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Agropastoral Economies and Land Use in Bronze Age Western Anatolia

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ABSTRACT

The Middle and Late Bronze Ages of western Anatolia (modern Turkey) remains poorly understood in comparison with its Mycenaean and Hittite neighbours, especially in agricultural economies and land use. Kaymakçı is the largest Middle and Late Bronze Age citadel excavated to date in western Anatolia and new archaeobotanical and zooarchaeological data from the site presented here shed new light on regional agricultural economies and land use. Agricultural practices at Kaymakçı focused on barley and bitter vetch farming and pig, caprine, and cattle husbandry within a diverse and extensive economic system that made substantial use of wild plants and animals for food, technology, and fuel. Goats and pigs were managed primarily for meat, while sheep and cattle were managed to produce a range of secondary products. Wood charcoal analysis reconstructs both deciduous and evergreen oak woodlands, which also dominate the contemporary landscape. In regional perspective, Kaymakçı is most similar to the northern Aegean agricultural tradition, but with elements of Anatolian practices as well, representing a hybrid position between the Aegean and Anatolian worlds as seen in other lines of archaeological evidence from the site.

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Introduction

The Middle and Late Bronze Ages (c. 2000–1200 BCE) saw the rise of regionally powerful states in both the Aegean world (the Minoan and Mycenean kingdoms) and central Anatolia (the Hittite Empire), leaving the region of western Anatolia a contested border zone with documented influence from both east and west (Glatz 2009; Mountjoy 1998; Roosevelt and Luke 2017). Polities that arose in this region faced the challenge of navigating political and economic networks with these powerful neighbours while managing local economies and relationships with peer polities. However, while considerable archaeological research on agricultural systems of the Late Bronze Age (LBA) has occurred in both the Aegean and Anatolian worlds in recent decades, such research has focused primarily on the citadel centres of the Mycenaean and Hittite heartlands (e.g. Tiryns [Kroll 1982; von den Driesch and Boessneck 1990] and Hattusa [Diffey et al. 2020; von den Driesch and Pöllath 2004]). Western Anatolia remains poorly documented in relation to its eastern and western neighbours, with only one site (Troy) where both botanical and faunal data have been published from LBA contexts (Çakırlar 2009; Riehl 1999; Riehl and Marinova 2008; Uerpmann 2003); faunal data also exist for Klazomenai (currently unpublished, save pig remains in Slim, Çakırlar, and Roosevelt 2020) and Beycesultan (Ducos 1965), while no botanical data have yet been published from any other site in the region other than a preliminary report from Beycesultan (Helbaek 1961; Figure 1). Recent excavations at the LBA citadel of Kaymakçı, the largest LBA site excavated to date in western Anatolia, were designed to reconstruct the paleoenvironmental and subsistence strategies of the site, and so have involved systematic collection and analysis of both archaeobotanical and zooarchaeological remains (Roosevelt et al. 2018; Shin et al. 2021; Slim, Çakırlar, and Roosevelt 2020). Kaymakçı thus offers a valuable new data point for understanding how LBA agropastoral economies functioned in the region.

Environmental archaeological research at Kaymakçı is multifaceted, involving the recovery and analysis of seeds (Ciftci et al. 2019; Shin et al. 2021) and animal bones (Slim, Çakırlar, and Roosevelt 2020), but also wood charcoal, mollusks, and

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Figure 1. Map of Anatolia and the Aegean, including all sites mentioned in the text.

paleoenvironmental lake cores. In this article, we present new data on woodland composition and fuel use, hunting of wild animals, and herd management of caprines and cattle, and then integrate these with summary results from recently published studies of macrobotanical remains and pig husbandry. The aim of this article is to use multiple lines of evidence to reconstruct strategies for agricultural production, the acquisition of wild food resources, and landscape modification by LBA occupants of Kaymakçı in order to recreate the agricultural economy and the landscape in which farming and herding occurred. We build from this reconstruction to discuss the role of Kaymakçı within both Aegean and Anatolian traditions of land use and agriculture.

The western Anatolian Late Bronze Age

The region of western Anatolia is recounted in Hittite textual sources as home to several kingdoms worthy of mention; among the most powerful of these was Arzawa and its LBA capital Apasa (almost certainly later Ephesos; Büyükkolancı 2007) alongside the overseas powers of Ahhiyawa (commonly accepted to be Mycenaean Greeks), who infringed upon Hittite hegemony in the west (Bryce 2005; Roosevelt and Luke 2017). The Hittite king Mursili II divided the lands of Arzawa into smaller vassal states in order to diminish their power and solidify Hittite hegemony in the region; one of these smaller territories was the Seha River Land, which best corresponds to the region of the Gediz River and Marmara Lake Basin, in which the site of Kaymakçı is located (Roosevelt and Luke 2017). Within this region of contested political control, with ongoing influence (though likely not continuous hegemony) from the Hittite Empire to the east, Mycenaean polities to the west, and other power centres in western Anatolia, leaders of Kaymakçı faced a complex political and economic landscape, in which agricultural decision making took place (Bryce 2005; Halstead 1992, 1996; Hoffner 1974).

A number of comparative studies have noted substantial differences between central Anatolian and Aegean agricultural regimes based on both faunal (Slim, Çakırlar, and Roosevelt 2020) and botanical (Riehl and Nesbitt 2003; Shin et al. 2021) remains. For example, pigs make up a greater proportion of LBA zooarchaeological assemblages from the southern Aegean (~17–32% of all domesticate bones) and, especially, the northern Aegean (~24–40% of all domesticates), than of assemblages from all sites in central Anatolia (~5–17% of all domesticates) (Slim, Çakırlar, and Roosevelt 2020, Figure 6). Zooarchaeological assemblages from western Anatolia contain consistent proportions of pig remains, around 15%, roughly intermediate between those of Central Anatolia and the Aegean (Ducos 1965; Uerpmann 2003). Botanical analyses have indicated a divide between agriculture focused on pulses and hulled wheats in the Aegean versus an emphasis on cereals, both barley and free-threshing wheats, in central Anatolia (Riehl and Nesbitt 2003; Shin et al. 2021). The only published botanical assemblage from western Anatolia, from Troy, generally resembles those of Aegean sites, with both pulses and hulled wheats numerous, barley dominant, and very little free-threshing wheat (Riehl 1999). These studies taken together suggest that Kaymakçı might resemble Aegean agropastoral patterns more than those of central Anatolia (especially since Kaymakçı lies in a Mediterranean climate zone, as detailed below) but that central Anatolian influences might also be present in animal husbandry, plant cultivation, or both.

Archaeology and Biogeography of Kaymakçı

Six citadel sites were identified through regional survey in the Marmara Lake Basin (Figure 2), with Kaymakçı the largest of these at 8.6 ha in walled extent (Luke et al. 2015; Roosevelt and Luke 2017). The Kaymakçı Archaeological Project (KAP) began excavations in 2014, documenting both MBA (c. 2000–1650 BCE) and LBA (c. 1650–1200 BCE) occupation (Roosevelt et al. 2018); the early LBA is much better represented among deposits studied to date, and the assemblages discussed here all date to the LBA. The site is divided into an inner citadel at the highest point of the walled area and other sectors on lower slopes and terraces (Figure 2 inset). Based on the size, location, chronology, and regional site survey, Kaymakçı was a regional centre and remains the most likely candidate for the capital of the Seha River Land (Roosevelt and Luke 2017). The interior of the site, and especially the inner citadel, encloses a large number of circular rock-cut or stone-built structures, which resemble grain storage silos found at other Bronze and Iron Age sites in Anatolia (e.g. at LBA Kaman Kalehöyük [Castellano 2018; Fairbairn and Omura 2005]); the specific function of

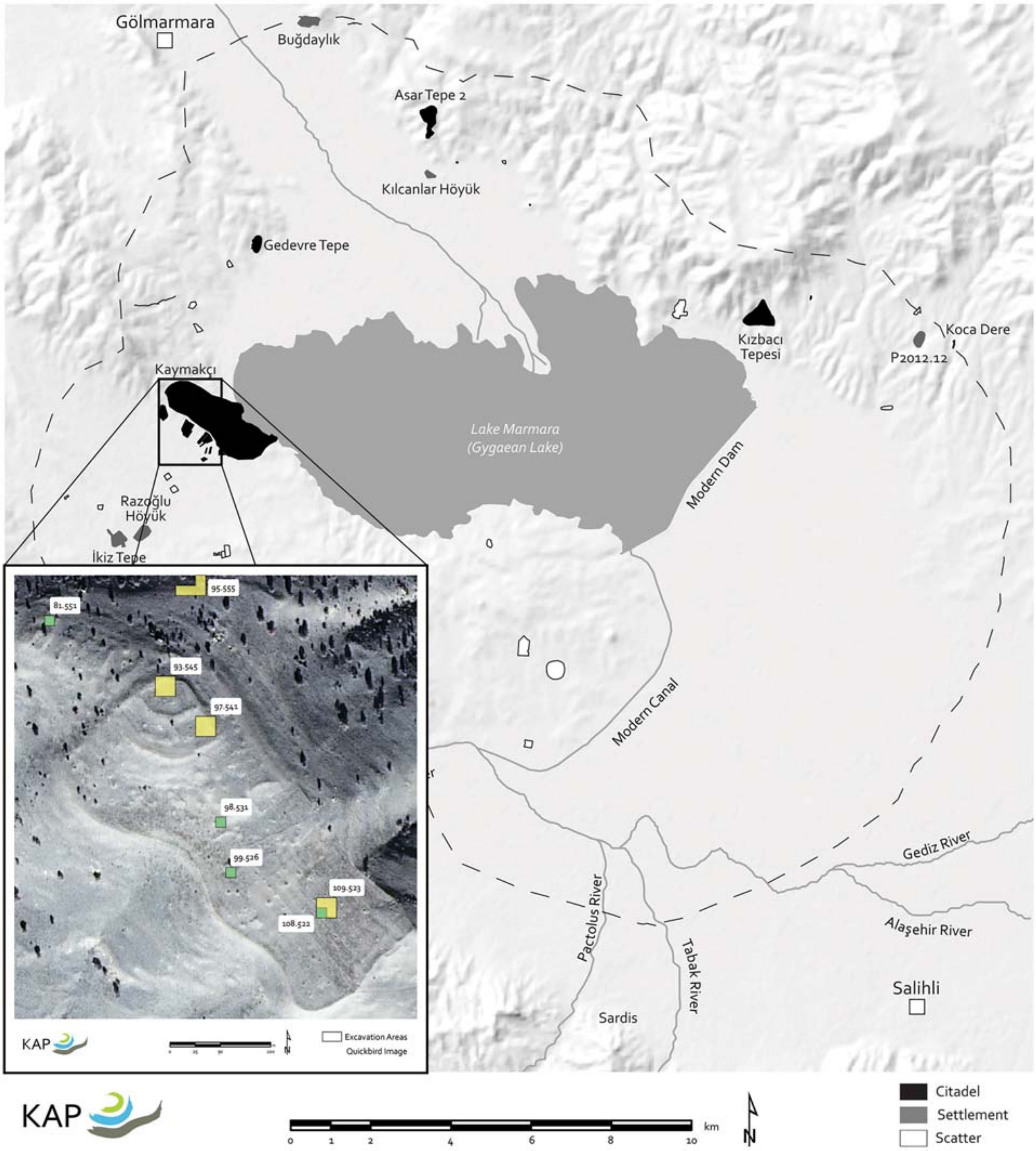

Figure 2. Map of Kaymakçı region, with contemporary sites identified through systematic survey noted; dotted line represents boundary of surveyed area. Inset: Quickbird image of Kaymakçı with excavation areas from 2014–2016 labelled; seed and faunal remains have been analysed from all areas, while charcoal has been studied only from areas coloured green.

Kaymakçı's structures, however, has not yet been determined conclusively (Roosevelt et al. 2018; Shin et al. 2021).

Lake Marmara is the dominant hydrological feature of the landscape (Figure 2), and the Gediz (ancient Hermus) and Alaşehir rivers once inundated the plain on a seasonal basis (Luke 2019; Luke and Cobb 2013). The lake is rich in fish and constitutes an important but heavily threatened bird habitat (Gül, Onmuş, and Sıkı 2013; Luke 2019). More than seven families of fish, including one endemic, several native, and a few translocated species, live in the lake today (İlhan and Sarı 2013; Tarkan et al. 2017). Prior to modern damming and hydrological control, the lake was fringed with wetlands subject to seasonal flooding (Gül, Onmuş, and Sıkı 2013); the extent of the lake during the LBA is currently under geological and paleoenvironmental investigation (e.g. Vardar 2018). Rainfall in the region is abundant, though seasonal, with the weather station at the provincial capital of Manisa averaging more than 700 mm of precipitation annually over the period 1930–2018 (Meteoroloji Genel Müdürlüğü 2020), although precipitation in the Marmara Lake Basin is lower, averaging between 500–600 mm per year over the second half of the twentieth century (Roosevelt 2009, 47–49). Little precipitation falls in the summer months (June through September). Landscape cover in the region today consists of open woodlands of deciduous and evergreen oak, steppe pastureland, and farms growing annual crops, olives, and grapes.

Materials and Methods

Botanical Analysis

Sediment samples were systematically collected from every archaeological context excavated; each sample was 10 L when at least that much sediment was available. No samples appear to represent primary residues of feature use or come from burned buildings; all are secondary accumulations of burned refuse, even within clearly defined features, as discussed at length elsewhere (Roosevelt et al. 2018; Shin et al. 2021). Large fragments of wood charcoal were also hand collected when encountered during excavation or sieving, as a supplement to charcoal recovered systematically through flotation sampling. This strategy for collection maximises comparability of contexts and minimises sampling biases (d'Alpoim Guedes and Spengler 2014; Pearsall 2015). Each sample was floated using a Siraf-style flotation tank (Nesbitt 1995; Pearsall 2015) at a nearby research centre; heavy fractions were sorted for both botanical and faunal remains onsite, with all material larger than 2 mm recovered, while light fractions were taken to the Boston University Environmental Archaeology Laboratory (EAL; 2014 samples) or the Koç University Archaeology Laboratory (2015 and 2016 samples) for analysis. A total of 328 flotation samples were analysed for this study from the 2014–2016 excavation seasons.

Sorting and analysis of light fractions followed standard protocols (Fritz and Nesbitt 2014; Pearsall 2015), as fully detailed in their initial publication (Shin et al. 2021). Analytical metrics include simple statistics, especially ratios (Marston 2014; Miller and Marston 2012). Wood charcoal was pulled from the 2 mm size fraction of the light fraction, but only material from the 2014 excavation season was available for detailed identification in Boston. A total of 204 flotation samples were examined for charcoal, with 61 containing fragments larger than 2 mm, alongside an additional 26 hand-collected samples. All samples were identified completely up to a maximum of 40 fragments (after Kováčik and Cummings 2018); only seven samples contained more fragments, and every one of these seven samples contained only oak charcoal. Hand-picked charcoal was examined in the same manner as flotation samples, but the two datasets are presented independently, as we assume that hand-picked samples likely represent only one or a few original charcoal pieces that were further fragmented during collection, transport, and analysis. A total of 821 charcoal fragments were examined. As all samples come from secondary or tertiary deposits of refuse, we interpret them as the long-term record of fuel use and disposal at the site, following best practices in the discipline (Chabal et al. 1999; Théry-Parisot, Chabal, and Chrzavzez 2010).

Wood charcoal were broken to expose fresh transverse, radial, and tangential sections, and examined using Leica binocular microscopes at a magnification of up to 40x and an incident-light microscope at magnifications of 50x to 400x. Charcoal remains were identified to genus or family level by comparison with modern reference specimens curated at the EAL and using published identification manuals (Akkemik and Yaman 2012; Crivellaro and Schweingruber 2013; Fahn, Werker, and Bass 1986; Schweingruber 1990; Schweingruber, Börner, and Schulze 2011, 2013). Dendroanthracological characteristics, such as the curvature degree of the growth ring, presence/absence of pith, presence/absence of bark, number of growth rings, and ray width were recorded for the most numerous taxa (Asouti, Ntinou, and Kabukcu 2018; Marguerie and Hunot 2007; Wright 2018). Curvature degree was recorded using the simple ordinal scale of Asouti, Ntinou, and Kabukcu (2018): CD1 (curvature degree 1) with no apparent curvature of the growth ring represents large diameter wood; CD2 with slight curvature represents medium diameter wood; CD3 with abrupt curvature represents small diameter wood. Data were plotted using Tilia (version 2.1.1) and Microsoft Excel. For consistency with other published regional studies, Latin names used here for all woody taxa follow the *Flora of Turkey* (Davis 1965–2000).

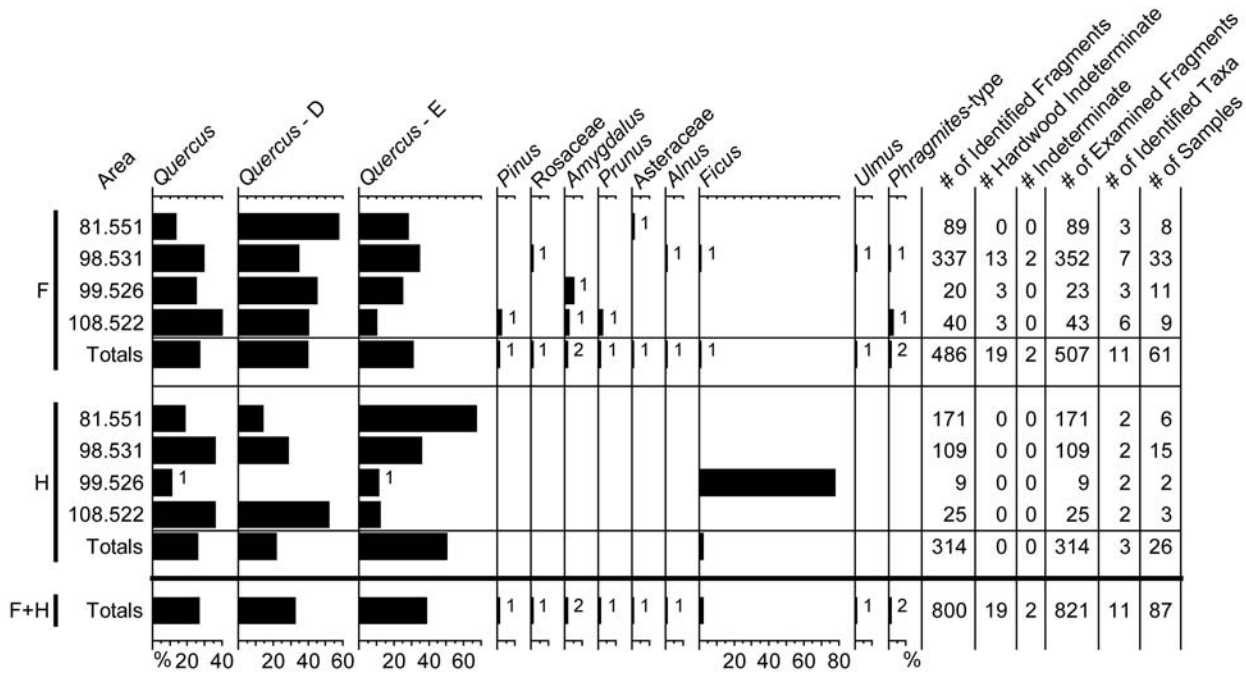

Figure 3. Anthracological diagram of percentage fragment counts of taxa identified at Kaymakçı, by excavation area and collection strategy (numbers 1–2 next to small bars on the diagram indicate number of charcoal fragments; F – flotation samples; H – hand-picked samples).

Faunal Analysis

Faunal remains were collected through three avenues: hand collection when encountered during excavation, systematic dry sieving of all excavated deposits through a 4-mm mesh, and recovery of all faunal remains from flotation heavy fractions, which were caught with a 2-mm mesh. Identifications were made with the aid of an onsite comparative collection and identification manuals (e.g. Schmidt 1972). Primary data recorded included taxon, element, side, completeness, sex, tooth wear stages (following Grant 1982), epiphyseal fusion, biometric dimensions (following Payne and Bull 1988; von den Driesch 1976), traces of pathological conditions, and taphonomic markers. Data analysis involved determination of relative abundance, based on Number of Identified Specimens (NISP; Davis 1987), and kill-off patterns for domesticates (Halstead 1985; Lemoine et al. 2014; Zeder 2006). Further details of biometric and ageing methods used on pig remains are given in their original publication (Slim, Çakırlar, and Roosevelt 2020). NISP and kill-off pattern analyses presented here include processed remains from hand-collected and dry-sieved deposits.

Landscapes of Kaymakçı

Woodland Structure

The wood charcoal assemblage of Kaymakçı is dominated by oak, with nearly 98% of identified charcoal fragments classified as one of three oak categories (Figure 3): *Quercus* (oak, too small or too vitrified for further identification), *Quercus* – D (deciduous oak), and *Quercus* – E (evergreen oak) (Table 1; Electronic Supplementary Material 1). The distinction between deciduous and evergreen oak is based on porosity and vessel arrangement in the transverse section; confident identification requires at least one entire growth ring for examination of vessel arrangement pattern in both the early and the late wood. For this reason, small fragments without a complete growth ring were more likely to be identified conservatively only as *Quercus*. Further identification to oak species based on wood anatomy is not possible in Turkey, where it can be difficult to distinguish the ∼18 species even among living trees (Davis 1982, 660; Schweingruber 1990). Of the two oak types identified in this entire assemblage, evergreen oak (*Quercus* – E) was slightly more abundant (38.5% of all fragments examined) than deciduous oak (*Quercus* – D = 32.7%).

Four Rosaceae charcoal fragments also were recovered, including *Amygdalus* (2 fragments), *Prunus* (1

Table 1. List of woody plants identified from flotation samples from 2014 excavation season, with total fragment counts.

Scientific Name	Common Name	Total Fragment Count
Quercus	Oak	213
Quercus – D	Deciduous oak	261
Quercus – E	Evergreen oak	308
Pinus	Pine	1
Rosaceae	Rose family	1
Amygdalus	Almond	2
Prunus	Cherry or plum	1
Asteraceae	Sunflower family	1
Alnus	Alder	1
Ficus	Fig	8
Ulmus	Elm	1
Phragmites-type	Common reed	2

Figure 4. Open oak woodland and shepherd's enclosure near Kaymakçı.

fragment), and Rosaceae (1 fragment), indicating almond, cherry/plum, and another member of the rose family, likely outside the Prunoideae subfamily. To distinguish almonds from cherries/plums (*Prunus* species), we followed key characteristics described by Asouti, Ntinou, and Kabukcu (2018, 27; also by Schweingruber 1990), which include wood porosity (ring- vs diffuse-porous) and ray width. Although both *Amygdalus* charcoal fragments exhibit ring-porous vessel arrangement, the ray width differed, with one showing mostly 8–10 seriate rays, and the other 1–3 seriate rays. According to Asouti, Ntinou, and Kabukcu (2018), variation in ray width is associated with growth form: small stem (narrow rays) vs. trunk (wide rays). The almond charcoal fragment with narrow rays from Kaymakçı was classified as medium diameter (CD2), confirming these conclusions. At least two species, *A. webbii* and *A. dulcis* (syn. *A. communis*), are reported to grow in the study area (Davis 1972, 22–27). *A. webbii* is native to southwestern Turkey, while *A. dulcis*, the sweet almond, may be native but has been naturalised throughout Turkey (Davis 1972, 22–24). The *Prunus* fragment cannot be assigned further to a species; according to Davis (1972) the wild taxa *P. spinosa*, *P. cerasifera* (syn. *P. divaricata*), and *P. cocomilia* can all be found in the study area, alongside cultivated *P. domestica* (plum), *P. avium* (sweet cherry), and P. *cerasus* (sour cherry).

Other tree taxa identified in this assemblage include *Ficus* (fig; 1% of all fragments; eight fragments, though seven of those come from a single hand-picked sample and may represent a single piece of wood), and single fragments of *Alnus* (alder), *Ulmus* (elm), and *Pinus* (pine). Non-tree taxa were scarce, with only one fragment of Asteraceae (sunflower family), likely a shrubby species such as sagebrush (*Artemisia*), and two fragments of a large diameter grass, likely *Phragmites* (common reed). Hardwood indeterminate and indeterminate charcoal fragments were too small or too vitrified for further identification; they represent only 2.5% of all examined charcoal.

From these taxa, we reconstruct an oak-dominated woodland as the most proximate woodland community to Kaymakçı. Today, open woodlands of evergreen *Quercus coccifera* (syn. *Q. calliprinos*) and deciduous *Q. ithaburensis* subsp. *macrolepis* cover the ridge on which Kaymakçı sits, with increasing forest density at higher elevations. Many non-farmed areas of the Marmara Lake Basin surrounding the lake include trees of one or both species in an open woodland (Figure 4). Such communities are maintained by caprine grazing, as *Q. coccifera* is resilient to grazing pressure, while many other tree taxa are negatively impacted (Zohary 1973, 356–357). Evergreen oaks are often found in association with deciduous and semi-evergreen oak species across Mediterranean Anatolia; *Q. coccifera* was present in widespread maquis communities with semi-evergreen *Q. infectoria* in the Akhisar area in the 1960s, also extending upland among deciduous *Q. ithaburensis*

Table 2. Wild seed taxa with a count of three or more carbonised seeds identified from flotation samples from 2014–2016 excavation seasons, arranged alphabetically by family; total includes counts of taxa excluded from this list.

Taxon	Family	Count
Chenopodium	Amaranthaceae	17
Suaeda	Amaranthaceae	3
Amaranthaceae	Amaranthaceae	4
Heliotropium	Boraginaceae	3
Lithospermum	Boraginaceae	6
Neslia	Brassicaceae	3
Brassicaceae	Brassicaceae	3
Gypsophila	Caryophyllaceae	7
Silene	Caryophyllaceae	7
Stellaria	Caryophyllaceae	5
Caryophyllaceae	Caryophyllaceae	15
Carex	Cyperaceae	3
Bolboschoenus	Cyperaceae	121
Cyperaceae inner seed	Cyperaceae	23
Cyperaceae	Cyperaceae	5
Astragalus	Fabaceae	3
Medicago	Fabaceae	4
Fabaceae	Fabaceae	13
Malva	Malvaceae	33
Fumaria	Papaveraceae	3
Bromus	Poaceae	10
Hordeum	Poaceae	8
Lolium	Poaceae	3
Phalaris	Poaceae	8
Triticoid-type	Poaceae	4
Poaceae	Poaceae	116
Polygonum	Polygonaceae	10
Rumex	Polygonaceae	7
Galium	Rubiaceae	3
Unknown inner seed		139
Unknown		167
Unidentifiable		38
Total		**821**

Note: Data from Shin et al. 2021, Table 4.

and *Q. cerris*, which are restricted to higher elevation ridgelines and mountain slopes (Zohary 1973, 283). A similar vegetation distribution persists, though less densely, today (Figure 4; unpublished fieldwork by Müge Ergun and Zeki Kaya in 2018 and 2019). It is likely that similar open oak woodlands are represented by the oaks in the charcoal assemblage, and we can infer based on their dominance in the charcoal assemblage that few trees of other species persisted within that environment. The fig, almond, and *Prunus* fragments may represent cultivated species (the fig nearly certainly so, based on phytogeography), leaving only a handful of fragments of wild trees other than oak in the charcoal assemblage.

Herbaceous Vegetation Communities

Herbaceous (non-woody) vegetation communities can be reconstructed based on wild plant seeds in the archaeobotanical assemblage. At sites with significant evidence of dung fuel use, grazing ruminants sample the landscape and those seeds are deposited within archaeological features onsite; this allows the reconstruction of rangeland plant communities (e.g. Marston 2012, 2017; Miller 1999), once the differential effects of ruminant gut damage are taken into account (Charles 1998; Spengler 2019). Kaymakçı, however, lacks evidence for significant dung fuel use (Shin et al. 2021). Thus, wild seeds in the archaeobotanical

Table 3. Wild animal taxa NISP counts, by collection method, from 2014–2016 excavation seasons; indeterminate specimens that might represent domesticates are excluded.

Scientific name	Common name	Hand collected (NISP)	Dry-sieved (NISP)	Heavy residue (NISP)	Total (NISP)
Class Osteichthyes	Bony fishes	271	96	1504	1871
Cyprinus carpio	Common carp			9	9
Cyprinidae	Carp family	9	5	129	143
Silurus glanis	Wels catfish	60	15	11	86
Osteichthyes indet.	Fish	202	76	1355	1633
Class Reptilia	Reptiles	22	3	0	25
Testudo sp.	Tortoise	22	3		25
Class Aves	Birds	40	19	2	61
Aves indet.	Bird	40	19	2	61
Class Mammalia	Mammals	208	50	7	265
Bos primigenius	Aurochs	1	1		2
Capra aegagrus	Wild goat	1			1
Capreolus capreolus	Roe deer	7			7
Cervus elaphus	Red deer	17	3		20
Dama dama	Fallow deer	46	5		51
Cervidae indet.	Deer	123	34	1	158
Sus scrofa	Boar	1			1
Lepus sp.	Hare	6	4	2	12
Muridae	Mouse	1		1	2
Rodentia indet.	Rodent	3	3	3	9
Felidae (large)	Cat family	1			1
Ursus arctos	Brown bear	1			1
Class Bivalvia	Bivalves	32	11	0*	43
Unio sp.	Freshwater mussel	26	10		36
Bivalvia	Bivalve	6	1		7
Class Gastropoda	Snails	24	3	0*	27
Landsnail	Land snail	20	3		23
Gastropoda indet.	Snail	4			4

*Shell from flotation heavy residues has not yet been studied.

Table 4. Cultivated seed counts, weight, ubiquity, and summary sample metrics (data from Shin et al. 2021)

Taxon	Sitewide Totals		
	Count	Weight (g)	Ubiquity %
Cereals			
Barley (*Hordeum vulgare*)	128	1.391	20.7%
Bread/hard wheat (*Triticum aestivum/durum*)	30	0.364	7.0%
Einkorn wheat (*Triticum monococcum*)	11	0.058	4.0%
Emmer wheat (*Triticum turgidum* sbsp. *dicoccum*)	4	0.057	1.8%
Wheat indeterminate (*Triticum* spp.)	13	0.178	8.2%
Cereal indeterminate	71	4.338	59.1%
Pulses			
Chickpea (*Cicer arietinum*)	50	1.947	9.1%
Grass pea (*Lathyrus* sp.)	2	0.023	1.2%
Lentil (*Lens culinaris*)	7.5	0.092	3.0%
Bitter vetch (*Vicia ervilia*)	381	5.465	21.6%
Common vetch (*Vicia sativa*)	2.5	0.019	0.6%
Pulse indeterminate	14.5	1.440	41.8%
Fruits			
Fig (*Ficus carica*)	5	0.003	1.5%
Grape (*Vitis vinifera*)	57	0.582	31.4%
Number of samples	328		
Total soil volume (L)	2760		
Total cultivated seed count	776.5		
Total cultivated seed weight (g)	15.957		
Total wild seed count	821		
Total wood charcoal weight >2mm (g)	42.742		
Mean density of charred material >2 mm (g/L)	0.019		

assemblage are interpreted as primarily originating as inclusions in harvested crop seeds: i.e. field weeds. Study of such weed floras can provide evidence on field location and methods of cultivation (Riehl 2014; Weiss and Kislev 2004). The more numerous wild seed taxa from the 328 flotation samples studied are listed in Table 2; full data are reported on a sample-by-sample basis by Shin et al. (2021).

Taxa that are numerous include grass seeds (especially *Bromus*, *Phalaris*, and *Hordeum*, which are both components of Anatolian steppe communities and common segetal weeds; Davis 1985); various small seeds of the Fabaceae and Caryophyllaceae families, which grow in native steppe and as field weeds; *Chenopodium*, a segetal weed that is also spread through deposition in ruminant animal dung (Spengler 2019); *Polygonum* and *Rumex*, both common plants of disturbed areas and field weeds; and, especially, *Malva* and *Bolboschoenus*. *Bolboschoenus* is the most numerous seed in the assemblage, totalling 24% of all identified seeds, and many, if not all, of the unidentifiable inner seeds are likely *Bolboschoenus* as well, as inner seeds are commonly preserved among the Cyperaceae. Both *Malva* and *Bolboschoenus* are plants of wet areas, growing along (and in the case of *Bolboschoenus*, within) streams and lakeshores. These taxa likely represent use of wetland areas surrounding Lake Marmara and/or the Gediz River. They may be weeds of crops grown in seasonally inundated fields along the lakeshore, or in the case of *Bolboschoenus* may represent deliberate collection of the plant for industrial uses of its leaves and/or stems for basketry or thatching.

Thus, we reconstruct at least three herbaceous vegetation communities in the region of Kaymakçı, alongside the woodland described above: (1) arable land, farmed with annual crops and attendant field weeds; (2) steppe grassland, likely grazed with some pressure by ruminant animals, judging by the high frequency of endozoochoric taxa (such as *Chenopodium*); and (3) wetland, where *Malva*, *Bolboschoenus*, and *Phragmites* (identified in wood charcoal analysis, possibly also a significant contributor to the unidentified Poaceae seed assemblage) grow. Open oak woodland typically shades an understory of steppe, as seen in Figure 4, so the woodland and steppe communities may have been, at least in large part, coterminous.

Wild Animal Ecologies

Faunal evidence also speaks to an abundance of wild animals hunted by inhabitants of Kaymakçı, reflecting the use of several ecological communities (Table 3). While several of these taxa are only represented by singular remains (e.g. large carnivores, including a bear and large felid, possibly a lynx or panther), and thus the result of unusual encounters in the region of Kaymakçı, others appear to have been dietary staples, especially fish and deer. Identified fish are exclusively freshwater species, including carp and catfish, almost certainly procured from Lake Marmara; most identified bivalves are freshwater mussels as well. Deer are likely to have inhabited the oak woodlands reconstructed above, with red and roe deer in denser deciduous oak forest and fallow deer ranging further into open woodlands. Of note is that wild boar, or at least pigs of comparable size, are almost absent from the faunal record. Birds were likely drawn to the lake and its wetlands in antiquity, as they are today (Gul, Onmus, and Siki 2013). They do not occur as commonly in Kaymakçı's faunal record as one might expect given the likely extent of the wetlands in antiquity (Vardar 2018).

Agricultural Economies

Farming Practices

Archaeobotanical analysis of 328 flotation samples, from excavation areas as marked on Figure 2, span the site. Presented here are only sitewide summary data (Table 4); complete data have been published recently in full detail (Shin et al. 2021). The most numerous and ubiquitous cultigens were barley (all hulled), free-threshing wheat (bread or hard wheat, the seeds of which cannot be distinguished), bitter vetch, chickpea, and grape. Less common were hulled wheats (both einkorn and emmer), lentil, common vetch, grass pea, and fig. Overall charred plant density

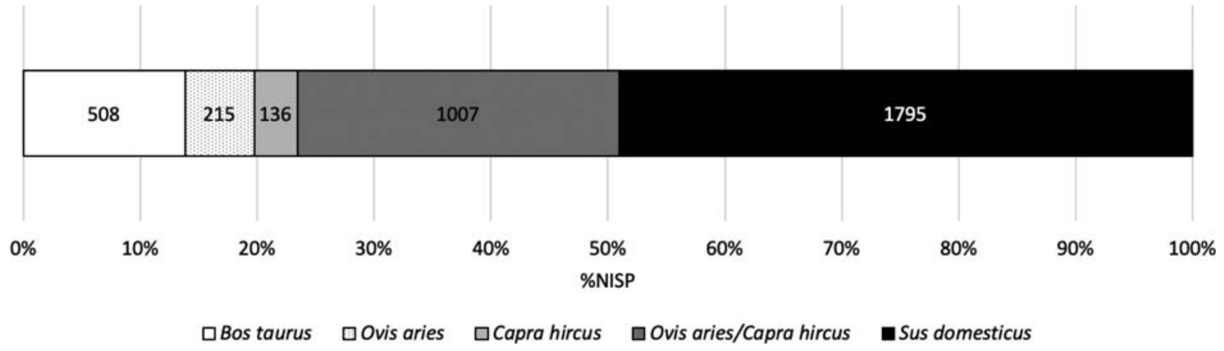

Figure 5. Relative proportions (%NISP) of domesticated meat animals from 2014–2016 excavation seasons; NISP is given for each taxon over the corresponding bar.

was low, presumably due to taphonomic factors related to the gradual abandonment of the site and its relatively shallow burial (discussed further in Shin et al. 2021).

Based on these results, Shin et al. (2021) reconstructed an agricultural economy with an emphasis on barley and pulse cultivation, as pulses form the plurality of recovered remains despite taphonomic biases against their survival via carbonisation relative to cereals. Both of the most numerous crops, barley and bitter vetch, can be grown in low-quality soils and under dry conditions. Free-threshing wheat and chickpeas represent secondary cultigens. Notably, both require higher quality soils and better water availability than barley and bitter vetch. The presence of grass pea, common vetch, and hulled wheats may represent incidental field weeds, as the few seeds of those species were dispersed across contexts. Grapes most likely were under local cultivation, due to their ubiquity and frequency, despite the absence of vine wood in the charcoal assemblage, and figs are rare components of both the seed and charcoal assemblage, also suggesting local, though infrequent, cultivation.

Animal Husbandry

Domesticates total 62% of all bones identified at Kaymakçı and appear to have provided the primary source of meat for inhabitants of the site. The most common domesticated animal in the Kaymakçı assemblage is pig, which comprises 49% of identified domesticates likely consumed as meat (Figure 5). Caprines, with a sheep to goat ratio of 1.6:1, total another 37% of domesticate remains. Cattle comprise the remaining 14% of the domesticate assemblage.

Mortality data, in the form of survivorship curves, give evidence for culling strategies and suggest objectives for the management of ruminant animal herds (Reitz and Wing 2008). Survivorship curves from Kaymakçı indicate that distinct strategies were pursued for different animals (Figure 6; raw data provided in Electronic Supplementary Material 2). Pigs were culled at early ages, with fewer than 40% surviving to 16 months of age, suggesting fall and winter culling if piglet births were confined to spring (Slim, Çakırlar, and Roosevelt 2020); those surviving past 16 months were killed at an even rate as they aged (Figure 6[a]). Abundant remains of fetal and neonate pigs within the site boundaries indicate that pregnant sows were kept within the urban boundary of Kaymakçı (Slim, Çakırlar, and Roosevelt 2020). Most cattle, in contrast, were kept to adult ages, with nearly 9 in 10 surviving beyond 3 years of age (Figure 6[b]). This pattern suggests that post-lactation milk production and/or traction were the primary aims of cattle herders (Vigne and Helmer 2007). Cattle are also prime livestock with which to maintain and exchange wealth (Arbuckle 2014). Sheep and goats display distinct patterns of culling, with sheep (Figure 6[c]) kept to older ages than goats (Figure 6[d]). These patterns correspond with a focus on meat from goat herds and a balanced strategy from sheep, involving both meat and secondary products; as sheep were kept to an age beyond which they would be reliable milk producers, this indicates their use for wool (Vigne and Helmer 2007). Combined NISP and mortality figures indicate that animal husbandry practices were diverse and that the inhabitants of Kaymakçı did not focus intensively on a single management strategy.

A recently published, detailed study of pig husbandry at Kaymakçı (Slim, Çakırlar, and Roosevelt 2020) used dental biometry to document the presence of multiple breeding populations of pigs that were consumed onsite. Slim, Çakırlar, and Roosevelt (2020, 13) suggest that this represents populations of pigs kept onsite and culled seasonally for meat, as well as capture of free-ranging pig populations: an intensive and an extensive pig-husbandry strategy. We thus find at Kaymakçı evidence for pluriform animal husbandry, involving at least two distinct pig-husbandry strategies, as well as distinct patterns of sheep, goat, and cattle slaughter resulting from emphasis on different economic goals: goats for meat, cattle for secondary products, and sheep for both. Additionally, wild animals, especially fish, comprised a significant secondary meat source, implying a seasonal cycle of food resources available from domesticated and wild animals.

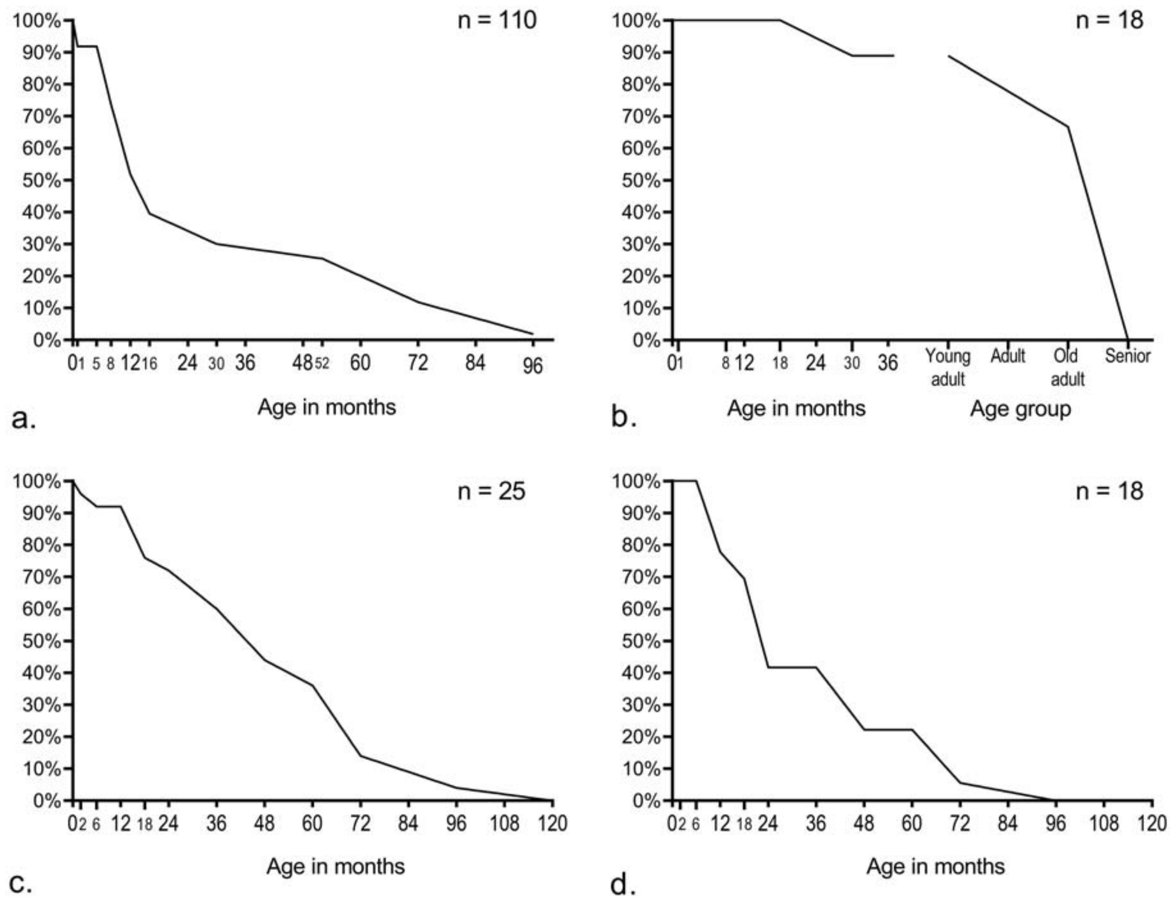

Figure 6. Mortality data for pigs (a), cattle (b), sheep (c), and goats (d), from 2014–2016 excavation seasons. Survivorship curves calculated based on mandibular wear from the following sources: sheep and goat (Zeder 2006), cattle (Halstead 1985), pig (Lemoine et al. 2014).

Discussion

Placing Agriculture and Land Use into the Landscapes of Kaymakçı

The Kaymakçı faunal and botanical assemblages represent a diverse array of animal and plant food resources. Although there is an emphasis on pig husbandry and the cultivation of barley and bitter vetch, all of these are versatile resources. Pigs supply only meat but were both intensively raised onsite and captured or hunted from free-ranging populations in the surrounding region. Both barley and bitter vetch can be cultivated across a variety of settings, including in poor soils unsuitable for other crops, and can be used both as human food and as animal fodder. Free-ranging pigs would thrive in a landscape with both deciduous and evergreen oak woodlands, which can extend the availability of acorns over more of the year (Pérez-Ramos et al. 2015). Pig herds, penned or free-ranging, and cattle would also do well in the well-watered areas down the hill from the settlement. Sheep and, especially, goats would have thrived in the open oak woodlands, which provide grass fodder for the former and leafy fodder for the latter. Sheep and cattle provided meat and milk, alongside wool from sheep and possibly traction from oxen. Wheat and chickpeas were farmed, and grapes were also consumed, though there is no evidence from the charcoal record for local vineyards, which produce abundant wood trimmings typically used locally as fuel (e.g. at Kınık Höyük: Castellano 2021); grapes may have been grown in home gardens. Wild animals, especially fish but also deer, birds, shellfish, and lagomorphs, were regularly eaten at Kaymakçı, supplementing protein from domesticated animals, perhaps on a seasonal basis (Slim, Çakırlar, and Roosevelt 2020, 13).

The landscape of Kaymakçı at the time the site was occupied appears to have resembled the present landscape in several significant ways. The Lake Marmara wetlands were likely expansive, capable of supporting populations of both carp and catfish. Wetlands, including both reedbeds and marshes conducive to sedge growth, were present along local waterways, drawing in seasonal bird populations, at least some of which were likely hunted. Reed thickets in these wetlands would have supported free-ranging pigs, as would oak woodlands with abundant acorn supplies available seasonally. Flat areas of alluvial soils along water courses, including those that were seasonally inundated, would have provided rich soils for wheat and chickpea farming. Barley and bitter vetch had the flexibility to be grown in poor-quality saline soils along the lake or in thin soils on dry hilltops and slopes. Large extents of oak woodlands existed of both evergreen and deciduous species. Grazing of ruminants in steppe grasslands, likely serving as an understory to open oak woodlands, would likely have occupied the hillslopes surrounding the Marmara Lake Basin, as seen today (Figure 4).

Differences are evident as well. Boar, which are subject only to protective hunting due to contemporary food traditions, are the only artiodactyl roaming the area today, taking over the niche occupied in the Late Bronze Age by free-ranging domesticated pigs, while deer are absent from the contemporary landscape. Dense, canopy deciduous oak forests are not present in the immediate vicinity of Kaymakçı today, but instead are only found at higher elevations in the mountains north and south of the Marmara Lake Basin (Zohary 1973). While the frequency of deciduous oak in the Late Bronze Age charcoal assemblage indicates ample local supplies of deciduous oak, it is not possible to determine what proportion of that is *Q. ithaburensis*, which adopts an open woodland structure in the presence of grazing animals, and what proportion is *Q. cerris*, which forms denser canopy forest. The absence of deer (particularly red deer) in the area today may be a result of the reduction of forest habitat since the Late Bronze Age, when their abundance suggests that dense oak forests were both more expansive and grew closer to the site than they do at present. It is quite likely that human use of deciduous oak forests led to their gradual replacement by open oak woodlands with an increased proportion of evergreen oaks, as has been documented elsewhere in the Mediterranean (e.g. the Southern Levant [Schiebel and Litt 2018] and Southwestern Anatolia [Kaniewski et al. 2008]). The lack of comparative, diachronic datasets currently available from the Marmara Lake Basin, however, precludes a detailed understanding of the extent and timing of this possible transition.

Implications for Regional Economic Networks

The environmental archaeological assemblages of Kaymakçı convey a singular story across categories of remains: diversity of subsistence strategies. Within a regional perspective, Kaymakçı demonstrates an intermediate position between Aegean (especially northern Aegean) and central Anatolian agricultural strategies, with an emphasis on extensive practices of herding and farming. We define intensive practices following Brookfield (1972), as strategies that aim to increase production from a given unit of land. Extensive strategies are the opposite, those that aim to increase production by incorporating more land but not increasing (or even decreasing) the yield of a given unit of area (Styring et al. 2017). While there is evidence for intensification of pig husbandry in the urban fabric of Kaymakçı through sty-keeping and culling at young ages, and of intensive, irrigated farming (perhaps of free-threshing wheat) in seasonally inundated areas, the multitude of extensive practices (in the husbandry of free roaming pigs, in dry-farmed cultivation of barley and bitter vetch, in the inclusion of substantial numbers of wild animals alongside domesticates) follows the pattern of the northern Aegean most closely (Shin et al. 2021, Table 6; Slim, Çakırlar, and Roosevelt 2020, 3, 15). That within western Anatolia Kaymakçı differs from Troy, Klazomenai, and Beycesultan reinforces the historical narrative that these sites belonged to different polities and made independent economic decisions regarding agricultural and subsistence strategies.

Diverse, extensive agricultural practices are not common at imperial and palatial centres in Anatolia and the Aegean. In contrast, under strong centralised political control, agricultural intensification tends to occur: for example, focused slaughter of young pigs across the Hittite heartland and at a number of Mycenaean palatial centres (Slim, Çakırlar, and Roosevelt 2020, 14) and the massive grain stores of Hittite centres, especially Hattusa (Diffey et al. 2020) and Kuşaklı (Castellano 2018), that included production from well-watered and manured fields (Diffey et al. 2020). A focus on diverse, extensive methods of cultivation has the advantage of minimising agricultural risk (Marston 2011), but also reduces potential yields from a given unit of land, a strategy often at odds with imperial demands for tribute and taxable surplus (Çakırlar and Marston 2019; Marston 2021; Rosenzweig and Marston 2018). In the case of Kaymakçı, the oak landscape, the lake and wetlands, and the mild climate provided resources that allowed risk-buffering strategies to coexist alongside moderate productivity. The sporadic evidence for intensification, however, provides further evidence that Kaymakçı operated independently of direct imperial control, in line with textual indications of the tenuous nature of Hittite control of the region (Roosevelt and Luke 2017). Despite these diversified strategies, the scale of settlement at Kaymakçı and neighbouring citadels, as well as unfortified sites in the region, may have had a landscape impact in changing forest structure from dense deciduous oak forest to open deciduous and evergreen oak woodlands. Although additional data is needed to verify this possible transition and its date at Kaymakçı, given that an Iron Age component to the site and comparative datasets in the Marmara Lake Basin are lacking, similar transitions in woodland structure are evident at other LBA settlements in Anatolia, such as Kaman Kalehöyük (Wright et al. 2015) and Gordion (Marston 2017; Miller 1999). The timing of widespread changes in woodland structure suggest that regional economic dynamics may have played a role in such transitions.

Conclusions

Environmental archaeological research at Kaymakçı provides new insight into the agricultural economies, landscapes, and networks of political control of western Anatolia during the Late Bronze Age. We identify a diversity of agricultural and subsistence practices that took full advantage of the multiple ecological zones of the Marmara Lake Basin: oak forests, lacustrine and riparian wetlands, and open steppe woodlands. We suggest that LBA agricultural practices and especially demands for fuel opened up oak forests, expanding the open woodlands seen today. The multiplicity of extensive agricultural strategies practiced at Kaymakçı belie Hittite claims of hegemony over the region, and instead suggest independence, at least in agricultural systems, from the close economic control of any imperial power. Indeed, Kaymakçı may well have itself commanded resources from neighbouring sites, if indeed it was a capital of the Seha River Land, serving as a regional economic centre. While agricultural strategies practiced at Kaymakçı resemble those of the Aegean, especially those of independent sites in the northern Aegean rather than of palatial centres of the Mycenaean heartland, elements of Anatolian agricultural practices are present as well. At Kaymakçı, the hybrid nature of agriculture reflects elements of both Aegean and Anatolian traditions in the production and use of multiple categories of artifacts, from pottery to personal adornment, tools, and weights (Roosevelt et al. 2018). Such finds illuminate the social and economic networks in which Kaymakçı engaged, and the complexity of such networks in the Late Bronze Age of western Anatolia.

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