Fig. 6). Nitrogen isotope data from Troy contemporary with the EBA sites in our study (Troy I/II, *c.* 2950-2350 BC—Blum and Riehl 2015) are limited to just three barley grains but indicate more intensive manuring than the glume wheats in our study, with $\delta^{15}N$ values ranging from *c.* 5-9‰ (Riehl and Marinova 2016, 327 Fig. 5). Whether or not this formed part of an overall higher input system of crop cultivation at this site is unclear, both due to the limited amount of material analysed and the potential for barley to be more intensively manured than other cereals to encourage rigorous early growth on which to graze livestock (Halstead 2006, 50; *cf*. Nitsch *et al*. 2017). Barley $\delta^{15}N$ values from Troy are more variable towards the end of the EBA (Troy IV, *c.* 2200/2150-1950 BC), with two samples of grain from the same structure clustering between *c.* 0 to 3‰ and *c*. 5 to 8‰.

5.3.1.2 Pulse cultivation

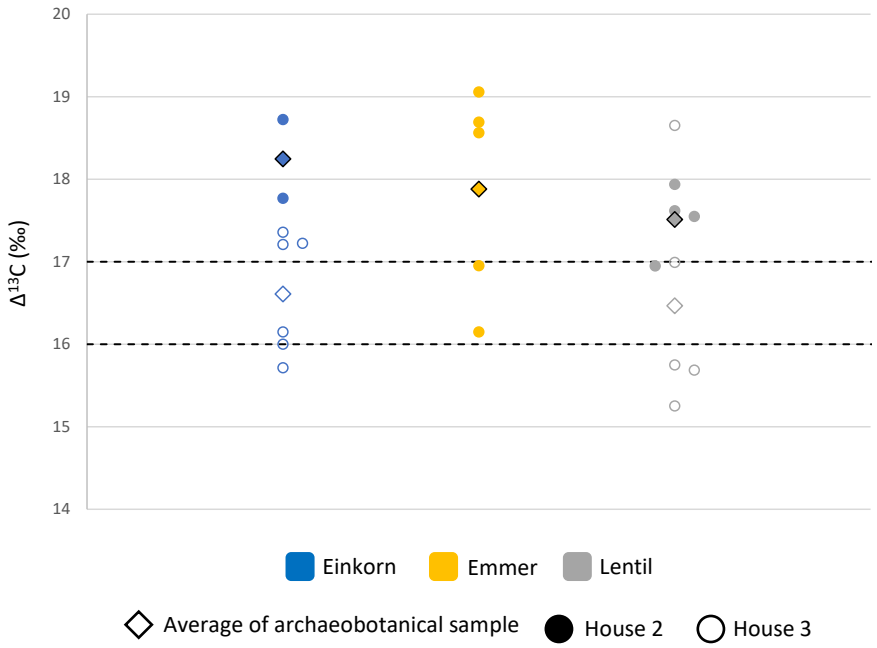
The $\Delta^{13}C$ values of EBA pulses from Liman Tepe and Çeşme-Bağlararası are consistent with moderate to well-watered growing conditions (Figure 6). Pulse values from each site are not significantly different from those of glume wheat from the same site (oneway ANOVA and post hoc Tukey's between pulses and glume wheat from Liman Tepe, p = .891; from Çeşme-Bağlararası, p = .925).

All bitter vetch seeds from Çeşme-Bağlararası and all but one lentil seed from Liman Tepe have $\delta^{15}N$ values over 1‰ (Figure 6). While pulse $\delta^{15}N$ values are less affected by soil enrichment than cereals, modern pulses that received particularly intensive manuring in Evvia, southern Greece, were found to have values ranging from 1‰ to above 4‰ (Fraser *et al*. 2011). Those grown without manure had values predominantly below 1‰. Low level manuring elevates pulse $\delta^{15}N$ values within the range of measurement error and is indistinguishable from unmanured values (Fraser *et al*. 2011). Pulse $\delta^{15}N$ values from Liman Tepe and Çeşme-Bağlararası are therefore consistent with high levels of manuring.

5.3.1.3 Contextual variation in stable isotope values

Figure 7 compares the $\Delta^{13}C$ values of cereals and pulses recovered from each of two adjacent longhouses at Liman Tepe. Both einkorn and lentil from House 2 have higher $\Delta^{13}C$ values than those from House 3. At present, no data are available for the expected variation in $\Delta^{13}C$ values for single grains grown under the same level of water availability, but a range of up to 1‰ was established for bulk samples of modern crops from the same growing condition (Wallace *et al*. 2013; Bogaard *et al*. 2016). The average $\Delta^{13}C$ values of einkorn from Houses 2 and 3 differ by 1.6‰ and are significantly different (t-

Figure 7: $\Delta^{13}C$ values of EBA crops from House 2 and House 3 in Liman Tepe.



test, p = .032), suggesting that the grains from each house derive from distinct growing conditions, although only two grains were analysed from House 2. The average $\Delta^{13}C$ values of lentil from the two houses differ by just over 1‰ but are not significantly different (t-test, p = .192). When the $\Delta^{13}C$ values of glume wheats (including emmer from House 2) and lentil from each house are grouped, however, they are significantly different (t-test, p = .006), suggesting that the occupants of House 2 had access to more well-watered plots than those of House 3. Crop $\delta^{15}N$ values from each house are not significantly different (t-test, p = .966).

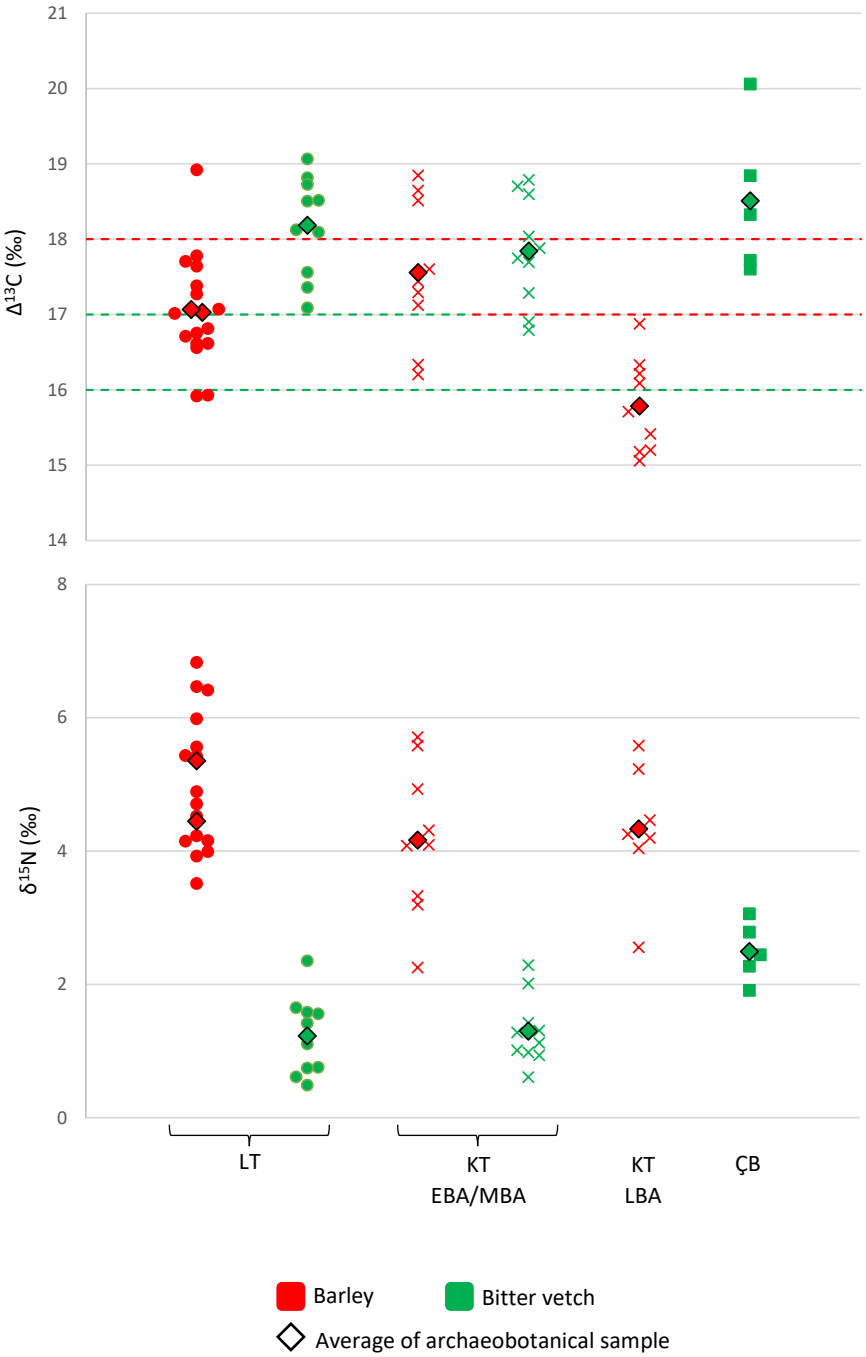
5.3.2 Middle and Late Bronze Age

5.3.2.1 Cereal cultivation

Figure 8 compares the $\Delta^{13}C$ values of barley from Kocabaş Tepe and MBA Liman Tepe with the reference values for poorly to well-watered cereals, adjusted for a 1‰ difference between barley and wheat grown under the same conditions (Wallace *et al*. 2013; Styring *et al*. 2017b). The values of barley from Liman Tepe and EBA/MBA Kocabaş Tepe span the ranges for poorly to well-watered crops, suggesting that some crops experienced drought stress while water was not a limiting factor to the growth of others. Barley $\Delta^{13}C$ values from LBA Kocabaş Tepe are significantly lower than both sets of earlier grains (oneway ANOVA and post hoc Tukey's between LBA Kocabaş Tepe and Liman Tepe, p = .003; between LBA and EBA/MBA Kocabaş Tepe, p = <.001). The average value of LBA barley is 15.8‰ and all grains fall below 17‰. This is consistent with conditions of drought stress (Wallace *et al*. 2011). These inferences also apply when the reference values are adjusted for a lower offset of 0.5‰ between wheat and barley grown under the same conditions. When adjusted for a higher offset of 1.5‰, the majority of grains from Liman Tepe and EBA/MBA Kocabaş Tepe are also consistent with poorly watered crops.

The $\delta^{15}N$ values of grains from each site/phase (Figure 8) are consistent with moderate manuring. The $\delta^{15}N$ values of each site/phase are not significantly different (Kruskal Wallis and post hoc Dunn between EBA/MBA Kocabaş Tepe and Liman Tepe, p = .334; between LBA Kocabaş Tepe and Liman Tepe, p = .545; between EBA/MBA and LBA Kocabaş Tepe, p = .799) and the standard deviation of values from each site/phase are lower than that of modern barley grains from the same manured field (Larsson *et al*.

Figure 8: $\Delta^{13}C$ and $\delta^{15}N$ values of MBA crops from the sites in our study. Dashed lines represent suggested 'boundaries' between crops grown under poor (low values), moderate and high (high values) water availability ($\Delta^{13}C$) based on analysis of modern crops (Wallace *et al*. 2013). Red dashed lines: reference values for barley, green dashed lines: reference values for pulses.



2019). This suggests a high level of consistency in the manuring of barley between each site/phase.

As in the EB I-II, the isotopic and functional ecological evidence align to suggest the utilisation of low-input systems of cereal cultivation at the sites in our study during the late third and second millennia. No isotopic data are available for MBA crops elsewhere in western Anatolia, but barley $\Delta^{13}C$ values from MBA Liman Tepe and EBA/MBA Kocabaş Tepe are comparable to those from Troy IV (Riehl *et al*. 2014, 367 Fig. 6). The $\delta^{15}N$ values of barley from MBA Liman Tepe and EBA/MBA Kocabaş Tepe are also comparable to the more intensively manured barley grains from Troy IV. $\Delta^{13}C$ values of barley from LBA Kocabaş Tepe are *c.* 2‰ lower than those from early LBA Troy VI (Riehl *et al*. 2014, 367 Fig. 6), suggesting that the former was grown on significantly drier soils. The $\delta^{15}N$ values of single barley grains from Troy VI are not published, but the average values from the early and late occupations of this phase fall between 5 and 6‰ (Riehl and Marinova 2016, 326 Fig. 4), indicating slightly more intensive manuring than at LBA Kocabaş Tepe.

5.3.2.2 Pulse cultivation

$\Delta^{13}C$ values of bitter vetch from MBA Liman Tepe and Çeşme-Bağlararası and EBA/MBA Kocabaş Tepe are consistent with well-watered conditions. Bitter vetch values from Liman Tepe and Kocabaş Tepe are both significantly higher than barley from the same site when an offset of -1‰ is used for barley (oneway ANOVA and post-hoc Tukey's between barley and bitter vetch from Liman Tepe, p = <.001; between barley and bitter vetch from Kocabaş Tepe, p = .008), suggesting that they had access to better watered soils. When barley $\Delta^{13}C$ values are offset -0.5‰, they are significantly lower than bitter

vetch at Liman Tepe (p = <.001) but not Kocabaş Tepe (p = .246). The average barley $\Delta^{13}C$ values remain *c*. 0.8‰ lower than that of bitter vetch at Kocabaş Tepe when offset -0.5‰, however.

Bitter vetch $\delta^{15}N$ values from MBA Liman Tepe and EBA/MBA Kocabaş Tepe have broad ranges but are overall consistent with intensive manuring. This aligns with the functional ecological evidence from these sites, with the pulse sample from Liman Tepe indicating higher arable fertility than the cereal sample and the pulse sample from Kocabaş Tepe loading towards the positive end of the discriminant function. Like barley, $\Delta^{13}C$ and $\delta^{15}N$ values of bitter vetch from Liman Tepe and Kocabaş Tepe are not significantly different (oneway ANOVA and post-hoc Tukey's of $\Delta^{13}C$, p = .918; of $\delta^{15}N$, p = .946), indicating overall similar crop management at the two sites. Bitter vetch $\delta^{15}N$ values from Çeşme-Bağlararası are significantly higher than Liman Tepe and Kocabaş Tepe (t-test between Çeşme-Bağlararası and Liman Tepe, p = .001; between Çeşme-Bağlararası and Kocabaş Tepe, p = .001) and all but one seed have values above 2‰, indicating particularly intensive manuring of pulses at this site.

6. Discussion

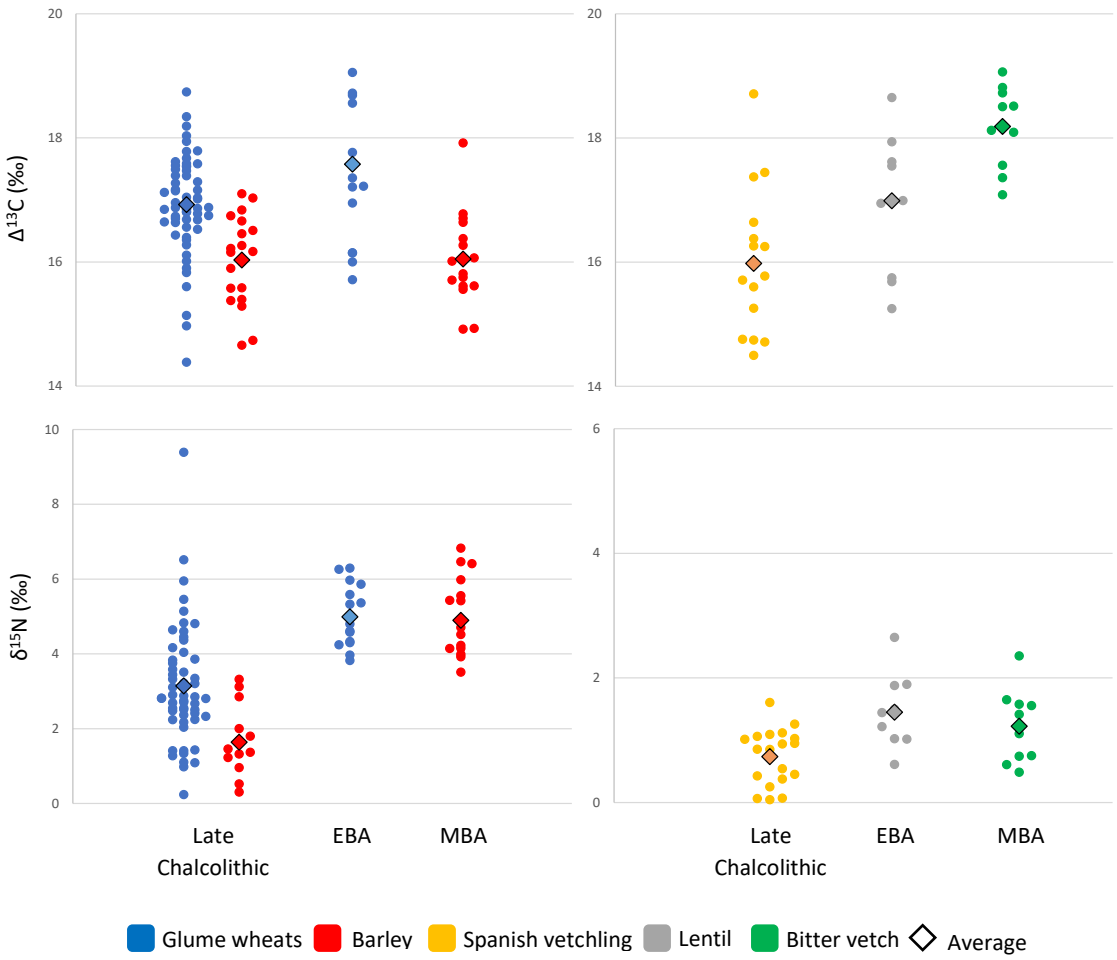
6.1 Temporal variation in farming strategies in the Izmir region

The results of the stable isotope and functional ecological analysis align to suggest that low-input cereal cultivation was coupled with high-input pulse cultivation at the sites in our study during the EBA and MBA. This suggests that cereals and pulses were not grown in rotation and resembles the practices of recent farmers in the Aegean engaged in extensive systems of land use (e.g., Halstead and Jones 1989). In these modern examples, cereals were cultivated on low-input outfield plots while pulses were grown

on smaller, more intensively managed plots closer to the home. This continues a farming system known to the Late Chalcolithic of the Izmir region (Maltas *et al*. forthcoming; in prep), suggesting an overall consistency in the nature of arable production between the late fourth and second millennia BC. Variation in crop choice and specific arable land management practices between sites and periods, however, suggest that this system was adapted to geographically and temporally specific ecological and cultural contexts.

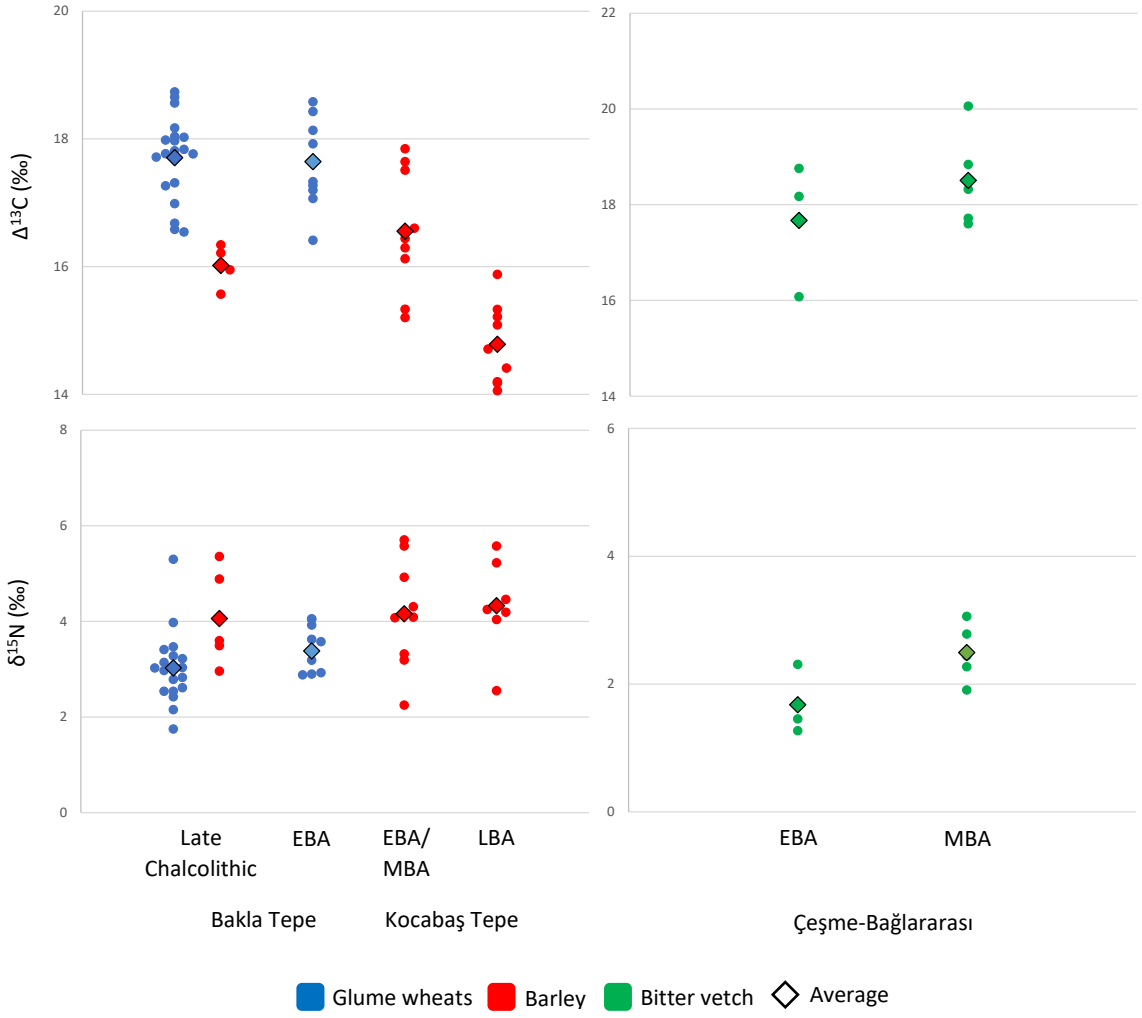
Figures 9 and 10 compare the stable isotope results for each period of occupation within the sites in our study, including those from Late Chalcolithic Liman Tepe and Bakla Tepe reported in an earlier study (Maltas *et al*. in prep). At Liman Tepe, $\Delta^{13}C$ values of glume wheats are broadly consistent between the Late Chalcolithic and EBA. Those of barley are also consistent between the Late Chalcolithic and MBA. The $\delta^{15}N$ values of EBA glume wheat and MBA barley are both significantly higher than the same species in the Late Chalcolithic, however (Kruskal Wallis and post-hoc Dunn between Late Chalcolithic and EBA glume wheat, p = <.001; between Late Chalcolithic and MBA barley, p = <.001). It is possible that this results from differences between the contexts sampled from each period, reflecting the varying abilities of specific Late Chalcolithic and Bronze Age households to mobilise livestock and/or labour for manuring. Additionally, however, long-shore transport between the fourth and third millennia BC had connected Liman Tepe to the mainland by the EBA (Goodman *et al.* 2009; Riddick *et al*. 2020). This is likely to have improved access to arable plots and reduced the transport costs associated with more intensive land management, plausibly facilitating an increase in manuring intensity.

Figure 9: $\Delta^{13}C$ and $\delta^{15}N$ values of Late Chalcolithic, EBA and MBA crops from Liman Tepe. Barley $\Delta^{13}C$ values are offset for a 1‰ difference between wheat and barley grown under the same conditions.



Pulse cultivation strategies also develop between the Late Chalcolithic and EBA. The replacement of the vetchling species with lentil and bitter vetch coincides with an increase in average pulse $\Delta^{13}C$ values. The values of individual EBA pulse seeds fall within the range of those from the Late Chalcolithic and are not significantly different (oneway ANOVA and post-hoc Tukey's, p = .311), however, suggesting that the growing conditions of the EBA were known to the Late Chalcolithic.

Figure 10: $\Delta^{13}C$ and $\delta^{15}N$ values of Late Chalcolithic, EBA, MBA and LBA crops from Bakla Tepe, Kocabaş Tepe and Çeşme-Bağlararası. Barley $\Delta^{13}C$ values are offset for a 1‰ difference between wheat and barley grown under the same conditions.



The near total replacement of glume wheats by barley in the crop spectrum of early MBA Liman Tepe suggests that the latter became the primary cereal crop during this period. This is supported by its comparable $\delta^{15}N$ values to EBA glume wheat (oneway ANOVA and post-hoc Tukey's, p = .855), contrasting with the lower amounts of manure applied to barley than glume wheat in the Late Chalcolithic. The $\Delta^{13}C$ values of MBA

barley remain comparable to those of Late Chalcolithic barley (oneway ANOVA and post-hoc Tukey's, p = 1) and significantly lower than those of EBA glume wheat when offset by both -1 and 0.5‰ (oneway ANOVA and post-hoc Tukey's, barley -0.1‰, p = .012; t-test, barley -0.5‰, p = .030), however, suggesting that increased manuring was not matched by an increase in crop water status.

In contrast, the replacement of lentil by bitter vetch in the early MBA coincides with a significant increase in pulse $\Delta^{13}C$ values (t-test, p = .009). These data betray a shift in cultivation strategies towards an investment in cereals cultivated under drier conditions than the preceding period and the redirection of well-watered soils and/or water management strategies towards pulses. The cultivation of barley on drier plots that received less manure than glume wheat at Liman Tepe in the Late Chalcolithic reflects an awareness of its ability to withstand less favourable growing environments, strongly suggesting a conscious investment in drought tolerant cereal cultivation at the onset of the MBA. Bitter vetch is also known as a relatively drought tolerant pulse (Basheer-Salimia *et al*. 2021), but whether or not this contributed to agricultural decision making by the occupants of Liman Tepe is unclear. The implications of these developments as a response to the impacts of the 4.2ka event will be considered below.

Agricultural developments in the Cumaovası plain show both shared and divergent trends with Liman Tepe (Figure 10). Unlike Liman Tepe, glume wheat $\Delta^{13}C$ and $\delta^{15}N$ values are consistent between the Late Chalcolithic and EBA at Bakla Tepe (oneway ANOVA and post-hoc Tukey's for $\Delta^{13}C$ between the Late Chalcolithic and EBA, p = 1; Kruskal Wallis and post-hoc Dunn for $\delta^{15}N$, p = .424). Like Liman Tepe, however, the crop spectrum of EBA/MBA Kocabaş Tepe is heavily dominated by barley and bitter vetch.

$\delta^{15}N$ values of EBA/MBA barley from Kocabaş Tepe are comparable to those of EBA glume wheat from Bakla Tepe (Kruskal Wallis and post-hoc Dunn, p = .169), but, unlike Liman Tepe, also Late Chalcolithic barley from Bakla Tepe (p = .968). $\Delta^{13}C$ values of EBA/MBA barley from Kocabaş Tepe are comparable to those of MBA Liman Tepe and significantly lower than those of EBA glume wheat from Bakla Tepe when offset -1‰ (two-tailed t-test, p = .012), suggesting a similar investment in the cultivation of cereals on dry soils to contemporary Liman Tepe. When offset just -0.5‰, $\Delta^{13}C$ values of barley from EBA/MBA Kocabaş Tepe are not significantly different to EBA glume wheat from Bakla Tepe (two-tailed t-test, p = .105), but the average value of barley remains 0.54‰ lower than glume wheat.

Like Liman Tepe, the cultivation of barley on drier soils than glume wheats at Late Chalcolithic Bakla Tepe reflects a history of exploitation for its drought tolerance attributes within the Cumaovası plain, suggesting an investment in drought tolerance in the late EBA-early MBA. As outlined above, bitter vetch $\Delta^{13}C$ values at EBA/MBA Kocabaş Tepe and MBA Liman Tepe are not significantly different, indicating a similar contrast between well-watered pulses and drier cereals at the two sites. The further reduction in barley $\Delta^{13}C$ values at LBA Kocabaş Tepe indicates the emergence of even drier growing conditions for this species.

Like Liman Tepe, the average $\Delta^{13}C$ values of pulses from Çeşme-Bağlararası increase between the EBA and MBA (Figure 10). The limited number of seeds analysed from each period make this difficult to interpret, however, and it is not statistically significant (t-test, p = .358). The average $\delta^{15}N$ values also increase between EBA and MBA, but this is also not significant (t-test, p = .061). In contrast to Liman Tepe and the Cumaovası plain,

the proportions of major crop taxa are largely consistent between the two periods at Çeşme-Bağlararası. As noted above, more major agricultural developments occur in the LBA with the introduction of new crop taxa.

These data reveal both shared and divergent trends in arable farming strategies in the Izmir region between the Late Chalcolithic and LBA, suggesting that farmers responded to both site-specific and shared stimuli. Despite this variation, however, extensive farming systems were practiced across the occupations of the four sites. In the following sections, we consider the implications of these agricultural developments for two key events within third millennium BC western Anatolia: the emergence of elite citadels in the later EBA and the 4.2ka event.

6.2 Implications for the agricultural basis of citadel elites in later EBA western Anatolia and the eastern Aegean islands

Provisions for the storage of grain on a large scale suggest that the centralisation of agricultural products was an important source of elite power within later EBA citadels (*cf.* Bachhuber 2015, 130-49). Nevertheless, the role of farming within the *emergence* of these elite economies is as yet poorly understood, with traditional narratives focussing on developments in metallurgy and trade (e.g., Şahoğlu 2005; Efe 2007). More recently, however, Çevik (2007) has suggested that the intensification of inter-regional exchange in Anatolia during the later EBA *followed* the emergence of local elites who sought to reinforce their power through exotic goods. This raises the potential of the agricultural economy as a key source of elite power. Similarly, Schoop (2011) has questioned the degree to which metallurgical production was exclusively under the control of elites and whether it can explain the social transformations of the later EBA. He has emphasised

the need to understand the staple economy of the fourth and third millennia BC in order to reveal the economic context surrounding the emergence of citadel elites. As the first diachronic study of crop cultivation and arable land management strategies within Bronze Age western Anatolia, our study is well placed to address this.

The large scale of arable storage within the citadel of Troy II suggests that later EBA cereals were cultivated in low-input, surplus producing farming systems comparable to the elite agro-economies of the LBA Aegean (Halstead 1995; Nitsch *et al*. 2019) and Anatolia (Diffey *et al*. 2020). In this study, we have shown that low-input farming systems were also utilised in the Izmir region in the earlier EBA. This suggests that the societal developments of the later EBA were not associated with dramatic changes in crop husbandry practices but may rather have been enabled by them. This highlights the potential importance of longer-term developments in the *organisation* of arable farming.

We previously suggested that these developments can be traced to what is, at present, the earliest evidence for low-input farming within the region, in the Late Chalcolithic. During this period, the coastal locations and large size of some settlements likely pushed arable land some distance from the home (Maltas *et al*. forthcoming; in prep). This plausibly favoured extensive systems of land use by reducing the viability of intensive farming based on high levels of tillage and manuring (*cf*. Jones *et al*. 1999). We suggested that the potential for productive inequality within these systems (outlined by Bogaard *et al*. 2019) was hindered in Late Chalcolithic settlements by cooperation and social risk spreading practiced by small-scale households to cope with the acute labour demands of crop cultivation at large scales. The widespread reorganisation of settlements around

the longhouse in EBA western Anatolia (Fidan *et al.* 2015) was a key turning point in this regard. Larger in size than earlier domestic structures, we suggest that they contained more extended family units capable of maintaining greater autonomy in arable production (*cf*. Flannery 2002). These are likely to have been more prone to the emergence of sustained wealth inequality within land-limited farming systems.

Plausibly as a result of these developments, a number of earlier EBA settlements contain evidence for social systems that explicitly signal a desire to dampen the potential for arable wealth inequality. At Demircihöyük, Eskişehir, the placement of household granaries at the centre the settlement (Korfmann 1983) mirrors the open and cooperative social environments of Late Chalcolithic settlements in western Anatolia (Maltas *et al*. forthcoming). This betrays high levels of social monitoring of agricultural products that may have fostered reciprocity and sharing between households. The location of storage structures outside the entrances of some longhouses at Bakla Tepe (Gündoğan *et al*. 2019) may have performed a similar function, while the bench lined *megaron* is consistent with the emergence of more formalised social structures for socio-political negotiation (*cf*. Bachhuber 2015, 76-82). Larger scale central storage structures at Karataş, Antalya (Warner 1994, 178), and Poliochni (Blue phase), Lemnos (Bernabó-Brea 1964), have been interpreted as places for the communal storage of agricultural products (Bachhuber 2015, 77-78; Massa and Tuna 2019). At Karataş, 12 clay-lined pits, two of which contained remains of *pithoi*, were located within the Central Complex, a building and courtyard encircled by a buttressed enclosure in the centre of the settlement. The absence of high-status artefacts from this area and the similar ceramic assemblages recovered from it and the habitation area of the settlement has led Bachhuber to suggest that it should be considered a socially inclusive corporate

space (2015, 77; Eslick 2009). At Poliochni, a large central granary was similarly associated with an architectural complex thought to possess a communal function (Bernabò-Brea 1964, 186-200; Bachhuber 2015, 78). In both cases, the centralisation of farming products may have worked to mobilise the agricultural surplus of individual farming households towards collective means (*cf*. Bachhuber 2015, 80).

The social inclusivity implied by these structures elaborates a common theme within earlier EBA western Anatolia. The widespread organisation of communities into settlements of tightly packed longhouses sharing walls and frequently uniform in size and/or layout emphasises community identity and social and economic equality (Ivanova 2013). Asymmetrical production between households is hinted at in some settlements, for example in the different capacities of built-in storage at EB II Çeşme-Bağlararası (Şahoğlu 2015) and provisions for preparing and serving food as well as the production of textiles between households at Demircihöyük (Bachhuber 2015, 65-67). The potential access to fields of differing water status between EB I-II households at Liman Tepe may also have resulted in productive inequality. But finds of high-status artefacts within settlements are sporadic and grave goods within the cemeteries of smaller settlements contain only limited evidence for socio-economic inequality (e.g., Bakla Tepe and Demircihöyük—Massa and Şahoğlu 2011; Massa 2014; Şahoğlu 2016). This suggests that long-term productive inequality was successfully mitigated against by the centralising structures outlined above.

This raises the question of how the wealthy and socially exclusive elites of the later EBA emerged from these equalising and inclusive social environments. A key line of evidence comes from the cemetery of Karataş, which contains the clearest evidence for wealthy

and high-status individuals within earlier EBA western Anatolia. Here, a single adult was buried within a stone-built chamber covered by a stone tumulus several metres wide (Mellink 1969; Massa and Şahoğlu 2011). The rest of the cemetery was composed of *pithos* burials. Burials of adults and children around the chamber also contained the most elaborate jewellery and the majority of gold and silver objects within the cemetery (Mellink 1969, 327; Alpers-Bordaz 1978, 262-78). The presence of potentially high-status and wealthy individuals at this site has been linked to its larger size than the smaller settlements for which other burial evidence is available (Massa and Şahoğlu 2011). While the roles of these individuals are, of course, not clear, it is also conspicuous they come from a settlement with a highly developed corporate structure. It is therefore plausible that they were associate with the function(s) of the Central Complex. This would suggest that wealthy and high-status individuals emerged as those in control of the corporate structures designed to dampen inequalities in agricultural production. From this perspective, the maintenance of ostensibly equalising and inclusive social environments would have been crucial to sustaining the centralising structures that facilitated the wealth and high-status of those in control. From this foundation, emergent elites may have expanded their wealth through controlled access to long-distance trade networks and precious metals, facilitating the blossoming of social differentiation and hierarchy of the later EBA. This shift in the focus of elite wealth, from the mutually beneficial centralisation of farming products to restricted access to resources, is mirrored in the transformation from an inclusive to exclusive elite social logic between the earlier and later EBA (*cf*. Bachhuber 2015, 107-29). Evidence for centralising institutions in earlier EBA settlements that would go on to become elite citadels is available from the eastern Aegean islands. At Poliochni, the large communal

granary of the EB I-II preceded deposits of gold and precious metal artefacts in the EB II-III (Bernabo-Brèa 1976, plates CCXL-CCLI). At the smaller site of Heraion on Samos, a communal storage structure dating to the early EB II preceded the construction of a large (c. 18.5 x 8 m) tripartite building of monumental construction thought to possess a social or political function in the EB II-III (Kouka and Menelaou 2018). Artefacts that could indicate an elite presence in the building are absent but architectural developments and artefactual remains in the EB II-III are thought to indicate a wealthy and social stratified settlement under the direction of a central authority. Comparable developments in western Anatolia are, at present, less visible but subterranean granaries with storage capacities well beyond the needs of individual households from Troy I (Thumm-Doğrayan 2016) hint at the pooling of farming products.

While further evidence for the nature of corporate/elite institutions across the EBA are necessary to test the inferences made here, this model works to harmonise the contrasting social environments of the earlier and later EBA with the emergence of elites over the long term. Importantly, this is based on robust archaeobotanical evidence for the nature of the agricultural economy.

6.3 Implications for the impact of the 4.2ka event in western Anatolia and the eastern Aegean islands

By revealing changes to agricultural production strategies across the third millennium BC, the results of our study have key implications for the potential impacts of the 4.2ka event in western Anatolia. Evidence for the onset of drier conditions roughly converging on 2200 BC within the Mediterranean Basin is well-established, but the persistence of wet conditions in some regions betray regional heterogeneity in climate patterns

(Staubwasser and Weiss 2006; Roberts *et al.* 2011; Bini *et al*. 2019). Climate proxies from the Aegean coast of Turkey are limited, but elsewhere in western Anatolia pollen and oxygen isotope evidence from Kureysler, Kütahya, indicate a drought around 2200 BC (Ocakoğlu *et al*. 2019). A drop in the level of Lake Iznik, Bursa, is also consistent with drier conditions around this time (Ulgen *et al*. 2012). In central Anatolia, drier conditions between *c.* 2300-2150 BC are also indicated by a negative water balance at Nar Gölü, Aksaray/Niğde (Dean *et al*. 2015). North-west of the Izmir region, cores from the northern Aegean Sea indicate drier conditions broadly contemporary with the 4.2ka event across a range of proxies (Erhmann *et al*. 2007; Kuhnt *et al*. 2007; Dormoy *et al*. 2009). While less temporally harmonious, an arid phase was recorded from speleotherm oxygen isotope values at Skala Marion Cave, Thassos, between 1900-1700 BC and has been linked to the 4.2ka event by the authors (Psomiadis *et al*. 2018). These data provide convincing evidence for the impacts of the 4.2ka event in the northern Aegean and inland western Anatolia, suggesting that drier conditions may too have been felt on the western Anatolian coast. Heterogenous climate patterns across western Anatolia are evident, however, with Karağol, Antalya, showing a *peak* in lake levels around 2000 BC (Foss 2006).

Archaeobotanical evidence for drier conditions has been sought at Troy, with the occupation of Troy IV overlapping with the 4.2ka event (Blum and Riehl 2015). Stable carbon isotope values of barley grains from Troy IV largely fall between *c*. 16.5 and 18‰ (Blum and Riehl 2015, 15 Fig. 22), consistent with moderate to low crop water status. The average value of barley grains from Troy IV is *c.* 0.5‰ lower than those from Troy II, indicating slightly drier growing conditions in the later period. Whether or not this reflects a drier climate is, however, ambiguous; as a secondary crop that plausibly

fulfilled flexible roles during the EBA at Troy, the drier growing conditions of barley in Troy IV than Troy II may simply reflect its cultivation on different, drier plots in the later period. The proportions of major crop taxa also change little in Troy IV compared to earlier periods (Blum and Riehl 2015, 14 Fig. 20), suggesting an absence of changes in agricultural decision making around the period of the 4.2ka event.

In contrast, our study has revealed a clear shift in agricultural decision making in the Izmir region towards an investment in drought tolerant barley and bitter vetch at the onset of the second millennium BC, plausibly in response to drier climatic conditions following the 4.2ka event. This took place despite an absence of isotopic evidence for drought stress in barley. This may reflect the successful combating of drier conditions through water management strategies, or that the 4.2ka event had relatively minor impacts on crop growing conditions despite its influence on agricultural decision making. The latter scenario aligns with stable isotope evidence for more minor impacts of the 4.2ka event on coastal than inland sites in the Middle East (Riehl *et al*. 2014). Variable responses to the 4.2ka event are also visible within the Izmir region, with the proportions of major crops changing little between the EBA and MBA occupations of Çeşme-Bağlararası.

The extent to which drier conditions at the end of the EBA may have disrupted agricultural production and contributed to the collapse of EBA III citadels is, therefore, unclear. Limited evidence for drought stress from Troy IV and the late EBA-early MBA sites in our study suggest that negative impacts on crop growing conditions may have been minor, whether through limited reductions in rainfall or successful water management strategies. This raises the potential for alternative explanations for the

widespread destruction of settlements, such as the disruption of long-distance trade networks (Bachhuber 2009; Massa and Şahoğlu 2015; Rahmstorf 2015). It is also possible, however, that agricultural production in the years immediately following the onset of the 4.2ka event was disrupted by drought in a way not recorded in the EB III and late EBA-early MBA archaeobotanical record from Troy, Liman Tepe and Kocabaş Tepe. The long-term impacts of the 4.2ka event on agricultural decision making within western Anatolia may also be visible in the dominance of barley within LBA cereal crop spectra (e.g., Çeşme-Bağlararası, Liman Tepe, Kocabaş Tepe, Troy—Riehl 1999, Kaymakçı—Shin *et al*. 2021, Çine-Tepecik—Maltas and Günel in prep) plausibly having its origins in the agricultural adaptations at the onset of the MBA.

7. Conclusion

Through an intensive suite of archaeobotanical analyses, we have produced an in-depth account of crop cultivation and arable land management strategies within the Izmir region across the Bronze Age. Functional ecological analysis of arable weeds revealed that cereals were cultivated under conditions of low arable fertility across the period. Isotopic evidence from the EBA and MBA suggested that cereals received moderate levels of manuring and that crop water status was not a limiting factor to growth. Pulses were intensively manured and moderately to well-watered. This coupling of low-input cereal and high-input pulse cultivation resembles the extensive agricultural systems employed by recent farmers in the Aegean and continues a farming system known from the Late Chalcolithic in Izmir. Against this continuity, crop choice and land management strategies were adapted to temporally and geographically specific ecological contexts. In the EBA, a spectrum of five major crops were cultivated across the study sites. This

was dominated by the glume wheats emmer and einkorn which were likely grown together as a mixed crop. Crop choice and arable land management strategies diverged between the study sites in the late EBA-early MBA. At Liman Tepe and in the Cumaovası plain they became oriented towards drought tolerance, with barley grown on drier soils than EB I-II glume wheats becoming the major cereal crop and water management strategies redirected towards pulses. At Çeşme-Bağlararası, cultivation strategies were consistent between the EBA and MBA. More major changes in crop husbandry are visible in the LBA at this site with the introduction of new crop species.

The potential for long-term productive inequality and wealth creation within extensive farming systems has key implications for the archaeological narrative of Bronze Age western Anatolia. We suggest that the widespread reorganisation of settlements around the longhouse in the EBA saw the emergence of communal and corporate social structures that worked to dampen sustained productive inequality between autonomous farming households. High-status and wealthy individuals plausibly emerged as those in control of these corporate structures while outwardly expressing community identity and equality. This may have formed the basis from which emergent elites expanded their wealth through controlled access to long-distance trade and precious metals in the later EBA. While the extent to which the 4.2ka event can be implicated in the 'collapse' of later EBA citadels remains unclear, the shift in farming strategies towards drought tolerance at MBA Liman Tepe and EBA/MBA Kocabaş Tepe provides the first clear evidence for its impact on agricultural decision making within western Anatolia. The sustained importance of barley within archaeobotanical assemblages from LBA western Anatolia reveal the longer-term impacts of agricultural developments during this period.

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Farming and land use strategies in Bronze Age western Anatolia and their implications for the emergence and collapse of coastal citadels

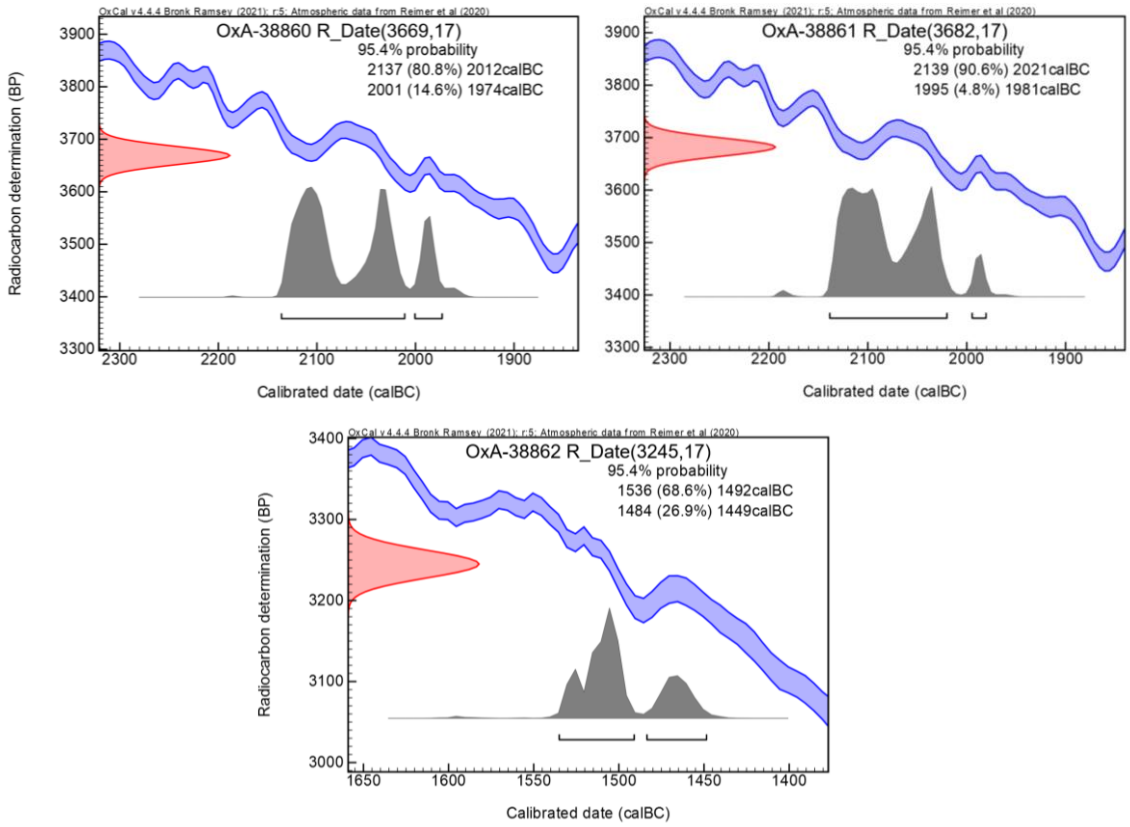
Supplementary material

1. Radiocarbon dates from Kocabaş Tepe

Supplementary Table 1: Radiocarbon dates from Kocabaş Tepe. Dates were calibrated using OxCal 4.4, IntCal 20 (Bronk Ramsey 2009; 2021) using atmospheric data from Reimer *et al*. (2020).

Sample	Material	Context	Date BP	Cal BC (2σ)
OxA-38860	Bitter vetch seed	Around storage *pithos*	3669 ± 17	2137-1974
OxA-38861	Bitter vetch seed	Refuse pit	3682 ± 17	2139-1981
OxA-38862	Barley grain	Floor of storage room	3245 ± 17	1536-1449

Supplementary Figure 1: Calibration curves for the radiocarbon dates reported in supplementary Table 1.



2. Materials and methods

2.1 Sampling, recovery and identification

Archaeobotanical samples from Liman Tepe, Bakla Tepe and Kocabaş Tepe were recovered prior to the establishment of a systematic sampling strategy. Material was typically sampled from visible concentrations of archaeobotanical remains and/or burnt deposits. At Çeşme-Bağlararası, soil samples were taken from all in-tact contexts. 40-60 litres of sediment were sampled from large excavation units and from each stratigraphic

layer of large pits. Smaller pits, vessels and concentrations of burnt sediment were sampled in their entirety. Samples from Liman Tepe and Çeşme-Bağlararası were processed by water flotation using an Ankara type flotation tank (*cf*. French 1971). Remains that floated (the flot) were collected in a 300 µm mesh and the rest (the heavy residue) was retained in a 1 mm mesh. Samples from Bakla Tepe and Kocabaş Tepe were processed by bucket flotation carried out on-site. Heavy residues from Çeşme-Bağlararası were retained but most from the other sites were discarded.

Samples were analysed using a low-power stereo microscope (7-45x) at the Ankara University Research Center for Maritime Archaeology (ANKÜSAM), Izmir. All samples were briefly scanned in order to establish their archaeobotanical richness. Those that contained 30 or more crop grains/seeds were selected for further analysis. A threshold of 30 identifiable items was chosen as the minimum amount considered to reflect the relative proportions of taxa within a sample to a reasonable degree of accuracy and reliability. Samples were sieved into >1 mm (coarse) and >300 µm (fine) fractions. Coarse fractions that were estimated to contain over 600 crop grains/seeds were randomly sub-sampled using a riffle box sample splitter such that a subsample of at least 300 identifiable items were extracted and analysed for each sample. This minimum number reflects the relative proportions of taxa to a high degree of accuracy and reliability (van der Veen and Fieller 1982). The fine fractions were sub-sampled such that 10-30 weed/wild seeds were identified where possible (excluding seeds of *Lolium* species, which dominated the weed assemblage). Counts of items in each fraction were multiplied up to provide the total counts for 100% of each sample.

Supplementary Table 2: The number of samples and range of contexts sampled from each period of occupation within the sites in our study.

Site	Period	No. of samples	Contexts sampled (number of samples)
Çeşme-Bağlararası	LBA	7	Pits (6), possible floor (1)
	MBA	3	Storage rooms (2), ash pit (1)
	EBA	4	Floors (1) and hearths (2) in longhouses, street (1)
Liman Tepe	LBA	1	Ash pit (1)
	MBA	6	Oval house (3), subterranean storage room (3)
	EBA	8	Longhouse floor (8)
Bakla Tepe	EBA	8	Longhouse (3), refuse pits (1), graves (3), unknown (1)
Kocabaş Tepe	LBA	4	Floor (1), broken pot (1), unknown (2) in storage room
	EBA/ MBA	4	Refuse pit (2), ashy deposit (1), around *pithos* (1) in storage room

Items were quantified to establish the 'minimum number of plant parts' represented using 'diagnostic zones' in order to prevent individual plant parts from being counted more than once (*cf*. Jones 1991). The embryo ends of cereal and *Lolium* grains and the bases of glumes were counted. For dicotyledonous taxa such as pulses, seeds of which often split in two halves, half seeds were counted as 0.5 and the total rounded up to a whole number. The minimum number of seeds and other plant parts was estimated for non-*Lolium* weed/wild and fruit taxa by visual inspection.

Plant taxa were identified by comparison with modern seeds from the reference collections at the Institute of Archaeology, University of Oxford, the Institute of Archaeology, University College London and the British Institute at Ankara, alongside published sources (e.g., Jones 1992; Nesbitt 2006; Sarpaki and Jones 1990). Lists of species geographically relevant to the sites were extracted from *Flora of Turkey* (Davis 1968-2000).

2.2 Identification of non-arable wild taxa

Following Charles (1998), Wallace and Charles (2013) and Bogaard *et al.* (2013), we used several criteria to establish the likelihood of archaeobotanical taxa to have derived from non-arable pathways. Those that fruit outside of the likely period of crop harvest, that would be unlikely to set seed under arable conditions and/or those that favour wetland or maritime habitats were considered unlikely to have grown and/or been harvested in seed with arable crops. We considered a June/July harvest period to be likely based on the practices of recent non-mechanised farmers from comparable climates elsewhere in the Aegean (Halstead 2014, 25; Halstead and Jones 1989).

We identified potential non-arable wild taxa further by assessing the likelihood of seeds to derive from animal dung burnt as fuel. Feeding experiments by Wallace and Charles (2013) identified that small and hard coated seeds were more likely to survive digestion by sheep, with a size threshold of 1.18 mm for maximum survival identified by Poppi *et al*. (1985). Gardener *et al*. (1993) found only a weakly negative correlation between size and survivability, however, with seed density showing a stronger positive correlation. We therefore considered taxa with dense or hard coated seeds and/or those smaller than 1.18 mm to have a greater chance of being dung-derived.

We assessed seed size for the archaeobotanical taxa with reference to modern specimens in order to consider potential changes in size due to charring (Charles *et al*. 2015). Data on seed hardness were sourced from the botanical literature (e.g., Bryson and Carter 2008). Data on flowering period and habitat preference were extracted from *Flora of Turkey* (Davis 1968-2000). We calculated fruiting time as starting one month after flowering onset and continuing until one month after the cessation of flowering.

Fourteen of 66 analysed taxa are considered likely to have entered the archaeobotanical record via non-arable pathways (supplementary Table 3). These include taxa adapted to wetland or coastal environments and species of shrubs that are unlikely to set seed under arable conditions. A further 12 taxa were classified as ambiguous in origin and may have entered the archaeobotanical record as arable weeds or via alternative pathways. This group was primarily composed of small and/or hard seeded taxa from dryland environments that could have derived from dung burning.

2.3 Sampling and preparation of crop remains for stable isotope analysis

We sampled grains for stable isotope analysis from a range of archaeological contexts. From Liman Tepe, we sampled grains of einkorn and emmer and seeds of lentil from the floors of two EB I-II longhouses. We aimed to test the hypothesis that einkorn and emmer were grown as a mixed crop, arising from their frequent co-occurrence in archaeobotanical samples from all three EBA sites. Samples from the MBA occupation of Liman Tepe were taken from concentrations of barley and bitter vetch within an oval house and from a large deposit of barley within the subterranean storage structures constructed on a terrace on the EB II-III bastion. No differences in $\delta^{13}C$ or $\delta^{15}N$ values were present between barley grains from the oval house and subterranean storage

Supplementary Table 3: The abundance and likely depositional pathways of arable weed/wild taxa. Only taxa present in three or more samples are shown. Taxa within each category are sorted by their abundance.

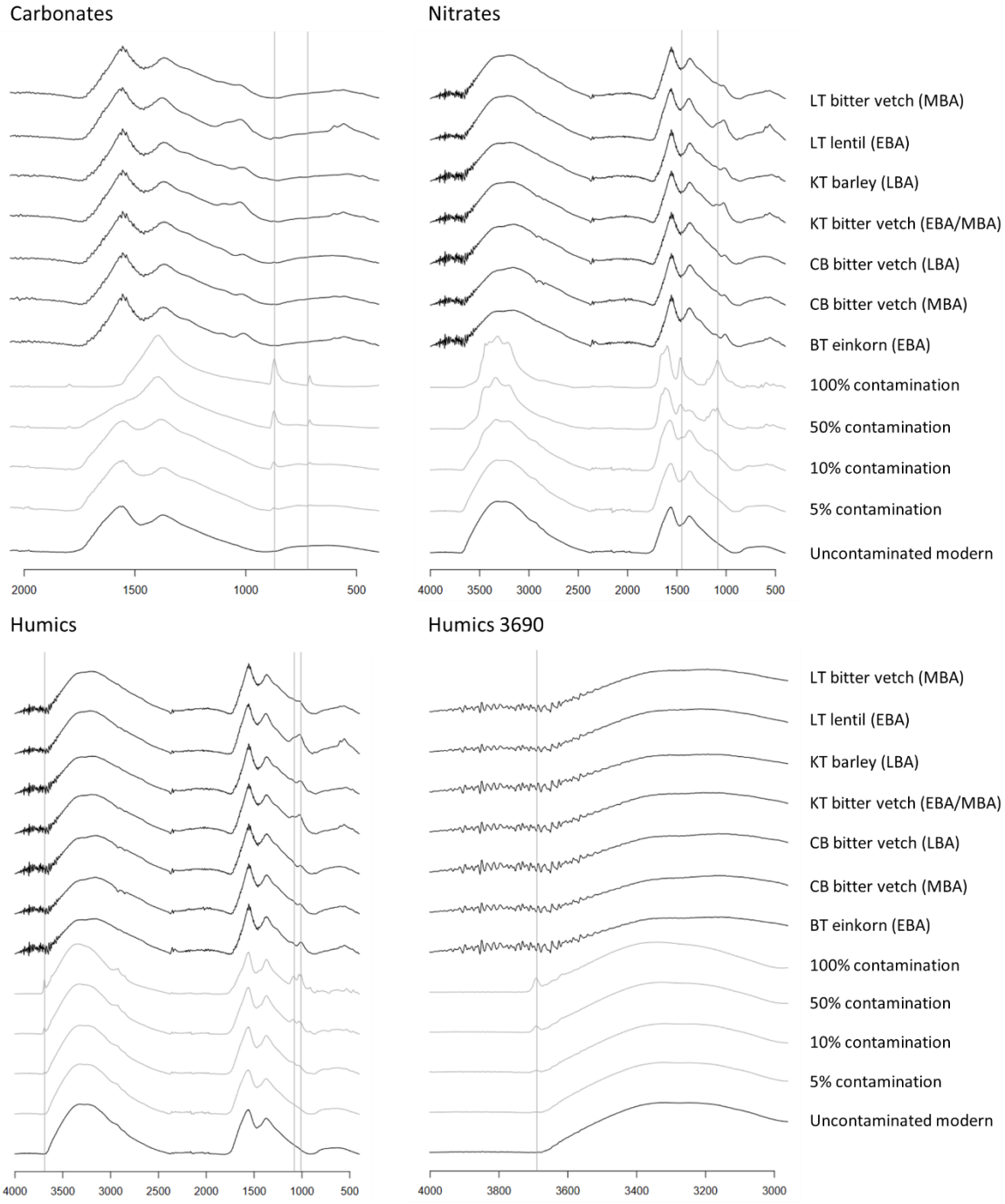
Family	Genus/species/type	Abundance (n = 2880)
Cyperaceae	*Scirpus maritimus* L. type	16
Lamiaceae	*Vitex agnus-castus* L.	10
Cyperaceae	Cyperaceae indet.	9
	Schoenus nigricans L.	8
	Eleocharis palustris (L.) Roem. & Schult. type	6
	Carex L. sp.	5
Chenopodiaceae	*Chenopodium album* L./ *opulifolium* Schrad. ex Koch & Ziz	141
Fabaceae	Small Fabaceae spp.	104
	Salsola ruthenica Iljin/*kali* L.	42
Poaceae	*Phleum subulatum* (Savi) Asch. & Graebn/*exaratum* Hochst. ex Griseb	19
Fabaceae	*Vicia hirsuta* (L.) Gray type	7
Poaceae	*Eragrostis* Wolf. sp.	6
Boraginaceae	*Heliotropium europaeum* L. type	4
Poaceae	*Lolium temulentum* L.	1499
	Lolium remotum Schrank. type	249
	Lolium L. small type	203
Malvaceae	Malvaceae indet.	70
Rubiaceae	*Galium spurium* L.	46
	Galium tricornutum Dandy	37
Poaceae	Large Poaceae indet.	24
	Phalaris aquatica L./ *paradoxa* L./*canariensis* L. type	19

	Phalaris coerulescens Desf.*/ truncata* Guss. Ex Bertol*/brachystachys* Link type	15
Fabaceae	Large Fabaceae spp.	12
	Scorpiurus muricatus L.	9
Poaceae	*Triticum boeoticum* Boiss	8
	Hordeum spontaneum (K. Konch) Thell.	7
Polygonaceae	*Rumex crispus* L./*obtusifolius* L.	7
Poaceae	*Avena* L. sp.	5
Thymeleaceae	*Thymelaea tartonraira* (L.) All.	5
Poaceae	*Hordeum* L. wild type	3

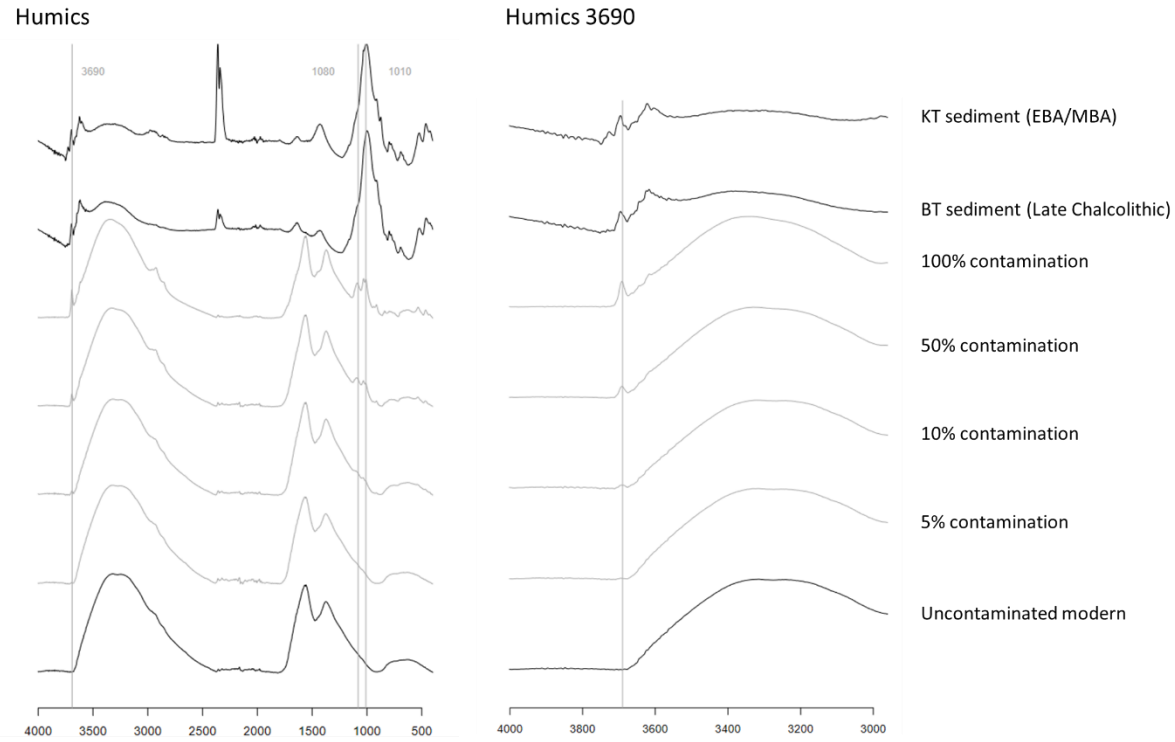
rooms, so we do not present the contexts separately in our study. From Çeşme-Bağlararası, we sampled einkorn grains and bitter vetch seeds from a hearth in an EB II longhouse. We also sampled bitter vetch seeds from an earlier MBA ash pit in the EB II settlement area. From Bakla Tepe, we sampled emmer grains from a pit containing EB II-III remains cut into the EB I settlement. Barley grains from Kocabaş Tepe were sampled from around a storage *pithos* from EBA/MBA levels of a storage room and from an LBA storage room floor. We also sampled bitter vetch seeds from an EBA/MBA refuse pit within a storage room.

We conducted FTIR analysis on grains from each site and period of occupation from which we would take samples for stable isotope analysis. Due to the very limited number of grains from EBA Çeşme-Bağlararası, we analysed an LBA seed alongside an MBA seed instead. In supplementary Figure 2, the FTIR spectra of archaeobotanical grains/seeds

Supplementary Figure 2: The FTIR spectra of archaeobotanical crop grains and sediment from the sites in our study compared to modern grains experimentally contaminated by Vaiglova *et al*. (2014). LT – Liman Tepe, CB – Çeşme-Bağlararası, BT – Bakla Tepe, KT – Kocabaş Tepe.



Supplementary Figure 2 (continued)



from the sites in our study are compared to modern grains experimentally contaminated by Vaiglova *et al*. (2014). Surface contaminants on archaeobotanical grains were not removed prior to the FTIR analysis. A minor source of humic contamination is indicated by peaks at 1080 and 1010 cm^{-1} in the spectra. Large peaks at 1080, 1010 and 3690 cm^{-1} in the spectra of sediment scraped off grains from Kocabaş Tepe and Bakla Tepe indicate the presence of humics, suggesting that sediment on the surface of the grains was the source of humic contamination. Grains were therefore not pre-treated but were gently scraped to remove any surface contaminants visible at x7-45 magnification.

Supplementary Table 4: The number of grains that underwent stable isotope analysis from the different contexts and periods of occupation of the sites in our study.

Site	Period	Context	No. archaeobotanical samples	No. grains/ seeds
Liman Tepe	MBA	Oval house	2	16
		Subterranean storage room	1	13
	EBA	Floor longhouse 2	3	15
		Floor longhouse 3	3	14
Çeşme-Bağlararası	MBA	Earlier MBA ash pit	1	5
	EBA	Longhouse hearth	2	8
Bakla Tepe	EBA	EB II-III refuse pit	1	9
Kocabaş Tepe	LBA	Storage room floor	1	9
	EBA/MBA	Around *pithos* in storage room	1	10
		Refuse pit in storage room	1	10

3. Results

3.1 Crops and economic taxa

The proportions of grains of different crop species recovered from the occupations of each site are likely to have been shaped by a range of taphonomic processes. The samples from EBA Liman Tepe and Çeşme-Bağlararası primarily derive from the occupation horizons of longhouses. They have mixed compositions of species and plant parts and plausibly represent domestic debris of crops stored and/or processed for consumption. The samples from EBA Bakla Tepe derive from various sources. Those from the EB I-II longhouses have mixed compositions and also likely represent domestic waste. Some samples derive from EB I-II graves and may have been used within funerary rites (Şahoğlu 2016). These are primarily composed of clean glume wheat grains and some barley grains. The sample from an EB II-III refuse pit has similar contents to those from the EB I-II longhouses and also likely represents domestic waste. Deposits of domestic waste are contexts into which plant remains enter from a range of activities, meaning that they are more likely to capture the range of plant taxa utilised by households than individual storage deposits (*cf.* van der Veen 2007). The EBA crop spectra from the sites in our study therefore provide a good indication of the range of staple crop species utilised during these occupations.

Archaeobotanical samples from Çeşme-Bağlararası derive from two later MBA storage rooms and an earlier MBA ash pit. They all contain a range of crop species and plant parts and likely represent secondary refuse deposits. The consistency in the crop spectrum between EBA and MBA Çeşme-Bağlararası is therefore unlikely to have been impacted by different taphonomic biases between the two periods. The samples from

MBA Liman Tepe derive from an oval house and a subterranean storage room. Those from the oval house were taken from two near pure deposits of barley and bitter vetch and likely represent stored crops. Those from the subterranean storage room derive from a large concentration of barley and also likely represent a storage deposit. The samples from EBA/MBA Kocabaş Tepe also derive from near pure deposits of grain in storage rooms and are therefore also likely to be the remains of stored crops. As storage deposits, these contexts provide more selective evidence for the range of staple crop species. Other species may have been cultivated that were stored elsewhere and therefore not represented in these samples. Indeed, while likely representing weedy contaminants, minor proportions of glume wheats at Liman Tepe and free-threshing wheat at Kocabaş Tepe in stores of barley could also indicate the cultivation of these crops. Despite this, however, the absence of storage deposits of glume wheats in the Liman Tepe oval house and the evident focus on large-scale storage of barley within the subterranean storage room and the Kocabaş Tepe storage rooms strongly suggest a focus on the cultivation of barley during the MBA and EBA/MBA occupations of these sites. This contrasts with the secondary status of this species in the EBA occupations of Liman Tepe and Bakla Tepe.

These inferences are supported by the LBA sample from Liman Tepe. Recovered from an ash pit, it contains crop grain and chaff in near equal proportions and likely represents burnt refuse material. The composition of the sample was, therefore, likely shaped by similar taphonomic processes to those from the EBA occupation of this site yet shows a similar dominance of barley as the MBA samples. The LBA sample from Kocabaş Tepe derives from the storage rooms and reflects the continued focus on barley within these contexts. The dominance of bitter vetch in the assemblage from LBA Çeşme is due to a

single pure concentration of this species recovered from a possible floor. The remaining samples derive from pits filled with refuse material and were therefore plausibly subject to the same taphonomic processes as the earlier samples from this site. The more equitable proportions of barley and wheat at LBA Çeşme, therefore, plausibly reflects the increased importance of the former during this period.

3.2 Stable isotope analysis

The full results of the stable isotope analysis are presented in supplementary Table 5. We assessed the reliability of the stable isotope determinations by comparing their C:N ratios to modern cereals and pulses charred by Fraser *et al*. (2013). Similar C:N ratios between the modern and archaeological grains suggests that the original $\delta^{13}C$ and $\delta^{15}N$ of the latter were not perceptibly distorted by post-depositional processes and can be reliably obtained. We compared the ratios of archaeological cereals to modern einkorn, emmer and hulled barley. No data were available for modern bitter vetch, so we compared the archaeological pulse seeds to modern lentil, pea and broad bean. The C:N ratios of the archaeological cereals ranged from 16.7 to 41.3. The modern cereals ranged from 17.9 to 28.2. The archaeological pulses ranged from 9.1 to 16.2. The modern pulses ranged from 8.8 to 13.1. The C:N ratios of archaeological and modern cereals are significantly different (two-tailed t-test, p = .005). This is likely due to high C:N ratios in a number of barley grains from Kocabaş Tepe and Liman Tepe (supplementary Figure 3), resulting from low %N (averaging 1.6%). The $\delta^{15}N$ values of these grains fall within the range of those with C:N ratios comparable to modern grains (supplementary Figure 4), however, suggesting that low %N did not distort grain $\delta^{15}N$ values.

The C:N ratios of archaeological and modern pulses are also significantly different (two-tailed t-test, *p*, = <.001). This is likely due to differences in the C:N ratios of bitter vetch and the modern reference taxa. The C:N ratios of the archaeological lentil are not significantly different to the modern pulses (two-tailed t-test, *p* = .956), but the majority of the archaeological bitter vetch grains have higher ratios than the modern pulses (supplementary Figure 3). The $\delta^{15}N$ values of bitter vetch are comparable to those of lentil, however, suggesting that this did not distort the isotopic results.

Following Szpak and Chiou (2019), we also plotted the $\delta^{15}N$ values against the C:N ratio of archaeological grains in order to assess the presence of patterns consistent with post-burial alteration of $\delta^{15}N$ values (*cf*. Hartman *et al*. 2020). Shown in supplementary Figure 4, no correlations were apparent. This suggests an absence of post-burial alterations of $\delta^{15}N$ values.

Supplementary Table 5: Full results of the stable isotope analysis. A charring offset of 0.11‰ and 0.31‰ have been subtracted from the values of δ13C and δ15N, respectively. Δ13C values were calculated after the charring offset was subtracted from δ13C. Grains are grouped by their archaeobotanical samples.

Grain	Site	Taxon	Period	δ13C (‰)	Δ13C (‰)	N (µg)	δ15N (‰)	%C	%N	C:N
LT151	Liman Tepe	Einkorn	EBA			106.1	5.4		3.1	
LT152	Liman Tepe	Einkorn	EBA	-23.8	17.8			48.1		
LT153	Liman Tepe	Einkorn	EBA			112.1	6.3		3.4	
LT154	Liman Tepe	Einkorn	EBA			95.5	3.8		2.6	
LT155	Liman Tepe	Einkorn	EBA	-24.8	18.7			40.4		
LT156	Liman Tepe	Einkorn	EBA			152.8	4.2		4.4	
LT171	Liman Tepe	Einkorn	EBA	-22.1	16.0	86.5	5.6	42.4	2.4	20.4
LT172	Liman Tepe	Einkorn	EBA	-21.9	15.7	106.1	6.3	42.5	3.0	16.7
LT173	Liman Tepe	Einkorn	EBA			88.9	6.0		2.9	
LT181	Liman Tepe	Einkorn	EBA	-24.0	17.4			44.2		
LT182	Liman Tepe	Einkorn	EBA			100.6	4.6		2.8	
LT183	Liman Tepe	Einkorn	EBA	-22.3	16.1	96.6	4.3	40.8	2.8	17.1
LT191	Liman Tepe	Einkorn	EBA			76.4	5.9		2.2	
LT192	Liman Tepe	Einkorn	EBA	-23.3	17.2			46.7		
LT193	Liman Tepe	Einkorn	EBA	-23.3	17.2			45.1		

LT161	Liman Tepe	Emmer	EBA	-23.1	17.0	94.4	4.8	39.8	2.7	17.5
LT162 DAB	Liman Tepe	Emmer	EBA	-24.2	18.7	77.2	4.0	44.9	2.2	23.9
LT163	Liman Tepe	Emmer	EBA	-25.1	19.1	69.6	4.3	38.0	1.9	23.1
LT164	Liman Tepe	Emmer	EBA	-22.3	16.1	107.6	4.6	44.2	3.0	17.1
LT165	Liman Tepe	Emmer	EBA	-24.6	18.6	77.9	5.3	42.4	2.2	22.2
LT131	Liman Tepe	Lentil	EBA	-23.6	17.5	91.8	0.6	32.2	3.7	10.1
LT132	Liman Tepe	Lentil	EBA	-23.1	16.9	95.6	1.0	37.1	3.8	11.5
LT133	Liman Tepe	Lentil	EBA	-24.0	17.9	85.4	1.9	38.2	3.6	12.3
LT135	Liman Tepe	Lentil	EBA	-23.7	17.6	79.6	1.5	33.1	3.1	12.4
LT141	Liman Tepe	Lentil	EBA	-21.8	15.7	117.2	1.4	42.1	4.6	10.6
LT142	Liman Tepe	Lentil	EBA	-24.7	18.7	113.8	2.7	41.9	4.6	10.7
LT144	Liman Tepe	Lentil	EBA	-21.4	15.3	85.6	1.0	36.7	3.4	12.8
LT145	Liman Tepe	Lentil	EBA	-23.1	17.0	131.4	1.9	41.5	5.3	9.1
LT146	Liman Tepe	Lentil	EBA	-21.9	15.7	110.6	1.2	35.5	4.4	9.3
LT201 DAB	Liman Tepe	Barley	MBA	-24.9	18.9	56.6	6.4	49.8	1.6	35.7
LT202	Liman Tepe	Barley	MBA			66.2	6.0		1.9	
LT203	Liman Tepe	Barley	MBA	-22.1	15.9			45.4		
LT204	Liman Tepe	Barley	MBA	-23.1	17.0	72.2	4.1	48.8	2.0	28.2
LT205 DAB	Liman Tepe	Barley	MBA	-22.9	16.8	72.2	4.5	49.4	1.8	31.4

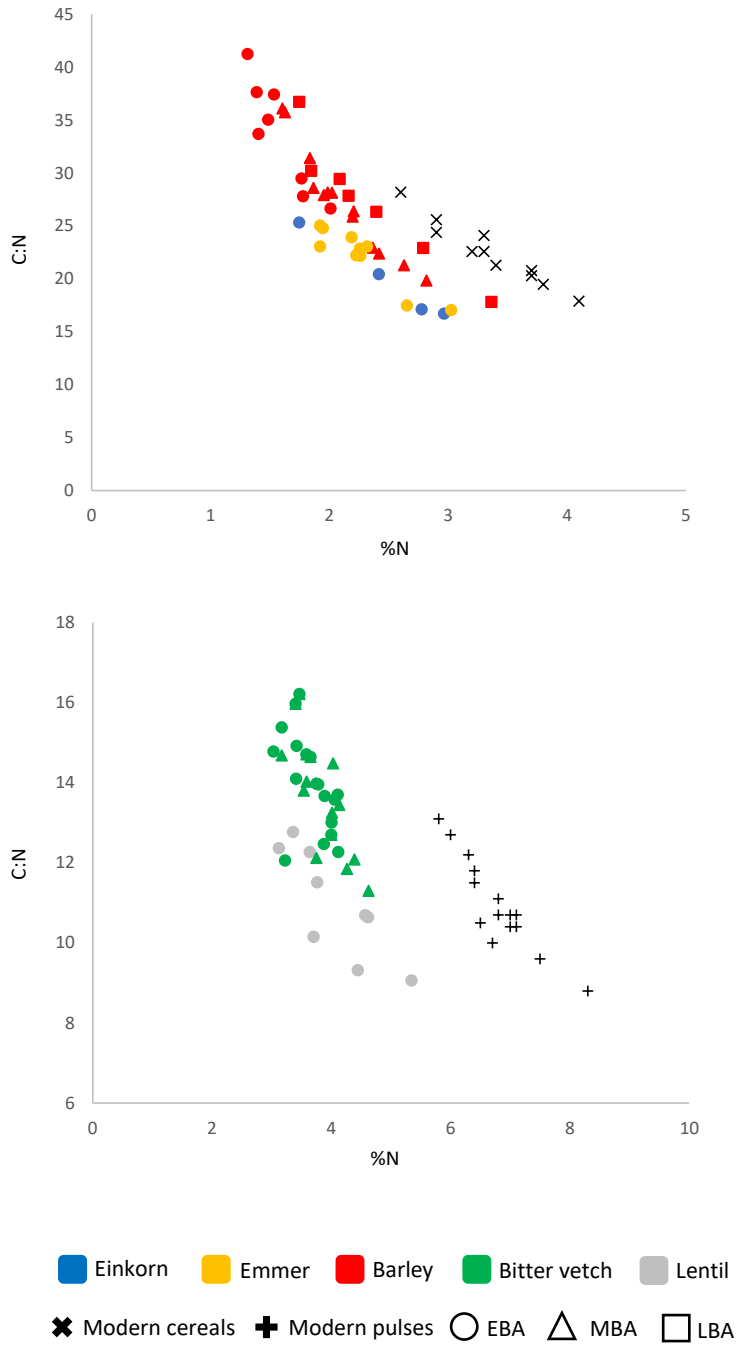
LT206	Liman Tepe	Barley	MBA			84.6	6.5		2.4	
LT207	Liman Tepe	Barley	MBA	-22.7	16.6			49.6		
LT208	Liman Tepe	Barley	MBA	-23.9	17.8			47.5		
LT209	Liman Tepe	Barley	MBA	-23.7	17.6	100.6	6.8	48.0	2.8	19.9
LT 2010	Liman Tepe	Barley	MBA	-22.1	15.9	66.2	3.9	45.8	1.9	28.6
LT 2011	Liman Tepe	Barley	MBA	-22.8	16.7	69.4	5.6	46.8	2.0	27.9
LT 2012	Liman Tepe	Barley	MBA	-23.2	17.1	55.6	5.4	49.7	1.6	36.1
LT 2013	Liman Tepe	Barley	MBA			94.2	4.2		2.7	
LT211	Liman Tepe	Barley	MBA	-22.9	16.8	141.3	5.4	46.6	2.4	23.0
LT212	Liman Tepe	Barley	MBA	-22.7	16.6	156.4	4.2	49.9	2.2	26.4
LT213	Liman Tepe	Barley	MBA	-22.7	16.6	210.1	4.7	48.7	2.2	25.9
LT214 DAB	Liman Tepe	Barley	MBA	-23.8	17.7	589.6	4.9	46.4	2.4	22.4
LT215	Liman Tepe	Barley	MBA	-23.4	17.3	477.8	4.0	48.0	2.0	28.2
LT216	Liman Tepe	Barley	MBA	-23.5	17.4	647.6	3.5	48.0	2.6	21.3
LT221	Liman Tepe	Bitter vetch	MBA	-24.6	18.5	94.1	0.8	39.0	3.7	12.1
LT223	Liman Tepe	Bitter vetch	MBA	-25.1	19.1	104.6	1.4	47.6	4.1	13.4
LT224	Liman Tepe	Bitter vetch	MBA	-23.5	17.4	115.6	1.1	44.8	4.6	11.3
LT225	Liman Tepe	Bitter vetch	MBA	-24.2	18.1	90.3	1.7	43.1	3.6	14.0
LT222 DAB	Liman Tepe	Bitter vetch	MBA	-24.5	18.5	102.3	0.6	50.0	4.0	14.5

	Liman	Bitter								
LT226	Tepe	vetch	MBA	-24.8	18.8	88.1	1.6	41.8	3.5	13.8
	Liman	Bitter								
LT227	Tepe	vetch	MBA	-24.8	18.7	81.4	2.4	39.9	3.2	14.7
	Liman	Bitter								
LT228	Tepe	vetch	MBA	-23.6	17.6	106.9	1.6	43.3	4.3	11.8
LT	Liman	Bitter								
2210	Tepe	vetch	MBA	-24.2	18.1	109.3	0.5	45.5	4.4	12.1
LT229	Liman	Bitter								
DAB	Tepe	vetch	MBA	-23.2	17.1	102.3	0.7	45.6	4.0	13.3
CB										
091	Çeşme	Einkorn	EBA			79.2	5.0		2.3	
CB										
092	Çeşme	Einkorn	EBA			78.8	6.2		2.9	
CB										
093	Çeşme	Einkorn	EBA			110.7	6.1		2.7	
CB										
094	Çeşme	Einkorn	EBA	-22.5	16.4			47.7		
CB										
095	Çeşme	Einkorn	EBA	-23.5	17.4	62.0	5.8	37.9	1.7	25.3
CB		Bitter								
101	Çeşme	vetch	EBA	-24.2	18.2	101.4	1.5	47.2	4.1	13.6
CB		Bitter								
103	Çeşme	vetch	EBA	-22.2	16.1	81.2	2.3	33.3	3.2	12.1
CB10		Bitter								
4DAB	Çeşme	vetch	EBA	-24.8	18.8	102.4	1.3	43.3	4.1	12.3
CB		Bitter								
111	Çeşme	vetch	MBA	-24.9	18.8	88.3	1.9	48.1	3.5	16.2
CB		Bitter								
113	Çeşme	vetch	MBA	-26.0	20.1	91.0	2.8	45.2	3.6	14.7
CB		Bitter								
114	Çeşme	vetch	MBA	-23.8	17.7	72.0	2.4	43.6	4.0	12.7
CB		Bitter								
115	Çeşme	vetch	MBA	-24.4	18.3	86.7	2.3	46.6	3.4	16.0
CB		Bitter								
116	Çeşme	vetch	MBA	-23.7	17.6	93.4	3.1	45.8	3.6	14.6
BT	Bakla									
161	Tepe	Emmer	EBA	-23.3	17.2	76.6	4.1	41.3	1.9	24.8

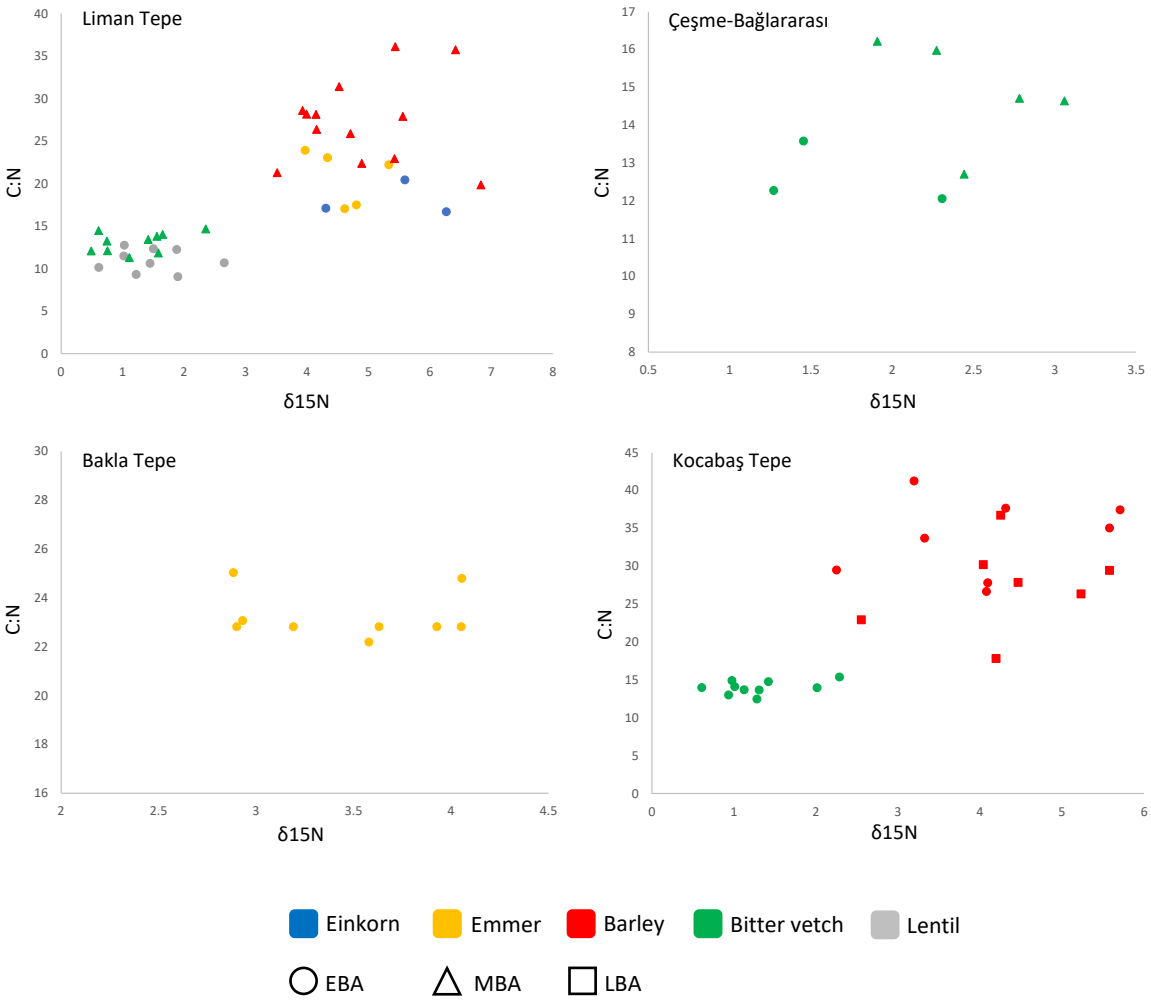
BT 162	Bakla Tepe	Emmer	EBA	-24.2	18.1	59.1	2.9	45.8	2.3	23.1
BT 163	Bakla Tepe	Emmer	EBA	-24.6	18.6	75.0	2.9	41.2	1.9	25.0
BT 164	Bakla Tepe	Emmer	EBA	-23.4	17.3	56.4	2.9	44.2	2.3	22.8
BT16 5DAB	Bakla Tepe	Emmer	EBA	-24.0	17.9	56.7	3.6	43.0	2.3	22.2
BT 166	Bakla Tepe	Emmer	EBA	-24.5	18.4	56.6	3.6	45.9	2.3	22.8
BT 167	Bakla Tepe	Emmer	EBA	-23.2	17.1	62.3	3.2	44.1	2.3	22.8
BT 168	Bakla Tepe	Emmer	EBA	-23.4	17.3	57.9	4.1	49.3	2.3	22.8
BT 169	Bakla Tepe	Emmer	EBA	-22.5	16.4	63.5	3.9	47.7	2.3	22.8
KT32	Kocabaş Tepe	Bitter vetch	EBA/ MBA	-22.9	16.8	104.8	1.1	48.3	4.1	13.7
KT33	Kocabaş Tepe	Bitter vetch	EBA/ MBA	-24.6	18.6	93.8	0.6	44.9	3.8	14.0
KT34	Kocabaş Tepe	Bitter vetch	EBA/ MBA	-24.1	18.0	96.7	2.0	45.2	3.8	14.0
KT35	Kocabaş Tepe	Bitter vetch	EBA/ MBA	-24.8	18.8	76.6	1.4	38.4	3.0	14.8
KT36	Kocabaş Tepe	Bitter vetch	EBA/ MBA	-24.0	17.9	99.6	1.3	41.4	3.9	12.5
KT37	Kocabaş Tepe	Bitter vetch	EBA/ MBA	-23.8	17.7	80.7	2.3	41.7	3.2	15.4
KT38	Kocabaş Tepe	Bitter vetch	EBA/ MBA	-23.0	16.9	99.3	0.9	44.6	4.0	13.0
KT39	Kocabaş Tepe	Bitter vetch	EBA/ MBA	-24.7	18.7	85.2	1.0	41.2	3.4	14.1
KT 310	Kocabaş Tepe	Bitter vetch	EBA/ MBA	-23.8	17.7	96.4	1.3	45.5	3.9	13.7
KT31 DAB	Kocabaş Tepe	Bitter vetch	EBA/ MBA	-23.4	17.3	85.6	1.0	43.7	3.4	14.9
KT11	Kocabaş Tepe	Barley	EBA/ MBA	-24.6	18.5	324.2	3.2	46.3	1.3	41.3

KT12	Kocabaş Tepe	Barley	EBA/ MBA			472.4	4.9		1.9	
KT13	Kocabaş Tepe	Barley	EBA/ MBA	-22.5	16.3	439.8	2.3	44.6	1.8	29.5
KT14	Kocabaş Tepe	Barley	EBA/ MBA	-24.9	18.8	364.2	5.7	49.2	1.5	37.4
KT15	Kocabaş Tepe	Barley	EBA/ MBA	-23.5	17.4	355.0	5.6	44.6	1.5	35.1
KT16 DAB	Kocabaş Tepe	Barley	EBA/ MBA	-23.7	17.6	416.6	4.1	42.4	1.8	27.8
K17 DAB	Kocabaş Tepe	Barley	EBA/ MBA	-24.7	18.6	94.1	4.3	44.8	1.4	37.7
KT18	Kocabaş Tepe	Barley	EBA/ MBA	-23.4	17.3			42.5		
KT19	Kocabaş Tepe	Barley	EBA/ MBA	-22.3	16.2	460.8	4.1	45.9	2.0	26.7
KT 110	Kocabaş Tepe	Barley	EBA/ MBA	-23.2	17.1	321.9	3.3	40.5	1.4	33.7
KT21	Kocabaş Tepe	Barley	LBA	-21.2	15.1	547.6	5.2	54.1	2.4	26.3
KT22 DAB	Kocabaş Tepe	Barley	LBA	-21.6	15.4			50.8		
KT23	Kocabaş Tepe	Barley	LBA	-22.4	16.2	263.2	4.3	55.0	1.7	36.7
KT24	Kocabaş Tepe	Barley	LBA	-21.4	15.2	360.8	2.6	54.8	2.8	22.9
KT25	Kocabaş Tepe	Barley	LBA	-21.9	15.7	217.4	4.5	51.6	2.2	27.9
KT26	Kocabaş Tepe	Barley	LBA	-22.5	16.3	137.0	4.0	47.8	1.8	30.2
KT27	Kocabaş Tepe	Barley	LBA	-22.2	16.1	126.1	5.6	52.6	2.1	29.4
KT28 29	Kocabaş Tepe	Barley	LBA	-23.0	16.9	172.0	4.2	51.3	3.4	17.8
KT 210	Kocabaş Tepe	Barley	LBA	-21.4	15.2			45.8		

Supplementary Figure 3: Archaeological grain C:N ratios plotted against %N compared to modern cereals and pulses charred by Fraser *et al*. (2013).



Supplementary Figure 4: Archaeological grain C:N ratios plotted against $\delta^{15}N$.



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Conclusion

In this project, I aimed to assess how agricultural production was adapted to the changing social and ecological environments of western Anatolia from the Late Chalcolithic to Late Bronze Age. In doing so, I aimed to suggest how arable farming may have contributed to the formation and collapse of the elite social and economic structures of the EB II-III. I did this by using a suite of archaeobotanical analyses, including stable isotope analysis of crop remains and functional ecological analysis of their associated weeds, to produce high-resolution data on crop husbandry and arable land management practices at Liman Tepe, Bakla Tepe, Kocabaş Tepe and Çeşme-Bağlararası in the Izmir region. I synthesised these data with evidence for the social morphologies of settlements to produce new insights into the social scales at which the agricultural economy was organised and the implications that this had for the emergence of elite wealth and power over the *longue durée*. In this concluding section, I outline how each of the objectives that structured this project were addressed and consider potential directions for further research.

1. Addressing the research objectives

1.1 Assess how the agricultural economy was organised within Late Chalcolithic settlements in western Anatolia

Contextual analysis of archaeobotanical remains from Liman Tepe and Bakla Tepe provided a means to investigate how the agricultural economy was organised at these sites. The storage and late-stage processing of crops within houses suggests that the household formed a basic socio-economic unit of production and consumption. The size

of Late Chalcolithic houses across western Anatolia and the volumes of intra-household storage suggests that they were occupied by small families. The active use of open space between houses, plausibly for cooking and/or other domestic activities, is consistent with high levels of social monitoring within settlements and suggests that household autonomy was mediated against broader community relationships through the sharing of food and/or domestic labour. This closely resembles the social morphologies of Late Neolithic settlements within the region. At Bakla Tepe, storage within the house was likely supplemented by extra-household storage structures. The large size of the structures and their lack of associations with individual houses suggest that they may have been used by multiple households. Even if not, however, they represent an overtly visible form of storage and suggest that high levels of social monitoring extended to the agricultural economy within this settlement. Comparable extra-household storage structures are known from other sites in coastal western Anatolia and the eastern Aegean islands. Extra-household storage in different structures is also present within the region. This contrasts with inland western and central Anatolia, where the bulk of sites only contain evidence for storage within the household. At a number of sites, the use of screens to conceal storage structures and/or house interiors betray concerns with privacy that contrast with the visibility of extra-household storage.

Differences in the location and visibility of storage point to corresponding differences in the organisation of the agricultural economy between coastal western Anatolia and further inland. This was plausibly associated with the emergence of more extensive farming systems along the coast (outlined below). Ethnographies of recent farmers engaged in extensive systems of land use reveal acute demands on labour during key points in the agricultural year. Under these conditions, the ability to mobilise labour was

crucial to the success of agricultural production and losses to household workforces a major hazard. For the small households of the Late Chalcolithic, cooperation beyond the household may have been essential to the long-term sustainability of agricultural production. Potentially communal and highly monitored storage may have provided a means of maintaining cooperative relationships through obligations to share in the fortunes of good and bad years. These cooperative and equalising structures align well with the lack of evidence for pronounced wealth inequality in the Late Chalcolithic compared with later periods, despite the use of forms of agricultural production that have been linked to the emergence of sustained high wealth inequality across western Eurasia. Differences in the nature and organisation of agricultural production in coastal western Anatolia and the eastern Aegean islands compared with inland western and central Anatolia provide further evidence for a cultural *koine* between the former two regions in the fourth millennium BC. This is supported by the cultivation of Spanish vetchling and winged vetchling at Liman Tepe and, possibly, Bakla Tepe, hitherto unique within mainland Anatolia but present on the Aegean islands during the Bronze Age. This joins the Izmir region further to the long-term agricultural history of the Aegean world.

1.2 Document and interpret evidence for the nature of crop husbandry and arable land management strategies in Late Chalcolithic western Anatolia

Through a suite of archaeobotanical and archaeological analyses, this research has produced new insights into the nature of crop husbandry and arable land management strategies in Late Chalcolithic western Anatolia. An increase in the size of storage structures plausibly used for agricultural products and a reduction in the diversity of crop species cultivated between the Late Neolithic and Late Chalcolithic in coastal

western Anatolia are consistent with the emergence of more extensive farming systems. At Liman Tepe and Bakla Tepe, this is supported by evidence from stable isotope analysis and functional weed ecology for low-input cultivation practices. Cereals were cultivated on fields with low soil fertility and mechanical disturbance that received low to moderate levels of manuring. Pulses were more intensively manured than cereals and were plausibly grown on smaller 'garden plots' closer to the home. This attests to a spatial differentiation in crop cultivation that resembles the practices of recent farmers in the Aegean engaged in extensive systems of land use. This contrasts with published functional ecological and isotopic evidence for the maintenance of moderately intensive cultivation systems in Late Chalcolithic inland western and central Anatolia, aligning with the more diverse crop spectra, smaller capacities of storage structures and greater household autonomy in agricultural production in these regions.

The use of extensive farming systems in Late Chalcolithic western Anatolia has key implications for the emergence of wealth inequality and elite individuals within the region over the *longue durée*. The large scales of agricultural storage within the citadel of Troy II suggests that the elite economies of the EB II-III utilised extensive farming systems to amass arable wealth. The results of this research strongly indicate that extensive farming was utilised within domestic contexts in the late fourth millennium BC. This suggests that, as in other areas of economic production, the agro-ecological basis of EB II-III citadels were laid by the Late Chalcolithic.

1.3 Investigate the nature and organisation of agricultural production in the EB I-II and its implications for the emergence of EB II-III elite agro-economies

The suite of analyses used to address the previous objectives were also applied to the EBA occupations of the study sites to produce new insights into the nature and organisation of agricultural production. EB I-II agricultural production remained low-input, with cereals grown on fields that received moderate levels of manure but were well-watered. Pulses were grown on plots that received more intensive manuring and had correspondingly higher soil fertility. Like the Late Chalcolithic, this attests to a spatial differentiation in crop cultivation that resembles the practices of recent farmers in the Aegean engaged in extensive systems of land use. A key point of divergence between the Late Chalcolithic and EB I-II is the organisation of the agricultural economy. The longhouses adopted as the basic domestic architectural unit in the EB I-II were larger in size than earlier domestic structures and plausibly contained more extended family groups. This may have fostered greater autonomy in agricultural production at the household level than in the Late Chalcolithic. This aligns well with archaeological evidence for increased autonomy in other aspects of the domestic economy alongside more formalised hosting and reciprocity between households. This scenario of independent households engaged in extensive, land-limited forms of agricultural production closely resembles the model proposed by Bogaard *et al*. (2019) for the emergence of sustained high wealth inequality within western Eurasia. Despite this, however, archaeological evidence expressing pronounced wealth inequality between households in EB I-II settlements in western Anatolia is rare. This was plausibly due to the emergence of social structures designed to dampen emergent arable wealth inequality. Some settlements, such as Demircihöyük, utilised high levels of social

monitoring familiar to the Late Chalcolithic with the extra-household storage of agricultural products. At others, such as Karataş, more formal corporate institutions emerged through which individual agricultural surplus may have been centralised and redirected towards communal purposes. While ostensibly egalitarian in function, evidence for high status and wealthy individuals in the cemetery of Karataş suggests that these corporate institutions may have facilitated the emergence of the elites. Emergent elites may have expanded their wealth and power from this agricultural base in the EB II-III through control over long-distance trade networks and metallurgical production.

1.4 Assess archaeobotanical evidence for the impact of the 4.2ka event on agricultural production and its potential role in the collapse of EBA citadels

Analysis of archaeobotanical samples from Liman Tepe and Bakla Tepe/Kocabaş Tepe in the Cumaovası plain provided an opportunity to detect changes in crop growing conditions and/or agricultural decision making following the 4.2ka event. During the EB I-II, the crop spectra of Liman Tepe and Bakla Tepe were dominated by the glume wheats with barley as a secondary crop. Lentil and bitter vetch were both well-represented. In contrast, the late EBA-early MBA spectra of Liman Tepe and Kocabaş Tepe were heavily dominated by barley and bitter vetch, both of which are regarded as relatively drought tolerant crop species. The cultivation of barley on drier fields than glume wheats at Late Chalcolithic Liman Tepe and Bakla Tepe reveals the past exploitation of its drought tolerance attributes at these sites. Stable isotope analysis of crop remains revealed that late EBA-early MBA barley was also cultivated under drier conditions than EB I-II glume wheats at both Liman Tepe and in the Cumaovası plain, despite receiving comparable amounts of manure (contrasting with the cultivation of barley on drier fields that also

received less manure than the glume wheats at Liman Tepe in the Late Chalcolithic). In contrast, at Liman Tepe, early MBA bitter vetch was cultivated on more well-watered plots than EB I-II lentil. These data reveal a clear shift in agricultural decision making between the EB I-II and late EBA-early MBA towards a focus on drought tolerant cereals cultivated on drier soils with water management strategies redirected towards pulses. This was plausibly a response to drier climatic conditions following the 4.2ka event. In contrast, the MBA crop spectrum of Çeşme-Bağlararası changed little from the EBA, indicating variability in the impacts of, and/or response to, the event.

The extent to which the 4.2ka event can be implicated in the collapse of EB II-III citadels is less clear. Carbon isotope values of late EBA-early MBA barley from Liman Tepe and Kocabaş Tepe are not consistent with drought stress, suggesting that the 4.2ka event may have had only limited impacts on the climate of coastal western Anatolia or that the impacts were successfully mitigated through agricultural adaptions. This aligns with the limited evidence for drought stress in EB III barley from Troy. It also is possible, however, that agricultural production in the years immediately following the onset of the 4.2ka event was disrupted by drought in a way not recorded in the EB III and late EBA-early MBA archaeobotanical record from Troy, Liman Tepe and Kocabaş Tepe.

1.5 Examine how farming strategies were adapted to different settlement forms and environmental conditions across Late Chalcolithic and Bronze Age western Anatolia

By reconstructing crop cultivation and arable land management strategies across the occupation of four sites spanning three landscapes and almost two millennia, this research has produced key insights into how farming strategies were adapted to different settlement forms and environmental conditions within western Anatolia. The

Late Chalcolithic occupants of Liman Tepe and Bakla Tepe adapted arable land management strategies to both shared and divergent challenges in the agricultural landscapes surrounding the settlements. At both sites, lower-input cereal cultivation and higher-input pulse cultivation were likely integrated within extensive systems of land use. This plausibly resulted from the coastal location of Liman Tepe and the large size of Bakla Tepe, both of which pushed fields some distance from the home and made frictions of distance in the transport of manure and labour restrictive to intensive cultivation. The glume wheats were cultivated as mixed crops at both sites, potentially as a means to spread the risk of failure between the slightly differing ecological requirements of the two species. Barley was also grown on drier soils than the glume wheats at both sites, likely exploiting its capacity to thrive under drier conditions than the glume wheats.

Strategies diverged in the amount of manure applied to barley. At Liman Tepe, barley received less manure than the glume wheats. This may have been due to the location of the settlement *c.* 150 m off the coastline, making the transport costs of hauling manure particularly restrictive. Late Chalcolithic farmers appear to have adapted by applying manure to the glume wheats and exploiting the ability of barley to thrive in more marginal growing environments. Isotopic data from Liman Tepe also reveals variation in manuring intensity between glume wheats grown on different fields. In contrast to Liman Tepe, barley received greater quantities of manure than the glume wheats at Bakla Tepe, potentially as a means to encourage rigorous early growth on which to graze livestock. Occupying a coastal plain and surrounded by potential arable land, the transport costs of hauling manure may have been less restrictive at Bakla Tepe, facilitating more intensive manuring practices than at Liman Tepe.

The archaeobotanical remains analysed from Liman Tepe were recovered from an *in situ* deposit of stored grain within a single house and plausibly derived from a single harvest. The variability in agricultural strategies at this site is therefore not simply a reflection of the practices of different households, but a single household within a single year. This hints at a flexibility employed by recent farmers in the Aegean, in which arable land management decisions were governed by a host of temporally specific factors such as environmental conditions, the availability of labour and the recent performance of different plots.

Low-input farming systems were used throughout the Bronze Age occupations of the four study sites, attesting to an overall consistency in the nature of arable farming in the Izmir region. Against this continuity, however, arable land management strategies were adapted to changing environmental conditions. EBA farmers at Liman Tepe utilised more intensive manuring practices than those of the Late Chalcolithic, plausibly in response to the settlement becoming connected to the mainland thereby reducing the transport costs associated with the hauling of manure. As outlined above, more major changes occurred between the EB I-II and late EBA-early MBA occupations of the study sites, plausibly in response to drier climatic conditions following the 4.2ka event. The long-term impacts of the 4.2ka event on agricultural decision making within western Anatolia may be visible in the dominance of barley in LBA crop spectra across the region.

2. Potential for further research

By synthesising evidence for arable farming practices and social organisation in western Anatolia from the Late Chalcolithic to Late Bronze Age, this project has produced a suite of new insights into the roles of agricultural production within cultural developments

over the *longue durée*. Further archaeobotanical samples from the contexts analysed in this research would be beneficial to test the inferences made here and provide further insights into the diversity of agricultural strategies utilised across the occupations of the study sites. This project has also highlighted a number of key research questions that require archaeobotanical sampling and analysis from a broader range of sites to address. Data on crop husbandry and land management practices from more Late Chalcolithic settlements in both coastal and inland western Anatolia are necessary to confirm whether differences in the organisation of the agricultural economy between these regions are linked to differences in the nature of agricultural production. In coastal western Anatolia and the eastern Aegean islands, as well as sites with large-scale agricultural storage in central Anatolia, more data would allow a better understanding of the social and ecological environments in which low-input, extensive farming systems may have emerged.

In the EBA, more archaeobotanical datasets are needed from the eastern Aegean islands to assess how agricultural production was adapted to the ecological conditions of this region and the extent to which cultural affinities with coastal western Anatolia are visible in farming practices. Analysis of archaeobotanical remains from EB I-II settlements such as Karataş would provide further insights into how arable farming was integrated within different centralising social structures and under what agro-economic conditions the highly developed corporate structures that may have formed the precursors to the elite citadels of the EB II-III emerged. A key gap in the dataset of this project was the lack of archaeobotanical material from the EB II-III occupation of Liman Tepe. Samples from later EBA citadels are essential to understand the nature of elite agro-economies during this period. A key question is whether agricultural products were

centralised from domestic production within lower towns or were produced on large scales by elite households themselves. Analysis of archaeobotanical samples from both citadel and lower town are necessary to address this. Isotopic and functional ecological analysis of existing archaeobotanical material from the citadel of Küllüoba would provide a valuable point of comparison to the coastal citadels. This would allow an assessment of how agricultural production strategies may have contributed to the differing scales of elite wealth and power between the two regions.

Extending stable isotope and functional ecological analysis to archaeobotanical datasets from both earlier and later periods would also prove valuable. These analyses are necessary to confirm whether Neolithic and Early Chalcolithic farming in western Anatolia utilised intensive forms of crop cultivation and to provide points of comparison through which to better understand the emergence of more extensive farming systems within the region. Archaeobotanical samples from the Middle Chalcolithic are necessary to understand the nature of agricultural production during this period and its implications for the process of extensification between the Neolithic/Early Chalcolithic and the Late Chalcolithic. Analysis of samples from more MBA and LBA sites would provide further insights into the potential long-term impacts of the 4.2ka event on agricultural decision making within the region. Insights into the elite agro-economies of the second millennium BC, the impacts of the climatic drying of the '3.2ka event' (*cf.* Knapp and Manning 2016) and how agricultural production was adapted in response would also provide valuable points of comparison with the later EBA.

In addition to further archaeobotanical research, a comparable approach to that of this project applied to faunal remains would provide key insights into how another aspect of

the farming economy was integrated within the cultural developments of Bronze Age western Anatolia. Archaeologically, excavations targeting non-domestic structures of the EB I-II are crucial to better understand how they may have developed into EB II-III citadel entities. Excavations within EB II-III lower towns are necessary to understand the nature of these occupations and their relationships to citadels. High-resolution recovery and contextual analysis of artefactual remains from the citadels themselves are also needed to provide further insights into how they functioned.

3. Final summary

This study has synthesised high-resolution data on crop cultivation strategies with evidence for the social morphologies of settlements to assess how agricultural production was adapted to the changing social and ecological environments of Bronze Age western Anatolia. In doing so, it has revealed the potentially major roles played by arable farming in the emergence of later EBA elite citadels over the *longue durée*. While the potential for farming systems to foster certain socio-economic conditions is emphasised in this research, the capacity for social structures to mitigate and/or redirect this is demonstrated repeatedly in the resulting narrative. This highlights the importance of considering 'economic' developments such as farming within their social contexts in order to understand their roles within broader cultural developments. Within Bronze Age western Anatolia, agricultural production emerges as an important but single factor within a host of historically contingent socio-economic conditions that facilitated the florescence of citadel and lower town.

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Appendix

Appendix Table 1: Raw data from the Late Chalcolithic assemblages, showing all quantified items. Contexts: 1 – floor of the burnt house, 2 – upper destruction layer of the burnt house, 3 – below EBA longhouse, 4 – floor of a grill-plan house, 5 – miscellaneous fills.

	Sample number		28339/1	27394/1	27381/2	27374/9	27393/1	27395/4	27372/11	27398/1	27398/7	27398/13	28410/5	G012C1	G012C2
	Site		LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT
	Context		1	1	1	1	1	1	1	1	1	1	1	1	1
	Taxa	**Plant part**													
	Crops														
Poaceae	*Triticum monococcum*	Grain	114	18008	7611	645	836	1075	1110	3451	1498	966	8	880	974
Poaceae	*Triticum monococcum*	Glume base	12	0	896	32	0	192	247	256	224	32	8	148	26
Poaceae	*Triticum dicoccum*	Grain	194	12712	5957	467	1244	1325	714	2373	1382	948	42	751	973
Poaceae	*Triticum dicoccum*	Glume base	38	0	2304	69	288	288	384	1188	64	128	9	95	325
Poaceae	*Triticum* cf. *spelta*	Glume base	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Hordeum vulgare*	Grain	484	185344	0	72	384	1824	0	4992	8032	1238	75	1105	1014
Poaceae	*Hordeum vulgare*	Internode	0	0	0	0	0	0	0	0	96	0	0	0	0
Poaceae	*Hordeum vulgare vulgare*	Internode	0	2048	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Hordeum vulgare distichum*	Lemma base	4	1024	0	0	0	0	0	0	16	0	0	0	0
Poaceae	Cereal indet.	Internode	0	0	0	0	0	0	0	0	0	0	0	0	0
Fabaceae	*Vicia ervilia*	Seed	0	0	0	0	0	0	0	0	0	16	1	0	0
Fabaceae	*Lens culinaris*	Seed	4	0	0	0	0	0	16	0	0	16	5	18	1
Fabaceae	*Lathyrus sativus*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Fabaceae	*Lathyrus ochrus*	Seed	0	0	0	0	0	0	0	0	32	0	0	3	1
Fabaceae	*Lathyrus clymenum*	Seed	0	2048	2432	112	16	544	32	0	64	64	0	18	0
Fabaceae	*Lathyrus* sp.	Seed	0	0	512	16	16	0	48	64	0	64	1	0	0
Fabaceae	*Pisum sativum*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Fabaceae	Pulse indet.	Seed	0	2048	384	0	16	128	32	0	0	0	0	0	0
Linaceae	*Linum usitatissimum*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
	Fruit/nut														
Moraceae	*Ficus carica*	Seed	16	2048	128	8	64	32	0	0	32	0	4	113	66
Moraceae	*Ficus carica*	Fruit	0	0	0	0	0	0	0	0	0	0	0	0	0
Oleaceae	*Olea europaea*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Vitaceae	*Vitis* sp.	Seed	4	0	0	0	0	32	0	0	32	0	0	0	1
	Nut indet.	Seed	0	0	0	8	0	0	0	0	0	0	0	0	0
	Fruit/nut indet.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
	Weed/wild														
Anacardiaceae	*Pistacia lentiscus*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Apiaceae	*Apium* /*Bupleurum* type	Seed	0	0	0	0	0	0	0	16	12	0	16	4	6
Apiaceae	*Coriandrum sativum*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Apiaceae/Dipsacea	Apiaceae/Dipsaceae	Seed	0	0	0	0	0	0	0	0	4	0	0	0	0
Asparagaceae	*Bellevalia* /*Ornithogalum* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae	*Artemisia* type	Seed	0	0	0	0	0	0	0	0	0	0	0	2	0

	Sample number		28339/1	27394/1	27381/2	27374/9	27393/1	27395/4	27372/11	27398/1	27398/7	27398/13	28410/5	G012C1	G012C2
	Site		LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT
	Context		1	1	1	1	1	1	1	1	1	1	1	1	1
	Taxa	**Plant part**													
	Weed/wild														
Asteraceae	Asteraceae type 1	Seed	0	8	0	0	0	0	0	0	0	0	0	0	0
Asteraceae	Asteraceae type 2	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae	Asteraceae type 3	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae	cf. Asteraceae	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae	*Hierachium* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	1
Boraganiceae	Boraginaceae type 1	Seed	0	0	0	0	0	0	0	0	4	0	0	0	0
Boraganiceae	Boraginaceae type 2	Seed	0	0	0	0	16	0	0	0	0	0	0	0	0
Brassicaceae	*Alyssum* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Brassicaceae	*Brassica /Sinapis* sp.	Seed	0	0	0	0	8	0	0	0	0	0	0	0	0
Brassicaceae	Brassicaceae small type 1	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Brassicaceae	Brassicaceae small type 2	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Brassicaceae	Brassicaceae type 1	Seed	0	0	0	0	0	0	0	0	0	0	0	1	0
Brassicaceae	Brassicaceae type 2	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Brassicaceae	*Bunias erucago*	Seed pod	0	8	0	0	0	0	2	0	0	1	0	0	0
Caryophyllaceae	Caryophyllaceae sp.	Seed	0	0	0	0	0	0	0	0	4	0	0	0	0
Caryophyllaceae	*Cerastium /Sagina* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Caryophyllaceae	*Silene* sp.	Seed	0	8	0	0	0	8	0	0	4	0	0	0	0
Chenopodiaceae	*Atriplex* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Chenopodiaceae	*Chenopodium album /opulifolium*	Seed	0	0	0	0	0	0	0	16	0	0	0	0	1
Chenopodiaceae	*Salsola ruthenica /kali*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cistaceae	cf. Cistaceae	Seed	0	0	0	0	0	0	0	0	0	0	8	0	0
Cistaceae	Cistaceae sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cistaceae	*Cistus creticus* type	Seed	0	0	32	0	16	0	0	0	0	0	0	0	0
Cyperaceae	*Carex* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae	*Carex* type 1	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae	*Cladium mariscus*	Seed	8	8	96	3	24	0	3	8	4	5	0	23	6
Cyperaceae	Cyperaceae sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	3
Cyperaceae	Cyperaceae type 1	Seed	0	0	0	0	0	0	0	0	0	0	8	0	0
Cyperaceae	*Schoenus nigricans*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	2
Cyperaceae	*Scirpus lacustris*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae	*Scirpus maritimus*	Seed	0	0	0	0	0	0	2	0	0	0	1	0	0
Cyperaceae	*Scirpus* type 3	Seed	0	0	0	0	0	0	0	0	0	1	0	0	0
Cyperaceae/Thyme	Cyperaceae/Thymelaeaceae sp.	Seed	0	8	0	0	0	0	0	0	0	0	0	0	0
Fabaceae	Large Fabaceae sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	2	0
Fabaceae	*Scorpiurus muricatus*	Seed	0	0	0	0	0	0	0	0	0	0	0	1	1
Fabaceae	Small Fabaceae spp.	Seed	40	51	0	1	80	24	0	16	0	0	16	22	9
Fabaceae	*Vicia hirsuta* type	Seed	8	8	0	0	16	0	0	0	0	0	0	0	2

	Sample number		28339/1	27394/1	27381/2	27374/9	27393/1	27395/4	27372/11	27398/1	27398/7	27398/13	28410/5	G012C1	G012C2
	Site		LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT
	Context		1	1	1	1	1	1	1	1	1	1	1	1	1
	Taxa	**Plant part**													
	Weed/wild														
Isoetaceae	*Isoetes histrix* type	Seed	0	0	0	0	0	4	0	0	0	0	0	4	0
Labiatae	Labiatae type 1	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Labiatae	Labiatae type 2	Seed	0	0	0	0	0	0	0	0	0	0	0	0	2
Labiatae	*Lamium* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Labiatae	*Marrubium* type	Seed	0	0	32	0	0	0	0	0	0	0	0	18	7
Labiatae/Asteracea	Labiatae/Asteraceae type 1	Seed	0	0	32	0	0	0	0	0	0	0	0	0	0
Labiatae/Asteracea	Labiatae/Asteraceae type 2	Seed	0	0	32	0	0	0	0	0	0	0	0	0	0
Labiatae/Asteracea	Labiatea/Asteraceae type 3	Seed	0	0	0	0	0	0	0	0	0	0	0	4	0
Labiatea	*Origanum* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	4	0
Linaceae	cf. *Linum* sp.	Seed pod	4	0	0	0	0	0	0	0	0	0	0	0	0
Malvaceae	*Malva sylvestris* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Malvaceae	Malvaceae sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	2	6
Plantaginaceae	*Plantago* cf. *maritima*	Seed	8	0	0	0	0	0	0	0	0	0	0	0	0
Plantaginaceae	*Plantago scabra*	Seed	0	16	0	0	0	40	0	0	14	0	0	0	0
Poaceae	*Aegilops* sp.	Glume base	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Agrostis /Catagrostis /Aira* type	Seed	8	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Avena* sp.	Seed	0	0	0	0	0	0	2	0	0	0	1	0	0
Poaceae	*Avena /Hordeum* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Brachypodium distachyon* type	Seed	0	0	0	0	0	0	0	0	4	0	0	0	0
Poaceae	*Briza humilis*	Seed	8	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Bromus diandrus* type	Seed	8	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Bromus rubens /rigidus /diandrus* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Bromus* sp.	Seed	0	0	0	0	0	0	0	0	4	0	0	0	0
Poaceae	*Bromus* type 3	Seed	0	8	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Cynodon dactylon*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Eragrostis* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Hordeum spontaneum*	Seed	0	8	0	0	0	0	0	8	16	1	0	0	0
Poaceae	Large Poaceae sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Lolium remotum* type	Seed	0	0	0	0	0	0	0	0	0	0	0	95	12
Poaceae	*Lolium small type*	Seed	10	512	0	45	36	0	159	633	235	0	4	4	20
Poaceae	*Lolium temulentum*	Seed	106	3072	4608	787	668	1344	1313	1415	1941	560	22	1343	208
Poaceae	*Phalaris aquatica /paradoxa / canariensis* type	Seed	8	0	8	0	48	0	0	0	6	0	0	0	0
Poaceae	*Phalaris* cf. *minor*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Phalaris coerulescens /truncata / brachystachys* type	Seed	8	0	0	0	0	32	9	0	6	0	8	10	0
Poaceae	*Phalaris* sp.	Seed	0	0	0	0	16	4	8	0	4	8	8	0	0

	Sample number		28339/1	27394/1	27381/2	27374/9	27393/1	27395/4	27372/11	27398/1	27398/7	27398/13	28410/5	G012C1	G012C2
	Site		LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT
	Context		1	1	1	1	1	1	1	1	1	1	1	1	1
	Taxa	**Plant part**													
	Weed/wild														
Poaceae	*Phleum* cf. *arenarium*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Phleum* cf. *phleoides*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Phleum subulatum /exaratum*	Seed	16	0	0	0	0	0	0	0	4	0	8	8	0
Poaceae	*Poa* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Poa trivialis* type	Seed	0	0	32	0	16	0	0	0	0	0	0	0	0
Poaceae	Poaceae panicoid type	Seed	4	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	Poaceae type 1	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	Small Poaceae sp.	Seed	8	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Triticum boeoticum*	Seed	20	0	8	4	0	0	2	32	0	2	1	7	1
Poaceae/Cyperace	Poaceae/Cyperaceae sp.	Stem	0	8	0	0	0	0	0	0	0	0	0	0	0
Polygonaceae	Polygonaceae sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygonaceae	*Rumex acetosella*	Seed	56	0	0	0	0	0	0	0	0	0	0	2	0
Polygonaceae	*Rumex conglomeratus /sanguineus*	Seed	0	0	0	1	0	0	2	0	0	0	8	0	0
Polygonaceae	*Rumex crispus /obtusifolius*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygonaceae	*Rumex* large type	Seed	0	8	0	0	0	0	0	0	0	0	0	0	0
Ranunculaceae	*Ranunculus* smooth type	Seed	0	8	0	0	0	0	0	8	4	0	0	0	0
Ranunculaceae	*Ranunculus sprunerians* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Rubiaceae	*Asperula* sp.	Seed	0	8	0	0	0	0	2	0	0	0	0	0	0
Rubiaceae	*Fumaria* type	Seed	0	0	0	1	0	0	0	0	0	0	0	0	0
Rubiaceae	*Galium aparine* type	Seed	0	8	0	0	0	0	0	0	0	0	0	0	0
Rubiaceae	*Galium tricornutum* type	Seed	0	0	0	0	0	8	0	0	0	0	0	0	0
Rubiaceae	*Sherardia arvensis*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Saxifragaceae	Saxifragaceae type	Seed	0	0	0	0	0	0	2	0	0	0	0	0	0
Solanaceae	Solanaceae sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Thymeleaceae	*Thymelaea* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Vitaceae	*Vitex agnus-castus*	Seed	0	0	8	1	0	0	0	0	0	1	1	0	0
	Weed/wild indeterminate	Seed/seed pod	8	0	0	0	0	0	0	0	0	0	8	0	0

	Sample number		G012C3	G3C1	G4C1	G4C2	SECI	DestrC1	FloorC1	Floor C2	NEC1	NEC2	FloorC3	8385/1	28271/7
	Site		LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT
	Context		1	1	1	1	1	1	1	1	1	1	1	2	2
	Taxa	**Plant part**													
	Crops														
Poaceae	*Triticum monococcum*	Grain	466	542	10422	12128	115	4054	73	2697	1273	4459	216	32	15
Poaceae	*Triticum monococcum*	Glume base	192	208	1109	1024	94	280	0	363	26	75	16	52	0
Poaceae	*Triticum dicoccum*	Grain	308	613	6092	13024	193	2952	165	2951	593	517	514	1	31
Poaceae	*Triticum dicoccum*	Glume base	68	168	1891	1449	158	1406	42	1143	146	299	53	2	16
Poaceae	*Triticum* cf. *spelta*	Glume base	0	0	0	0	0	16	0	0	0	0	0	0	0
Poaceae	*Hordeum vulgare*	Grain	629	943	378	416	748	5561	424	0	133	22	1008	114	177
Poaceae	*Hordeum vulgare*	Internode	0	0	0	0	0	0	0	0	1	0	0	0	0
Poaceae	*Hordeum vulgare vulgare*	Internode	0	0	0	0	0	0	4	0	8	0	0	39	0
Poaceae	*Hordeum vulgare distichum*	Lemma base	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	Cereal indet.	Internode	0	0	0	0	8	0	0	0	0	0	0	0	0
Fabaceae	*Vicia ervilia*	Seed	1	0	2	0	0	16	0	0	1	0	0	2	0
Fabaceae	*Lens culinaris*	Seed	1	2	0	0	19	0	0	0	0	1	0	0	1
Fabaceae	*Lathyrus sativus*	Seed	0	0	16	0	0	0	0	0	0	0	0	0	0
Fabaceae	*Lathyrus ochrus*	Seed	11	0	323	32	0	0	0	48	0	6	0	0	0
Fabaceae	*Lathyrus clymenum*	Seed	20	22	1463	1856	0	2	2	336	0	2	4	1	0
Fabaceae	*Lathyrus* sp.	Seed	7	0	239	64	0	65	2	160	0	6	0	0	0
Fabaceae	*Pisum sativum*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Fabaceae	Pulse indet.	Seed	0	8	810	96	0	2	0	144	0	2	0	7	0
Linaceae	*Linum usitatissimum*	Seed	0	0	0	0	1	0	0	0	0	0	0	0	0
	Fruit/nut														
Moraceae	*Ficus carica*	Seed	5	20	200	80	0	8	16	16	28	0	24	0	0
Moraceae	*Ficus carica*	Fruit	0	1	0	0	0	0	0	0	0	0	0	0	0
Oleaceae	*Olea europaea*	Seed	1	0	2	0	0	2	0	0	0	0	0	0	0
Vitaceae	*Vitis* sp.	Seed	5	4	45	0	0	0	0	16	6	1	0	0	0
	Nut indet.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
	Fruit/nut indet.	Seed	0	0	0	0	0	0	0	0	1	0	0	0	0
	Weed/wild														
Anacardiaceae	*Pistacia lentiscus*	Seed	1	0	0	0	0	0	0	0	0	0	4	0	0
Apiaceae	*Apium/Bupleurum* type	Seed	0	4	0	0	2	16	0	0	0	0	12	4	0
Apiaceae	*Coriandrum sativum*	Seed	2	0	0	0	0	0	0	0	0	0	0	0	0
Apiaceae/Dipsacea	Apiaceae/Dipsaceae	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asparagaceae	*Bellevalia/Ornithogalum* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae	*Artemisia* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae	Asteraceae type 1	Seed	0	0	0	0	0	0	0	0	0	0	0	4	0
Asteraceae	Asteraceae type 2	Seed	0	0	0	0	0	0	0	0	0	0	0	4	0
Asteraceae	Asteraceae type 3	Seed	0	0	0	0	0	0	0	0	0	0	0	4	0
Asteraceae	cf. Asteraceae	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae	*Hierachium* type	Seed	0	0	0	0	0	0	0	0	0	0	0	4	0

	Sample number		G012C3	G3C1	G4C1	G4C2	SECI	DestrC1	FloorC1	Floor C2	NEC1	NEC2	FloorC3	8385/1	28271/7
	Site		LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT
	Context		1	1	1	1	1	1	1	1	1	1	1	2	2
	Taxa	**Plant part**													
	Weed/wild														
Boraganiceae	Boraginaceae type 1	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Boraganiceae	Boraginaceae type 2	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Brassicaceae	*Alyssum* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Brassicaceae	*Brassica /Sinapis* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Brassicaceae	Brassicaceae small type 1	Seed	0	2	0	0	0	0	0	0	0	0	0	0	0
Brassicaceae	Brassicaceae small type 2	Seed	0	0	0	0	0	0	0	0	2	0	0	1	0
Brassicaceae	Brassicaceae type 1	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Brassicaceae	Brassicaceae type 2	Seed	2	0	0	0	0	0	0	0	0	0	0	0	0
Brassicaceae	*Bunias erucago*	Seed pod	0	0	2	2	0	0	0	0	0	0	0	0	0
Caryophyllaceae	Caryophyllaceae sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Caryophyllaceae	*Cerastium /Sagina* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Caryophyllaceae	*Silene* sp.	Seed	0	2	0	0	0	0	0	0	0	0	0	0	0
Chenopodiaceae	*Atriplex* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Chenopodiaceae	*Chenopodium album /opulifolium*	Seed	0	1	0	0	1	16	0	0	0	0	8	0	0
Chenopodiaceae	*Salsola ruthenica /kali*	Seed	0	0	0	0	0	0	1	0	0	0	0	0	0
Cistaceae	cf. Cistaceae	Seed	0	0	0	0	1	0	0	0	0	0	0	0	0
Cistaceae	Cistaceae sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	2
Cistaceae	*Cistus creticus* type	Seed	0	0	0	4	0	0	0	0	0	0	0	0	0
Cyperaceae	*Carex* sp.	Seed	0	0	4	0	0	0	0	0	0	0	0	0	0
Cyperaceae	*Carex* type 1	Seed	0	0	0	0	0	0	0	0	0	0	0	1	0
Cyperaceae	*Cladium mariscus*	Seed	28	7	110	12	1	8	6	176	5	0	12	0	0
Cyperaceae	Cyperaceae sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	4	0
Cyperaceae	Cyperaceae type 1	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae	*Schoenus nigricans*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae	*Scirpus lacustris*	Seed	0	0	0	0	0	0	0	0	0	0	0	1	0
Cyperaceae	*Scirpus maritimus*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae	*Scirpus* type 3	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae/Thyme	Cyperaceae/Thymelaeaceae sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Fabaceae	Large Fabaceae sp.	Seed	2	0	2	0	0	0	0	0	0	0	0	0	0
Fabaceae	*Scorpiurus muricatus*	Seed	2	2	2	2	0	0	2	16	2	1	0	0	0
Fabaceae	Small Fabaceae spp.	Seed	10	8	17	2	20	16	4	0	1	4	36	17	0
Fabaceae	*Vicia hirsuta* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Isoetaceae	*Isoetes histrix* type	Seed	0	1	4	0	0	0	0	0	0	0	0	0	0
Labiatae	Labiatae type 1	Seed	0	0	0	0	0	0	0	0	0	0	0	0	1
Labiatae	Labiatae type 2	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Labiatae	*Lamium* type	Seed	0	0	0	0	0	0	0	0	0	0	0	2	0
Labiatae	*Marrubium* type	Seed	2	0	0	8	0	0	0	0	0	0	0	0	0

	Sample number		G012C3	G3C1	G4C1	G4C2	SECI	DestrC1	FloorC1	Floor C2	NEC1	NEC2	FloorC3	8385/1	28271/7
	Site		LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT
	Context		1	1	1	1	1	1	1	1	1	1	1	2	2
	Taxa	**Plant part**													
	Weed/wild														
Labiatae/Asteracea	Labiatae/Asteraceae type 1	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Labiatae/Asteracea	Labiatae/Asteraceae type 2	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Labiatae/Asteracea	Labiatea/Asteraceae type 3	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Labiatea	*Origanum* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	2	0
Linaceae	cf. *Linum* sp.	Seed pod	0	0	0	0	0	0	0	0	0	0	0	0	0
Malvaceae	*Malva sylvestris* type	Seed	0	0	0	0	0	0	1	0	0	0	0	0	0
Malvaceae	Malvaceae	Seed	72	2	0	0	8	0	1	0	0	0	0	0	0
Plantaginaceae	*Plantago* cf. *maritima*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Plantaginaceae	*Plantago scabra*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Aegilops* sp.	Glume base	0	0	8	0	0	0	0	0	0	0	0	0	0
Poaceae	*Agrostis /Catagrostis /Aira* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Avena* sp.	Seed	0	0	4	2	0	0	2	0	1	0	1	1	0
Poaceae	*Avena /Hordeum*	Seed	0	0	0	0	0	0	0	0	0	0	0	1	0
Poaceae	*Brachypodium distachyon* type	Seed	0	0	0	0	0	0	2	0	0	0	0	4	0
Poaceae	*Briza humilis*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Bromus diandrus* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Bromus rubens /rigidus /diandrus* type	Seed	0	0	0	0	0	0	0	0	0	0	0	1	0
Poaceae	*Bromus* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	5	0
Poaceae	*Bromus* type 3	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Cynodon dactylon*	Seed	0	0	0	0	0	0	0	0	0	0	4	0	0
Poaceae	*Eragrostis* sp.	Seed	0	0	16	0	0	0	0	0	0	0	8	0	0
Poaceae	*Hordeum spontaneum*	Seed	0	2	0	0	0	8	1	0	0	0	0	0	0
Poaceae	Large Poaceae	Seed	0	2	32	16	0	0	0	0	0	0	4	2	0
Poaceae	*Lolium remotum* type	Seed	0	35	234	0	0	0	0	0	23	0	9	0	0
Poaceae	*Lolium small type*	Seed	28	109	226	224	5	635	5	202	42	56	9	0	1
Poaceae	*Lolium temulentum*	Seed	232	467	4584	3680	53	1773	107	7382	343	548	225	0	23
Poaceae	*Phalaris aquatica /paradoxa / canariensis* type	Seed	0	4	12	2	14	0	2	0	2	0	0	0	0
Poaceae	*Phalaris* cf. *minor*	Seed	0	1	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Phalaris coerulescens /truncata / brachystachys type*	Seed	16	4	16	16	0	0	0	0	0	0	8	8	0
Poaceae	*Phalaris* sp.	Seed	0	4	68	20	2	0	5	0	8	0	0	4	0
Poaceae	*Phleum subulatum /exaratum*	Seed	4	0	0	0	2	0	0	0	0	0	4	0	0
Poaceae	*Poa* sp.	Seed	0	2	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Poa trivialis* type	Seed	0	0	8	2	0	0	0	0	0	0	0	8	0
Poaceae	Poaceae panicoid type	Seed	0	0	0	0	0	0	0	0	0	1	1	0	0
Poaceae	Poaceae type 1	Seed	0	0	0	0	8	0	0	0	0	0	0	0	0
Poaceae	*Phleum* cf. *arenarium*	Seed	0	1	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Phleum* cf. *phleoides*	Seed	0	3	0	0	0	0	0	0	0	0	0	0	0

	Sample number		G012C3	G3C1	G4C1	G4C2	SECI	DestrC1	FloorC1	Floor C2	NEC1	NEC2	FloorC3	8385/1	28271/7
	Site		LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT
	Context		1	1	1	1	1	1	1	1	1	1	1	2	2
	Taxa	**Plant part**													
	Weed/wild														
Poaceae	Small Poaceae	Seed	0	0	32	0	2	0	0	0	0	0	0	0	0
Poaceae	*Triticum boeoticum*	Seed	5	0	20	2	1	32	0	32	6	3	0	89	0
Poaceae/Cyperace	Poaceae/Cyperaceae	Stem	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygonaceae	Polygonaceae	Seed	0	0	0	0	0	0	0	0	0	0	4	0	0
Polygonaceae	*Rumex acetosella*	Seed	0	5	0	0	0	0	0	0	0	0	0	0	0
Polygonaceae	*Rumex conglomeratus /sanguineus*	Seed	2	0	0	2	8	0	0	16	0	0	0	0	0
Polygonaceae	*Rumex crispus /obtusifolius*	Seed	0	0	2	0	0	0	0	0	0	0	0	0	0
Polygonaceae	*Rumex* large type	Seed	1	0	0	0	0	0	0	0	0	0	0	0	0
Ranunculaceae	*Ranunculus* smooth type	Seed	0	0	0	0	0	8	0	0	0	0	0	0	0
Ranunculaceae	*Ranunculus sprunerians* type	Seed	0	0	0	0	0	0	0	0	0	0	0	1	0
Rubiaceae	*Asperula* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	1	0
Rubiaceae	*Fumaria* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Rubiaceae	*Galium aparine* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Rubiaceae	*Galium tricornutum* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Rubiaceae	*Sherardia arvensis*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	1
Saxifragaceae	Saxifragaceae type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Solanaceae	Solanaceae	Seed	0	0	0	0	0	0	0	0	0	0	0	0	1
Thymeleaceae	*Thymelaea* sp.	Seed	0	0	8	0	0	0	0	0	0	0	0	0	0
Vitaceae	*Vitex agnus-castus*	Seed	3	0	6	4	1	0	0	0	0	0	0	0	0
	Weed/wild indeterminate	Seed/seed pod	0	2	4	0	0	4	2	0	0	1	0	3	0

	Sample number		27331/1	27310/4	27358/4	2004C1	2004C2	2004C3	7196	24132A	17264B	H15	17324	22357/A	22285B
	Site		LT	LT	LT	LT	LT	LT	LT	BT	BT	BT	BT	BT	BT
	Context		2	2	2	2	2	2	3	4	5	5	5	5	5
	Taxa	**Plant part**													
	Crops														
Poaceae	*Triticum monococcum*	Grain	3475	42	29	3326	1040	212	40	1274	18	1222	104	1649	27
Poaceae	*Triticum monococcum*	Glume base	0	8	2	694	35	12	0	2	0	531	2	1	0
Poaceae	*Triticum dicoccum*	Grain	2829	41	73	4118	176	319	10	70	13	667	159	958	39
Poaceae	*Triticum dicoccum*	Glume base	2272	14	0	2653	119	209	0	0	0	301	1	22	0
Poaceae	*Triticum* cf. *spelta*	Glume base	0	0	0	32	0	0	0	0	0	3	0	0	0
Poaceae	*Hordeum vulgare*	Grain	0	2	67	0	410	11	95	26	0	11	0	0	0
Poaceae	*Hordeum vulgare*	Internode	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Hordeum vulgare vulgare*	Internode	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Hordeum vulgare distichum*	Lemma base	0	0	0	0	0	0	1	0	0	0	0	0	0
Poaceae	Cereal indet.	Internode	0	0	0	0	0	1	0	0	0	0	0	0	0
Fabaceae	*Vicia ervilia*	Seed	0	0	0	112	0	0	0	0	0	0	0	5	0
Fabaceae	*Lens culinaris*	Seed	0	0	0	96	0	4	1	6	0	0	0	0	1
Fabaceae	*Lathyrus sativus*	Seed	0	0	0	8	0	0	0	0	0	0	0	2	0
Fabaceae	*Lathyrus ochrus*	Seed	0	0	0	328	3	7	0	0	0	0	0	10	0
Fabaceae	*Lathyrus clymenum*	Seed	352	1	0	668	0	24	3	0	0	0	0	2	0
Fabaceae	*Lathyrus* sp.	Seed	32	1	0	176	0	0	0	0	0	1	0	0	0
Fabaceae	*Pisum sativum*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	1
Fabaceae	Pulse indet.	Seed	32	0	0	248	1	1	0	0	0	0	0	1	0
Linaceae	*Linum usitatissimum*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
	Fruit/nut														
Moraceae	*Ficus carica*	Seed	64	0	4	32	2	4	0	0	0	0	0	0	0
Moraceae	*Ficus carica*	Fruit	0	0	0	0	0	0	0	0	0	0	0	0	0
Oleaceae	*Olea europaea*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Vitaceae	*Vitis* sp.	Seed	0	0	1	0	2	0	0	14	0	0	0	0	0
	Nut indet.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
	Fruit/nut indet.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
	Weed/wild														
Anacardiaceae	*Pistacia lentiscus*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Apiaceae	*Apium /Bupleurum* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Apiaceae	*Coriandrum sativum*	Seed	0	0	0	8	0	0	0	0	0	0	0	0	0
Apiaceae/Dipsacea	Apiaceae/Dipsaceae	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asparagaceae	*Bellevalia /Ornithogalum* sp.	Seed	0	0	0	0	1	0	0	0	0	0	0	0	0
Asteraceae	*Artemisia* type	Seed	0	0	0	0	2	0	0	0	0	0	0	0	0
Asteraceae	Asteraceae type 1	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae	Asteraceae type 2	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae	Asteraceae type 3	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae	cf. Asteraceae	Seed	0	0	0	0	0	0	0	0	0	1	0	0	0
Asteraceae	*Hierachium* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0

	Sample number		27331/1	27310/4	27358/4	2004C1	2004C2	2004C3	7196	24132A	17264B	H15	17324	22357/A	22285B
	Site		LT	LT	LT	LT	LT	LT	LT	BT	BT	BT	BT	BT	BT
	Context		2	2	2	2	2	2	3	4	5	5	5	5	5
	Taxa	**Plant part**													
	Weed/wild														
Boraganiceae	Boraginaceae type 1	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Boraganiceae	Boraginaceae type 2	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Brassicaceae	*Alyssum* type	Seed	0	0	0	0	2	0	0	0	0	0	0	0	0
Brassicaceae	*Brassica /Sinapis* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Brassicaceae	Brassicaceae small type 1	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Brassicaceae	Brassicaceae small type 2	Seed	0	0	0	0	4	0	0	0	0	0	0	0	0
Brassicaceae	Brassicaceae type 1	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Brassicaceae	Brassicaceae type 2	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Brassicaceae	*Bunias erucago*	Seed pod	0	0	0	0	0	0	0	0	0	0	0	0	0
Caryophyllaceae	Caryophyllaceae	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Caryophyllaceae	*Cerastium /Sagina* type	Seed	0	0	0	0	0	0	0	0	0	1	0	0	0
Caryophyllaceae	*Silene* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Chenopodiaceae	*Atriplex* sp.	Seed	0	0	0	0	0	0	0	0	0	1	0	0	0
Chenopodiaceae	*Chenopodium album /opulifolium*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Chenopodiaceae	*Salsola ruthenica /kali*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cistaceae	cf. Cistaceae	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cistaceae	Cistaceae	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cistaceae	*Cistus creticus* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae	*Carex* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae	*Carex* type 1	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae	*Cladium mariscus*	Seed	0	0	0	2	0	0	0	0	0	0	0	0	0
Cyperaceae	Cyperaceae	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae	Cyperaceae type 1	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae	*Schoenus nigricans*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae	*Scirpus lacustris*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae	*Scirpus maritimus*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae	*Scirpus* type 3	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae/Thyme	Cyperaceae/Thymelaeaceae	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Fabaceae	Large Fabaceae	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Fabaceae	*Scorpiurus muricatus*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Fabaceae	Small Fabaceae spp.	Seed	6	0	0	0	0	0	1	0	0	3	0	0	0
Fabaceae	*Vicia hirsuta* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Isoetaceae	*Isoetes histrix* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Labiatae	Labiatae type 1	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Labiatae	Labiatae type 2	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Labiatae	*Lamium* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Labiatae	*Marrubium* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0

	Sample number		27331/1	27310/4	27358/4	2004C1	2004C2	2004C3	7196	24132A	17264B	H15	17324	22357/A	22285B
	Site		LT	LT	LT	LT	LT	LT	LT	BT	BT	BT	BT	BT	BT
	Context		2	2	2	2	2	2	3	4	5	5	5	5	5
	Taxa	**Plant part**													
	Weed/wild														
Labiatae/Asteracea	Labiatae/Asteraceae type 1	Seed	0	0	0	0	0	0	0	0	0	1	0	0	0
Labiatae/Asteracea	Labiatae/Asteraceae type 2	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Labiatae/Asteracea	Labiatea/Asteraceae type 3	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Labiatea	*Origanum* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Linaceae	cf. *Linum* sp.	Seed pod	0	0	0	0	0	0	0	0	0	0	0	0	0
Malvaceae	*Malva sylvestris* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Malvaceae	Malvaceae	Seed	0	0	0	0	0	0	0	0	0	1	0	0	0
Plantaginaceae	*Plantago* cf. *maritima*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Plantaginaceae	*Plantago scabra*	Seed	0	0	1	0	0	0	0	0	0	0	0	0	0
Poaceae	*Aegilops* sp.	Glume base	0	0	0	0	0	0	0	0	0	0	0	0	2
Poaceae	*Agrostis /Catagrostis /Aira* type	Seed	0	0	0	0	2	0	0	0	0	0	0	0	0
Poaceae	*Avena* sp.	Seed	0	0	0	16	0	0	0	0	0	0	0	0	0
Poaceae	*Avena /Hordeum*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Brachypodium distachyon* type	Seed	0	0	1	0	0	0	0	0	0	0	0	0	0
Poaceae	*Briza humilis*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Bromus diandrus* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Bromus rubens /rigidus /diandrus* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Bromus* sp.	Seed	4	0	0	0	0	0	0	0	0	1	0	0	0
Poaceae	*Bromus* type 3	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Cynodon dactylon*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Eragrostis* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Hordeum spontaneum*	Seed	0	0	0	0	3	0	0	0	0	0	0	0	0
Poaceae	Large Poaceae	Seed	4	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Lolium remotum* type	Seed	48	0	6	109	0	2	0	0	0	0	0	17	0
Poaceae	*Lolium small type*	Seed	48	0	0	223	18	4	0	0	0	3	0	17	0
Poaceae	*Lolium temulentum*	Seed	1791	30	74	3009	167	222	3	0	0	380	11	698	2
Poaceae	*Phalaris aquatica /paradoxa / canariensis* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Phalaris* cf. *minor*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Phalaris coerulescens /truncata / brachystachys type*	Seed	10	0	0	0	2	0	0	0	0	11	0	1	0
Poaceae	*Phalaris* sp.	Seed	8	0	0	0	1	0	0	0	0	0	0	0	0
Poaceae	*Phleum subulatum /exaratum*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Poa* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Poa trivialis* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	Poaceae panicoid type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	Poaceae type 1	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Phleum* cf. *arenarium*	Seed	4	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Phleum* cf. *phleoides*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0

	Sample number		27331/1	27310/4	27358/4	2004C1	2004C2	2004C3	7196	24132A	17264B	H15	17324	22357/A	22285B
	Site		LT	LT	LT	LT	LT	LT	LT	BT	BT	BT	BT	BT	BT
	Context		2	2	2	2	2	2	3	4	5	5	5	5	5
	Taxa	**Plant part**													
	Weed/wild														
Poaceae	Small Poaceae	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Triticum boeoticum*	Seed	0	0	0	9	2	0	0	0	0	0	0	0	0
Poaceae/Cyperace	Poaceae/Cyperaceae	Stem	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygonaceae	Polygonaceae	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygonaceae	*Rumex acetosella*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygonaceae	*Rumex conglomeratus /sanguineus*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygonaceae	*Rumex crispus /obtusifolius*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygonaceae	*Rumex* large type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Ranunculaceae	*Ranunculus* smooth type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Ranunculaceae	*Ranunculus sprunerians* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Rubiaceae	*Asperula* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Rubiaceae	*Fumaria* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Rubiaceae	*Galium aparine* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Rubiaceae	*Galium tricornutum* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Rubiaceae	*Sherardia arvensis*	Seed	0	0	0	16	0	0	0	0	0	0	0	0	0
Saxifragaceae	Saxifragaceae type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Solanaceae	Solanaceae	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Thymeleaceae	*Thymelaea* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Vitaceae	*Vitex agnus-castus*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
	Weed/wild indeterminate	Seed/seed pod	0	0	0	2	4	0	0	0	0	1	0	0	0

Appendix Table 2: Raw data from the Bronze Age assemblages, showing all quantified items. Contexts: 1 – ashpit, 2 – central structure subterranean storage room, 3 – floor of oval house, 4 – floor of house 2, 5 – floor of house 3, 6 – floor of longhouse, 7 – street, 8 – winehouse storage room, 9 – eMBA ashpit, 10 – pit with Minoan ceramics, 11 – pit with Mycenaean ceramics, 12 – possible floor, 13 – EB II-III cut into EB I-II settlement, 14 – EB I-II burial, 15 – longhouse, 16 – unknown EBA context, 17 – storage room.

	Site		LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT
	Sample number		12179/A	12427	12419/A	12355/A	2110/A	2113/A	4130/A	4380/2	1724/1+17	1672/1+16	3529/2+35	3534/11+3	3581/1
	Period		LBA	MBA	MBA	MBA	MBA	MBA	MBA	EB I-II	EB I-II	EB I-II	EB I-II	EB I-II	EB I-II
	Context		1	2	2	2	3	3	3	4	4	4	4	4	5
	Taxa	**Plant part**													
	Crops														
Poaceae	*Triticum monococcum*	Grain	0	2	8	0	1	0	1	46	82	14	4	20	16
Poaceae	*Triticum monococcum*	Glume base	50	0	5	18	0	0	0	54	0	0	0	6	0
Poaceae	*Triticum dicoccum*	Grain	26	6	9	4	16	0	1	37	68	22	2	6	6
Poaceae	*Triticum dicoccum*	Glume base	142	4	1	10	0	0	0	160	0	8	0	4	0
Poaceae	*Triticum* cf. *spelta*	Glume base	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Triticum aestivum/durum*	Grain	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Triticum aestivum/durum*	Internode	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Hordeum vulgare*	Grain	96	454	617	433	168	0	13	10	11	12	2	5	4
Poaceae	*Hordeum vulgare distichum*	Internode	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Hordeum vulgare*	Internode	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Hordeum vulgare vulgare*	Lemma base	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Hordeum vulgare distichum*	Lemma base	0	0	0	0	0	0	0	0	1	0	0	0	0
Poaceae	Cereal indet.	Internode	0	2	0	0	0	0	0	0	0	0	0	0	0
Fabaceae	*Vicia ervilia*	Seed	10	4	0	0	45	104	105	5	1	4	2	0	0
Fabaceae	*Lens culinaris*	Seed	2	0	0	0	0	0	0	3	1	0	35	13	3
Fabaceae	*Lathyrus sativus*	Seed	0	0	0	0	0	0	0	0	0	0	2	0	0
Fabaceae	*Lathyrus ochrus*	Seed	0	0	0	0	0	0	0	2	0	0	0	0	0
Fabaceae	*Lathyrus clymenum*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Fabaceae	*Lathyrus* sp.	Seed	0	0	0	0	0	0	0	2	0	0	0	0	0
Fabaceae	*Pisum sativum*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Fabaceae	*Vicia faba*	Seed	2	0	0	0	0	0	0	0	0	0	0	0	0
Fabaceae	*Cicer arietinum*	Seed	0	0	0	0	0	0	2	2	0	0	0	0	0
Fabaceae	Pulse indet.	Seed	0	0	0	0	1	0	0	0	0	0	1	0	0
Linaceae	*Linum usitatissimum*	Seed	0	0	0	0	0	0	0	2	0	0	0	0	0
	Fruit/nut														
Moraceae	*Ficus carica*	Seed	0	0	0	0	0	0	0	84	0	0	0	0	0
Moraceae	*Ficus carica*	Fruit	0	0	0	0	0	0	0	1	0	0	0	0	0
Rosaceae	*Malus/Pyrus* sp.	Fruit	0	0	0	0	0	0	0	0	0	0	0	0	0

	Site		LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT
	Sample number		12179/A	12427	12419/A	12355/A	2110/A	2113/A	4130/A	4380/2	1724/1+17	1672/1+16	3529/2+35	3534/11+3	3581/1
	Period		LBA	MBA	MBA	MBA	MBA	MBA	MBA	EB I-II	EB I-II	EB I-II	EB I-II	EB I-II	EB I-II
	Context		1	2	2	2	3	3	3	4	4	4	4	4	5
	Taxa	**Plant part**													
	Fruit/nut														
Oleaceae	*Olea europaea*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Vitaceae	*Vitis* sp.	Seed	0	0	1	0	2	0	2	4	0	3	1	0	0
Vitaceae	*Vitis* sp.	Stalk	0	0	0	0	0	0	0	0	0	0	0	0	0
Vitaceae	*Vitis* sp.	Skin	0	0	0	0	0	0	0	0	0	0	0	0	0
Fagaceae	*Quercus* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
	Nut indet.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
	Fruit indet.	Fruit	0	0	0	0	0	0	0	0	0	0	0	0	0
	Weed/wild														
Anacardiaceae	*Pistacia lentiscus*	Seed	2	0	0	0	0	0	0	2	0	0	0	0	0
Apiaceae	Apiaceae cf.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Apiaceae	*Apium/Bupleurum* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Apiaceae	*Coriandrum sativum*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Apiaceae	*Tordylium* small type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Apiaceae/Dipsacea	Apiaceae/Dipsaceae sp.	Seed	0	0	0	0	0	0	0	1	0	0	0	0	0
Asparagaceae	*Bellevalia dubia/trifoliata*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae	*Artemisia* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae	Asteraceae cf. flat round type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae	Asteraceae cf. type 2	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae	Asteraceae large rounded type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae	Asteraceae large type 2	Seed	0	0	0	0	0	0	0	0	0	1	0	0	0
Asteraceae	Asteraceae cf. type 3	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae	Asteraceae wrinkled type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae	*Hierachium/Verbena* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae	Picris type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae	Small Asteraceae type 1	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae/Labiata	Asteraceae/Labiatae fat type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae/Labiata	Asteraceae/Labiatae type 1	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae/Labiata	Asteraceae/Labiatae large type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae/Labiata	Asteraceae/Labiatae very small type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Boraginaceae	Boraginaceae sp.	Seed	16	0	0	0	0	0	0	0	0	0	0	0	0
Boraginaceae	Boraginaceae small spiked type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Boraginaceae	Boraginaceae small type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Boraginaceae	Boraginaceae smooth type	Seed	16	0	0	0	0	0	0	0	0	0	0	0	0
Boraginaceae	Boraginaceae spiked type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Boraginaceae	*Echium* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Boraginaceae	*Heliotropium europaeum*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0

	Site		LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT
	Sample number		12179/A	12427	12419/A	12355/A	2110/A	2113/A	4130/A	4380/2	1724/1+17	1672/1+16	3529/2+35	3534/11+3	3581/1
	Period		LBA	MBA	MBA	MBA	MBA	MBA	MBA	EB I-II	EB I-II	EB I-II	EB I-II	EB I-II	EB I-II
	Context		1	2	2	2	3	3	3	4	4	4	4	4	5
	Taxa	**Plant part**													
	Weed/wild														
Brassicaceae	*Alyssum* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Brassicaceae	*Brassica nigra*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Brassicaceae	*Brassica/Sinapis* type	Seed	0	0	0	0	0	0	0	2	0	0	0	0	0
Brassicaceae	Brassicaceae large type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Brassicaceae	Brassicaceae medium flat type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Brassicaceae	Brassicaceae oval type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Brassicaceae	Brassicaceae cf. small type 2	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Brassicaceae	Brassicaceae cf. small type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Brassicaceae	Brassicaceae sub-round type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Brassicaceae	*Bunias erucago*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Caryophyllaceae	Caryophyllaceae sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Caryophyllaceae	*Cerastium/Sagina* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Caryophyllaceae	*Silene* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Chenopodiaceae	*Atriplex* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Chenopodiaceae	*Chenopodium album/opulifolium*	Seed	256	1	0	2	0	0	0	0	0	0	0	0	0
Chenopodiaceae	*Chenopodium ficifolium* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Chenopodiaceae	*Chenopodium murale*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Chenopodiaceae	*Salsola ruthenica/kali*	Seed	16	0	0	0	0	0	0	24	0	0	0	0	0
Cistaceae	Cistaceae sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cistaceae	*Cistus creticus*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Convolvulaceae	*Convolvulus* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae	*Carex* flat type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae	*Carex* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae	*Cladium mariscus*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae	Cyperaceae indet.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae	Cyperaceae small flat type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae	*Schoenus nigricans*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae	*Scirpus lacustris*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae	*Scirpus maritimus*	Seed	16	2	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae	*Scirpus* type 2	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae	*Scirpus/Eleocharis* type	Seed	0	0	0	1	0	0	0	0	0	0	0	0	0
Cyperaceae	*Scirpus/Eleocharis* type 3	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae/Thyme	Cyperaceae/Thymelaeaceae sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae	*Eleocharis* flat type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae	*Eleocharis* palustris type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae	*Eleocharis* type 2	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0

	Site		LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT
	Sample number		12179/A	12427	12419/A	12355/A	2110/A	2113/A	4130/A	4380/2	1724/1+17	1672/1+16	3529/2+35	3534/11+3	3581/1
	Period		LBA	MBA	MBA	MBA	MBA	MBA	MBA	EB I-II	EB I-II	EB I-II	EB I-II	EB I-II	EB I-II
	Context		1	2	2	2	3	3	3	4	4	4	4	4	5
	Taxa	**Plant part**													
	Weed/wild														
Euphorbiaceae	*Euphorbia helioscopa* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Euphorbiaceae	Euphorbiaceae sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Euphorbiaceae	*Mercurialis annua*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Fabaceae	Large pulse indet.	Seed	16	0	0	0	0	0	0	1	0	0	0	0	0
Fabaceae	*Medicago* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Fabaceae	*Medicago turbinata*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Fabaceae	*Scorpiurus muricatus*	Seed	0	0	0	0	0	0	0	1	0	0	0	0	0
Fabaceae	Small pulse spp.	Seed	16	0	0	1	0	0	0	42	0	0	3	1	7
Fabaceae	Small pulse sp. 2	Seed	0	0	0	0	0	0	0	0	0	1	0	0	0
Fabaceae	*Vicia hirsuta* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Isoetaceae	*Isoetes histrix* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Labiatae	*Clinopodium* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Labiatae	Labiatae type 1	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Labiatae	Labiatae type 2	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Labiatae	Labiateae indet.	Seed	0	0	0	0	0	0	0	1	0	0	0	0	0
Labiatae	*Lallemantia iberica*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Labiatae	*Lamium* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Labiatae	*Marrubium* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Labiatae	*Origanum* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Labiatae	*Teucrium* type	Seed	16	0	0	0	0	0	0	0	0	0	0	0	0
Labiatae	*Teucrium/Ajuga* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Linaceae	*Linum* cf.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Malvaceae	*Malva sylvestris* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Malvaceae	Malvaceae sp.	Seed	128	0	0	0	0	0	0	0	0	0	0	0	0
Papaveraceae	*Fumaria* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Papaveraceae	*Papaver somniferum*	Seed	0	0	2	0	0	0	0	0	0	0	0	0	0
Papaveraceae	*Papaver/Glaucium* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Papaveraceae	Papaveraceae sp.	Seed	0	0	0	2	0	0	0	0	0	0	0	0	0
Plantaginaceae	*Plantago* cf. *maritima*	Seed	0	0	0	0	0	0	0	1	0	0	0	0	0
Plantaginaceae	*Plantago scabra*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Plantaginaceae	*Plantago* cf.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Plantaginaceae	*Plantago* cf. very small type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Aegilops* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Agrostis/Catagrostis/Aira* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Avena* sp.	Seed	0	0	0	0	0	0	0	2	0	0	0	0	0
Poaceae	*Avena/Hordeum* wild type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0

	Site		LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT
	Sample number		12179/A	12427	12419/A	12355/A	2110/A	2113/A	4130/A	4380/2	1724/1+17	1672/1+16	3529/2+35	3534/11+3	3581/1
	Period		LBA	MBA	MBA	MBA	MBA	MBA	MBA	EB I-II	EB I-II	EB I-II	EB I-II	EB I-II	EB I-II
	Context		1	2	2	2	3	3	3	4	4	4	4	4	5
	Taxa	**Plant part**													
	Weed/wild														
Poaceae	*Brachypodium distachyon* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Briza humilis*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Briza maxima*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Bromus commutatus* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Bromus diandrus* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Bromus* narrow pointed apex type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Bromus rubens/rigidus/diandrus* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Bromus* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Cynodon dactylon*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Eragrostis* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Hordeum* cf. *geniculatum*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Hordeum* cf. *marinum* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Hordeum spontaneum*	Seed	0	0	4	1	0	0	0	0	0	0	0	0	0
Poaceae	*Hordeum* wild type	Seed	0	0	0	0	0	0	0	1	0	0	0	0	0
Poaceae	Large Poaceae indet.	Seed	0	0	0	0	0	0	0	8	0	0	0	0	0
Poaceae	*Lolium remotum*	Seed	0	0	0	0	0	0	0	0	8	0	1	0	0
Poaceae	*Lolium* small type	Seed	9	2	0	1	0	0	0	46	6	6	1	4	8
Poaceae	*Lolium temulentum*	Seed	71	0	8	0	0	0	0	250	206	54	21	26	53
Poaceae	Poaceae Panicoid type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Panicum* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Phalaris aquatica/paradoxa/ canariensis* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Phalaris* cf. *minor*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Phalaris coerulescens/truncata/ brachystachys* type	Seed	0	0	0	0	0	0	0	8	0	0	0	1	0
Poaceae	*Phalaris* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Phleum arenarium* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Phleum phleoides* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Phleum subulatum/exaratum* type	Seed	0	0	0	0	0	0	0	8	0	0	0	0	0
Poaceae	*Poa* dorsally compressed type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Poa* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Poa trivialis* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	Poaceae small ridged surface type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	Small Poaceae indet.	Seed	0	0	0	0	0	0	0	0	0	0	2	0	0
Poaceae	*Sporobolus virginicus*	Seed	0	0	0	0	0	0	0	8	0	0	0	0	0
Poaceae	*Triticum boeoticum*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0

	Site		LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT	LT
	Sample number		12179/A	12427	12419/A	12355/A	2110/A	2113/A	4130/A	4380/2	1724/1+17	1672/1+16	3529/2+35	3534/11+3	3581/1
	Period		LBA	MBA	MBA	MBA	MBA	MBA	MBA	EB I-II	EB I-II	EB I-II	EB I-II	EB I-II	EB I-II
	Context		1	2	2	2	3	3	3	4	4	4	4	4	5
	Taxa	**Plant part**													
	Weed/wild														
Polygonaceae	Polygonaceae indet.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygonaceae	*Polygonum* sp. 1	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygonaceae	*Polygonum* sp. 2	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygonaceae	*Rumex acetosella*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygonaceae	*Rumex conglomeratus/sanguineus*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygonaceae	*Rumex crispus/obtusifolius*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygonaceae	*Rumex* large type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygonaceae	*Rumex* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Ranunculaeae	*Adonis annua* type	Seed	0	0	0	0	0	0	0	1	0	0	0	0	0
Ranunculaeae	*Nigella sativa* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Ranunculaeae	*Ranunculus ophioglossus* type	Seed	0	0	0	0	0	0	0	1	0	0	0	0	0
Ranunculaeae	*Ranunculus* smooth type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Ranunculaeae	*Ranunculus sprunerians* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Rubiaceae	*Asperula* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	1
Rubiaceae	*Galium aparine*	Seed	0	0	0	0	0	0	0	0	0	1	0	0	0
Rubiaceae	*Galium spurium*	Seed	0	0	0	0	0	0	0	0	0	1	0	0	0
Rubiaceae	*Galium tricornutum*	Seed	16	0	0	1	0	9	0	2	0	0	0	0	0
Rubiaceae	Rubiaceae indet.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Rubiaceae	Rubiaceae ridged surface	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Rubiaceae	*Sherardia arvensis*	Seed	0	0	0	0	0	0	0	1	0	0	0	0	0
Saxifragaceae	Saxifragaceae ridged surface type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Saxifragaceae	Saxifragaceae smooth surface type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Solanaceae	Solanaceae sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Thymelaeateae	*Thymelaea* sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Thymelaeateae	*Thymelea tartonraira*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Vitaceae	*Vitex agnus-castus*	Seed	16	0	0	0	0	0	0	0	0	0	0	0	0
	Weed/wild indeterminate	Seed/seed pod	128	0	0	2	0	0	0	2	0	0	0	0	0

Site		LT	LT	CB	CB	CB	CB	CB	CB	CB	CB	CB	CB	CB
Sample number		3512/1+34	1648/1+16	Loc 612	21097/1	Loc 649	15145/1	Loc 231	Loc 208	Loc 644+5	Loc 846	28451/2	Loc 925	25015
Period		EB I-II	EB I-II	EB II	EB II	EB II	EB II	MBA	MBA	eMBA	LBA	LBA	LBA	LBA
Context		5	5	6	6	6	7	8	8	9	10	11	11	11
Taxa	**Plant part**													
Crops														
Triticum monococcum	Grain	9	10	14	6	9	2	0	6	17	9	30	0	0
Triticum monococcum	Glume base	0	0	0	7	4	20	18	9	8	1	43	0	0
Triticum dicoccum	Grain	4	2	10	10	24	18	39	23	207	6	57	12	3
Triticum dicoccum	Glume base	0	0	3	15	28	94	54	12	499	10	291	0	0
Triticum cf. *spelta*	Glume base	0	0	0	0	0	0	0	0	0	0	0	0	0
Triticum aestivum/durum	Grain	0	0	0	0	0	0	0	0	0	13	3	0	1
Triticum aestivum/durum	Internode	0	0	0	0	0	0	0	0	0	0	0	0	0
Hordeum vulgare	Grain	4	6	5	10	9	3	6	11	42	48	8	19	29
Hordeum vulgare distichum	Internode	0	0	0	0	0	0	0	0	0	0	0	0	0
Hordeum vulgare	Internode	0	0	0	0	0	0	0	0	0	0	0	0	0
Hordeum vulgare vulgare	Lemma base	0	0	0	0	0	0	0	0	0	0	0	0	0
Hordeum vulgare distichum	Lemma base	0	0	0	0	0	0	0	0	0	0	0	0	0
Cereal indet.	Internode	0	0	0	0	0	0	0	0	0	0	0	0	0
Vicia ervilia	Seed	0	4	5	2	4	5	1	1	17	10	3	1	1
Lens culinaris	Seed	2	6	1	0	0	0	0	0	0	5	5	0	0
Lathyrus sativus	Seed	0	0	1	0	0	0	0	0	0	1	2	0	0
Lathyrus ochrus	Seed	7	1	0	0	0	0	0	0	0	0	0	0	0
Lathyrus clymenum	Seed	0	1	0	0	0	0	0	0	0	0	0	0	0
Lathyrus sp.	Seed	2	0	1	1	0	0	0	0	0	0	1	0	0
Pisum sativum	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Vicia faba	Seed	0	0	0	0	0	0	0	0	0	0	1	0	0
Cicer arietinum	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Pulse indet.	Seed	2	0	2	1	2	1	0	0	2	1	1	0	0
Linum usitatissimum	Seed	0	0	0	0	0	0	0	4	0	0	1	0	0
Fruit/nut														
Ficus carica	Seed	0	0	62	3	0	13	8	1	8	48	4	0	2
Ficus carica	Fruit	0	0	0	0	0	0	0	0	0	0	0	0	0
Malus/Pyrus sp.	Fruit	0	0	0	0	0	0	0	1	0	0	0	0	0

Site		LT	LT	CB	CB	CB	CB	CB	CB	CB	CB	CB	CB	CB
Sample number		3512/1+34	1648/1+16	Loc 612	21097/1	Loc 649	15145/1	Loc 231	Loc 208	Loc 644+5	Loc 846	28451/2	Loc 925	25015
Period		EB I-II	EB I-II	EB II	EB II	EB II	EB II	MBA	MBA	eMBA	LBA	LBA	LBA	LBA
Context		5	5	6	6	6	7	8	8	9	10	11	11	11
Taxa	**Plant part**													
Fruit/nut														
Olea europaea	Seed	0	0	2	27	11	2	1	16	2	3	0	1	0
Vitis sp.	Seed	0	1	2	6	10	3	2	9	2	23	0	0	2
Vitis sp.	Stalk	0	0	0	0	0	0	0	0	0	0	0	0	0
Vitis sp.	Skin	0	0	0	0	0	0	0	0	0	0	0	0	0
Quercus sp.	Seed	0	0	0	2	1	0	0	0	1	1	0	0	0
Nut indet.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Fruit indet.	Fruit	0	0	0	0	0	0	0	0	0	0	0	0	0
Weed/wild														
Pistacia lentiscus	Seed	0	0	0	0	0	0	1	0	0	3	0	0	0
Apiaceae cf.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Apium/Bupleurum type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Coriandrum sativum	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Tordylium small type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Apiaceae/Dipsaceae sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Bellevalia dubia/trifoliata	Seed	0	0	1	1	0	0	0	0	0	0	0	0	0
Artemisia type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae cf. flat round type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae cf. type 2	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae large rounded type	Seed	0	0	0	0	0	0	0	0	0	3	0	0	0
Asteraceae large type 2	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae cf. type 3	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae wrinkled type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Hierachium/Verbena type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Picris type	Seed	0	0	0	0	0	0	0	0	0	2	0	0	0
Small Asteraceae type 1	Seed	0	0	0	0	0	0	0	2	0	0	0	0	0
Asteraceae/Labiatae fat type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae/Labiatae type 1	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae/Labiatae large type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae/Labiatae very small type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Boraginaceae sp.	Seed	0	0	0	0	0	0	2	0	0	0	0	0	0
Boraginaceae small spiked type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Boraginaceae small type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Boraginaceae smooth type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Boraginaceae spiked type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Echium sp.	Seed	0	0	0	0	0	0	1	0	0	0	0	0	0
Heliotropium europaeum	Seed	0	0	0	0	0	1	0	0	0	3	0	0	0

Site		LT	LT	CB	CB	CB	CB	CB	CB	CB	CB	CB	CB	CB
Sample number		3512/1+34	1648/1+16	Loc 612	21097/1	Loc 649	15145/1	Loc 231	Loc 208	Loc 644+5	Loc 846	28451/2	Loc 925	25015
Period		EB I-II	EB I-II	EB II	EB II	EB II	EB II	MBA	MBA	eMBA	LBA	LBA	LBA	LBA
Context		5	5	6	6	6	7	8	8	9	10	11	11	11
Taxa	**Plant part**													
Weed/wild														
Alyssum type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Brassica nigra	Seed	0	0	0	0	0	0	0	0	0	1	0	0	0
Brassica/Sinapis type	Seed	0	0	0	0	0	0	0	0	0	1	0	0	0
Brassicaceae large type	Seed	0	0	0	0	0	1	0	5	0	0	0	0	0
Brassicaceae medium flat type	Seed	0	0	8	0	0	0	0	0	0	0	0	0	0
Brassicaceae oval type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Brassicaceae cf. small type 2	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Brassicaceae cf. small type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Brassicaceae sub-round type	Seed	0	0	0	0	0	1	0	0	0	0	0	0	0
Bunias erucago	Seed	0	0	0	0	0	0	0	0	1	0	0	0	0
Caryophyllaceae sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cerastium/Sagina type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Silene sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Atriplex sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Chenopodium album/opulifolium	Seed	0	0	0	0	0	1	0	0	0	2	0	0	2
Chenopodium ficifolium type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Chenopodium murale	Seed	0	0	0	1	0	0	0	0	0	0	0	0	0
Salsola ruthenica/kali	Seed	0	0	0	2	0	0	7	0	0	1	0	0	0
Cistaceae sp.	Seed	0	0	0	0	0	0	0	0	0	1	0	0	0
Cistus creticus	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Convolvulus sp.	Seed	0	0	0	0	0	0	0	0	0	0	1	0	0
Carex flat type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Carex sp.	Seed	0	0	0	1	1	1	0	0	0	0	2	0	0
Cladium mariscus	Seed	0	0	0	0	0	1	0	0	0	0	0	0	0
Cyperaceae indet.	Seed	0	0	0	1	1	1	0	0	0	0	6	0	0
Cyperaceae small flat type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Schoenus nigricans	Seed	0	0	0	0	2	2	0	1	0	3	0	0	0
Scirpus lacustris	Seed	0	0	0	0	0	1	0	0	0	0	0	0	0
Scirpus maritimus	Seed	0	0	1	0	0	4	0	0	0	1	0	0	0
Scirpus type 2	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Scirpus/Eleocharis type	Seed	0	0	0	0	0	1	0	0	0	0	0	0	0
Scirpus/Eleocharis type 3	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae/Thymelaeaceae sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Eleocharis flat type	Seed	0	0	0	0	0	1	0	0	0	0	0	0	0
Eleocharis palustris type	Seed	0	0	0	0	0	3	0	0	0	1	2	0	0
Eleocharis type 2	Seed	0	0	0	0	0	0	0	0	0	1	0	0	0

Site		LT	LT	CB	CB	CB	CB	CB	CB	CB	CB	CB	CB	CB
Sample number		3512/1+34	1648/1+16	Loc 612	21097/1	Loc 649	15145/1	Loc 231	Loc 208	Loc 644+5	Loc 846	28451/2	Loc 925	25015
Period		EB I-II	EB I-II	EB II	EB II	EB II	EB II	MBA	MBA	eMBA	LBA	LBA	LBA	LBA
Context		5	5	6	6	6	7	8	8	9	10	11	11	11
Taxa	**Plant part**													
Weed/wild														
Euphorbia helioscopa type	Seed	0	0	0	0	0	0	0	0	1	0	0	0	0
Euphorbiaceae sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	1
Mercurialis annua	Seed	0	0	0	0	0	0	0	0	2	0	0	0	0
Large pulse indet.	Seed	0	0	0	0	0	0	0	0	1	0	2	0	0
Medicago sp.	Seed	0	0	0	0	0	0	0	0	0	1	0	0	0
Medicago turbinata	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Scorpiurus muricatus	Seed	0	0	1	2	0	1	0	0	2	0	2	0	0
Small pulse spp.	Seed	0	2	0	1	3	4	1	0	1	4	8	6	2
Small pulse sp. 2	Seed	0	0	0	0	0	0	0	1	0	0	0	0	0
Vicia hirsuta type	Seed	0	0	0	1	0	0	0	5	0	1	0	0	0
Isoetes histrix type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Clinopodium type	Seed	0	0	0	0	0	1	0	0	0	0	0	0	0
Labiatae type 1	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Labiatae type 2	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Labiateae indet.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Lallemantia iberica	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Lamium type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Marrubium type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Origanum type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Teucrium type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Teucrium/Ajuga type	Seed	0	0	0	0	0	0	8	0	0	0	0	0	0
Linum cf.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Malva sylvestris type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Malvaceae sp.	Seed	0	0	0	0	0	1	0	0	0	3	0	0	1
Fumaria type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Papaver somniferum	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Papaver/Glaucium sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	2	0
Papaveraceae sp.	Seed	0	0	0	0	0	0	0	0	0	1	0	0	0
Plantago cf. *maritima*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Plantago scabra	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Plantago cf.	Seed	0	0	0	0	0	0	0	0	0	1	0	0	0
Plantago cf. very small type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Aegilops sp.	Seed	0	0	0	0	0	0	0	0	1	0	0	0	0
Agrostis/Catagrostis/Aira sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Avena sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	1	2
Avena/Hordeum wild type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0

Site		LT	LT	CB	CB	CB	CB	CB	CB	CB	CB	CB	CB	CB
Sample number		3512/1+34	1648/1+16	Loc 612	21097/1	Loc 649	15145/1	Loc 231	Loc 208	Loc 644+5	Loc 846	28451/2	Loc 925	25015
Period		EB I-II	EB I-II	EB II	EB II	EB II	EB II	MBA	MBA	eMBA	LBA	LBA	LBA	LBA
Context		5	5	6	6	6	7	8	8	9	10	11	11	11
Taxa	**Plant part**													
Weed/wild														
Brachypodium distachyon type	Seed	0	0	1	0	0	0	0	0	0	0	0	0	0
Briza humilis	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Briza maxima	Seed	0	0	0	0	0	0	0	0	0	1	0	0	0
Bromus commutatus type	Seed	0	0	1	0	0	0	0	0	0	0	0	0	0
Bromus diandrus type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Bromus narrow pointed apex type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Bromus rubens/rigidus/diandrus type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Bromus sp.	Seed	0	0	0	0	0	0	0	1	0	8	0	1	0
Cynodon dactylon	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Eragrostis sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	2	0
Hordeum cf. *geniculatum*	Seed	0	0	0	0	0	0	0	0	1	0	0	0	0
Hordeum cf. *marinum* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	1
Hordeum spontaneum	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Hordeum wild type	Seed	0	0	0	0	0	1	0	0	0	1	0	0	0
Large Poaceae indet.	Seed	0	0	0	0	0	1	0	0	1	1	12	0	1
Lolium remotum	Seed	0	0	0	2	6	0	10	43	22	6	0	0	11
Lolium small type	Seed	9	13	3	5	4	11	3	17	10	6	4	0	2
Lolium temulentum	Seed	43	51	44	22	23	31	42	113	320	38	0	3	4
Poaceae Panicoid type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Panicum type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Phalaris aquatica/paradoxa/ canariensis type	Seed	0	0	8	1	1	2	0	0	0	0	5	0	2
Phalaris cf. *minor*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Phalaris coerulescens/truncata/ brachystachys type	Seed	0	0	0	0	0	1	0	0	0	0	0	0	1
Phalaris sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Phleum arenarium type	Seed	0	0	0	0	0	0	0	0	0	0	2	0	0
Phleum phleoides type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Phleum subulatum/exaratum type	Seed	0	0	0	0	0	1	0	0	0	0	2	0	0
Poa dorsally compressed type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poa sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poa trivialis type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae small ridged surface type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Small Poaceae indet.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Sporobolus virginicus	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Triticum boeoticum	Seed	0	0	0	0	0	0	0	4	1	0	0	0	0

Site		LT	LT	CB	CB	CB	CB	CB	CB	CB	CB	CB	CB	CB
Sample number		3512/1+34	1648/1+16	Loc 612	21097/1	Loc 649	15145/1	Loc 231	Loc 208	Loc 644+5	Loc 846	28451/2	Loc 925	25015
Period		EB I-II	EB I-II	EB II	EB II	EB II	EB II	MBA	MBA	eMBA	LBA	LBA	LBA	LBA
Context		5	5	6	6	6	7	8	8	9	10	11	11	11
Taxa	**Plant part**													
Weed/wild														
Polygonaceae indet.	Seed	0	0	0	1	0	0	0	0	0	2	0	0	0
Polygonum sp. 1	Seed	0	0	0	0	0	0	0	0	1	0	0	0	0
Polygonum sp. 2	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Rumex acetosella	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Rumex conglomeratus/sanguineus	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Rumex crispus/obtusifolius	Seed	0	0	0	0	0	1	2	1	1	1	1	0	0
Rumex large type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Rumex sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Adonis annua type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Nigella sativa type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Ranunculus ophioglossus type	Seed	0	0	0	0	0	1	0	0	0	0	0	0	0
Ranunculus smooth type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Ranunculus sprunerians type	Seed	0	0	0	0	0	0	0	0	1	0	0	0	0
Asperula sp.	Seed	0	0	0	0	0	0	0	1	0	0	0	0	0
Galium aparine	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Galium spurium	Seed	0	0	2	0	0	0	0	1	0	0	1	0	0
Galium tricornutum	Seed	0	0	0	0	0	0	2	0	2	1	0	0	0
Rubiaceae indet.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Rubiaceae ridged surface	Seed	0	0	0	0	0	0	0	0	1	0	0	0	0
Sherardia arvensis	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Saxifragaceae ridged surface type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Saxifragaceae smooth surface type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Solanaceae sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Thymelaea sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Thymelea tartonraira	Seed	0	0	0	1	0	0	0	0	0	1	3	0	0
Vitex agnus-castus	Seed	0	0	0	0	0	0	0	0	0	1	0	0	0
Weed/wild indeterminate	Seed/seed pod	0	0	1	1	0	3	22	1	0	9	5	0	0

Site		CB	CB	CB	BT	BT	BT	BT	BT	BT	BT	BT	KT	KT
Sample number		Loc 907	Loc 1282	24021/6	30111B + 3	17269AB	22340B	Grave 24	30244	30147A	36163A	?1998	IV-VI/a-e, (	7092/A
Period		LBA	LBA	LBA	EB II-III	EB I-II	EB I-II	EB I-II	EB I-II	EB I-II	EB I-II	EB I-II	EBA/MBA	EBA/MBA
Context		11	11	12	13	14	14	14	15	15	15	16	17	17
Taxa	**Plant part**													
Crops														
Triticum monococcum	Grain	0	0	0	12	143	42	39	10	6	0	41	0	0
Triticum monococcum	Glume base	0	0	0	10	0	0	0	8	38	0	7	0	0
Triticum dicoccum	Grain	19	18	0	203	132	26	2	6	4	0	0	0	0
Triticum dicoccum	Glume base	0	0	0	59	0	0	0	1	76	0	0	0	0
Triticum cf. *spelta*	Glume base	0	0	0	3	0	0	0	0	2	0	0	0	0
Triticum aestivum/durum	Grain	24	0	0	0	0	0	0	0	0	0	0	23	0
Triticum aestivum/durum	Internode	0	0	0	0	0	0	0	0	0	0	0	0	0
Hordeum vulgare	Grain	3	3	0	11	22	24	3	13	20	0	0	25	3
Hordeum vulgare distichum	Internode	0	0	0	0	0	0	0	0	0	0	0	0	0
Hordeum vulgare	Internode	0	0	0	0	0	0	0	0	15	0	0	0	0
Hordeum vulgare vulgare	Lemma base	0	0	0	0	0	0	0	0	0	0	0	0	0
Hordeum vulgare distichum	Lemma base	0	0	0	0	0	0	0	0	0	0	0	0	0
Cereal indet.	Internode	0	0	0	0	0	0	0	0	0	0	0	0	0
Vicia ervilia	Seed	5	9	749	3	1	0	0	0	1	82	6	2376	29
Lens culinaris	Seed	4	1	0	0	0	13	0	1	2	0	31	2	0
Lathyrus sativus	Seed	0	0	0	0	2	0	0	0	1	1	0	0	0
Lathyrus ochrus	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Lathyrus clymenum	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Lathyrus sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Pisum sativum	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Vicia faba	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cicer arietinum	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Pulse indet.	Seed	0	0	0	0	0	0	0	0	3	0	0	0	0
Linum usitatissimum	Seed	0	0	0	0	0	0	0	1	1	0	0	0	0
Fruit/nut														
Ficus carica	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Ficus carica	Fruit	0	0	0	0	0	0	0	0	0	0	0	0	0
Malus/Pyrus sp.	Fruit	0	0	0	0	0	0	0	0	0	0	0	0	0

Site		CB	CB	CB	BT	BT	BT	BT	BT	BT	BT	BT	KT	KT
Sample number		Loc 907	Loc 1282	24021/6	30111B + 3	17269AB	22340B	Grave 24	30244	30147A	36163A	?1998	IV-VI/a-e, (	7092/A
Period		LBA	LBA	LBA	EB II-III	EB I-II	EB I-II	EB I-II	EB I-II	EB I-II	EB I-II	EB I-II	EBA/MBA	EBA/MBA
Context		11	11	12	13	14	14	14	15	15	15	16	17	17
Taxa	**Plant part**													
Fruit/nut														
Olea europaea	Seed	0	1	0	0	0	0	0	0	0	0	0	0	0
Vitis sp.	Seed	0	0	31	65	0	0	0	0	0	0	0	1	0
Vitis sp.	Stalk	0	0	0	201	0	0	0	0	0	0	0	0	0
Vitis sp.	Skin	0	0	0	0	0	0	0	0	0	0	0	0	0
Quercus sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Nut indet.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Fruit indet.	Fruit	0	0	0	1	0	0	0	0	0	0	0	0	0
Weed/wild														
Pistacia lentiscus	Seed	0	1	0	0	0	0	0	0	0	0	0	0	0
Apiaceae cf.	Seed	0	0	0	0	0	0	0	2	0	0	0	0	0
Apium/Bupleurum type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Coriandrum sativum	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Tordylium small type	Seed	0	0	0	1	0	0	0	0	0	0	0	0	0
Apiaceae/Dipsaceae sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Bellevalia dubia/trifoliata	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Artemisia type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae cf. flat round type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae cf. type 2	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae large rounded type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae large type 2	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae cf. type 3	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae wrinkled type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Hierachium/Verbena type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Picris type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Small Asteraceae type 1	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae/Labiatae fat type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae/Labiatae type 1	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae/Labiatae large type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae/Labiatae very small type	Seed	8	0	0	0	0	0	0	0	0	0	0	0	0
Boraginaceae sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Boraginaceae small spiked type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Boraginaceae small type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Boraginaceae smooth type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Boraginaceae spiked type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Echium sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Heliotropium europaeum	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0

Site		CB	CB	CB	BT	BT	BT	BT	BT	BT	BT	BT	KT	KT
Sample number		Loc 907	Loc 1282	24021/6	30111B + 3	17269AB	22340B	Grave 24	30244	30147A	36163A	?1998	IV-VI/a-e, (	7092/A
Period		LBA	LBA	LBA	EB II-III	EB I-II	EB I-II	EB I-II	EB I-II	EB I-II	EB I-II	EB I-II	EBA/MBA	EBA/MBA
Context		11	11	12	13	14	14	14	15	15	15	16	17	17
Taxa	**Plant part**													
Weed/wild														
Alyssum type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Brassica nigra	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Brassica/Sinapis type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Brassicaceae large type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Brassicaceae medium flat type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Brassicaceae oval type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Brassicaceae cf. small type 2	Seed	0	0	0	0	0	0	0	0	1	0	0	0	0
Brassicaceae cf. small type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Brassicaceae sub-round type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Bunias erucago	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Caryophyllaceae sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cerastium/Sagina type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Silene sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Atriplex sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Chenopodium album/opulifolium	Seed	4	1	0	0	0	0	0	0	0	0	0	0	0
Chenopodium ficifolium type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Chenopodium murale	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Salsola ruthenica/kali	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cistaceae sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cistus creticus	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Convolvulus sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Carex flat type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Carex sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cladium mariscus	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae indet.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae small flat type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Schoenus nigricans	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Scirpus lacustris	Seed	1	0	0	0	0	0	0	0	0	0	0	0	0
Scirpus maritimus	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Scirpus type 2	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Scirpus/Eleocharis type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Scirpus/Eleocharis type 3	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae/Thymelaeaceae sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Eleocharis flat type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Eleocharis palustris type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Eleocharis type 2	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0

Site		CB	CB	CB	BT	BT	BT	BT	BT	BT	BT	BT	KT	KT
Sample number		Loc 907	Loc 1282	24021/6	30111B + 3	17269AB	22340B	Grave 24	30244	30147A	36163A	?1998	IV-VI/a-e, (	7092/A
Period		LBA	LBA	LBA	EB II-III	EB I-II	EB I-II	EB I-II	EB I-II	EB I-II	EB I-II	EB I-II	EBA/MBA	EBA/MBA
Context		11	11	12	13	14	14	14	15	15	15	16	17	17
Taxa	**Plant part**													
Weed/wild														
Euphorbia helioscopa type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Euphorbiaceae sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Mercurialis annua	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Large pulse indet.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Medicago sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Medicago turbinata	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Scorpiurus muricatus	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Small pulse spp.	Seed	9	0	0	1	0	0	0	0	0	0	0	0	0
Small pulse sp. 2	Seed	0	0	0	0	0	0	0	0	0	0	0	1	0
Vicia hirsuta type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Isoetes histrix type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Clinopodium type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Labiatae type 1	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Labiatae type 2	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Labiateae indet.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Lallemantia iberica	Seed	0	0	0	3	0	0	0	0	0	0	0	0	0
Lamium type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Marrubium type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Origanum type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Teucrium type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Teucrium/Ajuga type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Linum cf.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Malva sylvestris type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Malvaceae sp.	Seed	0	0	0	1	0	0	0	0	0	0	0	0	0
Fumaria type	Seed	0	0	0	5	0	0	0	0	0	0	0	0	0
Papaver somniferum	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Papaver/Glaucium sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Papaveraceae sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Plantago cf. *maritima*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Plantago scabra	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Plantago cf.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Plantago cf. very small type	Seed	4	0	0	0	0	0	0	0	0	0	0	0	0
Aegilops sp.	Seed	0	0	0	0	0	0	0	0	2	0	0	0	0
Agrostis/Catagrostis/Aira sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Avena sp.	Seed	1	0	0	0	0	0	0	0	1	0	0	0	0
Avena/Hordeum wild type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0

Site		CB	CB	CB	BT	BT	BT	BT	BT	BT	BT	BT	KT	KT
Sample number		Loc 907	Loc 1282	24021/6	30111B + 3	17269AB	22340B	Grave 24	30244	30147A	36163A	?1998	IV-VI/a-e, (	7092/A
Period		LBA	LBA	LBA	EB II-III	EB I-II	EB I-II	EB I-II	EB I-II	EB I-II	EB I-II	EB I-II	EBA/MBA	EBA/MBA
Context		11	11	12	13	14	14	14	15	15	15	16	17	17
Taxa	**Plant part**													
Weed/wild														
Brachypodium distachyon type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Briza humilis	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Briza maxima	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Bromus commutatus type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Bromus diandrus type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Bromus narrow pointed apex type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Bromus rubens/rigidus/diandrus type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Bromus sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Cynodon dactylon	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Eragrostis sp.	Seed	4	0	0	0	0	0	0	0	0	0	0	0	0
Hordeum cf. *geniculatum*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Hordeum cf. *marinum* type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Hordeum spontaneum	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Hordeum wild type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Large Poaceae indet.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Lolium remotum	Seed	0	0	0	61	5	0	0	14	36	0	0	2	0
Lolium small type	Seed	13	0	0	0	0	0	0	0	1	0	2	3	0
Lolium temulentum	Seed	7	4	0	0	0	0	0	0	0	0	0	4	0
Poaceae Panicoid type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Panicum type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Phalaris aquatica/paradoxa/ canariensis type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Phalaris cf. *minor*	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Phalaris coerulescens/truncata/ brachystachys type	Seed	0	0	0	0	0	0	0	0	4	0	0	0	0
Phalaris sp.	Seed	0	1	0	0	0	0	0	0	0	0	0	0	0
Phleum arenarium type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Phleum phleoides type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Phleum subulatum/exaratum type	Seed	8	0	0	0	0	0	0	0	0	0	0	0	0
Poa dorsally compressed type	Seed	4	0	0	0	0	0	0	0	0	0	0	0	0
Poa sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poa trivialis type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae small ridged surface type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Small Poaceae indet.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Sporobolus virginicus	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Triticum boeoticum	Seed	0	2	0	0	0	0	0	1	0	0	0	0	0

Site		CB	CB	CB	BT	BT	BT	BT	BT	BT	BT	BT	KT	KT
Sample number		Loc 907	Loc 1282	24021/6	30111B + 3	17269AB	22340B	Grave 24	30244	30147A	36163A	?1998	IV-VI/a-e, (	7092/A
Period		LBA	LBA	LBA	EB II-III	EB I-II	EB I-II	EB I-II	EB I-II	EB I-II	EB I-II	EB I-II	EBA/MBA	EBA/MBA
Context		11	11	12	13	14	14	14	15	15	15	16	17	17
Taxa	**Plant part**													
Weed/wild														
Polygonaceae indet.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygonum sp. 1	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygonum sp. 2	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Rumex acetosella	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Rumex conglomeratus/sanguineus	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Rumex crispus/obtusifolius	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Rumex large type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Rumex sp.	Seed	0	0	0	0	0	0	0	3	0	0	0	0	0
Adonis annua type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Nigella sativa type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Ranunculus ophioglossus type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Ranunculus smooth type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Ranunculus sprunerians type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asperula sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Galium aparine	Seed	0	0	0	0	0	0	0	2	0	0	0	0	0
Galium spurium	Seed	0	0	0	0	0	0	0	0	0	0	0	40	0
Galium tricornutum	Seed	0	0	0	0	0	0	0	0	0	0	1	10	0
Rubiaceae indet.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Rubiaceae ridged surface	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Sherardia arvensis	Seed	0	1	0	0	0	0	0	0	0	0	0	0	0
Saxifragaceae ridged surface type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Saxifragaceae smooth surface type	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Solanaceae sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Thymelaea sp.	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Thymelea tartonraira	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Vitex agnus-castus	Seed	0	0	0	0	1	0	0	0	0	0	0	0	0
Weed/wild indeterminate	Seed/seed pod	0	0	0	0	2	0	0	0	0	0	0	0	0

Site		KT	KT	KT	KT	KT	KT
Sample number		4027/B	4027/C	V-VIII/f-g	11034/A	11034/B	11002/B
Period		EBA/MBA	EBA/MBA	LBA	LBA	LBA	LBA
Context		17	17	17	17	17	17
Taxa	**Plant part**						
Crops							
Triticum monococcum	Grain	0	0	0	0	0	0
Triticum monococcum	Glume base	0	0	0	0	0	0
Triticum dicoccum	Grain	0	0	0	0	0	0
Triticum dicoccum	Glume base	0	0	0	0	0	0
Triticum cf. *spelta*	Glume base	0	0	0	0	0	0
Triticum aestivum/durum	Grain	0	1	3	1	0	0
Triticum aestivum/durum	Internode	0	0	0	0	0	0
Hordeum vulgare	Grain	47	382	1192	388	93	1110
Hordeum vulgare distichum	Internode	0	0	0	0	0	0
Hordeum vulgare	Internode	0	0	0	0	0	0
Hordeum vulgare vulgare	Lemma base	0	0	0	0	0	0
Hordeum vulgare distichum	Lemma base	0	0	0	0	0	0
Cereal indet.	Internode	0	0	0	0	0	0
Vicia ervilia	Seed	1	20	0	0	0	0
Lens culinaris	Seed	0	0	0	0	0	0
Lathyrus sativus	Seed	0	0	0	0	0	0
Lathyrus ochrus	Seed	0	0	0	0	0	0
Lathyrus clymenum	Seed	0	0	0	0	0	0
Lathyrus sp.	Seed	0	0	0	0	0	0
Pisum sativum	Seed	0	0	0	0	0	0
Vicia faba	Seed	0	0	0	0	0	0
Cicer arietinum	Seed	0	0	0	0	0	0
Pulse indet.	Seed	0	0	0	0	0	0
Linum usitatissimum	Seed	0	0	0	0	0	0
Fruit/nut							
Ficus carica	Seed	0	0	0	0	1	0
Ficus carica	Fruit	0	0	0	0	0	0
Malus/Pyrus sp.	Fruit	0	0	0	0	0	0

Site		KT	KT	KT	KT	KT	KT
Sample number		4027/B	4027/C	V-VIII/f-g	11034/A	11034/B	11002/B
Period		EBA/MBA	EBA/MBA	LBA	LBA	LBA	LBA
Context		17	17	17	17	17	17
Taxa	**Plant part**						
Fruit/nut							
Olea europaea	Seed	0	0	0	0	0	0
Vitis sp.	Seed	0	0	0	0	0	0
Vitis sp.	Stalk	0	0	0	0	0	0
Vitis sp.	Skin	0	0	0	0	0	0
Quercus sp.	Seed	0	0	0	0	0	0
Nut indet.	Seed	0	0	0	0	0	0
Fruit indet.	Fruit	0	0	0	0	0	0
Weed/wild							
Pistacia lentiscus	Seed	0	0	0	0	0	0
Apiaceae cf.	Seed	0	0	0	0	0	0
Apium/Bupleurum type	Seed	0	0	0	0	0	0
Coriandrum sativum	Seed	0	0	0	0	0	0
Tordylium small type	Seed	0	0	0	0	0	0
Apiaceae/Dipsaceae sp.	Seed	0	0	0	0	0	0
Bellevalia dubia/trifoliata	Seed	0	0	0	0	0	0
Artemisia type	Seed	0	0	0	0	0	0
Asteraceae cf. flat round type	Seed	0	0	0	0	0	0
Asteraceae cf. type 2	Seed	0	0	0	0	0	0
Asteraceae large rounded type	Seed	0	0	0	0	0	0
Asteraceae large type 2	Seed	0	0	0	0	0	0
Asteraceae cf. type 3	Seed	0	0	0	0	0	0
Asteraceae wrinkled type	Seed	0	0	0	0	0	0
Hierachium/Verbena type	Seed	0	0	0	0	0	0
Picris type	Seed	0	0	0	0	0	0
Small Asteraceae type 1	Seed	0	0	0	0	0	0
Asteraceae/Labiatae fat type	Seed	0	0	0	0	0	0
Asteraceae/Labiatae type 1	Seed	0	0	0	0	0	0
Asteraceae/Labiatae large type	Seed	0	0	0	0	0	0
Asteraceae/Labiatae very small type	Seed	0	0	0	0	0	0
Boraginaceae sp.	Seed	0	0	0	0	0	0
Boraginaceae small spiked type	Seed	0	0	0	0	0	0
Boraginaceae small type	Seed	0	0	0	0	0	0
Boraginaceae smooth type	Seed	0	0	0	0	0	0
Boraginaceae spiked type	Seed	0	0	0	0	0	0
Echium sp.	Seed	0	0	0	0	0	0
Heliotropium europaeum	Seed	0	0	0	0	0	0

Site		KT	KT	KT	KT	KT	KT
Sample number		4027/B	4027/C	V-VIII/f-g	11034/A	11034/B	11002/B
Period		EBA/MBA	EBA/MBA	LBA	LBA	LBA	LBA
Context		17	17	17	17	17	17
Taxa	**Plant part**						
Weed/wild							
Alyssum type	Seed	0	0	0	0	0	0
Brassica nigra	Seed	0	0	0	0	0	0
Brassica/Sinapis type	Seed	0	0	0	0	0	0
Brassicaceae large type	Seed	0	0	0	0	0	0
Brassicaceae medium flat type	Seed	0	0	0	0	0	0
Brassicaceae oval type	Seed	0	0	0	0	0	0
Brassicaceae cf. small type 2	Seed	0	0	0	0	0	0
Brassicaceae cf. small type	Seed	0	0	0	0	0	0
Brassicaceae sub-round type	Seed	0	0	0	0	0	0
Bunias erucago	Seed	0	0	0	0	0	0
Caryophyllaceae sp.	Seed	0	0	0	0	0	0
Cerastium/Sagina type	Seed	0	0	0	0	0	0
Silene sp.	Seed	0	0	0	0	0	0
Atriplex sp.	Seed	0	0	0	0	0	0
Chenopodium album/opulifolium	Seed	0	0	0	0	0	0
Chenopodium ficifolium type	Seed	0	0	0	0	0	0
Chenopodium murale	Seed	0	0	0	0	0	0
Salsola ruthenica/kali	Seed	0	0	0	0	0	0
Cistaceae sp.	Seed	0	0	0	0	0	0
Cistus creticus	Seed	0	0	0	0	0	0
Convolvulus sp.	Seed	0	0	0	0	0	0
Carex flat type	Seed	0	0	0	0	0	0
Carex sp.	Seed	0	0	0	0	0	0
Cladium mariscus	Seed	0	0	0	0	0	0
Cyperaceae indet.	Seed	0	0	0	0	0	0
Cyperaceae small flat type	Seed	0	0	0	0	0	0
Schoenus nigricans	Seed	0	0	0	0	0	0
Scirpus lacustris	Seed	0	0	0	0	0	0
Scirpus maritimus	Seed	0	0	0	0	0	0
Scirpus type 2	Seed	0	0	0	0	0	0
Scirpus/Eleocharis type	Seed	0	0	0	0	0	0
Scirpus/Eleocharis type 3	Seed	0	0	0	0	0	0
Cyperaceae/Thymelaeaceae sp.	Seed	0	0	0	0	0	0
Eleocharis flat type	Seed	0	0	0	0	0	0
Eleocharis palustris type	Seed	0	0	0	0	0	0
Eleocharis type 2	Seed	0	0	0	0	0	0

Site		KT	KT	KT	KT	KT	KT
Sample number		4027/B	4027/C	V-VIII/f-g	11034/A	11034/B	11002/B
Period		EBA/MBA	EBA/MBA	LBA	LBA	LBA	LBA
Context		17	17	17	17	17	17
Taxa	**Plant part**						
Weed/wild							
Euphorbia helioscopa type	Seed	0	0	0	0	0	0
Euphorbiaceae sp.	Seed	0	0	0	0	0	0
Mercurialis annua	Seed	0	0	0	0	0	0
Large pulse indet.	Seed	0	0	0	0	0	0
Medicago sp.	Seed	0	0	0	0	0	0
Medicago turbinata	Seed	0	0	0	0	0	0
Scorpiurus muricatus	Seed	0	0	0	0	0	0
Small pulse spp.	Seed	0	0	0	0	0	0
Small pulse sp. 2	Seed	0	0	0	0	0	0
Vicia hirsuta type	Seed	0	0	0	0	0	0
Isoetes histrix type	Seed	0	0	0	0	0	0
Clinopodium type	Seed	0	0	0	0	0	0
Labiatae type 1	Seed	0	0	0	0	0	0
Labiatae type 2	Seed	0	0	0	0	0	0
Labiateae indet.	Seed	0	0	0	0	0	0
Lallemantia iberica	Seed	0	0	0	0	0	0
Lamium type	Seed	0	0	0	0	0	0
Marrubium type	Seed	0	0	0	0	0	0
Origanum type	Seed	0	0	0	0	0	0
Teucrium type	Seed	0	0	0	0	0	0
Teucrium/Ajuga type	Seed	0	0	0	0	0	0
Linum cf.	Seed	0	0	0	0	0	0
Malva sylvestris type	Seed	0	0	0	0	0	0
Malvaceae sp.	Seed	0	0	0	0	0	0
Fumaria type	Seed	0	0	0	0	0	0
Papaver somniferum	Seed	0	0	0	0	0	0
Papaver/Glaucium sp.	Seed	0	0	0	0	0	0
Papaveraceae sp.	Seed	0	0	0	0	0	0
Plantago cf. *maritima*	Seed	0	0	0	0	0	0
Plantago scabra	Seed	0	0	0	0	0	0
Plantago cf.	Seed	0	0	0	0	0	0
Plantago cf. very small type	Seed	0	0	0	0	0	0
Aegilops sp.	Seed	0	0	0	0	0	0
Agrostis/Catagrostis/Aira sp.	Seed	0	0	0	0	0	0
Avena sp.	Seed	0	0	0	0	0	0
Avena/Hordeum wild type	Seed	0	0	0	0	0	0

Site		KT	KT	KT	KT	KT	KT
Sample number		4027/B	4027/C	V-VIII/f-g	11034/A	11034/B	11002/B
Period		EBA/MBA	EBA/MBA	LBA	LBA	LBA	LBA
Context		17	17	17	17	17	17
Taxa	**Plant part**						
Weed/wild							
Brachypodium distachyon type	Seed	0	0	0	0	0	0
Briza humilis	Seed	0	0	0	0	0	0
Briza maxima	Seed	0	0	0	0	0	0
Bromus commutatus type	Seed	0	0	0	0	0	0
Bromus diandrus type	Seed	0	0	0	0	0	0
Bromus narrow pointed apex type	Seed	0	0	0	0	0	0
Bromus rubens/rigidus/diandrus type	Seed	0	0	0	0	0	0
Bromus sp.	Seed	0	0	0	0	0	0
Cynodon dactylon	Seed	0	0	0	0	0	0
Eragrostis sp.	Seed	0	0	0	0	0	0
Hordeum cf. *geniculatum*	Seed	0	0	0	0	0	0
Hordeum cf. *marinum* type	Seed	0	0	0	0	0	0
Hordeum spontaneum	Seed	0	0	0	0	0	2
Hordeum wild type	Seed	0	0	0	0	0	0
Large Poaceae indet.	Seed	0	0	0	0	0	0
Lolium remotum	Seed	0	3	6	0	0	14
Lolium small type	Seed	0	1	3	6	0	10
Lolium temulentum	Seed	0	3	59	6	0	31
Poaceae Panicoid type	Seed	0	0	0	0	0	0
Panicum type	Seed	0	0	0	0	0	0
Phalaris aquatica/paradoxa/ canariensis type	Seed	0	0	0	0	0	0
Phalaris cf. *minor*	Seed	0	0	0	0	0	0
Phalaris coerulescens/truncata/ brachystachys type	Seed	0	0	0	0	0	0
Phalaris sp.	Seed	0	0	0	0	0	0
Phleum arenarium type	Seed	0	0	0	0	0	0
Phleum phleoides type	Seed	0	0	0	0	0	0
Phleum subulatum/exaratum type	Seed	0	0	0	0	0	0
Poa dorsally compressed type	Seed	0	0	0	0	0	0
Poa sp.	Seed	0	0	0	0	0	0
Poa trivialis type	Seed	0	0	0	0	0	0
Poaceae small ridged surface type	Seed	0	0	0	0	0	0
Small Poaceae indet.	Seed	0	0	0	0	0	0
Sporobolus virginicus	Seed	0	0	0	0	0	0
Triticum boeoticum	Seed	0	0	0	0	0	0

Site		KT	KT	KT	KT	KT	KT
Sample number		4027/B	4027/C	V-VIII/f-g	11034/A	11034/B	11002/B
Period		EBA/MBA	EBA/MBA	LBA	LBA	LBA	LBA
Context		17	17	17	17	17	17
Taxa	**Plant part**						
Weed/wild							
Polygonaceae indet.	Seed	0	0	0	0	0	0
Polygonum sp. 1	Seed	0	0	0	0	0	0
Polygonum sp. 2	Seed	0	0	0	0	0	0
Rumex acetosella	Seed	0	0	0	0	0	0
Rumex conglomeratus/sanguineus	Seed	0	0	0	0	0	0
Rumex crispus/obtusifolius	Seed	0	0	0	0	0	0
Rumex large type	Seed	0	0	0	0	0	0
Rumex sp.	Seed	0	0	0	0	0	0
Adonis annua type	Seed	0	0	0	0	0	0
Nigella sativa type	Seed	0	0	0	0	0	0
Ranunculus ophioglossus type	Seed	0	0	0	0	0	0
Ranunculus smooth type	Seed	0	0	0	0	0	0
Ranunculus sprunerians type	Seed	0	0	0	0	0	0
Asperula sp.	Seed	0	0	0	0	0	0
Galium aparine	Seed	0	0	0	0	0	0
Galium spurium	Seed	0	1	0	0	0	0
Galium tricornutum	Seed	1	0	0	0	0	0
Rubiaceae indet.	Seed	0	0	0	0	0	0
Rubiaceae ridged surface	Seed	0	0	0	0	0	0
Sherardia arvensis	Seed	0	0	0	0	0	0
Saxifragaceae ridged surface type	Seed	0	0	0	0	0	0
Saxifragaceae smooth surface type	Seed	0	0	0	0	0	0
Solanaceae sp.	Seed	0	0	0	0	0	0
Thymelaea sp.	Seed	0	0	0	0	0	0
Thymelea tartonraira	Seed	0	0	0	0	0	0
Vitex agnus-castus	Seed	0	0	0	0	0	0
Weed/wild indeterminate	Seed/seed pod	0	0	0	0	0	0